THE DESIGN OF NUTRITIONAL FOOD PRODUCTS
FOR A DEVELOPING COUNTRY

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of the requirements for the degree of Ph.D
in Product Development at Massey University

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ABSTRACT

A systematic methodology was developed for designing food products for the Philippines.

This was the initial stage of an investigation at Massey University into the application of quantitative product development techniques to the food industry in developing countries. A study of economic, nutritional and food industry conditions indicated that Taiwan, Korea and the Philippines best satisfied the conditions necessary for the use of product development in the food industry. The Philippines was chosen for this first investigation and the quantitative study was on the selection of raw materials in formulation according to their nutritional properties.

The selection of raw materials in the product development was made quantitative by use of linear programming. A linear programming model was developed to select, from a list of one hundred and seventy raw materials indigenous to the Philippines, a raw material mixture capable of satisfying twenty-six nutrient requirements as well as several interrelationships between nutrients, at a minimum cost. In the development of this model, investigations were made on the effects of altering nutritional requirements, raw material costs and compositional data and also the variety of raw materials. The linear programming model was found particularly useful for investigating the effects of changes in the nutritional requirements and in raw material costs, but rather unpredictable for changes in raw materials. The precision of the model was much greater than could be expected of the nutritional composition data.

The mixture of raw materials selected to meet the Philippine nutritional requirements was developed, using the product development system, to an acceptable canned meat-loaf-type product. This product

was selected, from a number of systematically generated product ideas, by a critical evaluation method, based on information on processed food eating patterns, food processing facilities and processed food distribution systems, obtained during a visit to the Philippines in 1973. This product was designed to be manufactured in large meat processing plants in the Philippines and distributed to the small stores throughout the country.

The linear programming model was also used to guide the design of a food product enriched with chemical nutrients and capable of rapid introduction to Philippine diets to supplement the basic rice meal. The linear programming technique provided quantitative data for evaluation of the feasibility of enrichment with various types of food materials and chemical nutrients, for the cost of various levels of enrichment and for design of product formulations, allowing for nutrient losses during processing. A coconut bun with nutrient enriched filling was developed. This product could be manufactured in the many bakeries scattered throughout the Philippines.

Chemical analysis of the two products showed reasonable agreement with calculated nutrient levels, but generally nutrient levels were below calculated levels, implying that some scaling up of nutrient requirements may be necessary for this model. The real value of the systematic methodology cannot be finally assessed until an attempt is made to implement the industrial production in the Philippines and introduce the products into the diets.

This first stage of the development of the raw material selection model has provided a basis for further work on inclusion of the other properties of the raw materials such as eating quality, so that a comprehensive model for the quantitative design of foods can be finally achieved.

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CHAPTER 1

INTRODUCTION

This thesis covers the initial stages of a major project on the application of modern product development techniques to the food industry of developing countries. The aim of the project is to bring about nutritional improvement through the introduction of suitable new food products. The project will systematically study raw materials, processing, distribution and consumer needs in South-East Asian countries for the design of acceptable products.

This chapter is an introduction to the whole project, discussing what is meant by product development, how it could be used in developing countries and which of these countries could make most effective use of food product development. A study of economic, nutritional and food industry conditions of different countries indicated that Taiwan, Korea and the Philippines best satisfied the conditions necessary to benefit from employing the product development method and the Philippines was chosen for this first investigation.

The overall aim of the project - to establish the design of food products on a systematic and quantitative basis - relies on the availability of factual and documented information. This thesis investigated the stage of raw material selection in a quantitative manner as this was an area where such information existed, with reference to the Philippines situation. These raw materials were formulated into nutritionally balanced food products compatible with processing facilities and food eating habits in the Philippines.

1.1 The evolution of the product development method in the food industry

Product development has been defined as industrial research to develop products and processes satisfying a known or suspected consumer need (1). More specifically, it is a method for selecting, evaluating and developing new products for a specific consumer need.

Prior to 1957, product development was carried out as applied research in the R & D sections of large manufacturing companies. Marketing and sales departments had little influence in selection of products for development - their function was to promote, distribute and sell the developed products. In 1957, it was suggested that a more efficient method for successful product development would involve co-ordination of marketing and technical departments (2). Thus marketing could evaluate proposed projects on the basis of market and economic research and technical departments could consider the projects' technical feasibility and cost (3).

The food industry, an extensively consumer-oriented and competitive industry, dependent on marketing and technical innovation, was quick to take up these ideas, particularly in the United States. In 1963, food technologists in industry considered this philosophy for the first time at a meeting in Missouri (4), and this was followed by symposia in 1965, 1967 and 1969 on advances in the method of product development (5,6,7). In 1967, a professional journal covering this field of research - Food Product Development - was first published, emphasising its significance as an important applied research method.

In large commercial food companies, product development is now established as a multi-disciplinary research method co-ordinating financial, marketing, food technology, engineering, packaging, advertising and sales activities to effectively select, evaluate and develop new food products. It is effective in these sophisticated companies but can it be used to improve the nutritional standards of a developing country by introducing new nutritional foods? The aim of this thesis is to investigate this application.

1.2 Place of product development in a developing country

Countries with low nutritional status also have poorer economies and lower levels of industrial development than countries with high nutritional status. The value of product development in the food industry of the poorer countries may therefore be restricted by basic limitations arising from economic, agricultural and industrial factors. Therefore, data from Asia, Europe and the USA were studied to find if quantitative economic and industrial standards could be deduced which would indicate when product development could be used effectively as a method of improving the nutritional status of a particular area.

1.2.1 The relationship between nutritional status and economic development

In 1967, the Food and Agricultural Organisation of the United Nations (FAO) used a Gross National Product per caput (GNP) of $US 300 per annum as the dividing line between a developing and a developed country (8). This does not show adequately the dynamic changes that occur in a country's development. Economic growth curves for the UK and USA from 1880 onwards, were drawn from historical data (9,10). These illustrated that the growth of GNP was exponential with time, and suggested an improved method of grouping countries into three stages of development according to rate of growth of GNP.

Stage 1 - no growth or very slow growth of GNP - underdeveloped countries
Stage 2 - gradual increase in rate of growth of GNP - developing countries
Stage 3 - rapid increase in rate of growth of GNP - developed countries

On this basis, countries could be grouped as follows :

<u>Underdeveloped group</u> :	Burma, Ceylon, India, Korea, Pakistan, Philippines, Thailand.
<u>Developing group</u> :	Portugal, Spain, Taiwan.
<u>Developed group</u> :	Australia, Canada, Japan, New Zealand, United Kingdom, United States of America.

When the calories, total protein and animal protein available per person per day were graphed for the years 1950 to 1968, the countries again fell into three groups (Table 1.1).

Because of these clearly defined patterns of parallel nutritional and economic development, an attempt was made to find a relationship between them. The calorie data were plotted against GNP (Fig.1.1): the points were scattered but generally showed a definite pattern, with a sharp increase in calorie content of the diet with increasing GNP up to about $200, then a slower increase up to $1000, and thereafter very little increase even with large increases in GNP. Also shown in Fig.1.1 is a curve, taken from a report of the United Nations Commission in Latin

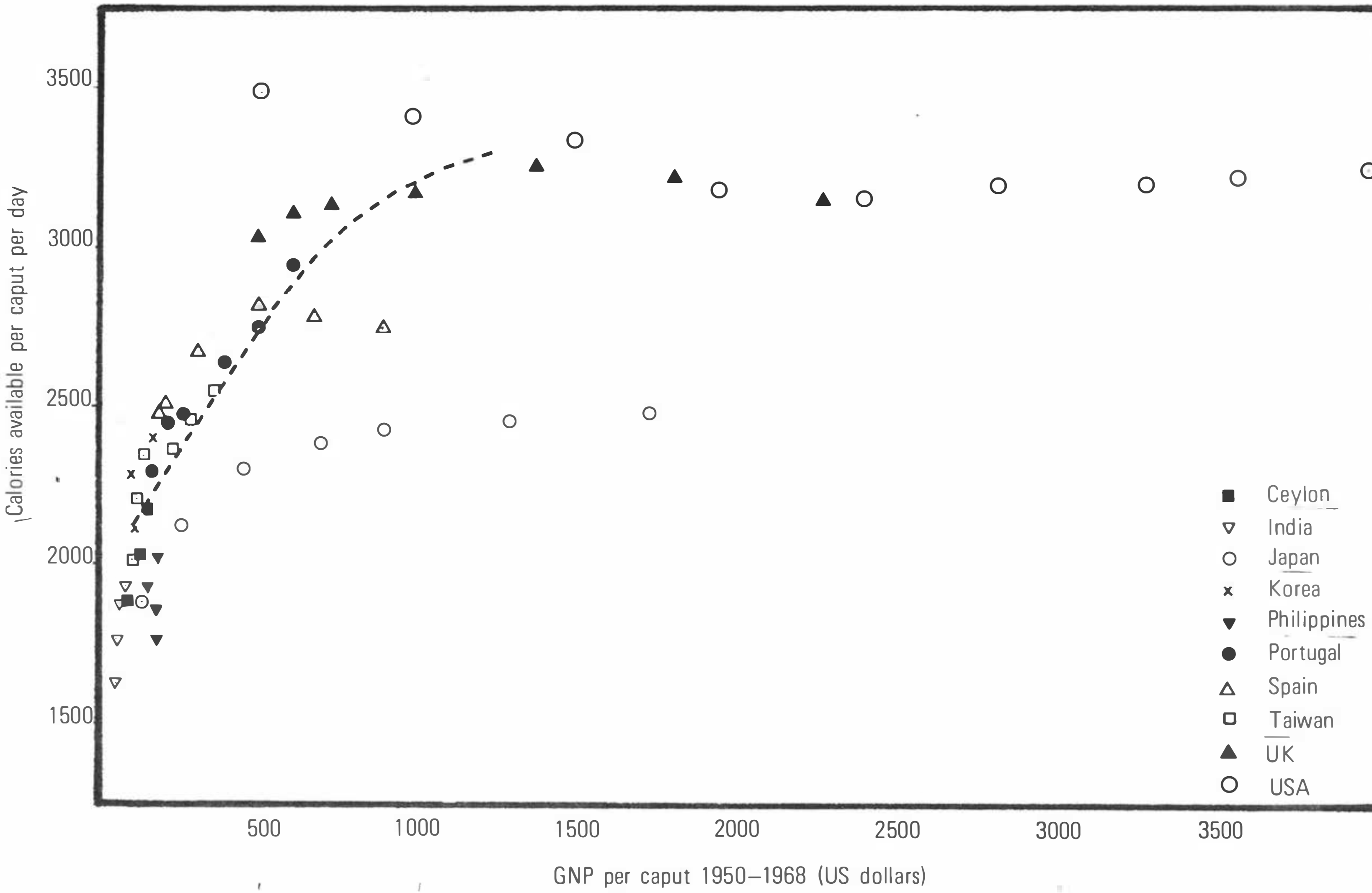


Figure 1.1 **Relationship between calories in the food supply and GNP for several countries**

See notes on statistical data in Appendix.

America in 1955 showing the same pattern (11). Data for Japan deviated from the general trend; whereas the overall pattern tended to level out around 3000kcal, Japanese intakes levelled out around 2500kcal.

Table 1.1 The characteristics of the three nutritional states

		Calories kcal/caput/d	Total protein g/caput/d	Animal protein g/caput/d
Underdeveloped group	constant, or slowly increasing low nutrient levels	<2200	<55	<15
Developing group	gradually increasing nutrient levels	2200-3000	55-85	15-40
Developed group	constant, or slowly increasing high nutrient levels	>3000	>85	>40

This overall pattern was clearer when protein level was plotted against GNP (Fig.1.2). There was a steep rise in protein intake for a small increase in GNP up to about $250, then a slower increase, the curve levelling around a protein level of 85g corresponding to a GNP of approximately $1000. Above this, the protein level increased only slightly with large increases in GNP. The Japanese data followed the general relationship but again levelled at lower values than the other countries.

The rapid growth period stopped at a slightly lower GNP for calories - 2500kcal at GNP $200 - than for protein - 70g at GNP $250; presumably because calories were cheaper than proteins in foods. The final very slow growth period, occurring around 3200kcal and 85g protein, started in both cases at about $1000 GNP. When other economic factors, such as energy consumption and passenger car density were graphed against total protein, the same type of relationship was obtained. To increase calorie and protein levels in the diet of underdeveloped countries, there must be economic development - an increase in GNP from approximately $100 to a minimum of $200. This can bring about a significant effect on the diet as protein levels can be raised to around 70g and calories to around 2800kcal.

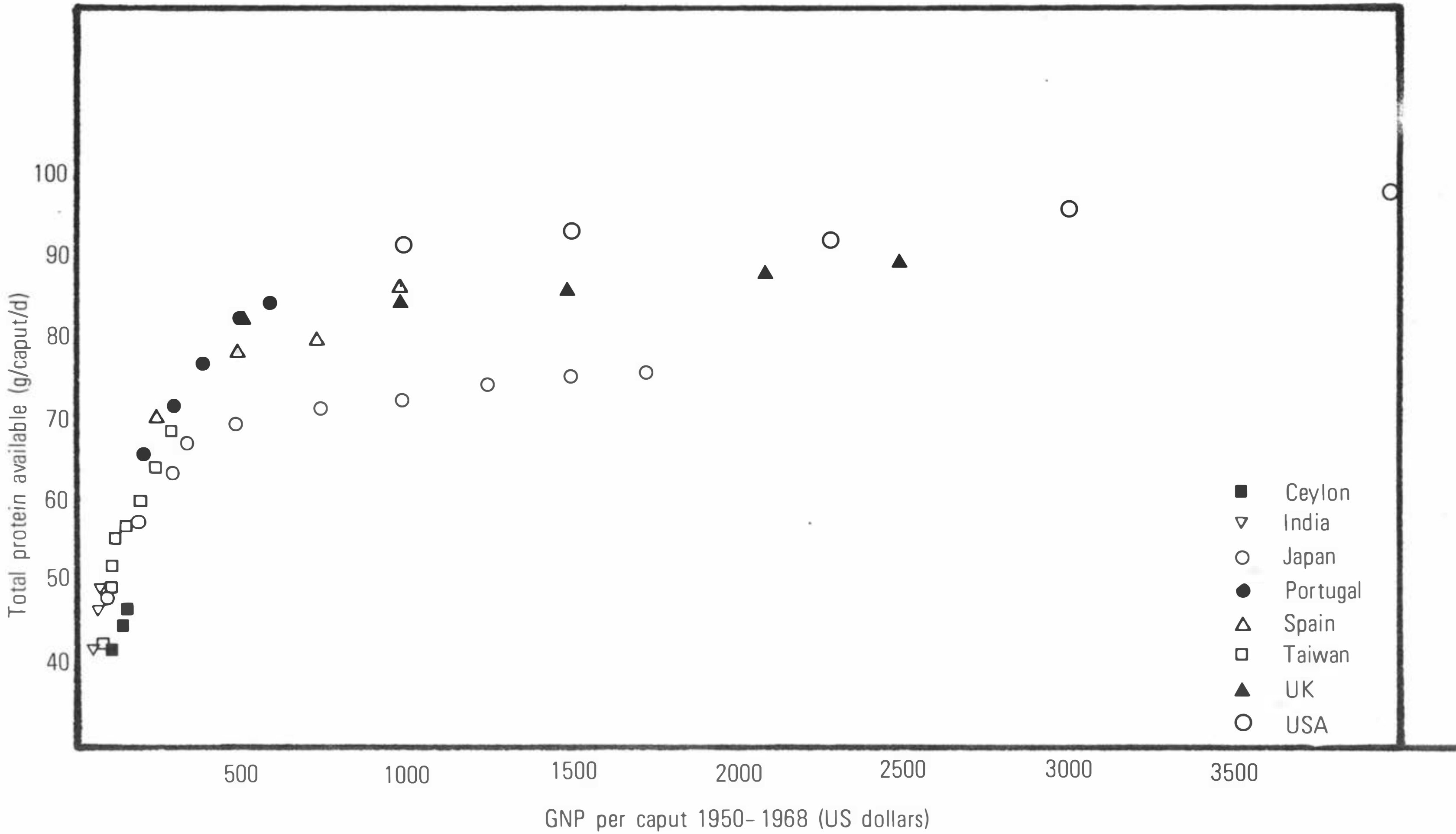


Figure 1.2 **Relationship between total protein in the food supply and GNP for several countries**

See notes on statistical data in Appendix.

It is at this point - emergence from the underdeveloped stage into the developing stage - that countries should be in a position to respond to accelerating economic growth by expansion of their industry, including the food industry.

1.2.2 The relationship of nutritional status to the size of the food industry

Establishment and development of the food processing industry could contribute nutritionally to a developing area, directly by increasing the quality and quantity of food available and indirectly by improving the general economy of the area (11,12,13); but no attempt has been made to quantitatively relate the size of the food industry and the nutritional status of an area. Protein levels were plotted against the food manufacturing output values for several countries in Fig.1.3. There was a gradual increase in protein with increase in food processing up to an output of $20 per caput, and then the rate of protein increase with increase in food processing slowed and there was only a very slight increase in intake of protein with quite large increases in food processing output: above about $60, the protein level did not increase further.

As food industry output increased there were two growth patterns reaching different final protein levels; for total protein, the two curves could eventually meet, but for animal protein this was unlikely. These separate pathways could be associated with differences in the traditional food habits of the countries involved. In Fig.1.3 (a), the upper pathway countries, except for Korea, were Western in outlook and the basic foods, even of the poor, would include some meat, milk, vegetables and cereals; but in the lower pathway countries, all in Asia, the basic diet would be lacking in animal protein foods, as mainly based on cereals.

Therefore, increasing the food industry would improve nutrition but other factors, notably the type of diet, could reduce this effect.

1.2.3 The effects of patterns of diet on nutritional status

The diets of selected countries are illustrated in Fig 1.4; the high and low pathway countries differed in intakes of milk and meat. Comparing Japan with UK, which had a slightly higher GNP per caput but a significantly higher protein level, the striking difference was the much

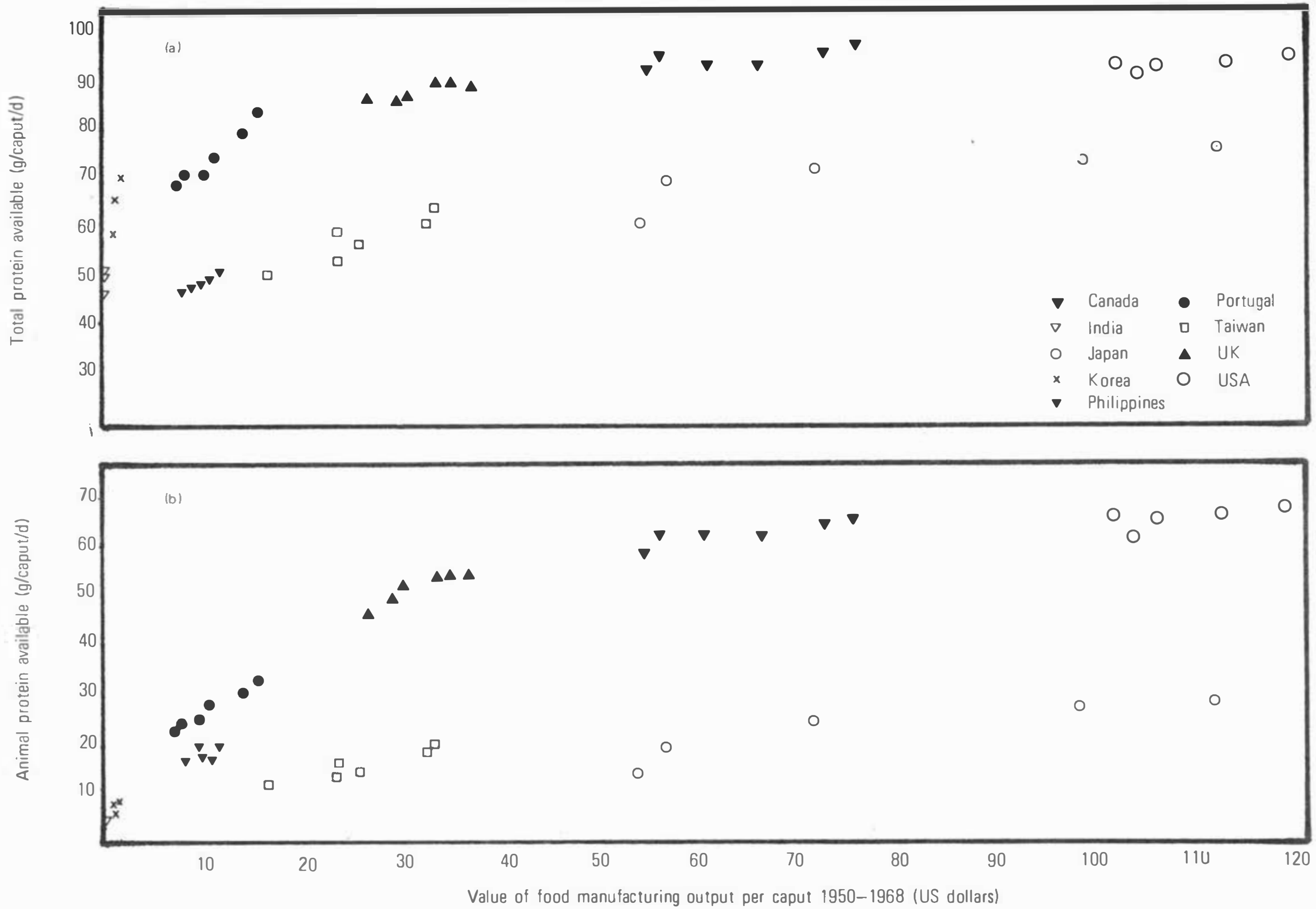


Figure 1.3 **Relationship between protein in the food supply and food manufacturing value for several countries: (a) total protein (b) animal protein**

See notes on statistical data in Appendix.

lower intake of meat and milk in Japan. Even the higher intake of pulses and fish did not give the Japanese diet as high a level of protein as UK. Compared with Portugal, with much lower GNP, Japan had lower protein and lower quantities of potatoes and starchy roots, vegetables, meat and milk but higher quantities of pulses, nuts and seeds, and eggs. Traditional dietary patterns were reflected in the fish, pulses and cereal diet of Japan compared with the animal protein based diets of UK and Portugal.

The unusual country on the upper pathway in Fig. 1.3 was Korea, with high total protein but low animal protein intake. The diet histograms, showed a high cereal content in the diet, much higher than any other Asian country (Fig.1.4). Korea, an underdeveloped country, achieved nearly as high a protein level in the diet as Japan, a developing country with higher GNP and food manufacturing output, by use of a high cereal diet instead of a fish/meat/pulse diet.

Pulses can also be useful in increasing protein levels. Comparing the diets of the Philippines and Taiwan, the fish, meat and cereal levels were similar but the low level of pulses, legumes and nuts in the Philippines' diet has kept the protein intake at a lower level. Turkey and United Arab Republic were other countries with a high protein level and a strong reliance on cereals and pulses (Fig.1.4). Their diets were similar to the Korean pattern, except for higher milk intake and lower fish intake.

Both cereal/pulse and animal product based diets can bring about increases in the protein levels of national diets. It is therefore important to consider the traditional dietary habits of different areas when planning nutritional improvement.

1.2.4 The relationship between nutritional status and the money spent on food

As a country develops, the buying of food for survival decreases in importance and there is more buying of food by choice - the "nutritional" and "economic" food requirements (15). Only the nutritional requirements need to be satisfied in underdeveloped areas, but both nutritional and economic requirements arise in developing areas. As personal income increases, the percentage of it spent on food decreases (16), and changes occur in the types of food eaten, the more

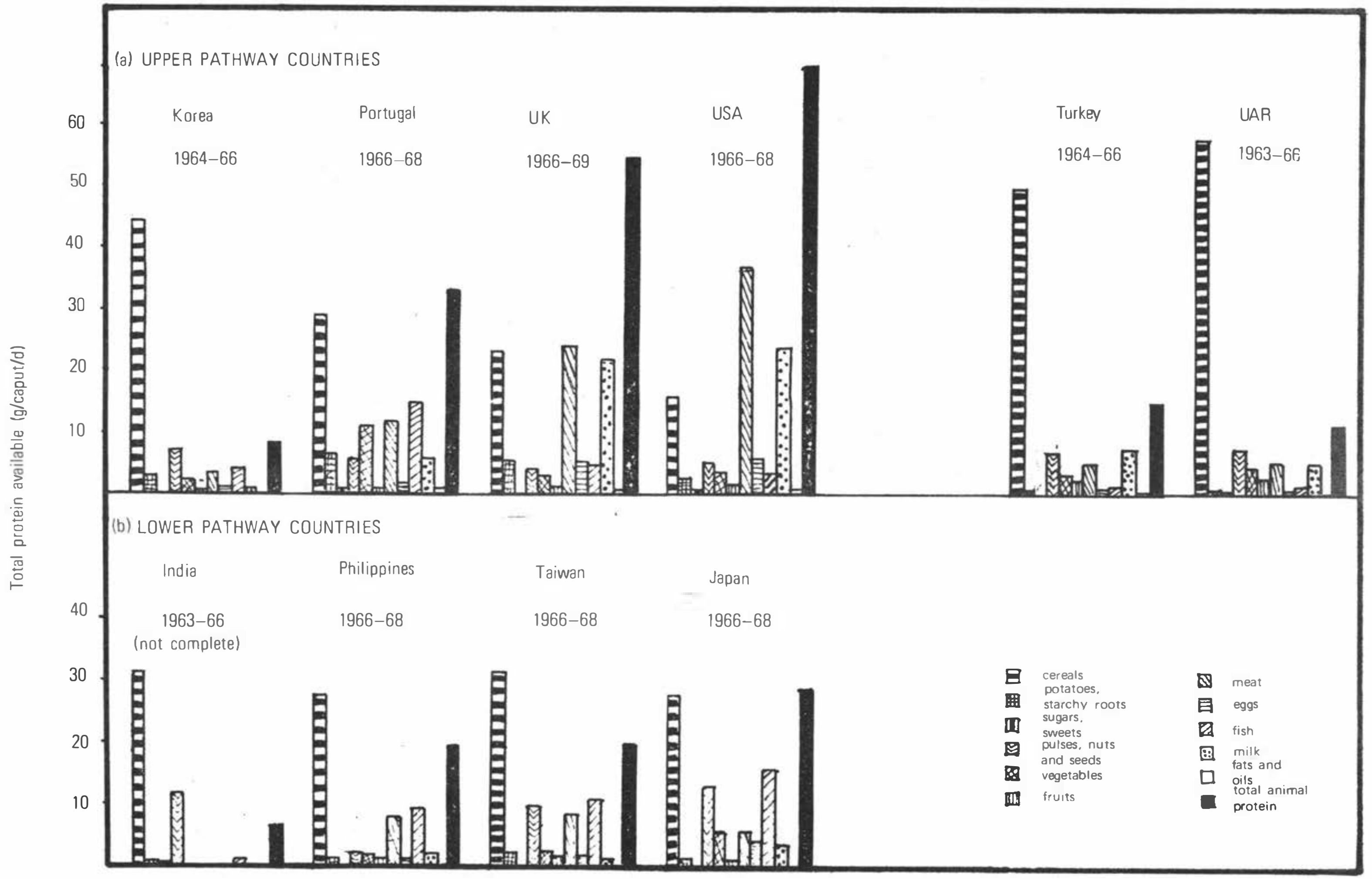


Figure 1.4 Sources of protein in the food supply of several countries

See notes on statistical data in Appendix.

expensive foods such as protein foods, increasing in the diet. This was true for the countries studied, but Japan and Taiwan followed this general relationship at lower protein levels than the other countries (Fig.1.5).

This suggested either that protein foods were not available to the population to the same extent as in the other countries, or that the Japanese and Taiwanese did not eat protein foods because of some cultural bias.

Availability is a major factor; Taiwan and Japan spend as much on food as the Spanish yet consume less protein and animal protein because meat and milk are less readily available.

Together with consideration of the traditional foods and how these may be improved or supplemented, the increased availability of nutritious foods through direction of production, marketing and distribution must also be planned for in the nutritional development of an area.

1.2.5 Interrelationships of the factors related to nutritional status

Langer and Henshaw developed mathematical relationships between population size, economic development and food supply for different countries (17). They postulated that a turning point between subsistence levels and higher living standards in a country corresponded to daily calorie intake of approximately 2700kcal, an income of $300 and a fuel energy consumption of 1.4 ton (1017kg) coal equivalent per head per year. Characterising the three stages of development described in 1.2.1 in a similar way, indicated that this turning point lay somewhat above the division between underdeveloped and developing countries (Table 1.2).

These classifications divided the countries into underdeveloped, developing and developed groups as described earlier, with the exception of Korea and Philippines which were sometimes classified as underdeveloped and sometimes as developing. These countries were thus probably in a transition stage. Using these divisions it could be deduced whether a country was economically capable of supporting or expanding its food industry to increase its nutritional status. In the underdeveloped group, it would be difficult economically to develop a food industry significantly to bring about a nutritional uplift until the whole economy

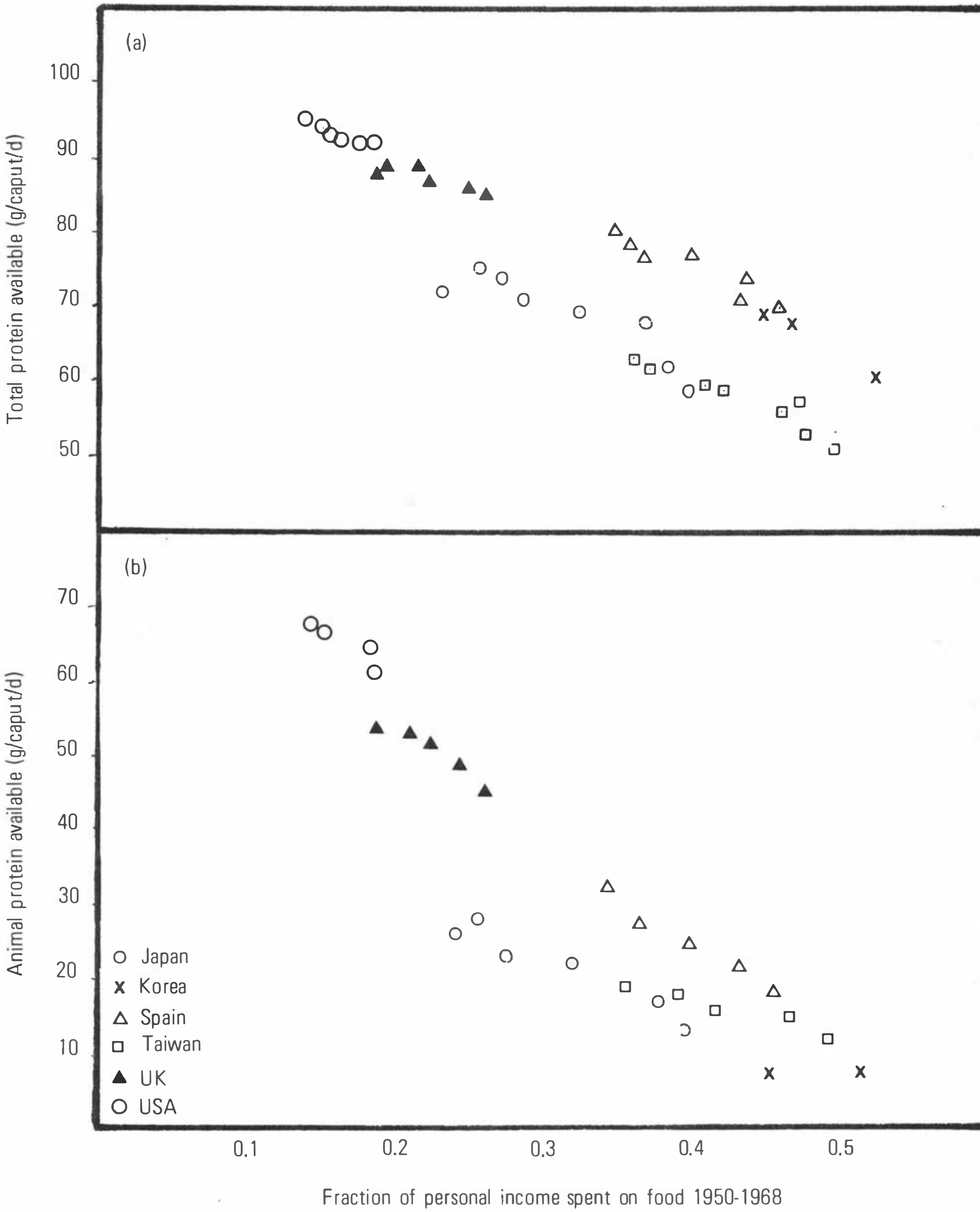


Figure 1.5 **Relationship between protein in the food supply and the fraction of personal income spent on food for several countries:**
(a) total protein
(b) animal protein

See notes on statistical data in Appendix.

began to develop; in the developing countries, expansion of the food industry was necessary, to at least an output of $20 per caput. It is at this stage that product development can be effectively employed. The role of product development in this critical stage in the development of a country, is to guide the expansion of the food industry through the design, production and marketing in an acceptable form, of the nutritional products required to satisfy the needs of the people, utilising the available raw materials to their best advantage.

Table 1.2 The characteristics of the three stages of development

	GNP $US/caput	Energy kg coal equ/caput	Calories kcal/caput/d	Protein g/caput/d	Animal protein g/caput/d	Food industry output $US/caput
Underdeveloped group	<200	<400 (0.45ton)	<2200	<55	<15	<20
Developing group	200-1000	400-2000 (2.2ton)	2200-3000	55-85	15-40	>20
Developed group	>1000	>2000	>3000	>85	>40	>20

1.2.6 Conclusion

The conditions needed before product development can play a significant role in the nutritional development of an area are sufficient economic growth (corresponding to around $200 GNP per caput); knowledge of local nutritional status and the effects on it of the availability of foods, and of the traditional dietary patterns; and a food industry sector capable of directed expansion to cater for the increasing demands of a developing nation.

Of the countries studied, Taiwan, Korea and the Philippines best satisfied these conditions.

The Philippines was chosen as the developing area for this investigation since :

1. Liaison was quickly set up with research centres and libraries in the Philippines in contrast to long delays experienced in corresponding with similar agencies in other countries.
2. English was the major commercial and technical language in the Philippines which facilitated correspondence and literature and industry research.
3. Comprehensive nutritional, economic, agriculture and industrial statistics were documented in the Philippines and were made available for this investigation. This was a considerable boon to the research.

1.3 The product development method

1.3.1 The stages in product development

In the organization of new product development in large companies, there has evolved a general sequence of logical steps which is illustrated in Fig.1.6. These steps are described briefly as :

1. Exploration. Objectives for the development are set by the company. This initiates the search for new product ideas, or process improvements to meet these objectives.
2. Screening. The ideas are examined to quickly determine which ideas warrant further study. This is the first of recurring evaluation stages in the sequence, in which each product idea is assessed.
3. Business analysis. Ideas are more fully developed and estimates are made through market research of the market sizes, demand and profitability. The technical feasibility in terms of capital requirement and development cost is also considered. This much more stringent evaluation stage selects only the most worthwhile product ideas.
4. Development. Ideas are transformed to the physical product, from the laboratory to pilot-plant scale production. Evaluation of these products for consumer acceptability and costing is carried out, and unsatisfactory products are dropped.
5. Testing. Developed products are test-marketed prior to releasing onto the market, in order to test all company functions involved in product launch as well as the market acceptability of the product. Any faults either in the product or the performance of the departments are discovered and rectified. The final decision must be made at this stage whether to drop the product or carry it into full commercialization.
6. Commercialization. Full scale production and marketing programmes

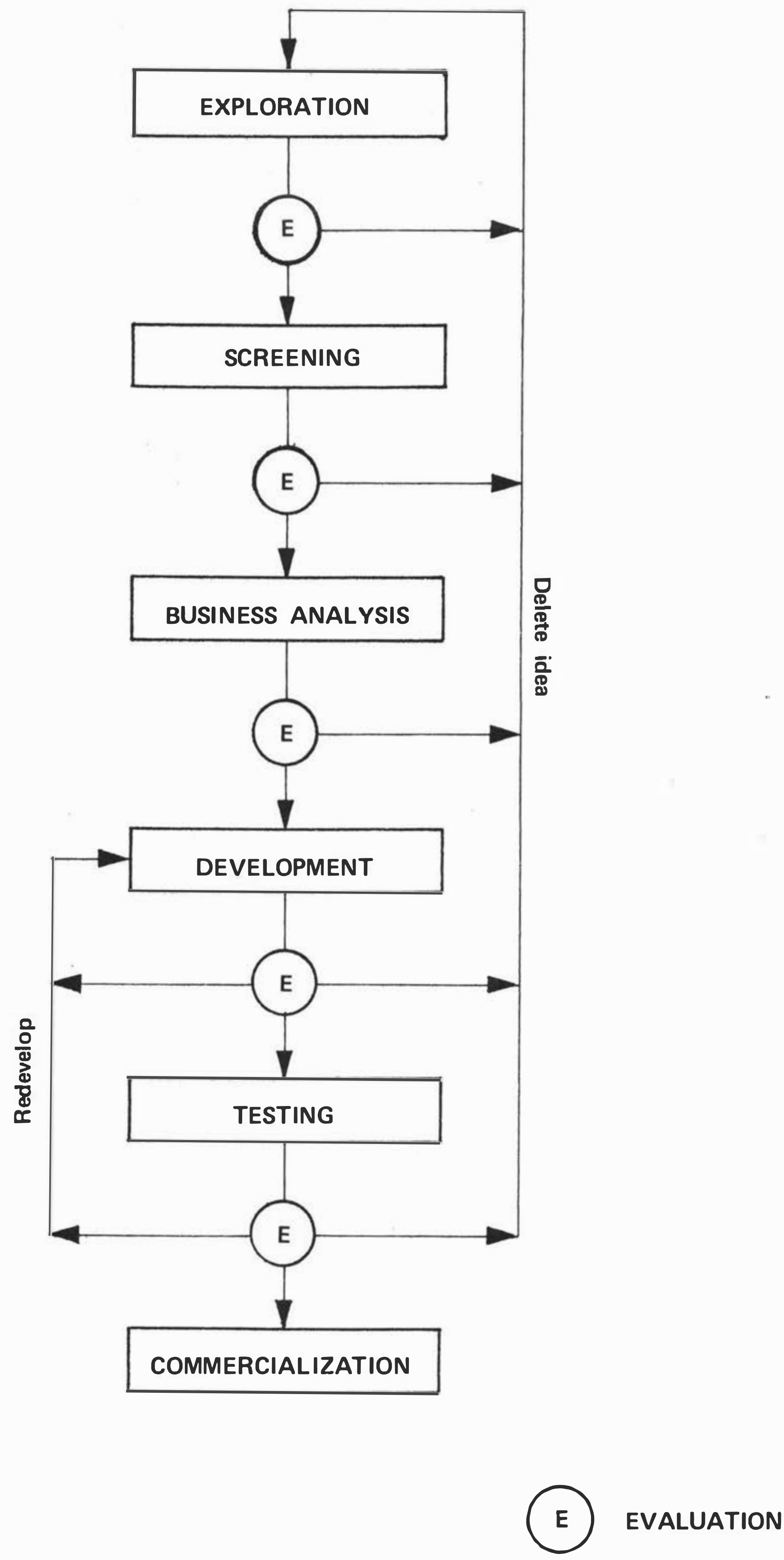


Figure 1.6 The stages in product development

Adapted from 'Management of new products,' Booz, Allen and Hamilton, Inc. New York, 1967.

are set up and put into operation to launch the product onto the market.

Thus suitable product ideas are carried through to development and commercialization after successive evaluation stages. This is a key factor of the product development method. As more information becomes available during the life of a project, evaluation becomes more stringent - thus the probability of successful ideas being selected is increased.

1.3.2 Quantitative techniques in the product development method

Product development techniques have been becoming increasingly quantitative in recent years. This has been to ensure objectivity in project management. For example :

Ideas are generated by systematic comprehensive methods e.g. Heuristic Ideation Technique (18)

Screening techniques use scoring charts which may include probability considerations (19)

Business analysis incorporates market forecasting, market surveys, return on investment analysis (20) and consumer buying models (21)

Development stages use formulation based on linear programming (22) scheduling and costing based on critical path method (23) and statistical experimental design and analysis (24)

Testing includes monitored test market trials, perhaps in conjunction with consumer buying models or advertising media testing (21)

Evaluations are based on Bayesian decision-tree methods or cost-benefit analysis (20)

In practice these methods are being incorporated into the stepwise product development method, so that the whole system can become dependent on quantitative parameters. These quantitative techniques depend on the collection of much marketing and technical information. Historical information which is cheap to obtain is used in the early evaluation stages. This progresses to direct gathering of facts from market research, laboratory and pilot-plant experiments and finally test-marketing with increasing cost in time and money. Commercial information such as sales figures, market statistics and consumer buying statistics can usually be obtained in commercial companies but are not generally available for the national food development situation. This does not mean that the product development method cannot be used; rather the method should be adapted to utilise the information that is available.

1.3.3 Food product development scheme for developing countries

A suitable food product development scheme was designed for a developing country and is shown in Fig. 1.7. Use is made of national survey statistics on population, food production, nutritional status and economic parameters such as disposable income and income distribution found generally in FAO and UN statistics sources. If national statistics are available from a particular country, then manufacturing industry, food and agricultural production and more detailed nutritional information, as well as reports on food marketing and food eating habits, may be available. This data is often considerably less accurate than that available for commercial product development. Surveys may also be carried out to gather more accurate and extensive basic information.

In this project, quantitative techniques will be investigated for their usefulness in this scheme of food product development.

1.3.4 Implementation of product development in a developing country

Whilst product development seems desirable for a developing country, its usefulness depends on practical and effective implementation into the industrial development sector. To be practical, requires both skilled personnel and the facilities to carry out product development activities. To be effective requires a workable system both for management of projects and for carrying out successfully completed projects through to full scale industrial production and marketing.

1. Training of personnel in product development approach. This should include undergraduate or postgraduate training in food product development followed by on-the-job training - working in a team on food development projects in the home country. This may require to be organized, in the early stages of such a scheme, by advisors from overseas but preferably it should be carried out by local food product developers. Training is essential to ensure that a bank of industrially-oriented development personnel is built up to encourage food industry development and nutritional improvement of the country.

2. Facilities for food product development. Technical and marketing research facilities are required - i.e. chemical, physical, microbiological,

EXPLORATION	Objective stated e.g. To develop nutritional food products utilising indigenous raw materials and existing processing facilities.
SCREENING	Ideas evaluated according to degree of fit with objectives based on information available on nutritional deficiencies, raw material availability, marketing and food eating habits
COMPREHENSIVE SCREENING	Best ideas investigated further by market or nutrition survey to estimate need, demand, disposable income etc. for area. Food industry surveyed to indicate capabilities. Preliminary costing, capital requirement, degree of subsidization etc. estimated.
DEVELOPMENT	Formulation of prototype product. Acceptability testing. Process development. Pilot plant tests of semi-production runs. Nutritional evaluation. Costing of processed product.
TESTING	Consumer test of acceptability, price. Test market for production, marketing performance.
COMMERCIALIZATION	Planning and setting up production and marketing backed by subsidy, if necessary. Launch onto market and/or distribute to welfare agencies, schools.

Figure 1.7 **Product development scheme for nutritional food products for a developing country**

taste-panel, and pilot-plant engineering equipment as well as library and market research facilities. Large scale industry could possible provide such facilities but this would not necessarily be in the interests of the country as a whole. Product development should be conducted in an industrial innovation institute with its own staff and facilities. This could be financed partly by industry but the greatest share should be from the government or other non-commercial sponsoring agency.

3. Management of projects. Trained personnel could work as individuals in charge of each project or as small teams on larger projects using the product development method of project management. The institute could initiate its own projects as well as conduct research for individual companies or industrial groups on a contract basis, always with the aim of nutritional improvement when proposing the introduction of new food products. Such organization would allow ample opportunity for training new graduates in the many facets of the product development approach.

An alternative to the establishment of a separate industrial innovation institute would be extension of government research laboratories to incorporate this system of project management, drawing on existing scientific personnel and facilities as required. This would not be as desirable as a separate institute, since the existing structure in government research laboratories is usually detached both from industry and from practical implementation of their research. Also, the introduction of the new product development approach in long established laboratories could cause organizational difficulties.

4. Industrial implementation. New products could be carried through to industrial production by :

1. Contracting projects from industry and setting up production and marketing in the company as part of the contract;
2. Initiating projects within the institute and tendering for production facilities from existing industry. This would include incorporation of process improvement, quality control and marketing as part of the project in the company.
3. Relying on funds from government or other sponsoring body to improve existing industry or build new plant when promising new proposals appeared from project work.

1.3.5 Other effects of product development in a developing country

Since it could guide the expansion of food industry, product development considerations could simultaneously encourage :

1. Efficient utilization of indigenous raw materials and raw materials suitable for local cultivation, which are economic sources of nutrients and of functional properties required in food products.
2. Expansion of agricultural production of these materials through increased demand from the industrial food processing sector as it expands into new food developments.
3. Stabilization of food prices since year-round supplies of food could become available through the expansion of the processed food industry. Thus the price fluctuations and nutritional problems associated with seasonal surpluses and deficits of fresh foods could be lessened.
4. Retention of indigenous food habits and food product ideas. The major defect of previous food improvement schemes has been the use of overseas food product forms and materials, alien to the receiving area, causing acceptability problems.
5. Expansion of local food industry as existing equipment and skills are utilized in new food products manufacture with associated increase in local employment, higher income and improvement in living standards.

CHAPTER 2

DEVELOPING NUTRITIONAL PRODUCTS FOR THE PHILIPPINES

After the selection of the Philippines as a suitable country to consider for the development of nutritional food products, the first step of exploration was to study the extent of the nutritional problem. Nutritional surveys conducted during the last few years were used to determine the difference between the actual and recommended food intakes. Study of possible methods of improving the nutritional situation indicated that the introduction of formulated, processed, nutritional food products might prove the most effective. The first problem was to select suitable raw materials for such products, and linear programming appeared the most useful quantitative method for this purpose.

2.1 Nutritional status in the Philippines

The Food and Nutrition Research Center (FNRC) in Manila has conducted extensive nutrition surveys in ten regions of the Philippines, covering the whole country during the ten year period 1957 - 1967 (Fig.2.1), thus data were available on the nutritional status of the Philippines.

The weighted average per caput daily intakes of nutrients are shown in Table 2.1. All nutrients were in deficiency according to the recommended allowances of the time, except for iron and niacin (25). There were very low intakes of calcium, riboflavin, vitamin A and thiamine. When revised recommended allowances were calculated from more recent nutritional requirements and population distribution statistics from the 1970 census, the extent of these deficiencies was lessened - particularly for calcium and riboflavin. Iron, however, was in severe deficiency since the higher revised requirement took account of the availability of the mineral from the diet as well as the higher female requirement. Vitamin C was in excess.

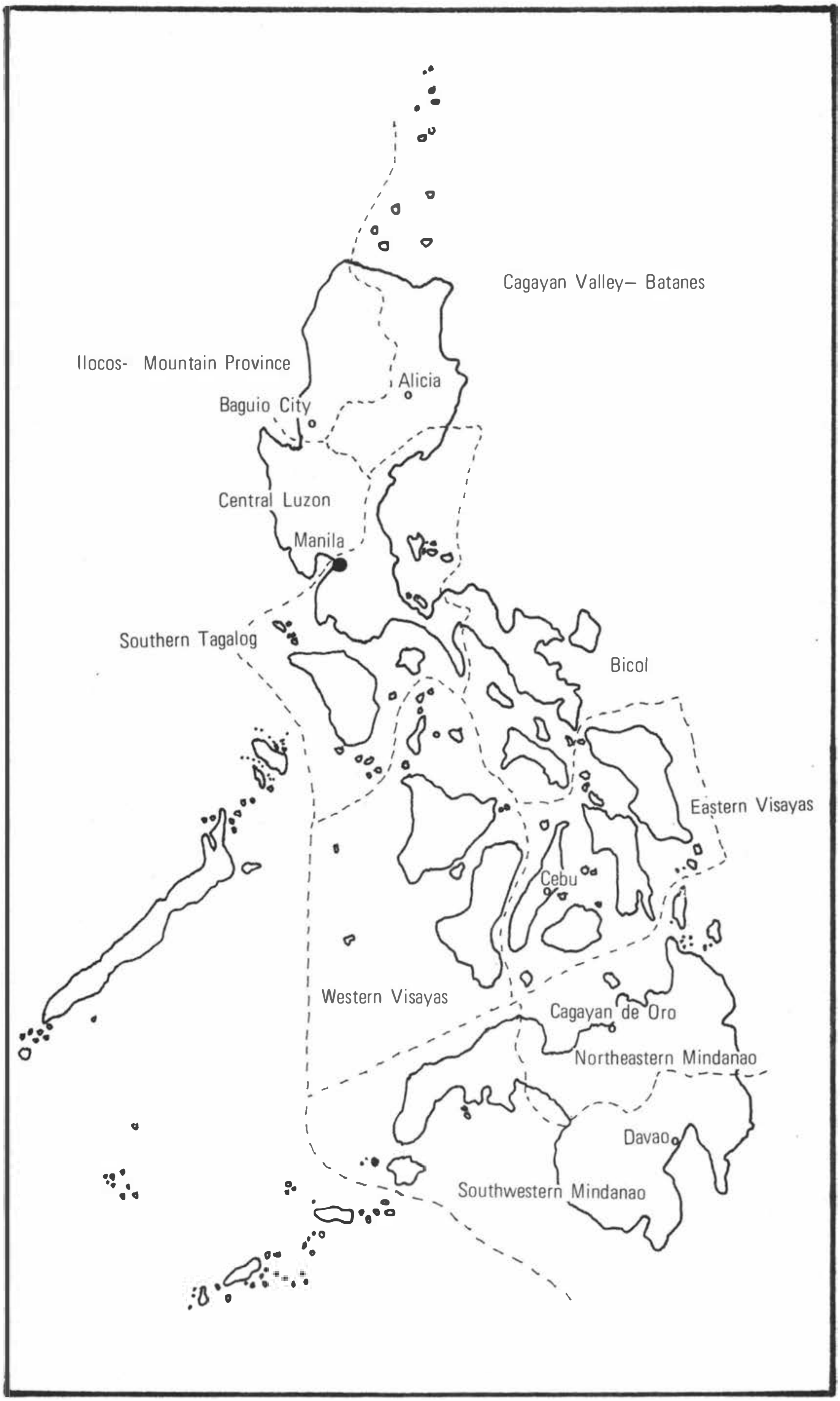


Figure 2.1 **The ten regions of the Philippines covered in FNRC nutrition surveys**

Table 2.1 The mean daily per caput nutrient intake compared to recommended allowances

Nutrient	Intake [a]	Recommended [a] allowance (RA) based on 1960 census	Intake percent of 1960 RA	Recommended [b] allowance (RA) based on 1970 census	Intake percent of 1970 RA	Availability [c] from 1970 Food Balance Sheet
calories (kcal)	1670	2190	76	2040	82	2110
protein (g)	46.9	54.4	86	50.4	93	54.6
calcium (mg)	340	1000	34	450	75	
iron (mg)	10	8	125	20.4	49	
vitamin A (iu)	1900	3800	50	4000	48	
thiamine (mg)	0.75	1.17	64	1.02	74	
riboflavin (mg)	0.49	1.36	36	1.02	48	
niacin (mg)	14.0	12.0	117	13.4	105	
vitamin C (mg)	65	72	90	29	224	

a. Weighted average for eight regions (Bicol and Central Luzon omitted as only pilot studies). Taken from summary report (25).

b. Calculated from more recent data. See chapter 3.

c. Corrected for population of 36 590 000 in Food Balance Sheet for the Philippines CY 1970, The Statistical Reporter (1972) 16 (1), 1.

The nutritional deficiencies were confirmed by biochemical testing of blood and urine samples of subjects (26). Serum carotene, riboflavin and thiamine were found to be at low or deficient levels in more than 70% of subjects, and haemoglobin and vitamin C at low or deficient levels in more than 50% of subjects. The haemoglobin deficiency was explained partly by low iron availability and also by the high incidence of intestinal parasites found during the clinical tests. The vitamin C deficiency could be explained by poor cooking methods causing destruction of vitamin C.

Clinical examination found mainly signs of deficiencies in vitamin A (in more than 45% subjects) and riboflavin (in more than 36% subjects) followed by niacin (in more than 27% subjects) and vitamin C (in more than 11% subjects). There was little incidence of thiamine deficiency (27).

Comparing the regional data with the national average conveyed the same pattern of nutrition throughout the nation (Table 2.2). The nutrients in greatest deficiency were vitamin A, riboflavin, thiamine and iron for all regions. There was a variation in nutrient intake across the regions. Ilocos - Mountain Province had the highest nutrient intakes while the lowest intakes were shown for Eastern Visayas. This variation was greatest for the most deficient nutrients - vitamin A, riboflavin and thiamine. Thus for a proportion of the population, the vitamin deficiencies and general nutrition were much worse than indicated by the average level. However, as each region showed to a greater or lesser extent the same deficiencies as identified in the national average, the average gave a good indication of the nutritional status of the nation on which to base national nutritional improvement programmes. The most recent data - again a national average - from the 1970 Food Balance Sheet indicated that an excess of calories and protein was available from the 1970 food supply, on a per caput basis. This did not imply that intakes were at this level, but suggested the possibility of improved nutritional levels in 1970. An FNRC nationwide nutrition survey, planned for mid 1973, should provide information on current national nutrition status. At this time, there have been no results published from this survey.

It is seen that the nutritional status of the Philippines is rather poor. Some nutrients are more seriously deficient than others. This means that proper utilization of the available nutrients is not possible, as nutrients are not efficiently utilized when deficiencies exist for other essential nutrients. Thus, the value of the encouraging protein level at around 90% requirement, is lowered by the serious deficiencies of calories and vitamins. Inadequate supplies of vitamin B6 will limit protein metabolism in the body. Protein will be used as an energy source when the calorie supply is not sufficient to meet requirements for energy. The calorie supply can itself be limited by insufficient availability of vitamins required for production of energy from food.

For optimal nutrition, there exists a balanced requirement for all nutrients which may be around recommended minimum levels. Improvement of

Table 2.2 Mean daily per caput intake of nutrients for eight regions of the Philippines [a]

Region / Nutrient	Metropolitan Manila 1958	Ilocos–Mountain Province 1960	Cagayan Valley–Batanes 1961	Southern Tagalog 1962	Western Visayas 1964	Eastern Visayas 1965	Southwest Mindanao 1966	Northeast Mindanao [b] 1967	Weighted mean intake [c]	Coefficient of variation on regional means [d]
calories (kcal)	1730	1970	1810	1710	1660	1500	1610	1750	1670	0.069
protein (g)	49.8	52.6	47.7	44.1	48.2	43.3	46.5	48.9	46.9	0.059
fat (g)	38.0	23.0	25.0	22.0	16.0	14.0	15.0	23.0	20.0	0.357
calcium (mg)	350	370	400	310	420	300	320		340	0.125
iron (mg)	10.2	12.0	12.0	8.0	10.0	9.0	9.0		10.0	0.132
vitamin A (iu)	2300	3050	2400	1450	2250	1200	1900		1850	0.256
thiamine (mg)	0.88	1.06	0.78	0.74	0.86	0.66	0.50		0.75	0.177
riboflavin (mg)	0.72	0.66	0.56	0.50	0.50	0.37	0.39		0.49	0.222
niacin (mg)	14.8	18.0	13.8	14.0	15.0	11.0	13.0		14.0	0.122
vitamin C (mg)	63.0	86.0	83.0	58.0	63.0	80.0	52.0		65.0	0.166

a. Taken from individual reports of the surveys in each region (113, 114, 115, 116, 117, 118, 119).

b. Full report not yet published. This data extracted from summary report for all regions (25).

c. Taken from summary report for all regions (25).

d. Coefficient of variability, V = standard deviation/mean.

the nutritional status can only be achieved by increasing the intake of all nutrients simultaneously to recommended levels. Most attention in the past has been given to increasing protein intake but this cannot be effective while severe deficiencies in other nutrients exist. The interaction of nutrients should be considered when planning nutritional improvement.

2.2 Methods of improving nutritional status

Nutritional status may be improved through dietary methods either by educating people to eat a varied and 'balanced diet' or by introducing nutritional food products.

2.2.1 The food group approach

In order to tackle the nutritional problems of the country the FNRC, in co-ordination with other agencies in the Philippines, actively encourages home dietary planning based on recommended allowances for the six major food groups - cereals, starchy roots and tubers, leafy vegetables, fruits and vegetables, dairy products and eggs, and meat, poultry and fish. As well as issuing pamphlets and other publications, they use trained field workers to give demonstrations and instruction in cooking practices and menu planning, in both urban areas and remote rural barrios (28). However over the period covered by the surveys little nutritional improvement was evident.

This food group approach cannot be effective when deficiencies exist in the supply of these foods. Quiogue noted that the recommended allowances for food groups could not be met from supplies in 1966 (29). Data available for 1970 indicated that the situation had not changed (Table 2.3). Only calorie-rich food groups - cereals, roots and tubers and sugars were available in excess of allowances but all protein and vitamin food groups were in deficiency. The allowance for milk and milk products was over four times the supply and eight times the daily intake.

The food group approach will not improve the nutritional status until there is a marked increase in the availability of the foods and it is necessary to look for other methods.

Table 2.3 Food group intake and allowances compared with availability[a]

Food group	Mean daily intake g/caput/d	Recommended allowance g/caput/d	Availability 1970 g/caput/d
cereals and cereal products	347	324	376
roots and tubers	58	80	81
sugars and syrups	18	33	45
pulses and nuts	7[b]	20	4
fruits and vegetables	187	359	213
meat, fish and marine products	121	172	146
eggs	5	17	8
milk and milk products	24	173	43
fats and oils	7	29	10

a. Taken from: Office of Statistical Co-ordination and Standards, Food supply situation in the Philippines CY 1970, The Statistical Reporter (1972) 16 (1), 11.

b. Slight excess due to home production not otherwise accounted for, or seasonal availability at time of survey, averaged out in annual food balance sheet.

2.2.2 Introduction of nutritional food products

Since 1940 many types of food products have been developed with high levels of protein, vitamins and minerals for use in developing countries. In recent years, in the Philippines and throughout the world, more emphasis has been placed on introducing this type of product in order to improve national nutritional status.

It is a very effective method, since products can be designed to be easily incorporated into the diet. These products can provide vital nutrients at specified levels and be available all the year round. This is not possible when fresh foods are relied upon, because of their nutrient variability and seasonal availability. It is also an effective method of utilizing the nutrients in the food resources which might not otherwise be available through poor cooking methods, storage losses, wastage or lack of popularity of the natural foodstuff.

The major difficulties have been in keeping the cost of these products low and in persuading the people to use these products. To use a formulated food in a meal usually implies a change in food habits. This is more a problem for rural peoples than for urban peoples who are surrounded by modern life styles and modern food products in the cities.

Nevertheless, many of the products developed have been successful.

The types of nutritional products. Those products for which information is available are listed in Table 2.4. These products can be divided into five major groups which indicate the historical evolution of product development in this area.

1. Attention was initially focussed on providing nutritious food mixtures for all the family which could be mixed with water to a gruel, soup or beverage or could be mixed with local foods e.g. Incaparina (1961), Multi-purpose food (1955).

2. Later there was greater recognition of the particular needs of young children and mothers and development of baby and weaning foods increased. These were normally of the gruel type e.g. Cerealina (1960s), Superamine (1967), Faffa (1968).

3. To further encourage commercial involvement in nutritional products, wider markets were sought with convenience-type foods which were taken as extra meals or food accompaniments. The introduction of artifical milk drinks e.g. Vitasoy (1940), Vitabean (1952) Saridele (1957), Miltone (1968), developed and this expanded into the soft drink area with Puma (1969), Saci (1968) and Samson. Alongside this, nutritious baked goods were being developed as ready-to-eat foods for urban areas and school feeding programmes - Modern Bread (1960s), Nutribun (1960s), Milk biscuit (1971).

4. Development has now expanded across the whole spectrum of food products with such products as soya noodles (1963), Golden Elbow macaroni (1968), meat analogue (1968) and coconut based snack foods (1970).

Nutritional products in the Philippines. Little information is available on products developed in the Philippines.

Table 2.4 Nutritional food products which have developed since 1940[c]

Food mixes, soup, beverage mixes	Baby foods	Drinks	Baked goods	Other types
Incaparina (Guatemala 61)	Solein (Brazil 63)	Puma (Guyana 69)	Protein-enriched cookies (Nicaragua 69)[b]	Soynoodle (Thailand 63)
Multi purpose food (Brazil 56)[a]	Cerealina (Brazil 60s)	Saci (Brazil 68)[b]		Golden elbow macaroni (Brazil 68)[b]
Peruvita (Peru 65)[a]	Duryea (Colombia 69)	Yoohoo (Iran 69)	Bread rolls (Peru 68)[b]	
Pochito (Colombia 67)[a]	Superamine (Algeria 67)	Milpro (India 70)	Bakery enrichment products from soy (Uganda 68)	Meat analogue (Pakistan 68)[b]
Conasupo (Mexico 60s)	Faffa (Ethiopa 68)	Miltone (India 68)		Coco-crunchies (Philippines 70)[b]
Fortifex (Brazil 63)	Ladylac (Senegal 66)[a]	Saridele (Indonesia 57)[a]	Kupangi biscuits (South Africa 61)	Coco-noodles (Philippines 69)[b]
Protea (Mexico 50s)	Cherish (Rhodesia 60s)	Vitasoy (Hong-Kong 40)	Milk biscuit (Zambia 71)	
Colombiharina (Colombia 67)	Bal-Amul (India 70)	Beanvit, Vitabean (Singapore/Malaysia 52)	Nutro biscuit (India 50s)	
Amama (Nigeria 59)[a]	Nutro-bebe (Mexico 69)[b]	Vitamilk (Thailand 60s)	Provite, Nutrovite biscuits (India 60s)	
Arlac (Nigeria 63)[a]	Dyno (Mexico 69)[b]	Polukmilk (Thailand 64)	Uniprotein biscuit (India 70)	
Simba/milk (Kenya 59)	Neche-Alim (Chile 68)[b]	Samson (Surinam)	Soyacookies (Thailand 63)	
Supro (Kenya 64)	Weaning food (Taiwan)[b]	Soymilk (Philippines 72)	Soyaflour (Thailand 63)	
Super Maeu (Mozambique 65)	baby food (Turkey)[b]		Modern bread (India 60s)	
Nutresco, Nutrovite, Protesco (Rhodesia 63)	baby food (Iran)[b]		Nutribun (Philippines 60s)	
Pronutro (South Africa 62)	baby food (St. Lucia 71)[b]			
Protone (South Africa)	baby food (Cuba)[b]			
Multipurpose food (India 55)				
Protamin (India 63)				
Bal-ahar (India 67)				
MCM (using coconut milk) (Philippines 72)[b]				

a. Production discontinued.

b. Product undergoing development or not commercially produced.

c. Adapted from: E. Orr, The use of protein-rich foods for the relief of malnutrition in developing countries: an analysis of experience. Tropical Products Institute Publication G73, 1972.

Of importance has been the development of the Nutribun, a nutritious baked product for use in school feeding programmes (30). Production has now expanded to levels of 100 million buns per day and the product is now also available through retail outlets. The formulation is based on donated ingredients - wheat flour and skim milk powder, but this is being partly replaced with local coconut flour and cheaper soy-flour. The donated ingredients are supplied to local bakeries who supply the other ingredients, bake and deliver the buns to schools. Pupils pay 5 - 10 centavos to cover costs.

A multi-purpose food based on a mixture of coconut flour, mung bean and skim milk powder has been developed at the FNRC for use as a food additive, porridge mix or beverage mix (CMM) particularly for young children. This has not progressed past the pilot-plant stage (31). Processes for other coconut based products have been developed at the FNRC viz. coco noodles (32) and coco-crunchies, a snack food (33). Soyamilks, coconut milk and filled milk products are produced commercially for use mainly in baby feeding. Several overseas formulations are available in retail stores which could be classified as nutritional foods - dried milks, beverage powders based on milk powder with added vitamins and minerals such as Ovaltine, Milo and baby food formulations based on milk - Lactogen, Enfamil. These products are fairly expensive and rarely reach the poorer people in urban or rural areas.

The US developed CSM - corn-soy-milk-food mixture - is donated for use in nutrition feeding programmes throughout the Philippines, primarily for young children.

Composition of nutritional foods. The majority of these products have been developed to provide high levels of protein of high biological quality. Usually vitamins and mineral levels have also been considered and in recent years amino acids have been included in formulations as their costs became lower.

Each food is generally specified to provide a percentage of the recommended daily allowance for the important nutrients in the food product e.g. Nutribun contains 38% protein, 30% Vitamin A, 30% niacin, 56% riboflavin, 50% thiamine, 33% calcium and 47% iron of the daily requirements for school children (30). It is assumed then that the balance of the nutrient requirements and others not incorporated are available from other foods eaten during the day. The value of such nutritional products will be lowered if these other nutrients are not made available. No food products have been designed to supply full nutritional requirements except in the medical field. (See Table 2.5 for typical food product compositions)

Table 2.5 Typical composition of nutritional food products [a]

Type of product	Range of composition			
	protein g/100g	calories kcal/100g	carbohydrate g/100g	fat g/100g
Food mixtures/beverage mixes	12-51	335-420	36-68	1.4-11.5
Baby foods	18-33	345-470	41-65	1.6-18
Drinks (liquid form)	3-3.5	n.a.	6-11	0.1-2.5
Baked goods	8-20	460 (1 only)	50 (1 only)	7-20
Others-- macaroni	20	350	66	2.2
coconut snack	29	350	56	0.8

a. Adapted from: E. Orr, The use of protein-rich foods for the relief of malnutrition in developing countries: an analysis of experience. Tropical Products Institute Publication G73, 1972.

Factors to be considered in the development of nutritional products :
From information collected on the degree of success of the products developed, the following reasons were given for failure for twenty such schemes.

1. Price of the product
2. Faulty promotion
3. Lack of knowledge of local food habits and preferences
4. Competition from donated foods issued through welfare agencies
5. Poor organoleptic acceptability of the product

These factors must be considered alongside nutritional criteria in the development of nutritional food products. A comprehensive list of factors which could be considered have been suggested as follows (34):

1. Local availability of the basic raw materials used in the formulation.
2. The basic materials should preferably be materials not presently fulfilling their maximum potential as human food.
3. The basic materials must have exact specifications on quality and processing conditions.
4. Processes that damage the quality of the protein should be avoided.
5. Products developed must be within the economic means of the particular population group for which they are intended.
6. Products must be easily transported and have a reasonable storage life under normal environmental conditions.
7. Products must be free from any toxic or deleterious influence backed by adequate animal testing.
8. The protein should be of a relatively high nutritional value.
9. Products must have an agreeable taste and odour and be acceptable to the population group.

The design of nutritional food products thus requires consideration of many factors, several of which are outside the technical area of formulating and testing the product. The product development method could incorporate the nutritional, consumer acceptability, technical and marketing criteria in its approach to the design of food products.

2.2.3 Conclusion

For improvement of the poor nutritional status of the Philippines, the introduction of nutritional food products seems more effective than employing the food group approach to meal planning. Well-designed nutritional products would allow better utilization of the food resources available. Prescribed levels of nutrients could be supplied in these food products so that estimation by the consumer of his daily food needs is made easier. The effects on nutritional status should be predictable from sales. Frequent offering of new formulations and product forms without change in nutritional value should provide a variety of products.

A wide variety of nutritional food products have been developed in recent years throughout the world and also in the Philippines. Particular emphasis has been placed on incorporating high protein levels in these products. The nutritional value of these foods could be impaired if the remaining nutrients were not supplied by the other foods in the diet. Food products should be designed to provide all the nutrients necessary for balanced nutrition. These products require to be developed particularly for areas, like the Philippines, where food and nutrient deficiency exists.

Apart from nutritional composition, other criteria must also be considered in the design of food products to ensure successful incorporation of them into the diet. In this investigation the main criteria considered will be :

1. Low costs of products.
2. Balanced nutritional content.
3. Use of indigenous raw materials in the formulation.
4. Organoleptic and cultural acceptability of products.
5. Ease of distribution of products in terms of adequate storage life, physical distribution systems and channels.
6. Adaptability to existing manufacturing facilities for smooth introduction of the product into industrial production.

The design of nutritional products for the Philippines will be investigated using the product development approach with these criteria chiefly in mind.

2.3 The raw material selection stage

If product development is to be used to design nutritional food products, the first step must be the selection of raw materials to be used. If this selection is considered objectively - using quantitative methods, then there should be no bias towards any particular industry, product type or process. It is suggested that raw material selection is a central consideration in the product development method (Fig.2.2). It can :

1. Initiate the product development sequence by providing a group of raw materials to be used for which product ideas can be proposed.
2. Be used in the formulation stage to design suitable prototype products for particular product or process ideas.
3. Be varied to take account of the effect on raw material properties of particular processes.

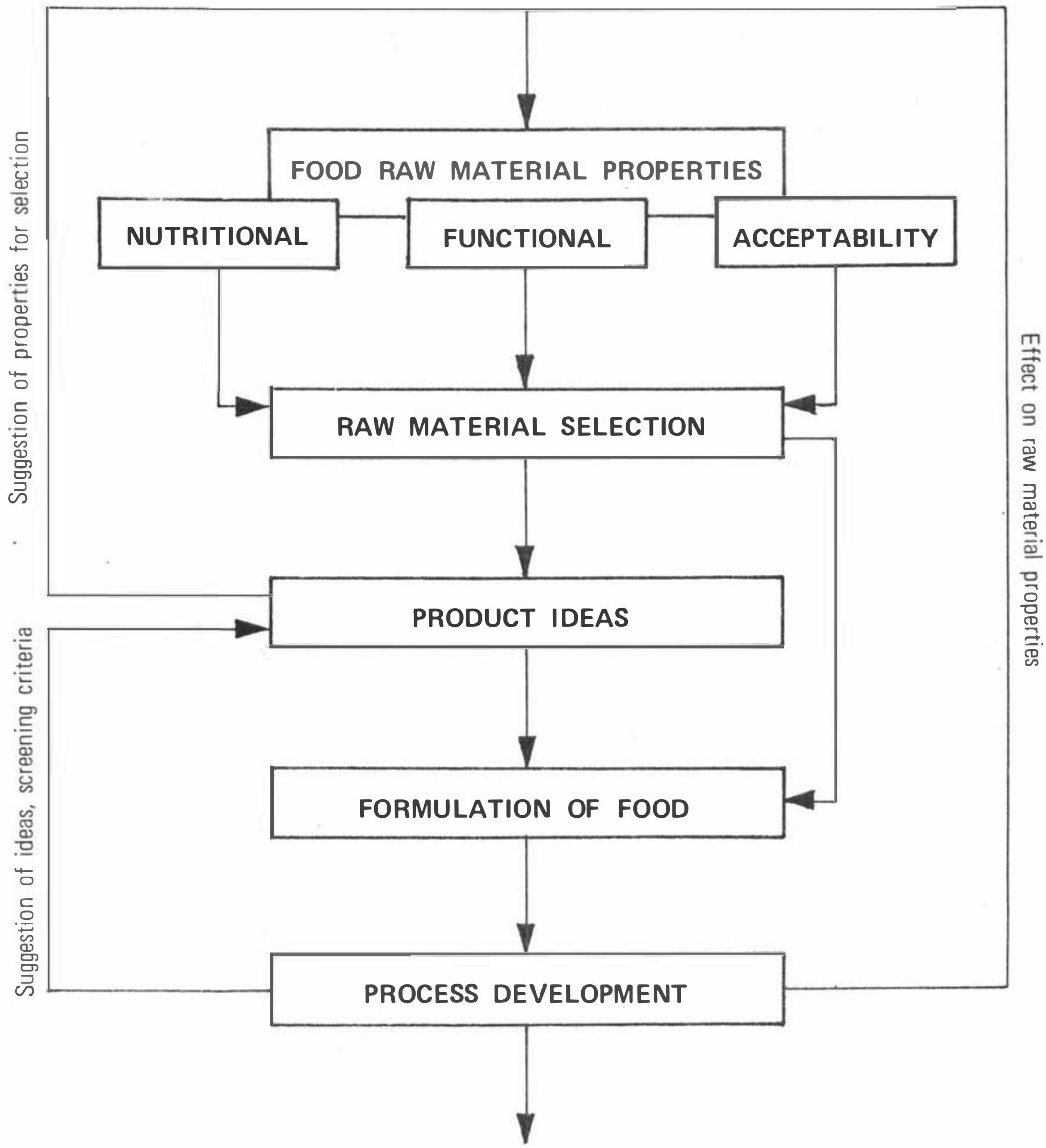


Figure 2.2 **Raw material properties in the product development method**

Selection of raw material is dependent on the properties of the material. These may be :

1. Nutritional e.g. protein content,
2. Functional e.g. viscosity, pH,
3. Associated with consumer acceptability, e.g. flavour, texture.

In any particular case, raw materials are selected from one or more of these properties in the design of food products, subject of course, to costs. For example, in nutritional foods high quality protein materials such as soybean flour, milk powder and egg are often used. In sausage products, bread-crumbs, semolina, rusk are used because of their waterholding properties. In baked goods, wheat flour is used both for its nutritional properties of calories, protein and vitamin content but also for its functional rheological property. In soft drinks, fruit flavours are usually selected as they have an association with juiciness, freshness and bright colours which the consumer desires.

Selection of raw materials in industry is fairly qualitative, relying on the experience of the developer with the materials and problem being considered. To quantify this procedure requires that all materials be assigned some value for each property, so that materials can be selected to economically provide these properties at specified values in the product. Problems occur in the assignment and combination of the property values. For nutritional properties, this is reasonably straightforward since nutrient composition values can be assigned which are additive in combination. It is much more difficult to assign values to functional and acceptability properties. A further difficulty is that the property value can vary according to whether : (i) the properties of the materials are to be selected on a general basis with no particular product or process in mind, (ii) the properties of the materials are defined for a particular product idea, or (iii) the raw material properties are modified quantitatively by the processing method envisaged.

Only nutritional composition values are widely available for food raw materials, so in this investigation nutrition was initially considered as a basis for raw material selection. Firstly, a general selection was made with no preconceived product or process ideas. Later, the effect of defined product and process characteristics on the selection was investigated.

2.3.1 Raw materials to be considered

The raw materials could include :

1. Indigenous agriculture and fishery produce.
2. Food materials which are currently imported or could be imported - dairy produce, meat produce.
3. Nutritious materials which could be grown in the Philippines in the future - soybeans, cottonseed.
4. Nutrient concentrates which could be imported or produced internally in the future - fish protein concentrate, coconut protein, synthetic amino acids.

Since it was required to utilize local materials in designed food products, initially only Philippine agriculture and fishery raw materials were considered. Raw materials from which selection is made may be chosen in two ways : either as a restricted list of materials which are produced in large amounts, have low cost and have particular nutrient properties, or as the full list of food raw materials produced in the country.

1. Restricted raw material list. This has been the approach used in most food programmes. The major raw materials which have been used in nutritional products fall into four groups - oilseeds, legumes, cereals, milk products (Table 2.6). This has been due to : (i) their low cost (ii) their high protein levels (iii) the high protein quality resulting from combinations of these materials caused by mutual supplementation of amino-acid deficiencies.

2. Full raw material list. This would be a more systematic approach as it would not select *a priori* any particular raw materials. Thus the most nutritionally effective and cheapest mixture of indigenous materials could be selected as formulation for food products. This was the approach used in this investigation.

Raw materials which are produced in large amounts in the Philippines are coconut, rice, corn, sugar cane, bananas, pineapples and fish. The Philippines is the largest exporter of copra in the world and is the main supplier of sugar to the United States. It exports a small proportion of its rice production, and also grows bananas and pineapples for export. Thus a significant proportion of the food production of the Philippines is removed from the available food supply. It may be that the value of these foods for foreign exchange should be weighed against their nutritional value for the people. There could be, of course, other sources of nutrients for the country - imported raw materials, increased agricultural production of nutritious crops, nutrient concentrates and synthetic nutrients.

Table 2.6 Main ingredients of nutritional food products [a]

Ingredient	Number of products containing this ingredient	Range of ingredient composition (per cent)
soybean	28	7-48
cottonseed	8	19-52
groundnut	10	15-75
chickpea	8	20-70
kidney bean	1	70
mung bean	2	na
legumes (not specified)	4	10-25
maize	15	42-85
rice	4	20-70
wheat	10	25-73
skim milk powder	24	4-25
casein	2	13 (1 only specified)
total products cited	47	

a. Adapted from: E. Orr, The use of protein-rich foods for the relief of malnutrition in developing countries: an analysis of experience. Tropical Products Institute Publication G73, 1972.

In this project, firstly, all raw materials produced were considered. Secondly, the effect of exports on availability of indigenous raw materials was taken into account together with consideration of imported sources of nutrients as a means of economically providing nutritious food.

2.3.2 Quantification of raw material selection

For the design of low cost food products based on raw materials selected according to nutritional properties, information was required of :

1. Nutrient composition of raw materials
2. Nutrient specifications for food products - in this case balanced nutrient requirements
3. Costs of raw materials

All this data could be obtained for the Philippines. It was therefore possible to quantitatively select raw materials.

In the quantitative approach to problem solving, the components of the problem are described as :

1. An objective, or series of objectives
2. The variables being considered
3. The restrictions, if any, on the variables
4. A description of the problem situation i.e. a model representing the relationships between the variables and the objectives
5. A method of indicating the best course of action i.e. for solving the problem

The raw material selection problem was therefore described by :

1. Objectives. The objectives of this problem were to meet all nutritional requirements and minimize cost. Typically only one objective could be considered so that these two factors had to be combined or a major one selected. The nutritional requirements involved several individual functions, one for each nutrient, and also several interrelationships between nutrients. A function required to be constructed combining all these expressions in order to consider the nutritional requirements as one objective. They could be handled more simply as restrictions. Minimization of cost was simpler as it was a

function only of the costs of individual raw materials.

2. Variables. The variables in this problem were the raw materials, the nutrients, and the costs.

3. Restrictions. The nutrient requirements were treated as restrictions on each nutrient.

4. Model. A mathematical model described the situation in this problem.

Minimize the cost function

$$\sum_{j=1}^{n} c_j x_j$$

where c_j represents the cost per unit weight of each item and x_j the weight of each item, for n food raw materials; subject to restrictions

$$\sum_{j=1}^{n} a_{ij} x_j \geq b_j \qquad i = 1,2,---m$$

where a_{ij} represents the content of each nutrient per unit weight of each item and b_j the minimum requirement for each nutrient in the mixture, for j nutrients. Another restriction was required to ensure that only positive amounts of each food raw material were selected.

$$x_j \geq 0 \qquad j = 1,2,---n$$

5. Solution method. The problem description fitted the standard conditions of the linear programming model (35). The linear programming technique seemed then a suitable quantitative method for solving this problem. This technique required relationships between variables to be linear.

Assuming the data represented the composition of each food raw material for each nutrient and that there were no interactions between food constituents affecting this composition, then for a mixture of raw materials the total nutrient availability was the sum of the nutrient contribution from each raw material in the mixture. Although there was inherent variability in all food raw materials, caused by many factors, food composition tables were the only source of representative nutrient contributions. Availability of nutrients is affected by the other substances present e.g. sugar-amino acid interactions lower the availability of the amino acid lysine, phytic acid lowers the availability of phosphorus, similarly with oxalic acid and calcium. Little quantitative information was available on levels of these other substances and the magnitude of their effect on the nutrients for this wide variety of raw materials. These effects were assumed to be another source of inherent variability of the nutrient composition data but were neglected on this initial investigation. However this important factor should perhaps be catered for in a more comprehensive model at some later stage.

For the cost expression, the assumption of linearity was questionable. It is generally observed that the cost of an item varies with the amount considered, becoming cheaper as the amount increases. This causes difficulty and generally the cost function is assumed to be linear, with restrictions on the amount of each item which can be used at a fixed cost. Provided costs are fixed then the linearity condition is valid, as in this problem where the cost data used was the average unit value of each item from national production statistics.

Conclusion. The raw material selection problem can be described by a model which allows the linear programming technique to be used as the method of solution.

CHAPTER 3

SETTING UP A LINEAR PROGRAMMING MODEL

Past applications of linear programming in the food industry are considered in this chapter before describing the methods of solving linear programming problems. The major section details the setting up of the model for the problem, with the description of cost and nutritional data and nutritional restrictions. The flexibility of the computer method of solution is illustrated, then the modifications required in the initial model in order to obtain a solution, are discussed.

3.1 A literature review of linear programming applied to food problems

Linear programming has grown to be one of the major techniques in the applied mathematical field of operational research. It is applied where several variables compete for resources, subject to specifications, such that an overall objective is optimized.

According to Norman and Bowrey (36) the first concepts of linear programming were laid by Von Neumann in 1928 in game theory but it was not until 1949 that Dantzig proposed the mathematical theory now regarded as governing the solution of linear programming problems (37). Evidence that Philpott, in 1940, proposed the first mathematical methodology of solving such problems was proposed by some German authors (38). Nevertheless Dantzig's work led to the definition of the Simplex method of solution which provided a general calculation technique for linear programming problems. This technique with certain modifications is essentially the solution method used in computer codes today for solving the larger problems.

The first application of the technique in the food area was described by Stigler in 1945, before the development of the solution method (39). His 'cost of subsistence' problem described the nutritional requirements for nine nutrients of a moderately active man which were to be supplied by the cheapest mixture of foods from a list of seventy-seven foods. By trial and error, comparing the nutrients per dollar of each food, eventually only nine foods were retained. Using various linear combinations of these, his minimum cost solution contained five foods - wheat flour, evaporated milk, cabbage, spinach and dried navy beans. "No one recommends these diets for anyone, let alone everyone" was Stigler's comment on this mixture but he went on to criticise other minimum diet costs set up by dieticians at that time, as including unscientific or subjective judgements of palatability, variety and cultural effects which he did not consider justifiable!

3.1.1 General nutritional models

Smith, in 1959, solved Stigler's problem using the Simplex solution method; nine foods were required - wheat flour, corn meal, evaporated milk, peanut butter, lard, beef liver, cabbage, potatoes and spinach with slight total cost savings but the mixture was still criticised as being unpalatable and monotonous (40). Smith made the first effort to take account of palatability in his models by considering only foods bought by 90% of a consumer panel over a year. He placed minimum levels on the most popular foods and provided for compatible foods e.g. butter with bread, yeast with bread flour so that when one of these was in the solution, the appropriate amount of the other was also included. An interesting variation of the nutrition problem was to minimize the calorie content of diets (41). By raising the calorie level above the minimum a greater variety of foods was allowed in the mixtures. Wirths and co-workers in 1964, indicated the minimum costs of food mixtures to provide the average man with firstly food for a full day's nutritional requirements, and secondly part of the day's requirement through a main meal, and also as a meat-based meal (42). Using food level specifications, these models took some account of food preferences, and of combinations of foods for serving as well as cooking.

3.1.2 Menu planning

Peryam modified Smith's 'diet problem' to the 'menu planning' problem (43). Linear programming was used to select the optimum mixture of institutional meals, at least cost or possibly maximum acceptability, subject to restrictions on minimum nutritional composition, frequency of repetition of dish, suitability of dish for different meals and acceptability rating of the dish (44). Eckstein developed a new computer technique - 'the random approach' - for selecting the menu items for meals, discounting linear programming since monotonous and poorly acceptable diets, were selected even though at the lowest cost. Such diets, she maintained, were not desirable in the menu planning field where acceptability was the main criterion governing consumption (45). Her computer method selected menu items randomly and compared their properties - cost, nutritional value, colour, texture, flavour, shape, frequency of usage, acceptability level - with predetermined restrictions. Thus items which met these acceptability criteria were selected for the menus of a forthcoming period (46).

Eckstein criticised the confusion involved in defining diet problems and menu planning problems, maintaining that the two problems should be better defined : diet problems should be used for animal feed formulation, whereas menu planning problems should describe the procedure for the human. In the latter, conditions and data were less well defined and psychological factors of preference, acceptability and variety had to be considered if the models were to be realistic (47).

3.1.3 Planning of food supplies on national and global scales

Several authors have considered the use of linear programming techniques for planning food requirements at the minimum cost for different countries and areas of the world. Sukhatme in 1961 calculated the required increase in supply of ten food groups necessary to bring the quantity and quality of the diet of the world up to a defined target level at the minimum cost (48). He had minimum constraints for some groups of foods - e.g. fruits, for providing vitamins - and upper constraints on others - e.g. projected maximum fish catch - as well as minimum nutritional constraints on calories for quantity, and animal protein and total protein for quality.

Wirths and co-workers in Germany were concerned with improving the quantity and quality of protein in developing countries subject to the 1975 target levels of food production and the nutritional levels proposed by FAO (38). As well as restrictions on calories and protein, they included restrictions on certain amino acids based on the FAO provisional pattern (1957). They used ten natural food groups : meat, cereals, fish, oils and fats, milk, eggs, fruit and vegetables, legumes and nuts, sugar and potatoes as well as industrial protein sources - fish protein concentrate, petroleum protein concentrate and synthetic amino acids. They found that on the basis of linear programming analysis, industrial protein production should be increased, as against conventional animal production on increasingly limited land, to provide the cheapest sources of good quality protein.

Hrubý used linear programming to estimate least cost allowances of the food groups for the nutritional requirements of the Czech people (49). He set a 'biological tolerance' - a range around his nutritional and food group requirements. For example, calories could be ± 5% of the recommended level and the food group requirements could be 5-15% above the actual usage. He considered firstly just meeting the recorded food consumption and then forcing in extra meat, milk, fruit and vegetables into these allowances. This work was similar to that of the Belgian team who estimated the minimum costs of providing ten nutrients in diets taking into account the food preferences of Belgians (50).

At the town level, Patrick reported that using linear programming to select minimum cost diets based on local foods could lower the food bill of the poor people of Cristalena, Brazil from 112.6% to 75.7% of the family income. Palatability could be included, but at higher costs which exceeded the income of the very poor families (51).

Thus linear programming has been used by a few workers in different parts of the world in research directed towards planning the food allowances of nations, countries and towns at the lowest cost necessary to provide the nutrients needed by their population. These approaches have provided useful plans but whenever some measure of food habits or preferences or non-nutritional factors were included in the models, increased costs resulted. The models then all seem to be evolving similar to Smith's approach in 1959 although not to such a detailed extent as he considered (40).

3.1.4 Food formulation

In the area of food product formulation, the problem more closely approaches the diet problem of Eckstein's definition. Here the problem is to formulate a food product either at the minimum cost or such that profit is maximized, from a mixture of raw materials of known cost, nutritional composition and sometimes physical and chemical properties, subject to specifications on nutritional composition, component composition, physical, chemical and organoleptic properties. This is the typical animal feedstuffs application - a blending problem. The technique has been applied in many industries where blending occurs - petroleum refining (52), glass manufacture (53), and not one of the least of these has been the food industry.

Golomski stated that use of the technique in the food industry began around 1952 in the meat industry (54). Examples of the contribution that linear programming makes to maximizing profits by selection of most profitable product lines, manufacturing plans, machinery usage and inventory control have been described e.g. fluid milk industry (55), fruit and vegetable processing (56), dairy processing (57), processed meat industry (58), grain processing (59). Apart from the food combination model of Smith (40) cited previously, very little has been reported in the literature of more specific formulation applications due to the highly competitive interests of the individual food firms conducting such research. The main reports found provided examples of how linear programming could be applied to food formulation problems but few original research papers have been published.

Minimum cost formulations of bakery products could be designed with required moisture, protein and raw material components (60); fruit salad compositions and sausage formulations could be designed based on legal regulations and composition ranges based on organoleptic quality (61). Other raw material properties can be considered by empirically determined relationships. For example, colour and emulsifying properties of meat and strength of flour are capable of consideration in linear programming-based design of food formulations (62).

This has been extended into process design where relationships between raw material properties, product quality factors and processing variables are determined, in order to use linear programming to select optimum processing conditions. For example, spaghetti quality - in terms of colour, cooked weight, firmness and cooking weight - has been optimized by selection of suitable processing conditions based on linear regression equations relating process and quality variables determined experimentally (63).

It is in these areas where empirical measurements are necessary, that much more investigation is required of relationships between raw materials and the various types of products and processes, so that the selection of raw materials for properties such as functional and consumer acceptability properties can become practicable.

In nutritional product design, few workers have progressed beyond direct nutrient composition. Cavins and co-workers worked on cereal-based food mixtures for supplementary feeding to malnourished children. They firstly minimized cost at a fixed protein level subject to restrictions on the amino-acid pattern, which was to approximate that of hen's egg, to select mixtures of cereals and soy-flour (64). Subsequently, they constrained the amino-acid pattern of their mixtures to lie between that of CSM (a satisfactory cereal blend mixture with high protein quality) and that of hen's egg, as maximum contents of certain cereals and oilseeds were desired in the formulations at minimum cost (65). The parametric linear programming technique was used to systematically vary the fixed level of each cereal or oilseed and minimum cost mixtures were determined subject to each set of conditions. The maximum level of the component materials was eventually found, as above this level the problem became infeasible. They showed that formulations of the mixture could be altered, if any constituent became scarce or overabundant, without much change in the quality of the protein or the cost and flavour of the mixture.

Pinto also considered the least cost, best essential amino-acid pattern problem in the Latin American context (66). The formulation of Superamine - a nutritious flour made from wheat flour, soy flour, skim milk powder, pea flour with added vitamins, minerals and amino acids - was calculated at least cost by linear programming using an analogue computer (67). This method was found to be much faster and more easily manipulated than the normal digital computer methods.

Thus some attempt has been made to design balanced nutritional foods, particularly high protein food supplements, where only amino-acid interrelationships have been considered. The concept of balance of all nutrient requirements in food products has not been investigated.

3.1.5 Relation of work in this thesis to previous work

Food formulations are required for nutritional food products for use in S.E.Asia which utilise indigenous raw materials and provide balanced nutrient levels with overall minimization of cost. Consideration must also be given to characteristics desirable in food products for the area, e.g. flavour, texture, colour, product form. This overall project merges national food planning and formulation problems. Information from the simpler problems reviewed above proved useful in model construction.

1. National food supply models considered the basic problem of obtaining prescribed nutrient levels from food raw materials.
2. Food formulation models considered palatability and functional properties.
3. Menu planning models considered acceptability and organoleptic characteristics.

A much larger model was required than used in previous nutrition models (Table 3.1). A large number of raw materials were needed to represent the indigenous food raw material supply of the Philippines. One hundred and seventy were included, a much larger number than considered in most previous models. Generally less than one hundred were dealt with; the models of Smith (40) and Smith (41) being the only exceptions.

To provide a balanced supply of nutrients in the food products, as many nutrients as possible were taken into account. Twenty-six were considered here, four trace vitamins, ten essential amino acids and fibre in addition to the nutrients typically included in past nutrition models - calories, protein, fat, calcium, phosphorus, iron, vitamin A, thiamine, riboflavin, niacin, vitamin C.

The concept of balanced nutrition was also included in terms of interrelationships between nutrient levels - calories and B-vitamins,

Table 3.1 **Summary of linear programming models in nutrition problems**

Year	Author	Area	Number of foods	Number of nutrients	Nutrients
1945	Stigler (39)	U.S.A.	77	9	calories, protein, Ca, Fe, vit A, thiamine, riboflavin niacin, vit C
1959	Smith, V.E. (40)	U.S.A.	73 83 572	12 12 12	as Stigler plus carbohydrate, fat, P included restrictions on foods.
1961	Smith, P.E. (41)	U.S.A.	400 30 40	8 8 8	as Stigler less calories; plus vit. E
1961	Sukhatme (48)	World	10 food groups	3	calories, animal protein, vegetable protein
1964	Wirths et al. (42)	Germany	38+3 vitamin tablets	12	as Stigler plus total fat, vegetable fat and animal protein
1965	Wirths et al. (38)	Developing nations	10 food groups	8	calories, protein, animal protein, isoleucine, lysine, methionine, threonine and tryptophan
1966	de Moor et al. (50)	Belgium	n.a.	10	as Stigler plus fat
1969	Hrubý (49)	Czechoslovakia	16 food groups	11	as Stigler plus animal protein and fat
1969	Inglett et al. (64)	general	6	7	protein, lysine, S-amino acids, isoleucine, threonine tryptophan, valine
1971	Patrick et al. (51)	Brazil	n.a.	n.a.	n.a.
1971	Pinto (66)	Brazil	n.a.	n.a.	included essential amino acids
1972	Cavins et al. (65)	general	6	11	protein and 10 essential amino acids

calcium and phosphorus, fat and calories, protein and calories, amino acids and protein. This aspect has been ignored in past models except for the amino-acid pattern in Cavin's model (64,65).

This investigation then while similar to earlier national food supply problems needed a much larger and more complex model in initial efforts to quantify the selection of raw materials based on their nutritional properties. Thus a basic model was designed to which other raw material characteristics such as functional and consumer acceptability properties could be incorporated later in the project.

3.2 The application of linear programming to the problem

To apply linear programming to a problem requires that a model be constructed describing mathematically, in terms of linear equations and inequalities, the relationships between the variables and the extent to which they may be limited or constrained. To illustrate its use in the present nutritional problem, a simplified example is : Find the cheapest mixture of raw materials A and B, costing 3 cents and 8 cents per 100g respectively to give the daily nutritional requirements of an adult man, described as 3000kcal of energy, 80g of protein and 45g fat. The compositions of A and B are :

	Food A	Food B
energy (kcal/100g)	150	100
protein (g/100g)	2	8
fat (g/100g)	3	1

The model of this system can be written as :

$$\text{minimize} \quad 3a + 8b \qquad (1)$$

$$\text{subject to} \quad 150a + 100b \geq 3000 \qquad (2)$$

$$2a + 8b \geq 80 \qquad (3)$$

$$3a + b \geq 45 \qquad (4)$$

$$a,b \geq 0 \qquad (5)$$

Expression (1) is the objective function. It represents the relationship between the variables which is to be optimized, in this case the cost of the mixture is to be minimized. Expressions (2), (3), (4) are the constraints, representing the limitations placed on known relationships between the variables. Thus (2) represents the calorie constraint that total calories from A and B - 150a + 100b - must at least equal the desired value of 3000. Similarly (3) represents the protein constraint and (4) the fat constraint. The constraint values 3000, 84, 45 are termed the right hand side. This group of inequalities and equalities also define the specifications or technology matrix of the model. The expression (5) - the non-negativity constraints - indicates that negative values for the variables a and b are not allowed in a practical problem. This simple problem can be solved graphically as shown in Fig.3.1. Any point in the area bounded by the lines governing the energy, protein and fat constraints - the feasible area - represents a suitable nutritional mixture but that with the lowest cost is sought. If the objective function is denoted by $z = 3a + 8b$, then decreasing the value of z from an arbitarily chosen value of 180 results in the line ECF coinciding with the feasible area at the vertex C. Any further decrease in z gives solutions outside the feasible area - infeasible solutions. The values of a and b at the vertex, 16 and 6 respectively, represent the optimum solution to the problem with the minimum cost of 96 cents.

It can be mathematically proven that when the objective is linear and the feasible area is convex and bounded by straight lines, an optimum solution will always lie at one of the vertices of the feasible area (68).

Larger models cannot be solved graphically like this but the basic procedure is similar. The mathematical methods essentially evaluate the objective function at selected vertices, so that the minimum value is reached. Dantzig's original Simplex method involves full calculation at each vertex, on every matrix element and requires large storage capacity in the computer and long computer operating times for optimization of large problems (37). The development of the Revised Simplex modification alleviated these problems somewhat and allowed larger matrices to be

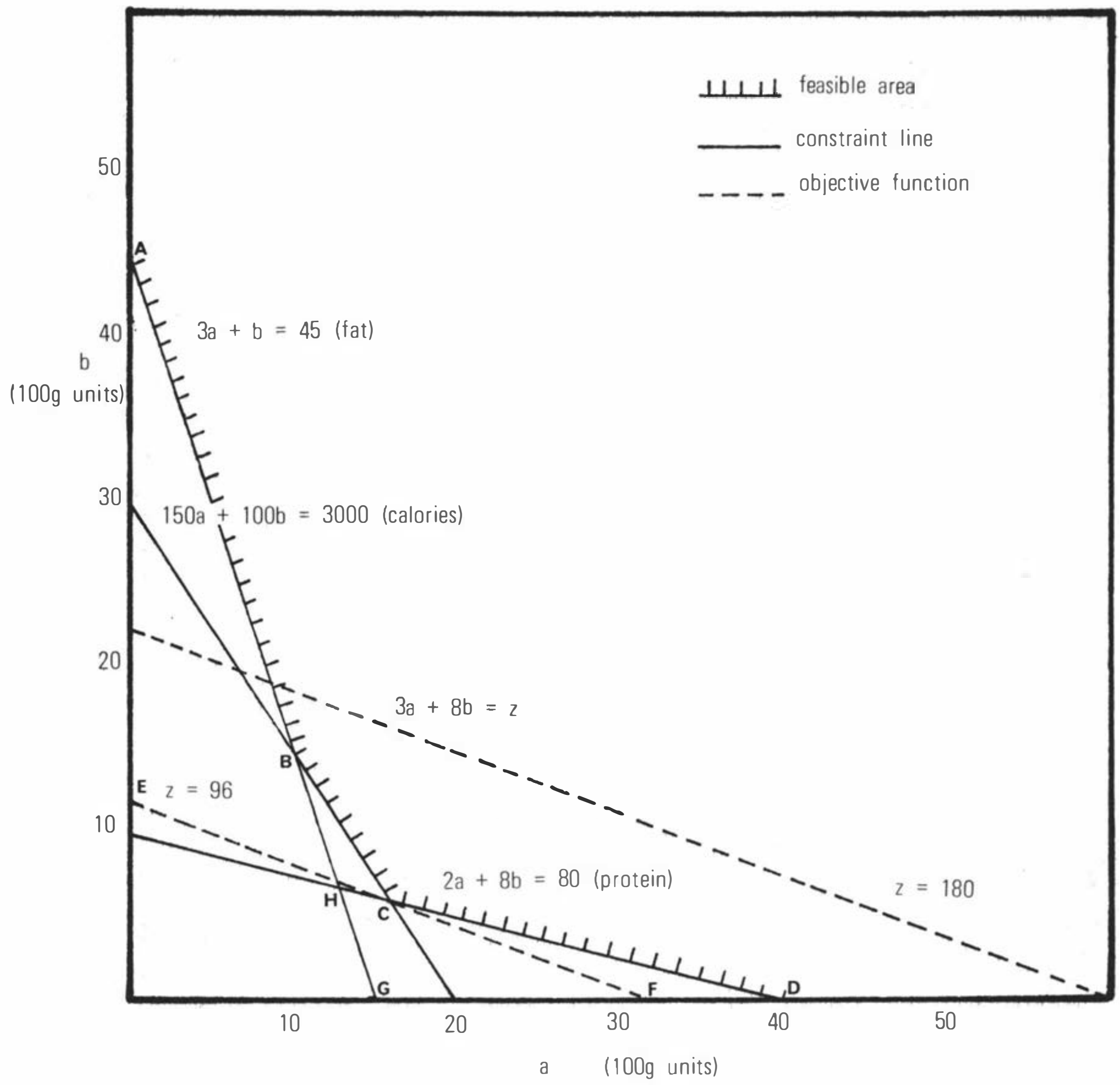


Figure 3.1 **Graphic representation of a linear programming model for a simple nutrition problem**

considered - computations are performed on fewer elements of the matrix and less data requires to be stored at each stage in the calculation. This method has been further revised to allow even more efficient handling of data with the product form of the inverse method (69). Appendix 1 illustrates the methodology of these procedures.

In this investigation, the computer program used for solving the linear programming problem uses the product form of the inverse method in its computation.

3.2.1 The linear programming model

The raw material selection problem can be described by a similar model; the objective is to minimize the total cost of the mixture; the technology matrix describes the availability of each nutrient from each food raw material and the requirement which is to be met for each nutrient in the mixture; and the non-negativity constraint retains each raw material level at a positive or zero value in the solution:

$$\text{minimize} \quad c_1 x_1 + c_2 x_2 + \ldots c_n x_n$$

$$\text{subject to} \quad a_{11} x_1 + a_{12} x_2 + \ldots a_{1n} x_n \begin{pmatrix} \leq \\ = \\ \geq \end{pmatrix} b_1$$

$$a_{21} x_1 + a_{22} x_2 + \ldots a_{2n} x_n \begin{pmatrix} \leq \\ = \\ \geq \end{pmatrix} b_2$$

$$\vdots \qquad \qquad \qquad \vdots$$

$$a_{m1} x_1 + a_{m2} x_2 + \ldots a_{mn} x_n \begin{pmatrix} \geq \\ = \\ \leq \end{pmatrix} b_m$$

$$\text{and} \quad x_1 \geq 0$$

$$x_2 \geq 0$$

$$\vdots$$

$$x_n \geq 0$$

where

- m is the number of nutrients or rows
- n is the number of food raw materials or columns
- a_{ij} is the number of units of ith nutrient in one unit of food raw material j
- b_i is the specified number of units of nutrient i required
- c_j is the cost of one unit of food raw material j
- x_j is the number of units of food raw material j in the solution

Setting up the problem in this form is compatible with computer programs designed to solve for each x_j.

The cost per unit for each food raw material was required to define the objective function. For the technology matrix, much more data had to be found: the composition of each nutrient in each raw material; and specifications of the nutrient levels required in the food mixture. The nutrient levels were based on the nutritional requirements of the population, and defined a minimum level for each nutrient, a maximum level in some cases and interrelationships between nutrients where necessary. These conditions had to be expressed in the linear equality or inequality form.

This data had to be prepared in a form suitable for input into the computer method used for solution.

3.3 Philippine cost and nutritional data

FAO agricultural and fishery statistics publications and information made available by the Philippines Bureaux of Agricultural Economics and Fisheries provided a list of the major indigenous food raw materials in the Philippines (70,71,72). This list was extended to include derivatives of these materials e.g. liver, intestines, kidney from meat animals. Thus a comprehensive list of one hundred and seventy indigenous food raw materials of the Philippines was obtained.

3.3.1 Costs

Costs were obtained from the value of production in agricultural production statistics, 1970 costs for thirty six materials from Philippine statistics, 1968 costs for fifty one fish species and thirteen other materials from FAO statistics. The remaining seventy costs were estimated by a Filipino member of staff and represented 1971 prices at the retail level (73).

This cost data could only be considered approximate, but provided relative scaling of the costs of the different food types. It was later found in experiments on the model that the accuracy of the costs was not important in finding the optimum, but of course minimum cost depended on the actual costs provided. Although completely accurate cost data were not available, it was necessary to express this data to the third decimal place after conversion calculations to US dollars in order to sufficiently scale the different food costs. This unit was most common in the initial stages of data collection where mixed units were obtained from the different sources. It would have been preferable to use the Philippine peso cost unit but initially the majority of the data from international statistics were expressed in US dollars. Later, when more recent data was obtained, the peso unit was employed (74).

3.3.2 Nutritional composition data

Data was sought on the composition of the food raw materials for the twenty six nutrients listed in Table 3.2.

Table 3.2 The nutrients considered in the problem

Proximate analysis	Minerals	Vitamins	Amino acids
calories	calcium	vitamin A	isoleucine
protein	phosphorus	thiamine	leucine
fat	iron	riboflavin	lysine
fibre		niacin	methionine
		vitamin C	cystine
		vitamin B6	phenylalanine
		vitamin B12	tyrosine
		pantothenic acid	threonine
			tryptophan
		folic acid	valine

The various sources of this data and their frequency of use, are indicated in Appendix 2. The major source was the publication of the Philippines Institute of Nutrition which provided full data on the composition of local raw materials for proximate analysis, minerals, vitamins and some amino acids (75). This was augmented with USDA food composition tables which included data on vitamin B6, B12 and pantothenic acid (76,77,78), British tables which also provided folic acid data (79) and earlier Philippines' tables (80). Philippine reports provided some vitamin B12 data (81) and at a later stage, recent data on folic acid and amino-acid composition of Philippine foods (82,83). Amino-acid data were taken chiefly from a recent FAO publication (84) and the Commonwealth Agricultural Bureaux Bulletin (85). Other minor sources were used. Approximately 68% of the elements of the matrix were defined from this data. To complete the matrix as fully as possible, estimations were made of nutrient composition data where possible.

Data was assumed for approximately 20% of the matrix elements from data of similar raw materials :

1. Where the raw material was similar to a documented type, the missing data was taken as that of the documented raw material. This estimation was most frequently used for vitamin B6, B12 and pantothenic acid, e.g. bonito was given tuna values for these vitamins; buffalo liver was given beef liver values for B6 and pantothenic acid; and amino-acid data for chicken were assigned to all poultry species.
2. Where individual raw materials belonged to a food group, data representative of the food group was used: folic acid values for most fish species were taken as that provided for low-fat fish; many of the offal products were assigned amino-acid values for offal of different animals; vitamin B12 content for all plants was taken as zero.
3. The majority of unrecorded fibre levels were for non-plant materials - meat, eggs and fish - which do not contain fibre so zero entries were recorded for these materials.
4. Minimum amino-acid compositions for the fruit group were assigned to individual fruits.

Data was calculated for approximately 6% of the matrix from related information which was available :

1. Where calorie values were not given an approximate value was calculated by multiplying the fat level by the factor 9kcal/g and protein and carbohydrate levels by the factor 4kcal/g. This calculation was made for beef and pig blood, cottonseed and goat's large intestine.
2. In many of the offal products, full data for amino acids was available for one animal species only. This data was scaled for the other products according to their relative protein content, e.g. the amino-acid content of the large intestine of beef, buffalo and goat was calculated from data for pig large intestine in this way and also turkey

liver amino acids were calculated from chicken liver data.

3. In obtaining data from different sources, the amino-acid total exceeded the recorded protein level in several cases, data was scaled down by the protein ratio method to correspond to the protein level found in the proximate analysis data e.g. the protein analysis for groundnut from Philippines tables and amino-acid data from FAO showed this discrepancy so the amino-acid composition was recalculated on the basis of the Philippine protein value.

4. Individual amino-acid levels for the citrus fruits - lemon, lime, pummelo - where not otherwise available were taken as those recorded for citrus pulp in the Commonwealth Agricultural Bureaux publication and then scaled according to their respective protein levels.

Approximately 6% of the matrix elements were blank. The majority of these were for trace vitamin data - vitamin B6, pantothenic acid and folic acid.

Nutrient units were expressed per 100g sample of the food to the accuracy of the unit described below, with some description of derivation of the nutrient composition data.

Calories:	nearest kilocalorie (kcal)	calculated using physiological energy factors for fat,protein and carbohydrate (9,4,4 where otherwise unknown)
Protein:	nearest tenth of a gram(g)	calculated from estimated nitrogen content of food assuming 16% nitrogen in protein. Other factors used for cereals, beans & nuts, milk (80)
Fat:	nearest tenth of a gram(g)	by extraction estimation
Fibre:	nearest tenth of a gram(g)	by extraction estimation
Calcium:	nearest milligram (mg)	total(no correction for oxalate or phytate salts which make some of the mineral unavailable to the body)
Phosphorus:	nearest milligram (mg)	total (no correction for presence as combined phytic acid)
Iron:	nearest tenth of a milligram (mg)	total (no correction for phytate unavailability or absorption)

Vitamin A:	nearest ten international units (iu)	where "trace", 5iu recorded 0.6μg β carotene = 1iu 1.2μg other carotenes = 1iu 0.3μg retinol (Vit A alcohol) = 1iu
Thiamine:	nearest one hundredth of a milligram (mg)	where "trace", 0.005mg recorded
Riboflavin:	nearest one hundredth of a milligram (mg)	where "trace", 0.005mg recorded
Niacin:	nearest tenth of a milligram (mg)	1mg niacin = 1 niacin equivalent = 60mg tryptophan tryptophan contribution not considered
Vitamin C:	nearest milligram (mg)	reduced form of ascorbic acid from USDA, total ascorbic acid from Philippines Food Tables
Vitamin B6:	nearest thousandth of a milligram (mg)	pyridoxal, pyridoxol and pyrodoxamine content; hydrochlorides corrected to free base
Vitamin B12:	nearest thousandth of a milligram (mg)	microbiological estimation
Pantothenic acid:	nearest thousandth of a milligram (mg)	pantothenate estimations corrected to pantothenic acid
Folic acid:	nearest ten thousandth of a milligram (mg)	generally total folate measured
Amino acids:	nearest milligram (mg)	average values of several independent assays for each amino acid; chromatographic estimations used where available

Edible portion compositions were used so that the solutions to the problem would give the nutritional composition of a mixture of raw materials prepared ready for processing. Generally there was no indication of the variation between samples in the food composition tables. Therefore no allowances could be made for variations in composition of some foods due to seasonal effects, area of production, time of harvesting, length of storage time prior to analysis. This was because these effects had not been quantified sufficiently to provide statistical allowances of variation within food composition data. Thus data only approximated the composition of raw materials, but as this was the only type of data available, its use in indicating the relative differences in nutritional composition between the different materials was considered justified.

3.4 Nutritional constraints

The constraints on the nutrient composition were expressed in terms of the weighted average recommended intake for the population distribution of the Philippines in 1968, the most recent figures (86), for calories, protein, calcium, vitamins A,C,B6,B12 and folic acid since such nutrient requirement data were published for different demographic groups (see Appendix 3). Constraints on the other nutrients were fixed by methods explained in the full discussion on nutrient allowances below.

Several nutrient allowances were available, based on the body weight of the individual or the average body weight of the different age groups in the population (87,88,89). Intengen (90) chose target weights for estimations of Philippines' allowances: one standard deviation above present weights for up to 19 year-old and an extra 3kg for the reference man and woman. These target body weights were not used in calculating minimum nutrient allowances since they did not represent the actual situation, but they could determine maximum allowances to retain nutrients in balance. Recorded Filipino body weight data (91) were used in calculating minimum nutrient allowances (see Table 3.3 and Appendix 3).

3.4.1 Energy requirements

For the 15 year old and under groups, Intengen used FAO/WHO allowances based on body weights (90). For the 16-19 years old group she used American allowances (92) but for this model, the lower FAO/WHO allowances were used, since higher allowances did not seem warranted. For adults, Florentino (91) calculated their requirements as the energy used up during activity on an average day by the Filipino reference man and woman, based on similar American calculations (92). These requirements were used here (Table 3.3). For the older age groups, FAO/WHO recommended a proportion of the reference man allowance due to lower activity and decreasing body weights in this group (87). Table 3.4 indicates these reduced allowances in this problem where calculations were based on both Filipino reference man and woman requirements.

Table 3.3 Estimation of the energy expenditure of reference Filipino adults[a]

		Male (25y)				Female (25y)			
		Rate of expenditure (kcal/min)		Total daily expenditure (kcal)		Rate of expenditure (kcal/min)		Total daily expenditure (kcal)	
Activity	Average time spent (h)	Present weight (53kg)	Target weight (56kg)	Present weight (53kg)	Target weight (56kg)	Present weight (46kg)	Target weight (49kg)	Present weight (46kg)	Target weight (49kg)
sleeping, lying	8	0.90	0.93	432	446	0.84	0.88	403	422
sitting	5	1.22	1.28	366	384	0.93	0.97	279	291
standing	6	2.04	2.13	734	767	1.27	1.33	457	479
walking	3	2.45	2.55	441	459	2.11	2.21	380	398
others	2	3.68	3.83	442	460	2.54	2.65	304	318
total [b]				2450	2550			1850	1950

a. Adapted from data of Florentino (91)

b. Total rounded up to nearest 50kcal.

The extra allowances for pregnancy and lactation were FAO allowances - 400kcal and 1000kcal per day respectively, the former covering the full 9 month period of pregnancy and the latter, 8 months lactation(87).

From this data (see Appendix 3) and population distribution (Appendix 4), the weighted average levels based on present weight and target weight requirements gave a lower calorie limit of 2030 and an upper limit of 2210kcal respectively.

Table 3.4 Calorie allowances for adult age groups

	Percent reference level	Present weight allowance kcal		Target weight allowance kcal	
		Male	Female	Male	Female
reference (20–29y)	100	2450	1850	2550	1950
30–39y	97	2400	1800	2500	1900
40–49y	94	2300	1750	2400	1850
50-59y	86.5	2150	1600	2200	1700
60–69y	79	1950	1500	2000	1550
70 and over	69	1700	1300	1750	1350

3.4.2 Protein requirement

These levels were taken directly from Intengen (90). Her data were based on the 1965 FAO/WHO Expert Group recommendations (88), stated in terms of reference protein with net protein utilization (NPU) of 100. A correction was made for the average NPU of 63 for the Filipino rice diet (90) since NPU could not be directly accommodated in the model (See 5.1.3). Further corrections were made so that the protein level provided at least 8% of total calories, a particular requirement for children (88). Lower percentages were initially obtained by Intengen's calculation method.

Calculations, based on this data (Appendix 3) provided range constraints of between 49.4 and 53.7g for protein.

3.4.3 Fat requirement

The British Medical Association Committee in 1961 stated that "(they were) unaware of any evidence that there was a minimum daily intake of fat required to maintain the health and well being of the human body" (93). Beaton and McHenry maintained that the only human obligatory reason for including fat in the diet was to supply the essential fatty acids but it was also desirable as a concentrated calorie source (9kcal/g), as a means of increasing palatability of food due to lubricating function and slow absorption rate causing high satiety and as a possible source of fat soluble vitamins (94). However, there are no recommended levels of intake although desirable ranges of fat levels in terms of percentage of total calories as fat are described in most national nutrient requirements: for UK, at least 25% rising to 35% for high physical activity; for Canada, a minimum of 25%; for Holland, a maximum of 30%; for South Africa, a range of 20-30% (94); for Australia, Hutchinson (95) followed the UK recommendations of 25% minimum, with 35% for very active persons, children and adolescents.

Davidson and Passmore (96), although admitting a lack of scientific precision in recommending fat intakes, maintained that "any community which wishes to feed well and in a civilised tradition (east or west) must obtain at least 20% of its energy from fat and that individuals in prosperous communities who lead sedentary lives and have reached middle age would be well advised to limit their fat intake to 25-30% of energy".

Although average levels of fat intake in Eastern countries did not approach these levels (see Table 3.5) it seemed that the range suggested as satisfactory - 20-35% total calories as fat - be selected as limits on fat content in the optimal food mixture. The lower limit thus provided enough fat for satiety, palatability factors and the upper limit sufficient increase for high energy requirements and some limit to possible health dangers due to excessive fat intake. This range corresponded with minimum fat constraints used in other models as direct fat constraints, equivalent to 32 and 34% calorie constraints (42,40). In this model constraints were expressed as interrelationships between total calories and fat levels.

Table 3.5 Calories from fat in Asian countries [a]

Country	Fat available g/caput/d	Calories available kcal/caput/d	Percent [b] calories from fat	Year [c]
Ceylon	44	2150	18	1968 T
Taiwan	54	2510	19	1968 T
India	24	1900	11	1966/67-1968/69 T
Japan	48	2460	18	1968 T
Korea	15	2430	6	1967 T
Pakistan	33	2230	13	1967/68 T
Philippines	30	2010	14	1968 T
Thailand	32	2100	14	1964-66 F

a. Calculated from data in FAO Production Yearbook 1969, FAO, Rome, 1970.

b. Rounded to nearest integer.

c. T is tentative, F is FAO estimate.

For input to the computer program , they were expressed as linear equations of the form:

$$LOFAT = 9.0FAT - 0.2CAL \geq 0$$

$$HIFAT = 9.0FAT - 0.35CAL \leq 0$$

where LOFAT represented the lower bound on the fat level; 9.0FAT the number of calories from fat (9kcal/g fat), 0.2CAL the 20% total calories factor. New matrix rows were formed for LOFAT and HIFAT the new columns for FAT and CAL with elements 9.0 and - 0.2 respectively. The LOFAT factor was constrained with a lower bound of zero (and upper bound of ∞) and HIFAT , the upper limit on fat content which was analogously defined, was constrained to an upper bound of zero and lower bound of $-\infty$ In this way, the fat level was fixed between 20% and 35% calories.

3.4.4 Fibre requirement

Plant fibre is recognised as an essential constituent of the diet giving bulk and consistency to faecal matter in the body to maintain laxation. There were no recommended fibre levels for the Philippines' diet. Almost no data were available on the levels necessary for humans. However, in 1956 Robinson reported that the daily need for crude fibre had been estimated in 1932 to be about 90 to 100mg per kg body weight or approximately 6g per day for the adult (97). It has been stated elsewhere that fibre equivalent to approximately 40kcal/d from hemicelluloses and 20kcal/d from celluloses could be absorbed by intestinal organisms(95). This, at the rate of 4kcal/g from carbohydrate, would be available from 15g/d mixed polysaccharides. This corresponded to the statement by Davidson and Passmore that "human diets contain up to 15g of cellulose daily depending on their content of fruit, vegetables and coarse cereals" (96). Since fibre is made up chiefly from celluloses, hemicelluloses and lignin these fibre levels seemed reasonable for use as constraints on fibre content i.e. lower limit of 6g/d and upper limit of 15g/d.

3.4.5 Calcium requirement

The levels recommended by Intengen (90) concurred with the upper limits of the FAO/WHO ranges (98), so this range was used to provide upper and lower limits for calcium requirements. The extra allowance for pregnancy was required only for the third trimester to provide for growth of the foetus, and an extra allowance for the lactation period was necessary due to loss of calcium in human milk. Appendix 3 shows the calcium requirements for the different age groups, from which the range constraints, 452 and 553mg, were calculated. Earlier workers, Wirths, Stigler and Hrubý (42,39,49) used higher levels of 800-900mg, but lower levels have been suggested by later nutritional research (98).

3.4.6 Phosphorus requirement

Philippines' sources gave no allowance but suggested that for children and pregnant women the phosphorus level should at least equal the calcium level with an intake on 150% the calcium level for other groups (90). Specific minimum requirements have been recommended only for infant children who are not breast fed: 6 months and younger require phosphorus at 2/3rds the calcium allowance and those up to 1 year at

4/5ths the calcium requirement. From 1 year onwards, the recommended level is the same as that for calcium (92). Beaton and McHenry stated that phosphorus levels up to 150% those of calcium were satisfactory for the American people (94). Wirths took this level as his lower limit but had no upper limit (42). However the definite requirement given for children and pregnant women of 100% calcium level was taken initially as the constraint. This interrelationship between calcium and phosphorus was defined as

$$PCON = P - CA = 0$$

where PCON represented the relationship that P (phosphorus) minus CA (calcium) equals zero.

3.4.7 Iron requirement

Since women have the highest requirement for iron due to menstruation losses, child-bearing requirements and lactation requirements, the FAO/WHO expert group reporting on iron requirements suggested that this female allowance be taken for all age groups to ensure that the needs of the female would be met (99). The requirement for menstruating women including basal losses was stated as 2.7 mg per day by Intengen, on target weight basis (90). However, the recommended intake is dependent on the absorption efficiency from the diet which FAO/WHO stated is related to the content of animal derived foods in the diet. In the Philippine diet, this amounted to 11% of total calorie intake, which corresponded to absorption of 15% iron from the diet on FAO/WHO scales (99). Thus the requirement for menstruating women was scaled up to 18 mg/d. Although there was no direct relationship implied between calorie intake and iron requirement, FAO/WHO recommended that the iron allowance be distributed according to calorie intake so that within households the female would obtain her full allowance. The average female calorie allowance (20-49y) for the target weight women was 1900kcal/d representing an iron allowance of 9.5mg/1000kcal and for present weight women the allowance was 17.6mg for an average calorie allowance of 1800kcal/d, or 9.8mg/1000kcal. Hence, a minimum level of 10mg iron per 1000kcal was selected to cover the iron requirements of the population. No extra allowance was considered for pregnancy or lactation since it was assumed that in receiving the full menstruation allowance there would be a sufficient store of iron to cover these extra needs. Other workers used lower levels of between 10 and 15mg in their models, where they considered only the male requirements in their constraints (39,40,42,49).

This iron relationship with calories was defined in linear equation form as :

$$LOFE = FE - 0.01CAL \geq 0$$

where LOFE indicated the lower limit of iron level, FE the iron level and 0.01CAL the calorie relationship (0.01mg Fe/kcal).

3.4.8 Vitamin A requirement

Intengen did not indicate how the Filipino requirements for vitamin A were evaluated except those for the adult male. In an attempt to calculate this data from the appropriate FAO/WHO expert group report (100) several problems appeared.

1. If the requirements were calculated from the FAO graph of retinol requirement per kg body weight against age then the allowances should be as described in Table 3.6. These calculations involved taking account of the average retinol content of vitamin A sources in the Philippines' diet, 13% (90).

This method of calculation taken from the FAO/WHO source (100), is described below for adults at present weight

Total retinol requirement = 53 x 12 = 636μg

Table 3.6 Calculation of vitamin A requirements for different age groups

Age group	Present weight	Retinol requirement per kg body weight	Retinol requirement total	Vitamin A from mixed sources [a]	Target weight	Retinol requirement total	Vitamin A from mixed sources [a]	Vitamin A requirement (Intengen)
	(kg)	(μg)	(μg)	(iu)	(kg)	(μg)	(iu)	(iu)
<6m	-	-	-	- [b]	-	-	- [b]	-
6–12m	8	34	272	2000	9	306	2500	1500
1–3y	11	20	220	1500	12	240	2000	2000
4–6y	15.5	15.5	240	2000	17	264	2000	2500
7–9y	20.5	15	308	2500	25	375	3000	3000
10–12y	28	16	448	3500	33	528	4000	4000
13–15y	39	15	585	4000	44	682	5000	5000
16–19y	50	13	650	4500	55	715	5000	5000
20 and over	53	12	636	4500	56	672	5000	5000

a. Rounded to nearest 500iu.

b. Requirement for non-breast-fed infants is lactation allowance of 3000iu.

The formula to obtain the amount of mixed vitamin A active compounds necessary to provide the equivalent of this amount of retinol is given by :

$$\text{Amount (X)} = \frac{\text{Recommended intake of retinol}}{0.167k + (1 - k)}$$

where k is the proportion of β-carotene in the vitamin A compounds in the diet. In the Philippines, the proportion of β-carotene has been estimated as 87%, the proportion of retinol being 13%.

$$\text{Thus} \quad X = \frac{636}{0.167 \times 0.87 + (1 - 0.87)}$$

$$= 2318\mu g$$

It was required to convert this to international units as the composition vitamin A in foods was described in those units.

Since 0.3μg retinol is 1iu and 0.6μg carotene is 1iu

$$\text{Then} \quad X = \frac{2318 \times 0.87}{0.6} + \frac{2318 \times 0.13}{0.3} = 4360\text{iu}$$

which was rounded up to 4500 iu.

2. It seemed that separate calculations were not made for females, even though data on their body weights were available. Instead the higher male requirement was used in all cases in agreement with the FAO/WHO published method. This also meant that no extra recommendation was required for pregnancy since this additional requirement would be covered by the higher allowance calculated on the male body weight.

3. The extra allowance for lactation was not calculated correctly by Intengen (90). She stated that 2000iu would be adequate for the lactation period to make up the loss due to breast feeding. For 850ml milk per day with an average content of 49μg retinol per 100ml (90) a loss of 420μg retinol per day would result, corresponding to a loss of 420/0.3 or 1400iu vitamin A. This seemed to be scaled up to 2000iu for safety. If this amount of lost vitamin A has to be made up from food then account of the concentration of carotenes in the diet must be taken in estimating the allowance by a similar calculation as that above. This yielded an allowance of 1530μg mixed vitamin A, equivalent to 2900iu or 3000iu if

rounded upwards. This level was also taken for 0-6 month old infants as their allowance was based solely on human milk composition: if breast fed, then their requirement would be met directly from breast milk; if weaned early then 3000iu of vitamin A from food would be required.

Thus minimum and maximum levels of 3900 and 4450iu vitamin A were calculated for the present and target weight populations. These levels were similar to the lower bound in Hrubý's model of 4000iu (49); Stigler (39) and Smith (40) used 5000iu and Wirths used a much higher bound, 8830, because of high carotene concentration (42).

3.4.9 Thiamine, riboflavin and niacin requirements

As recommended by the FAO/WHO group (99), requirements for these vitamins were reported in terms of the calorie allowances by Intengen, based on Philippines experiments (90):

1. Thiamine. Requirement of 0.4mg/1000kcal with additional 20% for individual variation, and 10% for efficient utilization resulting in an allowance of 0.5mg/1000kcal (cf FAO level of 0.4mg/1000kcal including 20% for variability).

2. Riboflavin. A requirement of 0.4mg/1000kcal with the 20% variability factor giving an allowance of 0.5mg/1000kcal (cf FAO level of 0.55mg/1000kcal).

3. Niacin. The same level as FAO/WHO was reported i.e. 6.6 niacin equivalents per 1000kcal, 1 niacin equivalent equalling 60mg tryptophan or 1mg niacin. Inclusion of the niacin/tryptophan interrelationship in the model would allow tryptophan to be selected as a source of niacin. This was not desirable since then the availability of tryptophan in the amino-acid pattern would be reduced, thus lowering the overall protein quality when tryptophan was limiting. The constraint was expressed then in terms only of niacin content of raw materials.

These three nutrient levels could be fixed directly by the calorie level. They were expressed as equations in the normal way :

$$LOTHIA = 1.0THIA - 0.0005CAL = 0$$

$$LORIBO = 1.0RIBO - 0.0005CAL = 0$$

$$LONIA = 1.0NIA - 0.0066CAL = 0$$

where LOTHIA , LORIBO , LONIA represented the limits of thiamine, riboflavin and niacin respectively; THIA , RIBO , NIA represented their levels and 0.0005CAL , 0.0005CAL , and 0.0066CAL represented their respective relationships with calories, CAL .
LOTHIA, LORIBO, LONIA were fixed at zero to represent these relationships.

3.4.10 Vitamin C (ascorbic acid) requirement

Philippines' recommendations (90) were somewhat higher than those of FAO/WHO (99) and National Research Council (92) (Table 3.7).

Table 3.7 Vitamin C requirements from various sources

Age group	Recommended intake (mg/caput/d)		
	Intengen [a] (Philippines)	FAO/WHO [b]	National Research Council (USA) [c]
< 12m	30	20	35
1–3y	35	20	40
4–6y	50	20	40
7–9y	60	20	40
10–12y	75	20	40
13–15y (male)	90	30	45
13–15y(female)	80	30	45
16–19y(male)	100	30	55
16–19y(female)	80	30	50
Adult(male)	75	30	60
Adult(female)	70	30	55
Pregnancy (2nd and 3rd trimester)	+30	+20	+5
Lactation	+80	+20	+5

a. Taken from Intengen (90).

b. Taken from FAO/WHO report (99).

c. Taken from NRC publication (92)

The minimum requirement was shown to be approximately 6.5mg per day in British experiments and in other studies, where excessive quantities of vitamin C were taken (75 - 350mg daily), only 21.5 ± 8.1mg was metabolised (99). On this evidence FAO/WHO recommended intakes of 30mg/d for adults, 20mg extra for the last 6 months of pregnancy and also the lactation period, and the level of 20mg/d for children up to 12y (99).

NRC related their requirements to body weight for age groups past 12y, according to the expression 2.5x $(\text{weight})^{0.75}$ (92). Since Filipinos body weight did not approach those of Americans their requirement should be lower.

The FAO/WHO figures did not include a margin for lability of the vitamin although individual variation was covered to some extent by the 30mg level (21.5 ± 8.1), so these levels could be too low for population estimates. The Filipino recommendations seemed excessive, even taking account of lability and individual variation, so these levels were not used as constraints. Initially the FAO/WHO levels were taken as lower limits and the American figures as upper limits on ascorbic acid allowances, providing a range for ascorbic acid of 29mg and 53mg from weighted average levels from the population distribution calculation. Previous workers used similar levels between 30 and 75mg in their experiments (39,40,42,49,50).

3.4.11 Vitamin B6 requirement

The data described in Appendix 3 was taken from the NRC report (92), there being no data from FAO/WHO or from the Filipino source. This provided an average population requirement of 1.68mg for vitamin B6.

3.4.12 Vitamin B12 requirement

Data shown in Appendix 3 was obtained from an FAO/WHO report (99) which corresponded with the NRC recommendations (92). This provided an average for the population of 0.002mg as minimum for vitamin B12.

3.4.13 Pantothenic acid requirement

No data on requirements were found but the NRC report indicated levels of intake in the US stated as satisfactory (92). Children and adults obtained between 5-10mg/d and breast fed infants received approximately 2mg/l milk so a similar level was taken as allowance for weaned infants. No constraint was used for this nutrient, at this time, save the automatically assigned lower bound of zero and upper bound of infinity.

3.4.14 Folic acid requirement

FAO/WHO estimated allowances from sparse clinical measurements then doubled up these levels to account for availability and lability in foods (99). NRC quoted higher requirements and also included a greater margin for safety (92). Both sets of data were used to indicate a range of recommended intakes (Appendix 3). Upper and lower constraints of 0.18 and 0.37mg were calculated.

3.4.15 Essential amino-acid requirements

Work on estimation of the requirements of the essential amino-acids for humans has been mainly on two fronts.

1. Absolute allowances. Rose, in a series of nitrogen balance experiments on humans over the period 1942-55, estimated the minimal requirements of the amino acids essential for maintenance of body nitrogen and took the highest requirement of his group of volunteers as the recommended minimum (Table 3.8). He doubled this value to represent the 'safe' level of intake (101). He also compared the male requirements with the lower requirements found for young women by Leverton (Table 3.8).

Holt and Snyderman (102) related their adult requirements to body weight, although Rose originally found no evidence for a relationship between body weight and amino-acid intake. For an average male weight of 60kg, these levels were also below those of Rose but they approximated the women's requirements of Leverton (Table 3.8).

It seemed then that adult requirements could not be definitely stated. For children, requirements were better established. Amino acids are needed not only for maintenance (the only requirement for adults) but also for growth, protein reserves and chemical maturation e.g. antibody formation after birth. Thus Holt and Snyderman indicated that the requirements of infants and young boys were much higher than those for adults (Table 3.8), mostly 2 to 4 times as much, with histidine becoming essential for infants (102).

Table 3.8 Essential amino acid requirements for various population groups

Amino acid	Minimum requirement (g/caput/d)					
	Adult males[a]	Adult females[a]	Adult males[b]	Boys[c]	Girls[d]	Infants[e]
l–isoleucine	0.70	-	0.47	0.98	1.0	1.07
l–leucine	1.10	0.62	0.51	1.71	1.5	1.35
l–lysine	0.80	-	0.36	2.06	1.6	0.93
l–methionine	1.10	-	0.23	0.95	0.80	0.41
l–phenylalanine	1.10	0.22	0.22	0.95	0.80	0.81
l–threonine	0.50	0.31	0.30	1.19	1.0	0.78
l–tryptophan	0.25	0.16	0.15	0.13	0.12	0.20
l–valine	0.80	0.65	0.54	1.16	0.90	0.95
l–histidine	-	-	-	-	-	0.31

a. Taken from Rose, (101).

b. Taken from Holt and Snyderman, (102), based on body weight of 60kg.

c. Taken from Holt and Snyderman, (102), based on body weight of 35kg.

d. Taken from Nakagawa et al, (103).

e. Taken from Holt and Snyderman, (102), based on body weight of 9kg.

Similar child requirements were reported for 8-13 year old girls (Table 3.8), a lower cystine level being recorded (103).

Many workers have stated that amino-acid requirement data cannot be used in determining protein requirements for population groups due to many factors (88,102,104,105,106). Harper summarized the variations inherent in measuring and using requirement data (105). For example, the difficulty in measuring the maximum rate of growth when using the growth factor (not applicable to adults), the precision of nitrogen balance methods, the influence of the past nutritional state of human subjects in experiments and the lack of knowledge on the part played by protein reserves in controlling requirements. His main contention was that any measurements made could not be comprehensive enough to cover all possible situations and needs of humans at any particular point in time.

The level of non-essential nitrogen in the diet was also important as this could become limiting at low concentrations of protein even when all essential amino-acid requirements were met. Also imbalances, either deficiencies or excesses, of one or more essential amino acids could upset requirements of other amino acids (88).

Thus the requirements for the different essential amino acids were affected by the condition of the human as well as the levels of other nutrients in his diet.

A simpler system of expressing requirements in terms of only two amino acids has been suggested by Payne (107). He maintained that methionine plus cystine and lysine were the most frequently limiting amino acids in foods and that 5% and 5.3% respectively of these amino acids in protein could be used to fix population requirements and to judge protein quality of foods.

Table 3.9 Estimation of limiting amino-acid requirements[a]

	Protein allowance[b] g/d	Lysine requirement[c] g/d	Methionine + cystine requirement[d] g/d
child (4y, 16.5kg)	25	1.03	0.97
boy (11y, 32kg)	36	1.48	1.4
man (18–35y, 65 kg)	45	1.86	1.75
woman (55–75y, 53kg)	36	1.48	1.4

a. Taken from the report of Carpenter (106).

b. Calculated as: net nitrogen requirement (N) x 6.25 x 1.2 (for individual variability) x 100/70 (for protein quality)

c. Calculated as: (N) x 6.25 x 1.2 x 100/90 (10% indigestibility) x 5.3/100.

d. Calculated as: (N) x 6.25 x 1.2 x 100/90 x 5.0/100.

In the example in Table 3.9, these amino acid levels conflicted with earlier data in that the children's requirement was lower than the adult level for these amino acids. This method presumed the amino-acid pattern of the diet and therefore was not useful for complete nutritional food specifications.

Overall then, it seemed inappropriate to use individual requirement data for population groups in a weighted average estimation for each amino acid.

2. Amino-acid pattern. Much more interest has been shown in considering the pattern of the amino acids in the food protein and through this suggesting satisfactory amino-acid levels.

An FAO/WHO expert group in 1957 reported a provisional amino-acid pattern for reference purposes (Table 3.10), which contained the most satisfactory ratios of essential amino acids in which undesirable interactions, competitions and excesses were reduced to a minimum (88).

Table 3.10 FAO/WHO provisional ideal amino-acid pattern

Amino acid	Recommended level g/100g protein		Recommended level in typical diet containing 50g protein g
isoleucine	4.2		2.1
leucine	4.8		2.4
lysine	4.2		2.1
methionine	2.2	total sulphur amino acids, 4.2	1.1
cystine	2.0		1.0
phenylalanine	2.8	total aromatic amino acids, 5.6	1.4
tyrosine	2.8		1.4
threonine	2.8		1.4
tryptophan	1.4		0.7
valine	4.2		2.1

For a typical diet for adults containing 50g protein per day, the levels of all the essential amino-acids were appreciably higher than Rose's safe levels except for phenylalanine and methionine (Table 3.10). This reference pattern was criticised with regard to the high lysine, methionine and cystine and tryptophan levels. Reducing these levels resulted in a pattern not much different from those of whole egg (hen) or human milk proteins (Table 3.11). It was suggested then that either of these two proteins be used as reference amino-acid patterns, preference for egg being felt due to it being more readily available for experiments and its high digestibility in animals and humans (88).

Table 3.11 Essential amino-acid patterns for preferred proteins[a]

	A/E ratio: essential amino-acid level to total essential amino-acid level (mg/g)		
	Provisional pattern 1957	Human milk protein	Hen egg protein
isoleucine	134	132	129
leucine	152	184	172
lysine	134	128	125
methionine	71	44	61
cystine	62	43	46
phenylalanine	89	114	114
tyrosine	89	112	81
threonine	89	99	99
tryptophan	45	34	31
valine	134	147	141

a. Taken from FAO/WHO report (88)

Although such a pattern suggests a high quality protein in a food, several factors could affect its value in the body. For example, the effect of vitamin deficiency on utilization of amino acids (particularly raising the tryptophan requirement when niacin deficient); the effect of the presence of inhibitors in some foods preventing enzymic digestion; the damage to proteins and amino acids, affecting availability, by processing methods, particularly heat; the effects of level and type of carbohydrate in the diet on utilization of protein and amino acids; the effect of deficient calorie intake below energy requirement allowing amino acids to be metabolised for energy before they can be utilized as nitrogen sources. Utilization also varies with the individual, for example the stage of growth, health history and whether lactation or reproductive states are involved. All these phenomena could affect the nutritive value of the protein and amino acids without appreciably altering the amino-acid pattern.

These factors of utilization, availability and individual variation have not been sufficiently quantified as yet to allow accurate use of amino-acid patterns for assessing protein and amino-acid requirements.

Nevertheless, the amino-acid pattern for egg protein seemed the most suitable system to define the desirable levels of amino acids, in the model, their individual requirements being dependent on the protein level in the mixture. The nutritional effects of calorie and vitamin levels would be removed by ensuring that their requirements were met and by introducing interrelationship conditions where necessary. The processing effects could be minimized by process design. However the individual variability effects, which exist also for all other nutrients, could not be considered except in terms of an average requirement. So some reduction in the calculated protein quality would be expected, but as the aim was for an amino-acid pattern similar to egg protein - the highest protein quality recognised - a high quality protein should result.

The egg pattern expressed as milligram amino acid per gram protein was used in defining the amino-acid relationships in the model (88), rather than the A/E method, used by Cavins (65), which would have meant formation of an expression for E the total essential amino-acid level. This pattern was :

isoleucine	66 mg/g protein;	leucine	88 mg/g protein;
lysine	64 mg/g protein;	methionine	31 mg/g protein;
cystine	24 mg/g protein;	phenylalanine	58 mg/g protein;
tyrosine	42 mg/g protein;	threonine	51 mg/g protein;
tryptophan	16 mg/g protein;	valine	73 mg/g protein.

Equations of the type CISO = 1.0ISO - 66.0PROT = 0 were defined for each amino acid to represent these relationships in the model. This method inherently fixed the desired level of non-essential amino acids but there was no restriction placed on this factor. It also allowed protein quality to be constrained, in terms of the chemical score index. This relates the level of each essential amino acid in a protein to the corresponding level of that amino acid in the standard egg protein (108). The lowest of these ratios, expressed as a percentage, fixes the chemical score of the protein. By considering any percentage of the egg amino-acid levels as lower constraints, the protein quality as chemical score, would be directly fixed if any amino acid was retained at its lower limit. At this stage then the chemical score was fixed on 100.

3.5 Development of the model for computer solution

3.5.1 Description of the problem matrix

The previous section presented the data to be used in the raw material selection problem using the linear programming technique.

The cost data provided one row in the matrix - the objective - containing coefficients in 170 columns, the cost for each of the 170 food raw materials.

The nutritional composition information described a further 26 rows in the matrix - one for each nutrient and coefficients for approximately 97% of the elements of the 170 columns.

Another row was incorporated into the matrix to describe the summation calculation of total weight of the food mixture. This had a coefficient of unity in each of its 170 column elements and no restrictions.

The restrictions on the nutrient levels required in the raw material mixture were expressed in one of three ways:

1. The weighted average daily requirement for the population based on the age-group distribution data for 1968. This applied to calories, protein, calcium, vitamins A,C,B6,B12 and folic acid.
2. A desirable level from limited studies. This applied to fibre.
3. Levels dependent on some defined interrelationship with another nutrient constrained elsewhere. This applied to fat, phosphorus, iron,

thiamine, riboflavin, niacin and essential amino acids. These were either a known nutritional interrelationship such as that between calories and B-vitamins, calories and fat, calcium and phosphorus, protein and amino acids; or a convenient method to describe requirements as some proportion of the diet as for the fat and iron relationship with calories.

The restrictions in the first two categories could be incorporated directly into the matrix as right hand sides thus providing another element in each of the 9 rows for these nutrients (See Table 3.12).

Table 3.12 Nutritional constraints for the linear programming model

Nutrient constrained	Row variable name	Restriction lower	Restriction upper
calories (kcal)	CAL	2030.0	2210.0
protein (g)	PROT	49.4	53.7
fibre (g)	FIB	6.0	15.0
calcium (mg)	CA	452.0	535.0
vitamin A (iu)	VITA	3900.0	4450.0
vitamin C (mg)	VITC	29.0	53.0
vitamin B6 (mg)	VITB6	1.68	∞
vitamin B12 (mg)	VITB12	0.002	∞
folic acid (mg)	FOLIC	0.18	0.37
pantothenic acid (mg)	PANTOA	0.0	∞

With the exception of pantothenic acid which was not restricted, the other restrictions required further rows and columns in the matrix to describe their restrictions in terms of relationships with other nutrients. For the 16 nutrients in this category a further 17 rows and 19 columns were thus added to the matrix (Table 3.13): calories with its relationship to fat (upper and lower restrictions), iron, thiamine,

Table 3.13 Nutritional constraints requiring linear expression of interrelationships between nutrients

Nutrient constrained	Relationship expression	Row variable name	Column elements	Restriction lower	Restriction upper
fat (lower limit)	0.2x calories level	LOFAT	9.0FAT - 0.2CAL	0	∞
fat (upper limit)	0.35x calories level	HIFAT	9.0FAT - 0.35CAL	-∞	0
phosphorus (fixed level)	1.0x calcium level	PCON	1.0P - 1.0CA	0	0
iron (lower limit)	0.01x calories level	LOFE	1.0FE - 0.01CAL	0	∞
thiamine (fixed level)	0.0005x calories level	LOTHIA	1.0THIA - 0.0005CAL	0	0
riboflavin (fixed level)	0.0005x calories level	LORIBO	1.0RIBO - 0.0005CAL	0	0
niacin (fixed level)	0.0066x calories level	LONIA	1.0NIA - 0.0066CAL	0	0
isoleucine (fixed level)	66x protein level	CISO	1.0ISO - 66.0PROT	0	0
leucine (fixed level)	88x protein level	CLEU	1.0LEU - 88.0PROT	0	0
lysine (fixed level)	64x protein level	CLYS	1.0LYS - 64.0PROT	0	0
methionine (fixed level)	31x protein level	CMETH	1.0METH - 31.0PROT	0	0
cystine (fixed level)	24x protein level	CCYS	1.0CYS - 24.0PROT	0	0
phenylalanine (fixed level)	58x protein level	CPHE	1.0PHE - 58.0PROT	0	0
tyrosine (fixed level)	42x protein level	CTYR	1.0TYR - 42.0PROT	0	0
threonine (fixed level)	51x protein level	CTHREO	1.0THREO - 51.0PROT	0	0
tryptophan (fixed level)	16x protein level	CTRYP	1.0TRYP - 16.0PROT	0	0
valine (fixed level)	73x protein level	CVAL	1.0VAL - 73.0PROT	0	0

riboflavin and niacin necessitated another 6 rows for each restriction equation incorporating two column variables, one of which was calories and the other the related nutrients i.e. a further 6 columns were defined; the protein relationship to the 10 amino-acids added another 10 rows and 11 columns, containing the protein and amino-acid variables; and the calcium to phosphorus relationship required another row to be formed and a further 2 columns.

The complete problem was thus described by a matrix incorporating 45 rows and 189 columns with bounds on 25 of the row variables. The matrix is illustrated in Fig.3.2.

3.5.2 Organization for computer solution

The linear programming problem was solved using the computer package program which was available at the Massey University Computer Unit - IBM Linear Programming System / 1130 (LPS/1130). This was designed for use on the 1130 series of IBM computers. At Massey, the IBM 1130 computer had a single disk storage drive and was linked to a 1442 card reader punch and a 1132 line printer.

The data was prepared according to the method described in the IBM LPS/1130 Program Description manual (109) and organized into an easily referenced order for checking : the food composition data was arranged in alphabetical order by name of food raw material; the row names were organized in the usual order found in food composition tables viz. calories, protein, fat, fibre, calcium, phosphorus, iron, vitamin A, thiamine, riboflavin, niacin, vitamin C, vitamin B6, vitamin B12, pantothenic acid and folic acid followed by the essential amino acids, and then followed by the cost, weight and interrelationship row names. This meant that output reports were in a recognisable order for easy reference.

This data was punched on 80-column data cards, one row item per card for each column or food material. Restrictions identified by the label MIX1A were punched as types UB (upper bound), LB (lower bound), FR (free, $-\infty$ to $+\infty$), FX (fixed or defined value), GT(defined value up to ∞) and LT (defined value to $-\infty$) where necessary. The data file was identified by the NAME LP1/WE which was used whenever the data was required for optimization or listing. The organization of

Rows \ Columns	Raw Materials (170 Columns)	CAL	PROT	FAT	CA	P	FE	THIA	RIBO	NIA	ISO	LEU	LYS	METH	CYS	PHE	TYR	THREO	TRYP	VAL	Constraints LB	Constraints UB
Objective Cost																						
CAL		1.0																			2030	2210
PROT			1.0																		49.4	54.5
FAT				1.0																	0	∞
FIB																					6.0	15.0
CA					1.0																452	553
P						1.0															0	∞
FE							1.0														0	∞
VITA																					3900	4450
THIA								1.0													0	∞
RIBO									1.0												0	∞
NIA	Nutrient									1.0											0	∞
VITC	Composition																				29	53
VITB6	Matrix																				1.68	∞
VITB12																					0.002	∞
PANTOA																					0	∞
FOLIC																					0.18	0.37
ISO											1.0										0	∞
LEU												1.0									0	∞
LYS													1.0								0	∞
METH														1.0							0	∞
CYS															1.0						0	∞
PHE																1.0					0	∞
TYR																	1.0				0	∞
THREO																		1.0			0	∞
TRYP																			1.0		0	∞
VAL																				1.0	0	∞
WT																					0	∞
LOFAT		-0.2		9.0																	0	∞
HIFAT		-0.35		9.0																	-∞	0
PCON					-1.0	1.0															0	0
LOFE		-0.01					1.0														0	∞
LOTHIA		-.0005						1.0													0	0
LORIBO		-.0005							1.0												0	0
LONIA	Zero	-.0066								1.0											0	0
CISO	Matrix		-66								1.0										0	0
CLEU			-88									1.0									0	0
CLYS			-64										1.0								0	0
CMETH			-31											1.0							0	0
CCYS			-24												1.0						0	0
CPHE			-58													1.0					0	0
CTYR			-42														1.0				0	0
CTHREO			-51															1.0			0	0
CTRYP			-16																1.0		0	0
CVAL			-13																	1.0	0	0

Figure 3.2 Linear programming matrix for the Philippine nutrition problem

input data and bounds is illustrated in Fig.3.3 and is commented on below.

1. Composition data : These were described - one item per card - for example as follows :

ALBACORE	CAL	99.0
ALBACORE	PROT	22.7
ALBACORE	FAT	0.2

2. Cost data : These were similarly punched e.g.

ALBACORE	COST	0.033

3. Interrelated variable expressions : Equations with names to represent new rows had been set up in these cases. The interrelated variables thus became columns with elements in each of these rows and so were punched in the same way. For example, in the case of calories from fat which was to have a lower limit at 20% total calories, this was expressed by

$$LOFAT = 9.0FAT - 0.2CAL$$

and was punched in on two separate cards, one for each element.

FAT	LOFAT	9.0
CAL	LOFAT	- 0.2

For the isoleucine / protein expression

$$CISO = 1.0ISO - 66.0PROT$$

two cards were required.

ISO	CISO	1.0
PROT	CISO	- 66.0

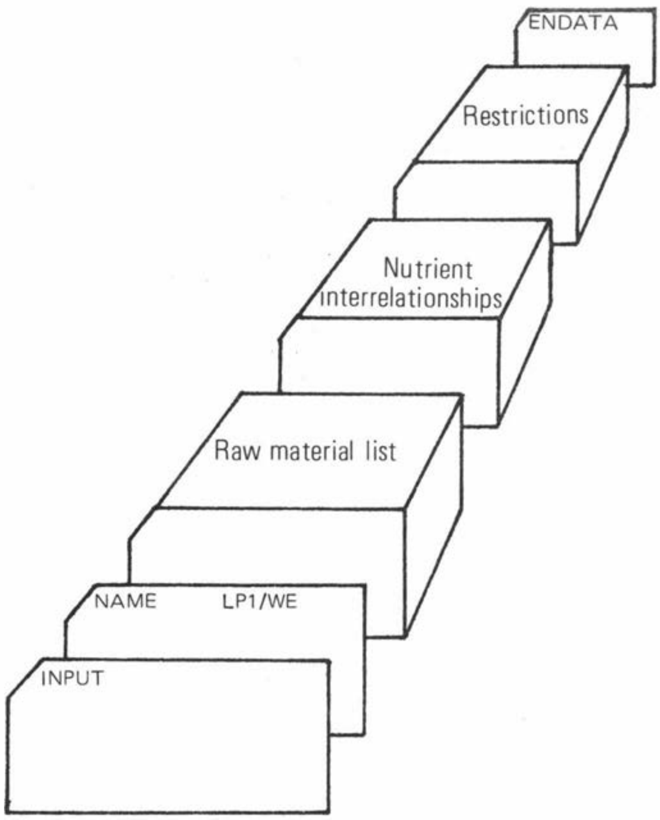


Figure 3.3 Organization of data for input to computer

4. Restrictions : These had a different format. Each type of bound had to be specified - UB for upper bound, LB for lower bound. On the same card, the name of the set of bounds had to be defined, the name of the variable being restricted and the value of the restriction. For example, the fibre limits of 6 to 15g were punched as

```
LB   MIX1A     FIB          6.0
UB   MIX1A     FIB         15.0
```

and the free range on cost as

```
FR   MIX1A     COST
```

Where interrelationship expressions defining the nutrient restrictions were described, the row variable was described similarly. For example the fat limits described by the row variables LOFAT and HIFAT were punched as

```
LB   MIX1A     LOFAT        0.0
LT   MIX1A     HIFAT        0.0
```

Note the use of LT type upper bound. This restricted the value of HIFAT between $-\infty$ and 0 . If UB had been used and set to zero this would have had the effect of fixing the variable on zero as the LPS/1130 system automatically set all variable lower bounds at 0.0 unless otherwise stipulated.

The program contained as well as the mathematical method of calculation, several procedures which could be selected by the user to allow flexibility in controlling the input data, updating, selecting limits to the problem, selecting the variable to be optimized, shortening solution time, analysing the solution and conditionally controlling the sequence of operations. The use of these procedures is illustrated in the following description of the commands needed to operate the computer system for the setting up and solution of a linear programming problem.

Data was INPUT with a NAME (in this case LP1/WE)

COLUMN SUMMARY

29	ALBACORE	6	CAL	10	PROT	2	FAT
1	CA	1	P	1	FE	1	THIA
1	RIBO	1	NIA	1	ISO	1	LEU
1	LYS	1	METH	1	CYS	1	PHE
1	TYR	1	THREO	1	TRYP	1	VAL
29	ANCHOVY	29	ATIS	29	AVOCADO	29	BANANA90
29	BANANA92	29	BARRACUD	29	BEEF	29	BESCAD
28	BLOODB	28	BLOODPIG	29	BONITO	28	BRAINB
28	BRAINBU	28	BRAINLAM	29	BSRAY	29	BUFFALO
29	CABBAGE	29	CAESIO	29	CASHEW	27	CASSAVA
29	CATFISH	29	CAVALLA	27	CHGIZZ	29	CHICKENY
29	CHICKPEA	29	CHICO	29	CHLIVER	29	COCOMAT
29	COCOY	28	COTSEED	29	COWPEA	29	CRAB
29	CREVALLE	29	CROAKER	29	DAPA	29	DUCK
29	EGGDUCK	29	EGGPLANT	29	EGGS	25	GAMET
29	GARLIC	18	GINGER	29	GLASSF	29	GNSHELL
29	GOAT	29	GOATFISH	29	GOBY	29	GOOSE
29	GRAPEFRT	29	GROUPER	29	GRUNT	29	HAIRTAIL
29	HARDTAIL	29	HEARTB	29	HEARTBU	29	HEARTGOA
29	HEARTLAM	29	HEARTPIG	29	HERRING	29	HORSE
29	JACKFRT	29	KAIMITO	29	KIDNEYB	29	KIDNEYBU
29	KIDNEYGO	29	KIDNEYLA	29	KIDNEYPI	29	LANZONES
26	LARINTB	26	LARINTBU	26	LARINTGO	26	LARINTPI
29	LEAJACK	29	LEMON	29	LIME	29	LIVERB
29	LIVERBU	29	LIVERGOA	29	LIVERLAM	29	LIVERPIG
29	LIZFISH	28	LUNGGOAT	28	LUNGLAM	28	LUNGPIG
28	LUNGSB	28	LUNGSBU	29	MANGO	29	MARBRAY
29	MILKBUFF	29	MILKCOW	29	MILKFISH	29	MILKGOAT
29	MOONFISH	29	MULLET	29	MUNGGR	29	MUNGRED
29	NEMIPTER	29	ONION	29	ORANGE	29	PAPAYA
29	PETSAY	29	PIGPEA	29	PILI	29	PINEAPLE
29	POMFRET	29	POMPANO	29	PORGY	29	PORK
29	POTATOES	29	PUMMELO	29	RADISH	29	RICE
29	RICEBR	29	RICEGLU	29	RKIDBEAN	29	RSCAD
29	RUNNERF	29	SARDINE	29	SBMACK	25	SEAWEED
29	SHARK	29	SHEEP	29	SHRIMP	29	SIGANID
29	SLIPMTH	26	SMINTB	26	SMINTBU	26	SMINTGOA
26	SMINTPIG	29	SMSHRIMP	29	SNAPBEAN	29	SNAPPER
29	SOURSOP	29	SOYBEAN	29	SPADEF	28	SPLEAVES
29	SPLEENB	29	SPLEENBU	29	SPLEENLA	29	SPLEENPI
29	SPMACK	29	SPYAM	29	SQUID	26	STOMB
26	STOMBU	26	STOMGOAT	26	STOMPIG	29	STRMACK
15	SUGARRAW	26	SUGCANEJ	29	SURGEONF	29	SWPOT
29	SWPOTWH	29	TARO	29	THREADFN	29	TOMATO
29	TONGUEB	29	TONGUEPI	27	TURGIZZ	29	TURKEY
29	TURLIVER	5	TURTLE	29	WATMELON	29	WHCORN
29	WHITING	29	WKIDBEAN	29	YAM	29	YCORN
29	YFINTUNA						

ROW SUMMARY

170	CAL	170	PROT	170	FAT	169	FIB
169	CA	169	P	169	FE	166	VITA
169	THIA	169	RIBO	169	NIA	169	VITC
146	VITB6	167	VITB12	153	PANTOA	145	FOLIC
167	ISO	167	LEU	167	LYS	167	METH
167	CYS	167	PHE	167	TYR	167	THREO
167	TRYP	167	VAL	170	COST	170	WT
2	CISO	2	CLEU	2	CLYS	2	CCYS
2	CMETH	2	CPHE	2	CTYR	2	CTHREO
2	CTRYP	2	CVAL	2	LOFAT	2	HIFAT
2	PCON	2	LOFE	2	LOTHIA	2	LORIBO
2	LONIA						

Figure 3.4 Row and column variables in the matrix listed by SUMMARY procedure

including the BOUNDS (identified by MIX1A). This NAMEd file could then have a SUMMARY printed to allow checking that all data had been INPUT and that there were no punching errors and recognition of data deficiencies in the matrix (Fig.3.4). The data could also be checked fully by MOVEing the DATA LP1/WE and stipulating by PUNCH PRINTER followed by the BCDOUT command that the data was to be printed out on the line printer. All the data was punched out by column name with each row variable name and the respective coefficient in the same format as INPUT cards.

The DATA on this file was then MOVEd along with BOUNDS required and the objective function COST which was to be MINIMIZEd. OPTIMIZEation was then called and the program brought the data matrix through simplex type iterations until SOLUTION OPTIMUM was reached and the solution printed on LPSOLUTION command (Fig.3.5).

```
MOVE
    DATA        LP1/WE
    BOUNDS      MIX1A
    MINIMIZE    COST
ENDATA
OPTIMIZE
LPSOLUTION
LPANALYSIS
```

Figure 3.5 Computer commands for optimization and post-optimization

In order to shorten the time taken for optimization in similar problems, a starting solution could be used to begin the iterations. Thus when a solution was obtained on an LPSOLUTION command, it could be stored by SAVESOLUTION when a NAME , say, LPSOL1 was allotted to it. To shorten solution time the DATA of this solution could be RESTOREd prior to the beginning OPTIMIZEation . (Fig.3.6).

```
MOVE
    DATA        LP1/WE
    BOUNDS      MIX1A
    MINIMIZE    COST
ENDATA
OPTIMIZE
LPSOLUTION
SAVESOLUTION
    NAME        LPSOL1
MOVE
    DATA        LP1/WE
    BOUNDS      MIX1A
    MINIMIZE    WEIGHT
ENDATA
RESTORE
    DATA        LPSOL1
OPTIMIZE
LPSOLUTION
SAVESOLUTION
    NAME        LPSOL2
```

Figure 3.6 Use of starting solutions in successive optimization operations

Permanent changes to DATA and BOUNDS were made using the REVISE procedure while temporary changes could be investigated with the MODIFY operation whose alterations only lasted the duration of that run. If these MODIFYed changes were required permanently in the data then they were REVISEd into the NAMEd file or INPUT into another NAMEd file which could then be MERGEd with other files when necessary, prior to OPTIMIZEation The MERGE procedures allowed separate DATA files to be stored and combinations of them tried out in any problem without changing the individual DATA files.

The LPSOLUTION report recorded the activity levels of the raw materials in the food mixture and total cost as well as the levels of the nutrients and other row variables in the optimum solution.

There was also a value for the REDUCED COST of each variable, which would be the COST change in the neighbourhood of the optimum solution if the bounds were relaxed for each variable whose activity level lay at an upper or lower bound in the solution. Also for variables not in the solution this indicated how much the cost of the variable would have to be reduced before entry into the solution.

When a feasible solution resulted a further report, an LPANALYSIS could be obtained providing more information on the effect that cost changes, availability changes or specification changes would have on the cost of the final blend and over what range of cost and activities the effect would be valid. COST/UNIT INCREASE and COST/UNIT DECREASE described the change in cost (of the whole mix) of changing a solution activity level in the neighbourhood of the solution. This change would be valid up to the level of INCREASED ACTIVITY for unit increase and down to the level of DECREASED ACTIVITY for unit decrease. LOWEST COST and HIGHEST COST would give the cost range wherein the solution activity of that variable would remain at the same level. If the cost changed to below the LOWEST COST level then the activity level would change to that under INCREASED ACTIVITY whilst if it exceeded the HIGHEST COST then the activity level would be that of DECREASED ACTIVITY.

LPPARAMETRIC allowed the effect of systematic changes of costs, coefficients or constraints to be examined. The changes to occur would be INPUT into a NAMEd file whose DATA would be called with the LPPARAMETRIC command. Stipulating in PARAMET REPORTS the number of steps in this gradual change, an LPSOLUTION report would be given after each feasible optimization. For example, decreasing the existing calcium upper limit of 900 down to 550 in 7 steps of 50 could be carried out with the sequence in Fig.3.7.

Conditional control procedures IF and IFNOT were available to allow bypassing of certain parts of the instruction sequence in the event of a specified non-desirable occurrence e.g. MAJOR error, INFEASIBLE SOLUTION or UNBOUNDED SOLUTION.

```
INPUT
NAME            PARCA
 UB MIX1A       CA          -   50.0
ENDATA
MOVE
    DATA        LP1/WE
    BOUNDS      MIX1A
    MINIMIZE    COST
ENDATA
RESTORE
    DATA        LPSOL5
MOVE
    PARAMET     REPORTS          7.0
ENDATA
LPARAMETRIC
    DATA        PARCA
```

Figure 3.7 **Computer commands for parametric adjustments to data**

It was thus possible to use this computer program quite flexibly with careful planning of procedures and organization of data to investigate variations of any problem and their solutions with the linear programming technique.

3.6 Obtaining an initial solution

The complete linear programming model was input to the computer system but a feasible solution could not be obtained. The artificial [a] variables associated with equality constraints on the amino acids leucine, lysine, methionine and tyrosine and on phosphorus could not be removed from the starting conditions in the calculations. This indicated that the equality constraints on these variables were too restrictive.

Releasing the amino acids from their fixed constraints to lower bounds at these levels and upper bounds equivalent to 150% of the lower limit removed the artificial variables from the solution, but the lower limit on folic acid could not be attained. This adjustment of amino-acid

a. These artificial variables are added automatically by the computer system to some constraints, particularly equality constraints, so that the solution method can begin (see Appendix 1).

levels was achieved by constraining the CISO, CLEU.....CVAL rows between 0 and $+\infty$ for the lower limit, and introducing 10 new rows, DISO, DLEU.....DVAL defining the 150% egg pattern levels which were constrained between $-\infty$ and 0 to describe the upper limits (See Table 3.14 for description of these new rows).

The folic acid level was 0.01mg below the requirement of 0.18mg causing the infeasibility. At this stage, it was desired to meet all the minimum requirements to retain full nutritional adequacy, if this was possible - so folic acid was retained at 0.18mg. Other nutrients were at their upper limits in this infeasible state. The upper limits were designed to keep all nutrients around requirement levels for nutritional balance but did not represent any nutritional maxima. It was justifiable then to release these nutrients constrained at their upper limits to try and remove the infeasibility. Thus the calcium, vitamin A and vitamin C upper bounds were relaxed to arbitrary limits of 900mg, 8000iu and 1000mg respectively. The first feasible solution, Formula 1, was obtained and is detailed in Table 4.1.

In comparison to the constraints in the model originally laid down, this revised model had these modifications :

1. Amino-acid levels were relaxed from being fixed at the egg pattern levels to being restricted within the range corresponding to 100 and 150 chemical score based on egg amino-acid pattern.
2. The calcium upper limit was raised from 553 to 900mg.
3. The vitamin A upper limit was raised from 4450 to 8000iu.
4. The vitamin C upper limit was raised from 53 to 1000mg.

In solving a linear programming problem, firstly artificial variables, added to start the solution process, are removed. If any remain, then the problem is infeasible, the infeasibility being caused by the restrictions associated with the retained artificial variable. In this problem, the equality constraints on four amino acids could not be satisfied. If all the artificial variables are removed, the problem may still be infeasible if other upper and lower limit constraints cannot be satisfied. Here the folic acid lower bound was incompatible with other model conditions.

These infeasibility conditions indicated how tight were the constraints in the model - equality constraints were more restricting on

Table 3.14 New row variables added to the matrix to describe upper limits on amino-acid pattern

Amino–acid constrained	Relationship expression	Row variable name	Column elements	Restriction lower	Restriction upper
isoleucine	1.5x66 protein level	DISO	1.0ISO - 99.0PROT	-∞	0
leucine	1.5x88 protein level	DLEU	1.0LEU - 132.0PROT	-∞	0
lysine	1.5x64 protein level	DLYS	1.0LYS - 96.0PROT	-∞	0
methionine	1.5x31 protein level	DMETH	1.0METH - 46.5PROT	-∞	0
cystine	1.5x24 protein level	DCYS	1.0CYS - 36.0PROT	-∞	0
phenylalanine	1.5x58 protein level	DPHE	1.0PHE - 87.0PROT	-∞	0
tyrosine	1.5x42 protein level	DTYR	1.0TYR - 63.0PROT	-∞	0
threonine	1.5x51 protein level	DTHREO	1.0THREO - 76.5PROT	-∞	0
tryptophan	1.5x16 protein level	DTRYP	1.0TRYP - 24.0PROT	-∞	0
valine	1.5x73 protein level	DVAL	1.0VAL - 109.5PROT	-∞	0

the feasible area than range constraints which were more restricting than open-ended lower bound constraints. Thus the initial model was extremely restricting with fourteen equality constraints and six narrow range constraints on nutrient levels.

Once it was seen that tight constraints caused infeasibility in a model, it would be wiser to initially consider the least severe restrictions that could be tolerated in order to achieve feasibility. It would be particularly necessary to reduce the number of equality constraints. When a solution was obtained, gradual introduction of more severe restrictions could be investigated in order to return to as near the original requirements as necessary for a satisfactory model.

CHAPTER 4

THE EFFECTS OF PROBLEM DATA MODIFICATION IN THE LINEAR PROGRAMMING MODEL

To obtain the initial feasible solution, several nutritional constraints had to be relaxed, and it was therefore necessary to develop the model further so that the nutritional objectives could be more closely met. In the course of this development, investigations were made of the effects of altering nutritional constraints, raw material costs, nutritional composition data and also the variety of raw materials. These modifications represented the types of alterations which could be expected for a dynamic nutrition model. The value of the linear programming system for guiding the modifications and indicating the sensitivity of the model to change was observed.

In the linear programming model, the factors which could be modified were :

1. Matrix columns. The raw material list could be augmented or shortened according to the availability of raw materials at a particular time, or for particular formulation requirements. The removal of raw materials from the list and later addition of new materials were both considered.
2. Matrix rows. The number of nutrients considered could be extended or shortened according to the number of nutrient specifications for the food being designed. This modification was not investigated, since it was fundamental to this research that requirements be considered for as many nutrients for which information was available. The constraints on the rows (the nutrient specifications) could be changed for different nutritional requirements and for modifications in the development of a model, such as this one, in which original nutritional constraints could not be met. In this model, several nutrient constraint changes were investigated.

3. Matrix coefficients. The cost and nutritional composition data could be revised regularly since costs could alter from time to time and more representative nutritional analysis data could become available. In this investigation, changes to both costs and nutrient compositions were considered.

The effect of making changes on row constraints and cost coefficients could be estimated from post-optimal analysis of any feasible solution. This analysis provides information of the magnitude of changes in each variable level that can be tolerated without altering the solution mix. Such information is valid only for change in a single variable. The value of this information for model development is discussed.

The modifications are described in the sequence in which they were investigated, for ease in following variable changes from solution to solution. Matrix column changes are described in sections 4.1, for removal of raw material and also in 4.4 for extension of the raw material list; matrix row changes of nutritional constraints in 4.2; and matrix coefficient changes in 4.3 for composition data changes and in 4,5 for cost data changes.

A linear programming model to select raw materials with satisfactory nutritional balance was thus developed and simultaneously the capability of the technique, for dealing with modifications of the types described, was investigated.

4.1 Matrix column modification - the effect of removing a raw material from the data file

Examination of the Formula 1 (in Table 4.1) mixture indicated that the raw materials radish and spiny yam were required at very high levels - 22% and 35% respectively of the total mixture weight. The incorporation of high levels of yam in a food formulation would not be expected to be difficult as such material is generally bland-flavoured and starchy and would probably provide a good foundation for formulation. Radish, however, is a fibrous, spicy vegetable which could prove overpowering and difficult to blend with other materials in a food mixture. Some modification could perhaps be made to the model to limit the concentration of highly flavoured materials in the mixtures.

The post-optimal analysis report for Formula 1 indicated that raw

Table 4.1 Nutritional and raw material compositions of feasible solutions

Nutrient content		Formula 1	Formula 2	Formula 3	Formula 4	Formula 5	Formula 6	Formula 7	Formula 8	Formula 9	Formula 10	Formula 11
calories	(kcal)	2150	2470 [a]	2470 [a]	2490	2470 [a]	2410 [a]	2470 [a]	2470 [a]	2470 [a]	2030 [a]	2030 [a]
protein	(g)	49.4 [a]	49.4 [a]	49.4 [a]	49.8	49.4 [a]	54.8	57.1	53.4	52.4	49.4 [a]	49.4 [a]
fat	(g)	49.4	54.8 [a]	74.6	55.4 [a]	56.8	54.9 [a]	54.9 [a]	54.9 [a]	54.9 [a]	45.1 [a]	78.5
fibre	(g)	15.0 [b]	15.0 [b]	15.0 [b]	10.4	15.0 [b]	15.0 [b]	15.0 [b]	15.0 [b]	15.0 [b]	9.6	15.0 [b]
calcium	(mg)	900 [b]	900 [b]	700 [b]	617	700 [b]	700 [b]	700 [b]	700 [b]	700 [b]	700 [b]	700 [b]
phosphorus	(mg)	900 [c]	900 [c]	1050 [b]	926 [b]	1050 [b]	1050 [b]	1050 [b]	1050 [b]	1050 [b]	1050 [b]	1050 [b]
iron	(mg)	23.7	27.2	27.2	27.4	35.7	31.0	26.6	31.7	35.0	24.4	35.3
vitamin A	(iu)	6250 [d]	18 050	12 150	7650	14 850	8 050	12 250	5 700	6 650	10 050	7 500
thiamine	(mg)	1.08 [c]	1.24 [a]	1.24 [c]	1.25 [c]	1.47	1.54	1.32	1.35	1.41	1.30	1.41
riboflevin	(mg)	1.08 [c]	1.24 [a]	1.24 [c]	1.25 [c]	1.47	1.69	1.55	1.24 [a]	1.28	1.23	1.08
niacin	(mg)	14.2 [c]	16.3 [a]	16.3 [c]	16.4 [c]	16.3 [a]	16.3 [a]	16.3 [a]	16.3 [a]	16.3 [a]	13.4 [a]	13.4 [a]
vitamin C	(mg)	240	370	320	530	310	750	860	350	370	310	200
vitamin B6	(mg)	1.68	3.10	2.71	5.38	2.88	5.84	7.26	3.05	3.07	2.15	1.77
vitamin B12	(mg)	0.017	0.013	0.008	0.007	0.009	0.010	0.012	0.007	0.009	0.008	0.003
pantothenic	(mg)	8.4	8.4	10.0	9.2	11.2	15.4	10.6	12.6	13.2	10.1	6.9
folic acid	(mg)	0.18 [a]	0.18 [a]	0.18 [a]	0.18 [a]	0.18 [a]	0.18 [a]	0.27	0.22	0.20	0.18 [a]	0.18 [a]
isoleucine	(CS)[e]	110	90	80 [a]	85 [a]	85 [a]	88.6 [a]	85 [a]	85 [a]	85 [a]	85 [a]	75 [a]
leucine	(CS)	130	109	102	100 [b]	100 [b]	100 [b]	98	100 [b]	100 [b]	98	90
lysine	(CS)	150 [b]	120 [b]	120 [b]	100 [b]	100 [b]	100 [b]	100 [b]	100 [b]	100 [b]	100 [b]	100 [b]
methionine	(CS)	100 [a]	80 [a]	83	86	85 [a]	88.4 [a]	93	90	90	93	75 [a]
cystine	(CS)	100 [a]	80 [a]	80 [a]	85 [a]	85 [a]	89 [a]	85 [a]	100 [b]	96	85 [a]	75 [a]
phenylalanine	(CS)	100 [a]	83	88	91	97	100 [b]	88	92	91	95	85
tyrosine	(CS)	129	97	84	92	96	96	86	85 [a]	85 [a]	85 [a]	76
threonine	(CS)	109	99	93	95	94	98	95	90	92	90	80
tryptophan	(CS)	100 [a]	80 [a]	80 [a]	85 [a]	94	90	85 [a]	85 [a]	85 [a]	85 [a]	75 [a]
valine	(CS)	105	93	89	90	88	93	85 [a]	89	90	88	83
cost	($US)	0.32	0.30	0.24	0.40	0.30	0.57	0.68	0.34	0.42	0.26	0.17
weight	(g)	1913	1799	1719	2095	1913	2904	2925	2092	2121	1458	1140
chemical score		100	80	80	85	85	88	85	85	85	84	75

Raw material content (g)

	Formula 1	Formula 2	Formula 3	Formula 4	Formula 5	Formula 6	Formula 7	Formula 8	Formula 9	Formula 10	Formula 11
avocado	—	—	—	—	—	267.1	23.6	249.9	248.8	—	—
banana, bungulan	—	—	—	744.4	—	587.6	269.2	—	—	—	—
banana, gloria	2.6	164.3	—	—	182.1	—	876.8	—	—	—	—
blood (beef)	5.3	—	23.4	—	—	—	—	—	—	—	2.9
brain (buffalo)	—	—	—	—	—	—	77.0	18.4	23.5	20.9	—
cabbage, chinese (petsay)	—	226.5	58.4	149.1	174.9	77.4	127.0	105.4	137.7	123.1	—
coconut, mature	15.3	—	109.9	56.1	115.9	—	—	68.5	32.8	72.7	189.2
corn, white	—	—	—	2.2	—	45.4	110.6	—	—	—	—
cottonseed	—	—	—	—	—	—	—	—	—	—	21.5
eggs (hen)	—	50.1	53.9	124.9	132.3	197.2	147.7	111.9	116.4	146.7	—
goosemeat	—	17.6	66.4	—	—	—	—	—	—	—	—
groundnut	—	—	—	—	26.7	—	—	—	—	—	—
grapefruit	—	—	—	—	—	587.2	—	—	—	—	—
intestine, large (beef)	—	81.6	28.6	31.3	9.9	13.8	—	10.7	24.9	—	—
intestine, small (buffalo)	—	—	—	—	—	—	22.5	6.2	27.4	—	—
lime	—	—	—	286.4	—	308.1	988.0	—	—	—	—
liver (beef)	17.2	—	—	—	—	—	—	—	—	—	1.6
liver (buffalo)	—	6.0	—	—	11.8	3.9	—	—	—	2.7	5.5
liver (lamb)	1.9	—	—	—	—	—	—	0.5	—	—	—
liver (turkey)	—	7.3	13.7	—	—	—	—	—	—	—	—
marbledstingray (fish)	82.1	—	—	3.7	—	—	—	17.1	—	12.2	30.7
milk (buffalo)	93.4	—	—	—	—	—	—	—	—	—	—
milk (cow)	81.7	—	—	—	—	—	—	—	—	—	—
onion	—	148.0	256.4	30.8	115.9	—	—	—	—	—	—
papaya	3.7	—	—	—	—	—	—	—	—	—	—
pilinut	—	—	0.9	—	—	—	—	—	—	5.9	30.5
radish	429.5	—	—	—	—	—	—	471.2	374.3	224.5	367.5
rice, brown	—	—	—	51.2	—	—	—	—	—	45.6	43.7
rice, glutinous	139.8	188.6	73.7	47.0	27.6	—	—	150.7	104.7	113.4	127.6
rice, polished	—	6.5	—	38.9	—	20.8	—	51.2	58.2	—	—
seaweed (gamet)	—	—	—	—	—	—	—	—	—	—	40.8
shrimp, small	—	16.5	—	—	—	—	—	—	—	—	—
sugar, raw	—	—	13.7	—	70.0	6.4	—	—	—	—	—
sugar cane juice	245.8	295.4	168.2	—	76.3	—	160.9	—	—	—	—
sweet potato	55.0	355.6	629.5	—	—	—	—	—	—	287.8	278.2
yam, spiny	675.1	224.5	221.9	528.7	969.9	788.8	121.3	830.3	973.4	402.2	—
yellow fin tuna	—	10.0	—	—	—	—	—	—	—	—	—

a. Held at lower bound
b. Held at upper bound
c. Held by equality restriction
d. Rounded up to nearest 50 iu.
e. Amino-acids expressed as for chemical score - percent of corresponding amino-acid level in egg protein.

material activity ranges were not too tight. However, a reduction in the level of radish by 11.5g to 418g was possible with increased cost. Reduction below this would cause a change in the solution mixture. What this change would be was not indicated in the analysis report, but it would be seen in the removal of radish. This was the simplest method of ensuring that radish did not dominate any solution.

4.1.1 Indicating the sensitive conditions in the model

The removal of radish caused infeasibility. The model conditions could not be satisfied without this raw material. The problem was seen to be with the artificial variable associated with the protein.

Since there was no indication from the infeasible solution report of how this problem occurred, calculations were made of the contribution each raw material made to the nutrient levels in each solution. Such calculations were made (using the computer program in Appendix 5), on the raw materials in Formula 1 and on the raw materials in the infeasible solution obtained when radish was removed. Table 4.2 describes this information for the most sensitive nutrients - calories, protein, calcium, vitamin A, vitamin C and folic acid. These nutrients were most frequently held at their bounds in Formula 1 and the infeasible solution.

Radish provided its greatest contributions to vitamin C (50%) and folic acid (24%) in Formula 1. It had lesser effect on calcium (15%) and much lower contributions to calories (4%) and protein (5%). When radish was removed, other materials were introduced - banana(bungulan), eggs, onion and shrimp - but all nutritional conditions could not be satisfied. It would seem then that radish was required to provide mainly folic acid with minimum contribution to calcium, calories and protein. The folic acid constraint had been the most expensive nutrient constraint to meet, hence the value of a rich source of this nutrient to the model. Calcium had been held down by an upper constraint, hence the value of materials low in calcium to the model. Calories and protein both defined interrelationships with other nutrients, and since several of these nutrients were at their lowest limits, then raw materials also low in calories and protein were desirable in the model. Radish was particularly suitable to satisfy all these sensitive conditions in the model.

Although this analysis gave some insight into the value of radish

Table 4.2 Contributions of foods to selected nutrients in mixtures

Raw material	Contribution to variable level (%)							
	calories	protein	calcium	vitamin A	vitamin C	folic	cost	weight
Formula 1								
banana (gloria)	0.1	0.1	0.0	0.3	0.2	0.1	0.2	0.1
blood (beef)	0.3	1.3	0.0	0.1	0.0	0.1	0.0	0.3
coconut, mature	2.1	1.2	0.5	0.0	0.2	2.4	0.4	0.8
intestine, large (beef)	14.5	6.5	0.9	0.3	1.1	0.0	10.3	3.4
liver (beef)	1.0	7.7	2.5	68.8	2.2	28.7	2.7	0.9
liver (lamb)	0.1	0.8	0.0	15.4	0.3	3.0	0.3	0.1
marbled ray (fish)	2.4	23.8	20.3	0.1	0.2	22.8	9.6	4.3
milk (buffalo)	5.3	10.2	22.4	2.4	0.8	0.2	10.2	4.9
milk (cow)	2.5	5.5	12.4	1.7	0.7	0.1	10.4	4.3
papaya	0.1	0.0	0.1	0.3	1.4	0.4	0.1	0.2
radish	4.2	5.2	15.3	0.3	44.9	23.9	18.7	22.5
rice, glutinous	23.7	19.5	2.6	0.0	0.0	7.8	11.6	7.3
yam, spiny	35.2	16.4	15.8	0.5	39.5	7.5	23.1	35.3
sugar cane juice	5.0	0.5	3.6	0.0	0.5	0.0	1.1	12.9
sweet potato	3.5	1.2	3.5	9.8	8.1	3.1	1.4	2.9
	100.0	99.9	99.9	100.0	100.1	100.1	100.1	100.2
Infeasible solution								
anchovy	1.1	10.0	15.2	0.4	0.2	8.1	2.3	1.4
banana (bungulan)	41.2	18.4	11.7	24.7	62.4	53.3	40.5	45.2
banana (gloria)	5.0	1.9	1.5	14.7	3.7	5.1	3.9	4.3
blood (beef)	0.4	2.1	0.1	0.3	0.0	0.1	0.1	0.4
eggs (hen)	7.6	24.4	8.4	29.5	0.3	4.6	9.5	4.8
intestine, large (beef)	14.4	6.3	0.9	0.5	0.7	0.0	7.4	3.1
liver (buffalo)	0.1	0.4	0.0	20.5	0.1	2.7	0.2	0.1
marbled ray (fish)	1.0	9.8	8.8	0.1	0.1	9.9	3.0	1.7
milk (cow)	1.3	2.7	6.6	1.5	0.2	0.1	3.9	2.0
onion	0.8	1.2	1.4	0.0	0.4	1.9	2.2	1.6
orange	2.7	1.9	9.0	3.2	12.3	6.8	10.4	11.5
papaya	0.4	0.2	0.5	2.0	4.1	2.1	0.5	0.9
shrimp, small	1.2	10.4	25.5	2.1	0.0	0.4	5.2	1.6
yam, spiny	22.9	10.4	10.5	0.6	15.8	5.0	11.0	21.3
	100.1	100.1	100.1	100.1	100.3	100.1	100.1	99.9

in the food mixture, it did not really explain the infeasibility found with the protein artificial variable. The protein artificial variable had magnitude of 2.8; this meant that the amino-acid constraints were met by a protein level corresponding to 49.4g but only when the total protein in the raw materials selected was actually 52.2g. With the raw materials available, the amino-acid constraints could not be met so that their relationships with protein could be satisfied. These relationships defined a range of 100-150% egg pattern; methionine, cystine, phenylalanine and tryptophan were limiting at the lower bound and lysine at the upper bound. The value of radish in the model also seemed to lie with its amino-acid pattern.

The contributions of the major constituents of Formula 1 and the infeasible solution to the levels of the limiting amino acids were examined to investigate how withdrawal of radish could have caused such infeasibility (Table 4.3).

Table 4.3 Percent contribution of selected foods to limiting amino-acid levels

	lysine	methionine	cystine	phenylalanine	tryptophan
Formula 1					
intestine, large (beef)	17.0	6.1	11.1	4.3	4.5
marbled ray (fish)	37.8	34.0	12.6	22.2	28.6
radish	4.3	2.8	40.2	7.2	2.2
yam, spiny	13.8	16.8	15.4	26.9	25.6
Infeasible solution					
banana (bungulan)	9.3	13.3	24.3	14.7	15.8
eggs (hen)	18.6	26.9	25.9	25.3	23.8
shrimp, small	8.7	9.7	5.6	7.4	7.6
yam, spiny	9.2	10.8	10.3	17.9	17.1

Radish was the major source of cystine for Formula 1. At the same time, it had a low contribution to the lysine level. When radish was removed the major sources of the limiting amino acids - eggs, banana, spiny yam - all had high contributions to the lower limiting amino acids but at the expense of having high contributions to lysine. Radish was required then to maintain the amino-acid balance, by providing high amounts of an amino acid limiting at its lower bound, cystine, and contributing poorly to an amino acid in rich supply and constrained at its upper bound, lysine.

Radish seemed to have been a key raw material in this model. It provided high levels of folic acid and cystine, nutrients whose lower limits were difficult to attain, together with low contributions to calories, calcium and lysine - nutrients which were difficult to constrain at the upper limits. Removal of radish caused the balance to be disturbed and conditions could no longer be satisfied. Contributions analysis indicated the sensitive constraints which could be changed to relieve the conflict:

1. Allow lower levels of folic acid and cystine
2. Allow higher levels of calories, calcium and lysine.

Changes in constraints to achieve feasibility. At this stage folic acid and calcium constraints were not changed. Folic was a defined lower requirement and the calcium upper bound was already much higher than desirable. If possible, these conditions had to be achieved in the mixture. Lowering the cystine limit would reduce protein quality. The present lower limit on amino acids defined protein with quality similar to egg protein. Lower quality could be tolerated without greatly affecting the nutritional value of the total mixture. Since any one of the amino acids at its lower limit would define the same protein quality, then reduction of all amino-acid limits would have the same effect as simply reducing cystine. Amino acids were constrained within the range 80-120% egg pattern levels. Therefore the range was also tightened to retain control of the overall amino acid pattern and the lysine level was not raised further.

As well as raising the upper bounds on calories, those of protein, vitamin A and vitamin C were also raised - in fact all were raised to infinity. This was partly to allow ease in obtaining feasibility by permitting higher levels of raw materials with large contributions to these nutrients. These raw materials might also provide folic and limiting amino acids. Also, as was indicated in the last chapter, the upper bounds were included to keep nutrient levels balanced around their requirement level. They could be removed since they were not required for any nutritional reason. High levels of vitamin A and vitamin C could be tolerated as these were labile nutrients. In order to keep calories and protein levels in check, protein calories were set at a minimum of 8% of total calories (88). The lower bound on calories was also increased to 2470, both to bring in raw materials rich in calories and also to force higher levels of thiamine, niacin, fat and iron, which were expected to reduce the cost (analysis on Formula 1). This corresponded to the maximum calorie level consistent with lower bound for protein of 49.4g.

The changes made were then :

calories - lower bound increased to 2470, upper bound removed
protein - upper bound removed; relationship included to maintain protein calories at least as 8% of total calories
vitamin A - upper bound removed
vitamin C - upper bound removed
amino acids - range constraint changed to between 80 and 120% of egg pattern

With these changes, a feasible solution resulted - Formula 2 in Table 4.1. Nutritionally the mixture was similar to Formula 1 except for higher calories, very much increased vitamin A level and a poorer quality protein. Folic acid was again the most expensive constraint to meet (reduced cost -0.085) but much less so than in Formula 1. All the limiting amino acids dropped down to their lower bounds except lysine which remained at the upper bound.

Foods which contributed highly to vitamin A and calories provided major contributions to the folic levels. This was the case for <u>chinese cabbage</u> and <u>sweet potato</u>. They also provided calcium at high levels which limited the amounts included, Cystine was primarily provided from <u>beef large intestine</u>, and <u>onion</u> and all other limiting amino-acids from <u>egg</u> and <u>glutinous rice</u> contributions.

This less restricted model provided a least-cost mixture at $0.02 less cost, 100g less bulk but with some loss to nutritional balance.

4.1.2 Discussion

In setting up a linear programming model for raw material selection according to nutritional criteria, it is important to consider a wide variety of food raw materials. The actual materials included in the list may determine the nutrient conditions which can be satisfied. In this case, much effort was required to adjust the model when one food raw material, radish, was removed from the list, as this material was found to contribute particularly to sensitive nutrients in the model. Other materials may not have been as critical. There was a need for a means of identifying the critical raw materials, so that the model could be developed to a less delicately balanced state and removal of raw materials did not cause conflict. The linear programming reports did not provide direct information on which raw materials were most critical for the delicate balance between nutrients and raw materials evident in the model except in terms of cost. For example from post-optimal analysis of Formula 1, the cost of the mixture was most sensitive to change in the level of beef blood,- reducing the solution level of 5.3g down to 5.1g would have increased the cost by 0.051 cents per gram. The effect of radish was less - 0.010 cent per gram, in reducing level from 429.5g down to 418.0g. This information was of little value in indicating the sensitivity of the model, when such a drastic effect was obtained in removal of radish, a seemingly insensitive food from the information given.

The nutrient constraint sensitivity information was much more useful in indicating the state of the model but again the value of this information was limited - since only the most costly nutrient constraints were identified. The presence of many constraints at their bounds with high cost effects would indicate a model very sensitive to change. In Formula 1, the model did not appear very sensitive on this criterion - only 14 of the 36 constraints were at their limits (7 at lower bounds, 3 at upper bounds, 4 as equalities) with folic acid being the only expensive constraint. It was necessary to make investigations beyond the solution reports of the linear programming system.

The calculation of contributions to nutrient levels for each food raw material in a mixture when used together with the linear programming report indicating the limiting nutrients identified these critical raw materials as those contributing highly to limiting nutrients. So for folic acid, the limiting nutrient, beef liver, marbled sting ray and radish were the key foods: reducing the level of one of these required that conditions be changed to allow high levels of one of the others in order to achieve the folic level. For example, reduction in beef liver would perhaps have required a relaxation of the upper bound on calcium to allow the possible inclusion of higher amounts of marbled sting ray to achieve the folic level.

This was a fairly simple approach. It did not indicate how sensitive the model was, but pointed to possible key foods for the sensitive nutrients. The whole model was too complex to understand the effects of individual raw materials on all the nutrient constraints. This system however could guide the modifications necessary when considering column variable or raw material changes. It was an attempt to provide more practical information in model development than was provided by the basic linear programming system. This was a major drawback in the system, since much time and expense was required to rectify the infeasible situation caused when a change was made in the variety of column variables in the model. Further research should be instigated to provide a more direct procedure for this purpose, but this was outwith the area of investigation of this thesis.

4.2 Matrix constraint modifications - the effect of varying nutritional constraints

Examination of the last solution (Formula 2) indicated a mixture with high calcium levels, high vitamin A, and a poorer quality protein than initially specified. In improving these nutritional levels, some increases in cost were to be expected. Relaxation of the tight equality restrictions on phosphorus, thiamine, riboflavin and niacin could reduce costs and achieve a less restricted model. This section describes the effects on cost and nutritional balance of mixtures when such nutritional constraints were adjusted.

4.2.1 Minimizing the calcium level in the mixture

The minimum level of calcium which could be tolerated in the model was found by changing the objective to minimization of calcium. The cost was merely summed to provide the total cost of this mixture.

Calcium at the level 532mg was found to be the lower limit. The cost had increased by $0.22 and the weight by 700g over the Formula 2 values. Vitamin A was reduced to 4150iu, fibre to around 7g and, of course, phosphorus to 532mg. Isoleucine became a limiting amino acid, while cystine rose above the lower limit.

The major raw material was banana (bungulan) which contributed to all nutrients, but several animal offal materials were required to provide trace vitamins and amino acids with minimum effect on calcium. Duck egg replaced hen egg as an amino-acid and vitamin A source due to the lower calcium content in the duck species.

Post-optimal analysis of this nutrient minimization problem gave information on the sensitivity of the solution to calcium composition data. The 'costs' in the output referred to calcium levels.

1. The most 'costly' constraint was folic acid, followed by thiamine, riboflavin and protein. In the case of folic acid and protein, reducing either of their lower limits by one unit would reduce the calcium by 45mg and 5mg respectively. Lowering either thiamine or riboflavin restrictions by one unit would further reduce calcium by 44mg and 10mg respectively. Increase in niacin and phosphorus levels would further reduce calcium slightly. The amino acids at their limits - isoleucine, methionine, phenylalanine and tryptophan at the lower limits and lysine at the upper limit - would each cause slight reductions in calcium if boundary restrictions were relaxed.

2. Inclusion of raw materials in the solution in many cases was subject to tight limits on their calcium content (see Table 4.4). This implied that the accuracy of the food composition data had to be much greater than was possible because of sample variation and accuracy of analysis. For example, a change in calcium content of banana (bungulan) from 11.0mg (quoted) to 11.03mg per 100g would alter the solution, yet the accuracy of calcium estimations was to the nearest milligram.

Similarly, several foods were excluded from the solution for only small deficiencies in calcium content which probably could not be justified by the accuracy of estimation (see Table 4.5).

It would seem that this technique was too precise for the data available, with such a sensitive solution. The precision indicated could never be possible in this type of problem, since there will never be a single accurate figure for each variable because of the varietal

Table 4.4 Critical calcium compositions of raw materials in calcium minimization solution

Raw material	Amount in solution g	Calcium content mg/100g	Range of calcium content for raw material to remain in solution at the defined level mg/100g
banana (bungulan)	1538.3	11.0	10.36 - 11.03
eggs (duck)	34.9	71.0	65.02 - 71.52
intestine, large (beef)	65.2	13.0	12.32 - 16.58
liver (beef)	1.5	130.0	128.68 - 135.55
lungs (buffalo)	57.2	20.0	12.37 - 20.13
pineapple	223.6	19.0	18.93 - 19.80
pork	52.9	6.0	2.79 - 7.88
rice, glutinous	15.0	17.0	16.91 - 18.66
seaweed	398.4	62.0	61.83 - 63.12
yam, spiny	90.1	21.0	19.95 - 21.06

and seasonal differences in raw material compositions.

Another defect in this optimization of a single nutrient was that although it was possible to do it for every nutrient in turn, conclusions would only be valid for each individual situation and could not be taken into account with sensitivity information found in other nutrient optimizations. Thus it was not possible to assess the sensitivity of the model to precision of all the compositional data.

The precision demanded by the linear programming method, both in sensitivity and also in expression of composition and specifications data, is a problem in a nutrition model where such information is inherently imprecise. However, this may not be too critical in this model. Firstly, in cost optimization, the precision of the nutrient composition would not be as critical since sensitivity would be based on cost data. Secondly, a precise solution is not required, rather a guide to selection of raw materials with specified nutritional properties.

Table 4.5 Critical calcium compositions of raw materials excluded from the minimum calcium solution

Raw material	Calcium content mg/100g	Reduced calcium content required in order to enter the solution mg/100g	Amount which could be included if calcium content lowered g
banana (gloria)	15.0	14.62	66.0
blue-spotted ray (fish)	25.0	23.00	3.0
gizzard, chicken	18.0	17.78	18.4
chico (starapple)	32.0	29.54	135.9
lemon	18.0	11.61	81.6
lime	17.0	10.70	129.0
marbled ray (fish)	223.0	200.54	3.7
orange	33.0	25.91	78.1
papaya	23.0	17.77	30.5
sugar cane juice	13.0	8.53	195.2
watermelon	8.0	3.09	68.4

4.2.2 Stepwise variation of the calcium constraint

Since the mixture with calcium at the minimum level had increased the cost substantially, the cost of mixtures with calcium levels between this minimum of 532mg and the upper bound of 900mg were determined using parametric linear programming. This permitted systematic change of any coefficients in the problem by a constant amount in each optimization step, the optimizations being carried out continuously without having to reset the problem. Starting from the Formula 2 solution with the upper bound on calcium at 900mg, the constraint was decreased by 50 units in seven steps down to 550mg. A feasible solution was obtained at each stage. The nutrient levels in the solutions are shown with those of Formula 2 and the minimum calcium solution in Table 4.6.

The calories, protein and calcium were always at a bound and

Table 4.6 Nutrient levels in solutions with stepwise variation of calcium

Nutrient	Formula 2	calcium upper limit (mg) 850	800	750	700	650	600	550	minimum calcium
calories (kcal)	2470[a]	2470[a]	2470[a]	2470[a]	2470[a]	2470[a]	2470[a]	2470[a]	2470[a]
protein (g)	49.4[a]	49.4[a]	49.4[a]	49.4[a]	49.4[a]	49.4[a]	49.4[a]	49.4[a]	49.4[a]
fat (g)	54.9	54.9	54.9	54.9	62.1	58.7	58.9	54.9	68.5
fibre (g)	15.0[b]	15.0[b]	15.0[b]	15.0[b]	15.0[b]	15.0[b]	15.0[b]	6.0[a]	6.6
calcium (mg)	900[b]	850[b]	800[b]	750[b]	700[b]	650[b]	600[b]	550[b]	532
phosphorus (mg)	900	850	800	750	700	650	600	550	532
iron (mg)	27.2	27.2	27.2	27.2	27.2	27.2	27.2	24.8	26.8
vitamin A (iu)	18040	16910	15630	16720	16570	15050	13620	9300	4150
thiamine (mg)	1.235	1.235	1.235	1.235	1.235	1.235	1.235	1.235	1.235
riboflavin (mg)	1.235	1.235	1.235	1.235	1.235	1.235	1.235	1.235	1.235
niacin (mg)	16.30	16.30	16.30	16.30	16.30	16.30	16.30	16.30	16.30
vitamin C (mg)	367	384	355	378	359	350	389	369	476
vitamin B6 (mg)	3.10	3.97	4.24	5.10	5.51	5.52	6.62	7.07	8.40
vitamin B12 (mg)	0.013	0.011	0.012	0.011	0.010	0.009	0.009	0.010	0.011
pantothenic acid (mg)	8.4	8.3	7.9	7.8	6.9	6.1	5.8	6.1	6.8
folic acid (mg)	0.18[a]	0.18[a]	0.18[a]	0.189	0.186	0.18[a]	0.18[a]	0.18[a]	0.18[a]
isoleucine [c]	90	89	90	89	88	85	80[a]	80[a]	80[a]
leucine	109	107	108	105	102	100	101	100	99
lysine	120[b]	120[b]	120[b]	120[b]	120[b]	120[b]	120[b]	120[b]	120[b]
methionine	80[a]	80[a]	80[a]	80[a]	80[a]	80[a]	80[a]	80[a]	80[a]
cystine	80[a]	80[a]	80[a]	80[a]	80[a]	80[a]	80[a]	80[a]	83
phenylalanine	83	84	83	83	80[a]	80[a]	80[a]	80[a]	80[a]
tyrosine	97	96	98	97	96	97	95	96	98
threonine	99	97	100	99	98	99	100	101	100
tryptophan	80[a]	80[a]	80[a]	80[a]	81	83	80[a]	80[a]	80[a]
valine (mg)	93	93	95	95	92	92	91	91	88
cost ($US)	0.300	0.306	0.312	0.319	0.329	0.347	0.393	0.460	0.518
weight (g)	1799	1861	1856	1917	1929	2025	2209	2243	2492

a. Held at lower bound.

b. Held at upper bound.

c. Amino acids expressed as percent corresponding amino-acid level in egg pattern.

folic acid levels fluctuated slightly from the lower bound throughout the changing restrictions on calcium. Vitamin A decreased steadily and vitamin B6 increased steadily as the calcium level decreased. The limiting amino acids, methionine, cystine and tryptophan remained limiting and were joined by isoleucine and phenylalanine at the lower calcium levels. The cost rose sharply when the calcium level dropped below 700mg (Fig.4.1).

Inclusion of raw materials in the solutions became more dependent on low contents of calcium and high contents of folic acid as the calcium constraint was lowered. An increase in the banana species (gloria) with lowering of calcium continued until the calcium level became too restrictive and the other banana species (bungulan), with lower calcium concentration, was included. Banana had high contributions to several nutrients especially folic acid, the most limiting constraint. High calcium and folic contents explained the steady decrease in chinese cabbage (petsay) and sweet potato as the calcium restrictions became tighter. This brought in seaweed to make up the calcium content, the folic acid contributions being dominated by the high amounts of banana in the solution (see Table 4.7).

From this investigation, the level of 700mg for the upper limit on calcium was selected as being the most satisfactory to reduce the calcium content of the mixture. This mixture was only $0.03 more costly than Formula 2; fewer nutrient constraints were difficult to meet, particularly folic acid and tryptophan; any further reduction in calcium caused the cost to rise steeply.

4.2.3 Relaxation of phosphorus constraint

Post-optimal analysis of Formula 1 indicated that savings in cost could be achieved by increasing the ratio of phosphorus to calcium. Similarly, post-optimal analysis of the calcium minimisation experiment indicated that increasing the ratio would lower calcium levels. Therefore if the phosphorus/calcium equality was relaxed, it was expected that cheaper solutions, more freedom in the selection of raw materials and lower levels of calcium would result.

Phosphorus equivalent to 150% of the calcium level is held to be the maximum satisfactory (90,92,94). A parametric experiment was designed

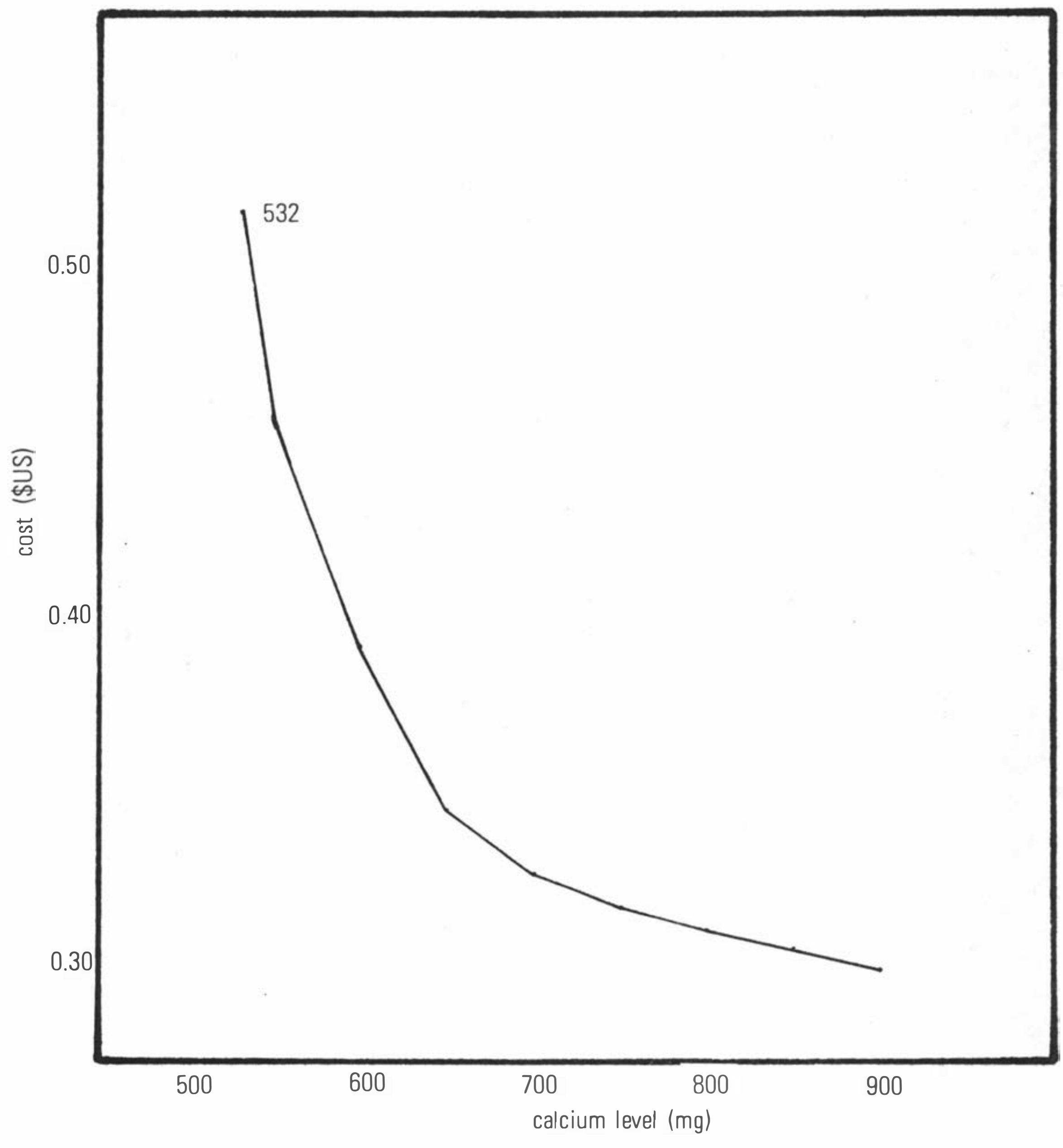


Figure 4.1 Effect on cost of parametrically adjusting calcium

Table 4.7 Percent contribution of selected raw materials to calcium and folic acid levels with stepwise variation in calcium

Calcium upper constraint	Raw material	Percent contribution to calcium	folic acid
900	cabbage, chinese	37.0	26.2
	sweet potato	22.5	19.8
850	cabbage, chinese	39.3	25.3
	sweet potato	22.9	19.0
	banana (gloria)	6.6	20.7
800	cabbage, chinese	38.7	23.4
	sweet potato	16.8	13.1
	banana (gloria)	9.1	26.9
750	cabbage, chinese	42.5	22.9
	sweet potato	18.8	13.1
	banana (gloria)	13.5	35.7
700	cabbage, chinese	46.9	24.0
	sweet potato	10.9	7.2
	banana (gloria)	17.0	42.7
650	cabbage, chinese	48.6	23.9
	banana (gloria)	18.7	45.0
600	cabbage, chinese	41.6	18.1
	banana (gloria)	21.0	44.7
	banana (bungulan)	4.4	12.6
550	cabbage, chinese	8.4	3.5
	banana (gloria)	16.4	33.3
	banana (bungulan)	12.0	33.2
	seaweed	34.4	0.0
532	banana (bungulan)	31.8	85.4
	seaweed	46.4	0.0

to investigate the effect on the minimum cost, of gradual relaxation of phosphorus levels from fixed at 100% of calcium levels (the present constraint) to range between 100 and 150% of calcium levels. An upper bound for the relationship was defined by HIPCON = P - CA $\leq$ 0 The parametric adjustment altered the coefficient of CA from 1.0 to 1.5 in 5 stages. The lower bound remained defined by PCON = P - CA $\geq$ 0 HIPCON could vary from $-\infty$ to 0 and PCON from 0 to $+\infty$ but the calcium upper limit of 700mg was retained. Thus the effects could be observed of increasing phosphorus levels whilst retaining a satisfactory relationship between calcium and phosphorus.

In each parametric step, both calcium and phosphorus remained at their upper limits. Folic acid was again limiting and became slightly more expensive to maintain at its minimum level, as phosphorus increased. Calories, protein, cystine and tryptophan remained at their lower bounds throughout and lysine at its upper limit.

The important raw materials for phosphorus were sweet potato, glutinous rice, egg and onion (Table 4.8). In the early stages, materials were included which contributed well to calcium, phosphorus and folic acid - banana (gloria), egg and glutinous rice. As higher levels of phosphorus became possible, still with restriction on calcium, materials with either balanced calcium and phosphorus levels and high folic content, or rich phosphorus contributions gradually replaced the earlier dominant materials. So banana, egg and glutinous rice were replaced by onion, coconut and goose meat. Sweet potato dominated throughout as it had balanced calcium and phosphorus levels with high folic acid.

The effect on cost was examined in Fig.4.2. There was a gradual fall in cost as the relationship between phosphorus and calcium was relaxed, but not as dramatic as that found in the calcium experiment. A substantial reduction in cost of $0.056 over that of Formula 2 was possible by allowing an upper phosphorus limit of 150% calcium (Formula 3). This range for phosphorus of between 100-150% the calcium level was nutritionally satisfactory and was incorporated in the model at this stage. Further slight savings in cost could have been possible with relaxation of thiamine, riboflavin and niacin restrictions; below 980mg phosphorus, lowering the thiamine and niacin and raising of riboflavin restrictions

Table 4.8 Percent contribution of selected raw materials to calcium, phosphorus and folic acid with relaxation of the calcium to phosphorus relationship

Phosphorus range relative to calcium level	Raw material	Percent contribution to calcium	phosphorus	folic acid
100%	banana (gloria)	17.0	21.6	42.7
	eggs (hen)	9.2	22.3	3.7
	rice, glutinous	2.3	12.7	5.0
	sweet potato	10.9	9.9	7.2
solution level (mg)		700	700	0.186
100–110%	banana (gloria)	9.1	10.5	23.6
	eggs (hen)	8.4	18.5	3.5
	onion	1.9	3.2	2.2
	rice, glutinous	3.6	18.4	8.3
	sweet potato	13.6	11.3	9.3
solution level (mg)		700	770	0.180
100–120%	banana (gloria)	4.7	9.6	2.0
	eggs (hen)	7.0	10.8	8.0
	rice, glutinous	5.6	26.0	12.8
	sweet potato	14.2	10.8	9.7
solution level (mg)		700	840	0.180
100–130%	eggs (hen)	4.5	8.4	1.9
	onion	9.4	13.5	10.8
	rice, glutinous	5.1	21.9	11.6
	goosemeat	0.5	6.2	0.8
	sweet potato	37.3	26.2	11.6
solution level (mg)		700	910	0.180
100–140%	coconut, mature	1.9	4.6	7.4
	eggs (hen)	4.6	8.0	1.9
	onion	11.5	15.3	13.2
	rice, glutinous	3.8	15.2	8.7
	goosemeat	0.7	9.0	0.8
	sweet potato	50.6	33.0	34.5
solution level (mg)		700	980	0.180
100–150%	coconut, mature	4.4	9.9	17.1
	eggs (hen)	5.7	9.2	2.4
	onion	12.5	15.4	14.2
	rice, glutinous	1.8	6.7	4.1
	goosemeat	0.9	11.1	1.1
	sweet potato	51.3	31.2	35.0
solution level (mg)		700	1050	0.180

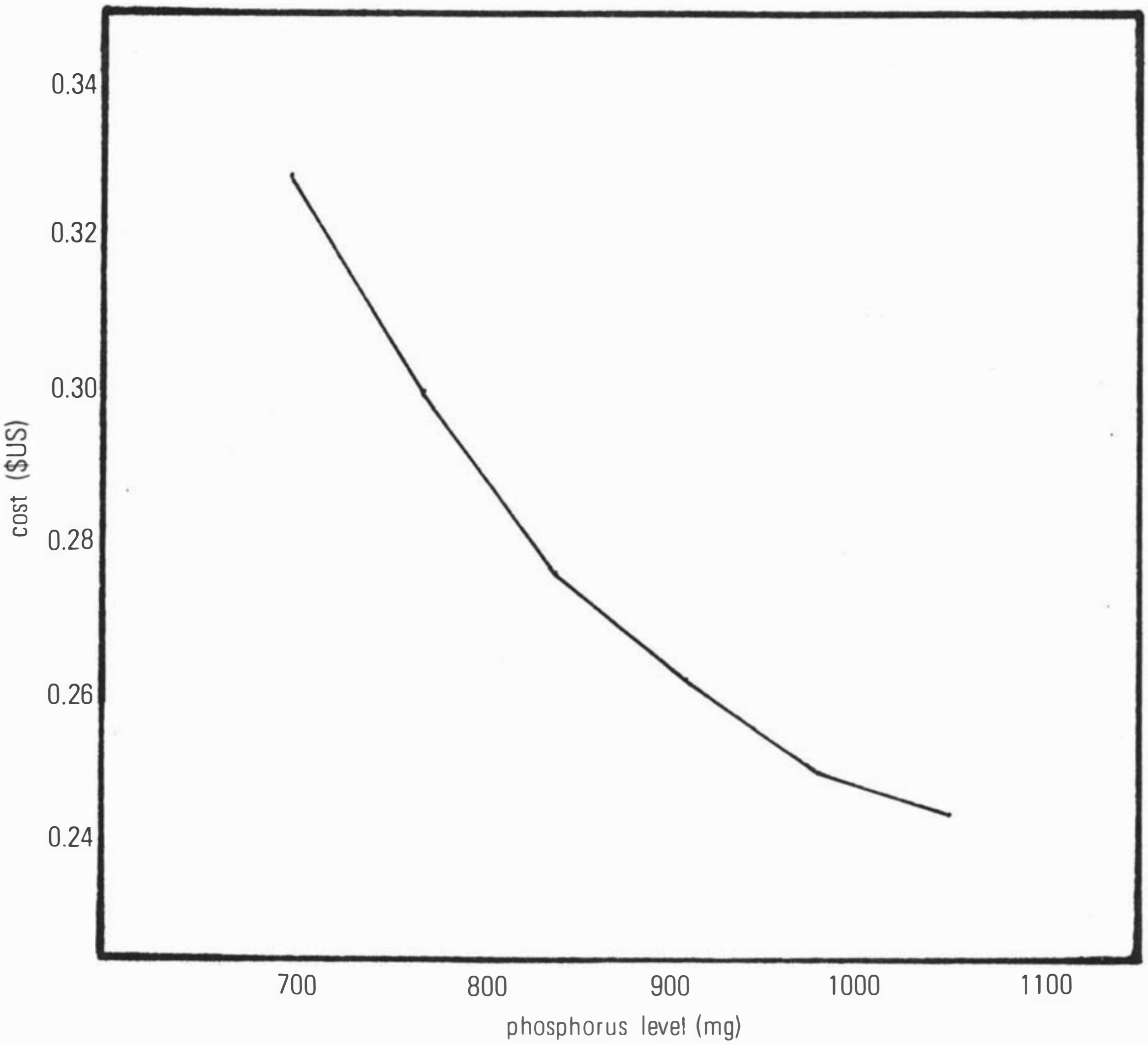


Figure 4.2 **Effect on cost of parametrically adjusting the calcium to phosphorus relationship**

were required; above 980mg phosphorus increases in both thiamine and riboflavin became desirable and the reduction in niacin became less important. These effects were investigated later.

4.2.4 Adjustment of amino-acid levels

In Formula 3, lysine lay at the upper limit of 120% and isoleucine, cystine and tryptophan at the lower limit of 80% egg pattern levels, defining a chemical score of 80. Higher quality protein could be achieved both by raising the amino-acid lower bound and by tightening the range specifications, to define a more balanced amino-acid pattern. Investigation was therefore made of how close the amino-acid levels could approach the target pattern of egg protein and of the consequent cost and protein quality changes.

The changes in protein quality were followed directly by the chemical score index and by several other parameters of protein quality which lent themselves to mathematical calculation:

1. Essential amino-acid index (EAAI). This is an index of protein quality based on the probability of each amino acid being available for protein synthesis and is calculated as the geometric mean of the ratio of each amino-acid level to the egg protein amino-acid level calculated as for chemical score above (110). It gives a higher index of protein quality than the chemical score. It indicates only the degree of balance of the amino acids relative to the standard egg protein pattern, but omits the limiting amino acid concept, which is probably more important in determining protein quality.
2. E/T ratio. The ratio of total essential amino acids to total amino-acid content indicates the level of non-essential amino acids in the protein (88). An amount of non-essential nitrogen must be supplied in the diet in order to achieve synthesis of nitrogen compounds and proteins in the body. Although such a level has not been specified, comparison of this ratio for the mixtures with that of other proteins indicates whether the E/T ratio is satisfactory e.g. egg protein with E/T = 3.2 is considered rather high while cassava with E/T of 1.3 is considered low.
3. Biological value (BV) and protein efficiency ratio (PER). These are biological measurements of protein quality and are determined by feeding experiments. BV indicates biological quality for maintenance

and PER, biological quality for growth requirements. Regression expressions were available to link both biological BV and measurements of PER with amino-acid compositions of proteins (111).

BV = 32.831 - 0.07897 (isoleucine) + 0.03628 (leucine) + 0.06267 (lysine) + 0.02171 (sulphur amino acids) - 0.01694 (aromatic amino acids) + 0.02649 (threonine) + 0.20899 (tryptophan) + 0.01048 (valine) - 0.00079 (non-essential amino acids) (r = 0.707)

PER = -1.2689 + 0.00237 (isoleucine) - 0.00046 (leucine) + 0.00214 (lysine) + 0.00249 (sulphur amino acids) + 0.00018 (aromatic amino acids) + 0.00033 (threonine) + 0.00587 (tryptophan) + 0.00462 (valine) (r = 0.742)

These indices measure different aspects of protein quality, based on amino acid composition. They were used in conjunction with chemical score to give some indication of the relative changes in mixture protein quality with adjustment of amino acid levels. A short computer program was written to calculate all these parameters - CS, EAAI, E/T, BV and PER - for each solution from amino acid and protein levels (Appendix 6).

Firstly, the high levels of lysine were brought down to the index level 100 by reducing the upper bound constraint from 120. The other conditions remained as for Formula 3. All the amino acids lay within the 80-86 index range except for leucine and lysine at 96 and 100 respectively. Isoleucine, methionine, cystine and trytophan were limiting. The chemical score did not alter, but all other protein quality parameters fell slightly due to the fall in lysine and leucine levels. Calories and protein remained at their minimum levels and folic acid became more expensive to attain at its lower limit. Calcium fell below its upper bound for the first time. The cost increased by $0.026. There were few changes in the raw materials selected. The major effect was the large reduction in sweet potato content, together with a lesser drop in goose meat content. There were increases in glutinous rice, spiny yam, and eggs to compensate for this. Sweet potato and goose meat would have been reduced due to their high contribution to the lysine. Glutinous rice, spiny yam and eggs had their lowest contributions to lysine but their highest to the limiting amino acids.

Raising the lower bounds on amino acids up to the 100 level was then investigated using the parametric technique. The maximum lower bound was found at the 85 level, as shown for Formula 4 in Table 4.1. Isoleucine, methionine, cystine and tryptophan were all limiting at the 85 level while leucine and lysine were held at the upper 100 level. The chemical score increased to 85 and the EAAI, E/T and PER indices all had values similar to Formula 3. The increased levels of the lower limiting amino acids had thus counteracted the fall in leucine and lysine levels in these indices. The exception was in BV which was reduced due to the lower lysine content.

As the amino-acid limits were increased, folic acid again became more expensive to achieve at its lower bound. Calories and protein exceeded their lower bounds in Formula 4. These were probably forced up to allow the amino acids to take up their higher levels; both calories and protein were at the minimum level of the protein/calorie relationship of 8% total calories as protein. Calcium was again below its upper limit. Vitamin A was substantially reduced from previous excessive levels. The cost increased to $0.402, an increase of $0.158 over Formula 3.

Large amounts of banana (bungulan), lime and spiny yam together with an increased level of eggs were included in the mixture. Lime contributed mainly to vitamin C and folic acid with a balanced but low contribution to amino-acid levels. It was more difficult to assess reasons for raw material changes since ten lower bounds were changed simultaneously. However, as isoleucine, methionine, cystine and tryptophan were most often limiting, foods which contributed highly to any of these would be expected to increase. This was shown for banana (bungulan) with its high contribution to cystine; egg was important as a high contributor to all the limiting amino acids but especially the sulphur-amino acids, methionine and cystine; and spiny yam was important as a source of tryptophan. Since these were the major raw materials, and they contributed highly to the levels of the limiting amino acids, it was assumed that the reason for no further improvement of the amino-acid pattern in the model, lay with these materials. Examination of Table 4.9 showed that banana (bungulan) had its highest contributions to vitamin B6 (70.6%), folic acid (41.4%) and vitamin C (36.3%). The constraints on all these nutrients would not prevent more banana coming into the solution since vitamins B6 and C had no upper bound, and folic acid was held at its lower bound. However, the high contributions to niacin (31.7%), riboflavin (17.9%) and thiamine (17.9%) which were restricted by equality

Table 4.9 Percent contribution of selected raw materials in Formula 4

	Percent contribution to nutrient levels by:		
	banana (bungulan)	eggs (hen)	yam, spiny
calories	28.4	8.2	23.8
protein	14.9	31.1	12.7
fat	5.4	24.8	0.5
fibre	21.4	0.0	40.6
calcium	13.3	15.0	18.0
phosphorus	12.9	24.3	21.1
iron	13.6	12.8	32.8
vitamin A	9.8	18.3	0.3
thiamine	17.9	7.0	34.0
riboflavin	17.9	39.1	8.5
niacin	31.7	0.8	19.3
vitamin C	36.3	0.2	13.9
vitamin B6	70.6	2.6	10.8
vitamin B12	0.0	71.5	0.0
pantothenic acid	21.1	21.8	36.3
folic acid	41.4	5.6	5.9
isoleucine	8.5	34.8	16.8
leucine	9.0	31.1	18.6
lysine	10.7	33.8	16.1
methionine	12.5	39.5	15.3
cystine	22.0	37.0	14.0
phenylalanine	12.5	33.8	23.0
tyrosine	11.3	33.5	20.9
threonine	11.7	32.7	18.8
tryptophan	14.3	33.9	23.4
valine	10.3	32.5	17.9
weight	35.5	6.0	25.2

constraints, probably explained why higher levels of banana (bungulan) could not be tolerated. Similarly eggs, had high contributions to riboflavin and also to leucine and lysine (both at their upper bounds). For spiny yam, major contributions were also made to niacin and thiamine as well as leucine and lysine.

It appeared that the tight restrictions on thiamine, riboflavin and niacin covered by the equality relationship with the calorie level, prevented further increase in amino-acid levels. Calories were not able to increase as this would have required an increased protein level which probably could not be tolerated with the demands on the available amino acids. Although these three major raw materials were selected in an attempt to suggest reasons why no further improvement was possible, the whole dynamic state of the model, the interrelationships of the constraints, nutrients and raw materials were too complex to explain fully.

Post-optimal analysis of Formula 4 confirmed that all the raw materials were in tight activity ranges and that the selection of raw materials was not cost sensitive; the constraints were the sensitive factors. The folic acid lower limit and the equality constraints were the most expensive to attain: reduction of the folic acid constraint would save $2.23 per mg; reduction of the niacin constraint would save $0.08 per mg; increase in the thiamine and riboflavin would save $0.90 and $1.11 per mg respectively.

Any of these changes would have to occur individually in order that such savings would result. This information suggested that simultaneous changes in these constraints should produce substantial cost savings and at the same time allow higher quality protein to be designed in the model.

4.2.5 Relaxation of thiamine, riboflavin and niacin constraints

The equality constraints on the respective relationships between thiamine, robiflavin, niacin and calories were altered to lower bound constraints. The lower bounds were at the same level as those previously fixed by the equality constraints. Niacin should have been reduced to make the model less restrictive but this was overruled by the aim to keep nutrients at least at their minimum requirement if a feasible solution was possible. Similarly, the folic acid constraint was not reduced.

The resulting solution (Formula 5 in Table 4.1) produced a cost saving of $0.103 over Formula 4. Folic acid was the only expensive nutrient to achieve but at lower cost than previously. Calories, protein, niacin, isoleucine, methionine and cystine were at their lower limits whilst fibre, calcium, phosphorus, leucine and lysine were at their upper limits. Vitamin A had increased to excessive levels. There was no effect on protein quality indices, except for slight increase in BV due to the higher level of tryptophan, the major variable in the regression.

There were a few changes in the raw materials selected. The mixture included very high levels of spiny yam with the unrestricted contribution to thiamine; increases in eggs and petsay with high contributions to riboflavin; and groundnut, liver (buffalo) and sugars to make up the balance of nutrients. The higher content of thiamine and lower content of niacin in banana (gloria) could explain its replacement of banana (bungulan) in this solution.

4.2.6 Further adjustment in amino-acid levels

With the model in this less restricted state, further increases in amino acid levels were studied. Preliminary experiments of maximizing expressions relating the limiting amino-acids isoleucine, methionine, cystine and tryptophan, indicated that :

1. Isoleucine reached the level of 89 when maximized by itself. At the same time, methionine, cystine and tryptophan remained at their lower limits equivalent to the index 85.
2. Methionine and cystine attained maxima of 95 and 99 when a function expressing their total was maximized. Under these conditions tryptophan achieved the level 94 but isoleucine remained limiting at 85.
3. Methionine achieved a maximum of 88.4, isoleucine 88.5, cystine 89 and tryptophan 90.7 when a function SUMAA = ISO + METH + CYS + TRYP was maximized, as the lower bound on all amino-acids was raised parametrically. Upper bounds were lowered simultaneously for these amino-acids to allow all levels to be raised without a high contribution to the maximum from any individual amino-acid. The lower bound on all other amino acids was at the level 89.

With all conditions as in Formula 5, except for lower bounds on methionine at 88.4, isoleucine at 89, and 89 on all other amino-acids a raw material mixture (Formula 6 in Table 4.1) was obtained with a cost of almost double that of Formula 5. Isoleucine, methionine and cystine were at their lower bounds and leucine, lysine and phenylalanine at the 100 level. Methionine was the limiting amino acid in the protein, which had a chemical score of 88. PER and EAAI increased with the higher amino-acid levels, but BV decreased slightly, probably due to the fall in the level of tryptophan in Formula 6. Calories, niacin and folic remained at their lower bounds. Calcium and phosphorus remained at their upper bounds. Protein moved above its lower bound to permit the higher amino-acid levels. Vitamin A was obtained at a more acceptable level.

Compared to Formula 4, the raw materials with major contributions to the limiting amino acids - eggs and spiny yam were able to increase without the restrictions on riboflavin and thiamine. However banana (bungulan) decreased, due probably to restrictions on fibre, calcium and phosphorus. The major effect was the introduction of high levels of fruit - avocado, lime and grapefruit in Formula 6. Avocado and lime provided significant contributions to the limiting niacin and amino acids. Lime was also a major provider of folic acid, another limiting nutrient. Grapefruit provided folic acid but did not have any major effect on amino acids.

It was deduced that no further improvement to amino acid levels was possible since the major amino acid contributors - eggs, spiny yam and banana (bungulan) were restricted from increasing by their high contributions to any or all of fibre, calcium, phosphorus, leucine and lysine, nutrients which were held at their upper bounds.

In comparison with Formula 5, (see Table 4.1) the nutritional improvements were in lowering the level of vitamin A and raising the protein quality. This was achieved at considerable cost and with mixture weight increase of almost one kilogram. The mixture solution consisted mainly of seasonal fruits: banana, lime, grapefruit and avocado with over 60% of the total weight of the mixture. Therefore the large extra cost for Formula 6 was not warranted over the lower cost for Formula 5.

4.2.7 Conclusion

Several nutritional constraints were thus considerably modified in developing the model to the conditions of Formula 5, at some sacrifice to the tight nutritional balance of Formula 2. However, the higher nutritional value of Formula 5, in terms of lower calcium, lower vitamin A, higher thiamine and riboflavin and improved protein quality, was achieved at no extra cost.

The linear programming system was found to be particularly suitable for investigation of changes in such nutrient constraints. Limiting constraints were directly indicated in solution reports and reduction in cost, possible through adjustment of these constraints, was detailed in REDUCED COST in solution reports without requiring the extensive and expensive post-optimal analysis report to be obtained. This report however was necessary to indicate sensitive raw materials and nutrients in solutions.

Optimization of nutrient levels gave the additional information of how sensitive a solution was to the raw material composition data for that nutrient. It was found that the precision of this information was much higher than could be expected of the data. This did not discount the technique as an excellent method for selection of raw materials. The precision of sensitivity information although indicating a model very sensitive to sometimes minute coefficient changes, should probably be ignored, when applied to particular raw materials.

Parametric linear programming was also found particularly useful as a means of evaluating the effect of different constraint levels of a single nutrient and also simultaneous changes in several nutrient constraints.

The information on the contributions of raw materials in solutions to the nutrient levels was found valuable in indicating why certain materials were selected and also which materials were limited by the constraints in the model.

4.3 The effect of altering coefficients in the matrix

Corrections were made to several coefficients of raw materials in the Formula 6 matrix. These were in the main, corrections to punching errors but also included recalculation of amino-acid levels for spiny yam and large intestine (beef). The change in spiny yam coefficients, which was a major correction of 40% reduction on the previous levels, was expected to affect the model conditions as spiny yam was the major raw material in the mixture. Large intestine (beef), also in Formula 6 but in a low amount, had major changes to non-limiting amino-acids so this could also have some effect on the model. The other changes, excepting minor changes to grapefruit and rice, were to materials not present in Formula 6 (Appendix 7).

When these changes were made in the model, the conditions of Formula 6 could not be met, but the less stringent conditions for Formula 5 were still achievable, although at double the previous cost (Formula 7 in Table 4.1). Nutrient levels were quite similar to those in Formula 5. Calories, fat and niacin were at their lower bounds while fibre, calcium and phosphorus were at their upper bounds. These nutrients were relatively inexpensive to maintain at these limits. Protein was well above its bound; iron and vitamin A had decreased slightly while vitamin C had increased almost threefold. Of the amino acids, isoleucine, cystine, tryptophan and valine were limiting and only lysine was held at the upper bound. There were slight reductions in all protein quality parameters but essentially there was no change in protein quality.

The raw materials were essentially those of Formula 6. High levels of fruits - banana (both species), lime and avocado - were required to push up the amino-acid levels with minimum effect on nutrients at upper bounds. Spiny yam was notably at much lower level than in Formulas 5 and 6, due to its lower contribution to amino-acid and folic levels together with its high effects on restricted nutrients, fibre, calcium and phosphorus. Offal materials - brain (buffalo) and small intestine (buffalo) were introduced to provide concentrated sources of amino acids. They also contributed to the high folic acid level which exceeded its lower bound for the first time.

The effect of this change in coefficients was to a certain extent predicted-nutrients at lower bounds were reduced in supply, therefore the lower bound was expected to be unachievable. However a less obvious case, might occur in such a problem, for example :

1. Correction of errors in data,
2. Inclusion of new nutritional data from more respresentative analyses as it became available,

3. Allowing for expected nutrient losses due to different processing methods.

In these cases, sensitivity information of the solution prior to implementing the alterations would not indicate the model changes which would be necessary to accommodate such coefficient alterations. Sensitivity was only in terms of the single variable being optimized, normally cost, so this was of limited value when several variable changes were being considered. If each nutrient was optimized individually, with all raw materials fixed at the levels in the solution being evaluated, the information on sensitivity of changes in all nutrient composition data would be of little value in the whole model, since :

1. The effect of only one change could be estimated,
2. Only sensitivity to one nutrient could be evaluated at one time, which again would not be valid in the multi-nutrient conditions of cost optimization,
3. The conditions would be unreal with raw materials held at limits which did not exist in the original cost optimization. Information would not be valid for the original least-cost solution.

In the case of cost changes, since there would be no restrictions, the effect would be on total cost and in the selection of the particular raw materials, so that no change in model conditions would be necessary.

Therefore, heuristic methods have mainly to be used when any changes to nutrient coefficients are made. Cases can only be studied by solving several individual problems - one after another.

4.4 Additions to the raw material list

Data were added to the Formula 7 matrix for three additional banana species - lakatan, latundan and saba, the most popular and abundant banana species in the Philippines. The species already included in the model - bungulan and gloria were also popular but had initially been selected to represent the extremes of nutrient compositions in bananas. This was also an appropriate opportunity to re-install the radish, which had been removed earlier in an effort to control the organcleptic properties of the food mixtures as well as to illustrate the sensitivity of the model to removal of materials. Re-incorporation of this material was expected to reduce the cost of attaining the limiting cystine and folic acid levels.

The solution obtained (Formula 8 in Table 4.1) cost half as much as Formula 7 and the weight was reduced by 800g. All nutrients at bounds were those identified in Formula 7: riboflavin dropped to its lower bound; vitamin A was reduced to a more satisfactory level; cystine joined leucine and lysine at amino-acid upper bounds; iscleucine, tyrosine and tryptophan became limiting at the lower bound of 85. There were slight increases in the protein quality parameters, but essentially there was no real change.

Of the raw materials in Formula 7, bananas, lime, sugar cane juice and white corn were replaced by some materials originally included in Formula 1 (the last mixture which contained radish) - coconut, large intestine (beef), liver (lamb) glutinous rice and radish. High amounts of spiny yam were again included. It was noted that no banana species were included in the mixture. Radish again was selected as a key contributor to previously limiting nutrients folic acid and cystine so that the large quantities of banana were not required to contribute to these limiting nutrients.

The effect of adding more raw materials to the list could not be predicted, unless prior knowledge was available, as in the case of radish. Again, a trial and error apprcach was required.

4.5 The effect of adjusting cost coefficients

As discussed earlier, post-optimal analysis indicated the range within which each raw material cost could vary without changing the solution mixture. This information was valid for a change in cost for only one material. The effect of a cost change outside the range limits were not identified.

Costs for most materials were increased, as it was recognised that costs had been assigned on an '100g as purchased' basis (from production, market or retail value) whilst nutritional data had been assigned on an '100g edible portion' basis. In several raw materials, where there was wastage associated with the raw material as purchased, costs were therefore too low. For one hundred and four raw materials, costs were scaled up equivalent to the costs of 100g edible raw material in order to rectify this inconsistency. (Appendix 8 indicates the changed data). It was expected that the cost would rise and that some cheaper materials would replace the more expensive materials.

The effect on Formula 8 of these increases in costs was observed in Formula 9 (see Table 4.1) and the cost was $0.08 higher. Nutritionally, there was little change, higher vitamin A and lower cystine levels were necessary to minimize the cost. All the raw materials selected were present in Formula 8, although their levels were altered. The small amounts of liver (lamb) and marbled sting ray (fish) in Formula 8 were eliminated in Formula 9.

Generally where their costs were not increased, raw materials were obtained at higher levels. The exceptions were glutinous rice which decreased and liver (lamb) which was eliminated. Also where costs increased, raw materials generally were obtained at lower levels. The exceptions were eggs, spiny yam and petsay which were required to provide limiting amino-acids and niacin.

The effect then was as expected - an increase in total cost with reduction in levels of those raw materials with increased cost.

4.6 Comparison of original constraints with those of modified model (Formula 9)

The original aim was to design mixtures with nutritional levels at or around the minimum requirement in order to achieve balanced nutrition. This had to be modified somewhat so that a feasible solution could be obtained, which satisfied at least the minimum requirements and also prevented excessive nutrient levels so that some measure of balanced nutrition was retained in the design.

Table 4.10 details the constraint changes made in developing the model to the Formula 9 stage compared with those originally considered. Most of the upper bound constraints were removed early on since these were not nutritionally specified; this applied to calories, protein, vitamin A and vitamin C. In order to retain a balance of calories and protein under these conditions, a relationship specifying that at least 8% total calories could be provided by protein, was introduced. The lower bound on calories, together with other constraints, had been adjusted earlier in efforts to obtain a feasible solution. This

Table 4.10 Comparison of constraints in the developed model with those considered originally

	Original constraints	Developed constraints
calories	2030 - 2210kcal	2470 kcal, minimum
protein	49.4 - 53.7g	49.4g, minimum calories from protein, 8% total calories, minimum
fat	calories from fat between 20 - 35% total calories	no change
fibre	6 - 15g	no change
calcium	452 - 553mg	452 - 700mg
phosphorus	100% calcium level	100 - 150% calcium level
iron	0.01mg per kcal energy, minimum	no change
vitamin A	3900 - 4450iu	3900iu, minimum
thiamine	0.0005mg per kcal energy	0.0005mg per kcal energy, minimum
riboflavin	0.0005mg per kcal energy	0.0005mg per kcal energy, minimum
niacin	0.0066mg per kcal energy	0.0066mg per kcal energy, minimum
vitamin C	29 - 53mg	29mg, minimum
vitamin B6	1.68mg, minimum	no change
vitamin B12	0.002mg, minimum	no change
panthothenic acid	no limit	no change
folic acid	0.18 - 0.37mg	no change
isoleucine leucine lysine methionine cystine phenylalanine tyrosine threonine tryptophan valine	100% egg pattern levels	85 - 100% egg pattern levels

could probably be lowered to the original limit with reduction in total cost, at this stage.

The upper limit on calcium was raised to allow feasibility and also to find more economic mixtures. This was aided by relaxing the equality relationship between phosphorus and calcium to allow higher levels of phosphorus within the range 100-150% calcium level, consistent with nutritional recommendations. Similarly, the equality relationships relating thiamine, riboflavin and niacin were relaxed so that minimum levels were set consistent with requirements for energy utilization of the calorie supply. Again cheaper mixtures resulted.

The basic objective of at least meeting minimum requirements, prevented the reduction of the folic acid and niacin constraints - the most difficult and costly constraints to meet.

The constraints defining amino-acid balance did not describe individual requirements. It was desired that the amino-acid pattern be similar to that of the reference protein of hen egg, or as close to this as possible. The original attempt of fixing this pattern identical to that of egg protein was too restrictive and caused infeasibility. These equality constraints were relaxed so that a pattern with all amino-acid levels higher than the reference resulted but this situation became untenable with later model modifications. However, the reduction of amino acids below reference levels, but retaining a balance of within 15% of egg pattern levels (in Formula 9) defined a better quality protein than the imbalanced pattern ranging over 50% of egg levels in Formula 1 since :

1. High levels of essential amino acids implied a lower amount of non-essential nitrogen in the protein. Non-essential nitrogen could become limiting especially at low protein intakes (88), as then essential amino acids would be utilized for synthesis of non-essential nitrogen compounds. Thus the true essential amino-acid pattern would be altered(88). Such conditions exist for egg protein with $E/_T$ = 3.3 and human milk protein with $E/_T$ = 3.1. Formula 1 amino-acid pattern had $E/_T$ of 3.7 - well in excess of these values. Formula 9 has a more desirable $E/_T$ of 3.0.

2. Imbalances of amino acids could interfere with the utilization of other amino acids (88). This effect would be more pronounced for amino

acids in excess of requirement pattern than for the lesser imbalance below the reference pattern. In the latter, all amino-acids could be utilized fully up to the level of the limiting amino acid, with extra of this balanced protein being necessary to achieve levels equivalent to egg. Excess amino acids could be utilised for other synthesis or for energy, causing imbalance of supply.

Cost would undoubtedly increase with further raising of the amino-acid levels closer to those of the reference pattern, and the cost of Formula 9 was already higher than could be tolerated by the incomes of the people for whom the food was being designed. Consideration of this was held over to the next section.

The model had thus been developed to satisfactory conditions consistent with nutritional objectives. The consideration of factors bearing on other objectives will be described in the next section.

4.7 Summary and conclusions

The raw material selection was developed to incorporate more satisfactory nutritional design, by adjusting model constraints, variables and coefficients. This adjustment also indicated the sensitivity of the model to such changes and the limitations of the computer system in identifying this sensitivity. Adjustments investigated were :

1. Changes in nutritional constraints - calcium, phosphorus, thiamine, riboflavin, niacin and essential amino acids.
2. Simultaneous changes in several coefficients - correction of nutritional composition and cost data.
3. Changes in the variety of raw materials available either by removing from or adding to the raw material list.

All these investigations illustrated the need to generally understand the relation between variables and constraints. By working with a model over a period, as described here - analysing infeasibilities, changing constraints and coefficients - a greater appreciation was obtained of the sensitivity of the model and the interrelationships between variables and constraints than possibly could ever be expected from a post-optimal sensitivity analysis on any single solution. The calculation of the contribution of each raw material in a mixture to the nutrient, cost and weight levels was also found useful for this purpose, and in directing experiments to remove infeasibility.

The linear programming system together with the parametric procedure provided a practical and flexible method for development of a nutrition model for selecting raw materials, provided only constraint changes were investigated. Changing matrix conditions - coefficients or variables could cause problems which may not be capable of reasoned explanation or speedy rectification. To minimize these problems it is advisable for future work on this type of problem to devise an effective and efficient means of checking and vetting all basic problem data prior to model development.

CHAPTER 5

MODIFICATION OF THE MODEL TO FIT PHILIPPINE FOOD COST AND WEIGHT CONDITIONS

The model developed (Formula 9) gave a satisfactory nutritional mixture. Further modifications were necessary to design mixtures more compatible with the cost and weight conditions associated with Philippine food habits. Two approaches were investigated to achieve this.

1. Reduction of particular nutritional restrictions concerning calories and protein quality, by directly altering their constraints.
2. Retaining the balance of all the nutrients but reducing the percentage that they achieve of total nutritional requirements. Parametric and goal programming were compared in this estimation.

5.1 Efforts to reduce cost and weight of mixtures closer to present Philippine diet conditions

With the model developed, mixtures were obtainable of high nutritional value but with costs greater than \$0.40 and total weight in excess of 2000g. The actual weighted average daily food expenditure and daily food intake, calculated from data obtained in the Philippine nutrition surveys were \$0.13 and 730g respectively. If these were taken as target values, then the cost and weight of the present mixture deviated widely from these values.

Some deviation of cost and weight over the target levels could be permitted since :

1. Subsidization of the cost of the final product by some Government or international agency might be possible. The cost to the consumer might then comply with present food expenditure.
2. The cost target represented mainly the money required to purchase extra food products over those produced in subsistence agriculture in

the rural areas or home gardens in the towns. It perhaps could not be expected that such a low cost be sufficient to pay for the full daily diet.

3. The total weight of a processed product might be lowered by the processing used e.g. dehydration. This of course would add higher processing cost to the final cost of the product.

4. Philippine food intakes were deficient in quantity as well as quality. From recent food balance sheet calculations intake appeared to have increased to 900mg (Table 5.1), but as this represented availability and not intake as measured in nutrition surveys, lower intakes were probably still prevalent. A change in food habits to incorporate higher food intakes was perhaps necessary to achieve improved nutrition. Compared with average diets of other countries (Table 5.1), food intakes of 2000g (as in Formula 9) corresponded to the intakes of the affluent Western nations. It could not be expected that people subsisting on an average food intake of 730g could suddenly adapt to intakes around 2000g. However, higher intakes should be possible as evident for diets of other poor countries with intakes of up to 1500g per day.

Table 5.1 Daily food intake for several countries[a]

Country	Mean per caput daily food intake (g)
United States	2220
New Zealand	2150
United Kingdom	1890
Japan	1480
Peru	1400
Egypt	1340
Mexico	1090
Philippines[b]	900
Ceylon	870
India	730

a. Taken from food supply statistics, FAO Production Yearbook 1970, FAO, Rome 1972.

b. More recent data than that available from nutrition surveys conducted over ten yearperiod 1958 - 1968.

The cost should be as near the present cost as possible so that the poorest people were able to purchase the formulated products. Such products would be attractive in terms of price to the less poor. The cheaper the cost and closer to the target cost, the more compatible such products would be with the cost aspect of Philippine food habits. Lowering of the weight of selected mixtures should be considered, but some deviation from the target weight may be required. This deviation should be restricted in order to minimize the change required in present food habits.

5.1.1 The effect of lowering the calories lower bound

In the last solution (Formula 9), calories, fat and niacin were at their lower limits and fibre, calcium and phosphorus were at their upper limits. Of the amino acids, isoleucine, tyrosine, and tryptophan were at their lower bounds and leucine and lysine were at their upper bounds. Relaxation of any of these constraints would result in a lowered cost of the mixture.

It was not desirable to alter the required nutritional restrictions if at all possible. Thus the upper bounds of fibre, calcium, phosphorus levels should not be changed unless necessary for feasibility.

The calorie lower limit, however, could be reduced to the original requirement of 2030. At the same time this would lower the requirements for fat and niacin.

When the calorie requirement was adjusted to 2030, with all other conditions as for Formula 9, the resulting solution Formula 10, had a cost reduction of $0.16 and a weight reduction of over 600g. Cost and weight were still well above target levels. Fat, niacin and folic remained costly to provide at their minimum requirements. Small cost savings could have been achieved by further lowering of the calorie bound. This was not desirable since it would mean considering a calorie level below the average requirement calculated; and as the calorie level determined the constraints on fat, iron, thiamine, riboflavin and niacin, reduction of the calories limit would then have reduced several other nutrients to deficient levels.

5.1.2 The effect of lowering protein quality

In Formula 10, isoleucine, cystine, tyrosine and tryptophan were at their lower bounds, equivalent to a chemical score of 85. In each case, relaxation of the requirement would lower costs but this would result in a mixture with a lower chemical score and therefore, poorer protein quality. The relationship between cost and the chemical score of the protein was therefore investigated using parametric programming.

Parametric adjustments of amino-acid lower bounds were carried out corresponding to a drop in chemical score from 85 to 60 in steps of 5 percent units, with finer scaling of 1 percent units between chemical scores 80 and 70. In these experiments, all amino-acid limits were reduced simultaneously since any amino acid could be at the minimum to define the chemical score of the protein. There would have been no point in maintaining non-limiting amino-acids at higher levels when cost saving was being investigated.

The effect of these changes on cost and weight of mixtures is illustrated in Fig.5.1. A dramatic fall in cost and weight with decreasing protein quality, particularly between chemical scores 85 and 80, was observed. Below chemical score 80 the effect on weight fell off; between 75 and 65, weight remained fairly constant and rose slightly at chemical score 60. In cost however, it was only below chemical score of 75 that the cost gradient relaxed. It seemed then that from a cost and weight point of view protein qualities corresponding to chemical score of greater than 80 were unwarranted. At chemical scores 60 - 65, the costs were near to target costs. However, protein qualities at this level offered no improvement and could in fact be worse than that of the Philippines' diet.

The usefulness of this information for selection of a maximum protein quality for the model depends on :

1. the cost and weight ranges that are desirable,
2. the lower limit on desirable chemical score for the protein

It has already been noted that the cost target was $0.13. Only at chemical score 60 did the cost come down to $0.13, but this was poor quality protein and would mean a higher protein content was necessary. Above this chemical score, however, costs rose steeply.

The weight of food eaten was 730g. Greater values could be tolerated but should not exceed 1500g. The weight of mixtures had a

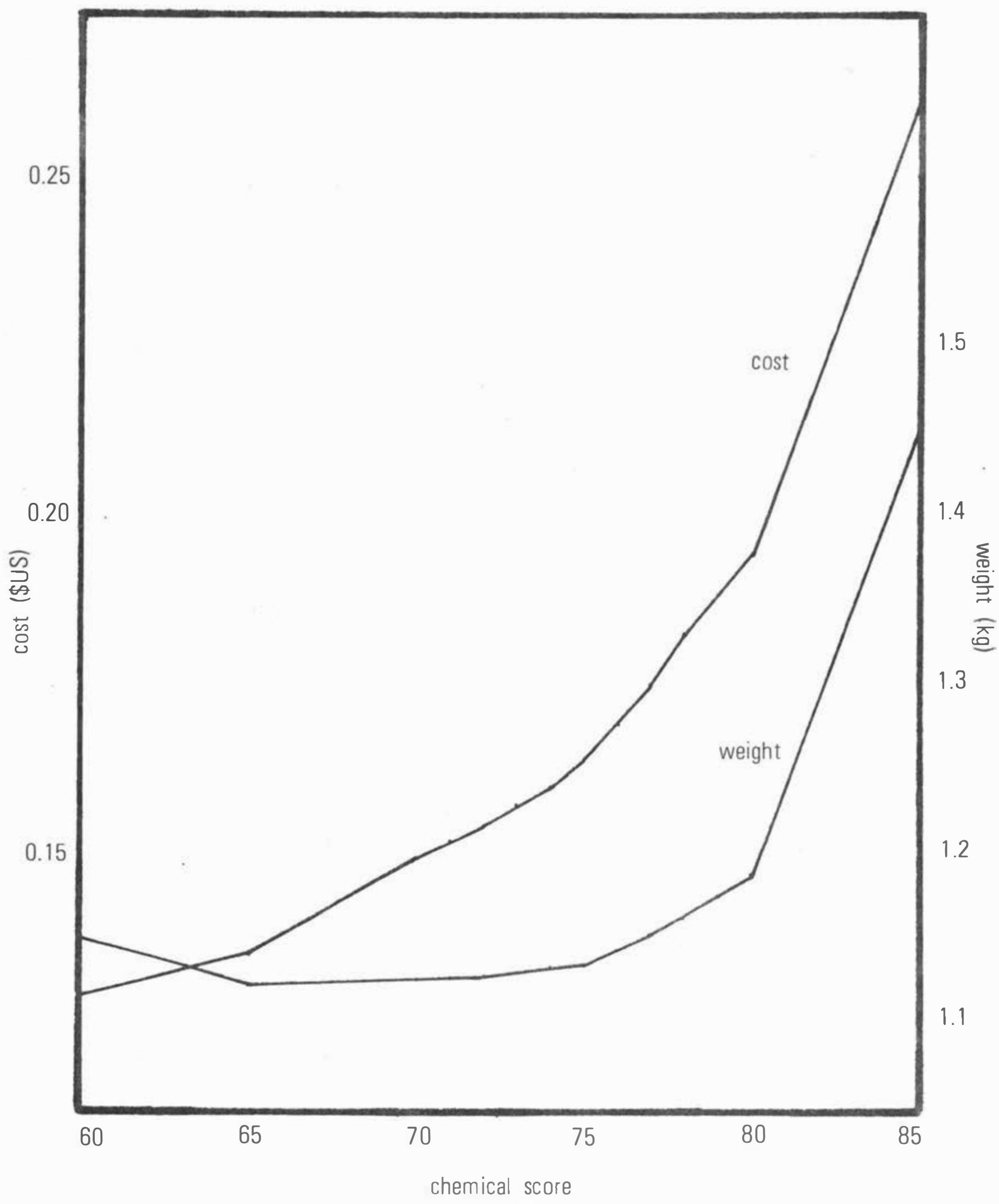


Figure 5.1 **Effect on cost and weight of parametrically adjusting chemical score restrictions**

minimum around 1130g which exceeded the target weight, but lay within the postulated acceptable range. Weight was essentially constant over the range of chemical score 65 - 75, so that the higher chemical score of 75 would be justified. However, cost at this point was $0.165, $0.035 greater than the target cost.

Figure 5.2 indicates the relationships found between the mathematical indices of protein quality. In all cases except 'biological value', there was a positive correlation of protein quality index with chemical score. The BV regression gave an odd relationship having high values at low chemical score but with positive correlation above chemical score 74. (This must have been due to the regression which explained only 50% of the variation). The major point to notice was that very little change was seen in the indices between chemical score 70 and 75.

A protein quality at least equivalent to a net protein utilization (NPU) of 63 was required, since this was the basis on which the protein requirement was calculated. There was no direct relationship between NPU and CS, but NPU was related to BV by the relation

$$\text{NPU} = \text{BV} \times \text{digestibility.}$$

The digestibility is a fraction which can only be measured biologically, but approximate values were assumed, in investigating protein quality changes. If the NPU of the mixture exceeded 63, which was likely at high chemical scores, then assuming digestibility below 100%, say 90%, the protein quality in terms of BV would require to be greater than 70. Assuming this correlated directly with chemical score, then the chemical score should be greater than 70. A higher NPU meant a lower protein requirement, so at the present protein requirement lower quality protein was possible in the model. Although this in itself was not undesirable, the balance of the model would be disturbed and therefore it should be avoided. Taking the higher CS value of 75 could prevent the lowering of protein quality as NPU could rise to around 68, on this basis. However the problem remained of having excess protein over requirement, since it could be reduced for higher quality protein. This effect is investigated in the next section.

Also, the extent of the availability and absorption of amino acids would affect the selection of a minimum protein quality. The amino-acid composition data are derived from chemical analysis, whereas

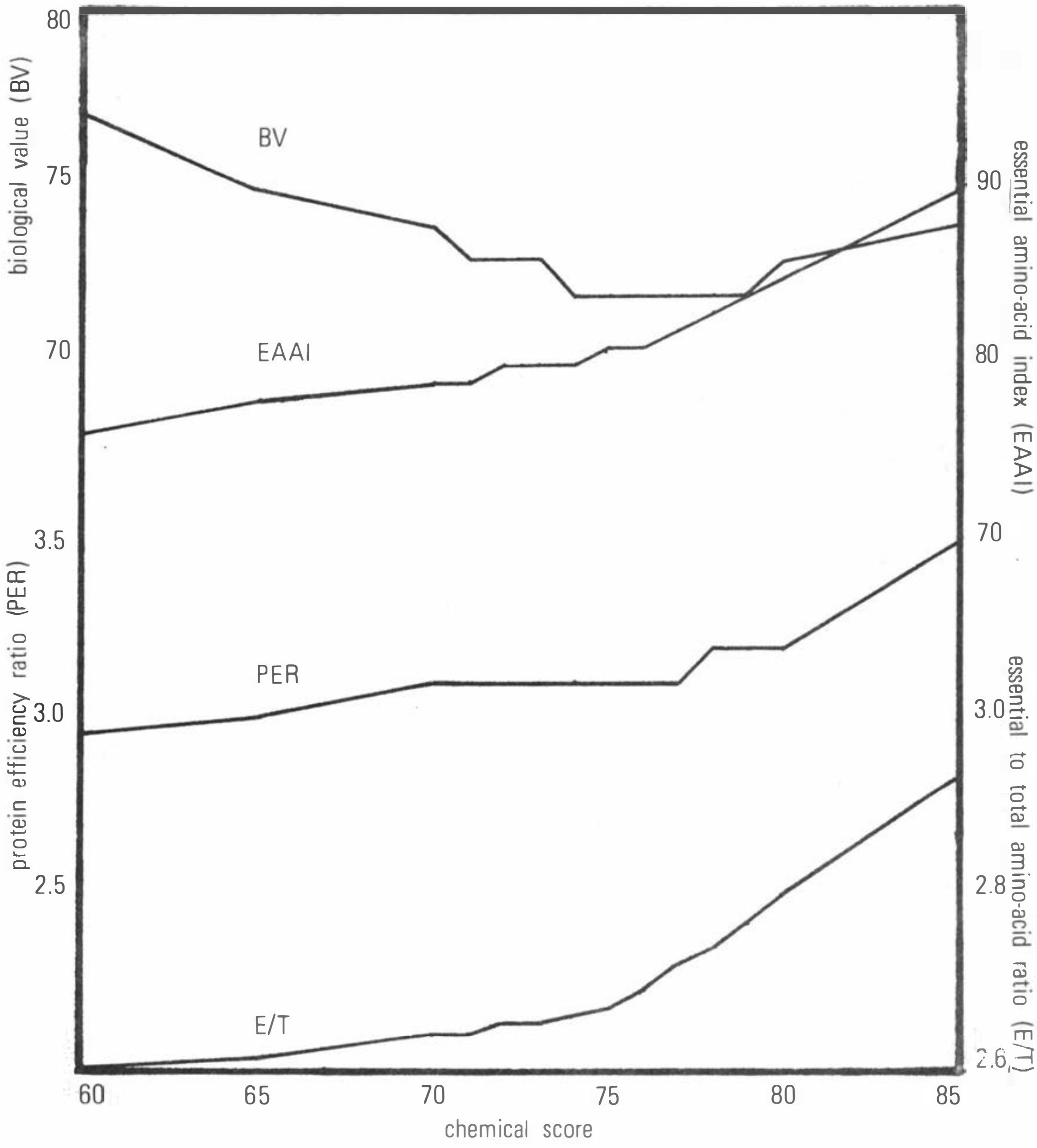


Figure 5.2 **Relation of designed chemical score with other protein quality indices**

protein quality is finally judged in the human by absorption of amino-acids in the gut. This absorption can be affected by the food materials providing the amino acids and by the availability of the amino acids in these foods. In the indices used here, it was assumed that absorption and availability were fully 100% of the chemically derived amino-acid levels. Only biological measurements can provide the true figures, but if this percentage is lowered to 95% for the limiting amino-acid, a chemical score of 70 is reduced to 68 and of 75 to 71; and if lowered to 90% these are reduced to 63 and 68 respectively.

Thus, the chemical score of 75 gave a safety margin not possible with the lower value of 70, to take account of these factors which could only be measured biologically.

Greater safety margins would be possible at higher chemical scores but the consequent higher cost and higher weights were undesirable.

Conclusion. Lowering the possible chemical score to 75 was justified in terms of cost savings ($0.165 against $0.262 for CS = 85), weight reduction (1140g against 1460g for CS = 85) and protein quality criteria. Any further reduction gave cost savings but an undesirable decrease in protein quality with no advantage in weight factor. The effect of enhanced protein quality on the protein requirement should be investigated. This solution, Formula 11 is shown in Table 4.1.

The protein quality of Formula 11 compared favourably with single food proteins in terms of the calculated indices (Table 5.2). Thus the mixture protein should add to the nutritional value of the designed food formulation.

5.1.3 Consideration of protein quality and its effect on protein requirement with a view to further reducing cost and weight

In most of the solutions obtained, particularly those at high chemical score, protein had been a limiting variable, so that relaxing its bound would only slightly reduce the total cost of the mixture; for each gram reduction of protein requirement, no more than 0.1 cent could be saved on the mixture cost, all other conditions remaining constant.

Table 5.2 **Comparison of protein quality of Formula 11 with that of other food proteins**

	chemical score CS [a]	essential amino-acid index EAAI [b]	biological value BV [c]	protein efficiency ratio PER [c]	essential to total amino-acid ratio E/T [a]
egg (hen)	100	100	94	3.9	3.22
pork	80	83	74	n.a.	2.67
fish	75	80	76	3.6	2.66
Formula 11	75	81	72 [d]	3.1 [d]	2.64
rice	75	73	64	2.2	2.61
soybean	70	83	73	2.3	2.58
casein	60	88	80	2.9	3.25

a. Taken from FAO, 'Amino-acid content of foods and biological data on proteins,' FAO, Rome, 1969 (84).

b. Taken from FAO/WHO report on protein requirements (88).

c. Taken from Oser (110).

d. Calculated, based on regressions of Perisse'etal (111). No biological measurement made. See text.

As noted earlier, the protein requirement in the model had been calculated on the basis of an NPU of 63 for the average diet of the Philippines. This meant a correction to the protein requirement for reference protein of NPU = 100 had been made such that

$$\text{Protein requirement} = \text{Reference protein requirement} \times \frac{100}{\text{NPU}}$$

which in this case $= \frac{3112.2}{63} = 49.4$

Therefore for higher NPU, the requirement for protein would be reduced.

At this stage, a protein quality limit in terms of chemical scores of 75 had been imposed. Thus the maximum NPU could be 75, for digestibility of 100%, if it was assumed that biological value and chemical score indices were directly correlated. Reductions in digestibility or biological value or both, due to availability and absorption effects, could lower this value but probably it would not fall below the assumed figure for NPU of 63, provided the chemical score limit was maintained at 75. There was therefore a possibility that a reduced protein requirement to a minimum of 41.5 (for NPU = 75) could be justified, although to be correct, biological measurement would be necessary to e stimate the true NPU.

It would be most convenient if the amino-acid levels which defined biologically the quality of protein, could be incorporated into an equation defining the protein requirement. Since the protein level defined the minimum level of each amino acid, then an equilibrium should be reached when minimizing cost between protein and amino-acid levels compatible with a protein quality constraint. The amino-acid levels would still be constrained to retain balance criteria.

The BV regression from FAO linearly related a protein quality index to amino-acid levels. Also there was a relation of BV to NPU, through digestibility which could be assumed to have a value, say, 90%.

$$\text{then} \quad NPU = BV \times 0.9$$

$$\text{and protein requirement is} \quad \frac{3112.2}{NPU} = \frac{3458}{BV}$$

This equation was not linear. It was only possible to consider this in an LP context if a function 1/BV could be defined but as BV amino acid relationship was linear, its reciprocal was also non-linear. The function 1/BV or 1/NPU could be given a fixed value in each individual problem but there would be no advantage over simply defining a new protein requirement. The only way to get over this problem would be to obtain the raw data used to deduce the BV regression so that a similar expression could be obtained relating 1/BV to the amino-acid levels.

To investigate the effect of reduced protein requirement, in the absence of a protein quality function, a range of possible values of NPU were chosen, 75, 72, 69, 66, 63 and their corresponding protein requirements calculated.- 41.5, 43.3, 45.2, 47.2 and 49.4g respectively. These values were used in successive cost optimizations as protein requirement in the model, the conditions otherwise remaining as for Formula 11.

Although the solutions obtained were similar nutritionally, there was a dramatic rise in weight and a very slight decrease in cost with reduction in protein level (See Fig.5.3).

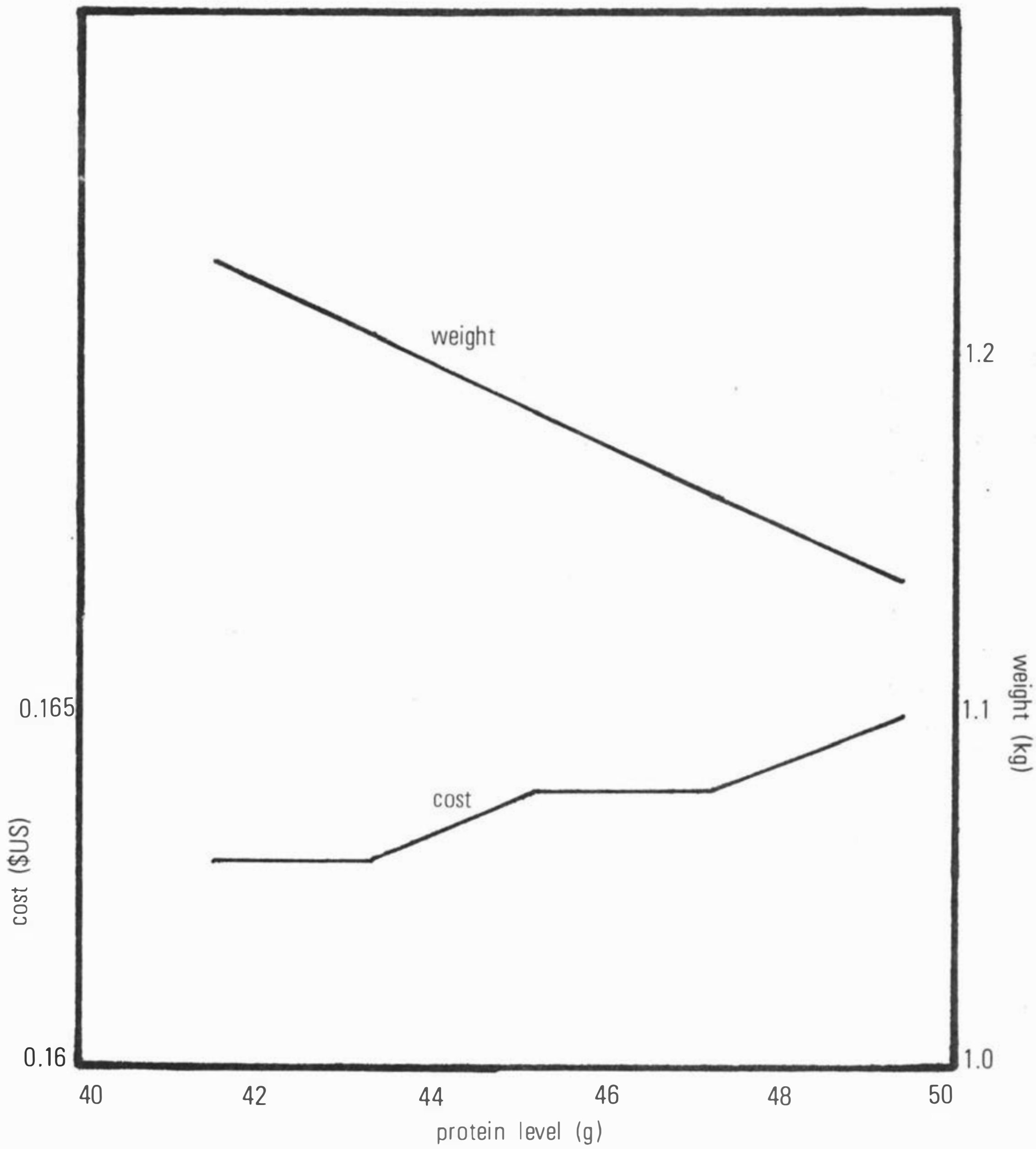


Figure 5.3 The effect on cost and weight of adjusted protein levels

Using this method then showed no advantage for cost and weight with a lower protein requirement. It seemed worthwhile then to retain the protein requirement at 49.4, thus providing excess of good quality protein.

5.2 Estimation of the maximum percentage of all nutrient allowances which could be obtained at the target cost and weight

Since nutritionally satisfactory mixtures could only be obtained with cost and weight in excess of target Philippine levels, another approach was used to estimate the level of balanced nutrition which could be achieved with these cost and weight conditions.

At the lower cost and weight, the model would only be able to satisfy some percentage of the nutritional requirements. In the same way as the limiting amino-acid percentage determined the protein quality, so the limiting nutrient percentage could determine the balanced nutritional quality. There were two methods available by which this could be estimated. Trials were made with both methods to test their practicability for the purpose.

1. Parametric adjustment of lower bound nutrient requirements, with upper bound on weight and minimization of cost. The parametric adjustments were percentage reductions in nutrient requirements which were continued till the cost reach $0.13. Several optimizations were required to achieve this but the number was unkown at the outset.
2. Minimization of the deviation of all nutrients from their minimum requirements with upper bounds on cost and weight. This method should indicate the limiting nutrient(s) and the maximum percentage of these nutrients directly in one optimization.

5.2.1 Parametric adjustment method.

In this method the lower bounds of the nutrients-calories, protein, fibre, calcium, vitamin A, vitamin C, vitamin B6, vitamin B12, and folic acid- were changed in steps of 5% of their minimum requirement. The relationships between the remaining nutrients and the above nutrients provided similar scaled adjustments directly to their lower bounds.

In order to shorten computer time, it was necessary to select a percentage level of all the lower bounds which would produce a feasible solution to begin the parametric adjustments; parametric adjustments are halted when infeasibility occurs. The 70% level was arbitrarily selected. The upper bound on weight was set at 750g, the average from the diet surveys rounded up to the nearest 50g.

Fortunately, a feasible solution resulted and the cost was less than \$0.13, so the first parametric adjustment at 5% increase i.e. 75% minimum level was run. The cost exceeded the target. The goal then lay between the 70 and 75% levels. Parametric adjustments by 1% stages, were begun again from the 70% level. It was found that 72% of nutrient requirements could be met within the cost and weight constraints, but at 73% the cost was exceeded.

This experiment took approximately 3 hours to obtain the final result. The time was short since luckily, the first optimization was close to the goal and relatively few adjustments were required to find the final percentage. The major disadvantage of this method was the need for making on-the-spot decisions based on solutions, so that the procedure could not be planned beforehand and run in batch processing by computer operator. However, this meant that greater control over the number of and size of parametric steps was possible in order to limit the computer run time.

Table 5.3 lists the nutrient levels obtained. The costly nutrient folic acid, together with vitamin B6, and calories, the major nutrient affecting weight of mixture, were found to be limiting under these conditions.

5.2.2 Minimization of deviation of nutrients from nutrient requirements

In this method, twenty six new equations were required to express the deviations of each nutrient from their respective minimum requirements. Another equation was required to total all the deviation variables, scaled to the same order of magnitude, in order to provide the objective which was to be minimized. This was an example of an extension of linear programming, known as goal programming (112).

The form of each deviation equation was :

$$CAL + FCAL - GCAL = GOALCAL = 2030$$

Table 5.3 Percent of minimum nutrient requirements possible within cost and weight restrictions

	Parametric solution	Goal programming solutions	
		Formula A.	Formula B
calories	72	39	100
protein	83	72	125
fat [a]	126	51	175
fibre	250	250	186
calcium	117	106	133
phosphorus	176	159	199
iron [a]	171	185	268
vitamin A	148	503	336
thiamine [a]	107	103	100
riboflavin [a]	74	109	128
niacin [a]	73	100	100
vitamin C	352	596	140
vitamin B6	72	108	65
vitamin B12	150	550	300
pantothenic acid [b]	98	161	105
folic acid	72	100	100
isoleucine [c]	75	96	69
leucine	93	105	100
lysine	100	140	113
methionine	75	100	77
cystine	75	100	48
phenylalanine	87	99	87
tyrosine	81	100	86
threonine	81	95	86
tryptophan	80	95	87
valine	82	94	89

a. Based on minimum calorie level of 2030kcal.

b. Based on 5mg, satisfactory level for US diets.

c. Minimum requirements of amino-acids based on solution protein level.

where GOALCAL was the name of the equation, CAL the variable for calories, FCAL the deviation of calories below the minimum requirement of 2030 and GCAL the deviation of calories above the minimum requirement. 2030 was the fixed value of GOALCAL which was input as a bound. All the nutrient deviation equations were similarly drawn up. Goals for thiamine, riboflavin, niacin, iron and fat were calculated according to their requirements based on the minimum calorie requirement of 2030. One hundred percent egg levels were used as goals for the amino acids in this experiment. The deviations of amino acids from their 100% levels were given by, e.g. for isoleucine :

$$ISO - 66PROT + FISO - GISO = GOALISO = 0$$

i.e.

$$DISO + FISO - GISO = 0$$

since the D terms had already been defined in the model. Similar expressions were input for all other amino acids. Pantothenic acid was given a goal of 5.0mg, the level indicated as satisfactory for US diets, in the absence of a defined requirement (92).

The total deviation equation summed all the F terms, as only deviations below requirement were to be considered. However, both positive and negative deviations were considered for amino-acids in order to retain balance and limitation of excesses. Only one of either the F or G term in each equation could come into the solution.

The deviations from each nutrient requirement involved many different units. Wide variations in the absolute magnitude of these units were thus possible. Only the magnitude would be considered in the optimization e.g. VITA was of the order 4,000 while VITB12 was around 0.002, a 10^6 difference in order of magnitude, which would be important when minimum deviations from so many targets were required - an adjustment by 0.001 on VITB12, a 50% deviation from the minimum, could be completely dwarfed by a 40 unit shift for VITA a 1% deviation. Therefore, the deviation factors required to be scaled so that they were all of similar magnitude. Since the deviations of nutrients from target minima were being considered, the deviation could be expressed as a percentage based on this minimum for each goal term.

The goal equations and the overall goal objective equation, GOALTOT , are shown in Table 5.4.

Table 5.4 **Goal programming data**

Row variable name	Column variables	Goal value	Scaling term (100/minimum requirement)
GOALCAL	CAL + FCAL - GCAL	2030	0.0493
GOALPROT	PROT + FPROT - GPROT	49.4	2.0243
GOALFAT	FAT + FFAT - GFAT	45.11	2.2167
GOALFIB	FIB + FFIB - GFIB	6.0	16.6667
GOALCA	CA + FCA - GCA	452	0.2212
GOALP	P + FP - GP	452	0.2212
GOALFE	FE + FFE - GFE	2030	4.9261
GOALVITA	VITA + FVITA - GVITA	3900	0.0256
GOALTHIA	THIA + FTHIA - GTHIA	1.015	98.5222
GOALRIBO	RIBO + FRIBO - GRIBO	1.015	98.5222
GOALNIA	NIA + FNIA - GNIA	13.398	7.4272
GOALVITC	VITC + FVITC - GVITC	29	3.4483
GOALB6	VITB6 + FB6 - GB6	1.68	59.5238
GOALB12	VITB12 + FB12 - GB12	0.002	50000.00
GOALPANT	PANTOA + FPANT - GPANT	5.0	20.00
GOALFOL	FOLIC + FFOL - GFOL	0.18	555.5556
GOALISO	DISO + FISO - GISO	0	0.0307
GOALLEU	DLEU + FLEU - GLEU	0	0.0230
GOALLYS	DLYS + FLYS - GLYS	0	0.0316
GOALMETH	DMETH + FMETH - GMETH	0	0.0653
GOALCYS	DCYS + FCYS - GCYS	0	0.0843
GOALPHE	DPHE + FPHE - GPHE	0	0.0349
GOALTYR	DTYR + FTYR - GTYR	0	0.0482
GOALTHR	DTHREO + FTHREO - GTHREO	0	0.0397
GOALTRY	DTRYP + FTRYP - GTRYP	0	0.1265
GOALVAL	DVAL + FVAL - GVAL	0	0.0277

Objective: GOALTOT =

0.0493FCAL + 2.0243FPROT + 2.2167FFAT + 16.6667FFIB
+ 0.2212FCA + 0.2212FP + 4.9261FFE + 0.0256FVITA
+ 98.5222FTHIA + 98.5222FRIBO
+ 7.4272FNIA + 3.4483FVITC + 59.5238FB6 + 50000FB12
+ 20FPANT + 555.5556FFOL + 0.0307FISO + 0.0307GISO
+ 0.0230FLEU + 0.0230GLEU + 0.0316FLYS + 0.0316GLYS
+ 0.0653FMETH + 0.0653GMETH + 0.0843FCYS + 0.0843GCYS
+ 0.0349FPHE + 0.0349GPHE + 0.0482FTYR + 0.0482 GTYR
+ 0.0397FTHREO + 0.0398GTHREO + 0.1265 FTRYP
+ 0.1265GTRYP + 0.0277FVAL + 0.0277GVAL

Minimization of the total deviation equation was carried out with upper bound on cost and weight of $0.13 and 750g respectively, with all lower bounds on nutrient constraints removed.

The optimization took just over 6 hours and the nutrient levels obtained are shown in Table 5.3, Formula A. Calories was the limiting nutrient at only 39% the minimum requirement, followed by fat and protein at 51 and 72 percent requirements respectively. All other nutrient requirements were met. A very high quality protein amino-acid pattern was obtained, chemical score at 94. However lysine was in excess at the 140% level.

This then provided the least absolute deviation of nutrients from minima. With no nutritional constraints, a rather nutritionally unbalanced mixture resulted. This method did not indicate the maximum percent requirements that could be obtained at the desired cost and weight, as was indicated in the parametric experiment.

A further optimization, with the lower bound on calories retained at 2030, produced another mixture with greater absolute deviation but with less imbalance. This time only vitamin B6 was deficient, at 65% level, but the amino-acid balance was completely disturbed with amino-acid levels varying from 48 for cystine to 113 for lysine (see solution in Table 5.3, Formula B).

The goal programming method would require to have minimum constraints on all nutrients, to prevent the possibility of such wide deviations from targets and thus to retain nutritional balance. Such constraints could be tightened parametrically towards the target nutrient levels. Much experimentation would be required with no advantage over the simple parametric method. With the much bigger matrix required to contain these relationships, computer times were necessarily much longer for optimization, more extensive punching and data input times were involved, rendering this goal programming method much less practical than the parametric method for this type of experiment.

5.3 Conclusion

Only 72% of the daily nutrient requirements could be obtained with cost and weight compatible with recorded Philippine food habits. This is to be compared with the extra cost of $0.035 and extra weight of about 400g necessary to meet full nutrient requirements. It was, of course, expected that it should cost more to obtain the extra nutrients. It was, however, hoped that this extra cost would be absorbed by some sort of subsidy, if any cost prejudice became apparent. It was felt then justifiable to consider Formula 11 for further development.

The raw materials of Formula 11 were selected solely on a nutritional basis at the minimum cost. Further investigations are required to incorporate other raw material properties - functional, organoleptic or consumer acceptability criteria - into the model to allow more comprehensive selection of raw materials for design of acceptable food products. However, these factors are not considered in the model in this thesis.

CHAPTER 6

DEVELOPMENT OF A NUTRITIONAL FOOD PRODUCT

The linear programming technique selected a mixture of raw materials for a nutritional food product to meet average nutritional requirements at the minimum cost. Selection was based on nutritional criteria only. Taking no account of other criteria - functional properties, acceptability factors, availability of raw materials, processing effects - meant that the selected raw materials represented the cheapest mixture capable of meeting nutritional requirements, since other constraints would further restrict the problem and raise costs.

It was decided to investigate the development of this mixture, Formula 11, to a suitable processed food product, using the product development system. The objective was to utilize this mixture in a processed food product which would be compatible with Philippine eating habits, could be manufactured on existing processing plant with minimum modification, and could be distributed throughout the country to reach both the rural and urban populations.

Firstly, background information was obtained on Philippine food eating habits, food industry conditions and processed food distribution, to more precisely identify the characteristics required of the product. Suitable product ideas were then generated, screened and evaluated for suitability. Finally, the development of the product and the process in the laboratory was undertaken.

6.1 Processed food eating habits in the Philippines

Generally, the Philippine diet consists of large quantities of rice and small portions of meat or fish with green leafy vegetables, followed by fresh fruit. From the FNRC nutrition survey reports, the intake of processed food was generally very low in the daily diet. However, the frequency of intake of processed foods was not indicated by this average intake level. Small amounts of processed food could be eaten regularly every day by some of the population and thus be a regular part of their diet. Investigation of this frequency factor, was carried out during a visit to Manila. Information was extracted from the raw data of the regional nutrition surveys at the FNRC offices.

6.1.1 Intake of processed foods

The intake of processed foods, as recorded in the nutrition surveys, is shown in Table 6.1.

Table 6.1 Intake of selected processed foods in Philippine regions[a]

	Mean per caput daily intake (g)						
	Metropolitan Manila	Ilocos–Mountain Province	Cagayan Valley–Batanes	Southern Tagalog	Western Visayas	Eastern Visayas	Southwest Mindanao
pan de sal	38.7	4.4	3.2	16.8	3.4	2.7	4.6
bread rolls (assorted)	4.5	1.0	0.6	3.1	2.0	2.5	
pan americano	3.9	1.1	0.5	0.8	1.0	1.3	1.1
biscuits	2.7	1.6	1.7	3.9	2.1	1.1	1.5
cake	2.1	0.4	0.5	0.5	0.5	1.0	1.2
noodles, pastas	4.5	2.5	3.5	3.7	2.1	3.7	1.9
native sausage	1.7	0.5	0.3	0.3	0.1	0.1	0.04
corned beef, luncheon meat	3.1	1.4	0.3	0.7	0.8	0.1	0.4
canned sausage	1.2	0.1	-	0.1	0.2	0.04	0.1
sardines	2.4	3.8	3.0	1.8	1.6	0.9	5.4
bagoong	2.5	13.8	17.4	2.3	4.5	7.0	5.8
evaporated milk	60.5	12.8	14.6	15.9	12.0	3.1	9.6
condensed milk	4.5	2.1	3.8	6.6	5.9	1.7	7.1
dried milk	5.0	4.8	1.6	3.0	3.3	0.5	3.4
butter	1.1	0.1	-	0.1	0.04	-	-
margarine	1.4	0.4	0.2	0.6	0.2	0.1	0.1
ground coffee	3.5	1.4	3.6	2.8	2.0	0.3	1.0
instant coffee	0.1	0.04	0.03	0.07	0.03	0.07	0.05
soft drinks	17.9	6.5	4.8	6.3	6.1	4.6	6.0
percent total intake	21.2	7.6	7.7	9.9	6.8	4.6	7.6

a. Taken from individual reports of the surveys in each region. (113, 114, 115, 116, 117, 118, 119).

The contribution of processed foods to the total diet was quite small, averaging 7% for all regions, except Manila with 21%. The area with lowest intake was Eastern Visayas - a group of islands rather isolated from the major islands of the country. It should be remembered that this data was collected over a period of ten years, so that it was likely that processed food intake had increased in all areas beyond the levels recorded. Certainly, during visits to all types of retail food stores in different parts of the country - from large supermarkets in the major cities, Manila and Cebu, to small grocery stores in provincial towns like Baguio City and small shops in villages like Alicia - a wide variety of processed foods was observed on display (see Appendix 9 for product lists).

The highest intakes were shown in all areas for baked goods, canned milk, bagoong (fish paste), soft drinks, in decreasing order. There were slight variations within regions. The rural areas, Ilocos/ Mountain Province, Cagayan Valley, Batanes and Eastern Visayas, showed preference for cheaper animal protein foods - bagoong, canned milk and sardines. Their consumption of baked goods and soft drinks was lower than other areas.

It seemed that beyond Manila, processed food intake was rather low. The lower consumption in other areas would be due to lack of disposable income to purchase processed food and also due to distribution problems associated with making processed foods available in these areas at low cost. The similar intake of soft drinks in the province indicated that processed foods could be made available and attractive to the provincial population.

6.1.2 Processed food products eating patterns

The information, as recorded in the nutrition survey reports, concealed several important features. With reference to processed food intake, it would be useful to know :

1. The popularity of the various processed foods as shown by the number of households utilizing processed foods.
2. The processed foods utilized at particular meal times.
3. The particular processed foods regularly included in meals.

From this information, eating patterns for processed foods could be deduced. This could indicate likely trends in processed food usage, as these foods become increasingly important in areas other than Manila.

Raw forms contained, the weights of individual foods served for each household, for each meal and for each of three consecutive days. Frequency data was compiled from these forms, on how many households served each processed food recorded, broken down by meal time and region. Table 6.2 presents this data summed across all regions, for the three day survey period.

Table 6.2 Frequency of serving processed foods in the Philippines [a]

	Number of household servings per 3 day period, total all regions (maximum 6879)				Total number of days served (maximum 21 for 7 regions over 3 days)			
	breakfast	lunch	dinner	snacks	breakfast	lunch	dinner	snacks [b]
pan de sal	1997	36	33	71	21	9	6	16
bread rolls (assorted)	393	42		180	21	10	8	17
pan americano	229	25	14	38	21	9	8	12
biscuits	181	83	31	299	20	12	11	18
cake	50	6	6	137	17	4	5	-
biscotcho	22	18	6	24	9	9	4	8
noodles, pastas	24	297	233	5	11	20	21	3
native sausage	112	42	62	2	19	14	17	-
meat loaf	30	2	5	-				
corned beef, luncheon meat	50	33	40	1	15	14	14	-
canned sausage	62	9	6	-	13	5	5	-
sardines	123	113	124	1	21	19	17	-
bagoong	653	1426	966	-	20	21	21	-
evaporated milk	1975	58	43	86	21	14	13	-
condensed milk	481	17	18	10	21	9	13	-
dried milk	156	19	7	23	21	6	5	-
butter	221	14	3	1	17	8	2	-
margarine	517	6	5	7	21	5	5	-
Milo/Ovaltine	39	-	5	6	-	-	-	-
ground coffee	2990	29	46	71	21	14	18	-
instant coffee	439	9	18	14	21	10	8	-
soft drinks	38	82	32	378	9	10	10	18

a. Taken from raw data sheets of regional surveys, made available by Food and Nutirition Research Center, Manila.

b. Snack data was available for only 6 regions, therefore maximum was 6 x 3 or 18.

Note. Not all foods were considered on each data sheet.

Except for pan de sal, evaporated milk, bagoong and ground coffee, the utilization of processed foods was infrequent. Across all regions, the basic commodities bread, canned meat, canned fish and noodles were consumed with significant frequency. However, products demanding more sophisticated technology - canned meats, canned fish - were less popular than the more traditional products - native sausage and fish paste (bagoong). The popularity of baked goods was surprising but they represented a convenient, ready-to-eat, cheap, filling food. It is likely that they were introduced during the 300 year Spanish period.

Apart from the use of bagoong, noodles and soft drinks, processed foods were utilized widely and at their greatest levels for the breakfast meal. Coffee was used at 44%, bread products at 45% and evaporated milk at 29% of total household breakfast servings. The breakfast utilization could be due to the convenience and ease of preparation characteristics usually associated with processed foods. The part of the population consuming processed food had a western style breakfast of coffee, bread with butter or margarine and sausage, meat or fish. This would be in line with the American influence in living style felt in the Philippines since the beginning of the century.

The other daily meals relied almost entirely on unprocessed foods with the exception of noodles which were popular at lunch and dinner meals. These would be generally the Chinese style noodles from mungbean starch (sotanghon) or rice starch (misua) which are widely consumed in the home and in foodshops throughout the country. Information was not available on the use of processed food in these foodshops, so that lunch eating patterns could not be more fully described. The only important items consumed as snacks were soft drinks and biscuits.

To indicate whether any of the processed foods were regularly consumed, the total number of days that each product was served in each area was computed and summed across all regions. This method took no account of the amount of each food consumed, or the number of households serving each product, but merely estimated the regularity of usage. All foods listed with the exception of noodles and soft drinks were regularly consumed for breakfast in the households concerned. More variability was associated with the lunch meal but noodles, bagoong and sardines were most regularly used at this meal time. At dinner there was least utilization of processed food and least regularity; bagoong and sardines and the native sausage, longaniza and chorizo, were most regularly taken at this meal.

Conclusion. The wide acceptance of processed foods for breakfast is important, particularly with regard to the relatively high utilization of baked goods. It would be expected that as processed foods became available to more Filipinos, this pattern would be accentuated throughout the country. It would seem then that nutritional processed foods should be designed for the breakfast meal at this stage since :

1. Processed foods are already acceptable as breakfast foods.
2. Processed foods with convenience and ease of preparation characteristics are particularly advantageous for breakfast.
3. Breakfast is generally regarded as the most essential meal of the day and as such is expected to be most nutritious (120).
4. Processed foods for breakfast - baked goods, canned meat and fish, canned milk - are capable of widespread distribution.

Penetration of processed foods associated with other meals would seem more difficult. Traditional systems of cooking raw foods for the lunch and dinner meals do not seem to have been affected to any extent by the availability of processed foods even in Manila.

6.2 Survey of the Philippine food industry

The food processing industry in the Philippines is the largest manufacturing sector in the country. In 1971, the food industry employed 88,000 people representing 21% of total manufacturing labour force, with production of value 5,000 million pesos, representing 25% of total manufacturing output (121).

In Fig.6.1 it can be seen that the contribution of the food industry to total manufacturing is declining, as other manufacturing industries develop. This could be partly due to the growth in importance of larger factories, being less labour intensive and forcing closure of smaller operations. This trend is evident within the food industry itself (Table 6.3).

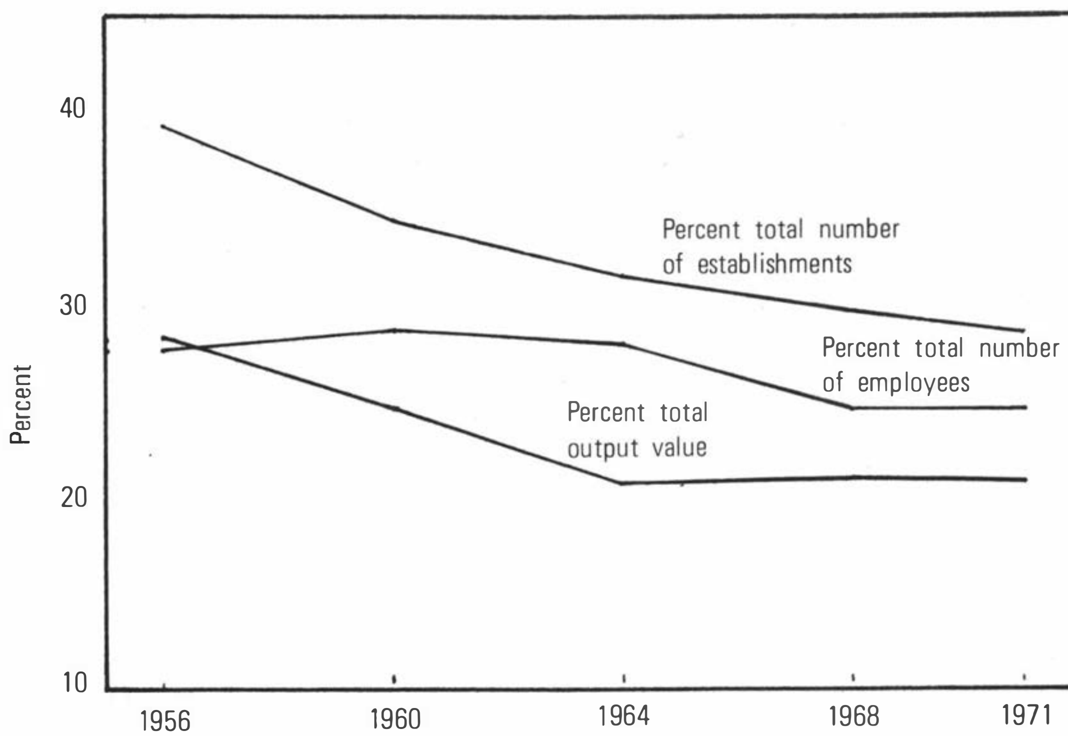


Figure 6.1 **Contribution of food manufacturing to total manufacturing industry in the Philippines**

Information taken from a directory of large manufacturing establishments indicated the number of factories involved in various types of food processing in the Philippines in 1967 as shown in Table 6.4 (122). This information was available only for factories employing more than 10 workers or with output greater than one million pesos. Thus the large proportion of small operations were not considered in these data.

The greatest number of large factories were concerned with baking, rice milling, manufacture of ice, soft drinks and pasta and noodle production. Apart from soft drinks manufacture, these operations were small units (on an employment basis) and were spread throughout the country. Distribution of products of these industries should be capable of covering the widest area, particularly for baked goods and rice. All other food processing industry was concentrated in the Greater Manila area. Good distribution to the large urban population would be expected, but only the larger companies could be capable of more extensive distribution to the provinces - meat processors and manufacturers of canned milk, canned fruit, biscuits, confectionery and soft drinks.

Thus facilities existed for most types of food processing operation, except notably for freezing and dehydration operations.

Table 6.3 **Contribution to total Philippine food industry of large establishments employing more than twenty employees [a]**

	Percent total establishments	Percent total employed	Percent total output value
1956	12	65	80
1960	13	70	84
1964	15	70	92
1968	13	73	92
1971	10	76	93

a. Adapted from data made available by Bureau of Census and Statistics, Manila (121, 122)

6.2.2 Types of processed food products

There was no statistical information available on the production of the food industries by product type. Detailed information on the shipment of products from the large processing factories was, however, available.

Table 6.5 indicates the quantities of various products shipped from the major food processing factories. Unfortunately this data was not comparable from year to year and did not represent total industry as different numbers of factories offered this information in different years.

Table 6.4 Food processing industry in the Philippines [a]

Type of processing factory	Number of factories by number of employees				Number of factories [b] in Greater Manila area
	10–19	20–99	⩾100	total	
slaughtering, meat packing	–	–	1	1	–
meat processing, canning	8	7	4	19	14
ice cream, flavoured ices	18	5	1[c]	24	4
butter	–	2[c]	1[c]	3	2
evaporated, condensed milk	–	–	4[c]	4	4
fluid milk	1	–	1[c]	2	1
dairy drinks, etc	–	1	2[c]	3	2
fruit, fruit juices, canned, preserved	1	2	3	6	2
vegetables, vegetable juices, canned, preserved	–	2	1	3	–
vegetable sauces, dressings	4	5	1	10	4
fish, seafoods, canned	–	1	1	2	–
fish, seafoods, cured, dried, smoked	8	1	–	9	–
fish sauce-patis	3	6	1	10	9
fish paste-bagoong	1	1	–	2	1
rice milling	104	32	3	139	–
corn milling	13	11	1	25	–
flour milling	–	–	7	7	3
bakery products (except biscuits)	424	72	1	497	91
biscuits, crackers, etc	9	11	4	24	10
sugar milling	6	7	24	37	1
muscovado milling	4	4	–	8	–
confectionery	7	21	7	35	20
cocoa, chocolate products	–	4	3	7	7
salted, candied fruits, nuts, seeds	6	2	–	8	2
macaroni, spaghetti, noodles	18	20	–	38	3
ice manufacturing	36	14	3	53	7
dessicated coconut	1	2	2[c]	5	–
cooking oil, margarine	2	7	1	10	2
coffee roasting, grinding	3	3	1	7	2
distilling, blending liquors	5	10	5	20	6
wine manufacturing	6	7	1	14	4
brewing, malt products	–	1	4	5	1
soft drinks	4	9	27	40	6
instant beverages	–	1	–	1	–
total	692	271	115	1078	208

a. Adapted from 'Directory of large establishments 1967' (122).

b. Includes Manila, Caloocan City, Pasay City, Quezon City, Pasig, Makati, Malabon, Mandaluyong, Navotas, Paranaque, Marikina.

c. Published data augmented where more recent factory known to have opened since 1967.

Table 6.5 Estimates of processed food production in the Philippines [a]

	Shipments of products from factories reporting (metric ton)					
	1960	1961	1962	1968	1969	1970
sausages (not canned)	1593[b]	964	2300[b]	1456	1217	1653
ham, bacon (not canned)	342	385	311	251[c]	368	468
sausages, canned	na[b]	987	na[b]	3639	2785	3025
canned meats, spread				1057	1004	818
meat loaf	593	368	359	267	145	356
native meat				152	338	295
ice cream, ice novelties[d]	983	1077	1190	1803	2211	2420
evaporated, condensed milk	118575	118355	221790	104229	105767	103476
fluid milk, reconstituted[d]	343	458	425	183	na	na
fruit, fruit juices, canned	40414	na	44654	148497	192982	210963
vegetables, canned	2864[e]	949	2167[e]	2365	1596	2179
veg/meat products, pork and beans	na[e]	1934	na[e]	3478	6298	3835
vegetable sauces, ketchup, etc	2247	3447	2557	4447	4024	4877
soy sauce[f]	1475	6389	6722	8483	9601	12202
fish sauce, patis[f]	na	2794	na	2430	4523	4585
fish paste, bagoong	na	1306	na	1879	na	na
bread, bread rolls[g]	16804	32552	21040	14635	12947	13497
cakes, other sweet goods[g]	4347	6982	3947	4471	4305	3682
biscuits, crackers[g]	13345	19767	15532	40506	46901	48570
macaroni, noodles	1186	6289	316	2672	2574	2100
dessicated coconut	55135	56397	80544	66678	64299	55423
margarine	4776	na	4290	5582	6760	6178
instant coffee	na	na	na	1843	2507	2689
soft drinks, carbonated[h]	62805	60573	67227	71651	89991	98361

a. Adapted from files and publications of Department of Commerce and Industry, Bureau of Census and Statistics, particularly 'Annual Survey of Manufactures: 1962, volume V1', and 1968, volume V11 (121) Data obtained only for shipments of products manufactured. Note that from year to year data is not comparable since different numbers of companies reported and in some years not all the products were included.

b. Sausage products, canned, and not canned, considered together.

c. No recorded data for bacon.

d. Unit of 1,000 gallons (4,550 litres)

e. Vegetables, canned and vegetable/meat mixtures (including pork and beans) considered together.

f. Unit of 1,000 litres.

g. No quantity data recorded. Shipment value in 1,000 pesos given. (Note change in value of peso in 1960 - 1961).

h. Unit of 1,000 cases.

Nevertheless, this information was valuable in indicating the wide range of products produced and in giving evidence of the type of technical know-how and processing facilities which exist. It indicated generally growth in production in all sectors of the food industry. Also, the largest food industries were identified: the products mainly for export - canned fruit, fruit juices and dessicated coconut; and the low-priced products for the domestic market - soft drinks, canned milks, bakery products, soy and fish sauce, canned meat and vegetables. Again the lack of production of frozen and dried products was evident.

6.2.3 Availability of processing equipment and technical know-how

During a visit to Manila, a restricted survey of the Philippine food industry was made to gain more detailed information on the type of equipment available and the technical know-how and degree of sophistication associated with technical operations. Twenty-two food companies throughout the country were visited. These companies ranged from very large, sophisticated operations to small backyard, family, cottage industry. Although only a small number of factories were visited, contacts were extremely co-operative and offered information on the processing and marketing of their products. This cross-section of the industry indicated the general status of food processing in the Philippines (see Appendix 10 for detailed description).

Canneries. Five canning factories were visited, Three were large, sophisticated operations, two canning meat products and the other pineapple. Two were smaller, family factories producing chinese sauce and mushrooms. Canning operations were fairly well developed at all levels in the Philippines, especially in the large companies where expertise in formulation, product development and engineering was available.

Frozen food plants. The two large meat companies were also producing chilled and frozen meat products. Three other factories were observed, ranging from a small immersion freezing unit for frozen chickens, to a plate freezing operation for fish products and to a large, fully automated, dairy complex. All these factories had large chiller and freezer storage space; in fact in the meat companies, processing was carried out in the chiller rooms. Although the frozen food sector was not as extensive as that of canning - probably due to distribution problems - it was fairly developed throughout the country.

Dehydration plants. From the statistics, this sector was the least developed, but it was a major home-based preservation process as evident in the immense quantities of dried meat and fish on display in the market places. Only two factories were visited : a modern desiccated coconut factory, using continuous tray-drying equipment, and a crude dehydrated soup operation, utilising pilot scale cabinet driers. So although a major preservation method for Philippine food, dehydration was not just yet widely developed in the food industry.

Extraction operations. The milling and refining of sugar and the extraction of coconut oil were the most developed industries in the Philippines but these essentially chemical industries, could not be considered for production of consumer products at this time. The production of noodles from wheat, rice and mungbean starches was in small scale units scattered throughout the country, with facilities and expertise for extraction, extrusion and drying operations.

Other major food industries were concerned with manufacture of bakery goods and soft drinks. Village bakeries were scattered throughout the country with small scale equipment varying from primitive to modern. The larger units in the cities and biscuit factories had continuous mixing and baking facilities. Soft drink operations were well developed with several plants in different parts of the country.

Traditional home-based industries were visited : fermentation of salted fish to fish sauce (patis) and fish paste (bagoong); production of native sweets from coconut and cashew nuts. Although varying from small scale to quite large operations, production methods were still primitive. These home industries were assisted by a government agency - NACIDA - whose aim was to develop them so that the experience and skill of these home food processors was better utilised through upgrading of processing and storage conditions.

Summary. This survey gave a very hurried but comprehensive picture of food processing in the Philippines. All processing methods were developed except for dehydration. Food industry was well developed in the large factories which were mainly in Manila. Here the variety of products, the scale of production, the sophistication of some processes and the number of technical personnel was surprising. The smaller units often had only one technical employee, if any, and depended on small scale batch equipment. Generally in all plants the standard equipment required for each process was available, in some form depending on the scale of the operation. All industries, large and small were labour intensive.

If a standard nutritional food product were to be manufactured with existing facilities, only the large factories would be capable of production on a scale large enough to effect some measure of national distribution. Of the smaller units, only noodle factories and bakeries scattered throughout the country could have sufficient total output to reach most of the population, through supplying their local areas. The lack of technical personnel in these smaller units could cause problems in introduction of such a standard product.

6.3 Processed food distribution in the Philippines

The design of food products capable of the most widespread distribution was being considered. It was necessary therefore to consider distribution and storage conditions for processed food products in the Philippines and to evaluate how effectively different products could reach the population.

6.3.1 Distribution channels

Figure 6.2 illustrates the distribution channels used by the food processing industry in the Philippines.

1. Major companies, mainly based in the Manila area, ship to all major ports on the other islands, and may or may not have their own trucks to distribute to outlying areas.
2. Some companies sell to wholesalers who ship or truck to retailers in outlying areas. Otherwise, they distribute to agents on each island who sell to retailers.
3. Merchants in market places, particularly in rural areas, supply the owners of road side stalls or shops (sari-sari stores), with a small quantity of goods, on credit, for example canned foods, sweets and biscuits. The shopkeeper carries the goods by public transport or on foot back to the stall, and then returns the following week to pay debts and replenish stocks.
4. Truck owners deliver to retailers, in a certain area, all types of items on behalf of several different wholesalers or agents. Due to the conditions and delivery times involved, generally canned food only moves through this channel.

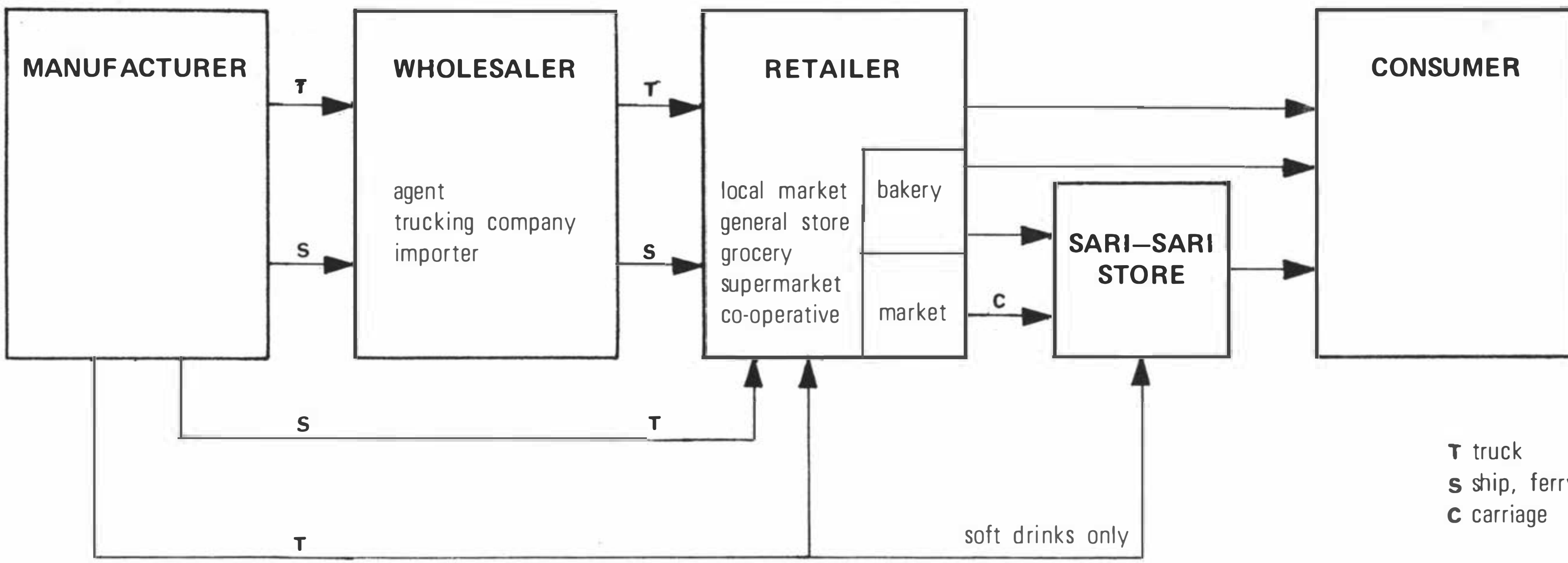


Figure 6.2 **Distribution channels for processed food in the Philippines**

5. Soft drink companies sell direct from their many trucks which penetrate to all sari-sari stores, provided they are on a road. This is the only channel which deals directly with the stall owner. Weekly or fortnightly return cycles are usually operated in distant outlying areas, with more frequent calls in urban areas.

6. Bakeries are scattered throughout the country and normally, outlying areas have at least a small bakery in a nearby village, if not in the major barrio (community unit smaller than village). Baked goods thus reach most of the population directly. Some of the isolated barrios may only receive small amounts of bread once a week when the sari-sari store owner goes up to market.

7. Isolated concentrated communities, such as large fruit plantations and sugar centrals, usually have a store which is operated by the management. The management buys in bulk in the nearest city or town, usually from wholesalers, and delivers to the site using company transport. Some consumer co-operatives occur in these isolated areas where the captive market ensures the economic feasibility of this retail system. There are few cases of this method of distribution.

For processed food products, the major distribution channels are the merchant / sari-sari store and the soft drink systems. The thousands of sari-sari stores were said to move the largest quantities of canned milk, canned fish and soft drinks in the country's marketing system. The widespread distribution of baked products across the country was similarly effective.

6.3.2 Storage systems

The storage life of processed foods in the Philippines determines the extent of distribution which can be achieved, and the type of distribution channel which can be used.

Few shops in outlying areas have refrigerators and relatively few stores in the cities, except large stores, have freezer or chiller cabinets. Refrigerated ships and trucks are available for shipping frozen or perishable foods to provincial centres but these foods have to be consumed soon after purchase due to lack of domestic refrigerated storage, thus frozen or chilled food products could not be considered for widespread distribution. Baked goods, native sausages and noodles - produced all over the country - are the only types of products with short storage life capable of widespread distribution, since the area around each processing unit can be served regularly. In order to achieve wide distribution, all other goods must be processed and packaged sufficiently to withstand the rigours of the long physical distribution period, the climate and the hygiene conditions of the Philippines.

The lack of cool storage in the home means that the food must be consumed soon after purchase, which necessitates the distribution of large amounts of small units of product, adding considerably to distribution cost.

Thus baked, cured, canned and dried products and soft drinks, providing satisfactory storage life and capable of utilizing existing distribution and storage systems could only be considered in the product design.

6.4 The generation of suitable product ideas

The background information on processed foods, food processing and distribution defined more precisely the characteristics required of a suitable nutritional product.

1. Compatability with eating habits. Product should be primarily a breakfast food, convenient, easy-to-use.
2. Compatability with processing facilities. Suitable processing facilities were for meat and fruit canning, baking, noodle and soft drink manufacture.
3. Compatability with distribution channels. Widest distribution was achievable if products reached sari-sari stores, either directly - soft drinks, or indirectly through merchants - canned goods, biscuits, baked goods, native sausages.

Suitable food product ideas had to be selected to match these characteristics. There was the greatest probability of the most suitable products being identified, if as many ideas as possible were initially generated.

6.4.1 Methods of generating product ideas

Several methods, used in private industry for obtaining product or project ideas, allow idea generation from completely unrestricted conditions to more orderly defined conditions.

1. Internal company sources. Suggestions from research and commercial staff, company records, customer complaints and suggestions are used. This is the most restricting source as only ideas similar to present products, with perhaps modification, are usually identified. It is useful when objectives are restricted and allows for least change within the company.

2. Extension of product attributes. Characteristics of the product are identified and extensions or alternatives for each characteristic suggested for new product ideas (123). This is a less restricted method but still constrains the ideas to the basic product concept being considered.

3. Variation of all product attributes. The previous method has been extended, in the product, morphology or heuristic ideation technique, to consider combinations of all possible product characteristics e.g. various product forms, various flavours, various packages, various processing techniques (124,125). This gives large numbers of possible combinations depending on the number of factors considered. This method is the least restricted as it considers all ideas, described by factor combinations but this means that large numbers of ideas are thrown up for consideration. This number is dependent on the actual factors considered and these can be restricted to specific company requirements or completely unrestricted where completely new concepts are to be investigated. This systematic method allows greatest assurances that a successful project idea will be identified.

4. Brainstorming. Executives, research scientists, and marketing men put forward in a discussion group, any possible idea for the solution of the problem, however wild it may seem. Some systems allow discussion of proposals while others prohibit criticism since it is said to reduce the flow of ideas. The ideas obtained from this method may be unrestricted but suggestions are constrained by each individual's imagination, knowledge, and personality traits. The lack of structure, as in previous methods, could allow the best project idea to be missed.

5. Psychological panels. The brainstorming method is taken out of the company structure. Depth interviewing or group suggestion panels are used, sometimes with consumers, to obtain suggestions of product faults, gaps in the market, changes in usage which might suggest new product ideas. Using randomly selected panel members in the synectics method, solutions

to problems are suggested indirectly and built on analogy and metaphor. Here the interaction of ideas is guided by a trained psychologist with contributions from marketing men also in the group (126).
Panel members may also be selected for their innovative potential, so that maximum idea generation is obtained (127).

These sophisticated group methods are expensive and time consuming and the value of them may be doubtful since whatever brilliant idea turns up, it depends on the imagination of the evaluator whether the idea is accepted. This same criticism, however, holds for all the other systems but the desk methods are much cheaper, simpler to run and probably as systematic and comprehensive as needed for most product or project idea generation problems.

In this study, ideas were sought for nutritional foods which fitted the Philippine environment. In this situation, neither company records nor staff could be used, nor could Philippine consumers be called on to examine product concepts. Ideas had to be generated in isolation by a systematic and unbiased method. The product morphology system was the most suitable, available, method with sufficient comprehensiveness for these conditions.

6.4.2 Identification of suitable ideas for the nutritional food product

The product morphology system required specifications of characteristics important to the product. The number of characteristics used, depended on how comprehensive a description was required : a small number allowed investigation of product ideas in a defined area. Characteristics selected were those considered to provide variations in basic concepts of food products suitable for Philippine conditions. Such a list was obtained by expanding the three major characteristics defined earlier.

1. <u>Eating habits characteristics</u>: product form e.g. bakery product, meat product, drink; organoleptic properties e.g. flavour, texture, colour; home preparation method e.g. baking, frying, boiling; portion control e.g. one meal unit, one day unit; portion design e.g. calorie units, adult units, family units.
2. <u>Processing characteristics</u>: processing required e.g. canning,

bottling, dehydration.

3. Distribution characteristics: preservation method e.g. canned, pickled, dried; storage method e.g. cupboard, refrigerator; packaging e.g. can, paper, film.

The characteristics selected were product form, home preparation method and preservation technology (combination of processing and preservation method). These were considered most suitable for indicating variations in basic product ideas. Organoleptic properties, portion control and design could be considered for any particular product. These would not provide basic concepts, merely various forms of a basic idea. Storage method and packaging would depend on the processing method used, so these were merely extensions of the preservation method.

The various factors considered within these characteristics were:

1. Product form: bread, bun, biscuit, sausage, meat loaf, soft drink, milk drink, noodles.
2. Home preparation method: boil, fry, grill, ready-to-eat.
3. Preservation technology: canning, dehydration, baking, pickling.

Each list of factors represented one dimension of a three-dimensional matrix which described all possible combinations of product ideas. Each three factor combination conveyed a food product concept. All such product concepts were screened in order to sort out those which were impossible or obviously impractical for the project. Figure 6.3 shows the morphology matrix, which described one hundred and twenty-eight possible combinations or product ideas, for example, canned bread to be boiled !

6.4.3 Preliminary screening for selection of feasible ideas

The extensive list of product ideas contained many irreconcilable combinations of factors. Some system of sorting out feasible concepts from the impossible ones was required.

Firstly, the list was studied by a panel of food technology students who were asked to select factor combinations, which suggested reasonable or acceptable or existing product ideas. The use of several opinions here eliminated any limitations of imagination which might exist when based on one opinion. Three sheets illustrating the three

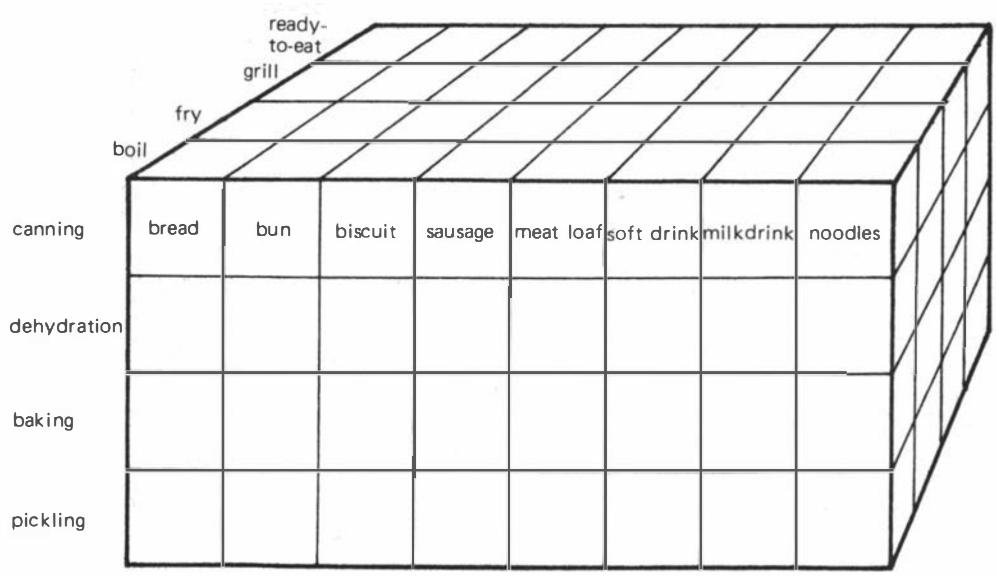


Figure 6.3 **Product morphology matrix for Philippine food product**

possible two-dimensional matrices - technology x preparation, technology x product form and product form x preparation - were passed randomly around thirty-three food technology students who were asked to tick each element describing a two-factor combination which suggested a reasonable or acceptable or existing product idea. It was felt that two-word combinations were simpler to visualize and easier to represent on paper than three-word combinations for this exercise. Any two-dimensional element which was acceptable was taken as a satisfactory product concept. No account was taken of the frequency of suggestion of any element as this was of no value since all possible ideas were to be considered.

The acceptable two-dimensional elements were combined to give ninety-three three-factor combinations describing acceptable product concepts. The thirty-five elements removed were pickled bread (4), pickled bun (4), pickled biscuit (4), boiled biscuits (3), baked soft drink (4), baked milk drink (4), fried soft drink (3), grilled soft drink (3), fried milk drink (3) and grilled milk drink (3).

The reduced list was then judged by a knock-out system, which was devised to remove those product ideas incompatible with the original objectives. The objectives were firstly placed in order of importance for screening.

1. Feasibility of formulation from raw material mixture
2. Compatibility with food eating habits
3. Compatibility with distribution patterns and storage systems
4. Compatibility with present processing conditions

Each idea was assessed against each factor in this order. In this way, ideas which could not meet the major criterion of being capable of formulation from the raw material mixture was immediately eliminated. Remaining ideas were then judged for compatibility with eating habits, and those remaining after this were screened for distribution fit. Finally the remainder were examined for fit with processing conditions.

The raw material mixture consisted of 1140g of mainly vegetable material with approximately 40% solids. Such bulk would require the intake of immense volumes of fluid, in the form of soft drink or milk drink products since only between 5-12% solids can normally be incorporated in these products. Such product ideas were therefore eliminated.

Boiled and fried bread, buns and biscuits and grilled biscuits were eliminated as generally, heating any type of baked product in the Philippines would be unnatural, and these products are assumed to be ready-to-eat. Grilling, for bread and buns was eliminated since it would represent only an alternative method of serving the ready-to-eat product. Dehydrated biscuits were eliminated as these were assumed synonymous with baked biscuits. Grilled meat products were also considered incompatible with general cooking methods. Boiling and frying of meat products were eliminated, except for dried sausage, since these were merely alternative methods of cooking ready-to-eat products. Of the noodle products, baked and dried noodles requiring frying or grilling or ready-to-eat were eliminated since these ideas did not fit common eating patterns.

Baked meat products were eliminated as these would be manufactured in a central plant and would require chilling or freezing to preserve them for wide distribution.

Canned baked goods were eliminated since placing canning facilities in the many small bakeries would be a major undertaking.

Similarly canned uncooked noodles (to boil) were eliminated as small noodle factories have no canning facilities. The large spaghetti and noodle factories in the major cities could incorporate the canning equipment but little advantage would be gained over present packaging systems.

6.4.4 Product concepts

On completion of the compatibility study, sixteen product ideas remained. These were examined and product concepts were developed more fully. Twenty product concepts were evolved from expansion of the three-factor-combinations:

Word combination	Idea generated	Product concept
bread/dehydrated/ ready-to-eat	1. Intermediate-moisture controlled bread	Lower water activity than normal bread. Longer shelf life. Few organoleptic problems. Could be manufactured by existing baking methods-formulation change only. Mix would be supplied to bakeries. Could be in loaf or small roll form. Would require outer packaging for carriage to outlying districts.
	2. Dried bread slices	Like 'biscotcho' (Toasted bread with sugar) if sweetened or 'biscott', if unsweetened.Would probably be regarded as a biscuit rather than bread. Such products commonly made at home and stored, not normally made at bakery. Should be easily manufactured in biscuit factories or bakeries if ingredients mix supplied.
bread/baked/ ready-to-eat	3. Conventional bread	Already widely consumed in loaf (sliced) form and in roll form so no difficulty in manufacture envisaged. Only problem would be the lack of gluten in the raw materials mix which would be supplied to bakers. This has been overcome in some speciality breads.

buns/ dehydrated/ ready-to-eat	4. Intermediate-moisture controlled buns	Similar comments to (1).Similar to flavoured roll products-pan de leche, pan de limon, pan de coco, and the yeast buns-enzymada-which are widely available, but not consumed at such high levels as plain bread products.
buns/ baked/ ready-to-eat	5. Conventional buns	Similar comments as (3) and (4).
biscuits/ baked/ ready-to-eat	6. Biscuits	Could be baked on existing biscuit equipment in the main centres. Could take many forms and flavours for variety. Cracker type likely most acceptable for bulk intake. Distribution good to outlying areas-long shelf life with adequate packaging. Raw materials mix would be supplied to all factories.

Note. For ease of introduction and control, a raw material mixture suitably formulated for the product would require to be supplied to all the bakeries scattered throughout the country for all the baked products listed above. Thus some central units for producing this mixture would be necessary for feasibility of these ideas.

sausage/canned/ ready-to-eat	7. Frankfurter in sauce or brine	Already a popular product. Likely to be heated before eating, though could be taken cold. Cost must be low. Facilities available in Manila for manufacture.Disadvantage may be large cans which limit stocks at sari-sari store. Long shelf life product.
	8. Vienna type sausage in sauce or brine	Similar comments to (7), except more flavoured sausage. Has advantage as smaller sausage,smaller cans can be used,aiding penetration to outlying sari-sari units.
sausage/ dehydrated/ boil	9. Dried sausage (native type)	Similar to longaniza and chorizo which are made from beef, pork, fat and spices. Shelf life probably 2 weeks if packaged.Usually only available at meat market,not often available at sari-sari store.Most popular processed meat product.Could be manufactured in central meat processing plant in Manila-distribution problem. Formulation may be difficult with the unconvential raw materials.

sausage/ dehydrated/ ready-to-eat	10. Intermediate-moisture controlled sausage	Product type not available. General acceptance of sausage should aid introduction of product. Luncheon type,precooked envisaged with extended shelf life up to 4 weeks possible, if packaged. Distribution could be widespread. Could be manufactured in central plant as formulation control important.
sausage/ pickled/ ready-to-eat	11. Fermented sausage	Not widely eaten-salami, bolonga available only in major centres,made at large meat processing plant. Cost main drawback,if cheaper consumption could increase. Would require to be sliced and packaged in consumer portions for ease of handling in retail stores. Good shelf life.
meat loaf/ canned/ ready-to-eat	12. Canned meat loaf	Most sought after processed meat type.Generally too expensive for regular consumption.Corned beef,beef hash,luncheon meat,chopped beef available in this form; particularly in small cans in sari-sari store.Lower priced product would increase consumption.Is eaten cold or heated(fried)with other meal items.Would be manufactured in central processing plant. Long shelf life product.
meat loaf/ dehydrated/ ready-to-eat	13. Intermediate moisture-controlled meat loaf	Similar comments to (10). Disadvantages would be the newness of this product and shorter shelf life and distribution compared to canned product.
	14. Dried meat loaf slices	Dried meat-tapa-is universally consumed.Generally meat slices sundried or air-dried in the home but major meat processing plants also manufacture it on a smaller scale than other processed products.Costs would have to be comparable with fresh meat.Could easily be handled by distribution system, if packaged,to reach villager at sari-sari store.Long shelf life.Difficulty may be in formulation and processing.

meat loaf/ pickled/ ready-to-eat	15. Pickled meat loaf	A new product. Nitrite/vinegar flavours acceptable in corned products and native meat dishes so flavours should be acceptable. Plain meat loaf may be more acceptable, as already known. Would require canning or other packaging to have suitable shelf life for distribution.
	16. Fermented meat loaf	Similar comments to (11)and (15). Fermented fish flavour preferred widely, so fermented vegetable mix may be acceptable.
noodles/ canned/ ready-to-eat	17. Spaghetti/ macaroni/noodles in flavoured sauce	Spaghetti in tomato sauce with or without sausages or meat balls available in urban supermarkets but not generally available. This type of meal often taken for lunch in food shops,but unknown outside large towns. Pork and beans widely available,though,so concept could be acceptable.Chinese style sauces, with or without meat pieces could be most acceptable as these are prepared in home for noodle dishes. Product would be made in canning plant rather than noodle factories, due to large throughput required. Raw material formulation for noodle and sauce processes would require to be supplied.Fits distribution system well.
noodles/ dehydrated/ boil	18. Conventional dried noodles	Spaghetti,macaroni(wheat),sotanghon (mung),bihon ,misua(rice)noodles are widely available in this form, but do not often reach sari-sari stores due to bulk in carriage. Traditional noodle processes may pose difficulties in adapting to unconventional raw material mix. Ingredients mix required for noodle factories.
noodles/ pickled/ boil	19. Pickled or fermented flavoured dried noodles	Noodle dishes commonly have meat, fish in vinegar or fermented sauces-bagoong,patis, soy. Flavouring prior to drying with these products could be attractive- but unlikely since condiments would be added anyway and increased cost would not be warranted. Similar comments to (18).

noodles/ pickled/ ready-to-eat	20. Noodles in pickled/ fermented sauce	Similar to (17), with pickled or fermented sauce,with or without meat.Established meal type in urban areas but may be strange in isolated rural areas.Use of common sauces used in rural areas-bagoong, patis,soy may decrease introduction problems.Product would be required to be canned or packed in strong film bags for distribution. Raw materials mix would be supplied to central factories.

6.5 Critical screening of product concepts

The list of product concepts now required to be more critically examined to select the most suitable and practical product or products for development.

Several methods have been proposed for screening product concepts in a semi-quantitative manner, most scoring systems following the general pattern of Fig.6.4.

Some measure of the overall assessment is made to judge the relative suitability of each product concept for the project. This depends on selection of screening factors, weighting of the factors, assigning of values to the factors for each product concept and then calculation of the overall rating for each product concept.

6.5.1 Selection of factors to assess the suitability of product concepts

Factors fall into two categories - market factors and technical factors. Market factors usually assess the potential size of the market, segmentation of the market, competition from other products, distribution problems and profitability. Technical factors cover processing difficulties expected, new equipment required, production capacity, development costs, storage life and packaging problems. In both cases, those factors, which have the greatest bearing on the project and can discriminate clearly between the ideas, are selected as criteria for the screening process.

In this project, this sytem has to be applied to the Philippine national situation and not to any particular company environment.

Nevertheless market and technical factors exist which are important to the project objectives.

Market factors. The possible penetration of each product into Filipino homes could be estimated. It was also important that the new food be readily incorporated into the diet of the Filipino so that maximum nutritional improvement could be achieved. This was assessed for each product by a measure of present usage of similar food products as a proportion of the total intake. Then, the maximum possible intake of the new food in the diet was estimated by calculating the fraction of the selected raw material mixture weight which could be incorporated in the daily meals of the people. Since breakfast was the major meal for processed food consumption, a measure of possible utilization of each food in the breakfast meal was used to describe the fit with the meal pattern. It was also important to identify any possible acceptability problems of the new food which could have a major bearing on the penetration of the food into the diet. Thus factors governing consumption and fit with eating habits were :

1. Proportion of total population which could consume each product
2. Frequency of consumption of each product
3. Present consumption of similar products
4. Estimated maximum daily consumption of each product
5. Breakfast utilization
6. Degree of acceptability

Distribution is a major factor in marketing considerations and so the ease of reaching all rural areas was assessed for each product idea. Factors bearing on the distribution effort were the storage life of the product, the longer this period, the greater the possibility of distribution over all areas from central or scattered production areas; the adequacy of existing distribution systems to cope with national distribution of each product, particularly to reach the greatest number of sari-sari stores; and the costs of distribution, since one central factory distributing nationally would have higher distribution costs than several factories scattered throughout the country and distributing to their local district. Distribution assessment factors were then :

7. Storage life
8. Existing distribution system adequacy
9. Distribution costs

Other marketing factors such as profitability and promotion effort were not considered here as assessments on these factors depended on specific company situations and on whether or not this type of project would be subsidized.

Technical factors. Assessment of possible problems in development of each product was necessary. At this stage, a primarily subjective assessment could only be made, based on information of similar processes in the literature. Production capacity would affect market size and penetration factors. Estimation of current output and expected output of factories capable of handling these product types was used to measure this factor. Also estimations were made of the ease of increasing production e.g. using other plant or building new factories, modification of equipment.

The effect of processing on nutritional value of the product needed to be assessed. Although extensive experimentation would be required to optimize nutrient retention in processing of these products, some estimation was made of the likely processing steps and possible sources of and degree of nutrient destruction. It was hoped that products would provide nutrient requirements in daily portion sizes. The bulk of the raw material mixture, weighing 1140g, could require that products be divided into smaller, more convenient portion sizes, these could cause problems in control of intake. The degree of difficulty of portion control of each product type was estimated. The technical factors were :

10. Development problems
11. Production capacity
12. Ease of increase of production
13. Processing effect on nutrient retention
14. Portion control

Other factors such as processing cost and capital cost were not included since these could not be assessed without knowledge of the specific plant situation or whether a subsidy would be available. It was aimed to utilize existing processing equipment with minimum modification. In this way, little capital investment should be necessary.

6.5.2 Weighting of factors

Before an overall rating score for each idea is calculated, the factors are weighted to account for the relative importance of the different factors to the project. For example, technical factors may be more important in some situations than marketing factors and are weighted accordingly (see Fig.6.4). Three methods of weighting factors are :

1. Weights may be assigned by ranking factors in order of importance. This assumes an ordinal scale of importance (128).
2. A maximum score number may be assigned to each factor, the different magnitudes of these numbers defining the relative importance of each factor to the project (129).
3. In the Churchman -Ackoff scale, these aspects are combined in that factors are ranked and the factor deemed most important given a weighting of unity and all others some fraction depending on their importance relative to this factor. Product concepts are ranked inversely for each factor and 'preferential position' of each product assessed by multiplying the ranking by weighting for each factor and adding across all factors (130).

The assignment of weights by subjective methods is criticized mainly because the factors, as judged, are normally not independent and contain some interaction between them. A complex method has been proposed (131) to evaluate weightings for factors which eliminate this interaction. This method defines for each factor distributions of probability for success or failure of a product concept, based on experience in the company. It is probably not worth all the extra effort to evaluate weightings in this way when screening at this stage. It has been shown (132) that the rating of product concepts is usually insensitive to small changes in factor weightings. It has also been suggested that Thurstone's Law of Comparative Judgement be used in the paired comparison of factors to obtain an interval scale of relative importance of factors which can subsequently be weighted accordingly (133).

In this project the fourteen factors were weighted subjectively on their relative importance to the objectives. Firstly, factors affecting the penetration of products into the diet, were weighted. The factors measuring the number of people who could be reached, the frequency of intake and the amount of each food which could be eaten were judged most important here. The degree of acceptability, breakfast utilization and present intake

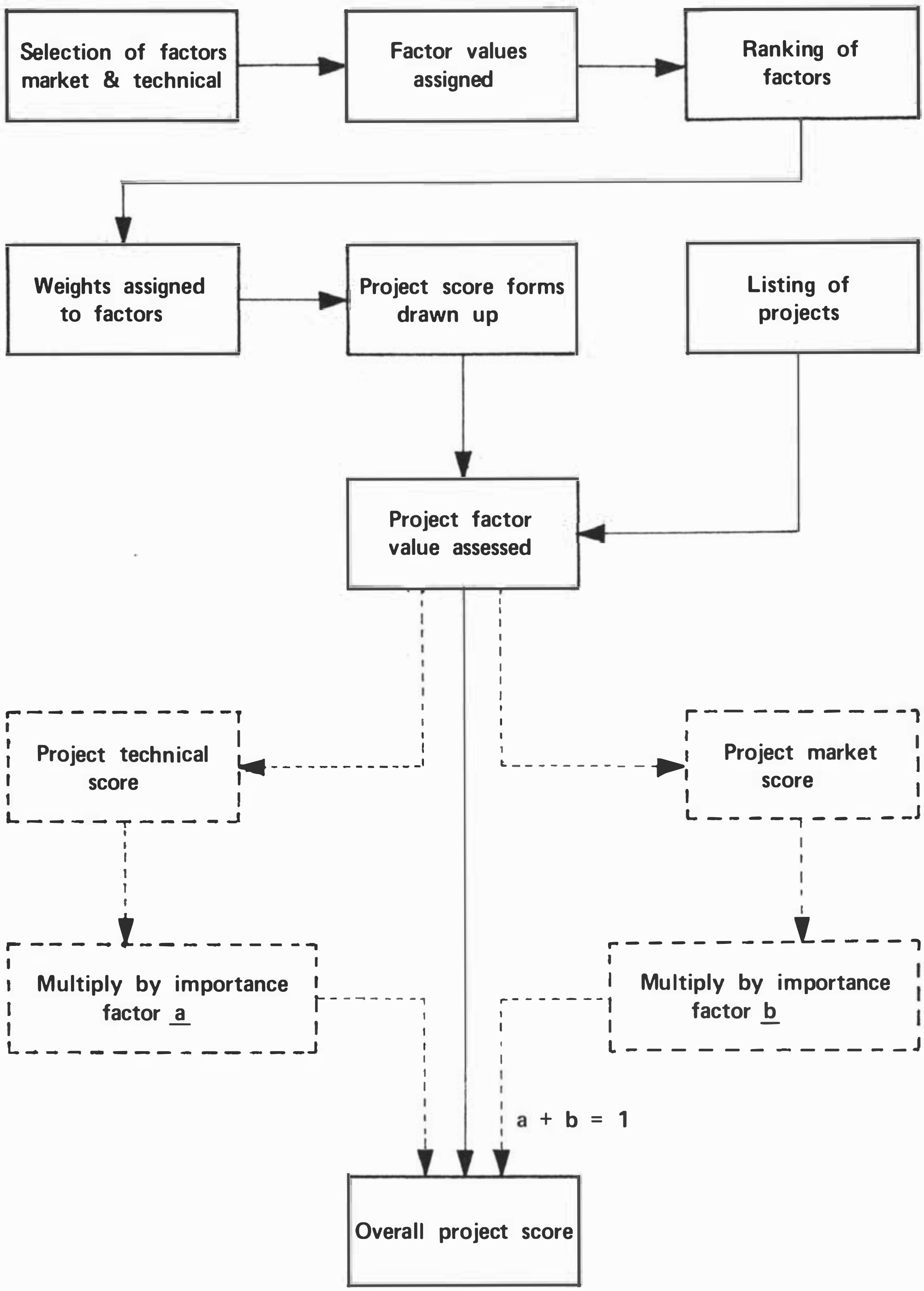


Figure 6.4 Scoring system for evaluation of projects

Taken from B.V. Dean and M. J. Nishry, Scoring and profitability models for evaluating and selecting engineering projects, Operations Research (1965) 13, 550 factors were weighted low since these had been considered to a great extent in earlier selection of product concepts. The distribution factors were considered more important than the diet penetration factors since without efficient distribution, no inroads to diet penetration were possible. Production capacity was judged of similar value due to the interdependence of this with distribution for widespread availability of products. The other technical factors were weighted slightly lower due to uncertainity of information for their assessment. The overall factor weightings were then :

1.	Estimated proportion of total population which would consume each product.	10
2.	Estimated frequency of consumption.	6
3.	Present consumption of similar products.	1
4.	Estimated possible maximum daily consumption of each product.	8
5.	Breakfast utilization possibility of each product.	2
6.	Degree of acceptability of each product for eating habits.	2
7.	Estimated storage life of each product.	10
8.	Adequacy of existing distribution for each product.	10
9.	Estimated distribution costs.	10
10.	Problems anticipated in development.	8
11.	Estimated production capacity.	10
12.	Ease of increase of production.	10
13.	Possible effect of processing on nutrients in each product.	7
14.	Problems anticipated in portion control.	4

6.5.3 Assigning values to factors and calculation of overall rating

Each product idea was assessed for its degree of fit with each factor and an appropriate value assigned to represent this. There are several ways of assigning this value.

1. This value may be a ranking, where the product concept which rates highest, with respect to a factor, is ranked first, the next second and so on. The best product concept is that with the highest ranking over all the factors (134).

2. This value may be a score, out of the maximum number for each factor, representing the degree of fit. An overall rating is obtained by adding all the individual scores (135).

3. The degree of fit may be described in a scoring system by several levels termed very good, good, average, poor, very poor which are

allotted scores of say 5,4,3,2,1 respectively. The divisions - good, average, poor - may be explicity defined (136) for each factor in order to retain consistency in rating each product idea.

4. This can be further refined by assessing the probability of attaining a particular level of fit in the overall score. There may be 0.9 probability of an idea having a very good fit for one factor and 0.1 probability of a poor fit with the same factor (137). This system was employed in evaluating product concepts for the Philippines as shown in Fig.6.5.

Each level of fit (A) had a numerical value (B) assigned to it - 10 for very good, 8 for good, 6 for average, 4 for poor, 2 for very poor. Then the probability that each product concept would reach any of the levels of fit was assessed. This assessment was quantitatively based where possible, as described in Appendix 11. The probability was multiplied by the value of the level of fit and summed for that factor. This gave the expected value (C) of the product concept for that factor. Then the expected value was multiplied by the respective factor weight to give the factor rating. Summing across all factors gave the overall rating (E) for each product, on an ordinal scale.

Factor	Development problems						Production capacity						Ease of production increase						
factor weight (D)	8						10						10						overall rating (E)
level of fit (A)	VG	G	A	P	VP	Total	VG	G	A	P	VP	Total	VG	G	A	P	VP	Total	
value of level (B)	10	8	6	4	2	(C)	10	8	6	4	2		10	8	6	4	2		
	probability of attaining these levels																		
dried bread slices	-	-	-	.2	.8	2.4	-	1	-	-	-	8	-	-	-	.4	.6	2.8	127.2
canned meat loaf	.4	.4	.2	-	-	8.4	-	-	-	1	-	4	.6	.4	-	-	-	9.2	199.2
dried noodles	-	-	.4	.3	.3	4.2	-	-	1	-	-	6	-	-	1	-	-	6	153.6

Figure 6.5 Illustration of scoring system used in product idea screening

This system was extended across all the factors considered, to provide a reasonably thorough and critical evaluation of the product concepts. Appendix 11 contains the full scoring sheet.

The overall ratings for the twenty product concepts were :

Canned meat loaf	596
Dried sausage	594
Intermediate-moisture bread	592
Intermediate-moisture buns	590
Fermented sausage	589
Dried meat loaf slices	584
Vienna sausage/canned	578
Intermediate-moisture sausage	577
Frankfurter/canned	574
Conventional buns	568
Noodles/canned in savoury sauce	566
Noodles/canned in fermented sauce	564
Pickled meat loaf	556
Fermented meat loaf	554
Conventional bread	552
Dried noodles	540
Pickled/fermented noodles	532
Intermediate-moisture meat loaf	522
Biscuits	522
Dried bread slices	485

Product concepts with the highest ratings were the most desirable for development. Some cut-off point had to be selected, concepts above this being selected for further evaluation. Such a cut-off point was indistinct as the five top concepts were rated similarly. However, the canned meat loaf, dried sausage and fermented sausage had the same basic process - chopped mix formulation; the intermediate bread and buns were baked yeasted doughs.

A decision had to be made at this stage as to which product to develop. It was decided to concentrate on the development of meat-type products, since major development problems were predicted in the evaluation for the baked products. Since the meat product concepts depended on a chopped-mix formulation, investigation was focussed on development of such a formulation from the raw material mixture.

6.6 Laboratory development of product

A simulated meat mixture, suitable for a canned meat loaf type product was developed from the raw material mixture. This development was undertaken on laboratory scale only, due to limitations on the availability of some of the raw materials in New Zealand.

6.6.1 Raw materials

Of the raw materials required (Table 6.6) radishes, sweet potatoes, glutinous and brown rice, fresh coconut, beef blood and beef liver were available in New Zealand. These would be similar to Philippine raw materials except for radish and sweet potato: the bulb variety of radish and the New Zealand sweet potato, kumera were used. Buffalo liver was not available and was replaced by additional quantities of beef liver. Marbled stingray (fish) was also not available, so common coarse textured fish was used - snapper or gurnard - depending on availability. The species of dried seaweed, gamet, was not identified and so a common imported dried seaweed, hoy-ty, represented this material. Cottonseed was not available in New Zealand, but cottonseed meal was obtained from Australia. Cottonseed oil was added back to the mixture to compensate for the oil extracted in the processing of the meal, since the raw material selected was whole cottonseed. The pilinut was native to the Philippines, and no other nut could be used to represent this material due to its exceptionally high fat content (~60%). Arrangements were made to import a small quantity of these nuts from the Philippines. Therefore, it was possible to simulate the selected raw material mix almost completely.

Table 6.6 Raw material amounts per kilogram batch of mixture

radish	322g
sweet potato	244
rice, glutinous	112
rice, brown	38
coconut, mature	165
pilinut	27
cottonseed	19
seaweed	36
blood (beef)	2.5
liver (beef)	6.2
fish	27

For ease of handling and for dividing and scaling up batches in experimental work a batch size equivalent to 1000g raw material mix was found convenient. Radish, sweet potato and blood/liver/fish mix were all stored in their respective batch units for convenience. The materials were prepared as follows :

Radish. The bulb or root varieties were used, cut from leaves, washed and peeled in a hand-operated abrasive peeler with high pressure water spray. Peeled material was blanched 7min in live steam, rapidly cooled in running water, and weighed into batch size units (322g) which were individually held in frozen storage.

Sweet potato. Tubers were chopped up by hand, washed and peeled in an abrasive peeler. Material was further chopped to approximately 1in cubes, blanched for 8min in live steam, cooled, weighed into batch units (244g), then stored in a freezer.

Glutinous and brown rice. The grains were ground to coarse flour in a vertical plate grinder. Each variety was held in bulk in sealed jars at room temperature.

Coconut. Whole fresh nuts were split and drained of coconut water. Meat was grated from the shell by holding under a rotating grater, similar to the grating stage in dessicated coconut operations in the Philippines. Grated coconut was held in sealed containers in chill storage.

Pilinut. Whole nuts were cracked in a crude vice arrangement, the kernels extracted and held in sealed jars in chill storage.

Cottonseed. Roughly ground cottonseed meal was sieved to separate gritty kernel particles from fine cottonseed flour. An appropriate amount of cottonseed oil was added to the raw material mixture to adjust the fat content to that of whole cottonseed (6g/1000g batch of total mixture or 6g/38g batch of cottonseed meal). The meal was held in bulk in sealed containers at room temperature. Cottonseed oil was held in chill storage.

Seaweed. The short, tough strips of seaweed were milled in a pin mill to coarse flour.

Beef blood, liver, fish. Due to the small quantities of these materials required, batch units of the fresh materials (blood stabilized with sodium citrate), were weighed and combined, packed in polythene and held in frozen storage (27g fish, 6.2g liver, 2.5g blood).

6.6.2 The basic process

Processing required fcr this product was envisaged at three levels of complexity as illustrated in Fig.6.6.

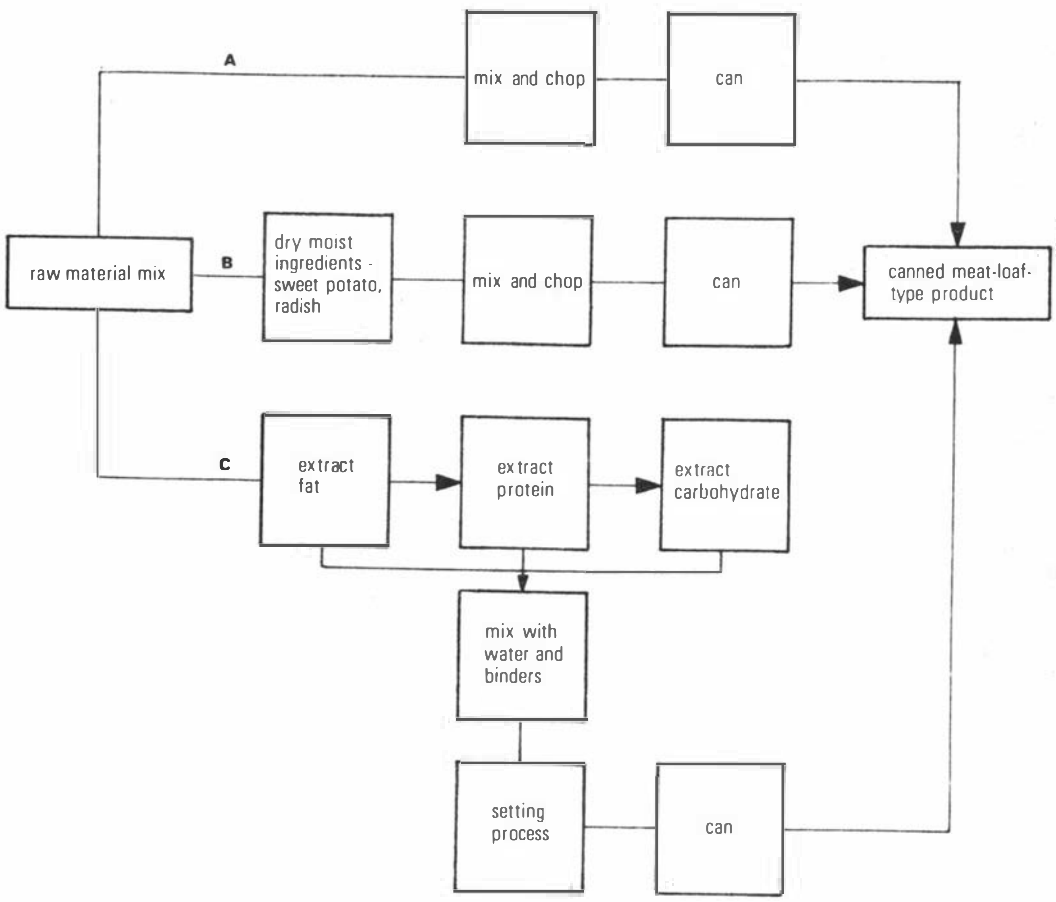


Figure 6.6 Possible process plans for meat loaf type products

System (A) was the simplest process with operations of chopping and mixing of ingredients, filling into the can, and heat processing. The heat should cook the materials and allow some setting of the mass to a solid loaf form. If a satisfactory product could be achieved by this pathway, this would be most adaptable to Philippine conditions since chopping, mixing, canning and retorting equipment were available in large meat packing plants.

System (B) was more sophisticated than (A), adding in another operation - that of dehydration of the wet ingredients - radish and sweet potato - this could be necessary to aid binding of the raw material mixture, if this was unsatisfactory with process (A). This would also reduce the bulk of final product. The disadvantage was that facilities for dehydration were the least developed of processing facilities in the Philippines and it could be difficult to manufacture this dry mix. Suitable drying facilities were not available in the meat packing plants which would be expected to produce this type of product.

System (C), a much more complex process, would be necessary if suitable texture and binding was not achievable by methods (A) or (B). Based on the general procedure for production of synthetic meat analogues it required a high level of both technology and investment in extraction plant to produce material of suitable textural quality. It was judged to be the least suitable process for the situation.

If systems (A) or (B) were not satisfactory, it could be necessary to review the choice of products, since system (C) would not be compatible with one of the primary objectives - suitability for manufacture on existing facilities in the Philippines, with minimum modification of plant. It was hoped therefore that a suitable product could be produced using process (A), the simplest system illustrated.

Mixing and chopping of mixed materials could conveniently be carried out in one operation, using a 'silent cutter' or a 'bowl chopper' as is commonly used in sausage manufacture. Such equipment was available in the large meat processing plants in the Philippines. Since processing similar to that for canned sausages was envisaged - materials were to be chopped and mixed, packed into cans and heat processed so that the material set to a solid, loaf-form - the sausage making process was simulated in the initial experimental work.

Typically sausage making is carried out in four stages - chopping of lean meat; addition of water, salt, additives; addition of binding materials such as breadcrumbs, skim milk powder; then final chopping with fatty materials. The initial chopping increases the surface area of the protein material so that efficient solution of the water soluble proteins is obtained by addition of the water. This is aided by the presence of salt. The fatty material is then chopped in and forms an emulsion with the water phase, stabilised by the soluble meat proteins and the added binder. Binders also affect the texture of the final sausage. The emulsion is set to a firm texture by any heat process such as boiling, smoking or canning.

Although the raw material mixture had quite different characteristics from those controlling the fat-protein-water interactions in meat sausage manufacture, (see Table 6.7) similar process steps were considered.

Table 6.7 **Comparison of composition of raw material mix with that of typical meat sausage formulation**

	Percent of total mix weight	
	Raw material mix	Typical sausage mix
fat	7	20-30
protein	5	13-18
moisture	60	50-60
carbohydrate	26	~ 12

The chopping times for each stage are critical for each type of sausage formulation, since they affect the stability of the emulsion formed and the fineness of the texture obtained. For initial trials on 1kg batches of raw material (Table 6.6), typical sausage processing times were used. The process steps considered were :

1. Chop protein materials - fish, liver, blood mix - 1 minute;
2. Chop with water rich materials - radish, sweet potato, and any added water - 2 minutes;
3. Chop with binding materials - glutinous and brown rice flours, cottonseed meal, seaweed flour - 1 minute;
4. Chop with fatty materials - coconut, pilinut and added cottonseed oil - 1 minute.

A pilot scale 'Schaarfen' bowl cutter (5kg capacity) was used and 200ml extra water had to be added to prevent the mixture clogging up in the machine.

This process produced a coarsely chopped mixture with a runny consistency and an unattractive grey/green colour. The only difficulty was in the chopping of the small amounts of fish/liver/blood mix. These materials, added in the first stage, were thrown from the rotating knives to the roof of the bowl chopper, to which they adhered. It was found necessary to halt the chopping cycle midway, in order to remove adhering materials so that more homogeneous mixing and chopping was obtained. Improvement was also found by adding the protein materials after the radish and sweet potato stage, the presence of this greater mass of material aiding the retention of the fish/liver/blood mix in the bowl.

The mixture was chilled overnight, which allowed the mass to equilibrate, and then tested for pH, moisture content and water retention (a measure of emulsification). Water retention was determined by measuring the water released on centrifugation of the material at 3000G. It was found that none of the added water was bound to the mixed material - there was no indication of emulsification in this process. The moisture content at 70% indicated that the raw material mix prior to water addition had moisture content of 64% which was 4% above that expected from calculations from food composition tables. The pH reading of around 6.0 indicated that full heat processing at least to lethality equivalent to $F_o = 2.8$ was necessary. Only if the pH were below 4.5 should reduced heat processing be considered.

The effect of heat on the mixture was investigated by cooking the material, filled into casings, in live steam for 20 minutes. It was found that the mixture became firmer in texture and the coarseness was reduced, Investigation of water retention of the cooked samples indicated that all the added water was retained. This would be due to the hydration and gelatinization of the rice, seaweed and probably cottonseed meal during the cooking of these materials. The setting or binding of the material was confirmed on retorting cans packed with the uncooked material at 121C for 80 minutes (16oz cans,301x409, containing 400g mix). The mixture was firmer in texture than the steamed samples and had browned significantly to produce a more appetising colour and a cooked flavour. A background bitterness was produced during the retorting process which detracted from the flavour.

From this preliminary investigation, it seemed that the simple mixing process could produce the type of product sought. Further stiffening of the texture and incorporation of acceptable spices and flavourings were necessary to improve the basic product.

6.6.3 Improvement of texture

The canned product had fairly firm texture, but it was rather moist and fell away on cutting. It was expected that the texture could be stiffened by either or all of the three processing changes:

1. Reducing the level of added water in the mix,
2. Incorporating binders and thickeners such as gums, alginates, cellulose derivatives,
3. Adjusting of chopping conditions in the process.

Only categories (1) and (2) were evaluated at this stage, due to the limited amount of raw materials available; chopping variation was considered later. It was found that reducing the added water from 200ml to 100ml per 1kg batch of material produced a less moist mix, but mixing and chopping was more difficult due to clogging. This difficulty was aggravated by reducing added water further to 50ml, so the added water in the formulation was only reduced to 100ml per 1kg batch.

Several hydrocolloid materials - natural gums, alginates and cellulosic derivatives - are used to give some degree of water binding in food products, varying from thickening to gelation. Their action is to complex water molecules so that a network is set up through the food binding the particles together. A screening system was set up for selection of the most suitable hydrocolloid for the mixture:

1. Only materials of no nutritional value should be used,
2. Only low concentrations of these compounds be added, to control costs and mixture bulk,
3. Materials which required the addition of other compounds to produce their binding effect were not suitable, for the same reason as (2),
4. The binding effect should be stable through heat processing or be

reversible if binding breaks with heat,

5. The material should be active at pH 6-7,

6. The cheapest material which is suitable should be used.

Thirteen non-nutritional hydrocolloids were assessed for suitability for this situation, by using a knockout system where any material not meeting any of the criteria was eliminated. Remaining materials were scored for each factor in assessing their suitability. Appendix 12 gives details of this assessment. The most suitable binders were locust bean gum, guar gum, agar, alginate, carboxymethyl cellulose.

To evaluate the hydrocolloids, a 2,500g batch of mixture was chopped and mixed as described earlier with the addition of 250ml water (equivalent to 100ml per 1kg batch). This was divided into 400g portions each of which was further chopped for 2min after sprinkling with one of the following binders.

1. Locust bean gum - 2% based on free water of 280ml/400g sample
2. Guar gum - 1% based on similar water content
3. Agar - 2% based on similar water content
4. Alginate (Manucol DM) - 3% based on similar water content
5. Carboxymethyl cellulose - 3% based on similar water content

A sixth mixture with no additive also underwent 2min further chopping. The binder proportions were based on common levels added to other products in which they had been successfully used.

Samples were filled into (301x409) cans and given the same heat processing cycle in the retort.

Table 6.8 indicates the results of evaluation of texture firmness by tenderometer measurement and also by a laboratory taste panel composed of faculty staff (mainly New Zealanders). The results were inconclusive. In fact in tenderometer and overall subjective assessment of texture, the control sample had highest ratings although overall there was no significant difference between samples. The CMC samples were assessed significantly poorer than the control on smoothness and overall texture due to a greasy, rubbery effect which was imparted by this material. It seemed then that the mixture did not require additives to modify the texture. Although not rated highly, the overall assessment of mixture was assessed at the "like slightly" level.

Table 6.8 Assessment of texture of product by tenderometer and taste panel measurements

Sample	Tenderometer time for penetration [a] (sec)	Toughness [b]	Smoothness [c]	Overall preference [d]
control	61	3.0	3.0	4.8
control + agar	56	3.3	3.0	4.6
control + alginate	55	3.4	2.5	4.3
control + CMC	55	3.8	2.3 [e]	3.5 [e]
control + guar gum	55	3.0	2.9	3.9
control + locust bean gum	56	3.0	2.8	3.9

a. Mean of four estimations. The higher the time, the tougher or firmer the sample.

b. Mean of eight judgements. Scores ranged from 6 for extremely tough to 1 for extremely mushy on a 6-point scale.

c. Mean of eight judgements. Scores ranged from 5 for excellent smoothness to 1 for very poor smoothness on a 5-point scale.

d. Mean of eight judgements. Scores ranged from 7 for 'like very much' to 1 for 'dislike very much' on a 7-point scale.

e. Significantly different from control at 5% confidence level.

6.6.4 Improvement of flavour

The basic mixture had a bland vegetable taste with a background of coconut, and after heat treatment in the can, it became slightly caramelised. An unacceptable bitterness also developed during heating. It was necessary then to incorporate a more suitable 'meat-like' flavour to the mixture and also to attempt to reduce the formation of the bitter flavour notes.

The basic seasonings used in meat loaves - salt, pepper, mace and garlic - were added to the mixture and various commercial meat flavours were tried on a trial and error basis. A laboratory taste panel composed of faculty staff was again used to test the acceptability of the various mixtures and considerable difficulty was found, no doubt due to the unconvential nature of the basic mixture to the New Zealand tasters! The tasters either liked or disliked the basic mixture and had difficulty in differentiating between flavoured mixtures. The background flavour of the mixture dominated the overall flavour at this stage.

The hedonic scale proved insensitive in comparing the mixtures and a ranking test was substituted for it. The respondents were asked to rank samples in order of flavour preference, 1 for best flavour, 2 for second best flavour and so on (see Fig.6.7 for form used). These ranking were converted to Fisher scores so that analysis of variance tests could be carried out (138) (see Appendix 13 for typical analysis). In Table 6.9 is an example of the results of a typical taste test during this flavour study.

Table 6.9 Comparison of commercial meat flavours in basic mixture

	6 taste panelists in ranking test Rank totals
Basic mixture	27 [a]
"Hamburger" flavouring	18
"Hamburger" flavouring and garlic	12
"Beef" flavouring	14
"Beef" flavouring and garlic	19

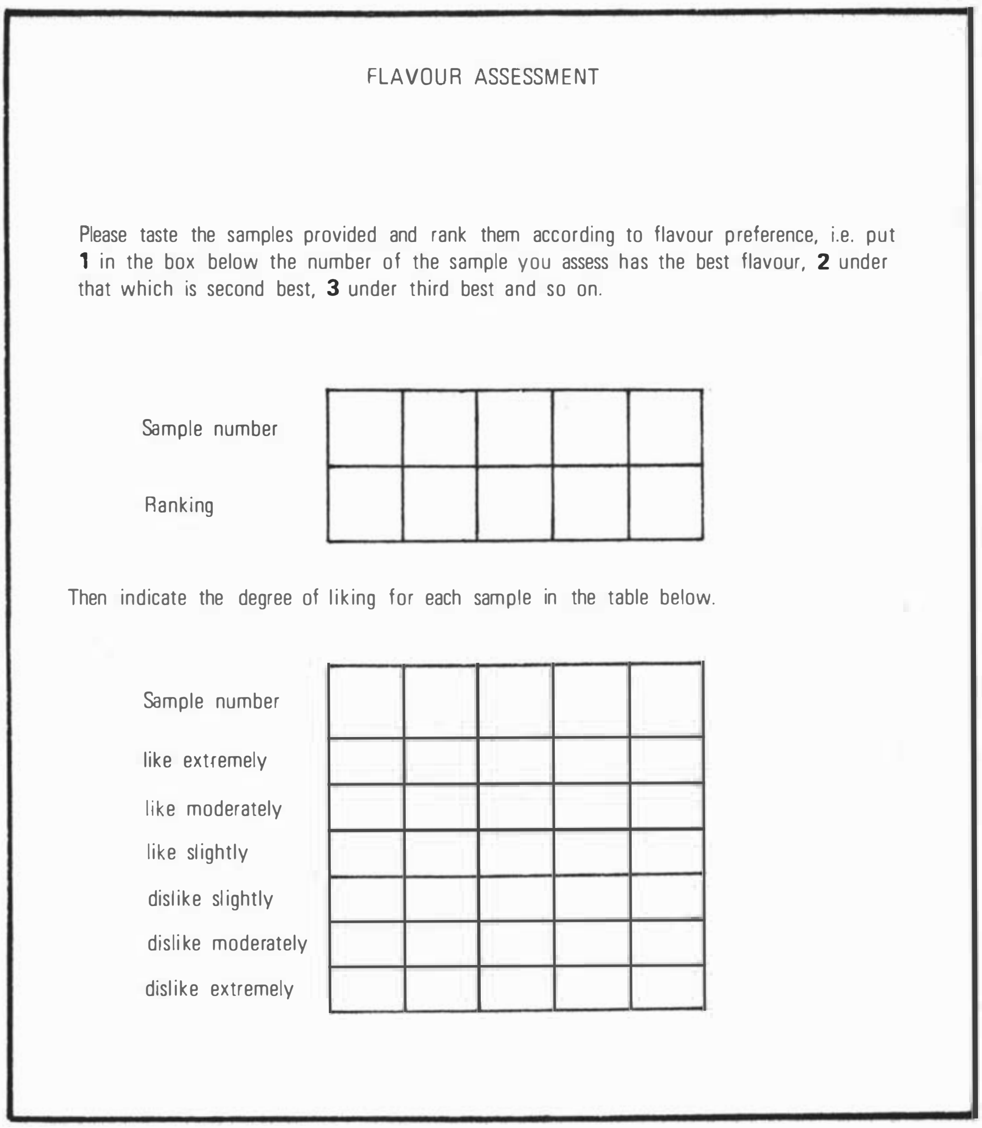
a. Significantly different at 5% confidence level.

The unflavoured sample was poorly rated compared to the meat flavoured samples but no difference could be determined between the different meat-mix samples. From a hedonic test with the same samples, in Table 6.10 it was seen that there was a gradation from extreme dislike to slight liking moving from the unflavoured samples, through those with beef flavouring to those with hamburger flavouring.

The effect of garlic was to reduce the degree of dislike of both the beef and hamburger flavoured samples, without increasing the degree of liking. With this small taste panel, imposed by the small amount of material available, significant differences between samples were not expected. Trends seen in assessments were useful in indicating which flavourings had greatest effect. All flavoured samples, on average were not well liked. It appeared that another strong background flavour,

Table 6.10 Comparison of commercial meat flavours in basic mixture

	6 panelists in hedonic test					
	like extremely	like moderately	like slightly	dislike slightly	dislike moderately	dislike extremely
Basic mixture	0	0	1	0	3	2
"Hamburger" flavouring	0	3	0	1	0	2
"Hamburger" flavouring and garlic	0	1	2	1	2	0
"Beef" flavouring	0	1	1	1	3	0
"Beef" flavouring and garlic	0	0	1	4	1	0



FLAVOUR ASSESSMENT

Please taste the samples provided and rank them according to flavour preference, i.e. put **1** in the box below the number of the sample you assess has the best flavour, **2** under that which is second best, **3** under third best and so on.

Sample number					
Ranking					

Then indicate the degree of liking for each sample in the table below.

Sample number					
like extremely					
like moderately					
like slightly					
dislike slightly					
dislike moderately					
dislike extremely					

Figure 6.7 Taste panel form for flavour assessment

blended with the mixture, was required rather than addition of a meat flavouring. The vegetable taste of the mixture was not compatible with meat flavourings.

It was suspected that the taste panel were influenced by the unconventional nature of the material. The New Zealand tasters did not truly represent the consumers for whom the product was designed; a consumer panel more representative of Philippine tastes in food was required for flavour development. There was only one Filipino student at Massey University, so students from other Asian countries were included - two Thai, two Vietnamese, one Malaysian and one Korean. It was assumed that the vegetable/cereal mix in form at least, would be familiar to them and that suitable spicing and flavouring could be incorporated to satisfy their concept of flavour associated with this type of product.

From Filipino sausage and meat loaf recipes, a list of common flavour additives was compiled. These included tomato sauce, salt, pepper, sugar, garlic, mace and ginger. A spicy, but not hot, tomato-based flavour seemed to be most suitable for the Philippine taste. Several trial and error mixes were made up using these seasonings in small samples of the basic mixture. It was found that all the seasonings could combine to provide an attractive flavour for the mixture.

The most suitable mixture developed was:

basic mixture	91.87%	1000g batch
tomato paste	6.61%	72g
salt	0.37%	4g
sugar	0.73%	8g
dried garlic powder	0.37%	4g
saromex mace flavour	0.11%	1.2g
ground dried ginger	0.06%	0.6g

A high level of tomato paste was required which could upset the nutritional balance of the mixture. The extra calories contributed by the tomato paste (82kcal/100g) could be metabolised fully by the thiamine, riboflavin and niacin included simultaneously at levels of 0.2mg, 0.12mg and 3.1mg per 100g paste respectively. Extra vitamin A (3300 in/100g) and vitamin C (49mg/100g) would be provided at no loss to nutritional balance. The only nutrient imbalance could be with protein, since the amino-acid pattern of tomato has chemical score 23 and therefore could lower the overall protein quality of the product. At this stage, raw materials were almost exhausted, so the assessment of these spices and flavourings by the consumer panel was left until the process variation experiments.

6.6.5 Process variables adjustments

At this stage, enough raw material remained to enable limited factorial experiments to be carried out to study the effects of some of the variables in the process on the acceptability of the product. Since texture and flavour were the only factors bearing on acceptability, a taste panel was used to assess these effects. The process variables which could affect these quality factors and which could be adjusted were:

1. Particle size of individual raw materials
2. The sequence of addition of raw materials to the bowl chopper
3. Chopping times in the bowl chopper
4. The amount of water added to the mix
5. The temperature of the chopping process
6. The time/temperature characteristics of the sterilization process

There was not enough material to investigate systematically all these variables, so those expected to have the greatest effect on texture and flavour were selected - chopping times, water addition and sterilization conditions.

The firmness of the final product could be increased either by a longer chopping time or by addition of less water. It was expected that the longer the chopping time, the finer the resulting mix, the greater the surface area of particles for binding contact and the firmer the resulting product. Reducing the amount of water would give a drier, firmer mix, but if the water were reduced too far, not enough water would be available for hydration and gelatinization of the cereal grains and grittiness might result in the final product.

The formation of the bitter compound might be reduced by either less heat treatment or by removal of the volatile precursors before heat sterilization. Steaming or exhausting the product in the can before closing would reduce the heat sterilization time and would have the added advantage of possibly causing the bitter compounds or their precursors to be removed from the product prior to canning. Some earlier experiments had shown that steaming of the mixture did reduce the bitter flavour.

The factorial experiments were planned for three chopping times - 6,8,10 minutes; two filling methods - cold fill and presteamed; and water addition as 5% and 10% by weight of the basic mix (Fig.6.8)

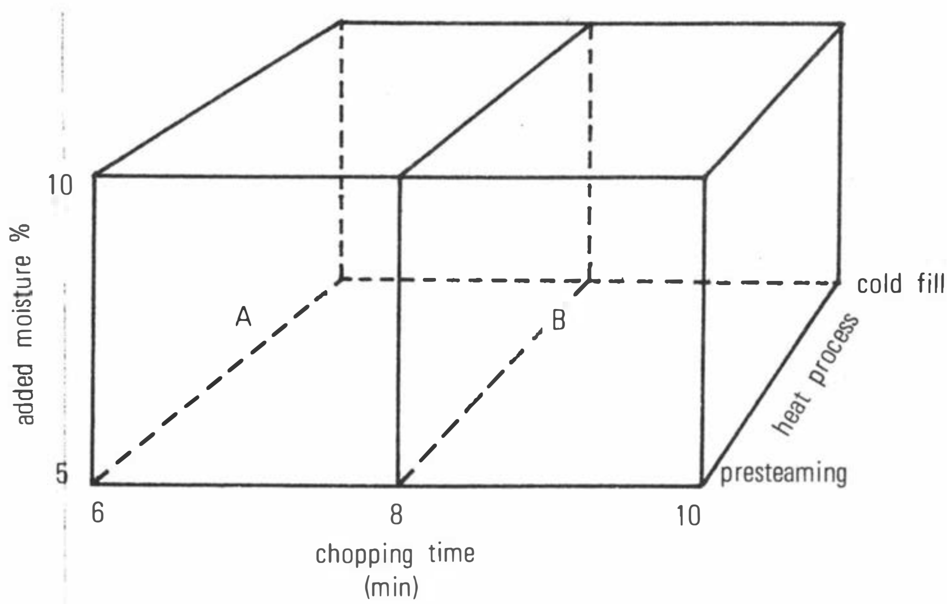


Figure 6.8 **Representation of process variable adjustments investigated for optimization of product quality**

This gave 12 experimental batches, all made with the flavoured mixture described in 6.6.4. The method of processing used is shown in Fig.6.9.

The twelve variations of the mixture were tested the next day by the panel of five Asian students. Samples were divided into two groups of eight, (described by cubes A and B in Fig.6.8) as this was the maximum number that the tasters could test at one panel. The eight samples of set A were tasted in the morning and those of set B in the afternoon of the same day. The meat loaves were removed from the can, cut into portions, steamed for 15 minutes, and tasted hot by the panel. The eight samples

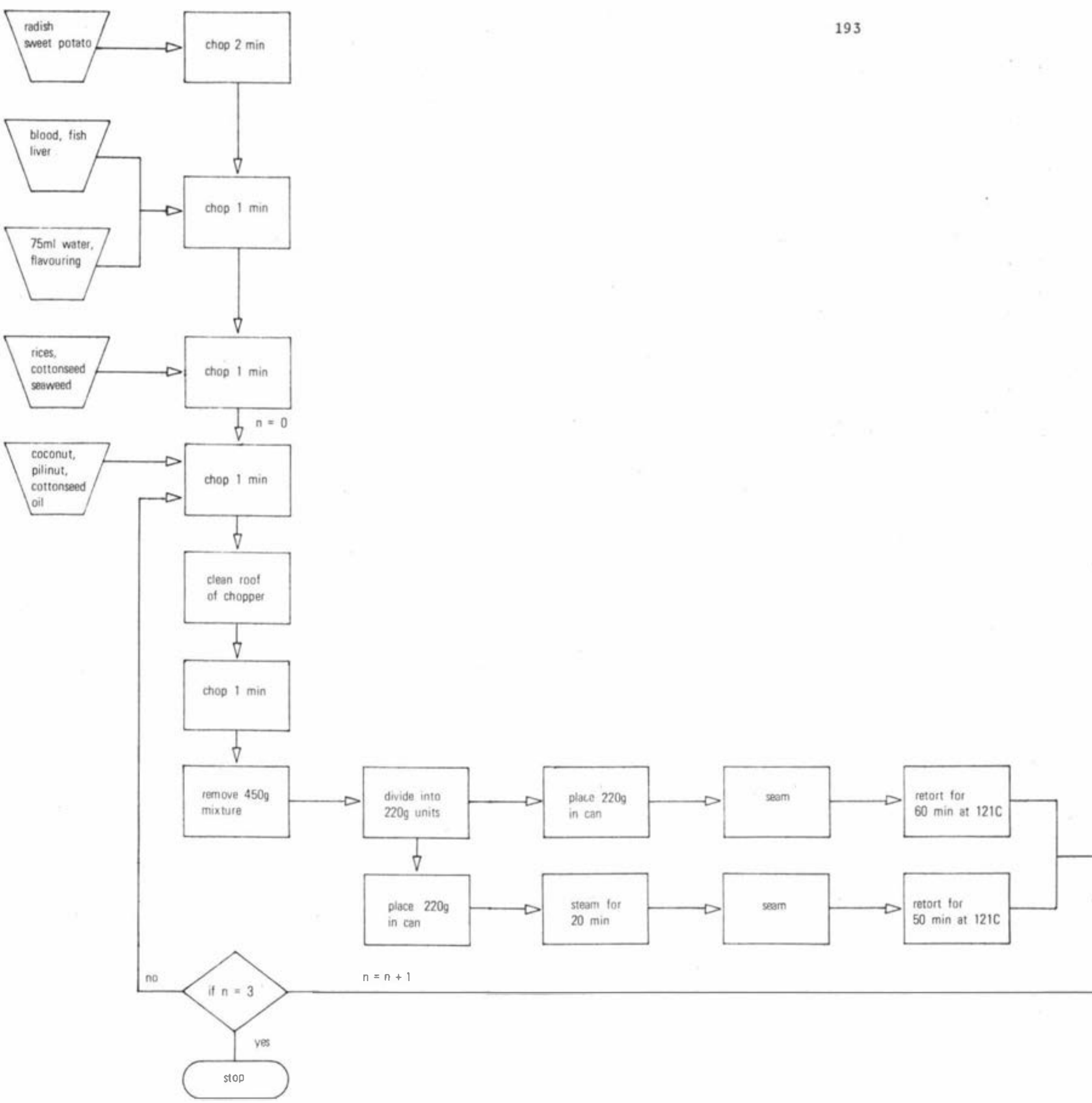


Figure 6.9 Diagramatic plan of process variable experiments

were presented together and were only identified by three figure random numbers. The panel was asked to rank the samples, 1 for the sample they liked best, 2 for the second best and so on. The results of the ranking are shown in Table 6.11 (see Appendix 13 for calculation of significance of results).

Table 6.11 Taste panel rankings for process variable experiments

Water addition	Chop time	Heat process	Rank total
Test A			
5%	6 min	presteamed	16
10%	6 min	presteamed	24
5%	8 min	presteamed	19
10%	8 min	presteamed	24
5%	6 min	cold fill	21
10%	6 min	cold fill	30
5%	8 min	cold fill	16
10%	8 min	cold fill	30
Test B			
5%	8 min	presteamed	26
10%	8 min	presteamed	30
5%	10 min	presteamed	20
10%	10 min	presteamed	27
5%	8 min	cold fill	18
10%	8 min	cold fill	20
5%	10 min	cold fill	19
10%	10 min	cold fill	20

In the first experiment, the four samples with 5% added water (rank total 72) were significantly better than the four samples at 10% added water (rank total 105), and there was also an improvement in the second experiment (83 and 97 respectively) although not statistically significant. It was concluded that the low moisture addition gave a more acceptable final product.

No difference was found in the mixing times. Rank totals for

for first experiment were 91 for 6min, 89 for 8min and for second experiment 94 for 8min, 86 for 10min so with from 6-10 minutes mixing there was no difference in acceptability.

Again, there was little difference over all the tastings for the samples cold filled and presteamed. In the first taste panel, the rankings were very similar but in the second taste panel, the cold fill samples were ranked higher than presteamed samples (rank totals of 77 and 103 respectively). More information on the interaction of these process variables was obtained by carrying out Yates analysis of the ranked data, converted to Fisher scores, adapted from Duckworth(139) (see Appendix 13).

Table 6.12 Mean effects of process variables [a]

Water addition (%)	Chop time (min)	Heat process	Code	Mean effect
Test A				
5	6	PS	(1)	0
10	6	PS	a	-3.15
5	8	PS	b	0.12
10	8	PS	ab	-0.16
5	6	CF	c	-1.16
10	6	CF	ac	-0.82
5	8	CF	bc	0.91
10	8	CF	abc	-0.70
Test B				
5	8	PS	(1)	0
10	8	PS	a	-1.295
5	10	PS	b	0.69
10	10	PS	ab	-0.285
5	8	CF	c	2.325
10	8	CF	ac	0.73
5	10	CF	bc	-0.685
10	10	CF	abc	0.34

a. Obtained from Yates analysis of ranked data converted to Fisher Scores (see Appendix for full analysis)

There were no significant treatments due to the large error variance obtained with such a small taste-panel. Examination of the magnitude of the mean effects gave some indication of how these process variables affected the consumer assessment of this product, although lack of significance and replication in this data precluded selection of optimum processing conditions.

In the first test, the main effect of water addition was largest - increase in water content to 10% lowered the assessment of the product. The magnitude of this effect was reduced in interaction with both chopping time increase and change of heat process conditions. All samples with high added water level were assessed significantly poorer when rankings were converted to Fisher scores for analysis of variance. The chopping time main effect and the secondary effect with cold fill process were positive, indicating improvement. Interaction of these with water increase gave deleterious effects, due probably to the dominating effect of the water addition. The change from presteaming to cold fill heat processes generally produced decreased assessments in this first test. The secondary interaction of cold fill with high added water reduced the negative main effect of the cold fill variable, but only with high chopping time and low added water was a positive effect obtained with the cold fill process. From this test, it seemed desirable to consider increased chopping time and either heat process provided the added moisture was at 5%.

In the second test, the effect of increasing water in all samples was deleterious. The increase of chop time to ten minutes always lowered assessment except for its main effect when low moisture and presteaming conditions were retained. The effect of process changes was reversed in this test, the change to cold fill being desirable. Interactions with other variables gave reduced effect and gave deleterious secondary interaction with longer chopping time. It could be desirable then to change to the cold fill process provided a chop time of eight minutes and low moisture addition were employed. Changing to ten minutes chop time could be preferred with retention of presteaming process and low moisture addition.

This analysis provided a guide to suitable processing conditions for the most acceptable form of the meat mix product. Added water was reduced from 10% level to 5% of mixture weight. The effect of chopping time and process conditions was not so clear due to the interactions between them. A chopping time of ten minutes could be used to advantage with the presteamed heat process. This process was used since it had advantages over the cold fill process of exhausting the product and shortening the heat process time. The final process is described in flow diagram form in Fig.6.10.

6.6.6 Final adjustments to flavour

Discussion with the panelists used in the previous product assessment test, indicated that the spicy tomato-based flavour was liked but that its acceptability could be improved by increasing the levels of salt, sugar, garlic and ginger. They would have preferred the product to be fried, rather than steamed, although the steamed product reminded some of familiar foods.

With the remaining raw materials, two batches of product were prepared according to the process described in Fig.6.10. Two levels of flavourings were tested: one incorporating 50% increase in salt, sugar, garlic and ginger, and the other 100% increase in these seasonings based on levels used in process variable experimental batches. Tomato paste and mace flavouring levels remained unchanged in the basic mix.

Each product was removed from the can, cut into standard portion size (2" diameter patty) and half of samples steamed for 10min while the other half were fried for 4 min at 176C (350F) and served hot to a six member Asian student panel. Four different samples were presented together to the panel, being identified only by three figure random numbers. The order of tasting samples was randomized among the six panelists. Panelists were asked firstly to rank samples in order of preference and then to indicate their opinion of flavour and texture of samples on a 6-point hedonic scale. Table 6.13 shows the results obtained for the ranking test.

The fried sample with highest spicing was significantly preferred over the others, both steamed samples being significantly poorer in acceptability. Analysis of variance indicated that both fried samples were significantly preferred over steamed samples (see Appendix 13).

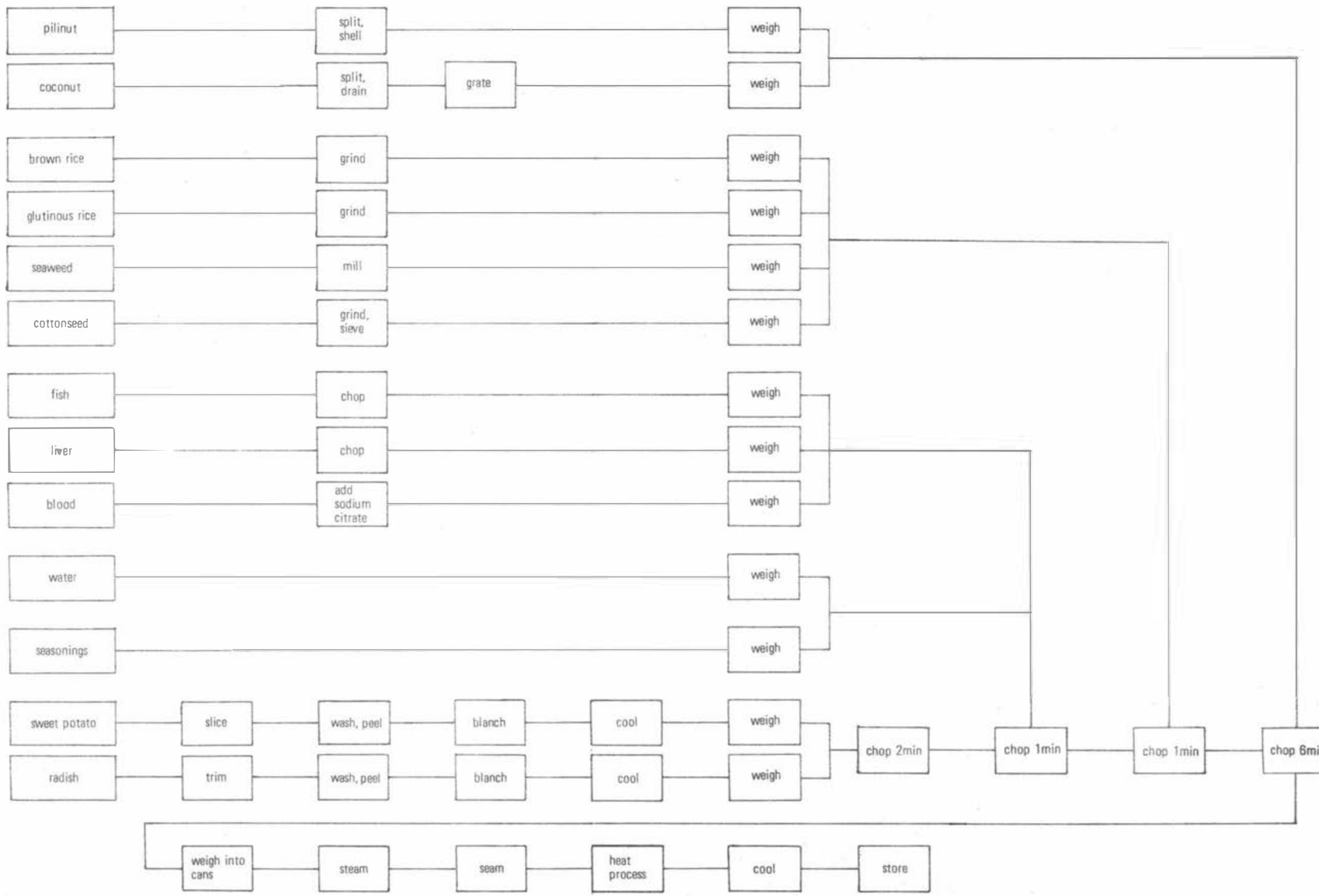


Figure 6.10 Flow diagram for meat-mix loaf production

Table 6.13 Rank totals for meat-mix flavouring assessment by Asian taste panel

	Rank total for 6 panelists
Higher spice level, steamed sample	19 [a]
Higher spice level, fried sample	8 [a]
Lower spice level, steamed sample	21 [a]
Lower spice level, fried sample	12

a. Significantly different at 5% confidence level.

Table 6.14 shows the hedonic ratings. For both flavour and texture, the high spice, fried sample was highly preferred, followed by the low spice fried sample. Both steamed samples were similarly rated for both texture and flavour at lower levels of acceptability. The interaction of high spicing and frying produced the most acceptable product, the frying factor being the most important. This could be due to interaction of flavours both in the mix and from the frying operation. The steaming operation could have interacted both with flavour intensity and the firmness of the samples, rendering them less acceptable. Overall flavour and texture ratings of all samples were in the acceptable range. Flavour ratings were generally higher than texture ratings. The more highly spiced material was most acceptable so the seasoning levels incorporated here were adopted for the final product formulation. The final formulation then consisted of:

basic mixture	90.38%	1000g batch
tomato paste	6.52%	72g
salt	0.72%	8g
sugar	1.45%	16g
dried garlic powder	0.72%	8g
saromex mace flavour	0.11%	1.2g
ground dried ginger	0.11%	1.2g

6.6.7 Processing description

The flow diagram in Fig.6.10 illustrates the processing steps required to produce the canned meat-mix loaf product from the raw material mixture. The processing consists of three main stages -

preparation, chopping and canning.

Table 6.14 Comparison of spice levels in final product formulation

	Frequency of scoring by 6 panelists			
	Higher spice, steamed sample	Higher spice, fried sample	Lower spice steamed sample	Lower spice, fried sample
Flavour assessment:				
Like extremely	0	4	0	0
Like moderately	2	2	1	5
Like slightly	2	0	4	1
Dislike slightly	2	0	1	0
Dislike moderately	0	0	0	0
Dislike extremely	0	0	0	0
Texture assessment:				
Like extremely	0	4	0	0
Like moderately	1	0	1	5
Like slightly	3	2	3	1
Dislike slightly	2	0	2	0
Dislike moderately	0	0	0	0
Dislike extremely	0	0	0	0

Preparation stage. It is assumed that all materials are obtained in the raw state and require to be prepared for processing on site. Generally materials should be prepared and weighed into batch size units and held in chill storage until required.

1. Fat materials - coconut, and pilinut are shelled; coconut is drained of water and grated on a rotating grater; pilinut is retained as whole kernel.

2. Dry materials - glutinous rice, brown rice, seaweed, cottonseed are ground to coarse flour, if not supplied in this form.

3. Meat materials - fish, liver and blood. Fresh materials are chopped

and weighed into batch units and mixed together. The mix should be frozen, if frozen storage available.

4. High moisture materials - radish and sweet potato are trimmed, washed and peeled. Radish is blanched for 7min in live steam, cooled rapidly in running water; sweet potato is chopped after peeling, blanched for 8min in live steam and cooled.

5. Seasonings. These should be obtained in already mixed form. The appropriate amount should be weighed out and mixed with the water added during the chopping stage.

Chopping stage.

6. Sweet potato and radish are added to a bowl chopper and chopped for 2min.

7. The fish/liver/blood mix is next added, together with flavourings and water; mixture is chopped for another 1min.

8. The dry materials are then added with chopping continuing for a further 1min.

9. Fat materials are finally added and the mixture chopped for further 6min; this cycle may be interrupted to remove materials adhering to the roof of the bowl chopper, which are added back to the bowl and chopping resumed till the end of the 6min period.

Canning stage.

10. The mixture is stuffed into cans (220g per 8oz can).

11. Uncovered cans are steamed for 20min.

12. Cans are seamed.

13. Cans are processed in steam retort for the appropriate time; 50min at 121C for 8oz cans.

14. Cooling water is introduced into the retort for 30min at the end of the heating cycle.

15. Processed product is stacked and stored.

6.7 The effect of processing on raw materials and nutrients

During the processing of the materials from the raw state to the final product, physical and chemical changes occurred which affected the final characteristics of the product both organoleptically and nutritionally. Such changes and their effect on raw materials and especially the nutrients in the mixture are discussed below.

6.7.1 The effects of processing on raw materials

Preparation. Of the preparation stages, only the blanching operation has any effect on the raw materials. Its main effect is to expel air and other gases from the vegetables which might cause pressure build up in the can. Thus any bitter volatiles are flushed out in this stage. At the same time some cooking is achieved which inactivates enzymes which could cause deterioration of radish and sweet potato during storage, e.g. enzymic browning. Some reduction in bacterial load also occurs in this operation. The heat and moisture also initiates gelatinization of starch in radish and sweet potato at this stage.
Chopping. Little change is expected during chopping apart from mechanical effects. Emulsification does not take place. Materials are merely chopped finely and mixed intimately, due to the design of the bowl chopper. The moisture both from added water and materials is made available to the dry materials, which could be partly hydrated in this stage. Some stickiness occurs due particularly to the binding property of the soluble polysaccharides of seaweed, so that all particles are held together in a fairly firm, stodgy mass.
Heat processing. It is at this stage that the product is cooked to a firm, uniform meat loaf consistency. The compacting of the texture in the product is due mainly to the gelantinization of starch in the mixture. The carbohydrate content is approximately 26% and this is mainly starch from the major constitutents in the mixture - radish, sweet potato, glutinous and brown rice. Gelatinization of this starch requires moisture and an increase in temperature. In this product, gelatinization occurs between 50 and 80C, from individual data recorded for sweet potato and rice starches (140). The moisture from the raw materials and added in the chopping is sufficient to swell the starch micelles during heating, so that the viscosity of the mix increases and eventually a gel-like starch continuum is formed. Heating also causes dispersion of the fats in the raw materials throughout the mixture and solubilises the polysaccharides in the seaweed adding to the overall binding of the cooked mixture.

Such a neutral mixture (pH 6) required a sterilization process at least equivalent to F_o of 2.8min. This is based on the process required for 12D reduction in spores of Cl.botulinum, the reference organism for heat processing calculations. Generally, an F_o value somewhat in excess of 2.8min is used in order to provide a safety margin for operator error and also to reduce levels of thermophilic organisms. In this process, F_o of 5min was chosen to evaluate the effect of heat treatment on the product by different processes. In commercial practice, a higher F_o may be required (141).

With this product, heating is by conduction only resulting in a long process time. The process time should be limited, since exposure to high temperatures for long periods results in appreciable reduction in nutritional value. Two processes were evaluated: conventional retorting after filling at 121C (2.02bars) for 60min followed by water cooling; and presteaming the product in cans for 20min prior to seaming and retorting at 121C for 50min, followed by water cooling. Retorts generally run at a maximum temperature of 121C and this temperature was therefore chosen to give the shortest processing time possible. The extent of heat processing was estimated by the traditional method, following the increase in temperature in the product in the centre of the can.

Figure 6.11 indicates the heat penetration curves for these packs alongside a plot of the death rate constant (k) for Cl.botulinum against temperature (142). Interpolation from these graphs gave plots of k against time for each process. From the areas under these curves, the extent of destruction of Cl.botulinum in the cans was evaluated. This was related to the standard 12D reduction equivalent to 2.8min at 121C. The cold fill pack had processing equivalent to F_o of 5.3, while the presteamed pack had slightly more severe conditions equivalent to F_o of 5.9. There was a slower come-up rate for the presteamed product over the range 80-115C, due in part to the difference in equilibration of the larger retort used, but mostly to the higher density of this pack caused by gelatinization of starch prior to retorting. In the cold fill pack, gelatinization occurred during retorting so that in the initial stages of heating, heat transferred to the centre of the pack through a less dense medium. There was not much difference between the degree of sterilization of these packs, but the hot fill process had the advantages of: exhausting air from the cans and so producing higher vacuum in the processed cans; flushing undesirable volatiles out of the mixture, making more moisture available for hydration and gelatinization; and exposing the product to the high retort temperature for a shorter time with expected reduction in heat damage to nutrients.

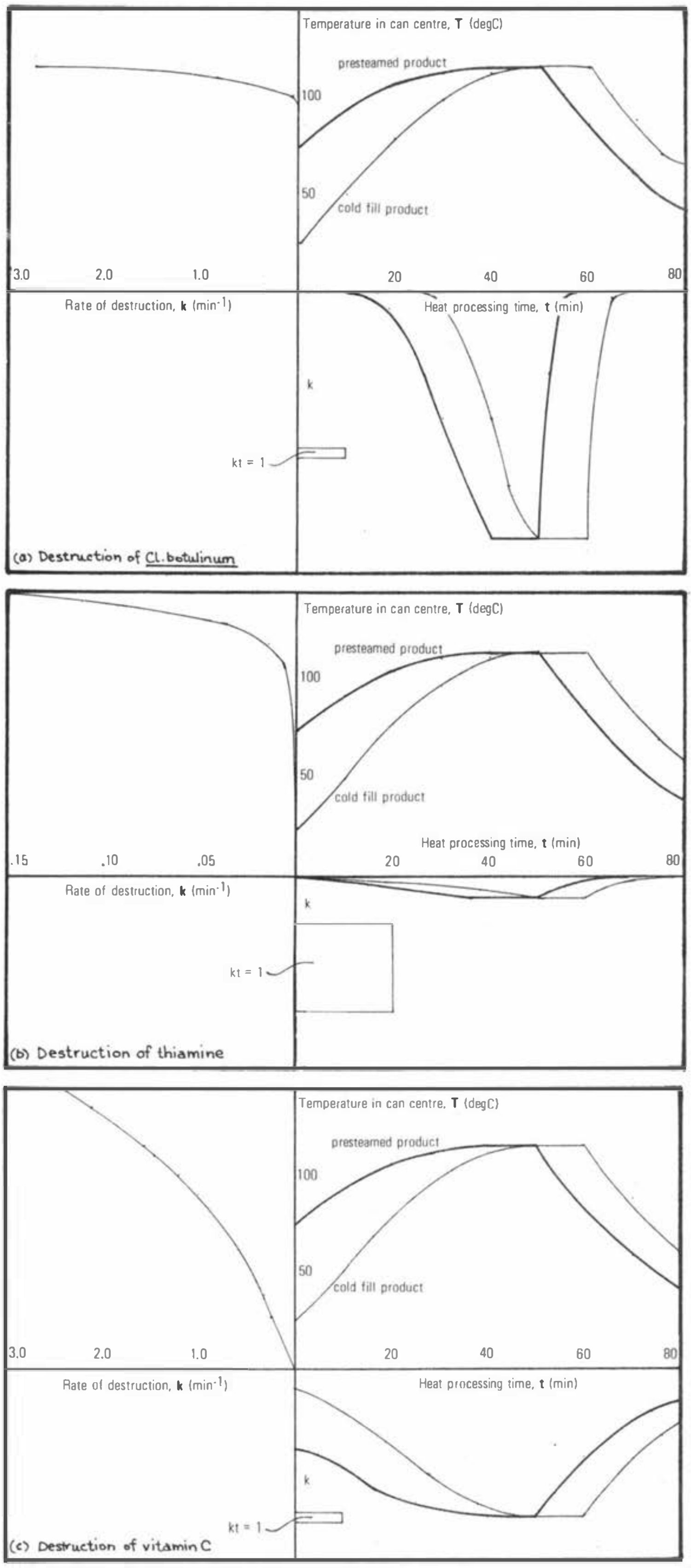


Figure 6.11 Heat penetration curves for two sterilization processes for the meat-mix loaf product with estimation of the extent of destruction of (a) *Cl. botulinum*, (b) thiamine and (c) ascorbic acid in these processes

6.7.2 The effect of processing on nutrients

Preparation. Only in the trimming, washing and blanching stages of radish and sweet potato preparation is any loss of nutrients expected. Since nutritional composition has been based on the 'edible' portion of raw materials, the effect of trimming on removing nutrients in or near the skin of the vegetables, is not applicable here, save to say that minimum trimming should be carried out. The washing step is important only for losses of water-soluble nutrients, when chopped materials are immersed in water after blanching (143). The rapid washing with high pressure water spray is not expected to leach vitamins appreciably in this process. The blanching stage, has been closely looked at in vegetable processing for leaching of water soluble vitamins. Generally, high temperature - short time blanches using live steam rather than water and cooling by cold air rather than running water provide maximum nutrient retention. Losses in thiamine, riboflavin, niacin and ascorbic acid range from 0-12% in a steam blanching process compared to a water blanching process with 5-36% loss (144). In this process, losses of these nutrients from radish and sweet potato are expected. Of other nutrients, some losses of pantothenic acid and vitamin B6 are also likely to occur but folic acid, supplied mainly by radish, is likely to be retained (144).

Chopping. The purely mechanical nature of this operation, with no external heating has no effect on the nutrients in the mixture.

Heat processing. The effect of heat processing on nutrient content is not well documented except for water soluble vitamins. In general, minerals, essential amino acids, niacin, riboflavin and pantothenic acid are stable during heat processing and storage of foods (85% retention) (145). Greatest losses are due to degradation of ascorbic acid and thiamine. In vegetables, losses of ascorbic acid of around 50-80% (145) and 25% (144) have been indicated. For thiamine, generally 20% loss is taken as average depending on process conditions, rising to 60-80% loss in slow conduction packs (144). Niacin and riboflavin are generally stable, losses of around 10% being expected (145). Vitamin A is generally stable to heat processing (146). Vitamin B6 losses of 43% and 63% and pantothenic acid losses of 26% and 46% are reported for processed meats and processed root vegetables respectively (147). Vitamin B12 appears to be stable in meat processing (145), while some losses in folic acid are expected although not characterised for this type of process (145,146).

Minerals are not affected by heat processing. The effects on protein and amino-acids are complex. Total amino-acid content may be unchanged after processing but the nutritive value of the protein is reduced as amino-acids are rendered unavailable by formation of complexes. Cooking of meats at 100C does not alter biological value, but autoclaving reduces the biological value to some extent(146); similarly for oilseed meals or nut meals. In this product, some loss of lysine and methionine due to Maillard browning is expected since reducing sugars are present in the sweet potato. Also, with the high level of carbohydrate present, some complexing of other amino acids with carbohydrate may occur, reducing their availability. Little effect on nutritional value has been reported after processing an oat dough for the same time as this product (143).

Since the effect of processing on nutrient levels has been expressed only in a percent retention form, for normally one set of time-temperature conditions, it is difficult to evaluate the extent of nutrient reduction for nutrients from one set of conditions to another, let alone from one product type to another. Data was available only on the rates of destruction of thiamine (148) and ascorbic acid (149,150) for different temperature and product conditions. With this information and using an analagous method to that used in estimating the degree of sterilization, it was possible to estimate the degree of destruction of thiamine and ascorbic acid in the centre of the product (151) (see Appendix 17 for calculations). For thiamine, destruction was around 33% and for ascorbiv acid, total destruction was indicated (Fig.6.11). There were slight differences in the extent of destruction for the two processing methods investigated, the hot fill process being slightly more severe, but this was hardly significant. For thiamine, destruction nearer the walls of the can would be much higher than at the centre so that total destruction would be much higher than indicated; total integration of time/temperature throughout the can would be necessary to evaluate this fully. Nevertheless this system was useful to indicate the relative effects of different processes on nutrient content, in process design.

Summarising, the heat process is expected to cause greatest destruction of ascorbic acid, thiamine, vitamin B6 and pantothenic acid. Protein quality may not be appreciably lowered, although reduction in availability of some amino-acids is expected. These deductions are taken from data on materials similar to those in this product. Heat processes in these cases were quite different from that used and conditions were also quite different, due to the unconventional mix used here. Only full analysis of this product before and after processing, can evaluate the effect of process on nutrient content. This is outside the scope of this work, at this stage.

6.8 Summary

A product similar in form to canned meat loaf was developed from the raw material mixture selected by linear programming. It was found that an acceptable product of this type could be processed using simple chopping and mixing operations followed by standard heat processing. Flavour and texture variations of the product, through inclusion of additives and adjustment of process variables were investigated. A satisfactory process for the product was established. The final product was judged highly acceptable by a small Asian taste panel.

Several comments should be made.

1. The bulk of the product was excessive. With the addition of 5% water and flavourings to a level of 10.6% based on 1000g batch, for the full requirements of raw material mix (1140g), the total intake would require to be 1320g. This could be packed in 3 cans containing 440g each of the processed mixture. It could be difficult to incorporate such bulky material into normal diets at these levels. It may then be necessary to consider the next most complex process of predrying some of the materials, radish and sweet potato, in order to reduce the bulk.
2. The product was versatile in how it could be prepared for meals by normal Philippine cooking methods. It could be sliced and fried, sliced and steamed, made into shapes (balls, rolls) and steamed, extruded into casings to provide a type of sausage. This could aid its use as a nutritional product in welfare feeding to reduce monotony and increase acceptability of the product. Such variety could compensate for the bulk of the material.
3. The heat processing given the material, reduced some of the nutrient levels in the product.This important aspect of nutrient loss due to processing was not considered in this product design, since the objective

was to indicate that nutritionally selected raw materials could successfully be combined into acceptable food form. However, for a practical nutritional formulation, consideration of nutritional loss due to processing must be given.

CHAPTER 7

USE OF THE LINEAR PROGRAMMING MODEL TO DESIGN A FOOD SUPPLEMENT

A model was developed to select a mixture of Philippine food raw materials for a general nutritional food product, which provided the full daily requirements of the population at minimum cost. No restriction was placed on the amount of each raw material available, in order that the best nutritional mixture of indigenous materials was identified. In the real situation, consideration must be given to the availability of raw materials from agricultural and fishery production, as this would affect the practicality of mixtures.

Consideration of the effect of raw material availability in the model, indicated the limitations of the present food supply and it appeared that in the short term, enrichment of the food supply would be necessary to achieve balanced nutrition. Of the possible enrichment methods described, the supplementation of the daily rice intake with processed, nutritional food products seemed most practical. The development of such a product was undertaken.

7.1 Consideration of raw material availability in the model

The raw materials were selected from items listed in agricultural and fishery production statistics. In the early stages of data collection, this data was obtained for the year 1968. At a later stage, more well-defined production and cost data for 1970 became available from the Philippines (152). At the same time, the 1970 population census data was published (153) which allowed updating of the nutritional requirements based on population age-distribution, which had previously been calculated on population estimates for 1968. The model was updated, at this point, to describe 1970 conditions.

7.1.1 Calculation of raw material availability

Information was obtained on the production of the raw materials in the harvested form. This data had to be corrected to the edible portion, then the per caput daily availability was determined. The weight units were corrected to 100g units to be compatible with units used in the model. For some of the raw materials, direct production statistics were not available. Their production was estimated from statistics of related materials. The majority (49) were estimated for meat offals - bas on their proportion of the carcass weight; twenty-five estimations were made to apportion food group production levels among the individual materials in each group; the amount of goats milk was derived from the number of goats; the sweet potato leaves amount from the production of sweet potatoes; and the amount of sugar cane juice from the production of sugar cane. Appendix 14 gives full details of this production data.

Some of the raw materials were produced in very small amounts and were removed from the model. Nineteen raw materials were deleted since their production levels were found to be too small for recording in FAO or Philippine statistics i.e. production was less than 500,000kg. Since sheepmeat was produced at low levels all its offal products were similarly insignificant (7 of the 19). The other materials deleted were: fish species - glassfish, goby, mullet, pomfret, shark, spadefish, threadfin and whiting; legumes - chickpea, pigeon pea and cottonseed; and horse meat.

A level of production was decided on to distinguish those foods with significant availability amounts which could be handled by the computer code. The significant production amount was limited by the smallest numerical value which could be output in the solution reports of the linear programming model developed. Values less than 0.001 units (equivalent to 0.1g since 1 unit represents 100g) in the model would be recorded as zero. The units could have been scaled to smaller units but this would have resulted in many problems in the scaling of nutrient units in the model. This level of 0.001 was then the most practical level to use in the problem and probably the smallest significant unit which could be considered for the weight of any component in a food mixture. This represented a total food content availability of 1,336,000kg per year. Fifty-seven raw materials with availability below this level were removed.

Three other raw materials were removed at this stage. Grapefruit and lime were removed since their production levels were duplicated by pummelo and lemon (the Philippine grapefruit and lemon, kalamansi respectively). Raw sugar was removed since it strictly was processed. Its production was considered in sugar cane juice data.

With these considerations, the number of raw materials in the model was reduced to 94.

7.1.2 Revising problem conditions in the model

Raw material constraints. The per caput daily availability amounts in 100g units were input as upper bound constraints on the activity level of each raw material. These were expressed to four decimal places, the last one being rounded off in the reports from the computer system. Table 7.1 lists these availability constraints.

Cost data. The costs of the food raw materials were updated as more accurate and representative costs had become available. For this section of the project, costs were expressed in Philippine pesos (P) as all costs were available from Philippine sources in the national currency. Such costs were for the raw material on an 'as purchased' basis, so they were corrected to correspond to 100g edible portion for each raw material. Table 7.1 lists the revised cost data.

Nutritional data. Data on folic acid content of several Philippine raw materials and amino-acid composition of meat raw materials had been received from the FNRC in Manila (82,83). The data files of these raw materials were updated at this stage.

Nutritional constraints. The constraints on the nutrients which were directly defined were updated at this stage. The average daily requirements for calories, protein, calcium, vitamin A, vitamin C, vitamin B6, vitamin B12, and folic acid were recalculated using the population age distribution data from the 1970 Philippine population census which had become available (153). Table 7.2 indicates that the revised nutritional constraints were very similar to those calculated earlier from the estimated population age distribution for 1968.

Table 7.1 Production and revised cost levels of raw materials with significant availability

	Upper bound on availability (100g unit)	Production less exports bounds (100g unit)	Cost per 100g (pesos)	Cost per 100g edible portion (pesos)
anchovy	.0110		.182	.243
atis (fruit)	.0013		.079	.158
avocado	.0095		.048	.069
banana (bungulan)	.0360	.0317	.073	.109
banana (gloria)	.0083	.0073	.073	.118
beef	.0131		.428	.428
big-eyed scad (fish)	.0101		.207	.414
blood (beef)	.0015		.115	.115
blood (pig)	.0095		.090	.090
bonito	.0076		.195	.310
buffalo	.0024		.424	.424
cabbage	.0279		.074	.090
caesio (fish)	.0061		.217	.443
cashew (fruit)	.0043		.058	.064
cassava	.2517		.031	.041
cavalla (fish)	.0034		.367	1.112
chicken (young)	.0115		.350	.574
chico (fruit)	.0038		.128	.152
coconut, mature	2.1178	.6676	.018	.032
coconut, young	.0119		.023	.164
cowpea	.0060		.175	.175
crab	.0018		.299	.712
crevalle (fish)	.0018		.210	.375
croaker (fish)	.0064		.214	.486
eggs (duck)	.0041		.029	.033
eggplant	.0467		.047	.052
eggs (hen)	.0428		.032	.037
garlic	.0064		.346	.398
ginger	.0025		.073	.099
groundnut	.0067		.092	.180
goatmeat	.0016		.380	.380
grouper (fish)	.0035		.463	.945
hairtail	.0054		.201	.365
herring	.0014		.194	.323
jackfruit	.0175		.083	.244
kaimito (fruit)	.0067		.072	.136
banana (lakatan)	.0370	.0326	.073	.106
lanzones (fruit)	.0114		.117	.172
intestine, large (pig)	.0019		.290	.290
banana (latundan)	.1371	.1208	.073	.100
lemon	.0027		.092	.242
liver (pig	.0037		.466	.466
lizardfish	.0080		.112	.249
lungs (pig)	.0017		.100	.100
mango	.0818		.094	.131
milk (buffalo)	.0135		.128	.128
milk (cow)	.0127		.118	.118
milkfish	.0491		.321	.472
milk (goat)	.0049		.154	.154
moonfish	.0010		.235	.490
mungbean, green	.0060		.164	.164
mungbean, red	.0060		.164	.164
nemipterid (fish)	.0134		.290	.644
onion	.0212		.108	.117
orange	.0175		.072	.100
papaya	.0281		.047	.076
cabbage, chinese (petsay)	.0105		.053	.065
pineapple	.1014	.0594	.047	.081
pork	.1558		.380	.380
potatoes	.0128		.067	.079
pummelo (fruit)	.0121		.031	.055
radish	.0034		.054	.079
rice, polished	2.0161	2.0157	.067	.067
rice, brown	.7837	.7835	.062	.062
rice, glutinous	.0412	.0411	.062	.062
kidney bean, red	.0015		.175	.175
round scad (fish)	.1017		.160	.390
banana (saba)	.2027	.1785	.073	.128
sardine	.0271		.188	.362
short-bodied mackerel	.0108		.286	.461
shrimp	.0145		.488	.775
slipmouth (fish)	.0207		.274	.721
intestine, small (pig)	.0029		.100	.100
shrimp, small	.0160		.488	.488
snapbean	.0015		.175	.175
snapper	.0033		.288	.655
soursop	.0046		.042	.060
sweet potato leaves	.0755		.048	.048
spanish mackerel	.0013		.337	.674
yam, spiny	.0054		.041	.050
squid	.0088		.274	.282
stomach (pig)	.0012		.175	.175
striped mackerel	.0108		.286	.461
sugar cane juice	2.3960	.8920	.012	.012
surgeonfish	.0019		.265	.640
sweet potato	.1783		.030	.034
sweet potato, white	.2967		.030	.036
taro	.0556		.035	.043
tomato	.0764		.077	.081
watermelon	.0348		.081	.131
corn, white	.7518		.049	.049
kidney bean, white	.0015		.175	.175
yam	.0157		.040	.046
corn, yellow	.7518		.043	.043

Table 7.2 Comparison of 1970 and 1968 average nutrient requirements

Nutrient	1968 [a]	1970 [b]
calories (kcal)	2030	2040
protein (g)	49.4	50.4
calcium (mg)	454	450
vitamin A (iu)	3900	4000
vitamin C (mg)	29	29
vitamin B6 (mg)	1.68	1.72
vitamin B12 (mg)	0.002	0.002
folic acid (mg)	0.18	0.185

a. Based on population distribution data estimated fro 1968 from UN Demographic Yearbook 1970 (86).

b. Based on population distribution data from 1970 census in 'National Summary Philippines 1970 Census of Population and Housing', Bureau of Census and Statistics, Manila, 1972.

7.1.3 The nutritional adequacy of the available food raw materials

With the raw material activity restrictions in the model, it was not possible to obtain a feasible solution. Many sources of infeasibility were evident in nutritional bounds as well as raw material availability bounds. It was not possible to obtain adequate or balanced nutrition from the available raw materials.

The nutritional value of the available food raw materials was estimated in order to identify the nutritional deficiencies causing the conflict. The linear programming system was used for this purpose by maximizing the total weight in the model with all nutrient constraints removed and raw materials constrained at their production availability levels. Several of the food raw materials were exported in large amounts, so a similar estimation was made to evaluate the effect of exports on nutrient availability.

With total production, many nutrient deficiencies were evident: seven of the sixteen non amino-acid nutrients were deficient and three of the ten amino acids had chemical score ratings below 70 (Table 7.3).

Table 7.3 **Availability of nutrients from raw materials in the Philippines of (a) total production and (b) total production less exports**

	Requirement per caput per day	Total production availability, per caput per day		Production less exports availability per caput per day	
calories (kcal)	2040	2330	(114)[h]	1820	(89)
protein (g)	50.4	49.9	(99)	44.0	(87)
fat (g)	45.4[a]	70.4	(155)	32.3	(71)
fibre (g)	6.0	15.7	(262)	8.9	(148)
calcium (mg)	450	255	(57)	194	(43)
phosphorus (mg)	450 [b]	1002	(223)	848	(188)
iron (mg)	20.4[c]	12.1	(59)	9.7	(48)
vitamin A (iu)	4000	1700	(42)	1650	(42)
thiamine (mg)	1.02[d]	1.24	(122)	1.17	(115)
riboflavin (mg)	1.02[d]	0.70	(69)	0.64	(63)
niacin (mg)	13.4 [e]	17.8	(133)	17.0	(128)
vitamin C (mg)	29	83	(286)	75	(260)
vitamin B6 (mg)	1.72	1.84	(107)	1.75	(102)
vitamin B12 (mg)	0.002	0.002	(100)	0.002	(100)
pantothenic acid (mg)	5.0 [f]	4.5	(90)	4.2	(84)
folic acid (mg)	0.185	0.153	(83)	0.149	(81)
isoleucine (mg)	3330 [g]	2350	(71)[i]	2080	(72)
leucine (mg)	4440	3940	(90)	3490	(90)
lysine (mg)	3230	2950	(92)	2620	(93)
methionine (mg)	1560	1420	(92)	1280	(94)
cystine (mg)	1210	370	(31)[j]	360	(34)[j]
phenylalanine (mg)	2920	1950	(67)	1770	(69)
tyrosine (mg)	2120	990	(47)	930	(50)
threonine (mg)	2570	2050	(81)	1860	(83)
tryptophan (mg)	810	410	(51)	370	(53)
valine (mg)	3680	2860	(79)	2530	(79)
cost (P)		0.74		0.66	
weight (g)		1138		833	

a. Minimum of 20% calories as fat.

b. Minimum of 100% calcium level.

c. Minimum of 1mg per 100kcal energy.

d. Minimum of 0.5mg per 1000kcal energy.

e. Minimum of 6.6mg per 1000kcal energy.

f. Minimum at 5mg, satisfactory level for U S diets.

g. Minima of amino-acids at levels corresponding to 50.4g of egg protein.

h. Bracketed figures indicate that percent of minimum requirement which is available.

i. Bracketed figures for amino-acids indicate the percent of the corresponding amino-acid in egg protein; the chemical score being given by the amino acid with minimum percentage (j).

With such deficiencies, it was not surprising that feasibility could not be attained. The most serious deficiencies were for vitamin A, calcium, iron and riboflavin which corresponded to the situation found in nationwide nutrition surveys (25).

Exports had very little effect on these deficient nutrients: their major effect was to render calories and fat deficient. The reduced fat level, halved due to exports, was attributed to exports of coconut products. The extent of coconut exports perhaps should be revised in order to prevent such deficiencies.

With such nutrient availability, it would not be possible to achieve balanced nutrition, let alone adequate nutrition.

7.2 Methods of improving the nutritional value of the available food supply

Several methods can be suggested to improve the nutritional value of the available food supply. For example:

1. Increase in agricultural and fishery production through use of high yielding crop species and expansion of fish farming systems.
2. Importation of nutritious food raw materials e.g. dairy products, meat products, soy flour.
3. Development of edible oil-seed processing industries e.g. coconut flour, cottonseed flour.
4. Enrichment of the food supply with chemical nutrients e.g. vitamin, mineral and amino-acid compounds.

Methods most suitable for this purpose should be (i) capable of rapid implementation (ii) effectively implemented with minimum change in food habits; and economically feasible.

The first two methods describe longer term methods of improvement. To be effective, agricultural economics planning should be used to plan production and imports so that sufficient of suitable species was eventually available for adequate and balanced nutrition. Extensive importing could be rapidly implemented if sufficient overseas funds were available. Economic analysis would be required to evaluate how much nutritional improvement could be afforded in the short term.

Development of the oilseed industry could be an effective method and could be rapidly implemented if sufficient capital was available for process and product development and plant construction. The production of coconut flour from the abundant sources of coconuts in the Philippines appears particularly suitable. Processes have been developed to pilot stage for the production of coconut flour from raw coconut but only a process for obtaining flour from dessicated coconut is in production in the Philippines (154). Tests have shown that this flour can be incorporated into many local foods with good acceptability and also can be used as a base in snack foods. The major disadvantage of the material is that nutritionally only calories, protein, fibre and iron are provided. The product also is expensive. This process does not provide a feasible method of cheap nutrition at this time. Other processes are not yet economically feasible for implementation.

Nutrient enrichment seems the most suitable method. Enrichment may be rapidly implemented provided overseas funds are available to import the compounds, there are no legal restrictions and an effective carrier for the enrichment is available. Such a carrier could be a food product which is commonly eaten, so that food habit problems are minimized. This would require design of a suitable food product to contain the enriching nutrients and represents another product development problem. The major drawback could be in the economics of this method. Currently most chemical nutrient prices are very low with the exception of a few amino-acids and linear programming could be used to design the most economic system of enrichment.

7.2.1 Enrichment with chemical nutrients

This approach has become increasingly widespread since 1900 when iodine was added to table salt to prevent goitre (155). During the war years, enrichment of bread with B-vitamins was introduced in USA and UK (156). In recent years, interest has broadened with the possibility of improving the protein quality of staple foodstuffs of developing countries by enrichment with synthetic amino-acids (157). All such enrichments have been considered only when a nutritional deficiency has been identified and the costs of the chemical nutrients have become low enough to keep the costs of the enriched foods within the reach of the target population.

There have arisen several philosophies of enrichment:

1. Addition of nutrients to foodstuffs to make good losses caused in processing and storage. This is also called restoration and has been a basic philosophy behind the addition of B-vitamins to milled cereals.

2. Addition of nutrients to a carrier food - generally a significant item of the diet - to remove deficiencies identified in the average diet of the population. This is also known as fortification. It has been the basic philospohy behind the addition of B-vitamins, calcium and iron to wheat flour in many countries, the addition of vitamin D to milk and the addition of lysine to cereals in Japan.

3. Addition of nutrients to foods which are interchangeable in the diet or are replacements for traditional foods, called food substitution. The major example of this type would be the enrichment of margarine with vitamin A to levels found in butter, the food it replaces in western diets.

4. Addition of nutrients to render a food nutritionally complete. This is generally for some special purpose e.g. baby food, medicinal food, emergency relief food or nutritional control food where the food is intended as the sole item of the diet. Such foods should be enriched with all the nutrients to requirement levels in each daily serving.

5. Addition of nutrients to render a food nutritionally self-sufficient, called supplementation. This has been considered mainly for foods which are high in calories. Vitamins are added at levels required to metabolise the total energy of the food. In a similar way, the vitamins required for metabolism of protein could be added. By such a method, there should be no deficiency or wastage of nutrients for optimum nutrition. This method has been suggested for enrichment of snack foods, baked sweet goods and confections, which are significant items in the American diet yet provide only 'empty calories' (158).

6. Addition of nutrients to common foods to facilitate selection of food items by the consumer according to nutritional quality. This philosophy provides for nutrients in food products to be in quantities at least to a defined proportion of the daily nutritional requirements. This is the 'nutrification' concept (159) which LaChance suggested for major foods in the diet. The defined proportion can be based on the daily calorie requirements for foods containing greater than 150 calories (155) or on the daily protein requirement for foods providing greater than 7% of calories as protein (159). LaChance suggests that the protein basis would be better since in western diets calories are generally eaten in

excess, so that excess nutrient intake would result. Nutrification would allow the consumer to easily select items to make up the daily nutrient quota.

Since a system is sought to enrich the available food supply, the nutritionally complete food concept is not applicable here. The replacement food approach only indirectly applies because the enriched food may become a major part of the diet and replace other items of the diet. Since it will be nutritionally designed, the replacement aspect need not be directly considered. Fortification of a carrier food provides a suitable basic philosophy for this enrichment situation. The carrier food could be the staple of the diet - rice - or a common meal additive or condiment - fish sauce, soy sauce - or some other popular food eaten daily. The restoration concept would be considered in determining the level of enrichment to take account of losses of nutrients in processing the enriched product. Enriching, to daily nutritional requirement levels and to egg pattern levels for amino acids, fulfils both the criteria of nutritional self-sufficiency and nutrification based on balanced nutrient levels, if enrichment of one food product is considered. If more than one product is required for practical enrichment, then these two aspects need not apply i.e. individual foods need not be nutritionally self-sufficient or balanced, provided the intake of the combined foods is encouraged. Thus the fortification of a carrier food seems the most appropriate basis to consider enrichment, so that the average daily nutritional requirements of the population are met from the food supply.

The recommendations of the American Medical Association, 1968, (158) provide suitable guidelines for fortification with nutrients.

1. The intake of the nutrient(s) should be below the desirable level in the diets of a significant number of people. Evidence of nutritional deficiencies in the food supply of the Philippines has been presented.
2. The food(s) used to supply the nutrient(s) should likely be consumed in quantities that would make a significant contribution to the diet of the population in need. Only food products which are consumed in high amounts regularly in the Philippines, should be considered.
3. The addition of the nutrient(s) should not create an imbalance of essential nutrients. Balanced contribution of nutrients should be

incorporated.

4. The nutrient(s) added should be stable under proper conditions of storage and use. The loss of expensive nutrients should be prevented by optimization of the process to minimize nutrient loss, by design of food with minimum preparation or preferably ready-to-eat and by effective packaging or treatment to prevent storage loss.

5. The nutrient(s) should be physiologically available from the food. Biologically available nutrient compounds should only be used and nutrient inactivation reactions should be prevented where possible. Such availability problems may only be catered for by appropriate over-enrichment with nutrients.

6. There should be reasonable assurance against excessive intake to a level of toxicity. For all commercial nutrients for food use, there has been no experience of toxicity at the levels of normal daily requirements being considered here, although at excessive levels some nutrients may be harmful e.g. vitamin A.

The Protein Advisory Group on amino-acid fortification recommended similar factors (160) but also added:

7. The processing of the food should be relatively centralised and its distribution through normal commercial or other channels should be amenable to control. The food must then be capable of production in existing large domestic processing establishments, or in government-controlled factories.

8. The cost of enrichment should not render the price of the food too expensive for widespread consumption.

Therefore the design of an enrichment system for the Philippine diet should be based on enrichment of foods with high daily consumption, whose processing and distribution are relatively centralised. The average daily nutritional requirements of the population should be met, with retention of nutritional balance, through normal intake of this food. Nutrients should be added at levels to take account of physiological availability and possible losses during processing and storage. Losses due to preparation by the consumer should be limited by designing the product as ready-to-eat or with minimum amount of preparation. The cost of the product should be within the reach of poorer segment of the population.

7.2.2 The medium of enrichment

A suitable carrier food which satisfied the criterion of being eaten daily and universally throughout the country is the staple of the diet, rice. Rice is a major constituent of the daily diet, is eaten in large amounts throughout the country (Table 7.4) by all income groups (Table 7.5). Rice is eaten normally at all three meals but at least once a day in every home (161).Enrichment of the daily rice intake would seem an appropriate system.

Table 7.4 The proportion of rice in the daily diet in 9 regions of the Philippines [a]

Region of nutrition survey		Intake of rice (polished) per caput per day (g)	Percent daily food intake as rice and rice products
Bicol	1957	390	44
Central Luzon	1957	424	49
Metropolitan Manila	1958	213	32
Ilocos– Mountain Province	1960	323	50
Cagayan Valley– Batanes	1961	241	34
Southern Tagalog	1962	273	44
Western Visayas	1964	165	37
Eastern Visayas	1965	84	23
Southwestern Mindanao	1966	225	35
Weighted average		224	σ = 80.7

a. Adapted from data in the individual reports of the regional surveys (113, 114, 115, 116, 117, 118, 119).

Taking the average daily rice intake per person from the FNRC nutrition surveys (224g) rather than that of the recent cereal consumption survey (311g), as a representative level, the question remains of how this can be enriched.

Table 7.5 The daily rice intake of different income groups in the Philippines[a]

		Intake of rice per caput per day (g)				
Survey period	Income group[b]	<P400	P400–799	P800–1499	≥P1500	Mean
Oct–Nov 1970		261	278	288	309	280
May–June 1971		303	303	330	334	311

a. Adapted from C. T. Aragon, L. B. Darrah, Cereal consumption patterns. The Statistical Reporter (1972), 16 (1), 47.

b. It was assumed that incomes referred to monthly earnings, since no indication of time period was specified in the report.

As can be seen from the nutrient supply from 224g of rice (Table 7.6), large deficiencies in calories, protein, fat and fibre exist. Protein could be obtained fron synthetic amino acids assuming 1g of amino acid is equivalent to 1g of protein. However with a requirement for at least a further 34g protein, such addition would be expensive. Calories and fat could be increased by addition of food fats or commercial oils or fats. To make good the calorie deficiency (1200kcal), 135g of fat would be necessary which certainly would cause palatability problems. Fibre could be supplied by cellulosic materials, but would best be provided by natural foodstuffs.

Direct enrichment of rice with the deficient nutrients does not appear feasible. It would seem more logical to consider another food product to accompany the daily rice intake, which would be high in calories and protein and contain the fibre, fat and the balance of other nutrients.

In this section, the development of a product, capable of enriching the rice intake, will be carried out so that a system of adequate and balanced nutrition can be made available in the Philippines. If this objective is not feasible, economically or practically, then a more suitable level of enrichment will be determined and a product designed to meet these specifications.

Table 7.6 Contribution to nutrient requirements of the average daily rice intake in the Philippines

Nutrient	Nutrient content in 224g rice	Percent of minimum requirement from 224g rice
calories (kcal)	824	40
protein (g)	16.6	33
fat (g)	1.1	3
fibre (g)	0.9	15
calcium (mg)	18	4
phosphorus (mg)	242	54
iron (mg)	2.7	13
vitamin A (iu)	0	0
thiamine (mg)	0.22	22
riboflavin (mg)	0.11	11
niacin (mg)	5.38	40
vitamin C (mg)	0	0
vitamin B6 (mg)	0.38	22
vitamin B12 (mg)	0	0
pantothenic acid (mg)	1.23	25
folic acid (mg)	0.022	12
isoleucine (mg)	815	25
leucine (mg)	1165	26
lysine (mg)	880	27
methionine (mg)	585	38
cystine (mg)	101	8
phenylalanine (mg)	506	17
tyrosine (mg)	181	9
threonine (mg)	535	21
tryptophan (mg)	116	14
valine (mg)	986	27

7.3 The selection of a suitable food product as the enrichment medium

The selection of a suitable food product and the development of such a product was carried out in the systematic manner described for the product development approach.

7.3.1 The exploration stage

Expanding the objectives of this part of the investigation indicates the criteria to be considered in the design of a suitable enrichment product.

1. The product should be similar to present popular food products i.e. those of high consumption which are regularly eaten.
2. Enrichment of such a product should be easily implemented into normal processing procedures for that product and should be easily controlled.
3. The processing method selected should be designed for least effect on the nutrients in the product, and should be compatible with existing processing facilities in the Philippines.
4. The organoleptic properties of the product should be acceptable for that type of product.
5. The product should have minimum preparation and have good storage life.
6. The cost of the product should be within the economic reach of the poorer members of the population.

Product ideas. For this type of product development, new product ideas were not proposed, rather existing product types capable of enrichment were sought. The types of processed food products which are commonly eaten throughout the country have already been discussed in Chapter 6 (see Appendix 11 for detailed information). This information suggested suitable product ideas which should satisfy the first criterion above.

Savoury sauces. The popular patis (liquid) or bagoong (paste) are produced from fermented fish and are used with almost all meals. It may be possible to enrich these sauces directly. Other popular savoury sauces used in the same way are tomato and banana ketchups. A similar product could be designed with nutrients added in the formulation. The major drawback would be that nutrients would require to be very concentrated as only small amounts of sauce would be taken with each meal. It is unlikely that the fat and calorie requirement could be met because of this problem.

Drinks. Soft drinks are very popular throughout the country. An enriched soft drink could be taken regularly with meals, as the liquid portion of the meal. The problem again of meeting the fat requirement is posed, but the calories could be contributed to by sugar in this product. Milk-type beverages of the Milo/Ovaltine type are fairly popular because of their health image, but their cost is the factor holding down consumption. This type of product may be more useful than soft drinks to act as the liquid portion of the meal and to carry the enriching nutrients. Fat may be incorporated in the formulation and the product already has a nutritional image which would aid in acceptability. A dried powder which can be mixed with water for serving would be the best form of this type of product. A range of flavours could be offered.

Baked goods. There is very high consumption of bread rolls (e.g. pan de sal), loaf bread (pan americano) and biscuits (particularly crackers) throughout the country. The bread products provide an ideal medium for enrichment with all the required nutrients, with the advantage that much work has already been done in other countries on enriched bread products. Bread products would be more desirable than biscuits as they could be incorporated as a regular meal item, just as they seem to be associated with breakfast in the Philippines. Biscuits would be thought of as mainly a snack food.

Noodles. Noodles are commonly eaten in the Philippines although they are mainly associated with lunch meals or with soups. Different starch materials are used - wheat, rice and mungbean. Pastas like macaroni also are popular. Provided consumption could be increased, this would be a good medium for enrichment. The major drawback is the need for cooking by boiling in water which would cause leaching of water-soluble nutrients.

Dried soups. Particularly in the urban areas these products are very popular due to low cost and convenience - chicken noodle, arroz caldo and mami are most popular, soups all having high cereal content. These could be enriched, and, provided distribution and consumption could be increased, would be a very suitable enrichment product. The drawback again is the required cooking procedure.

Native sausage. This dried, fermented or unfermented product, is popularly eaten with rice at all meal times in the Philippines. This could possibly be enriched.

Canned meats. The meat loaf type (corned beef, beef loaf) and sausages in sauce (pork and beans, vienna sausage) are popular but consumption is low due to cost. Formulated products of this type should be capable of enrichment. Costs must be reduced in order to make such products regular items of the diet.

7.3.2 The screening stage

Since the nature of selection of suitable product ideas has involved some screening of possible ideas according to the first criterion in the objective, this section describes more comprehensive screening used to select those ideas which best satisfied all the objectives.

Screening factors. A more detailed consideration of the objectives suggested the following factors for which each product was assessed.

1. Level of consumption. There should be a high daily intake of this product type. Nutrition survey information supplied data sufficient for this assessment. Factor weight was 5.
2. Frequency of consumption. If possible the product should be eaten with each meal, and regularly throughout the week. Again information was available from nutrition surveys to assess this factor for each product. Factor weight was 5.
3. Ease of enrichment. Existing processes for the product should easily incorporate the enrichment process. Otherwise research and development work will be required to facilitate enrichment. The degree to which each process required development was assessed subjectively. Factor weight was 10.
4. Processing effect on nutrients. The degree of destruction of both added nutrients and raw material nutrients caused by processing was assessed for each product. This affected the amount of chemical nutrients required to be added to account for processing losses and hence the cost of the product. Factor weight was 8.
5. Production capacity. The capacity of existing processes for each product in the Philippines was assessed. The higher this capacity, the

more people could be reached, and the more suitable such a product was for enrichment. Factor weight was 10.

6. Availability of raw material. It has been shown that indigenous raw material is not sufficient for full nutrition, therefore imported raw materials were probably required to a greater or lesser extent for the different products. The degree of reliance on imported raw materials was assessed for each product. Factor weight was 10.

7. Ease of distribution. Some products have much wider distribution than others. The storage life of each product dictates the required speed of distribution. The degree of fit of each product to existing distribution channels was assessed. Products with wide distribution were more desirable. A combination of these had a factor weight of 7.

8. Preparation need. The preparation that each product requires by the consumer cannot be controlled. If this could cause nutrient destruction e.g. boiling then such a product was less suitable than a ready-to-eat product with no preparation e.g.bread. Factor weight was 5.

Each factor weight was assessed according to its importance for fitting product characteristics to problem objectives. Thus, ease of enrichment, production capacity and raw material availability were weighted highly since these were the essential factors required for an effective enrichment system. Processing effect on nutrients and ease of distribution were judged of lesser importance and weighted accordingly, since such conditions could be improved on, if necessary, for any product situation. The other factors bearing on consumption characteristics and on preparation requirement were weighted low since they had already been considered to a certain extent in the selection of suitable product ideas.

Evaluation of products. Using these screening factors with the allotted weights on each product idea, the value of each product idea for the objectives was assessed, using the method of Chapter 6 (see Appendix 15 for full details).

Scores were:

Savoury sauce	514
Soft drink	473
Bread product	422
Biscuit	385
Noodles	373
Dried soup	366
Sausage	357
Milk beverage	332
Canned meat product	275
Maximum score	600

Those products with scores above 400 were selected as most suitable for further consideration viz. savoury sauce, soft drink, bread product.

7.3.3 More comprehensive screening

These product ideas were further evaluated through (i) estimation of their present popularity by conducting a consumer survey in the Philippines and (ii) estimation of the practical and economic feasibility of enriching these products with chemical nutrients.

Consumer survey A survey form was designed to obtain current information on the popularity and usage characteristics of the products being considered. Unfortunately, arrangements which had been made to carry out the survey with a contact in the Philippines were not carried out. Eventually after some months, a modified survey was carried out by a commercial market research company. The survey was not reliable because of the method used to sample the population and also was not very informative because of the modified questionnaire which was poorly designed. Nevertheless some of the information was useful (see Appendix 17 for questionnaire and this information). The survey of 202 households had been carried out using a systematic random sample in one area randomly selected from 10 areas of Quezon City, a city 20 miles from Manila.

Information relevent to evaluation of sauce, soft drink and bread products was derived from the forms. Savoury sauces, soft drinks and bread products were indeed bought by high percentages of the sample as shown in Table 7.7. Patis and soy sauce, both liquid sauces, had the highest popularity amongst sauces. Soft drinks, fruit juices and evaporated milk had highest popularity amongst the different drinks.

Pan de sal (bread rolls) and pan americano (sliced loaf bread) were much more widely bought than cakes and biscuits. The baked goods were less popular than most popular sauces and drinks, This could be due to poorer acceptability, storage properties or purely economic reasons. Information on the frequency and amount of each product purchased was poorly completed on the forms, so no conclusions were made on this factor.

Table 7.7 Selected information from consumer survey conducted in Quezon City, Philippines

Food product		Percent of respondents buying this product
Sauces	patis	92
	bagoong	66
	soy	85
	tomato catsup	81
	banana catsup	51
Drinks	soft drinks	93
	fruit juices	70
	evaporated milk	88
	condensed milk	48
	dried milk	45
	Milo	35
	Ovaltine	42
Baked goods	pan de sal	71
	pan americano	71
	rolls (other than pan de sal)	27
	rice cake	29
	chocolate cake	33
	crackers	16
	biscuits (assorted)	15

Eighty-five percent of respondents stated that nutritional quality in food was important to them; whilst 8% said it was important 'sometimes'. This may have been a leading question as asked but it indicated a high recognition of nutrition as a major characteristic of food products. Respondents indicated that they would prefer bread products to be made more nutritious in preference to drinks and sauces. The difference in this rating was significant at the 5% level.

The meagre information obtained on respondent socio-economic characteristics, indicated that the average household size was 7.4 persons (σ = 3.3), with an average of 2.9 children per household (σ = 2.3). There was therefore a high percentage of adults in households sampled. The income information was only obtained in 45% of forms with a range between P100 - P4,200 per month, so mean information was not calculated. Better data was obtained for monthly expenditure on food which showed an average of P423.6 (σ = 250.2). This variable data is better displayed in a frequency table (Table 7.8).

Table 7.8 Food expenditure of respondents in consumer survey

Monthly food expenditure per household (P)	Percent of respondents
< 200	16.2
200 - 400	42
401 - 600	26
601 - 1000	10.5
⩾ 1001	5.2

Over half the households had food expenditure less than P400/month. Taking the average household size of 7.4 persons represented a maximum of P2/caput/day for over half the sample. The enriched food product with the rice intake should not exceed this figure. This was much higher than the level of P0.51 calculated from nutrition surveys. It should be remembered that this survey was conducted in an urban area of a large city where incomes and standard of living on the average would be greater than those of rural areas where most of the population at nutritional risk, exist. Such a maximum cost would probably far exceed the food expenditure of rural people.

From this survey, it appeared that bread products were more acceptable in an enriched form than the familiar fish sauce or soft drink which probably were not considered as nutritious foods by the people. Pan de sal had the highest consumption among bread products, so a bread product of the small roll, bun type was most suitable.

Feasibility of enrichment. The cost and feasibility of enrichment of each of these products to the average daily requirement for each nutrient was evaluated using the linear programming technique.

Data on nutritional composition and cost of pan de sal, patis and carbonated soft drink were used to represent the present product formulations which should be enriched. Upper limits on the maximum intake of each of these products were estimated and used as constraints to ensure that practical solutions were obtained. Table 7.9 shows the data for this evaluation. The least-cost formulations were estimated for enriching with chemical nutrient and fat each of pan de sal, patis and soft drink up to the maximum intake levels of 200, 60 and 600g respectively. (see Appendix 8 for chemical nutrient and fat data used)

It was only possible to enrich pan de sal to the required nutrient levels whilst retaining the amino-acid balance. Soft drink and patis gave infeasible solutions due to problems in satisfying amino-acid balance constraints.

In terms then of nutritional requirements, only pan de sal provided a feasible basis for enrichment. The cost of the enrichment system was very high at P2.59, representing P0.77 for rice (224g), pan de sal (183g) and pork fat (70g) and P1.81 for enriching nutrients of which P1.80 was for amino acids. This cost required to be reduced for the product to be economically attractive. The high requirement for the amino-acids could be reduced by considering good protein sources in the dough formulation such as soy flour or by reducing the high level of protein quality (equivalent to chemical score of 100 at this stage).

On the practical side, only the bread product was capable of carrying the high level of nutrients and fat into the diet. There is a maximum level to which insolubles can be added to soft drinks without changing the product's characteristics. For high protein powders, up to 5% can usually be incorporated with stabilisers before the product becomes viscous and syrupy or gritty. It was feasible to incorporate

Table 7.9 Data used for evaluation of enrichment feasibility

Nutrient	Composition of food products (per 100g)		
	patis [a]	soft drink [b]	pan de sal [a]
calories (kcal)	49	30	320
protein (g)	10.6	0	10.1
fat (g)	0.3	0	4.5
fibre (g)	-	0	-
calcium (mg)	42	2	24
phosphorus (mg)	32	1	75
iron (mg)	9.3	0	3.0
vitamin A (iu)	170[b]	0	0
thiamine (mg)	0.005	0	0.22
riboflavin (mg)	0.08	0	0.15
niacin (mg)	4.1	0	3.0
vitamin C (mg)	0	0	0
vitamin B6 (mg)	0.0442[c]	0	0.04[g]
vitamin B12 (mg)	0.0062	0	0
pantothenic acid (mg)	1.0	0	0.52[g]
folic acid (mg)	0.0088[d]	0	0.03[g]
isoleucine (mg)	374[b]	0	389[b]
leucine (mg)	460[b]	0	690[b]
lysine (mg)	2000[b]	0	212[b]
methionine (mg)	389[b]	0	127[b]
cystine (mg)	-	0	195[b]
phenylalanine (mg)	239[b]	0	478[b]
tyrosine (mg)	-	0	389[b]
threonine (mg)	908[b]	0	283[b]
tryptophan (mg)	50[b]	0	119[b]
valine (mg)	578[b]	0	460[b]
cost (P)	0.33[e]	0.08[f]	0.20[h]
upper limit	60g[i]	600g[j]	200g[k]
cost of enrichment to daily nutrient requirement	infeasible	infeasible	P2.585

a. Data from Food composition tables recommended for use in the Philippines, (80).

b. Data from Food composition tables recommended for use in East Asia, FAO, Rome, 1972.

c. Data for anchovy in source (a)

d. Data for bagoong from Lontoc (81)

e. Taken as PO.75 per 8oz bottle.

f. Taken as PO.15 per 7oz bottle.

g. Taken from undergraduate research report, M. Wee, Food Technology Department, Massey University, 1973.

h. Taken as P1.20 for 20 units (30g units)

i. Taken as 5 tablespoonsful (12g) per day.

j. Taken as 3, 7oz bottles per day.

k. Taken as 6, 30g rolls per day (rounded up) high fat levels into such a product. For patis, the major drawback was the relatively small amount of sauce taken during the day. It is merely used as a condiment in cooking and with meals. The estimate of 60g (equivalent to 5 tablespoonsful) was a generous maximum. It was likely that nutrients apart from fat and calcium carbonate could be incorporated into such a sauce without too much change in characteristics. The level of intake required substantial increase to move high levels of fat and insoluble nutrients into the diet through this source. The other defect was that the majority of the production units for these fish sauces were small home factories, so that intervention in traditional processing for enrichment could be very difficult. The fish paste type sauce - bagoong was more amenable to enrichment since it was a semi-solid viscous paste, but again the home was the major source of production.

A bread product was the most practical method of enrichment. It was a bulky and solid product to which nutrients, soluble and insoluble could be added without appearance problems. Much work has already been done on enrichment of breads, particularly with minerals and vitamins and more recently high protein flours (162). The product, in roll form, would allow easy control of intake, as well as design of effective enrichment formulation. The other advantage was that bakeries in the Philippines already had experience of handling enriched bakery products, so that introduction of the process should cause few problems (30).

Summing up then, an enriched bread product similar in form to pan de sal was the most suitable medium for enrichment based on information on popularity of processed foods from a survey carried out in the Philippines, capability of meeting enrichment specifications and practical feasibility of the development of an enrichment process. The high nutrient specifications could require to be relaxed somewhat to enable an economically feasible product to be developed.

7.4 The development of the enrichment product

The development of the enriched bread was undertaken in five stages :

1. Technical information search on enriched bread doughs
2. Laboratory development of dough formulation
3. Computer selection of enrichment formulation

4. Acceptability of the enriched product to Filipinos
5. Process description

7.4.1 Technical information search

It was found that most work had been concerned with increasing protein levels in breads with materials such as soy flour, dried inactivated yeast, wheat germ, skim milk powder and synthetic lysine. Such information was relevant since in the formulation sought, a high protein content would relieve the requirement for high levels of costly synthetic amino-acids.

It appeared that soy fortification together with skim milk powder could be most practicable in terms of possible increase in nutritive value and cost. The drawbacks of high levels of soy flour (> 10%) have been the poor loaf volume, crumb, grain and freshness retention characteristics of bread quality. Levels of soy flour up to 5% however are widely used as bread improvers. Improvement of these quality defects seemed to require addition of sugar-fatty acid esters. An optimum process for 12% soy fortification required addition of 0.5% SSL (sodium stearoyl lactylate) (163). Sucrose tallowate (2.5%) and SSL (2%) were required to produce bread of high consumer acceptability with 16% soy fortification (164). For breads with 12-28% soy fortification, improved quality was possible with up to 24% soy fortification with the addition of 0.5% SSL (165). Full fat soy flour gave better results than the defatted variety. To incorporate oilseed flours at 25% fortification, it was necessary to change formulations of doughs and dough mixing times for acceptable loaf volume (166). Skim milk powder has been added up to levels as high as 25% (flour) for protein enrichment (167), but generally due to decreased loaf volume at high levels, 5% is the usual level incorporated (168).

Enrichment with vitamins and minerals has been successfully introduced in many countries, particularly for wheat flour (169). At the low levels required, no changes in organoleptic or processing characteristics of the flour have been found. Thiamine, riboflavin, niacin, iron, calcium, vitamins D, B6, E and vitamin A in a dry beadlet form have all been considered for wheat flour enrichment (170). Other vitamins and minerals have successfully been incorporated into the AID cereal mixture CSM (corn-soy-milk mixture) (171).

The organoleptic effects of addition of lysine to bread formulations have been considered (172). The taste threshold was found to be around 0.5% addition of lysine hydrochloride (based on flour weight). Above this level saltiness, bitterness and an after-taste developed. Crust browning increased with increase in lysine levels. This effect could be reduced by using lower temperatures (173). Methionine was reported to cause off odours with high temperature processes, particularly sterilization (174).

Turning to losses of nutrients caused by the heat effect of the baking process, little comprehensive information was found. Most work had been done on B-vitamin loss. For example, 15-20% losses of thiamine in the manufacture of European white breads (175,176); 25% loss of thiamine, 10-20% loss of riboflavin, and virtually no effect on niacin in Arabic breads baked under simulated primitive conditions (197) have all been reported. Vitamin C was essentially destroyed during baking (178). For the amino acids, only lysine has been studied to any extent. The loss during baking has been stated at around 10-15% (179). Investigations of the losses in eleven amino acids during the baking process showed the greatest losses occurred in the crust (180). Estimates of losses for essential amino-acids were - isoleucine 10%, leucine 5%, lysine 15%, methionine 15%, cystine 15%, phenylalanine 10%, tyrosine 15%, threonine 5%, tryptophan 10% and valine 5%. These losses were used in the design for the enrichment system. For the vitamins, the most suitable estimations of losses from the data collected were - thiamine 20%, riboflavin 20%, vitamin C 100%, vitamin B6 10% (145). In the absence of baking process information, losses of the other vitamins were estimated from data on average cooking losses - vitamin B12 5%, pantothenic acid 10%, folic acid 20%, vitamin A 10%. Minerals were assumed unaffected by the baking process.

In summary, a suitable bread dough formulation should be possible with substitution of soy flour up to 25% of wheat flour and incorporation of 5% skim milk powder, with modificiation of the process to obtain satisfactory quality characteristics. Additions of vitamins, minerals and amino-acids at low levels should not cause any problems. Consideration of nutrient losses during the baking process should be given in the formulation design both for nutrients in raw materials and also the added chemical nutrients.

7.4.2 Laboratory development of dough formulation

Using data provided by Marnett et al (163) as a starting point the development of a bread dough was conducted in stages:

1. Incorporation of a high level of soyflour in the dough
2. Incorporation of other raw materials - gluten, skim milk powder, fat
3. Production of product under factory conditions

Soyflour incorporation. Marnett's formulation was modified for a preliminary investigation of the effects of increasing soyflour on bread quality. Full-fat soyflour was used at this stage because it was cheaper than defatted soyflour and it also contributed fat to the mixture. The basic formulation consisted of:

100g wheat/soyflour mix
67g water
4.5g sugar
2.75g yeast
2.25g salt
2.0g lard (pork fat)
0.5g glyceryl monostearate (GMS) (emulsifying agent)
2.0mg bromate (oxidant)

Varying levels of soyflour were used in experiments by replacing a proportion of the wheat flour content with soyflour. The procedure followed the 100% sponge method, viz.

1. All ingredients, except salt and sugar, were mixed in a Kenwood Bowl Mixer for 3min using a dough hook, at No. 8 speed setting.
2. The dough was fermented for 1h at 28C (83F).
3. Salt and sugar were mixed in at the end of fermentation, at No.8 setting for a mixing time of 2min.
4. The dough was panned into greased trays and allowed to ferment for a further 30min at 32C (90F).
5. Bread was baked at 204C (400F) for 15min.

It was observed during the trials that the dough was very weak, sticky and lacked the pliability and sheen of a normal flour dough. The water absorption was also found to be higher than in normal doughs. A shorter mixing time was necessary as the dough became more sticky after more than 3min mixing at No.8 speed. Results of bread quality assessments on these initial dough formulations are shown in Table 7.10.

Table 7.10 Quality of bread obtained with varying levels of soyflour

Sample	Flour mix (100g)	Texture	Crumb colour	Soy flavour	Overall appearance
Formulation 1	10% soyflour 90% wheat	soft, open crumb	slightly yellow	none	flat loaf
Formulation 2	15% soyflour 85% wheat	slightly dense crumb, still soft	slightly yellow	just detectable	flat loaf
Formulation 3	20% soyflour 80% wheat	dense crumb	yellow	detectable	flat loaf
Formulation 4	25% soyflour 75% wheat	very dense crumb	yellow	detectable	flat loaf
Formulation 5	30% soyflour 70% wheat	very dense crumb	strong yellow	objectionable	flat loaf
Formulation 6	35% soyflour 65% wheat	very dense crumb	strong yellow	objectionable	flat loaf
Formulation 7	40% soyflour 60% wheat	very dense crumb	strong yellow	objectionable	flat loaf

The effect of increasing levels of soyflour (on a replacement basis) are demonstrated by prints of the crumb structure, as in Fig.7.1. Above 20% soyflour, a very dense crumb structure was obtained in which the air cells were few, small and sparsely distributed, and the cell walls were thick. The effect of soyflour on crumb and crust softness is illustrated in Fig.7.2. The texture was measured on a Penetrometer using a polyhedral probe and a 100g weight. A similar critical soyflour level was observed at 20-25% soyflour replacement. At this level there was a dramatic drop in softness, with no further effect at higher soyflour levels. Fig.7.3 shows the effect of full-fat soyflour on loaf volumes. As other workers

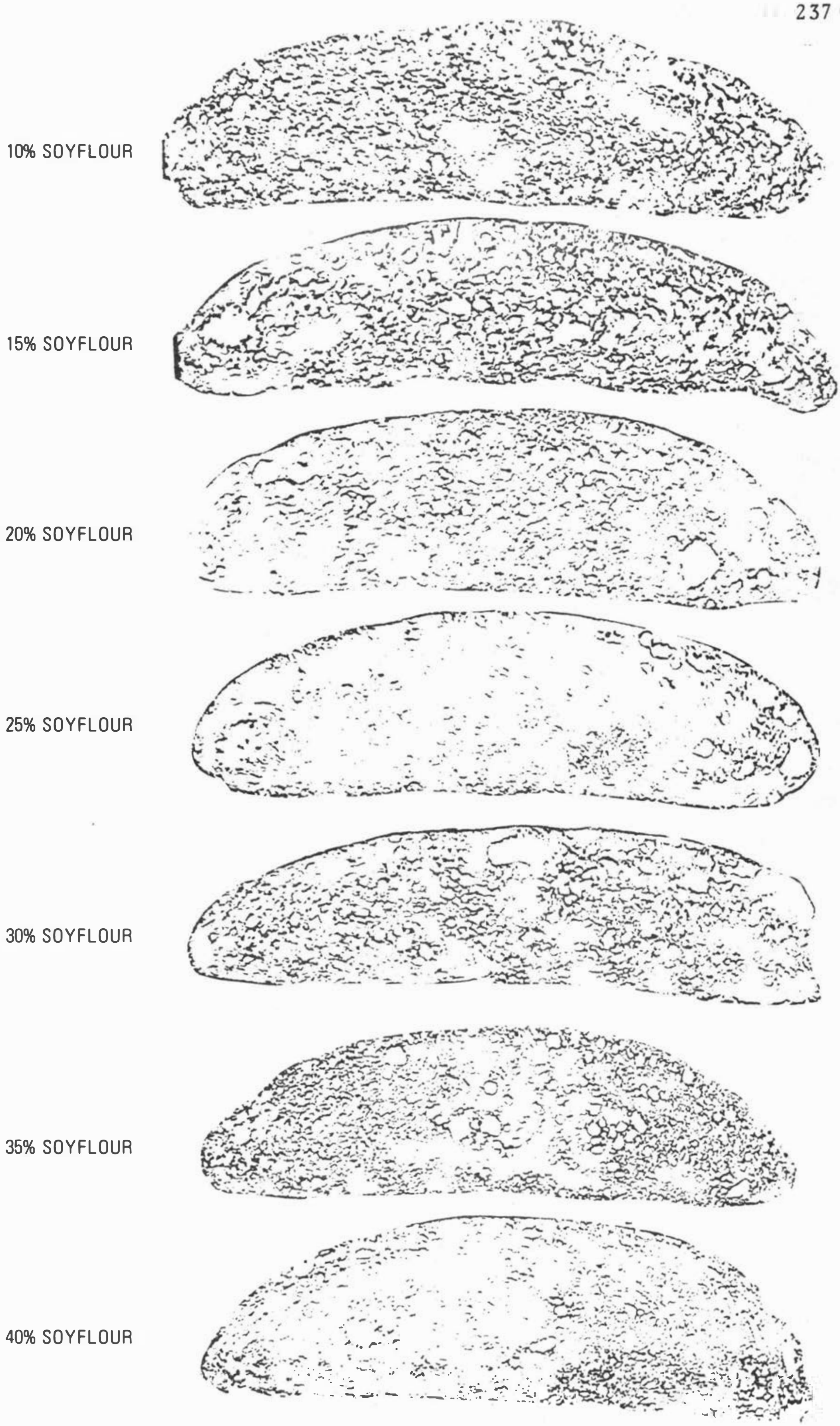


Figure 7.1 Effect on crumb structure of soyflour levels in bread products

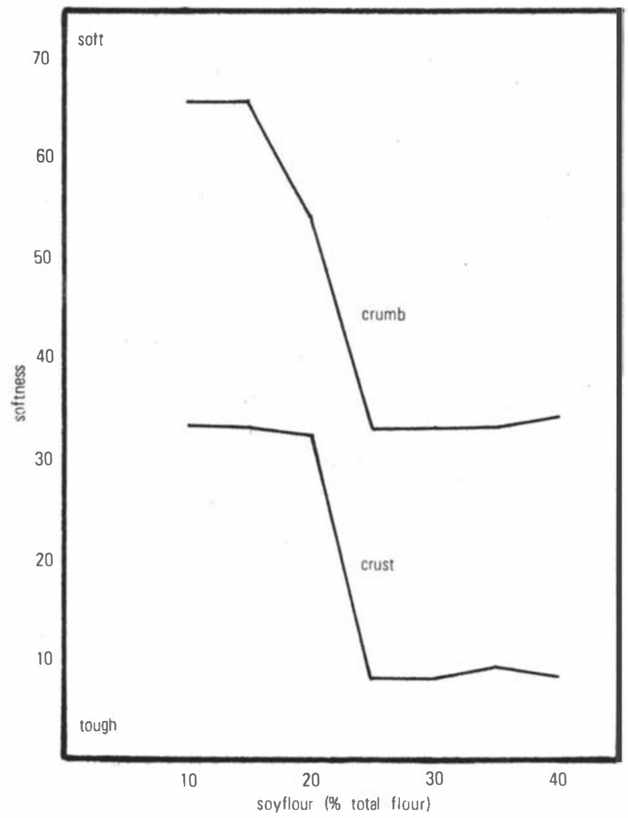


Figure 7.2 Effect on crumb and crust softness of soyflour levels in bread product, measured by penetrometer

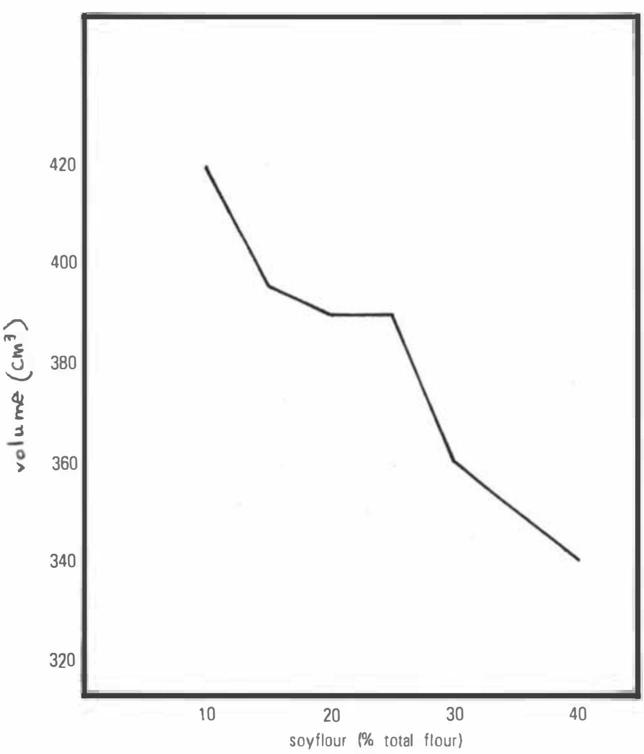


Figure 7.3 Effect on product volume of soyflour levels in bread product

had reported, increasing soyflour levels depressed loaf volume. There was also a critical range of 20-30% soyflour over which the volume depressing effect was greatest (indicated by the steeper slope in Fig.7.3).

It was concluded that the soyflour had had a deleterious effect on both loaf volume and texture when replacement of wheat flour with 20-25% soyflour was made. In terms of flavour, a detectable though not objectionable soy taste occurred at the 20% level, whilst at higher levels flavours were variously described as bitter, acidic and objectionable. It was obvious from the colour problems in both the crust and crumb that changes were required in baking conditions (e.g. reduction of temperature to 174C (350F) with baking time of 20 min). Defatted soyflour could be considered to lessen flavour and colour problems. It was decided then that with these changes, further tests would be restricted to 20% soyflour replacement level.

Incorporation of other materials in the dough

Gluten and skim milk powder (SMP). It has been found that SMP depressed loaf volume, caused stickiness and greening of the dough (181). Five percent of SMP based on flour weight, was the usual level used, whilst 25% appeared to be the upper limit reported (167). Gluten is the protein material responsible for the physical structure of the bread. Addition of extra gluten could prove a more open crumb texture and could reduce the effect of SMP on loaf volume. For subsequent tests, it was decided that 5% SMP and 5% gluten would be used. The formulation was unchanged except that the wheat/soyflour mixture consisted of 20g defatted soyflour and 80g wheat flour. A control was prepared without soyflour, SMP or gluten. Formulations tested are shown in Table 7.11. The preparation was similar to the previous experiment except for the change in baking temperature and time (174C for 20min).

The results of these trials are shown in Table 7.11 and it was concluded that:

1. SMP used by itself depressed loaf volume besides contributing to colour defects through the Maillard reaction.
2. Gluten had a beneficial effect on loaf volume, and could be used to offset the effect of SMP. A higher level of gluten than 5% would be beneficial when 5% SMP was included.
3. The crumb structure and crust thickness of the formulation were

poor and changes were necessary for improvement. Emulsifiers and improver additives could be required.

4. Soy fortification produced an inevitable darkening in colour which if properly controlled would not be objectionable. A longer baking time at a lower temperature, e.g. 25min at 149C, (300F) could be tried to control the colour effect.

5. The level of sugar could also be cut back in order to limit the Maïllard browning. It was decided then to reduce the sugar to 4.3g from 4.5g.

Table 7.11 Effects of gluten, SMP and soyflour on bread volume and softness

Sample	Additives	Volume (cm^3)	Softness of[a] crust	Softness of[a] crumb
Control	–	430	30.0	60.6
Formulation 8	20% soyflour	280	9.3	36.0
Formulation 9	20% soyflour 5% gluten	315	9.0	36.0
Formulation 10	20% soyflour 5% SMP	250	9.5	34.0
Formulation 11	20% soyflour 5% gluten 5% SMP	285	9.3	37.0

a. Measured by penetrometer, with polyhedral probe and 100g weight.

Fat increase. A high level of added fat was required in the enrichment system. In order to increase the level of fat in the dough, it was decided that a change to a high-fat dough formulation - hamburger bun formulation - would be tried. This formulation was modified to take account of findings in previous experiments. The basic formulation then was:

100g soyflour/wheat flour mix (20%soy,80%wheat)
60g water at 37-38C (98-100F)
7.0g gluten
5.7g lard
5.0g SMP
5.0g yeast
4.3g sugar
2.0g salt
1.4g Voltem (improver)
0.5g High-speed Dobrim (emulsifier)

Two samples were prepared in which the fat levels were 10% and 20% respectively, based on flour mix weight. A control mix was also prepared according to the basic formulation above. A straight dough method was the procedure used since this was normal practice for hamburger bun preparation,

1. Ingredients were mixed together in a Kenwood Bowl Mixer for 20min at speed No.8, to finish the dough at temperature 26C (78F).
2. The dough was moulded, and panned on greased trays.
3. It was proved for 50min at 38-42C/ 100-110% RH.
4. The buns were baked in a forced air oven at 149C (300F) for 25min.

The results, shown in Table 7.12, were so similar that no effect could be attributed to change in fat levels. The overall textures of the products were superior to any of the previous samples. It was decided then to use the high fat level of 20%, with the same formulation and procedure in further tests.

Test-bake under factory conditions. This was carried out in order to test the practicability of the formulation under large scale conditions. It was hoped that some of the problems occurring in the pilot-plant baking process, particularly excessive browning, could be overcome under more efficient large scale processing conditions. The procedure in the factory consisted of the following steps:

1. Mixing for 20min in a Hobart bowl mixer at No.3 speed setting.
2. Dividing, moulding and panning the dough rounds.
3. Proving at 42C/100%RH for 90min.
4. Baking in a dry air oven for 17min at 227C (440F).

Table 7.12 Effect of fat content on bread quality

Sample	Fat level (% flour)	Volume (cm^3)	Colour	Overall appearance
Contrc!	5.7	250	brown crust and light yellow crumb for all samples	thin crust, slightly open crumb
Formulation 12	10.0	250		thin crust open crumb
Formulation 13	20.0	245		thin crust open crumb

The colour problem was overcome through the use of a proper baking oven. Temperatures as high as 227C were used without any colour defects although under conditions in the laboratory pilot-plant undesirable darkening would have resulted. The increase in the proving time was attributed to milder factory conditions. It was suggested that for an economic throughput the proving time would have to be reduced by increasing yeast and improver (Voltem) levels. It was found that under factory conditions, the water absorption of the formulation increased so more water was required in the mix to give a satisfactory dough. Water was increased from 75% to 80% based on wheat flour weight (the traditional basis of formulae in the baking industry). On the whole the formulation performed satisfactorily under these conditions and a very acceptable product was produced.

Increasing yeast and improver levels. Formulations, as detailed in Table 7.13, were prepared, baked and quality measured in terms of volume and softness. All four samples had satisfactory volume, crumb and crust characteristics. It was observed that increase in yeast levels contributed more to the volume increase and crumb softness than did increase in improver levels. Formulation 16 was therefore selected as the most suitable since there was little difference in quality between it and Formulation 15, and it had a lower improver level, with corresponding lower ingredient cost.

Table 7.13 Effect of yeast and improver levels on bread quality

Sample	Additives	Volume (cm^3)	Softness of[a] crust	Softness of[a] crumb
Formulation 14	7.5g yeast 3.2g Voltem	580	55.0	53.0
Formulation 15	10.0g yeast 6.0g Voltem	710	138.5	119.5
Formulation 16	10.0g yeast 3.2g Voltem	700	137.5	100.5
Formulation 17	7 5g yeast 6.0g Voltem	650	86.5	77.5

a. Measured by penetrometer, with polyhedral probe and 100g weight.

At this stage it was decided that the development of the dough had been completed to a satisfactory stage. The final formulation, based on wheat flour weight, was:

Wheat flour	100g
Water	80g
Defatted soyflour	25g
Fat	25g
Yeast	10g
Gluten	9g
Skim milk powder	6.3g
Sugar	5.4g
Voltem	3.2g
Salt	2g
High-speed Dobrim	0.62g
Total weight	266.52g

7.4.3 Computer selection of enrichment formulation

The value of the enriched bread dough to the enrichment system was calculated from the nutritional composition of the ingredients. The total nutritional composition was reduced to take account of baking losses, by the percentage loss factors found in the literature (see 7.4.1).

In combination with 224g rice, which was converted to 670g boiled rice (with adjustments for cooking loss), the bread dough would only provide significant levels of nutrients, particularly calories, protein, fat, iron, thiamine and amino acids, if at least 100g of the product was taken. From Table 7.14 it was seen that even with 100g dough, there was still requirement for enrichment particularly of vitamin A, C and B6 and amino acids. The problem then was to evaluate how much enrichment was required, what it would cost and how it could be achieved.

Economic feasibility of dough enrichment. The linear programming model was used to evaluate the feasibility and cost of enriching the bread dough with chemical nutrients. Nutritional constraints were as for the model in 7.1.2. Data on composition, and cost of chemical nutrients were obtained from commercial companies and included in the model (Appendix 18 describes this data). Nutrient composition and cost data were introduced for a cheap source of fat, pork fat. Data were included for the baked dough and boiled rice nutrient compositions and costs. A lower limit of 100g was placed on the baked dough level. An upper bound of 200g was also set to represent the level above which it was assumed impractical to incorporate the bread product in the diet. With these constraints and the boiled rice level fixed at 670g, it was not possible to meet all nutritional conditions. The upper bound on the fat/calories relationship caused the conflict - any further increase in the fat level to raise calories was not possible. With conditions altered to allow only 90% of all requirements to be met a feasible solution was obtained. The cost of such a mixture was P2.41, P2.26 of which was for the enriched baked dough.

This was much too expensive to be practically implemented as an enrichment system. The cost of the mixture could be reduced by lowering the requirements for either all limiting nutrients, or only the most expensive chemical nutrients. Both these effects were investigated. In reducing nutritional requirements, it was desired to retain all nutrient levels in balance; so reductions were considered in terms of a percentage change in all direct nutrient requirements, the interrelated nutrients being changed simultaneously by the changes in the direct nutrient constraints. The most expensive nutrients were the synthetic amino acids.

Table 7.14 **Contribution of dough and rice to nutritional requirements**

	wheat flour	defatted soyflour	gluten	SMP	yeast	sugar	pork fat	total dough	estimated percent destruction during baking	baked dough	rice (boiled)	rice and dough	percent daily requirements
formula (g)	100	25	9	6.3	10	5.4	25	226.52					
percent total formula weight	37.52	9.38	3.38	2.36	3.75	2.03	9.38	100					
weight (g)										100	670	770	
calories (kcal)		33	13	8	11	8	85	295		295	136	431	21
protein (g)	4.5	4.8	3.3	0.9	1.43		0	14.9		14.9	14.7	29.6	73
fat (g)	0.49	0.14	0	0.02	0.04		9.38	10.1		10.1	1.3	11.4	25
fibre (g)	0.19	0.3	0	0	0.01			0.5		0.5	0.7	1.2	20
calcium (mg)	9.0	18.3	1.4	32.4	6.48			68		68	74	142	32
phosphorus (mg)	71.7	50	4.7	3.8	70.9			201		201	194	395	88
iron (mg)	0.49	1.13	0	0.007	0.705			2.33		2.33	4.0	6.3	31
vitamin A (iu)	0	13	0	0	0			13	10	11.7	0	12	0.3
thiamine (mg)	0.10	0.07	0	0.010	0.495			0.68	20	0.54	0.13	0.67	66
riboflavin (mg)	0.03	0.026	0	0.047	0.214			0.32	20	0.26	0.13	0.39	38
niacin (mg)	0.75	0.206	0	0.026	1.13			2.11	0	2.11	3.35	2.46	18
vitamin C (mg)	0	0	0	0	0			0	100	0	0	0	0
vitamin B6 (mg)	0.022	0.0535	0.002	0.0106	0.0225			0.110	10	0.10	0.40	0.50	29
vitamin B12 (mg)	0	0	0	0.0001	0			0.0001	5	0.0001	0.0	0.0001	5
pantothenic acid (mg)	0.19	0.164	0.0018	0.092	0.131			0.578	10	0.520	1.21	1.73	35
folic acid (mg)	0.004	0.005	0	0.0006	0.0237			0.039	20	0.031	0.021	0.052	28
isoleucine (mg)	163	221	119	54	85			642	10	578	812	1390	52
leucine (mg)	315	379	213	83	116			1106	15	1051	1160	2211	62
lysine (mg)	93	311	52	62	132			650	15	553	877	1430	55
methionine (mg)	65	62	49	24	23			223	15	190	583	773	62
cystine (mg)	114	65	54	10	13			256	15	218	100	318	33
phenylalanine (mg)	218	241	158	43	71			731	10	658	503	1161	50
tyrosine (mg)	104	153	112	40	60			469	15	399	181	580	34
threonine (mg)	120	189	80	39	81			509	5	484	523	1007	49
tryptophan (mg)	48	62	37	12	0			159	10	143	114	257	40
valine (mg)	185	234	121	54	107			701	5	666	985	1651	56

Reduction in their requirements could be achieved by relaxing protein quality conditions. At this stage the chemical score was constrained at 100 (range 100-110% of amino-acid pattern levels of egg protein). In order to retain amino-acid balance, percentage reductions in chemical score, i.e. in all amino-acid lower bounds, were investigated.

Figure 7.4 indicates the cost of enriched baked bread dough at various levels of chemical score and percentage of total nutrient requirements, obtained from parametric adjustments of these factors in the linear programming model.

Substantial reduction in cost was only seen in dropping the requirement level for nutrients from 90% to 80%. Below 80%, the savings were not as great. It was felt that the extra P0.10 (approx) required for 80% nutritional requirements compared to that for 70% levels was justified.

Much greater savings in cost were obtained through reducing the chemical score restrictions. Only with chemical scores below 90 did the cost fall below P1.00. Only with the chemical score of 70 did the cost approach P0.50, the average per caput daily food expenditure found in the national nutrition surveys.

It seemed that from the economic viewpoint, it was necessary to lower the nutritional value of the enrichment product. Even with 80% requirements being met and with protein quality equivalent to chemical score of 70, the cost of P0.55 would probably require some subsidy by government in order to be competitive with traditional bakery products. Although the bakery product seemed the most effective system of enrichment for processing, marketing and consumer conditions in the Philippines, the economic factor necessitated relaxation of the nutritional objective. This was due to the high costs of synthetic amino acids which were required to achieve the protein level as well as the individual amino-acid levels. It would be hoped that as the production of synthetic amino acids increases, their costs decrease to allow formulations of higher nutritional value to be feasible.

At this stage however, the lower nutritional quality had to be considered, necessitating that the further 20% of the nutritional requirements be supplied from other items in the diet. If money was

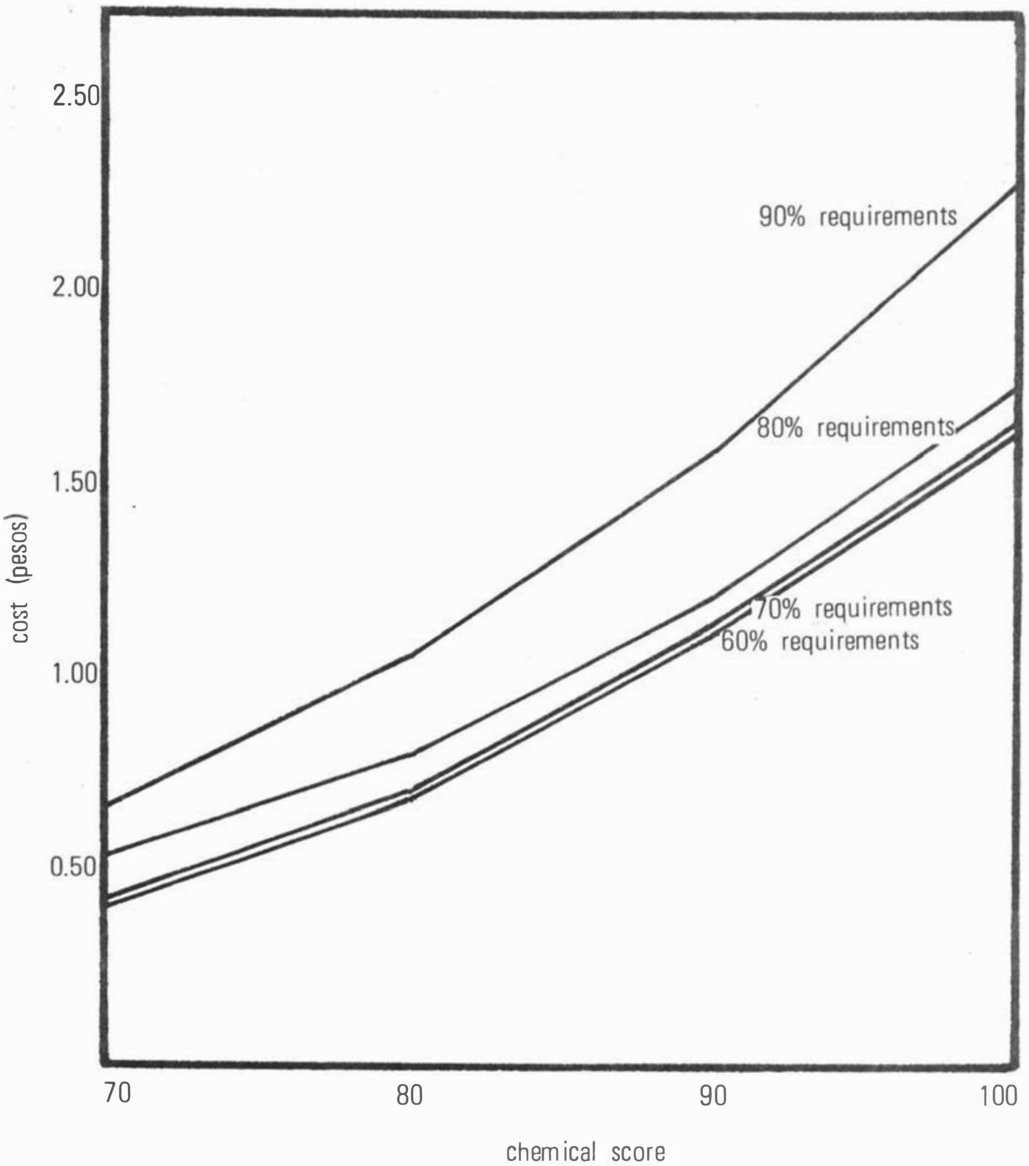


Figure 7.4 **Effect on cost of various nutritional requirement levels and chemical score levels for the enriched baked bread product**

available 20% more of the formulation could be supplied to achieve 100% nutrition.

Technical feasibility of dough enrichment. Together with the dough formulation and the rice, a mixture of chemical nutrients and fat was required in the enrichment system. (Table 7.15) The incorporation of the additives into the dough had to be considered for technical feasibility. The addition of the small amounts of vitamins and minerals required was not expected to cause any problems since this had been acceptable practice in the bakery industry for many years. The heat sensitivity of vitamin C would be the major problem. For the amino acids, their addition could cause flavour problems. The major problem would be the incorporation of the high level of fat. The dough already contained 20% fat which could not be increased much more without destroying the rheological properties of the dough.

Table 7.15 Enrichment mixture of boiled rice, dough and chemical nutrients

boiled rice		670g
baked dough		115g
pork fat		42.4g
calcium carbonate	683mg	
ferrous sulphate	47.6mg	
vitamin A palmitate	32 µl	
thiamine hydrochloride	60 µg	
riboflavin	380 µg	
nicotinamide	5mg	
l-ascorbic acid	23.2mg	
pyrodoxine hydrochloride	860 µg	
cobalamin	1.5 µg	
calcium D-pantothenate	2.4 mg	
folic acid	92 µg	0.762g
l-isoleucine	33.7mg	
l-cystine	197.6mg	
l-phenylalanine	67.2mg	
l-tyrosine	320.6mg	
l-threonine	87.0mg	
l-tryptophan	87.5mg	0.794g

It was decided therefore that the nutrient mixture should be formulated into a slurry or paste which could be used as a filling in the dough. In this way the satisfactory properties of the baked dough should be unaffected and the lesser heating effect in the centre of the product should not be as harmful to the sensitive nutrients. Although this represented a departure from the plain bread roll originally intended, the filled bun type of product was already familiar in the Philippines, both with savoury fillings of meat and mungbeans and with sweet fillings of cream, jelly, icing.

Design of the filling formulation. The nutrients mix itself did not provide an acceptable filling for the dough. In order to improve the consistency and flavour of the filling, other materials were required. It was decided then to consider protein materials which could perhaps reduce the requirement for the expensive synthetic amino acids. Cheap protein materials considered were skim milk powder and lactalbumin, the latter for its particularly high content of cystine. Coconut and sugar, indigenous materials, were considered for their calorie, fat, bulking and flavour contributions.

The linear programming model was again used to select the formulation for the enrichment system, with retention of the boiled rice and baked dough restrictions to ensure that the cheapest mixture for the total system was achieved. It was found necessary to place constraints on the levels of the filling ingredients in order to select a palatable filling of satisfactory consistency. Linear programming was used then in this problem to select a formulation based on product characteristics other than solely nutritional characteristics. To provide such product characteristic information, laboratory trials were necessary. Such tests were conducted with the filling ingredients, whence it was found:

1. The filling weight should not exceed half the dough weight in order to retain bun characteristics and to restrict the maximum weight of the total product.
2. The sugar level should lie between 15-20% filling weight for an acceptable sweet flavour.
3. Skim milk powder and lactalbumin contents should not exceed 15% of filling weight in both cases. Above these levels, the filling became a sticky, poor-bodied, gluey mass which was not acceptable.

4. Coconut could range from 50-65% of filling weight.
5. Water could range between 15-20% filling weight for a suitably moist filling.
6. No restrictions were placed on the fat level since the extra fat required could be added satisfactorily.

These conditions were expressed in terms of linear equations (Table 7.16) and with appropriate constraints, inserted into the linear programming model. Nutritional compositions of the filling ingredients were obtained from standard tables and corrected for estimated losses expected during baking. Current New Zealand export costs for lactalbumin and skim milk powder were included, whilst costs for other materials were obtained from Philippine sources.

Table 7.16 Filling constraints for enriched bread product in linear format

Ingredient	Condition	Column variables	Row variable name	Restriction lower	Restriction upper
filling	dough weight ⩾ 2 x filling weight	DOUGH - 2.0FILLING	WTRATIO	0	∞
sugar	sugar weight ⩽ 0.2 x filling weight	SUGAR - 0.2FILLING	HISUG	-∞	0
	sugar weight ⩾ 0.15 x filling weight	SUGAR - 0.15FILLING	LOSUG	0	∞
skim milk powder	SMP weight ⩽ 0.15 x filling weight	SMP - 0.15FILLING	HISMP	-∞	0
lactalbumin	lactal weight ⩽ 0.15 x filling weight	LACTALB-0.15FILLING	HILACT	-∞	0
coconut	coconut weight ⩽ 0.65 x filling weight	COCONUT-0.65FILLING	HICN	-∞	0
	coconut weight ⩾ 0.50 x filling weight	COCONUT-0.5FILLING	LOCN	0	∞
water	water weight ⩽ 0.2 x filling weight	WATER - 0.2FILLING	HIH20	-∞	0
	water weight ⩾ 0.15 x filling weight	WATER - 0.15FILLING	LOH20	0	∞

To evaluate whether higher nutritional value could be economically achieved with this product - dough plus filling - the parametric experiments carried out previously with dough, were repeated with dough plus filling. Although the filling ingredients reduced the requirement for synthetic amino acids, the high total cost of filling ingredients prevented savings in total bun cost. Only when 80% requirements were met with chemical score 70 was the cost of the product below that of the corresponding dough-only formulation (Fig 7.5). The cost saving was small, P0.05, but only at this level was the enrichment system economically feasible.

The formulation providing 80% nutritional requirements with chemical score of 70, from filled bun and rice, was selected then as the most economic and practical system of enrichment. The formulation of the filled bun is described in Table 7.17.

It was recognised at this point that correction of the nutrient contribution from chemical nutrients for losses during baking had been over-looked in the last experiment. Since the same minor overestimation of nutrient value had occurred throughout the experiment similar results would have been obtained, with slight cost differences which should probably be constant for each optimization. A correction to take account of nutrient losses to added chemicals, in the selected formulation resulted in an increase of cost of P0.002 with the slightly increased requirement of the chemicals (see Table 7.17).

Preparation of designed product. The formulation was prepared in the laboratory, Two buns were made from the mixture, since in one piece the product was too bulky. It was decided that dessicated coconut should be used in the product as this would be more readily available to bakeries and would be more practical if the enriched filling were to be supplied as a dry mix to neighbourhood bakeries. This necessitated adding 100g water to each 100g dessicated coconut to bring the moisture content up from 4% to that of fresh coconut of 52%.

Laboratory taste panels indicated that both colouring and flavouring agents were necessary to increase the acceptability of the filling. It was assumed that coconut sweets were commonly associated with a deep brown colour and a rich caramelized flavour, as in the popular native sweet, 'bukayo', in the Philippines. Brown colouring, and a combination of vanilla and caramel flavouring produced best colour and flavour results. Using brown sugar in the formulation complemented both colour and flavour.

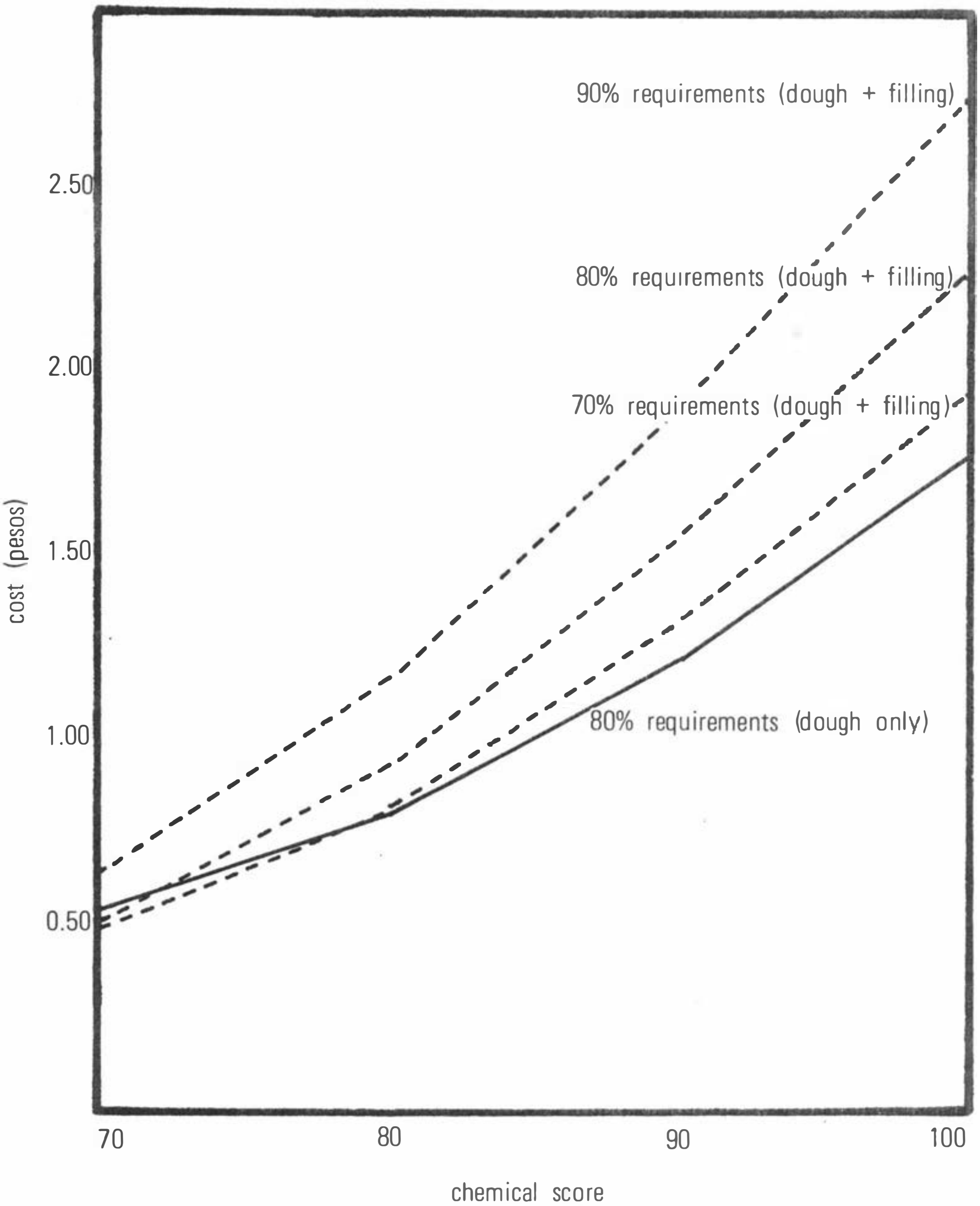


Figure 7.5 **Effect on cost of various nutritional requirement levels and chemical score levels for different enriched formulations**

Table 7.17 Enriched filled bun formulation

Ingredient	Ingredient levels with no correction for processing effect on chemical nutrients		Ingredient levels with correction made for processing effect on chemical nutrients		Batch size
	weight (g)	percent	weight (g)	percent	
DOUGH MIX	153.6	100	153.7	100	154g
wheat flour		37.5		37.5	
defatted soyflour		9.4		9.4	
gluten		3.4		3.4	
skim milk powder		2.4		2.4	
sugar		2.0		2.0	
salt		0.8		0.8	
pork fat		9.4		9.4	
yeast		3.8		3.8	
Dobrim		0.2		0.2	
Voltem		1.2		1.2	
water		30.0		30.0	
FILLING MIX	76.7	100	76.8	100	77g
coconut	38.4	50.0	38.4	50.0	
sugar	11.5	15.0	11.5	15.0	
water	11.5	15.0	11.5	15.0	
lactalbumin	6.4	8.3	6.4	8.3	
pork fat	9.0	11.7	9.0	11.7	
NUTRIENT MIX	1.43		1.37		1.4g
calcium carbonate	800mg		430mg		
ferrous sulphate	40.3mg		40.3mg		
vitamin A palmitate	32 µl		35 µl		
riboflavin	220 µg		280 µg		
nicotinamide	4mg		4mg		
l–ascorbic acid	23.2mg		232mg		
pyrodoxine hydrochloride	800 µg		890 µg		
cobalamin	1 µg		1.1 µg		
calcium D–pantothenate	2.05mg		2.27mg		
folic acid	70 µg		88 µg		
l–cystine	156.5mg		186.2mg		
l–phenylalanine	16.5mg		23.1mg		
l–tyrosine	299.4mg		355.9mg		
l–threonine	35.0mg		40.8mg		
l–tryptophan	49.6mg		56.5mg		
Total filling	78.13g		78.17		
Ingredient cost	PO.550		PO.552		

An acceptable coconut bun was prepared by the following procedure.

Filling

1. The dessicated coconut was rehydrated. Pork fat was weighed out and mixed with the coconut.
2. Dry premix of nutrients was weighed out, except for the liquid vitamin A palmitate which was weighed out separately. Lactalbumin was weighed and mixed with the nutrients.
3. Sugar and water were weighed out and mixed to dissolve the sugar.
4. The mixture of lactalbumin and nutrients, was added slowly to the sugar solution with stirring to form a slurry.
5. The slurry was mixed with stirring for 3min with the remaining ingredients.
6. Colouring and flavouring were added gradually during the mixing.

Dough

1. Dough ingredients were mixed for 20min, dough finishing at 26C (78F).
2. The dough was divided into 77g units and moulded into round balls.
3. The dough rounds were flattened into round shapes about 10cm in diameter and about 1cm thick.
4. The filling (39.2g) was placed in the centre of each dough piece.
5. The edges of the dough were brought up and sealed at the top with a pinching action.
6. The finished buns were placed with the sealed edges face downwards on greased trays.
7. The buns were proved at 38-42C (100F)/100-110%RH for 40min or until doubled in size.
8. The buns were baked in a hot air electric oven at 149C (300F) with forced air circulation, for 25min or in a dry air oven for 15min at 227C (440F).
9. The baked buns were allowed to cool on well ventilated racks for 1-1.5h.

7.4.4 Acceptability of the enriched product to Filipinos

The prepared product, together with a questionnaire, was sent to 12 of the 20 Filipinos who could be contacted in New Zealand, and who expressed willingness to take part in the acceptability test. These people were professional people or students who probably belonged to a higher income group than that of which the product was aimed. Several also had been away from the Philippines for some years and their tastes could have changed. Nevertheless, this represented the best Filipino panel available to us.

The results of the acceptability test indicated that the overall concept of the product, as an enrichment medium for incorporation in a predominately rice diet, was acceptable. Respondents rated highly the product appearance, dough texture and dough flavour. The filling was poorly rated - both for colour and flavour, but filling texture was satisfactory. Modifications were required in the filling: some of the respondents suggested for example, increasing the sugar level, darkening the colour, using fresh grated coconut. Respondents thought the cost too high and that subsidization would be required to reach the poorer segment of the population.

This small test indicated, that after modifications to the filling, the product would be acceptable for enrichment of the Philippines' diet.

7.4.5 Process description

Selection of a suitable process. The selection of a process compatible with conditions existing in the Philippines, was undertaken from three aspects:

1. Capital intensiveness. As it was envisaged that the product would be produced in the numerous small bakeries scattered throughout the Philippines to effect widespread distribution, it was not likely that any process requiring large capital investments in sophisticated equipment, e.g. continuous bakery equipment, would be accepted readily.
2, Simplicity of operation. It was desirable that the process should involve simple operational techniques and equipment, because many of the bakeries were operated by experienced, though not technically trained bakers, on a cottage-scale basis.
3. Compatibility with present processing methods. The equipment in a very simple bakery would consist mainly of balances, moulders, a proving cabinet and hot air rooms, wood or gas or in a few cases electric ovens. Although there were better equipped bakeries in larger cities of the Philippines, these were by far the minority in the country. Thus an

essentially manual process was required. It could be possible and necessary to incorporate a simple hand operated dough divider in some of the more primitive bakeries to ensure accurate control of measurements of dough weights.

From the development of the prototype product, it was determined that a suitable process consisted of:

1.	Nutrients preparation	dry mix form supplied for common batch sizes or weighed out in the required amounts at bakery
2.	Mixing of filling	in bowl mixer
3.	Mixing dough ingredients	in a bowl mixer, e.g. Hobart, or Baker Perkins Mixer, Model RKV2 having a capacity of 500lbs.
4.	Dough dividing	with hand operated dough divider, e.g. the Eberhardth which divides up to 30 pieces of dough at a time and moulds as well. Manual weighing may be required
5.	Filling buns	manual filling, and manual sealing of the dough ends
6.	Proving	steam proving, e.g. in a steam closet maintained at around 38-42C (100-110F)
7.	Baking	a normal baker's hot air oven, but primitive hot air room should be satisfactory
8.	Cooling	on well-ventilated racks
9.	Packaging	in twist-tie polyethylene, the cheapest packaging material available

As the project was not being undertaken for a particular company, it was not possible to make an estimate of equipment sizing or costing, since this would largely depend on the types of equipment existing in individual bakeries in the Philippines.

A condensed process-flow sheet for the production of the filled buns is shown in Fig.7.6; quality control checks required are also shown beside the appropriate steps.

Process description

Preparation of filling:

1. Ingredients are mixed in gradually, stirring all the while, for

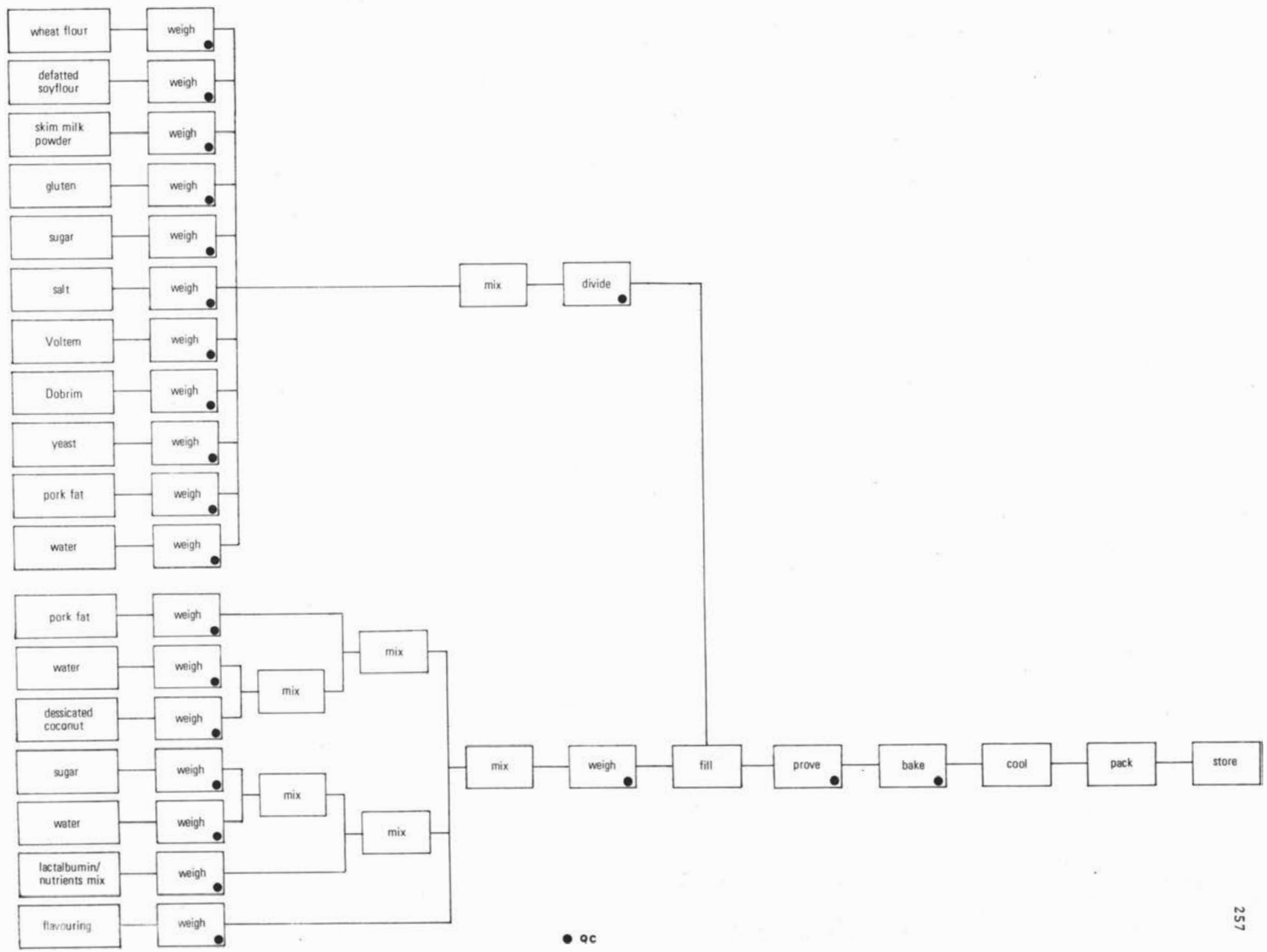


Figure 7.6 Flow diagram for enriched coconut bun production

about 3min.

2. The filling is covered, left aside until required.

Preparation of the buns:

1. Dough ingredients are mixed in a Hobart bowl mixer at speed No.2 initially, then at No.3 setting, for a mixing time of 20min.
2. The dough is divided into 77g pieces by hand weighing or on divider where available.
3. Each piece of dough is flattened with the palm of the hand; the weighed filling (39.2g) placed in the centre of the dough piece, and the ends sealed off at the top.
4. The buns are placed on greased trays with the sealed edges facing downwards.
5. Proving is allowed for 40min at 100%RH, and a temperature of 38-42C (100-110F).
6. The buns are baked in bakery hot air room or air oven if available for equivalent of 15min at 227C (100F).

7.5 Summary

Consideration of the availability of raw materials in the linear programming model confirmed that nutritional adequacy was not possible with the present food supply. Enrichment of the food supply appeared an effective and quickly implemented method of diet improvement.

The linear programming technique proved useful in the product development of a suitable food for enriching the diet, by providing quantitative data for evaluation of feasibility of enrichment with various types of products, the economics of various levels of enrichment and in design of product formulation.

The development of a filled coconut bun capable of providing 80% of the daily nutritional requirements was undertaken, with extra allowance made for possible nutrient losses during the baking process, in the formulation design. The product was found to be acceptable to Filipino tasters although slight product modifications and price subsidies would be necessary before introduction of the product to the Philippine diet.

CHAPTER 8

VALUE OF THIS RAW MATERIAL SELECTION MODEL

A systematic methodology using linear programming for selecting raw materials to satisfy nutritional criteria, has been developed for application in a product development scheme for the food industry of the Philippines. The system was used firstly to select a minimum cost mixture of indigenous raw materials which was capable of meeting Philippine requirements for twenty-six nutrients. Then, another mixture of raw materials was selected for the design of an enriched baked product capable of enriching the daily rice diet of the Filipino. These mixtures were developed to acceptable products.

The value of this selection system can only be tested by attempting to implement it in the food industry of the Philippines. Before this is done, some study of its value and limitations had to be made. Then, any changes to the system which may be necessary can be identified before the final industrial development.

8.1 Accuracy of nutritional composition of mixtures selected by linear programming

The two mixtures selected - unprocessed raw materials for the canned meat loaf and the baked bun with the enriched filling - were chemically analysed. The meat loaf mixture was tested before canning as allowance had not been made in the original selection for nutrient loss during the heat process. The baked filled bun was analysed because allowances had been made for processing losses. Because of the time and facilities available, it was not possible to analyse for all the nutrients. Only one sample of each product was analysed, so that the analyses cannot be taken as representative.

Table 8.1 shows the chemical analysis of the two mixtures compared with the calculated compositions from the linear programming optimization.

Table 8.1 Comparison of calculated nutrient composition with analytical composition of mixtures

	Meat-mix (raw, unprocessed)		Enriched coconut bun(baked)	
	Calculated from linear programming per 100g	Chemical analysis per 100g	Calculated from linear programming per 100g	Chemical analysis per 100g
calories(kcal)	170	294	383	440
protein(g)	4.1	4.2	15.9	13.5
fat(g)	6.5	16.8	18.4	25.8
fibre(g)	1.3		0.8	
calcium(mg)	58	114	151	180
phosphorus(mg)	88	90	182	162
iron(mg)	2.9	2.4	6.5	5.3
vitamin A(iu)	625	290	1685	1355
thiamine(mg)	0.11		0.45	
riboflavin(mg)	0.09		0.36	
niacin(mg)	1.12		3.91	
vitamin C(mg)	17		12	
vitamin B6(mg)	0.15	0.15	0.51	0.46
vitamin B12(μg)	0.25	0.32	0.53	4.19
pantothenic(mg)	0.58	0.32	1.47	1.42
folic acid(μg)	15.0	12.5	67	48
isoleucine(mg)	204	181	668	577
leucine(mg)	326	362	1193	1070
lysine(mg)	263	176	663	617
methionine(mg)	96	51	225	570
cystine(mg)	74	142	344	0
phenylalanine(mg)	203	194	695	615
tyrosine(mg)	131	154	600	202
threonine(mg)	168	154	569	437
tryptophan(mg)	49	177	205	58
valine(mg)	249	206	749	855

The surprising difference in the meat-mix loaf analysis was in the fat contents; the analysis was 16.8% as compared with the calculated fat of 6.5%. This was most likely caused by higher fat contents in the pilinuts or in the coconut but more analysis has to be done to confirm this. Because of the high fat content, the calorific value of the analysed sample was of course higher than calculated. The only analyses that were significantly low were vitamin A and methionine. Even though the calculated vitamin A was higher than necessary in the Philippine requirements, its lowered amount in the final mixture stressed the importance of specifying higher levels of vitamins in the model to allow for losses and variations. Unfortunately, it was not possible to analyse for the other common vitamins to see if this was also true for them, but the trace vitamins tended to be slightly lower than the calculated values. Although, the methionine was lower, the combined sulphur amino acids were similar to the calculated value - 193mg/100g and 170mg/100g respectively. Overall, agreement in the meat-mix loaf was reasonable, but much more analytical work is needed to confirm this.

In the baked coconut bun, which had been enriched with amino acids, the discrepancy in the analysed amino acids was difficult to understand. Isoleucine, cystine, phenylalanine, tyrosine, threonine and tryptophan were all added before baking but the tyrosine, and tryptophan were low in the final product and the cystine was not present. The total sulphur-amino acids were the same as calculated, 570mg/100g and 569mg/100g, but in the analysis this was all methionine while in the calculated composition it was 225mg/100g methionine and 344mg/100g cystine. This disagreement in the added amino acids could not be explained easily; it could have been caused by a sampling or analysis error but there could have been some effect in mixing and processing. Further work is necessary to overcome this problem. The remainder of the bun analysis agreed with the calculated values except for vitamin B12 and this high result was caused by inaccuracy in weighing out the small amount of cobalamin in the batch formulation.

This preliminary analysis showed that overall this system of nutritional formulation was of value, but there was a need for having higher levels of vitamins specified and for an investigation into the addition of amino acids for enrichment purposes.

8.2 Possibility of implementing production of these products

Introduction of these acceptable products, designed for their nutritional value, to the diet can only be effective through proper organization of production and effective promotion of the products.

8.2.1 Organization of production

Meat-mix loaf. This product was designed to fit with the processing facilities of large meat processors in Manila. Organization of production should not cause any problems in these factories, but procurement of the raw materials would need to be organized. The facilities of the large food market (Greater Manila Terminal Food Market) being built near Manila could be used for raw material sorting and grading. This market is designed to transport, receive, store and in some cases process agricultural and fishery produce from the thousands of farms in the Central Luzon area. All the vegetables, the rice, coconuts and fish would normally be available in this market. The materials obtained from the market could be obtained on a daily or weekly basis, depending on how the productioncycle fits in with normal factory operation. The supply of pilinuts, cottonseed and dried seaweed would have to be obtained directly from areas of production. These materials have good storage properties and so could be stored in the meat plants in bulk. The liver would be available as a by-product of the meat processing operations.

There may be a requirement for more flavour development work to be done, using Philippine taste panelists, so that the most acceptable product can be developed for all the different regions of the country. This work could be carried out in the Food Technology section of the Faculty of Home Economics at the University of the Philippines, Diliman.

Enriched coconut bun. Few organizational problems are expected with production of this product. It should fit in with the widely employed Nutribun production system (30). Donated ingredients are supplied to neighbourhood bakeries who bake and deliver buns to schools or sell them through their bakeshop. The imported ingredients - soy flour, skim milk powder, lactalbumin nutrient mix - could be supplied to bakers in the same way after demonstration of the process. The need for some type of dough divider for weight control would be important for production of a standard product in many different bakeries.

As part of the organization of production of these products, some system for accurately recording shipment and sales levels should be included. Thus, given standard products with desirable nutritional levels, the impact of such products on the nutrition of the area being supplied can be continuously appraised. Back-up market and nutrition surveys could also be run periodically by Food and Nutrition Research Center to estimate consumer usage of the products.

Sales and production information would normally be recorded by the large companies expected to produce the meat-mix product. However, in the many small bakeries such a recording system would be a new concept. Normally only production value is available, probably from income tax returns. Records of raw material supply should give a good indication of production but this would not give definite figures for the numbers of buns sold. Bakers could be trained to record the number of units of the enriched product which they produced and sold every day. This could be confirmed by giving some sort of token with each bun, which could be collected by schoolchildren. These tokens could be redeemable at school for price reduction on the next bun. Information of the number of tokens redeemed in a period could then be supplied to nutrition control authorities. This system would also have a promotional effect on sales.

8.2.2 The requirement for sponsorship

It is important that new products designed for nutritional improvement of diets be given the greatest encouragement for implementation in production, launching and promotion. This is costly and with new ventures implies some risk. To effectively introduce these products into industrial production, some sponsorship or subsidy would likely be necessary to underwrite costs of development work, promotions and some of the labour costs and factory overheads. This could be handled by the sponsoring agency, contracting to the company for production of the products. In this way, products could be quickly implemented into full scale production in a short time with little cost to factory or bakeries.

The actual price to the consumer could then be near the calculated minimum cost of raw materials. However, if this price seemed too expensive, further subsidy would be required. This subsidy could be incorporated in the token system for recording sales.

Once production and sales increased to profitable levels, subsidies could be gradually removed so that the companies take over the full responsibility for production of the products. The sponsoring agency, if not the government, should retain some influence through continual support of the production, so that periodical inspection and quality control can be carried out. In the small bakeries, it would be advisable to retain the contract system so that a continuous production of the standard product can be retained. The sponsoring agency could then retain responsibility for promotion.

8.2.3 The importance of promotion

One of the major causes of failure of new protein foods was noted as poor promotional effort (see Chapter 2). These two products have been designed to make most use of existing production and distribution systems, and to be compatible with Philippine eating habits. The limiting step in obtaining effective introduction to the diet is getting the consumer to purchase and eat the products. Effective promotion must be evolved to encourage the poorer people to spend their small amount of money on such products. This is a difficult problem when dealing with the situation where supermarkets and television are not available (the chief promotional tools of developed countries). Instead the available rescurces should be used. For example, local women could be trained to give cooking demonstrations and to give away free samples of the products in nutrition centres, schools and markets throughout the country. Buns could be promoted in schools through projects on nutrition; literature and display material being provided. The buns could at first be given away so that the children could taste them; then they could be sold for school meals, like the Nutribun. The price reduction on collection of tokens would have an added promotional effect.

In some areas, radio could be used to encourage usage of the products. Perhaps some well-known personality could be used to sponsor these products for nutritional benefits.

The usage of these products should be part of the applied nutrition programmes carried out by the Food and Nutrition Research Center and its affiliates throughout the country, so that official nutritional backing is given these products.

Promotion campaigns must be carefully planned and should be continuous throughout the life of the products, so that the products are always in the public eye.

8.3 Conclusions

8.3.1 Applicability of this raw material selection system in product development

The linear programming technique was used to select the raw materials according to their nutritional properties. Based on scant analytical data, the nutritional composition of the selected raw materials gave reasonable agreement with calculated data, although generally on the low side of specifications. The selected materials also were capable of successful formulation into an acceptable complete product in one case and an acceptable filling for an enriched baked product.

With some modifications to take account of variability in the nutrient composition data, linear programming would be a very suitable method for quantitative selection of raw materials in product development.

In this research, it has been possible therefore firstly to extend beyond earlier nutrition problems to include twenty-six nutrients as well as interrelationships between some nutrients in a linear programming model; and secondly to extend the applicability of these nutrition models to developing countries beyond the national food planning models to raw material selection models for the design of nutritional food products capable of production in local food industry and based on indigenous agricultural and fishery production.

8.3.2 Direction of further work

This raw material selection model can form the basis of the larger model planned to design food products with other properties besides nutrition - functional properties, acceptability properties and effects of processing on these properties.

Further work then should look at these criteria in turn to investigate how they can be accommodated with the nutrition model. It may be that some of these properties cannot be fitted to a linear model so that ancilliary models may be required.

1. Functional properties: such as viscosity, emulsification, and binding strength. These would require empirical investigation to establish the effect of combination of different materials on the functional properties.

2. Acceptability properties: such as colour, flavour, texture and appearance. These have been handled to a certain extent in menu planning models - only in terms of desirable characteristics of individual items on a meal plate - but the effect on these properties of combining different materials has not been studied. Empirical investigation would again be required to establish these combination effects. It could be possible to accommodate colour and flavour properties on some rating scale so that linearity could be approximated and hence these could be included in the linear programming model.

3. Effect of processing. It would be required to select those raw materials which could expect (i) least nutrient destruction, (ii) least loss of functional properties and (iii) least deterioration of acceptability properties in a food product formulation. Thus estimates of the effects of different processes on these properties for each raw material would be required. This could possibly be achieved by some reaction kinetic studies on groups of raw materials to indicate rates of change of properties with different processing conditions. Hence corrections could be made to the values of each property for each raw material for each individual process. Each process could then be looked at individually to select that with least cost or least effect on raw material properties. Linear programming could be used in the case of minimizing the destruction of nutrients through processing.

Thus future work will require extensive empirical investigation. It may be that the processing effect is the simplest to consider at the next stage, if sufficient information exists in the literature. However, with this initial nutrition model it would seem that the design of nutritional foods through product development can indeed be quantitatively based.

REFERENCES

1. EARLE, M.D. The science of product development and its application to the food industry. Massey University Publication, Palmerston North, New Zealand, 1973

2. BOOZ, ALLEN & HAMILTON, INC. The management of new products. 4th edition, New York, 1964 (1st edition, 1957, not seen)

3. JOHNSON, S.C. and C. Jones. How to organize for new products. Harvard Business Review (1957) 35 (3), 49 (not seen)

4. KLINGER, L.E. Co-ordinating food research with marketing. Food Technology (1963) 17 (11), 1368

5. New food products - from concept to marketing. Symposium, Food Technology (1965) 19 (10), 50

6. A major challenge in co-ordination. Forum in new product development. Food Technology (1967) 21 (11), 1443

7. Marketing and product development. Symposium. Food Technology (1969) 23, 290

8. FOOD and Agriculture Organization of the United Nations. Agricultural Commodities - Projections for 1975 and 1985. Rome, 1967, volume 1, page 5

9. DEANE, P. and W.A. Cole. British Economic Growth 1860-1965. Cambridge University Press, Cambridge, 1966

10. UNITED States Bureau of census. Long term economic growth 1860-1965. U.S. Department of Commerce, Washington, DC, 1966

11. UNITED Nations Economic Commission for Latin America. Analyses and projections of economic development. UN, New York, 1955, Part 1, page 30

12. LODGE, G.C. Food processing - key to economic development. Harvard Business Review (1966) 44 (Sept/Oct), 6

13. GOLDBERG, R.A. Agribusiness for developing countries. Harvard Business Review (1966) 44 (Sept/Oct), 81

14. AYLWARD, F. Some African problems. In Proceedings of symposium on science and technology in campaign against malnutrition. Proceedings of the Nutrition Society (1961) 20, 112

15. COCHRANE, W.W, A.B. Mackie and G.C. Chappell. Potential uses of farm products as aid to developing countries. Journal of Farm Economics (1963) 45 (5), 961

16. USDA Household Survey, 1965. In Arlin, M.T. The science of nutrition. Macmillan, New York, 1972 p. 201

17. LANGER, A. and P.S. Henshaw. The interacting effects of public health, fertility behaviour and general economy on standards of living. 1. Analytical approach leading to development of a country 'situation index' American Journal of Medical Sciences (1955) 230, 119. 2. Qualitative evaluation of factors responsible for conditions in countries with similar situations. ibid, 484 3. Quantitative evaluation of component determinants with respect to raising or maintaining present standards. ibid, 605

18. TAUBER, E.M. Systematic generation of ideas for new foods. Food Product Development (1971) 5 (2), 58

19. O'MEARA, J.T. Junior. Selecting profitable products. Harvard Business Review (1961) 39 (1), 83

20. PESSEMIER, E.A. New product decisions: an analytical approach. McGraw Hill, New York, 1966

21. GREEN, P.E. and D.S. Tull. Research for marketing decisions. Prentice-Hall, Englewood Cliffs, New Jersey, 1970

22. BEN RAJEB, M. and H. Brusset. Generalisation de la programmation linéaire pour l'optimisation de la formulation des melanges alimentaires. (General use of linear programming for optimization of blended food formulations. 1. Linear programming). Lebensmittel-Wissenschaft und Technologie 1.(1973) 6 (3), 97; 2. ibid, (1973) 6 (5), 179; and 3. ibid,(1973) 6 (5), 182

23. TATE, G. Development planning and control. Food Technology in New Zealand (1968) 3 (1), 17

24. HARE, L.B. Mixtures design applied to food formulation. Food Technology (1974) 28 (March) 50

25. QUIOGUE, E.S, G.M. Villavieja and V. Ramos. Summary results of the eight nutrition surveys conducted in the Philippines by the Food and Nutrition Research Center, NIST, NSDB. 1. Dietary phase. Philippine Journal of Nutrition (1969) 22, 61

26. ALEJO, L.G, B.V. Roxas, L.A. Salamat and M.D. Kuizon. Summary results of the eight nutrition surveys conducted in the Philippines by the Food and Nutrtion Research Center, NIST, NSDB. 2. Biochemical phase. Philippine Journal of Nutrition (1969) 22, 79

27. BAYAN, A.A, A.J. Matawaran and C.C. Gervasio. Summary results of the eight regional nutrition surveys conducted in the Philippines by the Food and Nutrition Research Center, NIST, NSDB. 3. Clinical phase. Philippine Journal of Nutrition (1969) 22, 90

28. INTENGAN, C.Ll. Private communication, Food and Nutrition Research Center, Manila, Philippines, 1973

29. QUIOGUE, E.S. Food consumption and supply in the Philippines. Philippine Journal of Nutrition (1966) 19 (3) 173

30. WEISBERG, S.M. Spotlight on baked goods for the developing world. Cereal Science Today (1973) 18 (2), 47

31. ALCAREZ-BAYAN. A. Evaluation of MCM as a high protein product. Philippine Journal of Nutrition (1972) 25, 191

32. ABDON, I.C. Coconut as a source of protein. Philippine Journal of Nutrition (1969) 22, 107

33. BRIONES, P.R, E.M. Payumo, E.A. Banzon and M.L. Torres. Coco-crunchies: a high protein snackfood. Philippine Journal of Nutrition (1970) 13, 14

34. WEE, M.E.S. Development of a nutritional food product for the Philippines. Undergraduate project report. Food Technology Department, Massey University, Palmerston North, New Zealand, 1973

35. DRIEBECK, N.J. Applied linear programming. Addison-Wesley, Reading, Massachusetts, 1969

36. NORMAN, J.R. and R.C. Bowrey. A review of linear programming techniques. British Chemical Engineering (1968) 13(11),1575

37. DANTZIG, G. Maximization of a linear function of variables subject to linear inequalities. Chapter XXIII in Koopmans, T. Activity analysis of production and allocation. Wiley, New York, 1951 (not seen)

38. WIRTHS, W, A. Becher and W. Prinz. Die ernährung von entwicklungsfähigen Völkern als lineares Entscheidungsmodell-unter besonderer Berücksiehtigung des Eiweissberdarfs. (The nutrition of developing populations in a linear model). Berichte über Landwirtschaft. (1965) 43 (3), 585

39. STIGLER, G.J. The cost of subsistence. Journal of Farm Economics (1945) 27, 303

40. SMITH, V.E. Linear programming models for the determination of palatable human diets. Journal of Farm Economics, (1959) 41 (2), 272

41. SMITH, P.E. The diet problem revisited: a model for convex economists. Journal of Farm Economics (1961) 43, 706

42. WIRTHS, W, A. Becher and W. Prinz. Versuche zur Berichnung von Minimalkosten der menschlichen Ernährung mit Hilfe der Linearen Programmierung. (Trials on the calculation of minimal costs of human diets by linear programming) Zeitchrift für Ernährungswissenschaft (1964) 39 (4), 39

43. PERYAM, D.R. Discussion : linear programming models for the determination of palatable human diets. Journal of Farm Economics (1959) 41 (2), 302

44. BALINTFY, J.L. Menu planning by computer. Communications of the Association for Computing Machinery (1964) 7 (4), 255

45. ECKSTEIN, E.F. Models for control of the nutritive content of menus planned by computer. Food Technology (1971) 25 (6), 600

46. ECKSTEIN, E.F. Menu planning by computer: the random approach to planning for consumer acceptability and nutritional needs. Thesis, Ph.D, Kansas State University, Manhattan, 1969

47. ECKSTEIN, E.F. Is the 'Diet Problem' identical to the 'Menu Planning Problem'? Management Science (1970) 16 (9), 527

48. SUKHATME, P.V. The world's hunger and future needs of food supplies. Journal of the Royal Statistical Society (1961) 124A, 463.

49. HRUBÝ, J. Versuch zur Bestimmung der optimal empfohlenen Lebensmittelmengen auf der Basis der Linearen Programmierung. (Attempts to find the optimal recommended amounts of food on the basis of linear programming). Zeitschrift für Ernährungswissenschaft (1970) 17 (10), 17

50. de MOOR, P, A. Hendrikx, M. Verhelst and J. vanderEecken. Het berekenen van de minimum kostprijs voor een medisch en sociaal verantwoorde voeding door middel van lineaire programmering. (Calculation of minimum costs for a medically and socially acceptable diet by linear programming). Voeding (1966) 27, 125

51. PATRICK, G.F. and M.H.R. Simões. Least-cost diets in Cristalena, Goiás, Brazil. Archives latino-americanos de nutrición (1971) 21 (3), 371. Original not seen. Abstracted in Nutrition Abstracts and Reviews (1972) 42 (2), No. 3903

52. DEAN, R. Use of linear programming in oil refinery operations. Process Control and Automation (1959) 6 (2), 59

53. JOHNSON, L.R. and M.P. Terrell. Calculation of empirical formulae by linear programming. Glass Industry (1968) 49, 760

54. GOLOMSKI, W.A. Linear programming in food blending. Annual Convention Transactions. American Society for Quality Control 17th Annual Convention, 1963, page 147

55. FRENCH, C.E. Computers for management. Agricultural Engineering (1964) 45 (6), 324

56. MAAS, A.C. Mathematical programming in the fruit and vegetable industry. Food Technology (1965) 19, 361

57. SNYDER, J.C. and L.L. Nelson. A management planning and control system. Food Technology (1967) 21, 1340

58. SWACKHAMER, G.L. and J.C. Snyder. A management control system for processed meat firms. Purdue University Agricultural Research Experiment Station, Research Bulletin No. 830, Lafayette, Indiana, 1967.

59. TILLMAN, F.A. and A. Ward. Decision-making in mill operations with linear programming. Cereal Science Today (1970) 15 (6),176

60. Anon. Solve tough problems with new math. Food Engineering (1963) 35 (4), 47

61. SKINNER, R.H. and G.B. Debling. Food industry applications of linear programming. Food Manufacture (1969) 44 (10), 35

62. BEN RAJEB, M. and H. Brusset. Generalisation de la programmation linéaire pour l'optimisation de la formulation des melanges alimentaires. 1. Programmation lineaire. (General use of linear programming for optimization of blended food formulations. 1. Linear programming.) Lebensmittel-Wissenschaft und Technologie (1973) 6(3), 97

63. WALSH, D.E, K.A. Ebeling and J.W. Dick. A linear programming approach to spaghetti processing. Cereal Science Today (1971) 16 (11), 385

64. INGLETT, G.E, W.F. Cavins, W.F. Kwolek and J.S. Wall. Using a computer to optimize cereal-based food composition. Cereal Science Today (1969) 14 (3), 69

65. CAVINS, J.F, Inglett, G.E. and J.S. Wall. Linear programming controls amino-acidbalance in food formulation. Food Technology (1972) 26 (6), 46

66. PINTO, G.F. Preparation of the best possible food mixtures. Archivos latino-americanos de nutrición (1971) 21 (2), 169. Original not seen. Abstracted in Nutrition Abstracts and Reviews (1972) 42 (1), No. 1304

67. BUFFA, A. Food technology and development. Food Engineering (1971) 43 (11), 79 and also 43 (12), 61

68. GASS, S.I. Linear programming-methods and applications. 2nd edition. McGraw Hill, New York, 1964

69. GARVIN, W.W. Introduction to linear programming. McGraw Hill, New York, 1960

70. FOOD and Agriculture Organization of the United Nations. FAO Production Yearbook 1969, Rome, 1970

71. FOOD and Agriculture Organization of the United Nations. FAO Fisheries Yearbook 1969, Rome, 1970

72. MIJARES, T.O. Private communication. Bureau of Agricultural Economics, Manila, Philippines, 1971

73. FERNANDEZ, W. Private communication. Massey University, Palmerston North, New Zealand, 1971

74. MIJARES, T.O. Private communication. Bureau of Agricultural Economics, Manila, Philippines, 1971

90. INTENGAN, C. Ll. Recommended dietary allowances for Filipinos - 1970 revision. Philippine Journal of Nutrition (1970) 23 (2),1

91. FLORENTINO, R.F. Energy requirements of Filipinos. Philippine Journal of Nutrition (1966) 19 (1,2), 50

92. NATIONAL Research Council. Recommended allowances. Food and Nutrition Board, National Academy of Sciences, Washington D.C. 7th edition, 1968

93. MINISTRY of Agriculture, Fisheries and Food. Manual of nutrition. 6th edition. H.M.S.O, London, 1961

94. BEATON, G.H. and E.W. McHenry. Editors, Nutrition: a comprehensive treatise. Academic Press, New York, 1964, vols 1 & 2

95. HUTCHINSON, R.C. Food for the people of Australia. Angus and Robertson, Sydney, Australia, 1958

96. DAVIDSON, S and S. Passmore. Human nutrition and dietetics. 4th edition. Livingstone, Edinburgh, Scotland, 1969

97. ROBINSON, C. Fiber in the diet. American Journal of Clinical Nutrition (1956) 4 (3), 288

98. JOINT FAO/WHO Expert Group. Calcium requirements. FAO Nutrition Meetings Report Series No. 30, FAO, Rome, 1962

99. JOINT FAO/WHO Expert Group. Requirements of ascorbic acid, vitamin D, vitamin B12, folate and iron. FAO Nutrition Meetings Report Series No. 47, FAO, Rome, 1970

100. JOINT FAO/WHO Expert Group. Requirements of vitamin A, thiamine, riboflavin and niacin. FAO Nutrition Meetings Report Series No. 41, FAO, Rome, 1967

101. ROSE, W.C. The amino-acid requirements of adult man. Nutrition Abstracts and Reviews (1957) 27, 631

102. HOLT, L.E. and S.E. Snyderman. Protein and amino-acid requirements of infants and children. Nutrition Abstracts and Reviews (1965) 35 (1), 1

103. NAKAGAWA, I, T. Takahashi, T. Suzuki and K. Kobayashi. Amino-acid requirements of children; quantitative amino-acid requirements of girls based on nitrogen balance method. Journal of Nutrition (1965) 86, 333

104. ALLISON, J.B. The ideal aminogram. In Proceedings of the Fifth International Congress on Nutrition. Federation of American Societies for Experimental Biology, Washington D.C. 1961, page 66.

105. HARPER, A.E. Advances in our knowledge of protein and amino-acid requirements. Federation Proceedings (1959) 18 (2), 104

106. CARPENTER, K.J. Problems in formulating simple recommended allowances of amino acids for animals and man. Proceedings of the Nutrition Society (1971) 30, 73

75. FOOD and Nutrition Research Center. Food composition tables recommended for use in the Philippines. Handbook 1 (4th revision), Manila, Philippines, 1968

76. WATT, B.K. and A.L. Merrill. Composition of foods - raw, processed and prepared. Agricultural Handbook No. 8, United States Department of Agriculture, Washington D.C. 1963

77. LEUNG, W.W, R.K. Pecot and B.K. Watt. Composition of foods used in far-eastern countries. Agricultural Handbook No. 34, United States Department of Agriculture, Washington D.C. 1952

78. ORR, M.L. Pantothenic acid, vitamin B6 and vitamin B12 in foods. Home Economics Research Report No. 36, United States Department of Agriculture, Washington D.C. 1969

79. McCANCE, R.A. and E.M. Widdowson. The composition of foods. Medical Research Council Special Report Series No. 297, H.M.S.O, 1960

80. PHILIPPINES Institute of Nutrition. Food composition tables recommended for use in the Philippines. Handbook No. 1 (1st edition), Department of Health, Manila, Philippines, 1951

81. LONTOC, A.V. and O.N. Gonzales. Vitamin B12 content of some Philippine plant foods. Philippine Journal of Nutrition (1968) 21 (3), 163

82. LONTOC, A.V, O.N. Gonzales and L.B. Dimaunahan. Folic acid content of some Philippine foods. Philippine Journal of Science (1966) 95, 311

83. SORIANO, M,I.C. Abdon and N.V. Santiago. Amino-acid content of some Philippine animal proteins. Philippine Journal of Science (1965) 94 (1), 1

84. FOOD and Agriculture Organization of the United Nations. Amino-acid content of foods and biological data on proteins. Nutrition Division, Rome, 1969

85. HARVEY, D. Tables of the amino acids in foods and feeding stuffs. 2nd edition.Technical communication No. 19. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks. England, 1970

86. UNITED Nations Organization. Demographic Yearbook 1969, New York, 1970

87. FOOD and Agriculture Organization of the United Nations. Calorie requirements. Nutritional Studies No. 15, Rome, 1957

88. JOINT FAO/WHO Expert Group. Protein requirements. FAO Nutrition Meetings Report Series No. 37, FAO, Rome, 1965

89. JOINT FAO/WHO Expert Group. Requirements of vitamin A, thiamine, riboflavin and niacin. FAO Nutrition Meetings Report Series No. 41, FAO, Rome, 1967

107. PAYNE, P.R. Effect of quantity and quality of protein on the protein value of diets. Voeding (1969) 30, 182 (not seen)

108. BLOCK, R.J. and H.H. Mitchell. The correlation of the amino-acid composition with their nutritive value. Nutrition Abstracts and Reviews (1946) 16, 249

109. INTERNATIONAL Business Machines World Trade Corporation. Program product: Linear programming system/1130 (LPS/1130) program description. Program number 5711-C01 2nd edition, New York, 1971

110. OSER, B.L. An integrated essential amino-acid index for predicting the biological value of proteins. p. 281. In Albanese, A.A. editor. Protein and amino-acid nutrition. Academic Press, New York, 1959

111. CRESTA, M.J. Perissé and M. Autret. Study of the correlations between biological and chemical measurements of food protein quality. FAO Nutrition Newsletter (1969) 7 (2),1

112. LEE, S.M. Goal programming for decision analysis. Auerbach Publishers, Inc. Philadelphia, 1972

113. FOOD and Nutrition Research Center. Nutrition survey of Metropolitan Manila. National Science Development Board, Manila, Philippines, 1962.

114. FOOD and Nutrition Research Center. Nutrition survey of Ilocos-Mountain Province region. National Science Development Board, Manila, Philippines, 1963

115. FOOD and Nutrition Research Center. Nutrition survey of Cagayan Valley-Batanes region. National Science Development Board, Manila, Philippines, 1963

116. FOOD and Nutrition Research Center. Nutrition survey of Southern Tagalog region. National Science Development Board, Manila, Philippines, 1965

117. FOOD and Nutrition Research Center. Nutrition survey of Western Visayas region. National Science Development Board, Keystone Printing Press, Manila, Philippines, 1968

118. FOOD and Nutrition Research Center. Nutrition Survey of Eastern Visayas region. National Science Development Board, Keystone Printing Press, Manila, Philippines, 1969.

119. FOOD and Nutrition Research Center. Nutrition Survey of Southwestern Mindanao region. National Science Development Board, Manila, Philippines, 1971

120. FOOD and Nutrition Research Center. Private communication. Manila, Philippines 1973

121. DEPARTMENT of Commerce and Industry. Preliminary report on the BCS annual survey of manufactures 1971. Bureau of Census and Statistics, Manila, Philippines, 1973.

122. DEPARTMENT of Commerce and Industry. Annual survey of manufactures: 1962 volume VI and also 1968, volume VII, Bureau of Census and Statistics, Manila, Philippines, 1965 and 1971

123. DEPARTMENT of Commerce and Industry. Directory of large establishments, 1967 economic census. Bureau of Census and Statistics, Manila, Philippines, 1971

124. DIEHL, R.K. Systematic generation of new product ideas: the method approach. Food Product Development (1969) 3(8), 26

125. KOTLER, P. Marketing management - analysis, planning and control. Prentice Hall, Englewood Cliffs, New Jersey, U.S.A., 2nd edition, 1972, chapter 13

126. REILLY, G. Extended creativity group - short cut for conceptualizing potential products. Food Product Development (1971) 5 (6), 36

127. HUSSEY, J. Creativity and idea generation through consumer groups. Food Product Development (1973) 7 (1), 28 and also (1973) 7 (2), 24

128. MOTLEY, C.M and R.D. Newton. The selection of projects for industrial research. 15th National Meeting of Operations Research Society of America, Washington D.C. (1959) (not seen)

129. MONTEITH, G.S. R & D administration. Iliffe Books Ltd, London, 1969, p. 52

130. CHURCHMAN, C.W, R.L. Ackoff and E.L. Arnoff. Chapter 6. Introduction to operations research, Wiley, New York, 1957 (not seen)

131. FREIMER, M. and L. Simon. The evaluation of potential new product alternatives. Management Science (1967) 13, B279

132. DEAN, B.V. and M. J. Nishry. Scoring and profitability models for evaluating and selecting engineering projects. Operations Research (1965) 13, 550

133. MONTGOMERY, D.B. and G.L. Urban. Management science in marketing. Prentice-Hall, Englewood Cliffs, New Jersey, 1969, p. 307

134. KOTLER, P. Marketing management-analysis, planning and control Prentice-Hall, Englewood Cliffs, New Jersey, 2nd edition, 1972, p. 480

135. KLINE, C.H. The strategy of product policy. Harvard Business Review (1955) July-August, 91

136. O'MEARA, J.T. Junior. Selecting profitable products. Marvard Business Review (1961) 39 (1), 83

137. KING. W.R. Quantitative analysis for marketing management. McGraw Hill, New York, 1967. p. 122

138. LARMOND, E. Methods for sensory evaluation of food. Canada Department of Agriculture, Publication No. 1284, Ottawa, 1970

139. DUCKWORTH, W.E. Statistical techniques in technological research: an aid to research productivity. Methuen, London, 1968

140. LEACH, H.W. Gelatinization of starch. In Whistler R.L. and E.F. Paschall. Starch: chemistry and technology. Academic Press, New York, 1965, volume 1, p. 289

141. BOARD, P.W. Determination of thermal processes for canned foods. Source - Biotechnology Department, Massey University, Palmerston North, New Zealand.

142. EARLE, R.L. Unit operations in food processing. Pergamon Press, 1966, p. 116

143. HARRIS, R.S. and H. von Loesecke, editors. Nutritional evaluation of food processing. John Wiley, New York, 1960.

144. CAIN, R.F. Water soluble vitamins - changes during processing and storage of fruit and vegetables. Food Technology (1967) 21, 998

145. BORENSTEIN, B. Vitamins and amino acids. In Furia, T. editor. Handbook of food additives. Chemical Rubber Company, Cleveland, Ohio, 1968, chapter 3.

146. LANG, K. Influence of cooking on foodstuffs. World Review of of Nutrition and Dietetics (1970) 12, 266

147. SCHROEDER, H.A. Losses of vitamins and trace minerals resulting from processing and preservation of foods. American Journal of Clinical Nutrition (1971) 24, 562

148. FELICIOTTI, F. and W.B. Esselen. Thermal destruction rates of thiamine in pureed meats and vegetables. Food Technology (1957) 11 (2), 77

149. VOJNOVICH, C. and V.P. Pfeifer. Stability of ascorbic acid in blends with wheat flour, CSM, and infant cereals. Cereal Science Today (1970) 15 (9), 317

150. WANNIGER, L.A. Mathematical model predicts stability of ascorbic acid in food products. Food Technology (1972) 26 (6), 42

151. EARLE, R.L. Private communication, Massey University, Palmerston North, New Zealand, 1974

152. BUREAU of Agricultural Economics. Private communication, Manila, Philippines, 1973

153. DEPARTMENT of Commerce and Industry. Advance report. National Summary Philippines 1970 census of population and housing. Bureau of Census and Statistics. Manila, Philippines, 1972

154. ABDON, I. Coconut as a source of protein. Philippine Journal of Nutrition (1969) 22, 104

155. BAUERNFEIND, J.C. Vitamin fortification and nutrified foods. In Proceedings of Third International Congress in Food Science and Technology, Washington D.C. 1970. p. 215

156. HARRIS, R.S. Supplementation of foods with vitamins. Journal of the Science of Food and Agriculture (1959) 7 (2) 88

157. SCRIMSHAW, N.S. and A. Altschul, editors. Amino-acid fortification of protein foods. MIT Press, Cambridge, Massachusetts, 1971.

158. BORENSTEIN, B. Rationale and technology of food fortification with vitamins, minerals and amino acids. CRC Critical Reviews in Food Technology (1971) 2 (2), 171

159. LACHANCE, P.A. Nutrification: a concept for assuring nutritional quality by primary intervention in feeding systems. Journal of Agricultural and Food Chemistry (1972) 20 (3), 522

160. FAO/WHO/UNICEF Protein Advisory Group. PAG Statement No. 9, Amino-acid fortification. United Nations, New York, 1970

161. INTENGAN, C. Ll. Personal communication. Food and Nutrition Research Center, Manila, Philippines, 1973.

162. MILNER, M. Editor. Protein-enriched cereal foods for world needs. American Association of Cereal Chemists, St. Paul, 1969

163. MARNETT, L.R, R.J. Tenney and V.D. Barry. Methods of producing soy-fortified breads. Cereal Science (1973) 18, 38

164. POMERANZ, Y and K.F. Finney. Protein-enriched breads. Process Biochemistry (1970) 8, 16

165. TSEN, C.C. and W.J. Hoover. High protein bread from wheat flour fortified with full fat soyflour. Cereal Chemistry (1973) 50, 7

166. MATTHEWS, R.H, E.J. Sharpe and W.M. Clark. The use of some oilseed flours in bread. Cereal Chemistry (1970) 47, 181

167. ROGERS, L.V. and H.H. Welton. High milk protein bread. Journal of Dairy Science (1959) 42, 62

168. DALBY, G. Protein fortification of bread: baladi bread as an example. In editor. Milner, M. Protein enriched cereal foods for world needs. American Association of Cereal Chemists, St. Paul, 1969.

169. HARRIS, R.S. Attitudes and approaches to supplementation of foods with nutrients. Journal of Agricultural and Food Chemistry (1968) 16 (2), 149

170. BROOKE, C.L. Enrichment and fortification of cereals and cereal products with vitamins and minerals. Journal of Agricultural and Food Chemistry (1968) 16 (2), 163

171. RUBIN, S.H. and W.M. Cort, Aspects of vitamin and mineral enrichment. In Editor Milner, M. Protein enriched cereal foods for world needs. American Association of Cereal Chemists, St. Paul, 1969

172. EHLE, S.R, N.L. Hause and D.E. Paul. Taste and texture evaluation of lysine supplemented baked products. Cereal Science (1959) 4, 74

173. MITSUDA, H. New approaches to amino acid and vitamin enrichment in Japan. In editor. Milner, M. Protein enriched cereal foods for world needs. American Association of Cereal Chemists, St. Paul, 1969, page 208

174. BEIGLER, M.A. Practical problems of amino acid fortification. In editor. Milner, M. Protein enriched cereal foods for world needs. American Association of Cereal Chemists, St. Paul, 1969, page 200.

175. DAWSON, E.R. and G.W. Martin. Vitamin B1 estimation in yeast and breadmaking. Journal of the Society of Chemistry in Industry (1941) 60, 241

176. HOFFMAN, C, T.R. Schweitzer and G. Dalby. The loss of thiamine in bread on baking and toasting. Cereal Chemistry (1940) 17, 737

177. MALEKI, M. and S. Daghir. Effect of baking on retention of thiamine, riboflavin and niacin in Arabic bread. Cereal Chemistry (1967) 44, 483

178. THEWLIS, B.H. Fate of ascorbic acid in the Chorleywood bread process. Journal of the Science of Food and Agriculture (1971) 22, 16

179. ROSENBERG, H.R. and E.L. Rhodenburg. The fortification of bread with lysine. 2. The nutritional value of fortified bread. Archives of Biochemistry and Biophysics (1952) 37, 461 (not seen). In Nutrition Abstracts and Reviews (1953) 23 (1), No. 607

180. HORN, M.J, C.C. Fifield, A.E. Blum and H.W. Warren. The distribution of amino acids in wheat and certain wheat products. Cereal Chemistry (1958) 35, 411

181. WILCKE, H.L, D.T. Hopkins, L F. Rentzel and L.W. Declue. Evaluation of linear programming techniques in formulating human diets with rat-feeding tests. Journal of Nutrition (1973) 103 (2), 179

182. Aragon C.T. and Darrah, L.B. Cereal consumption patterns. The Statistical Reporter (1972) 26, 47

APPENDICES

APPENDIX 1. Linear programming calculations

Using the example quoted in 3.2, the problem is stated as:

$$\begin{aligned} \text{minimize} \quad & 3a + 8b \\ \text{subject to} \quad & 150a + 100b \geq 3000 \\ & 2a + 8b \geq 80 \\ & 3a + b \geq 45 \\ & a,b \geq 0 \end{aligned}$$

The Simplex method of solution

To use the Simplex method, developed by Dantzig, the inequalities are made up to equalities by subtracting slack variables, denoting the amounts by which the constrained variables exceed the requirements. These slacks are similar to normal variables in that they must have positive values, i.e.

$$\begin{aligned} \text{minimize} \quad & 3x_1 + 8x_2 \\ \text{subject to} \quad & 150x_1 + 100x_2 - x_3 = 3000 \\ & 2x_1 + 8x_2 - x_4 = 80 \\ & 3x_1 + x_2 - x_5 = 45 \\ & x_1, x_2, x_3, x_4, x_5 \geq 0 \end{aligned}$$

Here x_1, x_2 represent the variables a, b respectively and x_3, x_4, x_5 are the slack variables. Normally it is possible to choose the slack variables to represent a starting feasible solution with the other variables initially set at zero. In the example, however, this would result in the slack variables taking on disallowed negative values. An initial solution or basis is obtained by adding artificial variables to each equation, which are similar to the other variables in that they must take only positive values. The artificial variables differ in that they are given some large unknown cost. They should thus be removed from the solution in the initial stages, as minimum cost is sought. The problem is fully stated as:

$$\begin{aligned} \text{minimise} \quad & 3x_1 + 8x_2 + x_6 + wx_7 + wx_8 \\ \text{subject to} \quad & 150x_1 + 100x_2 - x_3 + x_6 = 3000 \\ & 2x_1 + 8x_2 - x_4 + x_7 = 80 \\ & 3x_1 + x_2 - x_5 + x_8 = 45 \\ & x_1, \ldots\ldots\ldots, x_8 \geq 0 \end{aligned}$$

x_6, x_7, x_8 represent the artificial variables and w the large unknown cost associated with them. To determine the optimum solution, the model is expressed in matrix form

solution variables	cost	real variables		slack variables			artifical variables			solution value
		x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	
x_6	w	150	100	-1	0	0	1	0	0	3000
x_7	w	2	8	0	-1	0	0	1	0	80
x_8	w	3	1	0	0	-1	0	0	1	45
Cost		-3	-8	0	0	0	0	0	0	0
Σartificial cost		155	109	-1	-1	-1	0	0	0	3125

The variables in the basis or solution are indicated at the far left along with their costs. The remainder of the matrix contains all the other information in the model equations described earlier. The cost row contains the cost coefficients of all variables not in the solution. This is in the form $z - 3x_1 - 8x_2 - 0x_3 - 0x_4 - 0x_5 = 0$ where z is the total cost ($z=3x_1 + 8x_2$). The bottom row is formed by adding all coefficients corresponding to artificial variables in the solution which in this case involves all three rows. This supplementary row is used to ensure that all artificial variables are removed from the solution i.e. that bottom row becomes zero. If this is not possible then the problem is infeasible. After feasibility has been ascertained, the cost row is used to guide calculations to the minimum cost solution. It should be noted that variables in the solution x_6, x_7, x_8 always have a unit column or vector, i.e. unity in the row corresponding to the position of each variable in the solution vector.

The computational system involves the selection of the best column variable to improve the present solution, selection of the row variable presently in the solution to be removed and replaced by this column variable, recalculation of the matrix with these changes and testing if this new system is optimal. Each of these steps is called an iteration and once feasibility has been achieved, iterations correspond to moving from vertex to vertex in the solution space until the objective becomes optimal.

In the nutrition problem being considered, the initial solution is wholly an artificial basis and for the problem to be truly feasible, these artificial variables must be removed, i.e. forced to zero. The bottom row or secondary target function indicates that column x_1 would be best in the solution as the largest positive number occurs in this column. This number corresponds to the total cost of artificial variables (150w + 2w + 3w = 155w) relative to x_1 and as this is the largest figure, moving x_1 into the solution to remove an artificial variable would bring about the greatest reduction in artificial variable effect. The artificial variable to be removed from the initial basis is taken as that which leaves the solution values positive when the matrix is manipulated to a unit vector or column. In practice, this is the minimum value of the quotient solution value/row value for all positive elements in the column being inserted. In column x_1 this is the element corresponding to x_8 ($45/3 < \frac{3000}{150} < \frac{80}{2}$). This element is called the pivot and signifies the position of the column variable being entered and the row variable being removed from the current solution. Here x_1 replaces x_8 and one artificial variable is removed. Recalculation of the matrix elements results in the x_1 column becoming a unit vector and the x_8 column being removed. The calculations on the matrix are elementary row operations in order to express the basis variables x_6, x_7, x_1 entirely in terms of the non-basis variables. This is quickly achieved by following the rules:

1. Divide all row elements in the pivot row by the pivot
2. Calculate all other element values from the relationship
   New value = old value - (value in same column but pivot row x value in same row but pivot column) ÷ pivot
   or in matrix notation

1. $\alpha_{ij} = \alpha_{ij}/\alpha_{ik}$

2. $\alpha_{ij}' = \alpha_{ij} - (\alpha_{\ell j}/\alpha_{\ell k}) \times \alpha_{ik} \quad i \neq \ell \; ; \qquad \alpha_{\ell j}' = \alpha_{\ell j}/\alpha_{\ell k}$

where a_{ij} represents the element in row i and column j of the matrix; a_{ij}' represents the new value of this element being calculated; 1 identifies the pivot row or position of variable being removed and k the pivot column or position of the new basis variable.

Thus α_{31} is the pivot i.e. $\ell = 3$, $k = 1$.

and $\alpha_{11} = \alpha_{11} - \frac{\alpha_{31}}{\alpha_{31}} \times \alpha_{11} = 0$

$\alpha_{12}' = \alpha_{12} - \frac{\alpha_{32}}{\alpha_{31}} \times \alpha_{11} = 100 - 1 \times 150/3 = 50$

and so on for all elements in the matrix.

Thus the transformed matrix is:

solution variables	cost	x_1	x_2	x_3	x_4	x_5	x_6	x_7	solution value
x_6	w	0	50	-1	0	50	1	0	750
x_7	w	0	$\frac{22}{3}$	0	-1	$\frac{2}{3}$	0	1	50
x_1	3	1	$\frac{1}{3}$	0	0	$\frac{-1}{3}$	0	0	15
cost		0	-7	0	0	-1	0	0	45
Σartificial cost		0	$\frac{172}{3}$	-1	-1	$\frac{152}{3}$	0	0	800

This solution $x_1 = 15$, $x_2 = 0$ corresponds to the point G on the graph in Fig. 3.1 which is not in the feasible area. The infeasibility is shown in the matrix by the element a_{58} with the value 800 indicating the sum of the infeasibilities to be non-zero. However, this situation can be improved as there are still positive artificial costs in the bottom row, the largest corresponding to column 2. The cycle is repeated x_7 being removed and the matrix being transformed to:

solution variable	cost	x_1	x_2	x_3	x_4	x_5	x_6	solution value
x_6	w	0	0	-1	$\frac{75}{11}$	$\frac{500}{11}$	1	$\frac{4500}{11}$
x_2	8	0	1	0	$\frac{-3}{2}$	$\frac{1}{11}$	0	$\frac{75}{11}$
x_1	3	1	0	0	$\frac{1}{22}$	$\frac{-4}{11}$	0	$\frac{140}{11}$
cost		0	0	0	$\frac{-21}{22}$	$\frac{-4}{11}$	0	$\frac{1020}{11}$
Σartificial cost		0	0	-1	$\frac{75}{11}$	$\frac{500}{11}$	0	$\frac{4500}{11}$

This corresponds to the point H in the graphical representation. Again improvement is possible, x_5 replacing x_6 and leading to the matrix with no artificial variables in the basis:

solution variable	cost	x_1	x_2	x_3	x_4	x_5	solution value
x_5	0	0	0	$\frac{-11}{500}$	$\frac{3}{20}$	1	9
x_2	8	0	1	$\frac{1}{500}$	$\frac{-3}{20}$	0	6
x_1	3	1	0	$\frac{-1}{125}$	$\frac{1}{10}$	0	16
cost		0	0	$\frac{-1}{125}$	$\frac{-9}{10}$	0	96
Σartificial cost		0	0	0	0	0	0

The sum of infeasibilities is now zero, indicating that this is a feasible solution. The primary objective function corresponding to row 4 is now used to optimize the problem. However, no positive cost factors remain in this row, indicating that if any of the basis variables were replaced by x_3 or x_4 the cost would be increased and the situation rendered sub-optimal. The minimum cost is therefore 96 cents, corresponding to the element a_{46} in the last matrix. The optimal solution is a final mixture of 16 units (1600g) of x_1 or A and 6 units of B (600g) - thus meeting the calorie and protein requirements exactly ($x_3 = x_4 = 0$), exceeding the fat requirements by 9 units (9g) ($x_5 = 9$) and costing the minimum amount, 96 cents.

Summary of Simplex method for the nutrition problem

The simplex method is carried out by setting up the problem in matrix format with slack variables and artificial variables as required to remove inequalities from the expressions.

1. Obtain an initial basis (solution) usually from slack variables or artificial variables which exist as unit vectors in the matrix, the number of variables in the basis being equal to the number of rows.
2. In this problem artificial variables are present so a secondary target function is formed by adding up all the elements in each column corresponding to artificial basis variable rows.
3. Select the largest positive element in this objective row as the entering variable.
4. Select the variable to be removed by identifying the pivot as being the element with the minimum positive value of (solution value/ element) corresponding to each row.
5. Transform all elements of the matrix by formulae $\alpha'_{\ell j} = \alpha_{\ell j}/\alpha_{\ell k}$ and $\alpha_{ij}' = \alpha_{ij} - \frac{\alpha_{\ell j}}{\alpha_{\ell k}} \cdot \alpha_{ik}$ for $i \neq \ell$

   Where α'_{ij} is the transformed element corresponding to α_{ij} in the matrix; i indicates the row number, j the column number, 1 the pivot row number and k the pivot column number.
6. Check if the sum of infeasibilities element is zero.(a). If not continue steps 3 to 6 till the value is zero (see b) or until no more positive values exist in the secondary target row. In the latter case the problem does not have a feasible solution as one or more artificial variables cannot be removed. (b) A feasible solution has been reached which may or may not be the optimum. The secondary target function is removed and the initial objective is used in exactly the same way, following steps 3 - 5, until no positive elements remain in the objective row. The optimum solution has then been found, the values of the variables in the solution being given in the last column and the value of the objective in the last row of this column.

The Revised Simplex method of solution

The Simplex method is the basis of all modern computer codes for solving linear programming problems. Problems can be very large containing thousands of columns and hundreds of rows. The Revised Simplex method was developed by Dantzig in the early 1950's to reduce the amount of computation required.

The method is essentially the same as the Simplex method. However, calculations are performed only on the 'inverse' of the artificial sub-matrix drawn up start the Simplex method. This is an identity matrix. The specifications matrix is held unchanged throughout the calculations, although it is worked on by the inverse matrix to identify entering and leaving variables and the right hand side is worked on throughout with the inverse matrix to indicate the intermediate and final solutions.

The technique is illustrated below with the example of the previous section (Fig. A.1.1)

1. The matrix is set up from the data, incorporating slack and artificial variables where necessary. If artificial variables are required then a secondary target function is formed which is the negative of the sum of all the coefficients in each column corresponding to artificial variables in the initial basis (row 5). The identity matrix or inverse is denoted as matrix U and the problem matrix as A.

2. If the sum of the infeasibilities is < 0 ($a_{5,11}$) then the last row of U multiplies the matrix A to form a row vector δ_j (j = column number). If the sum of the infeasibilities is zero then move to step 7.

3. If all $\delta \geq 0$ then the sum of infeasibilities is at its maximum and so no feasible solution exists for the problem. If at least one $\delta_j < 0$ then that which is the minimum (max $|\delta_j|$) indicates the column a_k which will be introduced into the solution.

4. Multiply the entering vector in A by the matrix U. The variables a_1 to be eliminated from the solution is that corresponding to the minimum positive ratio - (solution value in that row/element in entering column in that row.)

5. The matrix U and the solution vector d, values are transformed by the formulae:

$$\alpha'_{ij} = \alpha_{ij} - \frac{\alpha_{\ell j}}{\alpha_{\ell k}} \cdot \alpha_{ik} \quad \text{for } i \neq \ell$$

$$\alpha'_{\ell j} = \alpha_{\ell j}/\alpha_{\ell k}$$

6. Using the transformed rows of U the steps are repeated until it is determined either that no feasible solutions exist or that the value of the sum of infeasibilities is zero at which point step 7 is carried out.

7. The primary objective function replaces the secondary function and similar calculations are performed.
   a) The matrix A is multiplied by the objective row vector (row 4) to obtain a row vector γ_j.

   b) If all $\gamma_j \geq 0$ then the objective is at its maximum and the corresponding basic feasible solution is optimum. The negative value of the total cost is the true minimum cost for the problem. If at least one $\gamma_j < 0$ then the minimum, δ_j identifies the column vector a_k to be introduced.

c) The identified column is multiplied by the matrix U and the pivot identified in the normal way to indicate the row to be eliminated a_1. If all the column elements are negative then the problem is unbounded and can be infinitely increased.

d) The matrix U and the solution vector are transformed in the normal way.

The steps are repeated until an optimum solution with either a finite or infinite value of the objective function is determined.

Fig. A.1.1 <u>Revised Simplex method calculations</u>

	Row index column	Basis variable index	Matrix A 1	2	3	4	5	Matrix U 6	7	8	9	10	Solution vector, d 11
	1	6	150	100	-1	0	0	1	0	0	0	0	3000
$\delta_k=\delta_1=-155$	2	7	2	8	0	-1	0	0	1	0	0	0	80
pivot=a_{31}	3	8	(3)	1	0	0	-1	0	0	1	0	0	45
	4	9	3	8	0	0	0	0	0	0	1	0	0
	5	10	155	-109	1	1	1	0	0	0	0	1	-3125
	1	6		50				1	0	-50	0	0	750
$\delta_k=\delta_2=\frac{-172}{3}$	2	7		($\frac{22}{3}$)				0	1	$\frac{-2}{3}$	0	0	50
pivot=a_{22}	3	1		$\frac{1}{3}$				0	0	$\frac{1}{3}$	0	0	15
	4	9		7				0	0	-1	1	0	-45
	5	10		$\frac{-172}{3}$				0	0	$\frac{155}{3}$	0	1	-800
	1	6					($\frac{500}{11}$)	1	$\frac{-75}{11}$	$\frac{-500}{11}$	0	0	$\frac{4500}{11}$
$\delta_k=\delta_5=\frac{-500}{11}$	2	2					$\frac{1}{11}$	0	$\frac{3}{22}$	$\frac{-1}{11}$	0	0	$\frac{75}{11}$
pivot=a_{15}	3	1					$\frac{-4}{11}$	0	$\frac{-1}{22}$	$\frac{4}{11}$	0	0	$\frac{140}{11}$
	4	9					$\frac{4}{11}$	0	$\frac{-21}{22}$	$\frac{-4}{11}$	1	0	$\frac{-1020}{11}$
	5	10					$\frac{-500}{11}$	0	$\frac{86}{11}$	$\frac{511}{11}$	0	1	$\frac{-4500}{11}$
	1	5						$\frac{11}{500}$	$\frac{-3}{20}$	-1	0	0	9
$\gamma_j \geq 0$	2	2						$\frac{-1}{500}$	$\frac{3}{20}$	0	0	0	6
opt.solution	3	1						$\frac{1}{125}$	$\frac{-1}{10}$	0	0	0	16
	4	9						$\frac{-1}{125}$	$\frac{-9}{10}$	0	1	0	-96
	5	10						1	1	1	0	1	0

The optimum solution has been found with $x_1 = 16$, $x_2 = 6$, $x_5 = 9$ and the minimum cost = 96.

This trivial problem does not indicate the real savings in computation achieved by this method since little extra calculation is involved in the Simplex method. However, in larger problems, with many more elements involved, the savings in computation and time are considerable especially in terms of computer storage, working and solution time.

Advantages of this Revised Simplex method include:

1. All matrix elements do not require to be transformed at each iteration as in the earlier Simplex method. If a matrix with m rows and n columns is involved then the Simplex method transforms essentially an m x (n-m) matrix at each iteration (the m columns of the basic variables (m) require transformation only to unit vectors so that the number of columns really transformed are n-m). While the Revised Simplex method transforms an (m+2) x (m+1) array which approximates to m x m. As there are normally very many more columns than rows (n >> m) this represents a reduction in computational effort and computer run time. Thus larger problems can be evaluated since more working storage would be available in the revised method.

2. The calculations are performed efficiently as only rows and columns necessary for each iteration are involved. Computer handling is simplified and quickened as only cumulative products are required and advantage can be taken of the large number of zeros usually present in the matrix. This removes the compound arithmetic required to calculate each matrix element in the earlier method.

The product form of the inverse method

This is a derivation of the revised method and offers more savings in computational effort and time as even less data is stored from one iteration to the next.

This is possible as elementary matrices only are stored instead of the inverse. An elementary matrix is a unit matrix with one unique column or row. In this example elementary matrices of the form below are stored. These correspond to the column variables which are consecutively introduced into the basis as the optimization proceeds.

$$\begin{bmatrix} 1 & 0 & \cdots & \alpha_{\ell k}/\alpha_{\ell k} & \cdots & 0 \\ 0 & 1 & \cdots & \alpha_{zk}/\alpha_{\ell k} & \cdots & 0 \\ \vdots & \vdots & & & & \vdots \\ 0 & 0 & \cdots & 1/\alpha_{\ell k} & \cdots & 0 \\ \vdots & \vdots & & & & \vdots \\ 0 & 0 & \cdots & \alpha_{mk}/\alpha_{\ell k} & \cdots & 1 \end{bmatrix}$$

where 1 indicates pivot row number
and k indicates pivot column number

As all elementary matrices are of the same form they can be uniquely stored by the computer solely by their column elements and an integer to denote to which column these elements belong. When the optimum solution is identified the elementary matrices premultiply the initial inverse (the identity matrix) to provide the final solution matrix. This system is illustrated below with the nutrition problem example.

In storage are held the matrix A, the starting inverse matrix B^{-1} and the solution vector d.

Row/col no.	A 1	2	3	4	5	d	Index of basis	B^{-1}				
1	150	100	-1	0	0	3000	6	1	0	0	0	0
2	2	8	0	-1	0	80	7	0	1	0	0	0
3	3	1	0	0	-1	45	8	0	0	1	0	0
4	3	8	0	0	0	0	9	0	0	0	1	0
5	-155	-109	1	1	1	-3125	10	0	0	0	0	1

Firstly the column variable entering is derived by obtaining the minimum element of the product of row 5 of B^{-1} and each column of A. This is column 1. The row to be eliminated is the minimum of the quotient of each element of $\underline{d}$ divided by each element of the column selected in $\underline{A}$ which is non-negative. In this case row 3 or x_8 is to be removed from the basis. This data is then stored as the elementary matrix.

$$\begin{bmatrix} 1 & 0 & \frac{-a_{13}}{a_{33}} & 0 & 0 \\ 0 & 1 & \frac{a_{23}}{a_{33}} & 0 & 0 \\ 0 & 0 & \frac{+1}{a_{33}} & 0 & 0 \\ 0 & 0 & \frac{-a_{43}}{a_{33}} & 1 & 0 \\ 0 & 0 & \frac{-a_{53}}{a_{33}} & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & -50 & 0 & 0 \\ 0 & 1 & \frac{-2}{3} & 0 & 0 \\ 0 & 0 & \frac{1}{3} & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 \\ 0 & 0 & \frac{155}{3} & 0 & 1 \end{bmatrix}$$

which is contracted as the vector $V_3 = (3; \; -50, -\frac{2}{3}, \frac{1}{3}, -1, 155/3$ in computer storage.

The new inverse is calculated by premultiplying the old inverse by the elementary matrix and $B^{-1}d$ is obtained for the solution values. The sum of the infeasibilities is -800 so a feasible solution has not yet been obtained. The product of row 5 of B^{-1} with A indicates the entering variable to be x_2. The column α_{i2} is formed from $B^{-1}A_{i2}$ - the product of the inverse and the second column of the matrix A. Examination of the quotients α_{i2}/d_i which are > 0 indicates that row 2 (x_7) should be replaced by x_2. The changes in the matrix are recorded in the elementary matrix vector Vp (p = 2). This process is continued as in the previous method until the sum of the infeasibilities is zero and in this case no further optimization is possible. The tables below indicate this stepwise process:

	Basis variables	Inverse Matrix B^{-1}					Solution value $B^{-1}d$	Inserted column $B^{-1}a_2$	Elementary matrix stored V_2
Iteration	6	1	0	-50	0	0	750	50	$-\frac{75}{11}$
1	7	0	1	$-\frac{2}{3}$	0	0	50	$\frac{22}{3}$	$\frac{3}{22}$
	1	0	0	$\frac{1}{3}$	0	0	15	$\frac{1}{3}$	$\frac{-1}{22}$
	9	0	0	-1	1	0	-45	7	$\frac{-21}{22}$
	10	0	0	$\frac{155}{3}$	0	1	-800	$\frac{-172}{3}$	$\frac{86}{11}$
Iteration								$B^{-1}a_5$	V_1
2	6	1	$\frac{-75}{11}$	$\frac{-500}{11}$	0	0	$\frac{4500}{11}$	$\frac{500}{11}$	$\frac{11}{500}$
	2	0	$\frac{3}{22}$	$\frac{-1}{11}$	0	0	$\frac{75}{11}$	$\frac{1}{11}$	$\frac{-1}{500}$
	1	0	$\frac{-1}{22}$	$\frac{4}{11}$	0	0	$\frac{140}{11}$	$\frac{-4}{11}$	$\frac{1}{125}$
	9	0	$\frac{-21}{22}$	$\frac{-4}{11}$	1	0	$\frac{-1020}{11}$	$\frac{4}{11}$	$\frac{-1}{125}$
	10	0	$\frac{86}{11}$	$\frac{511}{11}$	0	1	$\frac{-5320}{11}$	$\frac{-500}{11}$	1
Iteration 3	5	$\frac{11}{500}$	$\frac{-3}{20}$	-1	0	0	9		
	2	$\frac{-1}{500}$	$\frac{3}{20}$	0	0	0	6		
	1	$\frac{1}{125}$	$\frac{-1}{10}$	0	0	0	16	optimum	
	9	$\frac{-1}{125}$	$\frac{-9}{10}$	0	1	0	-96		
	10	1	1	1	0	1	0		

The computer codes merely store the vectors of the elementary matrices at each iteration along with the initial problem matrix and the starting inverse. The type of calculation illustrated is carried out but not all this information is stored. Many of the steps are carried out by induction from the elementary matrix vectors:

(a) the bottom rows are required at each iteration to evaluate which column variable should be introduced.

Iteration 1. row 5 each term α'_{5j} equals that in the initial inverse except for j = p which in this case is α_{53}

$$\alpha'_{53} = \sum_{i=1}^{5} \alpha^0_{5j} v_{j3} \qquad \alpha^0_{5j} \text{ initial inverse}$$

$$= (0\times-50) + (0\times-\tfrac{2}{3}) + (0\times\tfrac{1}{3}) + (0\times-1) + (1\times\tfrac{155}{3}) = \frac{155}{3}$$

$$\alpha_{5j} = (0 \quad 0 \quad \tfrac{155}{3} \quad 0 \quad 1)$$

Iteration 2. all terms α'_{5j} except for j = 2,3

$$\alpha'_{52} = \sum_{i=1}^{5} \alpha^0_{5j} v_{j2}$$

$$= \frac{86}{11} \text{ and } \alpha''_{5j} = (0 \quad \tfrac{86}{11} \quad 0 \quad 0 \quad 1)$$

$$\alpha'_{53} = \sum_{i=1}^{5} \alpha''_{5j} v_{j3} = 0 + \frac{86}{11} \times -\frac{2}{3} + 0 + 0 + \frac{155}{3} = \frac{511}{11}$$

$$\text{and } \alpha 5_j = (0 \quad \tfrac{86}{11} \quad \tfrac{511}{11} \quad 0 \quad 0 \quad 1)$$

Iteration 3.

$$\alpha'_{51} = \sum_{i=1}^{5} \alpha^0_{5j} v_{j1} \rightarrow (1\ 0\ 0\ 0\ 1) = a''_{5j}$$

$$\alpha'_{52} = \sum_{i}^{5} \alpha''_{5j} v_{j2} \rightarrow (1\ 1\ 0\ 0\ 1) = a'''_{5j}$$

$$\alpha'_{53} = \sum \alpha'''_{5j} v_{j3} = (1\ 1\ 1\ 0\ 1)$$

Similarly the columns $B^{-1}\alpha_k$, (k signifying column index) and $B^{-1}d$ are formed inductively from these vectors.

e.g. in Iteration 1 $B^{-1}\alpha'_{i2} = \alpha_{i2} + \alpha_{32}\, v_{i3}$ $\quad i \neq p$

$B^{-1}\alpha'_{32} = \alpha_{32}\, v_{33}$

so $B^{-1}\alpha'_{12} = 100 + 1\times(-50) = 50$

$B^{-1}\alpha'_{22} = 8 \quad + 1\times(-\frac{2}{3}) = \frac{22}{3}$

$B^{-1}\alpha'_{32} = 1\times\frac{1}{3} \qquad = \frac{1}{3}$

$B^{-1}\alpha'_{42} = 8 + 1\times(-1) \quad = 7$

$B^{-1}\alpha'_{52} = -109 + \frac{155}{3}\times 1 = \frac{-172}{3}$

Similarly for $B^{-1}d'_i = d_i + d_3 v_{i3}$ $\quad i \neq p \quad B^{-1}d'_3 = d_3 v_{33}$

i.e. $B^{-1}d'_1 = 3000 + 45\times -50 = 750$

$B^{-1}d'_2 = 80 - \frac{2}{3}\times 45 \quad = 50$

$B^{-1}d'_3 = \frac{1}{3}\times 45 \quad = 15$

$B^{-1}d'_4 = 0 - 1\times 45 \quad = -45$

$B^{-1}d'_5 = -3125 + \frac{155}{3}\times 45 = -800$

Similarly in other iterations all the required factors are derived from the elementary matrix vectors. Thus the large problem calculations are carried out much more efficiently in terms of working storage in the computer using the product form of the inverse. This development, allowing greater capacity for problem data storage, has made possible the solving of very large linear programming problems by computer.

APPENDIX 2 : Sources of nutrient composition and cost data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	Total less (34)+(35)
calories	148	11									1					2	1			2		1							4							170
protein	154	6									1					2	1			2		1		1						2						170
fat	148	11								2	1					2	1			3		1		1												170
fibre	56	3														1								1				108					1	113		170
calcium	153	4								2	1					1	1			2		1		1				3					1			170
phosphorus	152	4								2	1					1	1			3		1		1				3					1			170
iron	149	5									3					1	1			3	2	1		1				3					1			170
vitamin A	96	15									1	2				6	3			2	1	2	2					36					4	23		170
thiamine	155	5									2	1				1	1			2		1						1					1			170
riboflavin	155	5									1	2				1	1			2		1						1					1			170
niacin	155	5									2	1				1	1			1		1						1					1			170
vitamin C	74	19									1	1	1			4							3		1			64					1			170
vitamin B6				73					5									1										67					24			170
vitamin B12				53		63					2																	49					3	48		170
pantothenic acid				87							1	1																64					17			170
folic acid								11	11		1	1			9			3	1				4					104					25			170
isoleucine	18				70									12												1		39		2	21	4	3			170
leucine	18				70									12												1		29		2	21	4	3			170
lysine	18				70									25												1		29		2	18	4	3			170
methionine	18				70									30												1		20		2	22	4	3			170
cystine	18				66									15												1		40		2	21	4	3			170
phenylalanine	18				70									17												1		30		2	25	4	3			170
tyrosine	18				68									14												1		39		2	21	4	3			170
threonine	18				70									12												1		39		2	21	4	3			170
tryptophan					69									49												1		20		2	22	4	3			170
valine	18				70									12												1		39		2	21	4	3			170
cost			52				12																				36	70							66	
Total	1759	93	52	213	693	63	12	11	16	6	19	9	1	198	9	23	12	4	1	24	3	11	9	6	1	10	36	908	4	22	213	40	111	184	66	4590

1. Food composition tables for use in the Philippines, FNRC, Mainila, 1968 (80)
2. Composition of foods - raw processed and prepared, USDA, Agricultural Handbook No 8, Washington D.C., 1963 (76)
3. FAO Fisheries Yearbook 1969. (71)
4. Panthothenic acid, vitamin B6 and vitamin B12 in foods, USDA, Home Economics Research Report No. 36, Washington D.C. 1969 (78)
5. Amino-acid content of food and biological data on proteins, FAO, Rome, 1969 (8
6. Vitamin B12 content of some Philippine plant foods, Philippines Journal of Nutrition (1968) (81)
7. FAO Production Yearbook 1969, (70)
8. The composition of foods Medical Research Council Special Report Series No. 297, HMSO, London, 1960, p203 (79)
9. Source (8) p. 204
10. Kirk-Othmer Encyclopedia of Chemical Technology (1968), 3, 568.
11. Biochemist's Handbook, E & F. N. Spon Ltd., London, 1961.
12. Blood and other body fluids, P.L. Altman and D.S. Dittmer, Federation of American Societies for Experimental Biology, Washington D.C., 1961.
13. R.H. Grummer etal, Journal of Animal Science (1948) 7, 222
14. Tables of the amino acids in foods and feedingstuffs, Technical communication No 19, Commonwealth Bureau of Animal Nutirition (85).
15. Source (8) p 205.
16. Food composition tables recommended for use in the Philippines, Handbook No. 1, Philippine Institute of Nutrition, Manila, 1951 (80)
17. Composition of forty Philippine foods, raw and cooked, in terms of eleven nutrients, Bayen etal, Philippines Journal of Nutrition (1965) 18 (2), 91
18. Source (8) p 206.
19. Source (8) p 202.
20. Composition of foods used in far-eastern countries, USDA, Agricultural Handbook No 34, Washington D.C., 1952 (77)
21. Food values of portions commonly used, Bowes and Church, Tenth edition, J. B Lippincott Co., Philadelphia, 1966.
22. Table of food composition - Thailand, Ministry of Public Health, Nutrition Division, Bangkok, 1964.
23. Source (8), p 207.
24. Kirk-Othmer Encyclopedia of Chemical Technology (1965), 6, 414.
25. Personal communicetion, M. D. Earle, Massey University, 1972.
26. The amino acids of sugar cane, D. H. Perish, Journal of the Science of Food and Agricultura (1965) 16, 240.
27. Philippine Bureau of Agriculturel Economics.
28. Assumed data.
29. Data calculated from data of other raw materials.
30. Calculated from data in Documenta Geigy-Scientific Tables, Sixth edition, Geigy J. R. (S. A.), Basel, Switzerland, 1962 and source (11)
31. Based on content of related raw materials but scaled according to ratio of protein levels.
32. Based on analysis of tripe, from M. Wilson, Massey University.
33. No data recorded.
34. Zero data, also included in date of (28)
35. Costs from estimetes of Filipino at Massey University, elso included in entries in (28).

Density of matrix	94.5%
Assumed data	19.8%
Calculated data	6.1%
Zero data	5.5%
No data	2.4%

FOOD COMPOSITION AND COST DATA FOR PHILIPPINES FOODS.

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1972

PART 1. COST, WEIGHT UNIT, EDIBLE PORTION, CALORIES, PROTEIN, FAT, FIBRE, CALCIUM, PHOSPHORUS AND IRON.

PART 2. VITAMINS - VITAMIN A, THIAMINE, RIBOFLAVIN, NIACIN, VITAMIN C, VITAMIN B6, VITAMIN B12, PANTOTHENIC ACID AND FOLIC ACID.

PART 3. AMINO-ACIDS - ISOLEUCINE, LEUCINE, LYSINE, METHIONINE, CYSTINE, PHENYLALANINE, TYROSINE, THREONINE, TRYPTOPHAN AND VALINE.

FOOD	COST	WEIGHT UNIT	EDIBLE PORTION	CALORIES	PROTEIN	FAT	FIBRE	CALCIUM	PHOSPHORUS	IRON
	$US /100G	100G	PER CENT	KCAL/100G	G/100G	G/100G	G/100G	MG/100G	MG/100G	MG/100G
ALBACORE	0.0330	1.0000	77.0000	99.0000	22.7000	0.2000	0.0000	16.0000	191.0000	1.2000
ANCHOVY	0.0360	1.0000	75.0000	86.0000	17.9000	1.1000	0.0000	469.0000	378.0000	0.7000
ATIS	0.0200	1.0000	50.0000	93.0000	1.3000	0.4000	1.3000	41.0000	39.0000	0.9000
AVOCADO	0.0120	1.0000	70.0000	78.0000	1.0000	5.8000	1.2000	18.0000	23.0000	0.9000
BANANA90	0.0190	1.0000	67.0000	95.0000	1.0000	0.4000	0.3000	11.0000	16.0000	0.5000
BANANA92	0.0190	1.0000	62.0000	119.0000	1.1000	0.1000	0.3000	15.0000	19.0000	0.9000
BARRACUD	0.0360	1.0000	50.0000	92.0000	18.8000	1.3000	0.0000	58.0000	162.0000	0.6000
BEEF	0.0780	1.0000	82.0000	242.0000	18.6000	18.0000	0.0000	11.0000	172.0000	2.8000
BESCAD	0.0300	1.0000	50.0000	90.0000	20.4000	0.3000	0.0000	36.0000	168.0000	0.7000
BLOODB	0.0027	1.0000	100.0000	103.0000	12.0000	1.1000	0.0000	7.0000	24.0000	33.1000
BLOODPIG	0.0027	1.0000	100.0000	58.0000	13.4000	0.0500	0.0000	9.0000	26.0000	44.7000
BONITO	0.0290	1.0000	63.0000	127.0000	24.5000	2.5000	0.0000	52.0000	213.0000	16.3000
BRAINB	0.1020	1.0000	100.0000	130.0000	10.3000	9.4000	0.0000	11.0000	208.0000	2.4000
BRAINBU	0.1020	1.0000	100.0000	138.0000	9.4000	10.1000	0.0000	14.0000	254.0000	4.0000
BRAINLAM	0.0513	1.0000	100.0000	125.0000	10.9000	8.6000	0.0000	11.0000	188.0000	2.4000
BSRAY	0.0378	1.0000	41.0000	79.0000	18.3000	0.1000	0.0000	25.0000	99.0000	0.0500
BUFFALO	0.0680	1.0000	82.0000	100.0000	21.1000	1.1000	0.0000	128.0000	167.0000	4.0000
CABBAGE	0.0190	1.0000	82.0000	25.0000	1.7000	0.2000	0.9000	64.0000	26.0000	0.7000
CAESIO	0.0422	1.0000	49.0000	82.0000	17.8000	0.7000	0.0000	34.0000	178.0000	0.6000
CASHEW	0.0150	1.0000	90.0000	57.0000	0.7000	0.6000	0.3000	4.0000	13.0000	0.5000
CASSAVA	0.0080	1.0000	76.0000	141.0000	0.7000	0.1000	1.0000	24.0000	37.0000	1.5000
CATFISH	0.0360	1.0000	45.0000	94.0000	21.3000	0.4000	0.0000	31.0000	167.0000	2.0000
CAVALLA	0.0430	1.0000	33.0000	139.0000	19.6000	6.1000	0.0000	64.0000	186.0000	0.8000
CHGIZZ	0.0513	1.0000	100.0000	112.0000	21.8000	1.0000	0.0000	18.0000	71.0000	0.6000
CHICKENY	0.0167	1.0000	61.0000	200.0000	20.2000	12.6000	0.0000	14.0000	200.0000	1.5000
CHICKPEA	0.0150	1.0000	100.0000	366.0000	20.0000	6.4000	2.6000	106.0000	340.0000	3.8000
CHICO	0.0330	1.0000	84.0000	96.0000	0.5000	0.9000	3.0000	32.0000	9.0000	1.0000
CHLIVER	0.0513	1.0000	100.0000	129.0000	18.1000	3.9000	0.0000	14.0000	152.0000	3.5000
COCOMAT	0.0080	1.0000	56.0000	300.0000	3.9000	26.1000	2.1000	28.0000	95.0000	1.5000
COCOY	0.0150	1.0000	14.0000	99.0000	1.4000	5.5000	0.9000	10.0000	54.0000	0.7000
COTSEED	0.0120	1.0000	100.0000	349.0000	19.4000	19.5000	22.6000	179.0000	554.0001	49.0000
COWPEA	0.0256	1.0000	100.0000	356.0000	20.4000	1.5000	4.5000	59.0000	347.0000	6.5000
CRAB	0.0880	1.0000	42.0000	121.0000	19.8000	4.0000	0.0000	93.0000	152.0000	1.0000
CREVALLE	0.0400	1.0000	56.0000	92.0000	19.4000	1.0000	0.0000	93.0000	221.0000	1.2000
CROAKER	0.0300	1.0000	44.0000	85.0000	19.1000	0.4000	0.0000	35.0000	125.0000	0.6000
DAPA	0.0330	1.0000	60.0000	89.0000	20.5000	0.2000	0.0000	39.0000	220.0000	0.6000
DUCK	0.0167	1.0000	61.0000	326.0000	16.0000	28.6000	0.0000	10.0000	176.0000	1.6000
EGGDUCK	0.0840	1.0000	87.0000	180.0000	11.7000	12.6000	0.0000	71.0000	174.0000	2.8000
EGGPLANT	0.0120	1.0000	91.0000	24.0000	1.0000	0.2000	0.8000	30.0000	27.0000	0.6000
EGGS	0.0420	1.0000	87.0000	164.0000	12.4000	11.0000	0.0000	74.0000	180.0000	2.8000
GAMET	0.0175	1.0000	100.0000	199.0000	23.7000	1.2000	1.4000	472.0000	192.0000	31.6000
GARLIC	0.0890	1.0000	85.0000	122.0000	7.0000	0.3000	1.1000	26.0000	109.0000	1.2000
GINGER	0.0190	1.0000	74.0000	37.0000	1.1000	0.8000	1.0000	32.0000	28.0000	3.0000
GLASSF	0.0310	1.0000	45.0000	78.0000	17.4000	0.4000	0.0000	66.0000	150.0000	0.5000
GNSHELL	0.0240	1.0000	51.0000	274.0000	14.1000	19.4000	1.1000	50.0000	194.0000	1.9000
GOAT	0.0430	1.0000	75.0000	102.0000	22.0000	0.9000	0.0000	64.0000	177.0000	2.3000
GOATFISH	0.0300	1.0000	38.0000	92.0000	18.7000	1.3000	0.0000	91.0000	170.0000	0.9000
GOBY	0.0320	1.0000	39.0000	86.0000	19.7000	0.2000	0.0000	74.0000	133.0000	0.4000
GOOSE	0.0167	1.0000	61.0000	354.0000	16.4000	31.5000	0.0000	10.0000	176.0000	1.6000
GRAPEFRT	0.0250	1.0000	48.0000	22.0000	0.6000	0.0500	0.2000	17.0000	16.0000	0.3000

FOOD	COST $US /100G	WEIGHT UNIT 100G	EDIBLE PORTION PER CENT	CALORIES KCAL/100G	PROTEIN G/100G	FAT G/100G	FIBRE G/100G	CALCIUM MG/100G	PHOSPHORUS MG/100G	IRON MG/100G
GROUPER	0.0600	1.0000	49.0000	67.0000	14.9000	0.4000	0.0000	55.0000	173.0000	0.6000
GRUNT	0.0330	1.0000	35.0000	82.0000	18.4000	0.2000	0.0000	136.0000	184.0000	2.2000
HAIRTAIL	0.0300	1.0000	55.0000	85.0000	19.1000	0.4000	0.0000	74.0000	95.0000	0.6000
HARDTAIL	0.0270	1.0000	30.0000	96.0000	20.0000	1.2000	0.0000	45.0000	140.0000	0.6000
HEARTB	0.0513	1.0000	100.0000	133.0000	18.8000	5.9000	0.0000	11.0000	170.0000	4.1000
HEARTBU	0.0513	1.0000	100.0000	120.0000	17.4000	4.6000	0.0000	10.0000	156.0000	2.5000
HEARTGOA	0.0513	1.0000	100.0000	130.0000	17.1000	5.9000	0.0000	8.0000	154.0000	2.3000
HEARTLAM	0.0513	1.0000	100.0000	162.0000	18.1000	9.6000	0.0000	10.0000	151.0000	2.6000
HEARTPIG	0.0513	1.0000	100.0000	120.0000	16.4000	5.3000	0.0000	6.0000	139.0000	1.5000
HERRING	0.0390	1.0000	60.0000	101.0000	20.9000	1.3000	0.0000	191.0000	228.0000	1.4000
HORSE	0.0400	1.0000	82.0000	125.0000	20.0000	4.1000	0.0000	10.0000	150.0000	2.7000
JACKFRT	0.0210	1.0000	34.0000	97.0000	1.4000	0.4000	0.8000	23.0000	18.0000	1.1000
KAIMITO	0.0190	1.0000	53.0000	67.0000	0.7000	1.1000	0.7000	17.0000	13.0000	0.4000
KIDNEYB	0.0513	1.0000	100.0000	86.0000	15.3000	1.7000	0.0000	24.0000	158.0000	2.1000
KIDNEYBU	0.0513	1.0000	100.0000	80.0000	14.0000	1.8000	0.0000	14.0000	309.0000	2.9000
KIDNEYGO	0.0513	1.0000	100.0000	101.0000	15.9000	3.5000	0.0000	15.0000	189.0000	1.9000
KIDNEYLA	0.0513	1.0000	100.0000	105.0000	16.2000	3.3000	0.0000	18.0000	212.0000	4.2000
KIDNEYPI	0.0513	1.0000	100.0000	114.0000	15.4000	4.3000	0.0000	13.0000	198.0000	5.1000
LAKATAN	0.0190	1.0000	69.0000	111.0000	1.4000	0.2000	0.8000	15.0000	30.0000	0.8000
LANZONES	0.0300	1.0000	68.0000	57.0000	1.0000	0.3000	0.8000	19.0000	25.0000	0.9000
LARINTB	0.0513	1.0000	100.0000	484.0000	5.0000	47.0000	0.0000	13.0000	28.0000	3.6000
LARINTBU	0.0513	1.0000	100.0000	168.0000	9.3000	11.9000	0.0000	17.0000	61.0000	0.9000
LARINTGO	0.0513	1.0000	100.0000	62.0000	11.0000	2.0000	0.0000	12.0000	89.0000	1.1000
LARINTPI	0.0513	1.0000	100.0000	83.0000	9.6000	2.2000	0.0000	12.0000	89.0000	1.1000
LATUNDAN	0.0190	1.0000	73.0000	92.0000	1.2000	0.3000	0.5000	9.0000	42.0000	0.7000
LEAJACK	0.0370	1.0000	50.0000	87.0000	20.9000	0.2000	0.0000	38.0000	179.0000	0.5000
LEMON	0.0240	1.0000	38.0000	32.0000	0.4000	1.0000	0.1000	18.0000	12.0000	0.8000
LIME	0.0250	1.0000	59.0000	40.0000	0.8000	2.4000	0.3000	17.0000	11.0000	0.1000
LIVERB	0.0513	1.0000	100.0000	127.0000	22.2000	2.3000	0.0000	8.0000	312.0000	9.2000
LIVERBU	0.0513	1.0000	100.0000	111.0000	15.5000	1.7000	0.0000	16.0000	207.0000	6.8000
LIVERGOA	0.0513	1.0000	100.0000	136.0000	22.1000	3.4000	0.0000	17.0000	172.0000	1.0000
LIVERLAM	0.0513	1.0000	100.0000	142.0000	21.8000	4.0000	0.0000	21.0000	270.0000	4.5000
LIVERPIG	0.0513	1.0000	100.0000	123.0000	18.0000	2.8000	0.0000	11.0000	267.0000	14.0000
LIZFISH	0.0230	1.0000	45.0000	80.0000	18.2000	0.2000	0.0000	58.0000	170.0000	0.6000
LUNGGOAT	0.0513	1.0000	100.0000	98.0000	17.0000	2.1000	0.0000	15.0000	142.0000	2.5000
LUNGLAM	0.0513	1.0000	100.0000	99.0000	17.3000	1.7000	0.0000	19.0000	172.0000	1.8000
LUNGPIG	0.0513	1.0000	100.0000	76.0000	12.2000	1.8000	0.0000	14.0000	159.0000	3.1000
LUNGSB	0.0513	1.0000	100.0000	99.0000	17.1000	1.9000	0.0000	22.0000	138.0000	1.6000
LUNGSBU	0.0513	1.0000	100.0000	92.0000	18.6000	1.4000	0.0000	20.0000	53.0000	1.6000
MANGO	0.0240	1.0000	72.0000	57.0000	0.5000	0.2000	0.4000	8.0000	17.0000	0.5000
MARBRAY	0.0378	1.0000	36.0000	63.0000	14.3000	0.2000	0.0000	223.0000	156.0000	0.9000
MILKBUFF	0.0350	1.0000	100.0000	123.0000	5.4000	9.5000	0.0000	216.0000	101.0000	0.2000
MILKCOW	0.0410	1.0000	100.0000	65.0000	3.3000	3.6000	0.0000	137.0000	74.0000	0.6000
MILKFISH	0.0290	1.0000	68.0000	126.0000	17.6000	5.7000	0.0000	51.0000	161.0000	1.0000
MILKGOAT	0.0350	1.0000	100.0000	76.0000	3.9000	4.3000	0.0000	98.0000	78.0000	2.7000
MOONFISH	0.0360	1.0000	48.0000	122.0000	24.4000	2.0000	0.0000	22.0000	227.0000	1.2000
MULLET	0.0370	1.0000	49.0000	118.0000	19.3000	4.0000	0.0000	94.0000	186.0000	0.4000
MUNGGR	0.0256	1.0000	100.0000	356.0000	24.4000	1.0000	4.3000	125.0000	340.0000	5.7000
MUNGRED	0.0256	1.0000	100.0000	335.0000	21.9000	0.8000	4.4000	81.0000	313.0000	10.4000
NEMIPTER	0.0382	1.0000	45.0000	95.0000	19.0000	1.5000	0.0000	81.0000	185.0000	0.6000

FOOD	COST $US /100G	WEIGHT UNIT 100G	EDIBLE PORTION PER CENT	CALORIES KCAL/100G	PROTEIN G/100G	FAT G/100G	FIBRE G/100G	CALCIUM MG/100G	PHOSPHORUS MG/100G	IRON MG/100G
ONION	0.0280	1.0000	92.0000	48.0000	1.8000	0.2000	0.7000	34.0000	63.0000	0.7000
ORANGE	0.0190	1.0000	72.0000	24.0000	0.4000	0.1000	0.2000	33.0000	17.0000	0.2000
PAPAYA	0.0120	1.0000	62.0000	48.0000	0.6000	0.2000	0.6000	23.0000	10.0000	0.7000
PETSAY	0.0140	1.0000	82.0000	21.0000	1.8000	0.3000	0.7000	147.0000	33.0000	4.4000
PIGPEA	0.0150	1.0000	100.0000	286.0000	21.8000	1.0000	4.4000	128.0000	287.0000	4.5000
PILI	0.0160	1.0000	16.0000	645.0001	14.2000	68.5000	3.2000	119.0000	508.0000	2.6000
PINEAPLE	0.0120	1.0000	58.0000	50.0000	0.4000	0.2000	0.4000	19.0000	9.0000	0.2000
POMFRET	0.0470	1.0000	48.0000	98.0000	18.8000	2.0000	0.0000	40.0000	179.0000	0.6000
POMPANO	0.0360	1.0000	48.0000	100.0000	18.8000	2.2000	0.0000	40.0000	179.0000	0.5000
PORGY	0.0360	1.0000	45.0000	95.0000	21.1000	0.5000	0.0000	61.0000	188.0000	0.4000
PORK	0.0370	1.0000	78.0000	472.0000	11.2000	47.0000	0.0000	6.0000	116.0000	1.7000
POTATOES	0.0170	1.0000	85.0000	72.0000	2.4000	0.1000	0.4000	26.0000	49.0000	1.1000
PUMMELO	0.0080	1.0000	56.0000	59.0000	0.5000	0.3000	0.6000	30.0000	19.0000	0.7000
RADISH	0.0140	1.0000	68.0000	21.0000	0.6000	0.1000	0.6000	32.0000	21.0000	0.6000
RICE	0.0190	1.0000	100.0000	368.0000	7.4000	0.5000	0.4000	8.0000	108.0000	1.2000
RICEBR	0.0202	1.0000	100.0000	364.0000	8.8000	2.0000	0.8000	28.0000	252.0000	2.2000
RICEGLU	0.0268	1.0000	100.0000	364.0000	6.9000	0.8000	0.1000	17.0000	95.0000	1.1000
RKIDBEAN	0.0180	1.0000	100.0000	341.0000	19.3000	1.5000	3.8000	115.0000	353.0000	6.9000
RSCAD	0.0270	1.0000	41.0000	93.0000	18.7000	1.5000	0.0000	75.0000	212.0000	0.9000
RUNNERF	0.0320	1.0000	44.0000	90.0000	19.6000	0.7000	0.0000	30.0000	188.0000	2.4000
SABA	0.0190	1.0000	57.0000	95.0000	1.2000	0.4000	0.6000	23.0000	36.0000	0.9000
SARDINE	0.0370	1.0000	52.0000	110.0000	18.2000	3.6000	0.0000	90.0000	245.0000	1.7000
SBMACK	0.0380	1.0000	50.0000	92.0000	19.6000	0.9000	0.0000	52.0000	247.0000	1.0000
SEAWEED	0.0175	1.0000	100.0000	11.0000	1.2000	0.2000	0.1000	62.0000	8.0000	2.1000
SHARK	0.0350	1.0000	91.0000	81.0000	15.5000	1.0000	0.0000	60.0000	169.0000	2.8000
SHEEP	0.0430	1.0000	79.0000	317.0000	15.7000	27.7000	0.0000	9.0000	157.0000	2.4000
SHRIMP	0.0710	1.0000	63.0000	101.0000	19.6000	0.8000	0.0000	146.0000	215.0000	1.1000
SIGANID	0.0360	1.0000	44.0000	94.0000	19.8000	1.1000	0.0000	42.0000	139.0000	0.5000
SLIPMTH	0.0500	1.0000	38.0000	100.0000	18.3000	2.4000	0.0000	49.0000	148.0000	0.1000
SMINTB	0.0513	1.0000	100.0000	114.0000	16.4000	4.2000	0.0000	20.0000	173.0000	3.1000
SMINTBU	0.0513	1.0000	100.0000	151.0000	10.4000	9.7000	0.0000	16.0000	142.0000	1.7000
SMINTGOA	0.0513	1.0000	100.0000	74.0000	10.2000	3.4000	0.0000	20.0000	86.0000	0.6000
SMINTPIG	0.0513	1.0000	100.0000	74.0000	12.6000	2.3000	0.0000	9.0000	150.0000	2.4000
SMSHRIMP	0.0710	1.0000	100.0000	83.0000	16.6000	1.3000	0.0000	699.0001	279.0000	3.0000
SNAPBEAN	0.0154	1.0000	100.0000	376.0000	21.3000	2.0000	3.2000	42.0000	303.0000	4.2000
SNAPPER	0.0420	1.0000	44.0000	68.0000	15.6000	0.2000	0.0000	37.0000	134.0000	0.6000
SOURSOP	0.0110	1.0000	70.0000	63.0000	1.1000	0.1000	0.6000	16.0000	23.0000	0.6000
SOYBEAN	0.0300	1.0000	100.0000	405.0000	39.1000	17.0000	4.8000	296.0000	541.0001	12.2000
SPADEF	0.0400	1.0000	45.0000	105.0000	20.3000	2.0000	0.0000	66.0000	178.0000	0.8000
SPLEAVES	0.0197	1.0000	53.0000	53.0000	2.8000	0.5000	2.2000	107.0000	65.0000	6.0000
SPLEENB	0.0513	1.0000	100.0000	96.0000	17.2000	1.7000	0.0000	11.0000	201.0000	9.7000
SPLEENBU	0.0513	1.0000	100.0000	104.0000	21.2000	1.5000	0.0000	13.0000	103.0000	5.4000
SPLEENLA	0.0513	1.0000	100.0000	115.0000	21.1000	3.9000	0.0000	13.0000	206.0000	6.9000
SPLEENPI	0.0513	1.0000	100.0000	91.0000	16.1000	2.5000	0.0000	13.0000	206.0000	6.9000
SPMACK	0.0370	1.0000	50.0000	85.0000	17.6000	1.1000	0.0000	23.0000	236.0000	1.0000
SPYAM	0.0110	1.0000	82.0000	112.0000	1.2000	0.0500	0.8000	21.0000	37.0000	1.7000
SQUID	0.0390	1.0000	97.0000	88.0000	18.0000	1.2000	0.0000	40.0000	201.0000	1.6000
STOMB	0.0513	1.0000	100.0000	116.0000	15.1000	5.6000	0.0000	53.0000	51.0000	0.4000
STOMBU	0.0513	1.0000	100.0000	86.0000	18.7000	0.7000	0.0000	53.0000	55.0000	0.4000
STOMGOAT	0.0513	1.0000	100.0000	60.0000	9.8000	1.1000	0.0000	48.0000	84.0000	0.6000

FOOD	COST	WEIGHT UNIT	EDIBLE PORTION	CALORIES	PROTEIN	FAT	FIBRE	CALCIUM	PHOSPHORUS	IRON
	$US /100G	100G	PER CENT	KCAL/100G	G/100G	G/100G	G/100G	MG/100G	MG/100G	MG/100G
STOMPIG	0.0513	1.0000	100.0000	125.0000	13.1000	6.5000	0.0000	11.0000	106.0000	1.0000
STRMACK	0.0380	1.0000	62.0000	117.0000	21.4000	2.8000	0.0000	47.0000	197.0000	1.4000
SUGCANEJ	0.0014	1.0000	20.0000	44.0000	0.1000	0.2000	2.5000	13.0000	9.0000	0.1000
SURGEONF	0.0390	1.0000	41.0000	82.0000	17.8000	0.7000	0.0000	45.0000	169.0000	0.5000
SWPOT	0.0080	1.0000	88.0000	136.0000	1.1000	0.4000	0.7000	57.0000	52.0000	0.7000
SWPOTWH	0.0154	1.0000	86.0000	113.0000	0.6000	0.4000	0.6000	64.0000	42.0000	1.0000
TARO	0.0090	1.0000	81.0000	85.0000	2.4000	0.2000	0.4000	32.0000	64.0000	0.8000
THREADFN	0.0410	1.0000	35.0000	86.0000	18.4000	0.8000	0.0000	40.0000	152.0000	0.3000
TOMATO	0.0200	1.0000	95.0000	19.0000	1.0000	0.2000	0.8000	18.0000	18.0000	0.8000
TONGUEB	0.0513	1.0000	100.0000	218.0000	14.8000	15.2000	0.0000	42.0000	154.0000	1.5000
TONGUEPI	0.0513	1.0000	100.0000	274.0000	13.9000	23.8000	0.0000	17.0000	116.0000	1.1000
TURGIZZ	0.0513	1.0000	100.0000	157.0000	21.0000	7.3000	0.0000	6.0000	117.0000	1.3000
TURKEY	0.0167	1.0000	61.0000	262.0000	20.1000	20.2000	0.0000	23.0000	320.0000	3.8000
TURLIVER	0.0513	1.0000	100.0000	138.0000	17.3000	4.0000	0.0000	9.0000	185.0000	2.3000
TURTLE	0.0018	1.0000	24.0000	89.0000	19.8000	0.5000	0.0000	0.0000	0.0000	0.0000
WATMELON	0.0210	1.0000	62.0000	28.0000	0.5000	0.2000	0.5000	8.0000	7.0000	0.2000
WHCORN	0.0216	1.0000	100.0000	128.0000	4.4000	0.8000	2.2000	9.0000	119.0000	0.7000
WHITING	0.0370	1.0000	46.0000	95.0000	21.1000	0.5000	0.0000	110.0000	198.0000	0.8000
WKIDBEAN	0.0180	1.0000	100.0000	347.0000	18.8000	1.1000	4.3000	97.0000	272.0000	5.3000
YAM	0.0100	1.0000	86.0000	103.0000	1.9000	0.1000	0.7000	18.0000	54.0000	0.8000
YCORN	0.0154	1.0000	100.0000	188.0000	4.9000	1.9000	1.0000	4.0000	116.0000	0.4000
YFINTUNA	0.0290	1.0000	77.0000	104.0000	23.4000	0.5000	0.0000	48.0000	41.0000	2.4000

FOOD	VIT. A	THIAMINE	RIBOFLAVIN	NIACIN	VIT. C	VIT. B6	VIT. B12	PANT. ACID	FOLIC ACID
	IU/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G
ALBACORE	40.0000	0.0300	0.0500	9.8000	5.0000	0.4400	0.4200	0.0500	0.0001
ANCHOVY	50.0000	0.0100	0.0800	3.7000	3.0000	0.1440	1.0000	0.0500	0.0062
ATIS	5.0000	0.1000	0.0800	0.9000	43.0000	0.0200	0.2260	0.0020	0.0000
AVOCADO	135.0000	0.0400	0.0600	1.0000	11.0000	0.4200	1.0700	0.0020	0.0000
BANANA90	100.0000	0.0300	0.0300	0.7000	26.0000	0.5100	0.2600	0.0100	0.0000
BANANA92	620.0001	0.0400	0.0200	0.5000	16.0000	0.5100	0.2600	0.0100	0.0000
BARRACUD	5.0000	0.2000	0.0500	3.5000	0.5000	0.2000	0.2000	0.0500	0.0018
BEEF	40.0000	0.0800	0.1700	4.5000	0.0000	0.3300	0.4700	0.0100	0.0014
BESCAD	5.0000	0.0500	0.0900	7.4000	0.5000	0.2000	0.2000	0.0500	0.0044
BLOODB	108.0000	0.0050	0.0300	1.2000	0.5000	0.0000	0.1820	0.0020	0.0000
BLOODPIG	87.0000	0.0100	0.0100	0.5000	0.5000	0.0000	0.0320	0.0025	0.0000
BONITO	75.0000	0.1200	0.1300	14.8000	5.0000	0.9000	0.5000	0.0500	0.0030
BRAINB	0.0000	0.1300	0.1600	3.8000	18.0000	0.1500	2.6000	0.0000	0.0043
BRAINBU	0.0000	0.1600	0.2000	3.7000	12.0000	0.1500	2.6000	0.0000	0.0069
BRAINLAM	0.0000	0.1900	0.3100	3.3000	18.0000	0.1500	2.6000	0.0000	0.0040
BSRAY	5.0000	0.0400	0.0500	2.5000	0.5000	0.2000	0.2000	0.0500	0.0010
BUFFALO	40.0000	0.3800	0.2000	3.1000	0.0000	0.3300	0.4700	0.0100	0.0014
CABBAGE	75.0000	0.0500	0.0500	0.3000	62.0000	0.1600	0.2050	0.0200	0.0000
CAESIO	5.0000	0.0200	0.0200	2.9000	0.5000	0.2000	0.2000	0.0500	0.0031
CASHEW	25.0000	0.0200	0.0100	0.4000	197.0000	0.0200	0.0760	0.0020	0.0000
CASSAVA	0.0000	0.0400	0.0100	0.6000	41.0000	0.1100	0.5210	0.0000	0.0000
CATFISH	95.0000	0.4600	0.1200	3.1000	0.0000	0.2000	0.2000	0.0500	0.0025
CAVALLA	175.0000	0.1200	0.0800	5.5000	0.0000	0.2000	0.2000	0.0500	0.0091
CHGIZZ	0.0000	0.0600	0.2500	4.8000	4.0000	0.0300	0.7500	0.0000	0.0019
CHICKENY	410.0000	0.0800	0.1600	8.0000	0.0000	0.5000	0.9000	0.0030	0.0004
CHICKPEA	15.0000	0.1300	0.1600	1.2000	0.5000	0.5400	1.2500	0.0200	0.0000
CHICO	85.0000	0.0100	0.0100	0.3000	26.0000	0.0200	0.2520	0.0020	0.0000
CHLIVER	30680.0039	0.3000	4.4900	11.2000	35.0000	0.7500	6.0000	0.2200	0.0279
COCOMAT	0.0000	0.0400	0.0300	0.4000	3.0000	0.0440	0.2000	0.0280	0.0000
COCOY	0.0000	0.0700	0.0400	0.9000	4.0000	0.0440	0.2000	0.0280	0.0000
COTSEED	60.0000	1.2100	0.3100	4.4000	0.0000	0.9800	4.3200	0.0000	0.0000
COWPEA	10.0000	0.6500	0.3100	2.1000	0.5000	0.5620	1.0500	0.0200	0.0000
CRAB	300.0000	0.0700	0.1800	2.1000	2.0000	0.3000	0.6000	0.0500	0.0022
CREVALLE	5.0000	0.0200	0.1200	4.2000	0.5000	0.2000	0.2000	0.0500	0.0058
CROAKER	60.0000	0.0300	0.0600	2.3000	0.5000	0.2000	0.2000	0.0500	0.0025
DAPA	5.0000	0.0200	0.0800	5.3000	0.5000	0.1700	0.8500	0.0500	0.0012
DUCK	0.0000	0.0800	0.1900	6.7000	0.0000	0.5000	0.9000	0.0030	0.0004
EGGDUCK	2845.0004	0.2700	0.5600	0.1000	0.5000	0.1100	1.6000	0.0080	0.0047
EGGPLANT	130.0000	0.1000	0.0500	0.6000	5.0000	0.0810	0.2200	0.0100	0.0000
EGGS	1120.0002	0.0700	0.3900	0.1000	1.0000	0.1100	1.6000	0.0080	0.0040
GAMET	4370.0009	0.1600	1.1500	3.1000	2.0000	0.0000	0.0000	0.0000	0.0000
GARLIC	0.0000	0.2300	0.0800	0.4000	7.0000	0.1300	0.1300	0.0100	0.0000
GINGER	0.0000	0.0400	0.0400	0.6000	4.0000	0.0750	0.2030	0.0100	0.0000
GLASSF	5.0000	0.0100	0.0400	1.5000	0.5000	0.2000	0.2000	0.0500	0.0010
GNSHELL	35.0000	0.9400	0.2000	8.0000	11.0000	0.4000	2.8000	0.0550	0.0000
GOAT	0.0000	0.2100	0.3200	7.0000	0.0000	0.2750	0.5500	0.0030	0.0021
GOATFISH	105.0000	0.0200	0.0400	1.4000	0.5000	0.2000	0.2000	0.0500	0.0010
GOBY	5.0000	0.0200	0.0900	2.5000	0.5000	0.2000	0.2000	0.0500	0.0040
GOOSE	0.0000	0.0800	0.1900	6.7000	0.0000	0.5000	0.9000	0.0030	0.0004
GRAPEFRT	5.0000	0.0400	0.0200	0.2000	40.0000	0.0340	0.2830	0.0030	0.0000

FOOD	VIT. A	THIAMINE	RIBOFLAVIN	NIACIN	VIT. C	VIT. B6	VIT. B12	PANT. ACID	FOLIC ACID
	IU/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G
GROUPER	60.0000	0.0400	0.0400	4.3000	0.5000	0.2000	0.2000	0.0500	0.0090
GRUNT	7.0000	0.0200	0.1200	1.8000	0.5000	0.2000	0.2000	0.0500	0.0092
HAIRTAIL	65.0000	0.0300	0.0700	2.8000	0.5000	0.2000	0.2000	0.0500	0.0011
HARDTAIL	5.0000	0.0400	0.1600	7.3000	0.5000	0.2000	0.2000	0.0500	0.0010
HEARTB	40.0000	0.4800	0.8700	6.8000	14.0000	0.2500	2.5000	0.0030	0.0133
HEARTBU	30.0000	0.2400	1.2000	6.9000	6.0000	0.2500	2.5000	0.0030	0.0074
HEARTGOA	70.0000	0.6100	3.8200	5.4000	1.0000	0.2000	3.0000	0.0030	0.0052
HEARTLAM	70.0000	0.7000	0.7700	5.2000	1.0000	0.2000	3.0000	0.0030	0.0052
HEARTPIG	35.0000	0.2200	1.5600	5.2000	4.0000	0.3900	2.5000	0.0030	0.0032
HERRING	90.0000	0.0100	0.0700	7.5000	3.0000	0.3700	0.9700	0.0500	0.0100
HORSE	0.0000	0.0700	0.1200	4.3000	0.0000	0.3300	0.4700	0.0100	0.0014
JACKFRT	175.0000	0.0900	0.0500	0.9000	5.0000	0.0200	0.4570	0.0020	0.0000
KAIMITO	10.0000	0.0200	0.0200	0.8000	7.0000	0.0200	0.4440	0.0020	0.0000
KIDNEYB	660.0001	0.2300	3.3000	6.2000	15.0000	0.4300	3.8500	0.0600	0.0163
KIDNEYBU	335.0000	0.2200	2.6700	6.2000	15.0000	0.4300	3.8500	0.0600	0.0271
KIDNEYGO	690.0001	0.6500	5.7000	4.8000	15.0000	0.4100	4.5000	0.0600	0.0630
KIDNEYLA	690.0001	0.5900	5.6700	9.2000	15.0000	0.4300	4.5000	0.0600	0.0630
KIDNEYPI	121.0000	0.3800	1.7100	9.7000	12.0000	0.4500	3.2000	0.0600	0.0121
LAKATAN	600.0001	0.0300	0.0500	0.5000	14.0000	0.5100	0.2600	0.0100	0.0000
LANZONES	0.0000	0.0800	0.0400	0.9000	2.0000	0.0200	0.0500	0.0020	0.0000
LARINTB	30.0000	0.0400	0.0800	0.2000	4.0000	0.0000	0.0000	0.0000	0.0062
LARINTBU	30.0000	0.0300	0.1000	1.2000	4.0000	0.0000	0.0000	0.0000	0.0011
LARINTGO	30.0000	0.0400	0.1400	0.5000	4.0000	0.0000	0.0000	0.0000	0.0008
LARINTPI	30.0000	0.0800	0.2400	1.7000	4.0000	0.0000	0.0000	0.0000	0.0008
LATUNDAN	25.0000	0.0200	0.0200	0.6000	16.0000	0.5100	0.2600	0.0100	0.0000
LEAJACK	70.0000	0.3700	0.1100	2.7000	4.0000	0.2000	0.2000	0.0500	0.0091
LEMON	0.0000	0.0200	0.0100	0.2000	45.0000	0.0800	0.1900	0.0070	0.0000
LIME	30.0000	0.0200	0.0200	0.2000	52.0000	0.0430	0.1380	0.0070	0.0000
LIVERB	24940.0039	0.1700	0.7600	6.4000	31.0000	0.8400	7.7000	0.3000	0.0526
LIVERBU	49735.0079	0.1700	1.5400	11.1000	22.0000	0.8400	7.7000	0.3000	0.0286
LIVERGOA	50500.0079	0.5100	2.7900	10.6000	33.0000	0.3000	7.2000	0.2800	0.1040
LIVERLAM	50500.0079	0.3900	9.1100	16.1000	33.0000	0.3000	7.2000	0.2800	0.1040
LIVERPIG	44670.0079	0.3500	1.7900	13.2000	23.0000	0.6500	6.4000	0.2200	0.0651
LIZFISH	5.0000	0.0700	0.0900	2.6000	0.5000	0.2000	0.2000	0.0500	0.0010
LUNGGOAT	71.0000	0.1000	1.1600	2.9000	10.0000	0.0000	1.0000	0.0030	0.0035
LUNGLAM	71.0000	0.1000	0.4300	4.2000	10.0000	0.0000	1.0000	0.0030	0.0035
LUNGPIG	71.0000	0.1100	0.4100	3.1000	10.0000	0.0000	1.0000	0.0030	0.0007
LUNGSB	40.0000	0.1000	0.2700	3.5000	10.0000	0.0000	1.0000	0.0030	0.0047
LUNGSBU	25.0000	0.0700	0.2300	2.8000	18.0000	0.0000	1.0000	0.0030	0.0054
MANGO	2580.0004	0.0900	0.0500	0.7000	47.0000	0.0200	0.1600	0.0020	0.0000
MARBRAY	5.0000	0.0400	0.0500	4.4000	0.5000	0.2000	0.2000	0.0500	0.0010
MILKBUFF	160.0000	0.0400	0.1800	0.1000	2.0000	0.0400	0.3400	0.0003	0.0004
MILKCOW	130.0000	0.0400	0.1800	0.1000	2.0000	0.0400	0.3400	0.0003	0.0003
MILKFISH	675.0001	0.0100	0.0400	6.9000	0.5000	0.2000	0.2000	0.0500	0.0034
MILKGOAT	110.0000	0.0500	0.2700	0.1000	1.0000	0.0450	0.3200	0.0003	0.0001
MOONFISH	5.0000	0.0400	0.0900	10.7000	0.5000	0.2000	0.2000	0.0500	0.0010
MULLET	105.0000	0.0500	0.2600	4.6000	0.0000	0.4200	0.7500	0.0500	0.0086
MUNGGR	130.0000	0.6600	0.2200	2.4000	10.0000	0.5800	0.9750	0.0200	0.0000
MUNGRED	20.0000	0.6200	0.2500	1.9000	5.0000	0.5800	0.9750	0.0200	0.0000
NEMIPTER	60.0000	0.0200	0.0600	2.1000	0.5000	0.2000	0.2000	0.0500	0.0028

FOOD	VIT. A	THIAMINE	RIBOFLAVIN	NIACIN	VIT. C	VIT. B6	VIT. B12	PANT. ACID	FOLIC ACID
	IU/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G
ONION	0.0000	0.0300	0.0200	0.4000	5.0000	0.1300	0.1300	0.0100	0.0000
ORANGE	50.0000	0.1100	0.0200	0.2000	20.0000	0.0600	0.2500	0.0050	0.0000
PAPAYA	425.0000	0.0300	0.0300	0.4000	89.0000	0.0200	0.2180	0.0020	0.0000
PETSAY	3600.0004	0.0700	0.1300	1.0000	74.0000	0.1600	0.2050	0.0200	0.0000
PIGPEA	20.0000	0.5900	0.1600	2.3000	0.5000	0.3000	1.5000	0.0200	0.0000
PILI	45.0000	0.9500	0.1200	0.4000	0.5000	0.0600	2.8000	0.0280	0.0000
PINEAPLE	15.0000	0.0800	0.0400	0.2000	21.0000	0.0880	0.1600	0.0040	0.0000
POMFRET	5.0000	0.2700	0.1100	5.7000	0.5000	0.2000	0.2000	0.0500	0.0023
POMPANO	70.0000	0.3700	0.1100	5.7000	0.5000	0.2000	0.2000	0.0500	0.0091
PORGY	5.0000	0.0200	0.0900	7.5000	2.0000	0.2000	0.2000	0.0500	0.0010
PORK	0.0000	0.5400	0.1300	2.9000	0.0000	0.3500	0.6000	0.0030	0.0005
POTATOES	0.0000	0.1200	0.0600	2.2000	31.0000	0.2500	0.3800	0.0060	0.0000
PUMMELO	5.0000	0.0300	0.0100	0.1000	42.0000	0.0600	0.2500	0.0030	0.0000
RADISH	5.0000	0.0200	0.0300	0.3000	25.0000	0.0750	0.1840	0.0100	0.0000
RICE	0.0000	0.1000	0.0500	2.4000	0.0000	0.1700	0.5500	0.0100	0.0000
RICEBR	0.0000	0.3800	0.1800	6.6000	0.0000	0.5500	1.1000	0.0100	0.0000
RICEGLU	0.0000	0.1400	0.0300	2.0000	0.0000	0.1700	0.5500	0.0100	0.0000
RKIDBEAN	5.0000	0.3500	0.2100	2.2000	0.5000	0.4410	0.5000	0.0200	0.0000
RSCAD	120.0000	0.1400	0.1900	8.7000	0.5000	0.2000	0.2000	0.0500	0.0085
RUNNERF	5.0000	0.0500	0.0600	6.0000	0.5000	0.2000	0.2000	0.0500	0.0010
SABA	340.0000	0.0600	0.0400	0.6000	32.0000	0.5100	0.2600	0.0100	0.0000
SARDINE	50.0000	0.0100	0.1000	8.1000	0.5000	0.2400	1.0000	0.0500	0.0018
SBMACK	710.0001	0.0700	0.0900	7.1000	0.5000	0.5000	0.2400	0.0500	0.0086
SEAWEED	285.0000	0.0100	0.0050	0.1000	0.5000	0.0000	0.0000	0.0000	0.0000
SHARK	5.0000	0.0100	0.0200	1.9000	0.5000	0.2000	0.2000	0.0500	0.0010
SHEEP	0.0000	0.1500	0.2500	5.0000	0.0000	0.2750	0.5500	0.0030	0.0021
SHRIMP	250.0000	0.0700	0.0400	3.6000	0.0000	0.1000	0.2800	0.0020	0.0035
SIGANID	5.0000	0.1700	0.1800	4.6000	0.5000	0.2000	0.2000	0.0500	0.0010
SLIPMTH	110.0000	0.0200	0.1000	2.1000	0.5000	0.2000	0.2000	0.0500	0.0035
SMINTB	30.0000	0.0700	0.3200	1.5000	16.0000	0.0000	0.0000	0.0000	0.0040
SMINTBU	30.0000	0.0600	0.1800	3.0000	16.0000	0.0000	0.0000	0.0000	0.0042
SMINTGOA	30.0000	0.0400	0.1900	0.7000	14.0000	0.0000	0.0000	0.0000	0.0007
SMINTPIG	30.0000	0.1700	0.3300	2.9000	14.0000	0.0000	0.0000	0.0000	0.0007
SMSHRIMP	250.0000	0.0700	0.1500	2.4000	0.0000	0.1000	0.2800	0.0020	0.0063
SNAPBEAN	5.0000	0.6200	0.2300	2.4000	0.5000	0.0800	0.1900	0.0200	0.0000
SNAPPER	5.0000	0.0500	0.0800	3.7000	0.5000	0.2000	0.2000	0.0500	0.0010
SOURSOP	12.0000	0.0900	0.0700	0.9000	29.0000	0.0200	0.2530	0.0020	0.0000
SOYBEAN	50.0000	0.4400	0.1800	2.0000	0.5000	0.8100	1.7000	0.0550	0.0000
SPADEF	100.0000	0.0300	0.2700	5.2000	0.5000	0.2000	0.2000	0.0500	0.0026
SPLEAVES	5565.0009	0.1200	0.2000	0.9000	32.0000	0.2630	0.3800	0.0000	0.0000
SPLEENB	195.0000	0.1500	0.4400	4.7000	29.0000	0.1200	1.2500	0.0030	0.0068
SPLEENBU	95.0000	0.1200	0.4600	4.9000	30.0000	0.1200	1.2500	0.0030	0.0036
SPLEENLA	195.0000	0.1100	0.1800	4.6000	29.0000	0.1200	1.2500	0.0030	0.0053
SPLEENPI	195.0000	0.2100	0.4100	4.4000	29.0000	0.1200	1.2500	0.0030	0.0055
SPMACK	70.0000	0.0300	0.0800	5.7000	0.5000	0.5000	0.2400	0.0500	0.0023
SPYAM	0.0000	0.0800	0.0200	0.6000	14.0000	0.1100	0.6290	0.0100	0.0000
SQUID	177.0000	0.0100	0.0500	4.1000	0.5000	0.3600	0.1500	0.0500	0.0013
STOMB	55.0000	0.0400	0.1700	1.6000	3.0000	0.0000	0.0000	0.0000	0.0024
STOMBU	40.0000	0.0200	0.1200	3.7000	0.5000	0.0000	0.0000	0.0000	0.0019
STOMGOAT	40.0000	0.0600	0.3500	0.7000	2.0000	0.0000	0.0000	0.0000	0.0009

FOOD	VIT. A	THIAMINE	RIBOFLAVIN	NIACIN	VIT. C	VIT. B6	VIT. B12	PANT. ACID	FOLIC ACID
	IU/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G
STOMPIG	40.0000	0.0900	0.2900	2.4000	2.0000	0.000[illegible]	0.0000	0.0000	0.0009
STRMACK	70.0000	0.0300	0.2000	9.4000	0.5000	0.5000	0.2400	0.0500	0.0077
SUGCANEJ	0.0000	0.0100	0.0100	0.1000	0.5000	0.0000	0.0000	0.0000	0.0000
SURGEONF	800.0001	0.0300	0.0200	3.8000	0.5000	0.2000	0.2000	0.0500	0.0005
SWPOT	900.0001	0.1000	0.0400	0.6000	35.0000	0.2180	0.8200	0.0100	0.0000
SWPOTWH	60.0000	0.0900	0.0400	0.5000	53.0000	0.2180	0.8200	0.0100	0.0000
TARO	5.0000	0.1800	0.0400	0.9000	10.0000	0.1100	0.5210	0.0100	0.0000
THREADFN	5.0000	0.0300	0.0500	2.5000	0.5000	0.2000	0.2000	0.0500	0.0010
TOMATO	735.0001	0.0600	0.0400	0.6000	29.0000	0.1000	0.3300	0.0050	0.0000
TONGUEB	5.0000	0.0900	0.1800	3.6000	0.0000	0.1250	2.0000	0.0030	0.0017
TONGUEPI	5.0000	0.1700	0.2100	3.4000	0.0000	0.2800	2.0000	0.0030	0.0028
TURGIZZ	0.0000	0.0700	0.2400	5.9000	4.0000	0.0300	0.9090	0.0000	0.0019
TURKEY	5.0000	0.1200	0.1900	7.9000	0.0000	0.3250	0.7480	0.0030	0.0004
TURLIVER	17700.0039	0.2400	2.4600	15.6000	35.0000	0.7500	6.0000	0.2200	0.0279
TURTLE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WATMELON	170.0000	0.0200	0.0300	0.2000	6.0000	0.0680	0.3000	0.0060	0.0000
WHCORN	5.0000	0.2200	0.1000	1.8000	6.0000	0.2500	0.5800	0.0350	0.0000
WHITING	105.0000	0.0200	0.0400	5.3000	0.5000	0.2000	0.2000	0.0500	0.0010
WKIDBEAN	5.0000	0.4200	0.1800	1.7000	0.5000	0.5600	0.7250	0.0200	0.0000
YAM	0.0000	0.0700	0.0200	0.5000	4.0000	0.1100	0.6290	0.0100	0.0000
YCORN	435.0000	0.2600	0.1500	1.5000	10.0000	0.2500	0.5800	0.0350	0.0000
YFINTUNA	40.0000	0.1000	0.1100	13.2000	5.0000	0.9000	0.5000	0.0500	0.0030

FOOD	ISOLEUCINE	LEUCINE	LYSINE	METHIONINE	CYSTINE	PH-ALANI[illegible]E	TYROSINE	THREONINE	TRYPTOPHAN	VALINE
	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G
ALBACORE	1197.0002	1836.0002	2328.0004	657.0001	294.0000	916.0001	968.0001	1067.0002	320.0000	1784.0002
ANCHOVY	1056.0002	1763.0002	1802.0002	621.0001	243.0000	925.0001	774.0001	1027.0002	214.0000	1229.0002
ATIS	6.0000	14.0000	51.0000	7.0000	4.0000	10.0000	4.0000	12.0000	8.0000	15.0000
AVOCADO	47.0000	76.0000	59.0000	29.0000	10.0000	48.0000	32.0000	40.0000	15.0000	63.0000
BANANA90	32.0000	53.0000	46.0000	22.0000	30.0000	44.0000	29.0000	38.0000	13.0000	45.0000
BANANA92	32.0000	53.0000	46.0000	22.0000	30.0000	44.0000	29.0000	38.0000	13.0000	45.0000
BARRACUD	919.0001	1440.0002	1813.0002	478.0000	190.0000	7[illegible]3.0001	541.0001	919.0001	184.0000	1045.0002
BEEF	852.0001	1435.0002	1573.0002	478.0000	226.0000	778.0001	637.0001	812.0001	198.0000	886.0001
BESCAD	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
BLOODB	152.0000	2146.0004	1478.0002	186.0000	260.0000	1130.0002	673.0001	877.0001	281.0000	1445.0002
BLOODPIG	121.0000	2428.0004	1587.0002	198.0000	242.0000	1271.0002	673.0001	896.0001	290.0000	1569.0002
BONITO	1197.0002	1836.0002	2328.0004	657.0001	294.0000	916.0001	968.0001	1067.0002	320.0000	1784.0002
BRAINB	940.0001	1452.0002	1249.0002	371.0000	205.0000	464.0000	627.0001	714.0001	155.0000	947.0001
BRAINBU	940.0001	1452.0002	1249.0002	698.0001	205.0000	873.0001	627.0001	714.0001	291.0000	947.0001
BRAINLAM	447.0000	469.0000	676.0001	251.0000	174.0000	512.0001	436.0000	610.0001	164.0000	174.0000
BSRAY	1488.0002	1670.0002	2182.0004	634.0001	182.0000	774.0001	1082.0002	723.0001	275.0000	1078.0002
BUFFALO	852.0001	1435.0002	1573.0002	478.0000	226.0000	778.0001	637.0001	812.0001	198.0000	886.0001
CABBAGE	50.0000	86.0000	50.0000	17.0000	18.0000	49.0000	30.0000	61.0000	15.0000	68.0000
CAESIO	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
CASHEW	6.0000	14.0000	13.0000	0.0000	4.0000	10.0000	4.0000	12.0000	2.0000	15.0000
CASSAVA	28.0000	38.0000	61.0000	12.0000	1.0000	23.0000	7.0000	25.0000	18.0000	29.0000
CATFISH	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
CAVALLA	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
CHGIZZ	1118.0002	1875.0002	1657.0002	480.0000	218.0000	1134.0002	654.0001	1046.0002	218.0000	1286.0002
CHICKENY	1069.0002	1472.0002	1590.0002	502.0000	262.0000	800.0001	669.0001	794.0001	205.0000	1018.0001
CHICKPEA	1228.0002	1750.0002	2306.0004	566.0001	118.0000	1374.0002	402.0000	834.0001	120.0000	1150.0002
CHICO	6.0000	14.0000	40.0000	3.0000	4.0000	10.0000	4.0000	12.0000	4.0000	15.0000
CHLIVER	869.0001	1720.0002	1466.0002	453.0000	362.0000	815.0001	597.0001	1068.0002	253.0000	1068.0002
COCOMAT	182.0000	304.0000	216.0000	99.0000	10.0000	115.0000	39.0000	132.0000	27.0000	223.0000
COCOY	65.0000	109.0000	78.0000	36.0000	4.0000	41.0000	14.0000	47.0000	10.0000	80.0000
COTSEED	785.0001	1410.0002	1052.0002	309.0000	370.0000	1242.0002	686.0001	785.0001	297.0000	1105.0002
COWPEA	1357.0002	1830.0002	1363.0002	616.0001	82.0000	1442.0002	628.0001	961.0001	122.0000	685.0001
CRAB	745.0001	1388.0002	1262.0002	466.0000	202.0000	645.0001	581.0001	730.0001	184.0000	765.0001
CREVALLE	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
CROAKER	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
DAPA	822.0001	1344.0002	1631.0002	396.0000	133.0000	650.0001	627.0001	799.0001	220.0000	909.0001
DUCK	1069.0002	1472.0002	1590.0002	502.0000	262.0000	800.0001	669.0001	794.0001	205.0000	1018.0001
EGGDUCK	655.0001	1130.0002	910.0001	562.0001	199.0000	725.0001	630.0001	820.0001	152.0000	875.0001
EGGPLANT	52.0000	72.0000	63.0000	13.0000	6.0000	49.0000	46.0000	44.0000	12.0000	61.0000
EGGS	778.0001	1091.0002	863.0001	416.0000	301.0000	709.0001	515.0001	634.0001	184.0000	847.0001
GAMET	1010.0001	1270.0002	1690.0002	424.0000	237.0000	920.0001	708.0001	1010.0001	307.0000	1410.0002
GARLIC	20.0000	37.0000	63.0000	16.0000	115.0000	38.0000	58.0000	20.0000	20.0000	30.0000
GINGER	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GLASSF	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
GNSHELL	506.0000	958.0001	529.0001	173.0000	187.0000	745.0001	548.0001	390.0000	156.0000	625.0001
GOAT	778.0001	1203.0002	1275.0002	383.0000	200.0000	625.0001	515.0001	733.0001	198.0000	790.0001
GOATFISH	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
GOBY	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
GOOSE	1069.0002	1472.0002	1590.0002	502.0000	262.0000	800.0001	669.0001	794.0001	205.0000	1018.0001
GRAPEFRT	23.0000	22.0000	14.0000	2.0000	10.0000	30.0000	17.0000	12.0000	2.0000	31.0000

FOOD	ISOLEUCINE	LEUCINE	LYSINE	METHIONINE	CYSTINE	PH-ALANINE	TYROSINE	THREONINE	TRYPTOPHAN	VALINE
	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G
GROUPER	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
GRUNT	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
HAIRTAIL	1197.0002	1836.0002	2328.0004	657.0001	294.0000	916.0001	968.0001	1067.0002	320.0000	1784.0002
HARDTAIL	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
HEARTB	940.0001	1452.0002	1249.0002	376.0000	205.0000	783.0001	627.0001	714.0001	172.0000	947.0001
HEARTBU	940.0001	1452.0002	1249.0002	376.0000	205.0000	783.0001	627.0001	714.0001	172.0000	947.0001
HEARTGOA	821.0001	1368.0002	1522.0002	393.0000	171.0000	787.0001	496.0000	701.0001	154.0000	992.0001
HEARTLAM	869.0001	1448.0002	1611.0002	416.0000	181.0000	833.0001	525.0001	742.0001	163.0000	1050.0002
HEARTPIG	787.0001	1312.0002	1460.0002	377.0000	164.0000	754.0001	476.0000	672.0001	148.0000	951.0001
HERRING	1056.0002	1763.0002	1802.0002	621.0001	243.0000	925.0001	774.0001	1027.0002	214.0000	1229.0002
HORSE	1299.0002	1901.0002	2000.0002	560.0001	259.0000	762.0001	682.0001	781.0001	202.0000	1002.0001
JACKFRT	6.0000	14.0000	14.0000	2.0000	4.0000	10.0000	4.0000	12.0000	3.0000	15.0000
KAIMITO	6.0000	14.0000	42.0000	5.0000	4.0000	10.0000	4.0000	12.0000	5.0000	15.0000
KIDNEYB	940.0001	1452.0002	1249.0002	551.0001	205.0000	689.0001	627.0001	714.0001	214.0000	947.0001
KIDNEYBU	940.0001	1452.0002	1249.0002	504.0000	205.0000	196.0000	627.0001	714.0001	196.0000	947.0001
KIDNEYGO	700.0001	1320.0002	1113.0002	366.0000	159.0000	731.0001	413.0000	684.0001	223.0000	1049.0002
KIDNEYLA	713.0001	1345.0002	1134.0002	373.0000	162.0000	745.0001	421.0000	697.0001	227.0000	1069.0002
KIDNEYPI	678.0001	1278.0002	1078.0002	354.0000	154.0000	708.0001	400.0000	662.0001	216.0000	1016.0001
LAKATAN	32.0000	53.0000	460.0000	22.0000	30.0000	44.0000	29.0000	38.0000	13.0000	45.0000
LANZONES	6.0000	14.0000	14.0000	2.0000	4.0000	10.0000	4.0000	12.0000	3.0000	15.0000
LARINTB	180.0000	265.0000	390.0000	145.0000	65.0000	190.0000	135.0000	230.0000	55.0000	270.0000
LARINTBU	335.0000	493.0000	726.0001	270.0000	121.0000	353.0000	251.0000	428.0000	102.0000	502.0000
LARINTGO	396.0000	583.0001	858.0001	253.0000	143.0000	462.0000	297.0000	506.0000	121.0000	594.0001
LARINTPI	346.0000	509.0000	749.0001	221.0000	125.0000	403.0000	259.0000	442.0000	106.0000	518.0001
LATUNDAN	32.0000	53.0000	460.0000	22.0000	30.0000	44.0000	29.0000	38.0000	13.0000	45.0000
LEAJACK	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
LEMON	12.0000	21.0000	14.0000	6.0000	10.0000	12.0000	17.0000	12.0000	4.0000	17.0000
LIME	25.0000	42.0000	15.0000	2.0000	10.0000	25.0000	17.0000	25.0000	3.0000	34.0000
LIVERB	940.0001	1452.0002	1249.0002	1065.0002	205.0000	932.0001	627.0001	714.0001	355.0000	947.0001
LIVERBU	940.0001	1452.0002	1249.0002	744.0001	205.0000	651.0001	627.0001	714.0001	248.0000	947.0001
LIVERGOA	1149.0002	2122.0004	1503.0002	530.0001	243.0000	1017.0001	729.0001	1083.0002	243.0000	1370.0002
LIVERLAM	1134.0002	2093.0004	1482.0002	523.0001	240.0000	1003.0001	719.0001	1068.0002	240.0000	1352.0002
LIVERPIG	936.0001	1728.0002	1224.0002	432.0000	198.0000	828.0001	594.0001	882.0001	198.0000	1116.0002
LIZFISH	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
LUNGGOAT	968.0001	1331.0002	1354.0002	407.0000	218.0000	773.0001	550.0001	722.0001	207.0000	952.0001
LUNGLAM	824.0001	1467.0002	1357.0002	333.0000	210.0000	786.0001	600.0001	758.0001	246.0000	909.0001
LUNGPIG	968.0001	1331.0002	1354.0002	407.0000	218.0000	773.0001	550.0001	722.0001	207.0000	952.0001
LUNGSB	940.0001	1452.0002	1249.0002	376.0000	205.0000	783.0001	627.0001	714.0001	172.0000	947.0001
LUNGSBU	940.0001	1452.0002	1249.0002	376.0000	205.0000	783.0001	627.0001	714.0001	172.0000	947.0001
MANGO	6.0000	14.0000	52.0000	5.0000	4.0000	10.0000	4.0000	12.0000	8.0000	15.0000
MARBRAY	1488.0002	1670.0002	2182.0004	634.0001	182.0000	774.0001	1082.0002	723.0001	275.0000	1078.0002
MILKBUFF	210.0000	397.0000	308.0000	105.0000	53.0000	177.0000	197.0000	194.0000	58.0000	239.0000
MILKCOW	162.0000	328.0000	268.0000	86.0000	28.0000	185.0000	163.0000	153.0000	48.0000	199.0000
MILKFISH	1056.0002	1763.0002	1802.0002	621.0001	243.0000	925.0001	774.0001	1027.0002	214.0000	1229.0002
MILKGOAT	197.0000	353.0000	196.0000	50.0000	28.0000	142.0000	121.0000	164.0000	45.0000	242.0000
MOONFISH	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
MULLET	919.0001	1440.0002	1813.0002	478.0000	190.0000	703.0001	541.0001	919.0001	184.0000	1045.0002
MUNGGR	1257.0002	1820.0002	3979.0004	573.0001	63.0000	1391.0002	622.0001	795.0001	513.0001	1437.0002
MUNGRED	1390.0002	1945.0002	2800.0004	680.0001	123.0000	1478.0002	580.0001	1010.0001	460.0000	1450.0002
NEMIPTER	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002

FOOD	ISOLEUCINE	LEUCINE	LYSINE	METHIONINE	CYSTINE	PH-ALANINE	TYROSINE	THREONINF	TRYPTOPHAN	VALINE
	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G
ONION	20.0000	37.0000	63.0000	16.0000	115.0000	38.0000	58.0000	20.0000	20.0000	30.0000
ORANGE	23.0000	22.0000	43.0000	12.0000	10.0000	30.0000	17.0000	12.0000	6.0000	31.0000
PAPAYA	6.0000	14.0000	28.0000	1.0000	4.0000	10.0000	4.0000	12.0000	8.0000	15.0000
PETSAY	101.0000	104.0000	106.0000	11.0000	18.0000	54.0000	30.0000	59.0000	18.0000	79.0000
PIGPEA	1513.0002	2171.0004	1726.0002	711.0001	124.0000	826.0001	436.0000	918.0001	87.0000	1633.0002
PILI	549.0001	965.0001	533.0001	174.0000	188.0000	750.0001	588.0001	393.0000	157.0000	630.0001
PINEAPLE	6.0000	14.0000	14.4000	3.0000	4.0000	10.0000	4.0000	12.0000	5.0000	15.0000
POMFRET	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
POMPANO	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
PORGY	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
PORK	608.0001	897.0001	961.0001	321.0000	133.0000	496.0000	426.0000	583.0001	162.0000	616.0001
POTATOES	76.0000	121.0000	96.0000	26.0000	12.0000	80.0000	55.0000	75.0000	33.0000	93.0000
PUMMELO	16.0000	27.0000	17.0000	7.0000	10.0000	16.0000	17.0000	16.0000	5.0000	22.0000
RADISH	54.0000	75.0000	48.0000	10.0000	111.0000	48.0000	12.0000	42.0000	4.0000	71.0000
RICE	364.0000	520.0001	393.0000	261.0000	45.0000	226.0000	81.0000	239.0000	52.0000	440.0000
RICEBR	326.0000	669.0001	308.0000	202.0000	97.0000	432.0000	282.0000	343.0000	88.0000	475.0000
RICEGLU	255.0000	600.0001	269.0000	152.0000	83.0000	372.0000	235.0000	269.0000	90.0000	372.0000
RKIDBEAN	1246.0002	1710.0002	2710.0004	458.0000	81.0000	1373.0002	511.0000	898.0001	289.0000	1258.0002
RSCAD	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
RUNNERF	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
SABA	32.0000	53.0000	46.0000	22.0000	30.0000	44.0000	29.0000	38.0000	13.0000	45.0000
SARDINE	1056.0002	1763.0002	1802.0002	621.0001	243.0000	925.0001	774.0001	1027.0002	214.0000	1229.0002
SBMACK	1197.0002	1836.0002	2328.0004	657.0001	294.0000	916.0001	968.0001	1067.0002	320.0000	1784.0002
SEAWEED	51.0000	64.0000	86.0000	21.0000	12.0000	47.0000	36.0000	51.0000	16.0000	71.0000
SHARK	1389.0002	1709.0002	1930.0002	570.0001	182.0000	826.0001	739.0001	822.0001	224.0000	1101.0002
SHEEP	778.0001	1203.0002	1275.0002	383.0000	200.0000	625.0001	515.0001	733.0001	198.0000	790.0001
SHRIMP	745.0001	1388.0002	1262.0002	466.0000	202.0000	645.0001	581.0001	730.0001	184.0000	765.0001
SIGANID	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
SLIPMTH	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
SMINTB	940.0001	1452.0002	1249.0002	476.0000	205.0000	623.0001	627.0001	714.0001	180.0000	947.0001
SMINTBU	940.0001	1452.0002	1249.0002	302.0000	205.0000	395.0000	627.0001	714.0001	114.0000	947.0001
SMINTGOA	367.0000	541.0001	796.0001	235.0000	133.0000	428.0000	275.0000	469.0000	112.0000	551.0001
SMINTPIG	454.0000	668.0001	983.0001	290.0000	164.0000	529.0001	340.0000	580.0001	139.0000	680.0001
SMSHRIMP	745.0001	1388.0002	1262.0002	466.0000	202.0000	645.0001	581.0001	730.0001	184.0000	765.0001
SNAPBEAN	927.0001	1685.0002	1593.0002	234.0000	188.0000	1154.0002	559.0001	878.0001	223.0000	1016.0001
SNAPPER	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
SOURSOP	6.0000	14.0000	66.0000	8.0000	4.0000	10.0000	4.0000	12.0000	12.0000	15.0000
SOYBEAN	2424.0004	2373.0004	4279.0009	860.0001	207.0000	1865.0002	1036.0002	1576.0002	508.0000	2236.0004
SPADEF	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
SPLEAVES	106.0000	210.0000	157.0000	32.0000	24.0000	142.0000	86.0000	127.0000	42.0000	136.0000
SPLEENB	940.0001	1452.0002	1249.0002	376.0000	205.0000	783.0001	627.0001	714.0001	172.0000	947.0001
SPLEENBU	940.0001	1452.0002	1249.0002	376.0000	205.0000	783.0001	627.0001	714.0001	172.0000	947.0001
SPLEENLA	824.0001	1467.9001	1357.0002	333.0000	210.0000	786.0001	600.0001	758.0001	246.0000	909.0001
SPLEENPI	968.0001	1331.0002	1354.0002	407.0000	218.0000	773.0001	550.0001	722.0001	207.0000	952.0001
SPMACK	1197.0002	1836.0002	2328.0004	657.0001	294.0000	916.0001	968.0001	1067.0002	320.0000	1784.0002
SPYAM	53.0000	92.0000	58.0000	23.0000	16.0000	68.0000	46.0000	52.0000	18.0000	66.0000
SQUID	472.0000	773.0001	797.0001	274.0000	158.0000	414.0000	416.0000	469.0000	130.0000	626.0001
STOMB	755.0001	1329.0002	997.0001	393.0000	53.0000	664.0001	619.0001	725.0001	0.0000	861.0001
STOMBU	935.0001	1646.0002	1234.0002	486.0000	65.0000	823.0001	767.0001	898.0001	0.0000	1066.0002
STOMGOAT	490.0000	862.0001	647.0001	255.0000	34.0000	431.0000	402.0000	470.0000	0.0000	559.0001

FOOD	ISOLEUCINE	LEUCINE	LYSINE	METHIONINE	CYSTINE	PH-ALANINE	TYROSINE	THREONINE	TRYPTOPHAN	VALINE
	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G
STOMPIG	655.0001	1153.0002	865.0001	341.0000	46.0000	576.0001	537.0001	629.0001	0.0000	747.0001
STRMACK	1197.0002	1836.0002	2328.0004	657.0001	294.0000	916.0001	968.0001	1067.0002	320.0000	1784.0002
SUGCANEJ	1.0000	1.0000	1.0000	0.0000	0.0000	1.0000	1.0000	2.0000	0.0000	2.0000
SURGEONF	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
SWPOT	57.0000	69.0000	79.0000	33.0000	1.0000	62.0000	7.0000	45.0000	9.0000	68.0000
SWPOTWH	32.0000	41.0000	48.0000	17.0000	1.0000	27.0000	5.0000	25.0000	5.0000	36.0000
TARO	116.0000	196.0000	200.0000	62.0000	9.0000	198.0001	45.0000	106.0000	34.0000	144.0000
THREADFN	919.0001	1440.0002	1813.0002	478.0000	190.0000	703.0001	541.0001	919.0001	184.0000	1045.0002
TOMATO	20.0000	30.0000	32.0000	7.0000	7.0000	20.0000	14.0000	25.0000	9.0000	24.0000
TONGUEB	940.0001	1452.0002	1249.0002	592.0001	205.0000	503.0000	627.0001	714.0001	192.0000	947.0001
TONGUEPI	695.0001	1029.0002	1418.0002	264.0000	209.0000	639.0001	431.0000	681.0001	195.0000	778.0001
TURGIZZ	1071.0002	1806.0002	1596.0002	462.0000	210.0000	1092.0002	630.0001	1008.0001	210.0000	1239.0002
TURKEY	1069.0002	1472.0002	1590.0002	502.0000	262.0000	800.0001	669.0001	794.0001	205.0000	1018.0001
TURLIVER	830.0001	1644.0002	1401.0002	433.0000	346.0000	779.0001	571.0001	1021.0001	242.0000	1021.0001
TURTLE	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
WATMELON	6.0000	14.0000	2.0000	0.0000	4.0000	10.0000	4.0000	12.0000	1.0000	15.0000
WHCORN	273.0000	526.0001	220.0000	100.0000	27.0000	224.0000	75.0000	260.0000	26.0000	273.0000
WHITING	797.0001	1213.0002	1605.0002	484.0000	201.0000	639.0001	623.0001	718.0001	185.0000	1102.0002
WKIDBEAN	1180.0002	1448.0002	2080.0004	438.0000	11.0000	1100.0002	434.0000	862.0001	282.0000	1085.0002
YAM	85.0000	115.0000	114.0000	52.0000	3.0000	98.0000	21.0000	64.0000	32.0000	91.0000
YCORN	239.0000	572.0001	214.0000	100.0000	30.0000	255.0000	52.0000	377.0000	20.0000	251.0000
YFINTUNA	1197.0002	1836.0002	2328.0004	657.0001	294.0000	916.0001	968.0001	1067.0002	320.0000	1784.0002

APPENDIX 3: Nutrient allowances by age-group and body weight for the Philippines' population

	Body weight present [b] (PW) (kg)	target [c] (TW) (kg)	Energy allowance [d] (kcal/kg)	Recommended calorie intake [e] PW (kcal/d)	TW (kcal/d)	Protein allowance [h] (g/kg)	Recommended protein intake [i] PW (g/d)	TW (g/d)	Recommended calcium intake [l] (mg/d)	Vitamin A allowance [n] (ug retinol/d)	Recommended vitamin A intake [q] PW (iu/d)	TW (iu/d)	Recommended vitamin C intake low [r] (mg/d)	high [s] (mg/d)	Recommended folic acid intake low [r] (mg/d)	high [s] (mg/d)	Recommended vitamin ' 12 intake [r] (mg/d)	Recommended vitamin B6 intake [s] (mg/d)
<7m [a]	8.0	9.0	105	850	950	1.7	22	25	500 - 600		3000	3000	20	35	0.04	0.05	0.0003	0.4
7-12m [a]	8.0	9.0	105	850	950	1.7	22	25	500 - 600	34.0	2000	2500	20	35	0.06	0.10	0.0003	0.4
1-3y	11.0	12.0	108	1200	1300	1.06	24[k]	26[k]	400 - 500	20.0	1500	2000	20	40	0.10	0.15	0.0009	0.6
4-6y	15.5	17.0	94	1500	1600	0.97	30[k]	32[k]	400 - 500	15.5	2000	2000	20	40	0.10	0.20	0.0015	0.9
7-9y	20.5	25.0	77	1600	1950	0.92	32[k]	39[k]	400 - 500	15.0	2500	3000	20	40	0.10	0.20	0.0015	1.2
10-12y (male)	25.0	33.0	69	1750	2300	0.86	35[k]	46[k]	600 - 700	16.0	3500	4000	20	40	0.10	0.40	0.002	1.4
10-12y (female)	28.0	33.0	69	1950	2300	0.86	39[k]	46[k]	600 - 700		3500[p]	4000[p]	20	40	0.10	0.40	0.002	1.4
13-15y (male)	39.0	44.0	63	2500	2850	0.84	52	59	600 - 700	15.0	4000	5000	30	45	0.20	0.40	0.002	1.6
13-15y (female)	39.0	44.0	53	2100	2350	0.84	52	59	600 - 700		4000[p]	5000[p]	30	45	0.20	0.40	0.002	1.6
16-19y (male)	50.0	55.0	51	2550	2800	0.77	61	67	500 - 600	13.0	4500	5000	30	55	0.20	0.40	0.002	1.8
16-19y (female)	46.0	48.0	44	2050	2150	0.77	56	59	500 - 600		4500[p]	5000[p]	30	50	0.20	0.40	0.002	1.8
20-29y (male)	53.0	56.0		2450[f]	2550[f]	0.71	60	63	400 - 500	12.0	4500	5000	30	60	0.20	0.40	0.002	2.0
30-39y (male)				2400[g]	2500[g]													
40-49y (male)				2300	2400													
50-59y (male)				2150	2200													
60-69y (male)				1950	2000													
> 70y (male)				1700	1750													
20-29y (female)	46.0	49.0		1850[f]	1950[f]	0.71	52	55	400 - 500		4500[p]	5000[p]	30	55	0.20	0.40	0.002	2.0
30-39y (female)				1800[g]	1900[g]													
40-49y (female)				1750	1850													
50-59y (female)				1600	1700													
60-69y (female)				1500	1550													
> 70y (female)				1300	1350													
pregnancy (9 months)				400	400	6g/d [i]	10	10	600 - 700 [m]	[o]			20 [i]	5 [i]	0.20	0.40	0.001	0.5
lactation (8 months)				1000	1000	12.5g/d	20	20	600 - 700	[o]	3000	3000	20	5	0.10	0.10	0.0005	0.5

Note: For all other nutrient allowances, see text, chapter 3.

a. Allowances used only for infants, not breast-fed - based on extra allowance for lactation. Breast fed infants should obtain allowance through breast milk.
b. Taken from R. F. Florentino. Philippine Journal of Nutrition (1966) 19 (1.2), 50.
c. Taken from C. L. Intengen. Philippine Journal of Nutrition (1970) 23 (2), 1.
d. Taken from 'Calorie Requirements'. FAO Nutritional Studies No. 15, FAO, Rome, 1957.
e. Rounded to nearest 50 kcal.
f. Based on data of Florentino (b) and National Research Council. Report(s).
g. Allowances for over 30y age-groups, scaled down according to recommended percentage of 20-29y allowance by FAO (d).
h. Taken from FAO/WHO Expert Group. 'Protein Requirements'. FAO Nutrition Meetings Report Series No. 37, FAO, Rome, 1965.
i. For last 6 months of pregnancy.
j. Corrected for protein quality of Philippine diet equivalent to NPU of 63.
k. Corrected up to 8% total calories as protein.
l. Taken from FAO/WHO Expert Group. 'Calcium requirements'. FAO Nutrition Meetings Report Series No. 30, FAO, Rome, 1962
m. For last 3 months of pregnancy.
n. Taken from FAO/WHO Expert Group. 'Requirements of vitamin A, thiamine, riboflavin and niacin'. FAO Nutrition Meetings Report Series No. 41, FAO, Rome, 1967.
o. No extra allowance for pregnancy and lactation included in higher male requirement recommended for women (p).
p. Same allowance as males.
q. Based on retinol content of Philippine diet of 13%. For calculation see 3.4.8
r. Taken from FAO/WHO Expert Group. 'Requirements of ascorbic acid, vitamin D, vitamin B12, folate and iron'. Nutrition Meetings Report Series No. 47, FAO, Rome, 1970.
s. Taken from National Research Council. 'Recommended allowances'. National Academy of Sciences, Washington D.C., 1963.

APPENDIX 4: Demographic data - the population distribution of the Philippines.

Nutritional requirements were obtained in terms of levels for specific age groups. To determine weighted average allowances for the population, data on the age distribution of the Philippines population was obtained. In the UN Demographic Yearbook (1969) the last census was in 1960 and since then the mid-year population had been estimated by the U.N. Demographic Section.

The age groups described were not always those described in nutritional tables. e.g. Calorie tables described allowances for the age groups 0 - 12 months; 1 - 3 y; 4 - 6 y; 7 - 9 y; and the following for both male and female groups 10 - 12 y; 13 - 15 y; 16 - 19 y; 20 - 29 y; 30 - 39 y; 40 - 49 y; 50 - 59 y; 60 - 69 y; and 70 y and over group. Demographic data was described for groups 0 - 1 y; 1 - 4 y; 5 - 9 y; 10 - 14 y; 15 - 19 y ; 20 - 24 y and every decade from 25 y for both male and female groups.

The data in the demographic tables was modified to provide estimates of the population in each of the age groups required to assess nutritional allowances. The method used is illustrated in Table A.4.1 with the most recent demographic data viz. 1968.

For most nutrients extra allowances were necessary in the special cases of pregnant women, lactating women and non-breast-fed infants. No data was available on size of these population groups so the FAO/WHO method of calculation was used to obtain estimations of the extra allowance required for these special conditions.

1. Pregnant women. The number of pregnant women in any year was assumed to be 10% greater than the number of infant children (0 - 1 y) existing in that year. Thus for 1968, this would be 110% x 1,530,000 = 1,683,000.

However, during the calendar year each woman's pregnancy lasts 9 months therefore in calculating extra requirements for the year, 9/12 or 3/4 of the total number of pregnant women should be considered in calculations. Individual nutrients are required for different lengths of time during pregnancy so the allowances were calculated as fractions of this amount. Table A.4.2 indicates the fractions required in estimating extra allowances for pregnancy for the different nutrients. This system of calculation conflicted with that described in the FAO/WHO report on "Requirements of ascorbic acid, vitamin D, vitamin B12, folate and iron". (99) The allowance for number of pregnant women in the weighted average ascorbic acid requirement for a population, used in the calculation was taken as 2/3 of the figure obtained when 110% of the infant children was evaluated (required for 2nd and 3rd trimesters only). In other reports the method used was as described above. Presumably the ascorbic acid report considered the number of pregnant women in the year of study as equivalent to the number of pregnancies Hence the 2/3 factor was used directly. There is little basis for estimating the number of pregnancies in a year as miscarriages, abortions, deaths etc. could not be assessed. It is only possible to estimate the extra allowance required in that year due to the number of pregnant women which in a yearly period must be 3/4 of the number of pregnant women for a full term allowance, 3/4 x 2/3 or 1/2 of the number of pregnant women for allowances for the 2nd and 3rd trimesters of a pregnancy (or 6 months in that year) and 3/4 x 1/3 or 1/4 of the number of pregnant women for allowances for the final trimester (3 months) of pregnancy. This was the method used in the weighted average calculation.

Table A.4.1 Modification of population groups.

New age group	Derivation from age group in U.N. Demographic Yearbook Statistics	Estimated 1968 population in age group x 1000
0 - 1 y	no change	1530
1 - 3 y	0.75 (1 - 4 group)	4016
4 - 6 y	0.25 (1 - 4 gp) + 0.4 (5 - 9 y gp)	3508
7 - 9 y	0.6 (5 - 9 y gp)	3253.5
10 - 12 y male	0.6 (10 - 14 y male)	1376
10 - 12 y female	0.6 (10 - 14 y female)	1322
13 - 15 y male	0.4 (10-14 y male) + 0.2(15-19 y male)	1305
13 - 15 y female	0.4 (10 - 14 y female) + 0.2 (15 - 19 y female)	1255
16 - 19 y male	0.8 (15 - 19 y male)	1549
16 - 19 y female	0.8 (15 - 19 y female)	1494
20 - 29 y male	(20 - 24 y male) + (25 - 29 y male)	2843
30 - 39 y male	(30 - 34 y male) + (35 - 39 y male)	1891
40 - 49 y male	(40 - 44 y male) + (45 - 49 y male)	1301
50 - 59 y male	(50 - 54 y male) + (55 - 59 y male)	881
60 - 69 y male	(60 - 64 y male) + (65 - 69 y male)	472
70 + male	(70 - 74 y male) + (75 - 79 y male) + (80 - 84 male) + (85 plus)	237
20 - 29 y female	(20 - 24 y F) + (25 - 29 y F)	2777
30 - 39 y female	(30 - 34 y F) + (35 - 39 y F)	1878
40 - 49 y female	(40 - 44 y F) + (45 - 49 y F)	1308
50 - 59 y female	(50 - 54 y F) + (55 - 59 y F)	909
60 - 69 y female	(60 - 64 y F) + (65 - 69 y F)	506
70 + female	(70 - 74 y F) + (75 - 79 y F) + (80 - 84 y F) + (85 y plus)	271

2. Lactating women. In accordance with FAO/WHO recommendations, the numbers of lactating women in any year was assumed to be equal to the number of infant children less than 1 year old in that year. It was assumed that the average lactation period was 8 months or 2/3 of the year so that the 2/3 of the number of lactating women was taken when calculating the allowance for lactation during the year.

3. Infants not breast fed. Following on from the previous assumption the factor for the number of breast fed infants less than one year old in that year would correspond to the factor for lactation, i.e. 2/3 of the total number of infants. It would seem that a suitable factor for the number of infants who would not be breast-fed during that year would be 1/3 of the total number of infants. Using this system, whenever an extra allowance was calculated for lactation, [illegible] also covered the allowance for breast-fed infants and an extra allowance was required only for non-breast fed infants. (Table A.4.3)

Table A.4.2. Fraction of a year considered in estimating pregnancy allowances for several nutrients.

nutrient	time	fraction of pregnancy
calories	the full term	1.0
protein	2nd and 3rd trimester	0.67
calcium	3rd trimester	0.33
vitamin A	no extra allowance	-
vitamin C	2nd and 3rd trimester	0.67
folic acid	full term	1.0
vitamin B12	full term	1.0
vitamin B6	full term	1.0

Table A.4.3. Calculation of factors for population groups requiring extra nutrients.

	No. of infants (0-1)	Factor	Assumed population for allowance
pregnant women	1,530,(000)	0.75 x 1.1	1262000
lactation		0.67	1020000
not breast fed children (0-1)[a]		0.33	510000

a. This figure was halved to provide estimates of not breast fed (NBF) infants in the 0 - 6 month and 7 - 12 month age groups in the calculations

This population data was used in estimating the weighted average nutrient requirements for the Philippine population.

The weighted average calculation of the recommended intake of nutrients for the population.

The method used to evaluate the average requirement of nutrients was described by several FAO/WHO expert group reports (88,99). This involved multiplying the nutritional recommended intake for each age group by the number in the population of that group adding in special allowances for pregnancy, lactation and non-breast fed children and dividing the total by the total population for that year. The weighted average thus obtained would then be scaled up by a factor of 10% to allow for losses between retail level and intake through such effects as waste and cooking losses.

This weighted average was calculated for the nutrients allowances described for population groups - calories, protein, calcium, vitamin A, vitamin C, vitamin B6, vitamin B12 and folic acid. (See 3.4).

```
C        APPENDIX 5  PROGRAM FOR CALCULATION OF CONTRIBUTIONS OF RAW MATERIALS
                     TO NUTRIENT LEVELS




C
C      LOADS MATRIX ON DISK
C
C           INPUT      FIRST CARD HAS NAMES OF FOODSPECS, 1 CARD/ SPEC
C                           EG FAT, LEFT-JUSTIFIED  8A1
C
C                      MATRIX DECK FOLLOWS
C                           FORMAT   FOOD NAME
C                                    SPEC NAME
C                                    SPEC LEVEL
C                      LAST CARD     BLANK
C
       REAL LEVEL(30)
       INTEGER  COLNM(29,8), NAME1(8),SPEC(8),COLTP(8)
       INTEGER NAME2(8)
       DATA IND/1/
       DATA LEVEL/30*0.0/
       DEFINE FILE  1(200,80,U,INDEX)
C
C      READ IN NAMES OF FOOD SPECIFICATIONS
C
          DO 2 I = 1, 29
               READ(2,1)(COLNM(I,J),J=1,8)
    1                FORMAT(8A1)
    2     CONTINUE
          IFLAG = 1
C      READ THE CARD
C
  111     READ(2,3)NAME2,SPEC,AMT
    3          FORMAT(4X,8A1,2X,8A1,F14.0)
C              CHOICE ON FIRST TIME THRU
                    IF(IFLAG-1)4,4,6
C                        FIRST TIME THRU
    4                         IFLAG = 2
                              CALL MOVE(NAME2,1,8,NAME1,1)
                              GO TO 6
C
C                        NOT FIRST TIME THRU
C                             CHOICE ON CHANGE OF FOOD TYPE
    6                              IF(NCOMP(NAME2,1,8,NAME1,1))20,10,20
C
C                                  SAME FOOD TYPE,FIND SPEC NO
C
   10                                   DO 12 I = 1,29
                                             DO 11 J =1,8
                                                  COLTP(J)= COLNM(I,J)
   11                                        CONTINUE
                                             IF(NCOMP(COLTP,1,8,SPEC,1))
     X                                          12,15,12
   12                                   CONTINUE
```

```
                              WRITE(1,16)SPEC
   16                         FORMAT(' NAME '8A1' NOT FOUND'
     X                               ' CORRECT AND PUSH START'
     X                                )
                              PAUSE
                              GO TO 111
C
C                             SPEC NO IS I
C                             PUT AMT IN LEVEL(I)
   15                               LEVEL(I)= AMT
                                    GO TO 111
C
C
C                        NEW FOOD TYPE
C                             WRITE RECORD AND INITIALIZE
   20                               WRITE(1'IND)NAME1,LEVEL
                                    WRITE(3,123)NAME1
  123                                     FORMAT(' ' 8A1)
                                    IND = IND+1
                                    DO 21 J = 1,30
                                          LEVEL(J)=0.0
   21                               CONTINUE
                                    DO 22 J = 1,8
   22                                     NAME1(J) = NAME2(J)
C                             PUT AMT IN LEVEL(I)
                                    DO 32 I = 1,29
                                          DO 31 J =1,8
   31                                     COLTP(J)=COLNM(I,J)
                                          IF(NCOMP(COLTP,1,8,
     X                                    SPEC,1))32,35,32
   32                                     CONTINUE
                                                WRITE(1,16)SPEC
                                                PAUSE
                                                GOTO 111
   35                                     LEVEL(I) = AMT
                                          GO TO 111
C
C
C
   88       CALL EXIT
      END
```

```
C
C     PROGRAM TO READ RELATED DATA OFF DISK-- GIVEN FOOD NAME AND WEIGHT
C
C
C     INPUT     TYPE CARDS  AS FOR IST PROGRAM
C
      REAL  LEVEL(29),ROW (30),COL (30),MAT(30,29)
```

```
      INTEGER COLMN(29,8),NAME (200,8),NAME1(8),FOOD(30,8),KEEP(8),TOT(8
     X)
      DEFINE FILE 1(200,80,U,INDEX)
      DATA NO/0/,TOT/'T','O','T','A','L',3*' '/
C
C     READ SPECS AND NAMES
C
          DO 2 I =1,29
               READ(2,1)(COLMN(I,J),J=1,8)
    1          FORMAT(8A1)
    2     CONTINUE
          DO 3 I = 1,200
               READ(1'I)(NAME(I,J),J=1,8)
          CALL DATSW(0,IP)
          GOTO (31,3),IP
   31          WRITE(3,32)(NAME(I,J),J=1,8)
   32          FORMAT (1H ,8A1)

    3     CONTINUE
 1001          NO=0
C
C     READ  UNTIL BLANK REACHED
C
    4     READ(2,5)NAME1,WT
    5          FORMAT(8A1,F16.0)
               IF(NAME1(1)-16448)6,60,6
    6          NO = NO+1
C         FIND RECORD NO ON DISK
C
               DO 8 I   = 1,200
                    DO 7 J = 1,8
                         KEEP(J)= NAME(I,J)
    7               CONTINUE
                    IF(NCOMP(KEEP,1,8,NAME1,1))8,10,8
    8         CONTINUE
               WRITE(1,100)NAME1
  100               FORMAT(8A1,' NOT IN OUR FILE, FIX AND PUSH START')
               PAUSE
               GO TO 4
C
   10          NI = I
               READ(1'NI)KEEP,LEVEL
                    DO 11 I = 1,8
                         FOOD(NO,I)= KEEP(I)
   11               CONTINUE
                    DO 22  I = 1, 29
                         MAT(NO,I) = LEVEL(I) * WT/100.0
   22               CONTINUE
                    GO TO 4
C
C         FORM ROW AND COL TOTALS
   60          DO 61 I = 1,29
                    COL(I)= 0.0
   61               ROW(I)= 0.0
               DO 62 I = 1,NO
                    DO 62 J=1,29
                         ROW(I) = ROW(I) + MAT(I,J)
   62          CONTINUE
```

```
            COL(30) = 0.0
            DO 63 I = 1,29
                 DO 63  J = 1,NC
   63                 COL(I) = COL(I) + MAT(J,I)
C
C      OUTPUT
C
  201 FORMAT('1'T30' WEIGHTED VALUES FROM LP SOLUTION'//)
  202 FORMAT(' FOOD'6X,10(3X,8A1)/)
  203 FORMAT('0' 8A1,2X,10(E10.4,1X))
          I1=1
          I2=10
          DO 210 JJJ = 1,2
               WRITE(3,201)
               WRITE(3,202)((COLMN(I,J),J=1,8),I=I1,I2)
               DO 204 I = 1,NO
                    WRITE(3,203)(FOOD(I,J),J=1,8),(MAT(I,J),J=I1,I2)
  204          CONTINUE
               WRITE(3,203)TOT,(COL(I),I=I1,I2)
               I1 =11
               I2 =20
  210     CONTINUE
          I1= 21
          I2= 29
          WRITE(3,201)
          WRITE(3,202)((COLMN(I,J),J=1,8),I=I1,I2)
          DO 205 I = 1,NO
  205          WRITE(3,203)(FOOD(I,J),J=1,8),(MAT(I,J),J=I1,I2)
               WRITE(3,203)TOT,(COL(I),I = I1,I2)
C         FORM PERCENTAGES  (COL-WISE)
          DO 500 J = 1,29
               DO 500  I = 1,NO
  500               MAT(I,J) = MAT(I,J)/COL(J) * 100.0
         DO 701 J=1,29
              COL(J)=0.0
              DO 600 I=1,NO
  600              COL(J)=COL(J)+MAT(I,J)
  701    CONTINUE
          I1=1
          I2=10
          DO 610 JJJ=1,2
               WRITE(3,601)
               WRITE(3,602)((COLMN(I,J),J=1,8),I=I1,I2)
               DO 604 I=1,NO
                    WRITE(3,603)(FOOD(I,J),J=1,8),(MAT(I,J),J=I1,I2)
  604          CONTINUE
               WRITE(3,603)TOT,(COL(I),I=I1,I2)
               I1=11
               I2=20
  610     CONTINUE
          I1=21
          I2=29
          WRITE(3,601)
          WRITE(3,602)((COLMN(I,J),J=1,8),I=I1,I2)
          DO 605 I=1,NO
  605          WRITE(3,603)(FOOD(I,J),J=1,8),(MAT(I,J),J=I1,I2)
               WRITE(3,603)TOT,(COL(I),I=I1,I2)
C
```

```
C      OUTPUT
C
  601 FORMAT('1'T30' PERCENT CONTRIBUTIONS OF FOODS TO NUTRIENT LEVELS'/
     X/)
  602 FORMAT(' FOOD'6X,10(3X,8A1)/)
  603 FORMAT('0'8A1,2X,10(F7.2,4X))
C
C
C
                GOTO 1001
  287      CALL EXIT
      END
// XEQ          01
*FILES(1,BILL)
// XEQ           1
*FILES(1,BILL)
```

```
C       APPENDIX 6  PROGRAM FOR CALCULATION OF PROTEIN QUALITY INDICES

      REAL ISO,LEU,LYS,NESS,METH
      REAL CS(10)
      INTEGER TITLE(13)
  1   READ (2,21)ISO,LEU,LYS,METH,CYS,PHE,TYR,THREO,TRYP,VAL,PROT,WT,TIT
     1LE
 21   FORMAT(10F8.2/2F8.2,13A1)
      TEAA=ISO+LEU+LYS+METH+CYS+PHE+TYR+THREO+TRYP+VAL
      NESS=PROT*1000-TEAA
      WRITE(3,50)TITLE,ISO,LEU,LYS,METH,CYS,PHE,TYR,THREO,TRYP,VAL,NESS,
     1TEAA,WT
 50   FORMAT(1H1,13A1//' DATA'/10X,' ISO',4X,' LEU',4X,' LYS',4X,' METH'
     1,3X,' CYS',4X,' PHE',4X,' TYR',4X,' THREO',2X,' TRYP',3X,' VAL',4X
     2,' NONESS',4X,' TOTEAA',5X,' WT'//10X,10(F7.1,1X),2(F9.1,1X),2X,F6
     3.1//)
C     CALCULATION OF ESSENTIAL AMINOACID INDEX, EGG REFERENCE FAO(1965)
      EAAI=(625/PROT)*((ISO/415.*LEU/553.*LYS/403.*METH/197.*CYS/149.*PH
     1E/365.*TYR/262.*THREO/317.*TRYP/100.*VAL/454.)**(1./10))
C     CALCULATION OF CHEMICAL SCORE (MITCHELL AND BLOCK) EGG REFERENCE
      CS(1)=(ISO*625.)/(PROT*415.)
      CS(2)=(LEU*625.)/(PROT*553.)
      CS(3)=(LYS*625.)/(PROT*403.)
      CS(4)=(METH*625.)/(PROT*197.)
      CS(5)=(CYS *625.)/(PROT*149.)
      CS(6)=(PHE *625.)/(PROT*365.)
      CS(7)=(TYR *625.)/(PROT*262.)
      CS(8)=(THREO*625.)/(PROT*317.)
      CS(9)=(TRYP *625.)/(PROT*100.)
      CS(10)=(VAL*625.)/(PROT*454.)
      CSMIN 0
      CSMIN CS(1)
      DO 42 I=2,10
      IF(CS(I)-CSMIN)41,41,42
 41   CSMIN CS(I)
 42   CONTINUE
      WRITE(3,51)CSMIN
 51   FORMAT(' CHEMICAL SCORE IS',4X,F6.2//)
      DO 81 I=1,10
      IF(CSMIN-CS(I))81,60,81
 60   GOTO (61,62,63,64,65,66,67,68,69,70),I
 61   WRITE(3,71)
 71   FORMAT(' LIMITING AMINOACID IS ISOLEUCINE')
      GOTO 81
 62   WRITE(3,72)
 72   FORMAT(' LIMITING AMINOACID IS LEUCINE')
      GOTO 81
 63   WRITE(3,73)
 73   FORMAT(' LIMITING AMINOACID IS LYSINE')
      GOTO 81
 64   WRITE(3,74)
 74   FORMAT(' LIMITING AMINOACID IS METHIONINE')
      GOTO 81
```

```
65    WRITE(3,75)
75    FORMAT(' LIMITING AMINOACID IS CYSTINE')
      GOTO 81
66    WRITE(3,76)
76    FORMAT(' LIMITING AMINOACID IS PHENYLALANINE')
      GOTO 81
67    WRITE(3,77)
77    FORMAT(' LIMITING AMINOACID IS TYROSINE')
      GOTO 81
68    WRITE(3,78)
78    FORMAT(' LIMITING AMINOACID IS THREONINE')
      GOTO 81
69    WRITE(3,79)
79    FORMAT(' LIMITING AMINOACID IS TRYPTOPHAN')
      GOTO 81
70    WRITE(3,80)
80    FORMAT(' LIMITING AMINOACID IS VALINE')
81    CONTINUE
C     CALCULATION OF E TO T RATIO ( G PER G NITROGEN )
      ETOT=TEAA*0.00625/PROT
      WRITE(3,102)(CS(I),I=1,10)
102   FORMAT(//' DEFICIENCIES FOR CHEMICAL SCORE CALCULATIONS'/10X,10(F7
     1.2,1X))
C     CALCULATION OF BIOLOGICAL VALUE AND PROTEIN EFFICIENCY RATIO
      SULAA=METH+CYS
      AROMA=PHE+TYR
      BV= 6.25/PROT    *(-0.07897*ISO&0.03628*LEU&0.06267*LYS-0.01694*AR
     1OMA&0.02171*SULAA&0.02649*THREO& 0.20899*TRYP&0.01048*VAL-0.00079*
     2NESS)+32.831
      PER=-1.2689+(0.00237*ISO-0.00046*LEU&0.00214*LYS&0.00018*AROMA&0.0
     10249*SULAA&0.00033*THREO&0.00587*TRYP&0.00462*VAL)*6.25/PROT
C     CALCULATION OF A TO E RATIOS (MG PER G)
      AEISO ISO/TEAA*1000
      AELEU LEU/TEAA*1000
      AELYS LYS/TEAA*1000
      AEMET=METH/TEAA*1000
      AECYS=CYS /TEAA*1000
      AEPHE=PHE /TEAA*1000
      AETYR=TYR /TEAA*1000
      AETHR THREO/TEAA*1000
      AETRY TRYP/TEAA*1000
      AEVAL VAL/TEAA*1000
C     CALCULATION OF AMINO ACID CONTENT PER 100G PROTEIN
      RISO ISO/10 /PROT
      RLEU LEU/10 /PROT
      RLYS LYS/10 /PROT
      RMETH=METH/10/PROT
      RCYS =CYS /10/PROT
      RPHE=PHE/10/PROT
      RTYR=TYR/10/PROT
      RTHRE THREO/10 /PROT
      RTRYP TRYP/10 /PROT
      RVAL VAL/10 /PROT
      WRITE(3,101)ETOT
101   FORMAT(//' E TO T RATIO IS',F5.2)
      WRITE(3,103)AEISO,AELEU,AELYS,AEMET,AECYS,AEPHE,AETYR,AETHR,AETRY,
     1AEVAL
103   FORMAT(//' A TO E RATIOS'/10X,10(F7.2,1X))
```

```
      WRITE(3,104)RISO,RLEU,RLYS,RMETH,RCYS,RPHE,RTYR,RTHRE,RTRYP,RVAL
104   FORMAT(//' GRAMS OF AMINO ACIDS PER 100G PROTEIN'/10X,10(F7.2,1X))
      WRITE(3,105)BV,PER
105   FORMAT(//' BV IS',F7.2,10X,' PER IS',F6.2)
      WRITE(3,106)EAAI
106   FORMAT(//' ESSENTIAL AMINOACID INDEX IS',F8.4)
      GOTO 1
114   CALL EXIT
115   END
// XEQ
```

APPENDIX 7: Changes made to matrix data for Formula 7

Raw material	Variable	Old Coefficient	New Coefficient
Blood (pig)	vitamin C	0.36	0.5
Brain (buffalo)[a]	protein	19.4	9.4
	niacin	2.7	3.7
Brain (lamb)	phosphorus	180	188
Barracuda	thiamine	0.06	0.2
Blue spotted ray	vitamin B6	0.02	0.2
	pantothenic	0.02	0.2
Buffalo	iron	2.9	4.0
	niacin	3.12	3.1
Crab	vitamin B12	0.010	0.00222
Dapa	vitamin A	10.0	5.0
Goat	niacin	6.98	7.0
Grapefruit[a]	calcium	17.1	17.0
	iron	0.26	0.3
Grunt	niacin	1.0	1.8
Heart (lamb)	vitamin B6	0.3	0.2
Horse	cost	0.4	0.04
Intestine, large (beef)[a]	isoleucine	940	180
	leucine	1452	265
	lysine	1249	390
	cystine	205	65
	tyrosine	627	135
	threonine	714	230
	valine	947	270
Intestine, large (goat)	riboflavin	0.12	0.14
Leather jacket	phosphorus	200	179
Liver (beef)	calcium	130	8.0
Liver (buffalo)	niacin	11.2	11.1
Marbled stingray (fish)	vitamin B6	0.02	0.2
	pantothenic	0.02	0.2
Milk (goat)	vitamin A	160.0	110.0
	vitamin C	1.3	1.0
Mullet	calories	94.0	118.0
Orange	thiamine	0.1	0.11
Papaya	folic	0.02	0.002
Pompano	calcium	38.0	40.0
	niacin	2.7	5.7
	vitamin C	4.0	0.5
Rice[a]	cost	0.010	0.019
Shark	fibre	0.5	0.0
Intestine, small (buffalo)[b]	thiamine	0.07	0.06
Small shrimp	vitamin B12	0.0081	0.00636
Snapbean	calories	378	376
Snapper	fibre	21.0	0.0
	vitamin C	21.0	0.5
	vitamin B12	0.1	0.001
Yam, spiny[ab]	vitamin A	5.0	0.0
	folic	0.002	0.01
	isoleucine	89.0	53.0
	leucine	154.0	92.0
	lysine	97.0	58.0

	methionine	38.0	23.0
	cystine	27.0	16.0
	phenylalanine	114.0	68.0
	tyrosine	76.0	46.0
	threonine	86.0	52.0
	tryptophan	30.0	18.0
	valine	110.0	66.0
Stomach (beef)	vitamin C	3.4	3.0
Stomach (buffalo)	niacin	3.5	3.7
Surgeonfish	niacin	4.0	3.8
Sweet potato	vitamin A	1111.0	900.0
Taro	calories	81.0	85.0
Watermelon	thiamine	0.03	0.02
	folic	0.002	0.006
Yam	folic	0.002	0.01

a Raw materials included in the solution of Formula 6

b Raw materials included in the solution of Formula 7, after revisions of coefficients as detailed in this table.

APPENDIX 8: Cost data changes for Formula 9

Raw material	Original cost	Edible portion	Revised cost
albacore	0.033	77	0.043
anchovy	0.036	75	0.048
atis	0.020	50	0.040
avocado	0.012	70	0.017
banana (bungulan)	0.019	67	0.028
banana (gloria)	0.019	62	0.031
barracuda	0.036	50	0.072
beef	0.078	82	0.095
big-eyed scad	0.030	50	0.060
bonito	0.029	63	0.046
blue-spotted ray	0.038	41	0.092
buffalo	0.068	82	0.083
cabbage	0.019	82	0.023
caesio	0.042	49	0.086
cashew	0.015	90	0.017
cassava	0.008	76	0.011
catfish	0.036	45	0.080
cavalia	0.043	33	0.130
chicken	0.017	61	0.027
chico	0.033	84	0.039
coconut, mature	0.008	56	0.014
coconut, young	0.015	14	0.107
crab	0.088	42	0.210
crevalle	0.04	56	0.071
croaker	0.03	44	0.068
dapa	0.033	60	0.055
duck	0.017	61	0.027
eggs (duck)	0.084	87	0.097
eggs (hen)	0.042	87	0.048
eggplant	0.012	91	0.013
garlic	0.089	85	0.105
ginger	0.019	74	0.026
glassfish	0.031	45	0.069
groundnut	0.024	51	0.047
goat	0.043	75	0.057
goatfish	0.030	38	0.079
goby	0.032	39	0.082
goose	0.017	61	0.027
grapefruit	0.025	48	0.052
grouper	0.060	49	0.122
grunt	0.033	35	0.094
hairtail	0.030	55	0.055
hardtail	0.027	30	0.090
herring	0.039	60	0.065
horse	0.040	82	0.049
jackfruit	0.021	34	0.062
kaimito	0.019	53	0.036
lakatan	0.019	69	0.028
lanzones	0.030	68	0.044
latundan	0.019	73	0.026
leather-jacket	0.037	50	0.074

lemon	0.024	38	0.063
lime	0.025	59	0.042
lizard fish	0.023	45	0.051
mango	0.024	72	0.033
marbled stingray (fish)	0.038	36	0.105
milkfish	0.029	68	0.043
moonfish	0.036	48	0.075
mullet	0.037	49	0.076
nemipterid	0.038	45	0.085
onion	0.028	92	0.030
orange	0.019	72	0.026
papaya	0.012	62	0.019
petsay	0.014	82	0.017
pili	0.016	16	0.100
pineapple	0.012	58	0.021
pomfret	0.047	48	0.098
pompano	0.036	48	0.075
porgy	0.036	45	0.080
pork	0.037	78	0.047
potatoes	0.017	85	0.020
pummelo	0.008	56	0.014
radish	0.014	68	0.021
roundscad	0.027	41	0.066
runner fish	0.032	44	0.073
saba	0.019	57	0.033
sardine	0.037	52	0.071
short-bodied mackerel	0.038	50	0.076
shark	0.035	91	0.038
sheep	0.043	79	0.054
shrimp	0.071	63	0.113
siganid	0.036	44	0.082
slipmouth	0.050	38	0.132
snapper	0.042	44	0.095
soursop	0.011	70	0.016
spadefish	0.040	45	0.089
sweet potato leaves	0.020	53	0.037
spanish mackerel	0.037	50	0.076
spiny yam	0.011	82	0.013
squid	0.039	97	0.040
striped mackerel	0.038	62	0.061
sugar-cane juice	0.001	20	0.007
surgeonfish	0.039	41	0.095
sweet potato	0.008	88	0.009
sweet potato (white)	0.015	86	0.018
taro	0.009	81	0.011
threadfin	0.041	35	0.117
tomato	0.020	95	0.021
turkey	0.017	61	0.027
turtle	0.002	24	0.008
watermelon	0.021	62	0.034
whiting	0.037	46	0.080
yam	0.010	86	0.012
yellow-fin tuna	0.029	77	0.038

APPENDIX 9: Processed foods carried by retail stores in different areas of the Philippines[a]

Product type	Area Type of store	Makati(Manila) supermarket	Baguio City large store	Alicia, Isabela sari-sari store
Baked goods				
bread rolls		x	x	x
loaf bread		x	x	
cakes		x	x	
cake mixes		x	x	
biscuits		x	x	x
noodles		x	x	x
Chilled, frozen products				
fresh meat - beef, pork, lamb		x		
frozen meat - beef, pork, lamb		x		
frozen chicken		x		
frozen fish		x		
frozen vegetables		x	x	
ice cream		x	x	
cured meats - sausages		x	x	
- ham, bacon		x	x	
fish		x		
Canned products				
corned beef, meat loaf		x	x	x
vienna sausage		x	x	x
luncheon meat		x	x	
spreads-liver, potted meat		x	x	x
native sausage		x	x	
tuna fish		x	x	
sardines		x	x	x
mackerel (salmon)		x	x	x
beans		x	x	
pork and beans (baked beans)		x	x	x
tomato sauce		x		
soup		x		
milk - condensed		x	x	x
- evaporated		x	x	x
fruit		x	x	x
fruit juices		x	x	x
Dehydrated products				
meat		x		
fish		x		
milk		x	x	x
soups		x	x	

Dairy products				
fresh milk		x		
cheese (processed)		x	x	x
butter		x	x	
margarine		x	x	x
Sauces				
patis (fish sauce)		x	x	x
bagoong (fish paste)		x	x	x
tomato		x	x	x
banana		x	x	
soy		x	x	x
chilli		x		
worcester		x		
jams, jellies		x	x	
Drinks				
Ovaltine		x	x	x
Milo		x	x	x
Toddy		x	x	
instant coffee		x	x	
ground coffee		x	x	x
tea		x	x	x
Soft drinks				
Coke	} cola	x	x	x
Pepsi	} cola	x	x	x
Cosmos	} cola	x	x	x
orange		x	x	x
Lem-o-lime	} lemonade	x		
Teem	} lemonade	x		
7-up	} clear lemonade	x	x	x
Sprite	} clear lemonade	x		

a Data obtained during survey in Phillippines, March, 1973.

APPENDIX 10: Availability of processing equipment and technical know-how in Philippine food industry

During a visit to Manila, a restricted survey of the Philippine food industry was made to gain more detailed information, on the type of equipment available and the technical know-how and degree of sophistication associated with technical operations. Twenty-two food companies throughout the country were visited. These companies ranged from very large, sophisticated operations to small backyard family cottage industry. Although only a small number of factories were visited, contacts were generally extremely co-operative and offered information on the processing and marketing of their products. This cross-section of the industry indicated the general status of food processing in the Philippines. The types of operations observed were:

1. Canneries - meat packing, fruit and vegetable products.
2. Frozen food plants - fish, meat, chicken, ice-cream and dairy products.
3. Dehydration plants - dessicated coconut, dehydrated soups.
4. Extraction operations - starch noodle, coconut oil, sugar production.
5. Miscellaneous - biscuits, confectionery, fish sauce and paste operations.

Canneries. Five canning factories were visited; three were large sophisticated operations, two canning meat products, near Manila, and the others pineapple, in Cagayan de Oro, on Mindanao.

The meat companies were well equipped with modern meat processing equipment - bowl choppers, mincers, brining tanks and automatically controlled smokers. All meat preparation was carried out in chilled rooms. Canning lines were semi-automatic. Generally batch vertical retorts were used. Cans were made on site in one company. The companies operated their own slaughterhouses. Large freezing storage space was used for storing raw materials and cured and frozen meat cuts for the retail trade. Both companies produced a large variety of products. The market sizes for canned meats and pork and beans (baked beans) were estimated at 20,000 and 35,000 cases per month respectively. One company had 60%and the other 10% of these markets. These companies were highly technical. The larger company had several professional staff. Extensive quality control systems and market research surveys were being used. This company had just completed an extensive survey of meat products consumption and consumer attitudes to meat products.

The pineapple canning company visited on Mindanao, part of a US corporation, was the major tin can producer of the country. This highly automated factory had sixteen canning lines with automatic sealing, but depended on manual filling and grading in fruit packing. Tomato sauce, and fruit juice were also produced, on fully automated plant, using vacuum evaporator for the latter. Seven orbitorts and two horizontal retorts were used. An average of 900,000 cases per month was produced. This company was highly technical in approach as it had its own extensive plantations and employed scientists from agricultural, chemical, and engineering disciplines in their operation.

The smaller factories visited were specialist producers. One, in Cebu, produced a Chinese sauce for the Chinese stores and hotels, on small pilot scale equipment, with manual filling and seaming. A 1,000 can retort was available. Output was 48,000 cans (1,000 cases) per month. The other, near Baguic. City, was growing mushrooms on rice straw, grading and canning them mainly for the hotel trade. Two manual can seamers and three vertical retorts were used with two canning lines. Output was 1,000 cans per month in the season. These units were essentially family businesses, operated by an entrepreneur with no real technical qualifications. Thus it appeared that canning was fairly developed at all levels in the Philippines. Especially in the large companies, expertise in formulation, product development and engineering was available. It was noted that all these operations were still highly dependent on a large labour force.

Frozen food plants. The meat companies already described also produced chilled and frozen meat products. Three more factories were visited. These ranged from a small immersion freezing unit producing frozen chickens to a plate-freezing plant for fish products to a large, fully automated dairy products complex. The meat companies and the fish freezing plant, to a lesser extent, produced a range of cured meat products - bacon, ham and sausages, which were frozen or chilled for retail sale.

Imported meat from Australia and New Zealand (mainly beef) was thawed, portioned and refrozen for retail packs at these factories. The meat companies also produced frozen retail portions of local meats. Bacon and ham were produced in greatest quantity and had the largest processed meat market (approx. 125,000 kg/month). This amount conflicted with recorded statistical data. Next, sausages of all types - native, western, smoked frankfurters, luncheon, bologna, salami - were produced generally in large quantity (estimated market size 30,000 kg/month). Products with lowest output were frozen meat cuts (market size 28,000 kg/month). All the usual equipment for curing, smoking and all sausage making was available in these factories although to a much lesser extent in the smaller fish freezing plant. Freezing in the meat companies was in large blast freezing rooms in one case but was contracted out in the case of the larger company. Processing was carried out in chill rooms and products were stored in large frozen storage rooms.

In the Bacolod City fish freezing plant, meat product freezing was also carried out in a small blast freezing unit catering for 3 ton of product per hour. Fish product packs - shrimps, crabs, prawn, filleted fish - milkfish - were frozen in three contact freezers capable of processing about 70 kg product in a 4h cycle. Output of frozen fish was 10 tonne/month. A large cold store was available for storage. This factory had 80 employees, most of whom were used for washing, gutting, cleaning and grading fish. Most of their shellfish was exported, but other products, particularly frozen milkfish (bangos) were popular in the local market. This company employed a chemical engineer as production manager and appeared to have a technically and market-oriented management.

The chicken plant in Cebu reared most of its chickens on site (7,000 birds). This small unit (48 employees) was well planned with a chain carrying birds throughout all steps in the process in a chilled room. Equipment included rubber roto-plucker, spin chilling tank, vacuum packer (manually operated) and shrink tunnel and spray-pool immersion freezer, using propylene glycol. Production was 12,500 birds per week which represented about 15% of the frozen chicken market. This company, operated by an entrepreneur-manager, had no technically qualified personnel.

The dairy products complex was the most recent food industry in the Philippines. This was operated by the San Miguel Corporation, the largest company in the Philippines. They are developing further into the food industry after many years in brewing and soft-drink manufacture. With extension of their dairy products interests in this complex, they have recently started a frozen chicken operation and soon to embark on meat processing. The dairy factory was a fully automated plant producing ice-cream; pasteurising and bottling fresh milk, chocolate milk and reconstituted milk for the Manila area (14 million-40 million litres/year); manufacturing sterilised chocolate milk drink, yoghurt, cottage cheese and similar dairy products (2 million litres/year) manufacture of margarine and reworking New Zealand butter (1 million kg/year). Apart from fresh milk from their 2,000 cow dairy herd (450 cows milked daily producing 7,000 litres milk) all production was based on imported New Zealand dairy products. All processing was carried out in positive pressure rooms and was continuously controlled from a master control board. The most up-to-date plant for each process was used. Huge chillers, freezers and warehouses were available for storage. Distribution covered the whole country, particularly for ice cream, and was entirely controlled by the company which had a large fleet of refrigerated trucks and its own refrigerated ship. This was a highly technically oriented company and was one of the few factories visited which had a research and development section, employing applied scientists. Quality control, product and process development were well operated. Total work force numbered 840.

Therefore, although the frozen food sector of the industry was not as extensive as that of canning, its place in the Philippine food industry was fairly developed. Since mainly centred in Manila, the major problem associated was in distribution but this could be overcome at least for major cities on the coasts with refrigerated shipping.

Dehydration plant. As seen from the statistics, this sector of the food industry was the least developed. Only two plants were visited - a modern dessicated coconut factory and a crude dehydrated soup operation in a large factory. However much dehydration was carried out in the home and in backyard factories, as could be seen by the immense quantities of dried meat and fish on display in local markets.

The dessicated coconut operation, on the southern shores of Mindanao, depended on a large labour force for grating the coconut from the fresh fruit, but the blanching and drying operations (tray drying) were continuous and fully automated to the bag-filling stage in a positive pressure section of the factory. The management was very conscious of quality control and particularly hygiene control methods. Production (30,000 kg/day) was mainly for the USA and was shipped directly from a wharf at the factory. Work force numbered 800.

The small dehydrated soup operation was producing 10-15 million sachets per year and was virtually the only manufacturer of this product in the country. Raw materials were chopped and ground in pilot scale equipment and dried in 4 cabinet driers, then packed on pilot scale equipment into sachets with addition of flavourings, etc. at this stage. This unit was a section of a large Unilever edible oil refinery and manufacturing plant, and was managed by highly qualified personnel. Labour was obtained from other departments when required.

Other dehydration operations required in the manufacture of noodles are described for extraction plant below.

Although a major process for Philippine food, dehydration was not yet widely developed in the food industry, it essentially remains a home-based preservation process.

Extraction operations. The sugar milling and refining and coconut oil industries were the most developed industries in the country. These operations were in different parts of the country. They employed large work forces, and were necessarily highly mechanized operations, managed by engineers. Their products however could only be considered industrial products for export as very small proportions of their output was available directly to the Filipino consumer. As such, it is categorised as a heavy industry in Philippine statistics and not as food industry. Such operations could not be considered for production of processed food for the domestic market, so further description will not be given. It would be hoped that eventually the copra processors will be able to produce edible coconut flour after oil extraction, instead of animal feed.

Other extraction operations applicable were the production of noodles from starchy raw materials, wheat, rice and mungbean. These were carried out in many small factories throughout the country (38 in 1967), normally by Chinese families using traditional processes. One factory visited, produced 600 kg/day of sotanghon, mungbean starch noodle, which was estimated as 50% of the total Manila market for this product. The process was semi-mechanized using essentially home-made equipment - stone grinders and a pressure extruder. A chilled room was used to store the extruded noodles overnight prior to sun drying for 2 days. Thirty employees were involved in this traditional operation, with no technical knowledge other than skill through experience with the process.

Apart from noodle manufacture, the extraction industries in the Philippines could not be considered for production of consumer food products at this time. The noodle operations provide small scale units scattered throughout the country, with facilities and experience for extraction, extrusion and drying operations.

Miscellaneous operations. Other major food industry in the Philippines was concerned with bakery goods manufacture and soft-drinks. Information was obtained from major producers in these industries.

It was not possible to obtain information on village bakery or bake-shop operations since these were so diverse and scattered throughout the country. Generally however these operations were small scale, run by families with equipment varying from simplest dough mixers, scales and hot-air rooms for proving and baking (heated by burning wood below the floor) to pilot scale mixers, moulders and proving cabinets and gas or electric ovens. Products were generally sold through the owner's shop or through local shops. A biscuit factory visited utilized two modern continous gas-fired ovens and continous mixers, rollers and cutters in manufacture of high quality biscuits. Biscuits were packed in batch machines then packed into large metal cans for storage and distribution, to prevent infestation and dampness. Production was around 10,000 kg/day and represented 30% of the total biscuit market.

Soft drinks operations are well developed in the Philippines with several large companies competing in the large market estimated at 100 million cases in 1972. The two major companies have several plants throughout the country to enable their efficient distribution system, direct to each village stall, to function effectively. One company has 16 bottling plants and 700 trucks in operation. Equipment is semi-automatic in most cases, to allow flexibility in operation for different products, bottle sizes and quality control.

Other processing operations visited were essentially traditional home-based industries. The production of fish sauce (patis) and fish paste (bagoong) from the fermentation of salted fish was seen from the small backyard vat to development in one family factory to 1000 concrete vats producing

20,000 bottles of patis and 500 cases of bagoong per month. Although the scale of this operation was large, the actual conditions were still primitive, particularly for bottling and canning.

Filipinos are fond of confectionery and several of their native sweets are traditionally produced in particular areas of the country. The sweetened grated coconut sweet 'bukayo' is produced in almost every homestead in Dagupan, a small town north of Manila. Again operations varied from small one family units, with primitive operations to larger units employing 30-40 people with home-made continuous cooking equipment. Another sweet made in another area from cashew nuts, 'tourrones de casuy' was also produced on different scales, although still on backyard industry basis. These home industries are assisted by a government agency - NACIDA - which aims to develop and improve them while still retaining their home basis. The experience and skill of these home food processors is to be better utilized through upgrading processing and storage conditions.

For baked products then, modern equipment was not available but certainly baking facilities and knowledge were available throughout the country. For biscuits, large companies in Manila were well equipped with plant and know-how. Soft drinks also were well developed and certainly had the most efficient food distribution system in the country. Small backyard industries producing native products were scattered widely throughout the country, but facilities, except for fermented fish products, were not capable of development to national food industry.

<u>Summary</u>. This survey gave a very hurried but comprehensive picture of food processing in the Philippines. All processing methods were developed except for dehydration. Food industry was well developed in the large factories which were mainly in Manila. Here the variety of products, the scale of production, the sophistication of some processes and the number of technical personnel was surprising. The smaller units often had only one technical employee, if any, and depended on small scale batch equipment. Generally in all plants the standard equipment required for each process was available in some form, depending on the scale of the operation. All industries, large and small, were labour intensive.

If a standard nutritional food product were to be manufactured with existing facilities, only the large factories would be capable of production on a scale large enough to effect some measure of national distribution. Of the smaller units, only noodle factories and bakeries, scattered throughout the country, could have sufficient total output to reach most of the population, through supplying their local areas. The lack of technical personnel in these smaller units could cause problems in introduction of such a standard product.

APPENDIX 11: Evaluation of product ideas generated in Chapter 6

The degree of fit of each food product idea with each screening factor, was assessed systematically, as described below.

1. Population fraction. From the information presented in 6.1, the percentage of household servings of the product being considered was determined.

Table A11.1 Percentage of household servings utilizing various food products

Food product	Percent total household servings in 3 day period across all 7 survey regions.[a]			
	Breakfast	Lunch	Dinner	Snack
pan de sal	29.0	0.5	0.5	1.0
bread	3.0	0.4	0.2	0.6
flavoured rolls	5.7	0.7	na[b]	2.6
biscuits/cookies	2.6	1.2	0.5	4.3
biscotcho (dried bread)	0.4	0.3	0.1	2.0
noodles	0.4	4.3	3.5	0.1
native sausage	1.6	0.7	0.9	0
canned sausage	0.9	0.1	0.1	0
canned meat loaf	1.2	0.5	0.7	0

a. Obtained from raw files of 7 nutrition survey reports in FNRC, Manila
b. Included with pan de sal

Data for dried meat consumption was not available, but in some of the survey reports its intake was similar to that of native sausage, so the same population fraction was assumed. Products were then rated:-

very good - products served at over 10% household servings

good - products served at between 5-10% household servings

average - products served at between 2-5% household servings

poor - products served at between 1-2% household servings

very poor - products served at less than 1% household servings.

2. Frequency of consumption. Using the data in 6.1, the total number of days each food type was served in the 3 day survey period in the 7 regions surveyed was determined. In this way, the extent to which each product was a regular part of the diet was estimated.

Table A11.2 Frequency of utilization of various food products

Food product:	Number of days served in 7 regions (maximum 7 x 3 = 21)				
	Breakfast	Lunch	Dinner	Snacks (only 6 areas, maximum = 18)	Total
pan de sal	21	9	6	16	52
bread	21	9	8	12	50
flavoured rolls	21	10	8	17	56
biscuits/cookies	20	12	11	18	61
biscotcho (dried bread)	9	9	4	8	30
noodles	11	20	21	3	55
native sausage	19	14	17	2	52
canned sausage	15	14	14	-	43
canned meat loaf	13	5	5	1	24

Again dried meat data was taken to be similar to that for native sausage.

Products were rated:

very good	with frequency total	70
good	with frequency total	60 - 70
average	with frequency total	50 - 60
poor	with frequency total	30 - 50
very poor	with frequency total	30

3. Present intake. Table A11.3 records information on the percentage of average daily food intake of the products considered taken from food surveys.

Table A11.3 Food product intake as percentage of average per caput daily food intake

Food product	Percent daily food intake from nutrition surveys [a]	Percent daily food intake from cereal survey [b]
pan de sal	1.6	3.4
bread	0.2	1.9
flavoured rolls	0.3	0.2
biscuits/cookies	0.3	0.6
noodles	0.4	1.2
native sausage	0.1	
dried meat	0.05	
canned sausage	0.05	
canned meat loaf	0.2	

a. Taken from average of 7 regional surveys conducted by FNRC (113,114,115,116,117,118,119)
b. Adapted from report of national cereal survey (183)

Although these levels were very low it was hoped to increase them. Nevertheless products were rated, the most recent data being used for cereal products.

very good	for products with intake	> 2% total diet
good	for products with intake	1-2% total diet
average	for products with intake	0.5-1% total diet
poor	for products with intake	0.2-0.5% total diet
very poor	for products with intake	< 0.2% total diet.

4. Maximum possible intake. A quantitative measure of this factor was estimated according to information in Table A11.4. The raw material mixture of weight 1140g was corrected to equivalent weight with moisture content corresponding to that normally associated with each product type. In this way, the required intake of the raw material mixture in the form of each product was estimated. Estimates were made of the probable maximum number of servings, of typical size which would normally be expected to be taken during the day in the Philippine diet. The ratio of the total mixture weight required to be eaten to the estimated maximum for each food type was calculated. (Table A11.4)

Table A11.4 Ratio of the required intake of raw material mixture relative to maximum possible product intake

Food type	Average moisture[a]	Common unit weight	Estimated max.daily intake(g)	RM mixture weight(1140g) corrected to moisture content in col(2) (g)	Ratio of required intake (5) to estimated max. intake (4).
(1)	(2)	(3)	(4)	(5)	(6)
pan de sal	25	30g	180[b]	610	3.3
bread	23	20g/ slice	160[c]	590	3.8
flavoured rolls	24	30g	180[b]	600	3.3
biscuits	2.7	200g/ pack	100[d]	470	4.7
noodles	12	400g/ pack	110[e]	520	4.7
canned noodles	83	330g (12oz can)	660[f]	2640	3.8
sausage	25	60g	360[g]	610	1.7
dried sausage	4	75g	450[g]	475	1.0
dried meat	4	500g/ pack	500[h]	475	1.0
canned sausage	60	450g/ can	450[i]	1140	2.5
canned meat loaf	62	450g/ can	450[i]	1200	2.7

a. Obtained from standard food composition tables.
b. Assumes 2 units per meal, total 6.
c. Assumes 2 slices per meal plus 2 snacks, 1 slice each, total 8 slices.
d. Assumes half packet biscuits eaten throughout the day.
e. Assumes 2 meals with 55g dried noodles rehydrated to 330g serving, total 110g.
f. Assumes 2 meals each with 1 can (330g) of canned spaghetti type product.
g. Assumes 3 meals with 2 units each, total 6.
h. Assumes taken at all meals in some prepared form.
i. Assumes 6 slices or pieces (1 can pack) taken as for (g).

Thus the degree to which each food type would require an increase in food intake was estimated. This could indicate the possible ease of incorporation of such products into the daily diet. High ratios (>1.0) indicated a major change in food intake would be required if full nutrition was to be supplied solely by that type of product e.g. dried noodles require portions 5 times greater than the estimated maximum. Thus the product types could be graded on the ratio scale for this factor.

very good	1 - 1.5
good	1.6 - 2.5
average	2.6 - 3.5
poor	3.6 - 4.5
very poor	> 4.5

5. Breakfast utilization. This was evaluated from information in Table A11.2

very good	if frequency eaten with breakfast	> 20
good		15 - 19
average		12 - 14
poor		9 - 11
very poor		< 9

6. Degree of acceptability. Products were rated subjectively as follows:

very good — If the product was not new, i.e. appearance and organoleptic properties were familiar and could be used as the existing product.

good — If the product was similar to a present product, with only slight modifications, perhaps in appearance, which could lower acceptability.

average — If product concept was not new but the product was organoleptically different from present products. Some promotion and education would be required to gain acceptability.

poor — Product was new and strange organoleptically. Significant promotional effort and education required.

very poor — Product was really new and acceptance of this type of product could require extensive promotion and education effort.

Acceptability problems anticipated for each product which aided the fitting of products into these categories, were:

Breads: Conventional bread would be most acceptable, slight probability of organoleptic problems requiring education. Dried bread slices although similar to biscotcho would have the highest risk possibilities of this group. Rated average to very good.

Buns: Buns had higher ratings than breads due to flavour masking properties. The moisture controlled bun was rated lower due to slight possibility of appearance problems. Rated average to very good.

Biscuits: There could be slight organoleptic problems but with the wide variety of biscuits possible there should be few acceptability problems. Rated good to very good.

Sausages: Simulated meat would be essentially a new concept but the product form was highly acceptable. Problems were expected in acceptability, especially for native sausages - dried, fermented and the new concept - controlled moisture. Vienna fermented sausage was rated higher because of the greater possibility of flavour masking, if required. Problems with frankfurter texture and flavour were anticipated with simulated meat. Rated poor to good.

Meat loaves: The texture problems associated with sausages were not expected to be as great. Several new products were in this group - dried meat loaf slices, pickled meat loaf, fermented meat loaf and moisture-controlled meat loaf - which would require educational and promotional effort to a greater or lesser extent. Rated very poor - good.

Noodle products: Dried noodles presented the least acceptability risk, except for pickled or fermented flavoured noodles which would require heavy promotion. Canned noodles in sauce were known, but probably not widely in the rural areas. Spaghetti and meat balls in tomato sauce was common in urban areas. Ready-made noodles with fermented or pickle sauce, although a common home-made product, would be essentially a new idea requiring extensive promotion. Rated very poor to good.

7. Storage life Subjective judgements were also made for this evaluation.

very good: Products with long storage lives, over 6 months, and good keeping quality when opened. Preservation little dependent on packaging.

good: Packaged, preserved products with shelf life 1-6 months before opening. Packaging considerations more important.

average: Products with shelf life 2-4 weeks, dependent on packaging selection.

poor: Products with shelf life 1-2 weeks, extremely dependent on packaging to achieve this.

very poor: Products with very short shelf life. For extended shelf life, say up to 1 week, packaging very important.

Products were assessed as follows

Breads: Fresh bread would have the shortest shelf life and would be dependent heavily on packaging to maintain a week long shelf life. Dried bread slices would have longest shelf life but packaging would be important to extend this. Rated mainly very poor to average.

Buns: Similar to equivalent bread products.

Biscuits: Although good keeping quality expected, packaging would be important to extend it. Rated average to very good.

Sausages: Canned products would have extensive shelf lives, followed by dried and fermented products. Packaging would be more important in these products to extend shelf life. Moisture controlled sausage would be expected to keep only 2 or 3 weeks with adequate packaging. Rated poor to very good.

Meat loaves: Similar considerations as for sausages, with dried meat slices having possibly a greater packaging requirement than dried sausages. Rated poor to very good.

Noodles: Again canned products and dried products were expected to have few storage life problems. Rated very good.

8. Distribution adequacy. Assessment of products for this factor was made from information described in 6.3. Ratings were allotted as follows.

very good — National distribution system already existed capable of handling large volumes of this product. Product easily handled by sari-sari store.

good — Distribution systems required some development to move large volumes of this product over the country. Product easily handled by sari-sari store.

average — Existing distribution required extension or re-organization to move large volumes of this product. Product not as suitable for present sari-sari store situation.

poor — Distribution system needed to be expanded to achieve coverage outside main centres.

very poor — Distribution system required to be set up for this product to achieve widespread coverage.

Products were assessed as follows:

Bread, buns: Extensive coverage of the country possible through scattered factories, but some development of distribution required for efficient movement of product to areas surrounding each factory. Rated average to good.

Biscuits: Packaged biscuits, particularly cracker type, reach sari-sari store in greater volume than canned meats - since lower weight and cheaper but similar inefficient distribution used. Rated very good to average.

Sausages: Native, fresh types only reach isolated areas if produced by market butcher. Good distribution for certain urban centres. Needs major re-organization of processed meat distribution - chilled trucks etc. - to achieve significant controlled national coverage. Rated good to poor. For canned types, inefficient method of reaching to sari-sari store although significant extension to this outlet. Some re-organization necessary to increase sales through this outlet e.g. soft-drink type distribution. Rated good to average.

Meat loaves: Similar comments as for sausages.

Noodles: For canned products, processed meat distribution system could be applied, although products essentially new. Similar comments as for canned sausage. Rated good to poor. For dried products, no significant distribution to rural stores (rarely reaches sari-sari) but should be able to fit into biscuit distribution system. Average to poor.

9. Distribution cost. The more factories there are the greater chance that the product could be produced in more than one factory in different areas so that national distribution costs would be lower (Table 6.4). This is particularly true of the large number of bakeries, many of which are in rural areas and could cheaply supply the products to their own area through their own shops. (Supplying the raw material mix along with normal flour supply should present no problems). The meat plant and biscuit factories are in urban centres and only the large ones could afford extensive distribution to cover the cost of distribution in sales volume. The lower the bulk density of the product the more expensive freight charges.

Assessments were rated as follows:

very good — Low distribution costs expected as large number of plants close to outlets. Products with high bulk density keep down cost of widespread distribution.

good — Fewer production plants although scattered across the country. Bulk density less advantageous.

average — Fewer production plants and tend to be concentrated in main centres. Bulk density less advantageous.

poor — Small numbers of factories with poorly developed distribution systems. Product bulk density poor.

very poor — Only small factories or a few in Manila. Bulk density very low.

Products were assessed thus:-

Bread, buns: Capable of manufacture in the many small bakeries and cheaply transported. Rated good to very good.

Biscuits: Only large central manufacturing units. Widespread distribution costly although bulk density attractive. Rated poor to good.

Sausages, meat loaves: Only central processing plants. Bulk density dependent on whether or not canned. Rated poor to average.

Noodles: Conditions for canned products similar to canned meat products, rated poor to average. Dried products with better bulk density and larger number of production units throughout the country, rated poor to good.

10. Development problems. The types of processing envisaged for each product were assessed for their relative degree of difficulty, in terms of the severity of problems which could arise in the course of their development. For all products, the mixture of raw materials would probably require basic operations

of blanching, chopping and grinding to obtain a stable 'homogeneous' material suitable for formulation. No problems were anticipated in these stages.

The major problems were likely to occur in the methods of preparation of the raw material mixture in a suitable form for baking, extruding to meat products or noodles. These methods could be (1) simple mixing, or if this was not suitable (ii) drying of some of the moist materials (total mix moisture approx 60%) and adding back some of the water at the mix stage, if necessary, or (iii) recourse to protein extraction methods to achieve textural properties for the desired product forms, with consequent problems in development of processing methods for this materials mix.

Assessments were made as follows:

<u>very good</u>	Few problems anticipated.
<u>good</u>	A major problem to be overcome.
<u>average</u>	Several problems to be overcome but not judged too difficult.
<u>poor</u>	Several difficult problems which may be difficult too solve.
<u>very poor</u>	Major problems requiring fundamental research.

<u>Baked goods</u>. The major problem would be obtaining a satisfactory product in the absence of gluten. Non-gluten breads were feasible technically, but their organoleptic properties were quite different from normal bread. It could be possible that legume proteins from coconut and pilinut, if extracted could provide an alternative protein matrix, but this would be a basic research problem which was outside the scope of this work. Biscuits would not have these problems to the same extent, particularly if considered as dried pressed cakes. Rated poor.

<u>Meat products</u>. Simulated meat pieces could be necessary for these products, the manufacturing technology of which could pose problems with the mixture of raw materials to be used. This could require protein extraction, leaving the major problem of utilization of the non-protein residue. However, simple mixing and chopping could be satisfactory for meat loaf and sausage products. Organoleptic problems associated with the raw material mixture should be least for meat loaf products, as vegetable materials could be incorporated into this product which would not be possible with the sausage type products. Emulsion problems, colour, flavour and texture problems could occur also with the simulated meat products, but these were not expected to be as difficult as for the baked good formulation. Rated average to very good.

<u>Noodle products</u>. The problems anticipated were akin to those of baked products i.e. the formation of a suitable dough and the colour effects. Fortunately the manufacture of noodles from different plant materials is traditional in many parts of the world, so that these difficulties could perhaps be overcome. However, such manufacture usually involves starch extraction from the material with discard of the residue. There would then be the major problem of utilization of this residue material with the raw material mixture being considered. The canned-in-sauce products could alleviate this problem but it could be insurmountable for dried noodles. Rated average to good.

11. Production capacity. For evaluation of this factor it was assumed that the output of food products of the type being considered was limited by the capacity of plant and factories. The most recent value of shipments of products for 1970 was taken to represent present capacity in the different food processing industries (Table 6.5). This assumed that reporting companies produced the bulk of the products in their industry.

Canned meats. The capacity of canneries was estimated as the total production of meat products in canned form given in statistics calculated as follows

Sausages (canned)	3,025	(metric tons)
Liverspread, potted meat etc. (canned)	818	
Luncheon, meat loaves (canned)	356	
Native meat products (canned)	295	
Total	4,494	metric tons

Assuming an average can size of 450g this was equivalent to a daily cannery capacity of 27,000 cans product per day. If products could be formulated to standard can size, cannery capacity based on these figures suggested that 27,000 people could be reached daily by this type of product at one can per head per day. This applied then to canned sausage and meat loaf products.

Sausages, meat loaf products (not canned). The capacity of production of these products was estimated to be limited by the capacity of mincing, chopping, extrusion equipment in the processed meat industry. This was taken as the total production of this product group, whether canned or not, taken from manufacturing statistics.

i.e.	Sausages (not canned)	1653	metric tons
	Sausages (canned)	3025	
	Liverspread etc. (canned)	818	
	Luncheon, meat loaf (canned)	356	
	Native meat products (canned)	295	
	Total	6147	metric tons

If used for sausages only and taking a typical sausage unit weight of 60g. then daily capacity would be 280,000 units. Assuming that the mixture could be formulated so that six such units could be eaten daily then approximately 47,000 people could be fed daily on this basis. This estimation applied to moisture-controlled sausage and fermented sausage. The unit weight of dried sausage was 75g at 4% moisture, which presumed a wet mix weight of 96g at 25% moisture. Thus capacity for dried sausages, assuming drying conditions available, would be 175,000 units per day. Assuming also that six units could be eaten daily, then approximately 27,000 people could be reached daily with this product.

For meat loaf-type products, assuming a common unit weight of 450g then daily capacity of such products would be 37,400 units. If one unit could be consumed daily, then 37,000 people could be fed on this type of product. The common unit size for dried meat (tapa) of 500g at 4% moisture implied a meat loaf formulation at 60% moisture of 1200g. Thus 14,000 units could be produced daily. Assuming each unit could be taken daily, then 14,000 people could be reached daily with this product.

Noodle products. The 1970 statistics were taken for estimation of production capacity. Thus, 2,100 metric tons would represent noodles production on a dry basis (12% moisture) which would be equivalent to approximately 10,900 metric tons on a cooked basis (83% moisture as in canned spaghetti). A standard pack of 400g dried noodles implied a daily capacity of 14,400 packs per day. If formulation allowed noodles to be taken at the estimated maximum level of 110g/day (on dry basis) to fully utilize the nutritional mixture then 52,000 people could be reached daily with this product.

For canned, noodle-type products a standard unit pack of 340g (12oz) implied a daily capacity of 88,200 packs. Assuming possible consumption of 2 packs per day then 44,000 people could be fed in this way. Canning facilities in fruit and vegetable industries would require to be used for these products as capacity exceeded that assumed for the meat industry.

Bakery products. There was no data available on the amount of baked goods produced in the Philippines, but the value of goods produced (in pesos) was recorded for bread and bread rolls considered together and also for biscuits. Through assumption of the cost of each unit, the total production capacity of each product was estimated.

For bread and bread rolls, no breakdown of data into the different products was given. It was assumed, for this estimation, that the total production could be considered either as wholly bread rolls or as wholly loaf bread, since similar equipment was required for both types of product.

For bread rolls, the 1973 retail price for twenty 30g units (600g) was P1.00, which was equivalent to P0.60 at 1970 prices. The 1970 production value of P13,497,000 corresponded then to production of 1,230,000 units. Taking six units as the maximum daily intake, then 205,000 people could be reached with this product type. This applied also to moisture-controlled buns and conventional buns. For loaf bread, the 1973 retail price for 400g loaves was equivalent to P0.90 in 1970. Based on the 1970 production value, this corresponded to production of 15 million loaves (6000 metric tons.)

Assuming a possible daily intake of 8x 20g slices of bread (0.16 kg) then the number of people reached daily would be 104,000.

The production of biscuits and cookies (1970) was P33,642,000 and for crackers and pretzels P12,114,000. Biscuits retailed for P4.50/1½lb tin in 1973 or P2.70 in 1970 value, so that production corresponded to 850,000 kg. Crackers retailed for approximately P2.00/ 1lb(1973) or P1.20 in 1970, so that production was estimated at 458,000 kg. Total facilities for biscuit making were therefore equivalent to 1308 metric tons. At a daily intake of 100g then 36,000 people could be reached with biscuit type products.

Daily capacities were estimated as equivalent to intake for

200,000 - 800,000 people	of	bread roll products
100,000 - 400,000 people	of	bread products
52,000 people	of	dried noodle products
47,000 people	of	sausage products (not canned)
44,000 people	of	canned noodle products
37,000 people	of	meat loaf products (not canned)
36,000 people	of	biscuits
29,000 people	of	dried sausage
27,000 people	of	canned meat products
14,000 people	of	dried meat loaf slices

Although it could never be anticipated that production of any of these products could be sufficient for the whole population of 36.6 million or the rural population of 24.9 million, the degree to which the meagre production facilities existed to supply a fraction of the population could be used to compare existing production capacity. Thus the higher the number of people which could be reached by any product type, the greater the production capacity and the more desirable that product for development.

Products were rated as follows

very good	≥	200,000 people/day
good	≥	100,000 people/day
average	≥	40,000 people/day
poor	≥	20,000 people/day
very poor	<	20,000 people/day

12. Ease of production increase. Ratings were allotted as follows:

very good Plant capacity can easily be increased or other factory facilities can be used.

good Some modification to equipment or some new equipment would be necessary.

average Major new equipment required.

poor Probably requires a new factory to be built.

very poor Several new factories throughout the country would be required.

Baked goods. Equipment for increasing the throughput of bakeries given unrestricted raw material would require major capital expenditure which for the large number of neighbourhood bakeries was out of the question. These bakeries provided the bulk of the manufacture of bread and bread rolls, buns. However, new neighbourhood bakeries could be easily set up, if subsidized. There was a greater possibility of large urban bakeries increasing their throughput, particularly biscuit makers, by purchase of continuous ovens, larger mixers, moulders, cutters, etc. Ratings were poor for bread and bread rolls, poor to average for biscuits and very poor to poor for dried bread.

Meat products. (not canned) The increase in production of these products was probably limited by raw material supply rather than equipment. However larger capacity mincers, extruders, smokehouses and drying cabinets could probably be obtained with moderate expense by the large meat processing plant centred in Manila. Rated good for intermediate-moisture products, good to average for dried products and fermented products.

Canned meat products. Here the possibility for using other canning facilities was important. In 1970 fruit canneries packed 211×10^6 kg product, vegetable canneries 6×10^6 kg compared with meat packers with 4.5×10^6 kg product. Thus provided the product could be produced in large enough quantity using existing meat processing facilities there was significant opportunity for increasing output utilizing other canning facilities. This could be important in any interim period when new plant might be constructed. Rated very good to good.

Noodle products. The major limitation here was extrusion and dehydration equipment. These could be manufactured in the country easily although costs could be significant for the several small factories scattered across the country. Subsidies would be required. There was little possibility of using other factories since dehydration and noodle extrusion equipment was not widely used. Again more of these typically small units could be built in several areas to increase production and distribution of these products. Canned products which did not require full drying cycle, would rate higher on this factor, since extensive canning facilities were available for increasing output. Canned products were rated good and dried products were rated average.

13. Processing effect on nutrient retention. This factor measured the possible destruction of nutrients, particularly vitamins and amino-acids, in the formulation and processing of these products. Only qualitative estimations were made at this stage since the unconventional materials mix did not allow any direct deductions to be made from the literature.

It was assumed then for this evaluation that the destruction of nutrients in processing varied with the degree of heat treatment (essentially the only process concerned here). Thus products having little or no heat treatment should have maximum nutrient retention - moisture controlled meat loaf and sausage. The destruction of nutrients was assumed to increase in the order drying (cabinet type), baking (higher temperature) and canning. Fermentation and pickling were expected to have some effect on nutritional value but less than any heat process.
Ratings were:

very good — Processes with little or no heat treatment - moisture controlled meat loaf and sausage.

good — Processes where heat treatment was not severe but other processes could affect nutrient availability - pickled and fermented foods.

average — Dehydration processes with moderate heat treatment with expected effects on amino-acid availability and heat labile vitamins.

poor — Processes with severe heat treatment and major effects on amino-acids, particularly lysine and heat-labile vitamins.

very poor — The conventional canning process - with long heating cycles with severe effects on vitamins. The effect would be greater for solid-pack products (meat loaves) than sauce-type products (noodles, sausages).

14. Portion control. It was envisaged that the desired nutritional product would be available in a size which contained the daily requirements of nutrients. This could be a single unit to be eaten during the day or it could be divided into smaller units with a certain number of units to be eaten during the day to fulfill needs. For evaluation, portions meeting the former description were much more desirable for control of intake, ease of purchase, distribution and assessment of nutrient improvement if any survey was to be attempted. The latter type of portion would be less manageable as it required the consumer to eat several portions which he could possibly distribute among his family to the detriment of nutritional aims; it required the consumer to buy the requisite number of units deemed necessary for his nutrition and; it allowed little control of the number of units being purchased per head which could be important for any nutritional improvement assessment.

The products were assessed for this factor according to their portion control manageability which was influenced by the volume and weight of the different products. (See Table A11.4)

The total weight of raw materials is 1140g with 60% moisture.

Bread. In a bread moisture basis of 23%, the required intake would be about 590g. It was estimated that 8 slices could be taken daily resulting in bread slices of weight of 160g. The 590g would be a very unacceptable portion size for this type of product. Also the portion control would be difficult as the product would be sold as a loaf and control of the number of slices eaten per head impossible. Rated poor.

Bread rolls, buns. The equivalent weight was 610g (25% moisture) and represented buns of 100g units (assuming 6 per day). This was also rather large (over three times present product size) but could be more acceptable than bread especially if flavour varieties for instance were incorporated. However control would be just as difficult since the product would have to be bought by the unit in portions of six for each person. Rated poor.

Biscuits The equivalent weight of product each day was 470g (3% moisture) representing 1lb or around 40 normal biscuit units per day. This number could be less with larger biscuits but would still be greater than bread slices. Assuming a possible intake of 10 units per day, these would have to weigh nearly 50g each which would be quite inacceptable. The control was even worse than for bread slices. Rated very poor.

Sausages. These would be divided into single units by virtue of product name. (i) Dried - equivalent weight 475g (4% moisture) and assuming possible intake of 6 units per day. Units would be about 80g each. This was similar to local product. The control would be difficult since several units require to be eaten daily. Probably less difficult than for baked goods. Rated very good.

(ii) Fermented, moisture-controlled - equivalent weight 610g (25% moisture) which implied bigger units than in (i) of 100g each. These are less desirable than dried sausages for portion control. Rated average.

(iii) Canned sausages - equivalent weight of 1100g (60% pack moisture) would require two 16oz cans to be consumed daily. From the control aspect this was the most manageable unit so far but the size of the units would affect this practically. Rated good.

Meat loaves. These products would not be in simple units and could be similar to the bread loaf portion control in that division of the product would be difficult to control.

(i) Dried slices implied an equivalent weight of 475g (4% moisture) which in six slices would have the same assessment as dried sausage but would probably have the advantage of less bulk. Rated very good.

(ii) Fermented, pickled and moisture controlled products would have equivalent weight similar to the sausage products. A solid block of sausage of 610g suggested an easier product than 1200g for meat loaf products for distribution and portion control. Division among more than one person would be expected with this mass of product however. Slightly less desirable than sausage products. Rated average.

(ii) Canned meat products with equivalent weight of over 1200g (62% pack moisture) would be higher in assessment to the similar sausage product as bulk could be less. Rated good.

Noodle products.

(i) Dried products represented weights of 520g per day. Assuming a 600% increase on cooking made the control of intake at the level of over 3kg of noodles the least practicable of the products listed. Rated very poor.

(ii) Canned products with equivalent moisture to canned spaghetti in tomato sauce of 83% required an intake of 2600g per day. This would require approximately 5 cans, which was extremely impractical. Rated very poor.

Products were scaled on continuum for this factor on their practicability for portion control.

very good	-	dried meat loaf slices dried sausage
good	-	canned meat loaf canned sausage
average	-	moisture controlled sausage, fermented sausage moisture controlled meat loaf pickled, fermented meat loaf (some probability of good as may be canned)
poor	-	bread rolls, buns, bread, intermediate-moisture bread dried bread
very poor	-	biscuits dried noodles canned noodles

The assignment of these ratings for all the factors and for each product is shown in Table A.11.5.

Table A11.5 Evaluation score sheet for product ideas.

FACTOR	POPULATION FRACTION						FREQUENCY OF CONSUMPTION						PRESENT INTAKE					
FACTOR WEIGHT	8						6						1					
FACTOR LEVEL	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total
1 Intermediate-moisture bread	1					10			1			6	1					10
2 Dried bread slices					1	2				1		4			1			6
3 Conventional bread	1					10			1			6		1				8
4 Moisture-contolled buns		1				8			1			6				1		4
5 Conventional buns		1				8			1			6				1		4
6 Biscuits			1			6		1				8			1			6
7 Frankfurter in brine/Sauce					1	2					1	2					1	2
8 Vienna sausage in brine/sauce					1	2					1	2					1	2
9 Dried sausage				1		4			1			6					1	2
10 Moisture-controlled sausage				1		4			1			6					1	2
11 Fermented sausage				1		4			1			6					1	2
12 Canned meat loaf				1		4				1		4					1	2
13 Moisture-controlled meat loaf				1		4				1		4					1	2
14 Dried meat loaf slices				1		4			1			6					1	2
15 Pickled meat loaf				1		4				1		4					1	2
16 Fermented meat loaf				1		4				1		4					1	2
17 Noodles canned in sauce			1			6			1			6		1				8
18 Dried noodles			1			6			1			6		1				8
19 Pickled/fermented flavoured noodles			1			6			1			6		1				8
20 Noodles canned in pickled/fermented sauce			1			6			1			6		1				8

FACTOR	MAXIMUM INTAKE						BREAKFAST UTILIZATION						DEGREE OF ACCEPTABILITY					
FACTOR WEIGHT	8						2						2					
FACTOR LEVEL	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total
1 Intermediate-moisture bread			1			6	1					10		.8	.2			7.6
2 Dried bread slices				1		4				1		4		.2	8			6.4
3 Conventional bread				1		4	1 1					10	.1	.8	.1			8.0
4 Moisture-contolled buns			1			6	1					10		8	2			7.6
5 Conventional buns			1			6	1					10	.1	.8	1			8.0
6 Biscuits					1	2		1				8	.1	.9				8.2
7 Frankfurter in brine/Sauce		1				8			1			6		.2	.6	.2		6.0
8 Vienna sausage in brine/sauce		1				8			1			6		.3	.7			6.6
9 Dried sausage	1					10		1				8		.2	.8			6.4
10 Moisture-controlled sausage		1				8		1				8		.2	.6	.2		6.0
11 Fermented sausage		1				8		1				8		.3	.6	.1		6.4
12 Canned meat loaf			1			6			1			6	.2	.6	.2			8.0
13 Moisture-controlled meat loaf			1			6			1			6			.5	.5		5.0
14 Dried meat loaf slices	1					10		1				8			.3	.5	.2	4.2
15 Pickled meat loaf			1			6			1			6			.3	.3	.4	3.8
16 Fermented meat loaf			1			6			1			6			.3	.4	.3	4.0
17 Noodles canned in sauce				1		4				1		4	.1	.3	.3	.3		6.4
18 Dried noodles					1	2				1		4		.8	.2			7.6
19 Pickled/fermented flavoured noodles					1	2				1		4			.4	.1	.5	3.8
20 Noodles canned in pickled/fermented sauce				1		4				1		4		.1	.4		.5	4.2

FACTOR	STORAGE LIFE						DISTRIBUTION ADEQUACY						DISTRIBUTION COST					
FACTOR WEIGHT	10						10						10					
FACTOR LEVEL	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total
1 Intermediate-moisture bread			.2	8		4.4		.5	.5			7.0	.3	.7				8.6
2 Dried bread slices	.1	.6	.3			7.6	.3	.4	.3			8.0		6	2	2		6.8
3 Conventional bread				.2	8	2.4		5	.5			7.0	.3	.7				8.8
4 Moisture-contolled buns			.2	.8		4.4		5	5			7.0	.3	.7				8.6
5 Conventional buns				.2	8	2.4		.5	.5			7.0	.3	.7				8.6
6 Biscuits	.2	.6	.2			8.0	.3	.4	.3			8.0		.6	.2	.2		6.8
7 Frankfurter in brine/Sauce	1					10		4	.6			6.8			.4	.6		4.8
8 Vienna sausage in brine/sauce	1					10		4	.6			6.8			.4	.6		4.8
9 Dried sausage	.3	.5	.2			8.2		.2	4	.4		5.6			.7	.3		6.4
10 Moisture-controlled sausage			.5	.5		5.0		.2	.4	.4		5.6			.6	.4		5.2
11 Fermented sausage		.8	.2			7.6		.2	.4	.4		5.6			.6	.4		5.2
12 Canned meat loaf	1					10		.4	.6			6.8			.4	.6		4.8
13 Moisture-controlled meat loaf			.5	.5		5.0		.2	.4	.4		5.6			.6	.4		5.2
14 Dried meat loaf slices	.2	.5	.3			7.8		.2	.4	.4		5.6			.7	.3		5.4
15 Pickled meat loaf		.3	.4	.3		6.0		.4	.6			6.8			.4	.6		4.8
16 Fermented meat loaf		.3	.4	.3		6.0		.4	.6			6.8			.4	.6		4.8
17 Noodles canned in sauce	1					10		.2	.6	.2		6.0			.4	.6		4.8
18 Dried noodles	.6	.4				9.2			.6	.4		5.2		.5	.5			7.0
19 Pickled/fermented flavoured noodles	.6	.4				9.2			.6	.4		5.2		.5	.5			7.0
20 Noodles canned in pickled/fermented sauce	1					10		.2	.6	.2		6.0			.4	.6		4.8

FACTOR	DEVELOPMENT PROBLEMS						PRODUCTION CAPACITY						EASE OF PRODUCTION INCREASE					
FACTOR WEIGHT	8						10						10					
FACTOR LEVEL	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total
1 Intermediate-moisture bread					1	2.0		1				8				1		4.0
2 Dried bread slices				.2	8	2.4		1				8				4	6	2.8
3 Conventional bread					1	2.0		1				8				1		4.0
4 Moisture-contolled buns					1	2.0	1					10				1		4.0
5 Conventional buns					1	2.0	1					10				1		4.0
6 Biscuits				.4	.6	2.8				1		4			.2	.8		4.4
7 Frankfurter in brine/Sauce	.2	.2	.6			8.4				1		4	.4	.8				8.8
8 Vienna sausage in brine/sauce	.2	.2	.6			8.4				1		4	.4	.6				8.8
9 Dried sausage		.3	.4	.3		6.0				1		4		.3	.7			6.6
10 Moisture-controlled sausage		.4	.4	.2		6.4		1				6		1				8.0
11 Fermented sausage		.3	.4	.3		6.0		1				6		.5	.5			7.0
12 Canned meat loaf	.4	.4	.2			8.4				1		4	.6	.4				9.2
13 Moisture-controlled meat loaf		4	4	.2		6.4				1		4		1				8.0
14 Dried meat loaf slices		.3	.4	.3		6.0				1		4		.3	.7			6.6
15 Pickled meat loaf	.2	.2	.6			8.4				1		4	.4	.6				8.8
16 Fermented meat loaf	.2	.2	.6			8.4				1		4	.4	.6				8.8
17 Noodles canned in sauce		.3	.4	.3		6.0			1			6		1				8.0
18 Dried noodles			.4	.3	.3	4.2			1			6			1			6.0
19 Pickled/fermented flavoured noodles			.4	.3	.3	4.2			1			6			1			6.0
20 Noodles canned in pickled/fermented sauce		.3	.4	.3		6.0			1			6		1				8.0

FACTOR	PROCESSING EFFECT ON NUTRIENTS						PORTION CONTROL						TOTAL SCORE
FACTOR WEIGHT	7						4						
FACTOR LEVEL	10 VG	8 G	6 A	4 P	2 VP	Total	10 VG	8 G	6 A	4 P	2 VP	Total	
1 Intermediate-moisture bread			.2	.8		4.4				1		4.0	592
2 Dried bread slices			.2	.2	6	3.2				.6	.4	3.2	485
3 Conventional bread				1		4.0				1		4.0	552
4 Moisture-contolled buns			.2	.8		4.4				1		4.0	590
5 Conventional buns				1		4.0				1		4.0	568
6 Biscuits				1		4.0				.2	.8	2.4	522
7 Frankfurter in brine/Sauce				.1	.9	2.2		.7	.3			7.4	574
8 Vienna sausage in brine/sauce				.2	.8	2.4		.8	.2			7.6	578
9 Dried sausage			.5	.3	.2	4.6	.6	.4				9.2	594
10 Moisture-controlled sausage	.1	.2	.3	.4		6.0			1			6.0	577
11 Fermented sausage		.3	.3	.4		3.8			1			8.0	589
12 Canned meat loaf					1	2.0	.1	.9				8.2	596
13 Moisture-controlled meat loaf	.1	2	.3	.4		6.0			.9	.1		5.8	522
14 Dried meat loaf slices			.5	.3	.2	4.6	.7	.3				9.4	584
15 Pickled meat loaf		.4			.6	4.4	.3		.7			7.2	566
16 Fermented meat loaf		.2	.2		.6	4.0	.3		.7			7.2	554
17 Noodles canned in sauce				.2	.8	2.4					1	2.0	566
18 Dried noodles			.4	.6		4.8					1	2.0	540
19 Pickled/fermented flavoured noodles			.4	.6		4.8					1	2.0	532
20 Noodles canned in pickled/fermented sauce				.4	.6	2.8					1	2.0	564

APPENDIX 12: The evaluation of hydrocolloids for binding.

Several non-nutritional thickeners and binders were evaluated. Information on their properties of gelation, thickening, heat effect on viscosity, pH stability and cost were collected for each compound. A knockout screening system was used where compounds not meeting any of the selection criteria were eliminated (Table A.12.1). Remaining materials were scored out of five for each factor.

Concentration. Most compounds required low concentrations of around 1% for significant thickening (based on water only), but some required lower concentrations - agar (0.5%), carageenin (0.2 - 0.5%), xanthan (0.25%). Gum arabic required very high concentration, 50%, - so this compound was eliminated at this stage.

Requirement for presence of other substrates. Pectins required Ca^{++} ions or sugar; carageenins, K^{+} or Ca^{++} ions for best effect; alginates usually required Ca^{++} ions. Pectins and carageenins were eliminated here but alginates were retained as they were usually manufactured in a compounded form with a source of calcium and a sequestring agent.

Heat effect. Any thickener had to be able to withstand canning conditions and also further cooking procedures such as frying, boiling, which may be employed, prior to eating. Most of the compounds had decreasing viscosity with increase in temperature, but in some cases this was reversible. In this latter category were agar, alginates (usually some degradation) carboxymethylcellulose. Other compounds were stable to heat processing viz. locust bean gum, guar gum, xanthan gum, avicel, gum tragacanth. In all cases prolonged heating caused some degradation but a normal heat processing cycle would not be expected to have this effect. Only gum karaya was eliminated here.

pH stability range of remaining compounds was sufficiently wide to cover this product which had a pH value of around 6.

The remaining criterion of cost indicated that locust bean gum, guar gum, gum tragacanth were the cheapest compounds. However their supply was limited. Next came carboxymethylcellulose (CMC) which was readily available. Higher levels were required of CMC for thickening, so the cost would be further increased relative to the others. The cheaper alginates with lower requirements than CMC, would be cheaper per unit, but agar with its lower requirement its cost/unit could be similar to alginates. Unfortunately cost information was not available for xanthan gum which appeared the most suitable material. It was not available. Of those remaining thickeners, several had had applications in meat-loaf type products and canned products - locust bean gum (LBG), guar gum, agar, alginate, CMC. These then were selected for investigation of their use in improving the texture of the nutritional mixture. Gum tragacanth was not investigated since it had similar properties to LBG and guar gum and was more expensive.

Table A.12.1. Table for hydrocolloid screening.

	Concentration required	Requirement for other substrate	Heat effect on viscosity	pH stability	Cost	Total
gum arabic	0	-	-	-	-	-
gum karaya	2	3	0	-	-	-
locust bean gum	3	3	5	2	5	18
guar gum	3	3	4	2	5	17
gum tragacanth	3	3	5	2	4	17
pectin	3	0	-	-	-	-
low-methoxy pectin	3	0	-	-	-	-
agar	4	3	4	2	1	14
carageenin	5	0	-	-	-	-
alginate	3	2	3	2	3	13
xanthan gum	5	3	5	2	-	-
carboxymethyl cellulose	2	2	4	2	3.5	13.5
methyl-cellulose	2	3	4	2	-	-

APPENDIX 13. Analysis of experiments

1. Process variation experiments

Experiment A

		Chop time			
		6 min		8 min	
	Water added	5%	10%	5%	10%
Heat process	Presteamed	(1)	a	b	ab
	Cold fill	c	ac	bc	abc

Rankings	Respondents					Rank total
(1)	8	1	1	4	2	16
a	4	8	5	6	1	24
b	7	3	4	2	3	19
ab	1	2	8	5	8	24
c	2	7	2	3	7	21
ac	5	6	6	8	5	30
bc	3	5	3	1	4	16
abc	6	4	7	7	6	30

Converting to Fisher scores, after Larmond (138)

						Total score	Rank order
(1)	-1.42	1.42	1.42	0.15	0.85	2.42	A
a	0.15	-1.42	-0.15	-0.47	1.42	-0.47	E
b	-0.85	0.47	0.15	0.85	0.47	1.09	C
ab	1.42	0.85	-1.42	-0.15	-1.42	-0.72	F
c	0.85	-0.85	0.85	0.47	-0.85	0.47	D
ac	-0.15	-0.47	-0.47	-1.42	-0.15	-2.66	H
bc	0.47	-0.15	0.47	1.42	0.15	2.36	B
abc	-0.47	0.15	-0.85	-0.85	-0.47	-2.49	G

Analysis of variance

	sum of squares	degrees of freedom	mean square	F
samples	26.85	7	3.836	41.3**
error	2.97	32	0.0929	
total	29.82			

** significant difference at 1% level

	2	3	4	5	6	7	8
Minimum significant ranges (from Larmond) for 32 degrees of freedom at 5% level	2.89	3.04	3.12	3.20	3.25	3.29	3.32
Multiply by standard error R_p	0.394	0.414	0.425	0.436	0.443	0.448	0.453

The range between samples A and H is 0.48 + 0.53 = 1.01, which is greater than the minimum significant range R_8 of 0.453. A is then significantly different from H.

Continuing for the other ranges between samples:

A - G = 0.48 + 0.50 = 0.98 $> R_7$

A - F = 0.48 + 0.14 = 0.62 $> R_6$

A - E = 0.48 + 0.09 = 0.57 $> R_5$

A - D = 0.48 - 0.09 = 0.39 $< R_4$

A,B,C,D were significantly different from E,F,G and H at 5% level

i.e. The samples with lower water addition were preferred, regardless of chopping time or processing conditions. The best rank totals (16) were given for A and B, which confirms this deduction.

Yates analysis on Fisher scores

	(1)	(2)	(3)	(4)	(5) Divide (4) by 4	(6) Square of (4) ÷ 40
(1)	2.42	1.95	2.32	0	0	0
a	-0.47	0.37	-2.32	-12.68	-3.15	4.020
b	1.09	-2.19	-4.70	0.48	0.12	0.0058
ab	-0.72	-0.13	-7.98	-0.64	-0.16	0.010
c	0.47	-2.89	-1.58	-4.64	-1.16	0.538
ac	-2.66	-1.81	2.06	-3.28	-0.82	0.269
bc	2.36	-3.13	1.08	3.64	0.91	0.331
abc	-2.49	-4.85	-1.72	-2.80	-0.70	0.196

	sum of squares	degrees of freedom	mean square	F
Total	138.12	39		
Between treatments	5.101	7	0.728	0.175
Within treatments	133.02	32	4.157	

F is not significant

No significant treatments from results, though the major effect was bc (column (A)) i.e. increasing choptime to 8min and cold fill process. This effect was reduced slightly if presteamed process used (b).

Effect of water addition. Increase to 10%

presteamed	at 6min chop	(a)	drop	over (1)
	at 8min chop	(ab)	drop	over (1)
cold fill	at 6min chop	(ac)	up	over (c)
	at 8min chop	(abc)	up	over (c)

Water at 10% had deleterious effect in presteamed process, but in cold fill process some improvement was seen with added water.

Effect of chop time. Change to 8min

presteamed	at 5% water	(b)	up	over (1)	
	at 10% water	(ab)	down	over (1)	
cold fill	at 5% water	(bc)	up	over (c)	up over (1)
	at 10% water	(abc)	up	over (c)	

Interaction between choptime and water increase only at low moisture improvement with both heat processes.

Effect of process. Change to cold fill

6min chop	at 5% water	(c)	down	over (1)
	at 10% water	(ac)	down	over (1)
8min chop	at 5% water	(bc)	up	over (b)
	at 10% water	(abc)	down	over (b)

Mainly decrease in liking with change to cold fill, except for interaction of choptime and low water continuing to give improvement for bc. Effect was greatest for c, decreasing for ac, abc, but only with desirable low water, high choptime (bc) was improved effect obtained.

It seemed desirable then to consider increased chop time provided moisture kept low at 5%, either heat process giving improved effect.

Experiment B

		Chop time			
		8 min		10 min	
	Water added	5%	10%	5%	10%
Heat process	Presteamed	(1)	a	b	ab
	Cold fill	c	bc		abc

Rankings	Respondents					Rank total
(1)	7	5	3	5	6	26
a	3	6	7	7	7	30
b	4	1	8	2	5	20
ab	5	7	4	8	3	27
c	8	4	1	3	2	18
ac	2	8	5	4	1	20
bc	1	3	6	1	8	19
abc	6	2	2	6	4	20

Converting to Fisher scores

						Total score	Rank order
(1)	-0.85	-0.15	0.47	-0.15	-0.47	-1.15	F
a	0.47	-0.17	-0.85	-0.85	-0.85	-2.55	H
b	0.15	1.42	-1.42	0.85	-0.15	0.85	E
ab	-0.15	-0.85	0.15	-1.42	-0.47	-1.80	G
c	-1.42	0.15	1.42	0.47	0.85	1.47	A
ac	0.85	-1.42	-0.15	0.15	1.42	0.85	D
bc	1.42	0.47	-0.47	1.42	-1.42	1.42	B
abc	-0.47	0.85	0.85	-0.47	0.15	0.91	C

From similar analysis of variance on the Fisher scores, as for Experiment A, there was found to be significant difference between samples at 1% confidence level, but using Duncan's Multiple Range Test, no sample was different from any other.

Yates analysis on Fisher scores.

	(1)	(2)	(3)	(4)	Divide by 4 (5)	Square of entry in (4) ÷ 40 (6)
(1)	-1.15	-3.70	-4.65	0.00	0.00	
a	-2.55	-0.95	4.65	-5.18	-1.295	0.6708
b	0.85	2.32	-4.05	2.76	0.69	0.1904
ab	-1.80	2.33	-1.13	-1.14	-0.285	0.3249
c	1.47	-1.40	2.75	9.30	2.325	2.1373
ac	0.85	-2.65	0.01	-2.92	0.73	0.2132
bc	1.42	-0.62	-1.25	-2.74	-0.685	0.1877
abc	0.91	-0.51	0.11	-1.36	0.34	5.5739

	sum of squares	degrees of freedom	mean square	F
Total	132.5377	39		
Between treatments	5.5739	7	0.7963	0.02
Within treatments	126.9638	32	3.97	

F is not significant

Although not significant greatest effect was c i.e. cold fill process at 5% water and 8 min chop time. This effect was reduced by either increasing water to 10% (ac) and increasing chop time to 10 min (abc). The effect of moving to 10 min chop time was improvement but, in combination with 10% water addition or cold fill process this improvement was reduced.

Effect of water addition increasing to 10%

presteamed at 8min chop (a) drop over (1)
at 10min chop (ab) drop over (1)

cold fill at 8min chop (ac) drop over (c)
at 10min chop (abc) drop over (c)

i.e. increasing water reduces liking

Effect of chop time increasing to 10min

presteamed at 5% water (b) up over (1)
at 10% water (ab) drop over (1)

cold fill at 5% water (bc) drop over (c)
at 10% water (abc) drop over (c)

So increasing chop time to 10 min, mainly no inprovement.

Effect of process changing to cold fill

8min chop time at 5% water (c) up over (1)
at 10% water (ac) up over (1)

10min chop time at 5% water (bc) down over (b)
at 10% water (abc) down over (b)

Choptime important for process effect, reverse effect at 8min and 10min

2. Assessment of final product by Asian taste panel

Seasonings per 1000g mix

Sample code no.	175.	902	563	746
tomato paste	72g	72g	72g	72g
salt	8	8	6	6
sugar	16	16	12	12
garlic	8	8	6	6
mace salt	1.2	1.2	1.2	1.2
ginger	1.2	1.2	0.9	0.9
Total flavouring	106.4	106.4	98.1	98.1
Preparation	Steamed	Fried	Steamed	Fried
Patty	10 min	2 min each side 176C	10 min	2 min each side 176C
Rankings	2	1	3	4
	3	1	4	2
	3	1	4	2
	3	1	4	2
	4	2	3	1
	4	2	3	1
Rank total	19[a]	8[a]	21[a]	12

a significantly different at 5% level

Converting to Fisher scores, and with analysis of variance in the same way as before, gave significant difference between samples at 1% confidence level.

Further analysis (Duncan's Multiple Range Test) indicated 902 and 746 were significantly preferred.

APPENDIX 14: Availability calculations.

Table A.14.1 shows the data and the steps in the calculation of the total daily per capita availability of the major agricultural and fishery species of the Philippines in 1970.
The columns in this table are described as follows:-

1. Edible portion as a percentage of the total weight. It allows correction of harvested weight of produce to that considered edible and supplying nutrients. EP was taken from food composition tables.

2. Production amount in kilograms was obtained for each material from Philippines or FAO statistics in most cases. However, the production of several materials e.g. animal offals, individual banana species were calculated from other production data since their direct production statistics were not recorded. These calculations are described fully below.

3. Export amount in kilograms was obtained for only a few materials from Philippine and FAO recorded statistics. The major crops of the Philippines - coconuts, bananas, sugar, pineapples and rice-are the major exports. Since they had already been exported in 1970 these amounts could not be considered as available to the population for food. The effect of these exports on the availability of nutrients was investigated.

4. Related data indicates assumptions employed in the calculations of availability of some of the raw materials.

5. Available amount lists the result of subtracting exports from production.

6. Food content corrects the previous column figure for the edible amount in the total availability i.e. EP x available amount.

7. Availability/head/day indicates the food content divided by the population figure and converted to 100g units per day to be compatible with the units employed in the computer model.

Assumptions used in estimating production and export data (Table A.14.2)

A. Production data

1. Animal products

Production statistics were not available for meat and animal offal for 1970. However data on the number of different meat animals held on farms for several years up to 1970, the number of each animal species slaughtered and total dressed weight of yearly kill up till 1968 for all species and to 1969 for several species, was available. The number of animals slaughtered in 1970 was calculated using the 1970 animal census figure and the most recent percent kill data. The average dressed weight of carcass of each animal was taken as the most recent from the recorded data and the total production of carcass meat of different species estimated. Table A.14.3 records this data.

Table A14.1 Raw material availability data

	Edible portion %	Production amount kg		Exports and related data kg	Available amount kg	Food content amount kg	Availability 100g unit/ caput/day
albacore	77	400 000	(2)				a
anchovy	75	19 600 000	(2)		19 600 000	14 700 000	0.0110
atis (fruit)	50	3 428 500	(1)		3 428 500	1 714 250	0.0013
avocado	70	18 090 200	(1)		18 090 200	12 663 100	0.0095
banana (bungulan)	67	896 021 400[b]	(1)	106 791 700	63 138 400[c]	42 302 700	0.0317
banana (gloria)	62	896 021 400[b]	(1)	"	15 784 600[c]	9 786 500	0.0073
barracuda	50	500 000	(2)				a
beef	100	22 261 200	c		22 261 200	18 254 200	0.0137
big-eyed scad (fish)	50	26 900 000	(2)		26 900 000	13 450 000	0.0104
blood (beef)	100	2 003 500	c	4.5% animal wt (4)	2 003 500	2 003 500	0.0015
blood (pig)	100	12 724 000	c	"	12 724 000	12 724 000	0.0095
bonito	63	16 000 000	(2)		16 000 000	10 080 000	0.0076
brain (beef)	100	37 800	c				a
brain (buffalo)	100	6 700	c				a
brain (lamb)	100	a	(1)				a
blue-spotted ray (fish)	41	300 000[b]	(2)				a
buffalo	82	3 951 600	c		3 951 000	3 240 300	0.0024
cabbage	82	45 421 900	(1)		45 421 900	37 246 000	0.0279
caesio (fish)	49	16 600 000	(2)		16 600 000	8 134 000	0.0061
cashew (fruit)	90	6 315 000	(1)		6 315 000	5 683 500	0.0043
cassava	76	442 222 600	(1)		442 222 600	336 089 200	0.2517
catfish	45	200 000	(2)				a
cavalla (fish)	33	13 600 000	(2)		13 600 000	4 488 000	0.0034
gizzard (chicken)	100	426 400	c(5)				a
chicken (young)	61	25 079 500	c		25 079 500	15 298 500	0.0115
chickpea	100	a	(3)				a
chico (fruit)	84	5 985 600	(1)		5 985 600	5 027 900	0.0038
liver (chicken)	100	501 600	c(5)				a
coconut, mature	56	226 193 400[b]	c(1)	40 000 (3)	113 056 700	63 311 800	0.0474
coconut, young	14	226 193 400[b]	c	1nut = 1kg (7)	113 056 700	15 833 500	0.0119
cottonseed	100	< 500 000	(3)				a
cowpea	100	8 000 000[d]	(3)		8 000 000	8 000 000	0.0060
crab	42	5 800 000	(2)		5 800 000	2 436 000	0.0018
crevalle (fish)	56	4 400 000	(2)		4 400 000	2 464 000	0.0018
croaker (fish)	44	19 500 000	(2)		19 500 000	8 580 000	0.0064
dapa (fsih)	60	1 631 000	(11)		1 631 000	978 600	a
duck	100	688 800	c				a
eggs (duck)	87	89 415 000 pc	(1)	1 egg = 70g (8)	6 259 000	5 445 400	0.0041
eggplant	91	68 598 600	(1)		68 598 600	62 424 700	0.0467
eggs (hen)	87	1 312 457 000 pc	(1)	10 eggs = 500g (3)	65 622 900	57 091 900	0.0428
seaweed (gamet)	100	400 000[b]	(2)				a
garlic	87	9 762 300	(1)		9 762 300	8 493 200	0.0064
ginger	74	4 459 500	(1)		4 459 500	3 300 000	0.0025
glassfish	45	a	(2)				a
groundnut	51	17 402 500	(1)		17 402 500	8 875 300	0.0067
goatmeat	76	2 822 200	c		2 822 200	2 144 900	0.0016
goatfish	38	800 000	(2)				a
goby (fish)	39	< 500 000	(2)				a
goosemeat	100	9 600	c				a
grapefruit	49	Taken as pummelo					
grouper (fish)	49	9 500 000	(2)		9 500 000	4 655 000	0.0035
grunt (fish)	35	300 000	(2)				a
hairtail	55	13 000 000	(2)		13 000 000	7 150 000	0.0054
hardtail (fish)	30	1 000 000	(2)				a
heart (beef)	100	142 500	c				a
heart (buffalo)	100	25 300	c				a
heart (goat)	100	a	c				a
heart (lamb)	100	a	(1)				a
heart (pig)	100	678 600	c				a
herring	60	3 100 000	(2)		3 100 000	1 860 000	0.0014
horsemeat	100	a	(1)				a
jackfruit	34	68 851 400	(1)		68 851 400	23 409 500	0.0175
kaimito (fruit)	53	16 937 200	(1)		16 937 200	8 976 700	0.0067

kidney (beef)	100	77 900	c				a
kidney (buffalo)	100	13 800	c				a
kidney (goat)	100	a	c				a
kidney (lamb)	100	a	(1)				a
kidney (pig)	100	678 600	c				a
lanzones (fruit)	68	22 376 300	(1)		22376300	15215900	0.0114
intestine, large (beef)	100	191 400	c				a
intestine, large (buffalo)	100	34 000	c				a
intestine, large (goat)	100	a	c				a
intestine, large (pig)	100	2 488 300	c		2488300	2488 300	0.0019
leather-jacket (fish)	48	100 000	(2)				a
banana (lakatan)	69	896 021 400[b]	(1)	106 791 700	63 138 400[c]	43 565 500	0.0326
banana (latundan)	73	896 021 400[b]	(1)	"	220 984 300[c]	161 318 500	0.1208
lemon	38	9 411 700	(1)		9 411 700	3 576 500	0.0027
lime		Taken as kalamansi, Philippine lemon					
liver (beef)	100	436 300	c				a
liver (buffalo)	100	77 500	c				a
liver (goat)	100	a	c				a
liver (lamb)	100	a	(1)				a
liver (pig)	100	4 976 500	c		4 976 500	4 976 500	0.0037
lizardfish	45	23 600 000	(2)		23 600 000	10 620 000	0.0080
lungs (goat)	100	a	c				a
lungs (lamb)	100	a	(1)				a
lungs (pig)	100	2 262 000	c		2 262 000	2 262 000	0.0017
lungs (beef)	100	220 400	c				a
lungs (buffalo)	100	39 100	c				a
mango	72	151 666 500	(1)		151 666 500	109 119 900	0.0818
marbled stingray (fish)	36	300 000[b]	(2)				a
milk (buffalo)	100	18 000 000[d]	(3)		18 000 000	18 000 000	0.0135
milk (cow)	100	17 000 000[d]	(3)		17 000 000	17 000 000	0.0127
milkfish	68	96 500 000	(2)		96 500 000	65 620 000	0.0491
milk (goat)	100	6 558 600	c		6 558 600	6 558 600	0.0049
moonfish	48	2 800 000	(2)		2 800 000	1 344 000	0.0010
mullet	49	<50 000	(2)				a
mungbean, green	100	15 990 700[b]	c		15 990 700	15 990 700	0.0060
mungbean, red	100	15 990 700[b]	c		15 990 700	15 990 700	0.0060
nemipterid (fish)	45	39 700 000	(2)		39 700 000	17 865 000	0.0134
onion	92	30 698 700	(1)		30 698 700	28 242 800	0.0212
orange	72	32 509 500	(1)		32 509 500	23 406 800	0.0175
papaya	62	60 461 600	(1)		60 461 600	37 486 200	0.0281
cabbage, chinese (petsay)	82	17 144 300	(1)		17 144 300	14 058 300	0.0105
pigeonpea	100	a	(3)				a
pilinut	16	2 365 200	(1)		2 365 200	378 400	a
pineapple	58	233 430 500	(1)	56 117 930 (EP) (10)		79 271 800	0.0594
pomfret	48	<50 000	(2)				a
pompano (fish)	48	400 000	(2)				a
porgy (fish)	45	400 000	(2)				a
pork	100	226 209 800	c	92% w/o bones (6)	208 108 400	208 108 400	0.1558
potatoes	85	20 104 300	(1)		20 104 300	17 088 700	0.0128
pummelo (fruit)	56	28 764 800	(1)		28 764 800	16 108 300	0.0121
radish	68	6 590 100	(1)		6 590 100	4 481 300	0.0034
rice, polished	100	5 233 408 400[b]	(1)	1 200 000 (3)	5232 208 400	2 691 971 200[c]	2.0157
rice, brown	100	5 233 408 400[b]	(1)			1 046 441 700[c]	0.7835
rice, glutinous	100	5 233 408 400[b]	(1)			54 938 200[c]	0.0411
kidney bean, red	100	5 815 200[b]	(1)		5 815 200	5 815 200	0.0015[c]
round scad (fish)	41	331 400 000	(2)		331 400 000	135 874 000	0.1017
runnerfish	44	1 900 000	(2)		1 900 000	836 000	0.0006[a]
banana (saba)	57	896 021 400[b]	(1)	106 791 700	418 291 700[c]	238 426 300	0.1785
sardine	52	69 700 000	(2)		69 700 000	36 244 000	0.0271
short-bodied mackerel	62	46 500 000[b]	(2)		46 500 000	28 830 000	0.0108[e]
seaweed	100	400 000[b]	(2)				a
shark	91	<50 000	(2)				a
sheepmeat	76	a	(1)				a
shrimp	63	30 700 000	(2)		30 700 000	19 341 000	0.0145
siganid (fish)	44	1 200 000	(2)				a
slipmouth (fish)	38	72 800 000	(2)		72 800 000	27 664 000	0.0207

intestine, small (beef)	100	369 500	c				a
intestine, small (buffalo)	100	65 600	c				a
intestine, small (goat)I	100	a	c				a
intestine, small (pig)	100	3845 500	c		3 845 500	3 845 500	0.0029
shrimp, small	100	21 400 000	(2)		21 400 000	21 400 000	0.0160
snapbean	100	5 815 200 [b]	(1)		5 815 200	5 815 200	0.0015 [c]
snapper	44	10 100 000	(2)		10 100 000	4 444 000	0.0033
soursop	70	8 694 500	(1)		8 694 500	6 086 200	0.0046
soybean	100	1 195 300	(1)				a
spadefish	45	4 000	(11)				a
sweet potato leaves	53	190 162 400	c		190 162 400	100 786 100	0.0755
spleen (beef)	100	51 200	c				a
spleen (buffalo)	100	9 100	c				a
spleen (lamb)	100	a	c				a
spleen (pig)	100	226 200	c				a
spanish mackerel	50	3 547 000	(11)		3 547 000	1 773 500	0.0013
yam, spiny	82	8 828 100	(1)		8 828 100	7 239 000	0.0054
squid	97	12 100 000	(2)		12 100 000	11 737 000	0.0088
stomach (beef)	100	476 400	c				a
stomach (buffalo)	100	84 600	c				a
stomach (goat)	100	a	c				a
stomach (pig)	100	1 583 400	c		1 583 400	1 583 400	0.0012
striped mackerel	62	46 500 000 [b]	(2)		46 500 000	28 830 000	0.0108
sugar, raw	Taken as sugar cane juice						
sugar cane juice	20	$16\,000 \times 10^6$ (cane)	(3)	$10\,043 \times 10^6$ (c)	5956 225 000	1 191 245 000 (9)	0.8920
surgeonfish	41	6 200 000	(2)		6 200 000	2 542 000	0.0019 [c]
sweet potato	88	731 393 900 [b]	(1)		270 615 700 [c]	238 141 800	0.1783 [c]
sweet potato, white	86	731 393 900 [b]	(1)		460 778 200 [c]	396 269 300	0.2967 [c]
taro	81	91 628 300	(1)		91 628 300	74 218 900	0.0556
threadfin (fish)	35	<50 000	(2)				
tomato	95	107 449 800	(1)		107 449 800	102 077 300	0.0764
tongue (beef)	100	95 700	c				a
tongue (pig)	100	452 400	c				a
gizzard (turkey)	100	400	c				a
turkey	100	31 950	c				a
liver (turkey)	100	500	c				a
turtle	24	800 000	(2)				a
watermelon	62	74 860 800	(1)		78 860 800	46 413 700	0.348
corn, white	100	2 008 212 600 [b]	(1)		2 008 212 600	2 008 212 600	0.7518 [c]
whiting	46	< 50 000	(2)				a
kidney bean, white	100	5815 200 [b]	(1)		5 815 200	5815 200	0.0015 [c]
yam	86	24 413 100	(1)		24 413 100	20 995 300	0.0157
corn, yellow	100	2 008 212 600 [b]	(1)		2 008 212 600	2 008 212 600	0.7518 [c]
yellow-fin tuna (fish)	77	1 685 000	(11)		1 685 000	1 297 450	a

(1) Private communication. Philippine Bureau of Agricultural Economics
(2) FAO Fisheries Yearbook 1970, FAO, Rome, 1971
(3) FAO Production Yearbook 1970, FAO, Rome, 1971
(4) Calculated from private communication, Massey University, 1973
(5) Calculated from G. J. Mountney, Poultry Products Technology, AVI, Westport, Connecticutt, 1966, p.63
(6) Calculated from E. H. Callow, Journal of Agricultural Science (1948) 38, 174
(7) FAO Trade Yearbook 1970, FAO, Rome, 1971
(8) From; A. L. Winton and K. B. Winton, 'The Structure and Composition of foods', Wiley, New York, 1937.Volume 3
(9) Raw sugar weight taken as 12% raw cane weight from J. M. Patarau, By-Products of Cane Sugar Industry, Elsevier, Amsterdam, 1969
(10) Calculated from data in Campbell's Book, Vance Publishing Corporation, Chicago, 3rd edition, 1950.
(11) Private communication. Philippine Bureau of Fisheries, 1973

a. availability too low to be significant in the computer method, see text.
b. other species included in this data.
c. calculated data, see text.
d. FAO estimate

Table A.14.2. Raw materials for which availability was calculated from production of related materials

Raw material group		No. of raw material items	
Beef and beef offal	a	12	
Buffalo and buffalo offal	a	10	
Pork and pig offal	a	11	
Goatmeat and goat offal	a	8	
Chicken and chicken offal	a	3	
Turkey and turkey offal	a	3	
Goosemeat	a	1	
Duckmeat	a	1	49
Sugarcane juice	b	1	
Sweet potato leaves	b	1	
Goatsmilk	b	1	3
Banana species	c	5	
Rice species	c	3	
Corn species	c	2	
Sweet potato species	c	2	
Coconut species	c	2	
Mung bean species	c	2	
Dried bean species	c	3	
Rayfish species	c	2	
Mackerel species	c	2	
Seaweed species	c	2	25

a. Availability calculated from estimation of proportions of individual items in the carcass weight of animal species. The carcass weight was estimated from animal live weight statistics.

b. Availability derived from related data.

c. Assumptions were made to apportion the group total production data (which was available) among the individual species, in the absence of recorded data. See later for details.

Table A.14.3. Meat production estimations

	percent slaughtered [a]	1970 census [b]	Total Kill	Average dressed(kg) wt/animal [c]	Total carcass meat production kg.
beef	8.5	1,678,700	142,700	156	22,261,200
buffalo	0.5	4,431,500	22,200	178	3,951,600
pork	73.0	6,455,600	4,712,600	48	226,204,800
sheep	insignificant	insignificant	-	-	-
goat	29.5	771,600	227,600	12.4	2,822,200
horse	insignificant	294,500	-	-	-
chicken	36.0	56,998,800	22,799,500	1.1	25,079,500
turkey	5.0	141,300	7,100	4.5	[d] 31,950
goose	7.5	133,100	10,000	0.96	[d] 9,600
duck	35.5	2,132,100	756,900	0.91	[d] 688,800

a. Calculated from slaughter and census statistics 1968,1969-to nearest 0.5%.

b. Bureau of Agricultural Economics, Manila. Private Communication.

c. Calculated from slaughter and total kill weight statistics,1968,1969, Bureau of Census and Statistics, Manila.

d. Insignificant production - less than the significance unit - 1,336,000kg.

With adjustment to take account of the wastage and bones from the carcass weight, the amounts of the different meats available were obtained. Data was then collected on representative weights of offal materials as percentages of carcass weight for the various animal species Table A.14.4 shows the factors used for meat product proportion of animal carcass at significant availability levels.

Table A.14.4. Percentage of carcass weight and total estimated availability for different animal offal species

	Beef[a]	Buffalo[b]	Pig[c]	Goat[d]	Chicken[e]
estimated carcass availability	(metric tons) 22,261.2	3,951.6	226,204.8	2,822.2	25,079.5
blood	(4.5)[f] 2,003.5	h	(4.5)[g] 12,724.0	-	-
brain	(0.2) 44.5[h]	h	-	-	-
heart	(0.6) 133.6[h]	h	(0.3) 678.0[h]	h	-
kidney	(0.4) 89.0[h]	h	(0.3) 678.6[h]	h	-
large intestine	(0.9) 200.4[h]	h	(1.1) 2,488.3	h	-
liver	(2.0) 445.2[h]	h	(2.2) 4,976.5	h	(2.0) 501.6[h]
lungs	(1.0) 222.6[h]	h	(1.0) 2,262.0	h	-
small intestine	(1.7) 378.4[h]	h	(1.7) 3,845.5	h	-
spleen	(0.2) 44.5[h]	h	(0.1) 226.2[h]	h	-
stomach	(2.1) 467.5[h]	h	(0.7) 1,583.4	h	-
tongue	(0.4) 89.0[h]	h	(0.2) 452.4[h]	-	-
gizzard	-	-	-	-	(1.7) 426.4[h]

a. Average percentages from experimental data for 10 N.Z. steers. Private Communication M.D. Earle 1972.

b. Assume same percentages as beef since no buffalo data available. Since all beef values insignificant then buffalo values insignificant.

c. Percentages calculated from New Zealand data of oldest pig (28w) in McMeekan, C.P. Journal of Agricultural Science (1940) 30, 276.

d. No goat data available but assuming proportions of same order as for pig, all offal would have insignificant production.

e. Percentages calculated as lowest figure for chickens described in G.J. Mountney, "Poultry Products Technology", AVI, Westport, Conn, 1966, p65.

f. Percent live weight, live weight = 2 x carcass wt.(FAO).

g. Percent live weight = 125% carcass wt. (McMeekan 1940).

h. Insignificant production < 1,336,000kg (see text)

— material not included in raw material list.

From these calculations, it was seen that only five offal products, of the total list of 49 animal products from pig, blood of pig and beef, beef, buffalo meat, pork, goat meat and chicken, had large enough production levels to be significant for the problem.

2. Banana varieties

In the original list of materials two banana varieties, bungulan and gloria, were selected to represent the extremes of nutrient composition variation found in the food composition tables. Information from nutrition surveys in the Philippines which became available at a later stage indicated that these varieties were not the most widely eaten of the various banana species grown. The three major varieties were saba, latundan, and lakatan. Compositional and cost data were obtained for these materials and put into the model. No data were however available on the production amounts of each banana species. It was assumed then that after exports had been considered, the amounts of each banana species available to the population were in the same proportions as seen for the average daily intake of each banana species in the nutrition survey reports. (113,115,116,117,118). Table A.14.5 indicates this basis for the estimation of banana species availability.

Table A.14.5 Estimation of availability of five banana varieties

Survey area	banana variety	Percent total banana intake[a]				
		bungulan	gloria	saba	latundan	lakatan
Cagayan/Batanes		8	4	49	31	8
Metropolitan Manila		9	1	30	41	19
Eastern Visayas		1	-	77	17	2
Western Visayas		8	0.7	72	21	0.7
Ilocos-Mountain		13	4	37	33	11
Rounded average %(RA)		8	2	53	28	8
Estimated available amount based on RA of total production[b]		63,138,400	15,784,600	418,219,700	220,984,300	63,138,400

a. Calculated from individual survey reports (113,115,116,117,118)

b. Total production of 78,229,700kg.

3. Rice varieties

Data on the production of the three types of rice considered - polished rice, unpolished rice or brown rice and glutinous rice was not available. Again only a total group figure for rice production and export amounts was published. The same technique as used for estimating the individual production of banana varieties was used in this case as illustrated in Table A.14.6.

Table A.14.6. Estimation of production of three rice varieties

Survey area	per cent total rice intake[c] polished rice[a]	brown rice	glutinous rice[b]
Cagayan/Batanes	64	35	0.9
Eastern Visayas	56	42	1.5
Western Visayas	83[d]	17	0.4
Ilocos-Mountain	91	5	3.2
Rounded average % (RA)	73.5	25	1.5
Estimated availability[e] based on RA . (g/h/d)	201.6	78.4	41.2

a. Includes rice cake intake.

b. Includes glutinous rice cake intake.

c. Calculated on total rice products less noodle, poprice and flour intake data from individual surveys.

d. Includes enriched rice.

e. Total production is 5,233,408,400kg.

4. Sweet potato varieties

From food composition tables and nutrition surveys, two species of sweet potato, the yellow and white varieties, had been identified, the major difference being the high vitamin A content in the yellow variety and the virtual deficit of this nutrient in the white variety. No individual production data was available and the system described above was applied to estimate the production of the two varieties (Table A.14.7).

Table A.14.7. Estimation of the production of two sweet potato varieties

Survey area	Percent total sweet potato intake[b] white	yellow
Cagayan/Batanes	89	11
Metropolitan Manila	28	72[a]
Ilocos-Mountain	72	28[a]
Rounded average % (RA)	63	37
Estimated production based on RA (kg)[c]	460,778,200	270,615,700

a. Includes violet variety.

b. Calculated from individual nutrition surveys. (113,115,116).

c. Total production = 731,393,900kg.

5. Coconut varieties

Production data for coconuts was given in terms of the number of nuts harvested. This was converted to a weight unit by the conversion suggested in FAO Trade Yearbook; 1000 nuts = 1000kg. Export of coconut was very high but data was available only in terms of the processed products copra, copra meal, dessicated coconut and coconut oil. Factors were obtained from the literature of the yield of copra, coconut oil and dessicated coconut from raw coconut. Thus the amount of raw coconuts which were processed for export could be estimated as well as the number of raw coconuts available for food. Table A.14.8 illustrates these calculations.

Table A.14.8. Calculation of coconut availability

Material	Conversion factor to raw coconut(%)	1970 Production[c] level (kg)	Original coconut (kg)
Copra	200[a]	1,656,170,500	3,312,341,000
Dessicated coconut	2320[b]	70,007,000	1,625,162,500
Food nuts	-	226,193,400	226,193,400
		Total production	5,163,696,900
Exports			
Copra	200[a]	447,442,628	894,885,256
Dessicated coconut	2320[b]	60,241,145	1,398,455,152
Coconut oil and cake	200[a]	582,587,633	1,165,175,226
Food nuts	-	40,000	40,000
		Total exported production	3,458,555,634
		Availability therefore	1,705,141,266

a. Taken from R.N. Shreve, 'Chemical Process Industries' McGraw Hill, 2nd. edition, 1956.

b. Estimated from moisture content change. Raw coconut meat has 52% moisture and when dessicated around 4% moisture, so 1kg dessicated coconut originates from 13kg raw coconut meat.

Raw coconut meat is 56% of original raw coconut, so 1 kg dessicated coconut originates from 23.2kg raw coconut

c. Taken from data supplied by Bureau of Agricultural Economics, Manila, 1972.

Coconuts are harvested at a young stage for food, and mainly at the mature stage, primarily for industrial oil extraction but also to a certain extent for food. Availability data was required for both types as there were significant differences in their nutrient composition levels.

The Philippines Food Balance Sheet for 1969 (FAO) showed that mature and young coconuts occurred in the food supply at similar levels, so that where food nut production data was given, the availability could be assumed to be halved between young and mature coconuts. It was assumed that only mature nuts were both exported and processed to copra, oil, copra cake and dessicated coconut.

Total production	5,163,696,900kg	total nuts
including	226,193,400kg	food nuts i.e. 113,096,700kg young
and	113,096,700kg	mature nuts.

All other nuts are processed (assumed mature), and in total production

5,050,600,200kg	mature nuts
113,096,700kg	young nuts.

Production less exports availability

	1,705,141,200kg	total nuts available after export,
assuming only mature nuts exported:		then
	113,096,700kg	young nuts remain
and	1,592,044,500kg	mature coconuts remain.

The amounts shown above were taken to represent the availability of raw mature coconut and raw young coconut from total production and after discount of exported processed and food nuts.

6. Corn, mung bean, dried bean, ray, mackerel and seaweed varieties

One total production figure had been obtained for each of these food groups, each of which had two or more species to take account of nutrient composition variations. In all cases, there was no information on the production intake or availability of the individual species. So the total availability amount was assumed to be divided equally between the different varieties in each group.

7. Goat milk production

No published data of production was available for this item. In FAO statistics, goat milk production and goat numbers were available for several eastern countries. The average yield of milk from each goat was estimated for these areas. The least value of milk yield/goat was applied to the goat population data in the Philippines in 1970, to provide an estimate for the possible production of goat milk. (See Table A.14.9).

Table A.14.9. Estimation of goat milk production

Country	1970 yield of milk(kg)/goat[a]
Afghanistan	16.2
India	8.4
Japan	20.4
Korea	90.9
Pakistan	42.6

a. Calculated from FAO Production Yearbook 1970 data.

Using the Indian value as a minimum yield figure, the 1970 Philippines' goat population of 771,600 would yield 6,558,600kg milk.

8. Sweet potato leaves production

Sweet potato (kamote) leaves in the Philippines are a popular additive to meals. A production figure could not be obtained for this material. From data supplied by the Philippines Food and Nutrition Center, a bundle of kamote leaves as sold in markets weighed approximately 130g. It was assumed that a bundle of this size was harvested from one plant yielding approximately 500g of sweet potato. Thus from the total sweet potato production in 1970 of 731,393,900kg it was estimated that 190,162,400kg of sweet potato leaves were available in 1970.

9. Sugar cane juice production

This material was not produced as such in the Philippines, but was obtained from extracting raw cane in the home or simply chewing on cane. It is widely consumed throughout the country as cane production is widespread. Sugar cane juice is the raw material from which refined sugar is extracted and its theoretical availability can be estimated from sugar produced and sugar cane harvested in the country. The calculations for this estimation are described in the following section.

B. Export data

Export data were found only for bananas, coconuts, pineapples (in syrup), rice, and sugar. The banana, coconut (in the shell) and rice data were directly subtracted from the production figures found. Calculations were required to estimate the amount of raw material - sugar cane in the case of sugar and raw pineapple in the case of pineapple in syrup - processed for export to obtain the net availability of each of the raw materials from production after export.

1. Sugar cane processed

From data supplied by the Philippine Bureau of Agricultural Economics,

Raw sugar produced in 1970 1,926,610,900kg
Raw sugar exported in 1970 1,225,340,500kg

So raw sugar used domestically 701,270,400kg

The conversion from sugar cane to raw sugar is given approximately by Patarau as 100 metric tons of sugar cane yields 11.2 tons raw sugar, i.e. a 12.2% yield

So sugar cane processed for export = 10,043,775,000kg
and total cane processed to sugar = 15,791,893,000kg

The latter figure corresponds to the FAO Production Yearbook Value of $16,000 \times 10^6$kg. The difference would be taken up in sugar cane juice used for native wine, sweets, and probably also to conversion factors used and rounding.

Taking the FAO value as the total production availability of sugar cane and the Philippine data for production, the availability of sugar cane for Philippine consumption was estimated This was corrected to sugar cane juice equivalent by the edible portion factor given in the FNRC Food Composition Tables, 1968 of 20% sugar cane weight.

Total production	$16,000 \times 10^6$kg sugar cane	=	$3,200 \times 10^6$ sugar cane juice
Production less export availability	$5,956,225 \times 10^3$kg sugar cane	=	$1,191,245 \times 10^3$kg sugar cane juice

2. Raw pineapple processed

Exports of canned pineapple in syrup in 1970 was 86,366,043kg. From a variety of formulations for this product detailed in Campbells Book, the most representative formula (for 12oz cans) indicated 65% of the weight to be pineapple. On this basis, of the 86,366,043kg canned pineapple in syrup exported 56,117,900kg would be pineapple. The total production of pineapple, 233,430,500kg in 1970, was converted to the edible weight 135,389,700kg, before subtracting the exports to yield the available pineapple amount of 79,271,800kg.

Note: References cited in these calculations are detailed fully in Table A14.1.

APPENDIX 15: Effect of process calculations

The effect of processing conditions on destruction of spores of *Cl. botulinum*, and on thiamine and ascorbic acid levels during sterilization of meat-mix product, was calculated as follows.

The general procedure was given the (i) time/temperature conditions within a can and (ii) the relationship between the destruction rate constant for any reaction and temperature, the relationship between time and destruction rate could be derived. Hence a measure of the degree of destruction was estimated.

1. *Clostridium botulinum* spores

Assuming first order destruction reaction.

$$\ell n\ C/C_0 = -kt$$

where C is present concentration of spores and C_0 is initial concentration of spores

$$\therefore k = -1/t\ \ell n\ C/C_0$$

k is the destruction rate constant
t is the time

For thermal death C/C_0 is taken as 10^{-12} i.e. 12D reduction in spores is assumed.

$$\therefore k = -2.303/t\ .-12 = 12 \times 2.303/t$$

The following data were calculated for different temperatures by substituting in the above equation graphically derived times from the thermal death time curve for *Cl. botulinum* spores (142).

Temperature °F	Temperature °C	time for 12D destruction (min)	k (calculated) (min^{-1})
200	99	460	0.060
220	104	125	0.221
230	110	36	0.768
240	116	10	2.764
250	121	2.8	9.87

Thus data of T vs k was available. (Fig 6.11). k vs t for the two sterilization processes, was derived from this and the heat penetration curves. (Fig 6.11) The area under the k vs t curve represented kt and so $-\ell nC/C_0$ for the destruction process.

For the <u>hot fill (presteamed) process</u> $kt = 57.8 = -\ln {}^{C}/_{C_0}$

$$\text{so } \log {}^{C}/_{C_0} = \frac{-57.8}{2.303} = -25.1$$

i.e. 25D reduction in spores

Since 12D is equivalent to F_0 of 2.8 min. then 25D is equivalent to F_0 of ${}^{25}/_{12} \times 2.8$ or <u>5.9 min.</u>

For <u>cold fill process</u> $kt = 52$

$$\text{or } \log {}^{C}/_{C_0} = \frac{-52}{2.303} = -22.6$$

$$\text{i.e. } F_0 \text{ of } \frac{22}{12} \times 2.8 = \underline{5.3 \text{ min}}$$

So F_0 values were very similar for these two processes, the cold fill being slightly less severe.

2. <u>Thiamine</u> From data of Feliciotti and Esselen (148), destruction rate constants for several temperatures and different products were available. Taking data for that with highest destruction rate constant, beef liver, as representative of greatest thiamine destruction likely, in these two processes, a curve was drawn of k vs T. Thus the k vs t curve was derived for the two processes analogous to that for *Cl. botulinum.* (Fig. 6.11).

Similarly kt provided a measure of thiamine destruction by each process.

<u>Hot fill process</u> $kt = 0.42$

$$\log {}^{C}/_{C_0} = \frac{-0.42}{2.303} = -0.183$$

There is no standard destruction amount, so the fraction ${}^{C}/_{C_0}$ can be derived

$$\text{i.e. } {}^{C}/_{C_0} = 0.66$$

so destruction of thiamine was 34%.

<u>Cold fill process</u> $kt = 0.38$

$$\log {}^{C}/_{C_0} = \frac{-0.38}{2.303} = -0.165$$

$$\text{So } {}^{C}/_{C_0} = 0.68$$

so destruction of thiamine is 32%.

Thus again processes were very similar in effect. This gave destruction only at the centre point of can. Integration of destruction throughout the can would be required to accurately predict total destruction, but this method was useful to estimate the relative degree of destruction of nutrients by different processes.

3. Vitamin C An analogous method was used. Data for vitamin C destruction at different temperatures was not available for canning processes. A paper detailing losses of vitamin C in storage at different temperatures, 26°, 37° and 45°C provided data to represent k vs T (149). This was extrapolated to higher temperatures assuming Arrhenius kinetics.

Thus k vs t data was made available to evaluate the processes

Hot fill process $kt = 83.3$

$$\therefore \log C/C_0 = \frac{-83.3}{2.303} = -35.2$$

$$\text{so } C/C_0 = 6.3 \times 10^{-37}$$

i.e. complete destruction of vitamin C

Cold fill process $kt = 87.3$

$$\therefore \log C/C_0 = \frac{-87.3}{2.303} = -37.8$$

$$\text{so } C/C_0 = 1.6 \times 10^{-38}$$

i.e. complete destruction of vitamin C

So both processes were again equivalent, giving complete destruction of vitamin C at the centre of the can and, of course, throughout the can. The high lability of vitamin C, even at comparatively low temperatures meant that in conduction heat processes, extensive destruction of this vitamin was inevitable.

APPENDIX 16: Evaluation of enrichment product ideas

1. Level of consumption

Using data previously compiled from nutrition surveys, the amount of each product taken as a percentage of the diet was estimated.

pan de sal/rolls	3.6%	(183)
bread	1.9%	(183)
biscuits	0.2%	(183)
noodles	1.2%	(183)
soft drink	1.0%	(113-119)
milk beverage (canned milk)	2.4%	(113-119)
sauces (bagoong, patis)	1.0%	(113-119)
canned meat loaf	0.15%	(113-119)
sausage	0.07%	(113-119)

A rating of very good given for proportion 2%

good	"	"	"	1-2%
average	"	"	"	0.5-1%
poor	"	"	"	0.2-0.5%
very poor	"	"	"	0.2%

2. Frequency of consumption

Data compiled from nutrition surveys was again adapted to evaluate products. The number of meals in each of the three days at which each product was served in the seven regions was calculated.

pan de sal/bread	52
biscuits	61
noodles	55
soft drink	47
milk beverage (canned milk)	30
sauces (bagoong, patis)	61
canned meat loaf	43
sausage	52
maximum possible	81

A rating of very good given for servings 60

good	"	"	"	56-60
average	"	"	"	51-55
poor	"	"	"	41-50
very poor	"	"	"	60

3. Ease of enrichment in processing

Rating evaluated as follows:-

very good - Present process can easily incorporate enrichment, assuming no legal problems - soup mixes, noodles, meat products.

good - Some research required to design suitable enrichment process - bread products, biscuits.

average - Problems associated with adapting traditional processes to enrichment, particularly for backyard industry. - fermented sauces, bakery products to a certain extent.

poor - Major development required to design enrichment process without destroying product characteristics - milk beverage, soft drink.

very poor - Product and process require full development on completely new ventures.

4. Process effect on nutrients

Rating assessed as follows:-

very good - Nutrients may be added at end of process and/or little or no heat treatment is required - soft drink, sausage.

good - Heat treatment not significant but other processes may affect nutrient availability - fermentation of sauces.

average - Low temperature drying processes will have some effect on labile vitamins and amino-acid availability - dried soups, noodles, milk beverage.

poor - Baking processes with severe heat effects on nutrients - bread products, biscuits.

very poor - Heat sterilization processes have greatest effect on nutrients - canned meat products.

5. Production capacity

Estimations of production capacity in the Philippines for some of these product types had already been made - bread products, noodles, canned meat loaf, biscuits, native sausage - in terms of the number of people who could be reached per day based on expected daily intake of each product. (See Chapter 6). This estimation was made also for dried soups, milk beverage, soft drink, savoury sauces.

Dried soups   Output of the only manufacturer (Unilever) was a maximum of 15 million envelopes per year. (1973)
Assuming each envelope can feed 2 people twice a day, the daily capacity was approximately 83,000 people.

Milk beverage   There was no information on production of this type of product in the Philippines, Milo and Ovaltine were imported directly or packed under licence. It was assumed that instant coffee manufacturers could use their plant in part to manufacture a dried milk beverage based on imported milk.

1970 production of instant coffee was	2,689,000kg
Assuming 50% of this could be used for milk-type powders i.e. capacity of	1,345,000kg

If the daily intake was estimated at 60g, then daily capacity was sufficient to reach 64,000 people.

Soft drink   San Miguel, the largest soft drinks manufacturer in Philippines, estimated total sales of soft drinks in 1972 as 10×10^6 cases (20 bottles). Taking this as capacity, and intake at 2 bottles/head/day meant
Number of people who could be reached was 274,000 people.

Sauces   Production of sauces in 1970 was

patis	4585 $\times 10^3$ kg	
bagoong	1879	(1968)
tomato	4877	
soy	12202	
mayonnaise	4005	
Total	27,548 $\times 10^3$ kg	

Assuming all of these could be enriched and a daily intake per head of 60g, meant a capacity of

1,150,000 people per day

Capacities were estimated at

savoury sauce	1,150,000
soft drink	274,000
bread product	200,000
dried soup	83,000
milk beverage	64,000
noodles	52,000
biscuit	36,000
sausage	29,000
canned meat product	27,000

Ratings were as follows:-

very good	200,000	people/day
good	100-200,000	" "
average	40-100,000	" "
poor	30- 40,000	" "
very poor	30,000	" "

6. Raw material availability

Ratings were allotted as follows:-

very good - Product utilizes mainly local raw materials - fish sauces.

good - Product depends slightly on overseas imports - soft drinks, sausage.

average - Significant requirement for imported raw materials - soups, noodles.

poor - High requirement for imported raw materials - bread product biscuit, canned meat product.

very poor - Entirely dependent on imported materials - milk beverage

7. Ease of distribution

The distribution problems associated with bread products, biscuits, canned meat products, native sausage and noodle products have been described previously.

Soft drink - Excellent distribution direct to sari-sari stores and to all retail outlets. No problems with storage life. Rated very good.

Dried milk drink - Present products not extensively distributed particularly as slow mover due to high cost. Could fit into coffee, cocoa distribution which is widespread. Good storage life. Rated good to average.

Dried soups - Fairly extensively distributed product to major centres. Should be capable of extension to rural areas perhaps with biscuit distribution. Excellent storage properties. Rated good to average.

Sauces - Only well-known brands extensively distributed. Home production of fish sauces often sold in local stores. Good shelf life. Distribution requires more organisation. Rated good to average.

For others see earlier

Noodles - Rated average to poor
Bread products - Rated good to poor
Biscuits - Rated very good to average
Sausage - Rated good to poor
Canned meat - Rated good to average

8. Preparation need

Products scaled as:-

very good	-	ready-to-eat, no handling or preparation required - bread, biscuit, soft drink, sauce.
good	-	requires implement to open package, no cooking - canned meat.
average	-	needs mixing but no heating - milk beverage.
poor	-	needs heating only - sausage, canned meat.
very poor	-	needs mixing with water and heating - soups, noodles.

The product ideas were evaluated by scoring each one for the probability of attaining an assessment of very good to very poor for each factor. (Table A16.1, see method in Chapter 6). Thus products were scaled for their value in the project.

The scores were:-

savoury sauce	514
soft drink	473
milk beverage	332
bread product	422
biscuit	385
noodles	373
dried soup	366
sausage	357
canned meat food	275

Table A.16.1 Scoring of ideas for enrichment product

FACTOR	LEVEL OF CONSUMPTION						FREQUENCY OF CONSUMPTION						EASE OF ENRICHMENT					
WEIGHT	5						5						10					
	VG	G	A	P	VP	Total	VG	G	A	P	VP	Total	VG	G	A	P	VP	Total
savoury sauce		1				8	1					10			1			6
soft drink		1				8				1		4				.8	.2	3.6
milk beverage	1					10		.4	.4	.2		6.4				1		4.0
bread product	1					10			1			6		.6	.4			7.2
biscuit			1			6	1					10		1				8
noodles		1				8			1			6	.8	.2				9.6
dried soup					1	2					1	2	.8	.2				9.6
sausage					1	2			1			6	.8	.2				9.6
canned meat product					1	2				1		4	.8	.2				9.6

FACTOR	PROCESS EFFECT ON NUTRIENTS						PRODUCTION CAPACITY						RAW MATERIAL AVAILABILITY					
WEIGHT	8						10						10					
	VG	G	A	P	VP	Total	VG	G	A	P	VP	Total	VG	G	A	P	VP	Total
savoury sauce		1				8	1					10	1					10
soft drink	.8	.2				9.6	1					10		1				8
milk beverage			1			6			1			6					1	2
bread product				1		4	1					10				1		4
biscuit				1		4				1		4				1		4
noodles			.6	.4		5.2			1			6			1			6
dried soup			1			6			1			6			1			6
sausage	.4	.4	.2			8.4					1	2		1				8
canned meat product					1	2					1	2				1		4

FACTOR	EASE OF DISTRIBUTION						PREPARATION NEED						TOTAL SCORE
WEIGHT	7						5						
	VG	G	A	P	VP	Total	VG	G	A	P	VP	Total	
savoury sauce		.6	.4			7.2	1					10	514
soft drink	1					10	1					10	473
milk beverage		.7	.3			7.4			1			6	332
bread product		.6	.2	.2		6.8	1					10	422
biscuit	.6	.3	.1			9.0	1					10	385
noodles			.5	.5		5.0					1	2	373
dried soup		.7	.3			7.4					1	2	366
sausage		.3	.5	.2		6.2				1		4.0	357
canned meat product		.5	.5			7.0		.2		.8		4.8	275

APPENDIX 17: Consumer survey information

1. Questionnaire

NUTRITIONAL FOOD PRODUCT SURVEY

PLEASE FILL IN THE SPACES BELOW:

address 37 Mapagkawanggawa No. of people in the house 25 person age [illegible] monthly income in household ₱3,000 no. of children in household 12 estimated monthly amount spent on food ₱1,800 (pesos)

1. Please check which of the following sauces and pastes you buy and which you make at home. If you buy the sauces, state the number of bottles, jars or cans bought each time, giving the size of the container regular or large (if in any other quantity state clearly), and the number of times you buy this amount per month.

Sauces & Pastes	Bought	homemade	Bottles: No. of times bought in a month	Size	Jars No. of times bought in a mo	Cans No. of times bought in a mo.	Size
✓Patis	✓		4 x a week	= 16/mo			
✓Fish Bagoong	✓		2 x a week	= 8/mo.			
✓Soy sauce	✓		4 x a week	16/mo			
✓Tomato Catsup	✓		4 x a week	16/mo.			
Banana Catsup							
Others.....							

2. In what ways do you use sauces and pastes? (please chech where appropriate).

As a seasoning during cooking________ As an accompaniment to rice________
As an accompaniment to other dishes________ All of the above________
Other uses________

4. Please check which of the following drinks you buy and which you make at home. Include all drinks consumed inside and outside the home. If bought, state the number of bottles, cans or packets bought each week, giving the size of the container.

Drinks	Bought	homemade	bottles No. per week	Size oz.	Cans No. per week	oz.	
Soft drinks							
Fruit Juices							
Evaporated milk							
Condensed milk							
Powdered Milk							
Milo							
Ovaltine							
Fruit Concentrates							

Others	:	:	:	:	:	:

5. What are your family's favourite soft drinks, fruit juices and beverages? List in order of preference.
Soft drinks 1. Pepsi 2. Seven-Up 3. Sarsi
Fruit juices 1. Welch's grape 2. pineapple-Del Monte 3. orange-Sunkist

6. Where are each of the following drunk and by which members of your family?

	Place of Consumption: At home	Outside	Consumed by: Whole Family	Adults	Children
Soft drinks					
Fruit juices	✓		✓		
Milk beverage		✓			✓

7. Please check which of the following breads are bought, the amount bought each time and the number of times you buy per week.

		No. of loaves or pieces bought each time	No. of times bread is bought per week
Pan de sal	✓		
✓ Pan americano	✓	6	14
Rolls			
Others			

8. Please list the types of cakes and biscuits you buy, and wt. per week

Cakes	Biscuits	weight per week
Rice cake		
Cassava		
Chocolate		
Sponge		
Others		

10. Is nutritional quality in food product important to you?
Yes ✓ No ______ Sometimes ______

11. Which product would you prefer to be made more nutritious-sauces, drinks, bread or cakes and biscuits? Please put them in the order of your preference, placing 1 before your first choice, 2 before your second choice and 3 before your third choice.

Sauces 2 Bread 1 Drinks ______ Cakes and biscuits 3

12. Please check which of the following noodles you buy, Include all types of noodles consumed inside and outside the home. Indicate the amounts and frequency of buying.

Noodles	Bought	Amount per buy	Frequency of buying
Miki			
Macaroni	✓		2 x a week 8/mo
Bihon			
Misua			
Sotanghon	✓		2 x a week 8x/mo

13. Which noodle would you prefer to be made nutritious? Please put them in order of preference.

Order of preference	type of Noodle
1	Macaroni
2	Sotanghon
3	Misua

If you are to choose among different rolls having different fillings, which will you choose? Approximately how much of each will you buy per week?

	bought	weight per week
tuna rolls		
hamburger rolls		
adobo rolls		
spam rolls		
egg rolls		
chicken rolls		
others		

TABLE A.17.1 Summary of selected information obtained in consumer survey

1. Processed foods purchased in households

SAUCES	number	percent
Patis	186	92
Bagoong	133	66
Soy	172	85
Tomato	163	81
Banana	102	51
Other	2	1
Missing	2	1
Total	202	

NOODLES		
Miki	107	53
Macaroni	152	75
Bihon	127	63
Misua	124	62
Sotanghon	125	62
Spaghetti	3	1
Missing	15	7

DRINKS	number	percent
Soft drinks	188	93
Fruit juices	142	70
Evap. milk	177	88
Cond. milk	84	42
Dried milk	96	48
Milo	91	45
Ovaltine	70	35
Fruit conc.	87	43
Missing	3	1

BREADS	number	percent
PandeSal	144	71
Americano	143	71
Rolls	54	27
Missing	9	4
CAKES		
Rice cake	59	29
Cassaca cake	36	18
Chocolate	66	33
Sponge	36	18
Other	9	4
Missing	102	51
BISCUITS		
Assorted biscuits	31	15
Crackers	32	16
Other	2	1
Missing	153	76

2. Rating of popularity of drinks (score 1 for most preferred)

SOFT DRINKS	Score	(1-3)
Pepsi	1.6[a]	
Coke	1.5[a]	
Sarsi and similar	2.3	
F-Up	2.4	
Sprite	2.3	
Orange	2.1	
Others	2.3	
Total missing	18	

FRUIT JUICES	
Pineapple	1.5
Orange	1.5

	Score
Kalamansi	1.7
Grape	2.0
Lemon	2.1
Mixes	2.0
Total missing	39

3. Rating of products preferred to be enriched (score 1 for most preferred)

	Score (1-3)
BAKED GOODS	
Bread	1.7[a]
Drinks	2.0
Sauces	2.1
Cakes/biscuits	1.9
Missing	50
Macaroni	1.6
Sotanghon	2.0
Bihon	2.0
Miki	2.0
Misua	2.4
Spaghetti	1.9
Chicken noodle	1.1
Soup mixes (dried)	1.8
Missing	51

a. Significantly preferred at 1% level of confidence.

APPENDIX 18: Information on chemical nutrients and fat used in enrichment investigation

CHEMICAL NUTRIENT	COST(pesos)	WEIGHT UNIT	COMPOSITION	SOURCE
calcium carbonate $CaCO_3$	0.00335	1 gram	400mg Ca	Koch Laboratories, UK $US0.05/100g[a]
calcium phosphate $CaHPO_4.2H_2O$	0.00558	1 gram	233mg Ca 180mg P	Gollin(NZ)Ltd.$NZ0.28/lb[b]
ferrous sulphate $FeSO_4 7H_2O$	0.00136	100 milligram	20.2mg Fe	Gollin(NZ)Ltd.$NZ1.50/kg[b]
vitamin A palmitate (water miscible)	0.00371	100 microlitre	10,000iu vitamin A	Roche(NZ).$NZ4.09/kg[b]
thiamine hydrochloride	0.00103	10 milligram	10mg thiamine	Roche(NZ).$NZ11.40/kg[b]
riboflavin	0.00271	10 milligram	10mg riboflavin	Roche(NZ).$NZ29.92/kg[b]
nicotinamide	0.00042	10 milligram	10mg niacin	Roche(NZ).$NZ4.60/kg[b]
l-ascorbic acid	0.00045	10 milligram	10mg vitamin C	Roche(NZ).$NZ4.91/kg[b]
pyrodoxine hydrochloride	0.00111	10 milligram	10mg vitamin B6	Roche(NZ).$NZ12.25/kg[b]
cobalamin	0.00563	100 microgram	0.1mg vitamin B12	Sigma Laboratories(US)$US800/100g[a]
calcium-D-pantothenate	0.00058	10 milligram	0.8mg calcium 9.2mg pantothenic	Roche(NZ).$NZ6.38/kg[b]
folic acid	0.00068	1 milligram	1mg folic acid	Roche(NZ).$NZ75.00/kg[b]
L-isoleucine	0.03685	100 milligram	100mg isoleucine 0.1g protein	Ajinimoto,Kyowa Hakko and others (Japan) $US55-65/kg ac
L-leucine	0.00536	100 milligran	100mg leucine 0.1g protein	Ajinimoto,Kyowa Hakko and others (Japan) $US8-10/kg ac
L-lysine hydrochloride	0.00201	100 milligram	80mg lysine 0.08g protein	Ajinimoto,Kyowa Hakko (Japan) $US3-6/kg ac
DL-methionine	0.00201	100 milligram	100mg methionine 0.1g protein	A inimoto,Nihon Kataku and others (Japan) $US3-4/kg ac
L-cystine	0.01005	100 milligram	100mg cystine 0.1g protein	Nihon Rikagaku (Japan) $US15-20/kg ac
L-phenylalanine	0.01675	100 milligram	100mg phenylalanine 0.1g protein	Ajinimoto, Yoneyama Kagaku (Japan) $US25-30/kg ac
L-tyrosine	0.00670	100 milligram	100mg tyrosine 0.1g protein	Ajinimoto, and others (Japan) $US10-15/kg ac
L-threonine	0.02680	100 milligram	100mg threonine 0.1g protein	Ajinimoto and others (Japan) $US40-50/kg ac
L-tryptophan	0.02680	100 milligram	100mg threonine 0.1g protein	Kyowa Hakko and others (Japan) $US40-50/kg ac
L-valine	0.01340	100 milligram	100mg valine 0.1g protein	Kyowa Hakko and others (Japan) $US20-25/kg
Pork fat	0.364	100 gram	100g fat 902k	Caren Food Products (Philippines) P3.64/kg

a. Conversion rate of P6.7 per $US

b. Conversion P9.06 per $NZ

c. Lower limit of price range used

APPENDIX 19: Notes on International Statistical data used in Chapter 1.

Most of the data used in this analysis was obtained from U.N. sources - U.N. Statistical Yearbook, Yearbook of National Account Statistics, F.A.O. Production Yearbook - and individual countries' statistical literature. Much of the raw data had to be reworked to enable comparisons between countries to be made and notes on the procedure used are given below.

1. Population: Estimated mid-year population from U.N. Demographic Yearbooks.

2. Monetary value: All data was converted to US dollars for the year concerned using exchange rates for each year from UN Statistical Yearbooks.

3. Food manufacturing output: The major source was a report of the Economic Commission for Asia and the Far East in 1966. Also values were calculated for Canada, U.K. and Portugal from indices of food production and index weights from the Supplement to the Monthly Bulletin of Statistics 1963, Canadian Statistical Review 1971, Yearbook of National Account Statistics 1969. US data was obtained directly from the 'Statistical Abstract of the United States 1970'.

4. Fraction of personal income spent on food: The amount spent on food was calculated by multiplying percent private consumption expenditure of GNP by GNP value (both data from UN Statistical Yearbooks) and this value by the percent food expenditure of private consumption expenditure, this data being calculated from the Yearbook of National Accounts Statistics 1969. Personal income data was obtained from the UN Statistical Yearbooks.

5. Nutrients in food supply: The calorie, total protein and animal protein intakes were taken directly from estimates of the composition of the food supply at the retail level reported in the F.A.O. Production Yearbook 1969. These were obtained from food balance sheets either supplied by individual countries or calculated by F.A.O. to give approximate figures worked out from production, export, import, stock movement, manufacturing and population statistics. As a measure of the actual intake of these nutrients, this data was probably very inaccurate since no consideration was made of losses occurring after delivery of the foods to the retailer, i.e. storage losses, cooking losses, plate waste etc., which could be highly significant in some regions. However, this data was alone in providing some estimate of the nutritional status of areas.

Sources of Statistics

CENTRAL STATISTICAL OFFICE Annual Abstract of Statistics 1937-1947, H.S.M.O., London, 1948.

DEANE, P. & COLE, W.A. British Economic Growth 1860-1965, Cambridge University Press, Cambridge, 1966.

DOMINION BUREAU OF STATISTICS Canadian Statistical Review, Ottawa, 1971, April, page 31.

MITCHELL, B.R. Abstract of British Historical Statistics, Cambridge Press, Cambridge, 1972.

UNITED NATIONS Supplement to the Monthly Bulletin of Statistics 1963, New York, 1964.

UNITED NATIONS (1970) Yearbook of National Accounts Statistics 1969, New York, 1970.

UNITED NATIONS Economic Commission for Asia and the Far East. Industrial development for Asia and the Far East, United Nations, New York, 1966, Volume IV.

BUREAU Of Census Long term economic growth 1860-1965, United States Department of Commerce, Washington D.C., 1966.

BUREAU Of Census Statistical Abstract of the United States 1970, United States Department of Commerce, Washington D.C., 1970.