A QUANTITATIVE MODEL FOR THE DESIGN OF NUTRITIOUS AND ACCEPTABLE FOODS

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ABSTRACT

A quantitative model was developed for the systematic selection of raw materials for nutritious and acceptable Thai foods. The basis for the quantitative model was linear programming. Unlike most other applications of this technique which considered only nutritional needs, this model also took into account the consumer's requirements for an acceptable food. The development of the model formed part of a research programme in the Food Technology Department of Massey University which is investigating quantitative product development techniques.

The linear programming model was used firstly to select raw material mixes which would satisfy the daily nutritional requirements of the Thai people. Selection was made from a list of 151 available raw materials - 144 indigenous Thai raw materials and 7 New Zealand dairy products. The requirements for 26 nutrients were satisfied. These included protein, fat, calories, fibre, 3 minerals, 9 vitamins and 10 essential amino acids. The lack of specific upper limits on most of the nutrients resulted in solutions with a gross nutritional imbalance. Recent investigations indicate that such imbalances may be detrimental to human health and it is suggested that a more satisfactory diet is one where all nutrients are balanced, at or near their lower requirement levels. Considerable problems exist in achieving a balanced diet using range constraints in the linear programme due to the probability of solution infeasibilities.

Goal programming, an extension of linear programming, has been used in other fields of research to minimize the deviation of solution variables from specific goals. This technique showed potential in attaining a balanced nutritional diet where the goals represented the requirements for specific nutrients. A goal programming model was devised which firstly achieved a balance of essential amino acids as close to that of egg protein as possible. Secondly, a solution was obtained where all 26 nutrients were at

the 'optimum' balance. The achievement of a balanced nutritional diet resulted in a large increase in cost and indicated the importance of careful definition of the requirements for nutritional balance in future research where cost minimization is a priority.

The raw materials selected by both goal and linear programming were totally unacceptable as ingredients in a Thai food dish without extensive processing to change both flavour and texture of the mixture. It was more logical to provide a procedure for raw material selection on the basis of their combined acceptability in a Thai food dish. Nonmetric multidimensional scaling was used to derive a 3 dimensional configuration of 40 raw materials from consumer information on the use of these raw materials in Thai food dishes. The axes of this space represented the dominant properties of raw materials in determining food dish acceptability. An ideal point was located in this space. This point was defined as the 'optimum' combination of raw material properties required in a Thai food dish.

Nonmetric multidimensional scaling provided the basis for derivation of metric scale values for the 40 raw materials and the ideal point. These values were used to derive a linear function relating raw materials to food dish acceptability. This function was used in the linear programming model together with nutritional constraints to provide a systematic method of raw material selection for nutritious and acceptable Thai food dishes. The raw material mixes selected by this model showed a marked improvement over those chosen by the linear programme subject to only nutritional constraints.

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PREFACE

Food product development is the procedure by which raw materials are selected and then combined through a system of processing into a food product acceptable to the final consumer. For many years, product development has been based more in intuition than on objective judgement. There has, however, been a gradual infiltration of quantitative techniques in recent years in an attempt to bring greater objectivity into the system of product development. Some examples of these techniques are:

Idea generation by systematic methods
Market evaluation based on Bayesian decision tree methods or cost benefit analysis
Formulation based on linear programming methods
Business analysis including market forecasts, market surveys and buyer simulation models.

The introduction of these techniques has been largely in a haphazard fashion. The Food Technology Department at Massey University has begun a research programme to develop a systematic approach to the application of quantitative techniques through all stages of product development. The design of nutritional products for consumers in developing countries is being used as the basis for this programme. An overview of the entire research programme is given in a thesis by Edwardson (41).

Edwardson provided an objective procedure for the selection of raw materials to be used in low cost nutritional products for the Philippines. The major problem encountered by Edwardson was the incompatibility of raw materials selected by linear programming based on nutritional criteria. It was only possible to produce an acceptable product from these raw materials through extensive processing and addition of flavouring ingredients.

It was the object of this thesis to both complement and extend Edwardson's work with the application of the linear programming model to the selection of raw materials for the production of low cost food dishes which would meet the nutritional needs of people in Thailand. Emphasis was placed on the extension of Edwardson's model to include consumer acceptance criteria. A procedure was devised whereby raw material selection was made on the basis of their predicted acceptability in Thai food dishes.

Thailand was chosen as the environment for the study in preference to the Philippines because a cooperative programme had recently begun between the Department of Chemical Technology at Chulalongkorn University in Bangkok and the Food Technology Department at Massey University. Information on Thailand was therefore more readily available.

Thailand has a reasonable supply of food raw materials and even exports rice and sugar, but problems of malnutrition still exist, particularly in the North and North-east regions of the country. There is a definite need for the locally grown raw materials to be put to the best use through their optimum combination in acceptable food dishes. In this thesis, considerable emphasis was placed on the selection and use of indigenous raw materials.

Supplementation of local materials with imported foods has played an important role in the design of nutritional food products. Included among the most commonly used supplements are dairy products. The use of some dairy products as ingredients in local Thai dishes was evaluated both as complements to indigenous raw materials in the supply of essential nutrients and on their general acceptability in these dishes.

This thesis first reviews the availability of foods in Thailand and then suggests how the linear programming model could be used to design nutritional foods. The nutritional compositional data for a wide variety of indigenous raw materials and imported dairy products were collected, and the per capita daily requirements of the different nutrients in Thailand were found. Using this information in the linear programming model, raw material mixes were selected to meet the nutritional needs of the general Thai population.

Goal programming, which is basically an extension of linear programming, was applied in the selection of raw material mixes to give nutritionally balanced diets. This technique was also used to evaluate dairy products as complements to indigenous raw materials in providing firstly an ideal balance of essential amino acids and secondly a balance of all 26 nutrients which were considered in the model.

A procedure for raw material selection based on their acceptability in combination in food dishes was obviously required in the linear programming model. A review of the literature relating to sensory evaluation and consumer acceptance of foods failed to provide any procedure which might be used directly. The problems of definition and measurement of the raw material properties which influence the acceptability of food dishes directed the research toward a study of multivariate techniques. Nonmetric multidimensional scaling was identified as a technique which could not only resolve the properties but could also provide metric scale values for these properties which might be used directly in the linear programming model.

A subset of the original list of raw materials was selected. Proximities data on these raw materials were obtained from consumer surveys in Thailand and were subjected to multidimensional scaling analysis. A 3 dimensional spatial configuration of the raw materials was derived and the axes of this space were identified as the dominant properties of the raw materials in determining their acceptability in Thai food dishes. A linear function was derived relating these raw material properties to the acceptability of food dishes in which the raw materials are used. The function was included in the linear programming model together with nutritional constraints to provide a quantitative model for the selection of raw material mixes for nutritious and acceptable Thai food dishes.

CHAPTER 1

THE ENVIRONMENT AND THE MODEL

1.1 The environment

The Kingdom of Thailand was known as Siam until 1939 when the title of Thailand (land of the free) was adopted. A kingdom throughout its history, Thailand has never experienced colonial rule. The country with an area of 200,000 square miles has a population verging on 40 million, headed by a constitutional monarchy, His Majesty King Bhumibol Adulyadej exercising nominal power. Actual responsibility for public affairs is taken by the council of ministers with the prime minister at the head.

1.1.1 The population

According to the 1970 census (130), the population of Thailand stood at 34.4 million people. With an annual growth rate of 3.3 percent this figure would be nearing 40 million by the end of 1975.

In 1970, less than 10 percent of the nation lived in urban communities. The Kingdom's capital, Bangkok, was the only city of substantial size with a population close to 3 million. Only two other cities had populations exceeding 50,000, these were Chiengmai and Nakhon Ratchasima.

Approximately 85 percent of the population are of Thai ethnic origin and 12 percent of Chinese descent. The remaining 3 percent include Malays (in the South), a variety of so called hill tribe people along the border with Burma and Laos and a sizeable group of Vietnamese refugees in the Northeast along the Mekong River.

Age distribution within the population is marked by a high ratio of children to adults, largely due to a rising birth rate and a drop in the infant mortality rate. The 1970 census indicated that 46 percent of the population is under fifteen years of age, 49 percent is between fifteen and sixty, and only 5 percent is over sixty years of age.

1.1.2 Health and welfare

By Southeast Asian standards, living conditions are relatively high. Income levels are low by Western standards but there is little stress because of lack of cash. Average per capita income is equivalent to about US$200. This, however, bears little significance to the standard of living because of the large rural population with its self sufficiency, bartering system and low emphasis on accumulation of wealth.

In times of need, Thais have traditionally turned to close friends and neighbours or relied on the local Buddhist temple. Since the end of World War II, however, systematic government activities and programmes conducted by the Ministry of Public Health and by the Department of Public Welfare have assumed a greater part of the load. In the area of public health, operations by these agencies include the construction of new hospitals, programmes to control communicable diseases, the establishment of health centres to bring medical services to rural areas, the expansion of institutions to train medical personnel and the institution of a nationwide programme of health education. In the area of public welfare, the government is active in the provision of housing for low income families, the development and improvement of potable water supplies, the construction of sewage and sanitation projects, and the operation of a number of projects catering to the aged, young, disabled and other needy citizens. The health and welfare activities of the government are supplemented by more than fifty private charitable organizations and by various external welfare organizations, particularly specialized agencies of the United Nations. Despite the considerable advances in the field of public health, sanitation and welfare, much still needs to be done. Many parts of the country, especially the Northeast Khorat Plateau region, suffer from chronic water shortages and sewage disposal is inadequate in most areas.

1.1.3 Diet and nutrition

The supply of food in most areas of Thailand is good. Although the Thai people can be considered as better off from a nutritional point of view than many other Southeast Asian countries, the variety of foodstuffs is often limited and the reliance on a practically all-rice diet provides inadequate protein, vitamins and calcium. Nutritional diseases are therefore prevalent in many areas.

Although several small scale nutritional studies have been carried out, few national surveys have been made covering a broad spectrum of nutrients and nutritional problems. The last major study, carried out in 1960 by an interdepartmental committee on nutrition (90), summarized its findings as follows:

1. Total calorie intake for the population fell 100kcals below the estimated average requirements of 1871kcals.
2. There was dietary and biochemical evidence of thiamine deficiencies, but clinical signs of beri beri were not observed.
3. A deficit of riboflavin existed in the population but clinical significance of this deficit was not clear.
4. Niacin seemed adequate in all respects.
5. Protein malnutrition appeared limited to the infant and small child.
6. Vitamin A malnutrition probably existed, particularly in the infant and the small child.
7. Fat intake was generally low.
8. Vitamin C intake was adequate.

Although this study is now fourteen years old its findings and recommendations are for the most part relevant today. In 1971 nutritional mal-adjustments accounted for deaths of 9.1 per 100,000 people and ranked eighth on the list of causes of death. The Report of the Interministerial Working Group for the Development of National Food and Nutrition Policy Guidelines for Thailand (91) also recognized malnutrition as "one of the major problems affecting the life and well-being of the population of Thailand". Table 1.1 shows the occurrence of nutritional deficiency among patients attending 62 hospitals in 57 provinces of Thailand in 1970. These figures are likely to be a gross under-estimate of the malnutrition cases due to the under-reporting by hospitals and the many people who never reach hospitals.

Table 1.1 Occurrence of nutritional deficiency among patients attending 62 hospitals in 57 provinces of Thailand (1970).

Diseases	Number of patients
Protein-caloric malnutrition	
a) kwashiorkor	123
b) marasmus	28
c) unspecified	1043
Vitamin deficiency diseases	
a) vitamin A deficiency	386
b) vitamin B1 deficiency (beri beri)	3556
c) vitamin B2 deficiency	1598
d) niacin deficiency (pellagra)	26
e) vitamin C deficiency (scurvy)	176
f) vitamin D deficiency (rickets)	85
g) vitamin K deficiency (hemorrhagic disease of infants)	4
Diabetes mellitus	4008
Simple goitre	3347
Anemia (iron deficiency)	9219
Urinary calculi	6712
Obesity	218
Sprue	295
TOTAL	30,824

a. Taken from the Report of the Interministerial Working Group for the Development of National Food and Nutrition Guidelines for Thailand, February, 1973 (91).

Hence, although food intake can be considered high by Southeast Asian standards, the lack of nutritional balance is leading to diseases of malnutrition in many areas. Rice, which supplies about 80 percent of the daily intake, is the basis of almost all meals, at every income level. To the maximum extent that the budget will allow, the basic rice diet is supplemented by fish, meat, eggs, poultry, vegetables and a variety of fruits. Fish is a major source of protein although it is often unavailable in the North and Western mountains and the Northeast Khorat Plateau. The fish may be salted, dried, pickled, fermented, boiled or eaten raw. Pork, beef and poultry are available in limited amounts and are eaten, particularly in urban areas, as often as they can be afforded. Most common garden vegetables are plentiful and are eaten individually or in salads. There is an abundance of fruits including bananas, papayas, pineapples, mangos, limes, rambuttans, mangosteens and pomelos, to name a few.

Eating habits vary only slightly between urban and rural areas. In urban areas, more vegetables and meat products are eaten and canned goods are more in demand. In the countryside, people usually eat two meals a day but have frequent snacks. Even in the urban areas there is a tendency to eat little but often, especially among the lower classes. Most of these 'snacks' are obtained from a variety of restaurants where urban Thais utilize about 10 percent of their total household expenditure or approximately one quarter of their total expenditure on food (see Table 1.3).

1.1.4 Household income and expenditure

In most Southeast Asian countries, marked variations in income exist between region and between types of residence within a single region. The same is true of Thailand. The most marked differences in household incomes occur between the urban and rural areas. In rural areas over half the population earned less than 6000 baht per year, whereas in urban areas only 4.6 percent earned less than 6000 baht per year (131). Over the whole Kingdom, the average income in urban areas is approximately three times that of the rural areas. In spite of this marked difference in income, it would be foolish to conclude that the standard of living of the rural population is correspondingly lower than that of the urban dwellers. The reliance on a cash economy is still much lower in the rural areas, hence the need for a high monetary income is less than in the cities. Differences in income may be compared with more validity between urban or rural residences in different regions. Whereas the villagers of Northeast Thailand earned on average about 3000 baht in 1969 (131), the average income of the villagers in the central region was about twice this amount (see Table 1.2).

Table 1.2 Cumulative percentage of households having income less than a specific class, municipal area and village[a].

Income class	Whole Kingdom	North	Central	North east	South	Bangkok-Thonburi
Municipal areas						
less than bht. 3000	0.9	1.7	1.2	1.3	0.9	0.5
" " " 6000	4.6	12.7	6.1	5.0	7.2	1.7
" " " 12,000	22.7	40.3	23.9	27.3	34.7	15.0
" " " 18,000	43.8	59.2	49.7	48.0	56.5	35.0
" " " 30,000	73.3	80.5	80.5	77.6	80.0	67.0
" " " 48,000	87.2	93.5	90.4	87.6	91.0	84.0
" " " 60,000	91.7	94.8	93.6	92.2	94.8	89.6
baht 60,000 or more	100.0	100.0	100.0	100.0	100.0	100.0
Villages						
less than bht. 3000	26.7	18.0	7.0	50.3	16.6	1.1
" " " 6000	53.0	51.9	25.0	73.2	53.8	10.0
" " " 12,000	80.3	82.2	63.3	89.8	85.9	33.0
" " " 18,000	90.6	93.5	81.1	95.0	93.4	59.6
" " " 33,000	97.6	99.2	94.3	98.7	99.1	84.4
baht 33,000 or more	100.0	100.0	100.0	100.0	100.0	100.0

a. Taken from Socio-Economic Survey B.E.2511-2512 (1968,69). Report by the National Statistical Office of Thailand (131).

In 1969, the average expenditure per household in the urban areas was 1996 baht per month, as compared to 669 baht per month for a rural household. By far the highest proportion of this income in both areas was devoted to food, 47.73 percent in urban areas and 48.43 percent in rural areas (131) (see Table 1.3).

Table 1.3 Percent expenditure per household[a] for consumer goods and services[b].

	Municipal area	Rural area
Food	47.73	48.43
1. prepared at home	36.55	41.14
2. away from home	11.18	6.29
Lodging, electricity, fuel and water	12.40	9.16
Clothing	8.12	12.07
Transportation	6.90	5.54
Recreation and education	6.76	3.36
Medical and personal care	5.44	7.46
Gifts, taxes and miscellaneous expenses	7.48	8.51
Tobacco and alcoholic beverages	5.18	5.48

a. Household sizes: rural - 5.7 persons
municipal - 5.8 persons

b. Table taken from Socio-Economic Survey B.E.2511-2512 (1968,69). Report of the National Statistical Office of Thailand (131).

Of the near 50 percent of total household expenditure spent on food, about 40 percent is used to purchase rice, 30 percent for meat and poultry and the remaining 30 percent for fruit, vegetables, beverages and prepared meals. Considerable variation exists in the distribution of expenditure on food between towns and villages. Probably the most marked differences occur in the expenditure on rice, where according to the 1962-63 household expenditure survey (129) 46.4 percent of the total expenditure on food went on rice and cereals in the villages compared with 23.2 percent in the towns. Another marked difference occurs in the amount spent on prepared meals. In 1962-63, 20.5 percent of total expenditure on food went to the purchase of prepared meals in towns as compared with 7.2 percent in villages (129), (see Table 1.4).

Over the whole Kingdom 70 percent of the bulk intake of food consumed is rice; fruit and vegetables account for 15 percent, while meat and poultry comprised only about 8 percent of all food consumed in 1962-63 (129). Once again considerable

Table 1.4 Household expenditure. Percent distribution of expenditure on various food groups[a].

Group	Total Kingdom	Bangkok-Thonburi	Towns	Villages
All food and beverage	100.0	100.0	100.0	100.0
Rice and cereals	37.8	14.9	23.2	46.4
Meat, poultry, fish and eggs	30.3	31.6	33.5	29.0
Fruit and vegetables	11.2	11.7	13.7	10.5
Beverages	1.6	5.0	2.8	0.7
Prepared meals	12.8	30.3	20.5	7.2
Other foods	6.3	6.5	6.3	6.2

a. Taken from the Household Expenditure Survey for Thailand 1962-63 (129).

variation exists between towns and villages in the relative amounts of foods consumed. In 1962-63, villagers consumed 18.7 percent more rice than town people and 43.5 percent more than dwellers in the Bangkok-Thonburi area (129). Town people, however, consumed almost three times the amount of meat consumed by villagers. More eggs and vegetables were also eaten in towns than in villages (see Table 1.5).

Table 1.5 Quantities of foods consumed by food groups (1962–63)[a].

Food group	kg. consumed per capita			
	All Kingdom	Bangkok-Thonburi	Towns	Villages
Rice and cereals	167.2	99.1	134.5	177.8
Meat	8.2	16.4	16.0	6.3
Poultry	3.0	5.4	3.2	2.8
Fish	9.3	15.8	10.8	8.5
Eggs[b]	2.3	5.7	3.7	1.7
Vegetables	19.7	36.4	37.0	17.2
Fruits	14.4	7.8	15.2	14.9
Oils and fats	1.0	2.5	1.6	0.8
Sugar and sweets	2.4	3.2	2.4	2.4
Salt; spices etc.	3.1	0.9	2.0	3.4

a. Taken from the Household Expenditure Survey for Thailand 1962-63.
b. Estimated at 55g per egg.

The use of rice characterizes regional food consumption patterns and distinguishes the Northeast and North from the rest of the Kingdom. In these two regions over 180kg of rice was consumed per capita per year in 1962-63 (129), of which about two thirds was glutinous rice. In other regions, rice consumption was nearly 160kg per capita per year with only small quantities of glutinous rice being used. The North and Northeast regions also consumed less meat, poultry, fish and eggs than other regions with a yearly per capita consumption of 19kg in 1962-63 compared with 32kg in the East, 26kg in central regions and 22kg in the South (129).

1.1.5 Agriculture and industry

Agriculture traditionally has been the mainstay of economic life in Thailand. This is likely to remain so for some time despite the steady increase in the value of the industrial component of the economy. There has been a decrease in the Kingdom's dependence on agriculture, particularly since World War II. To a large extent, the rapid expansion in industry has been planned to utilize the agricultural and mineral resources that previously had been mostly exported. Emphasis has been placed in the last decade on the food processing industries and on power and construction industries. Whereas in 1959, agriculture accounted for 37.9 percent of the gross domestic product (G.D.P.), in 1969 it had dropped to an estimated 29.5 percent, while manufacturing rose in the same period from 11.9 percent to 16.0 percent of G.D.P. In 1969, the food and beverage industry accounted for 41 percent of manufacturing establishments employing ten people or more. The receipts from these industries accounted for 38 percent of the receipts from manufacturing industries (132).

The major food crops include rice, corn, groundnuts, sugarcane, cassava root, coconuts, mungbeans and soybeans. The most important livestock are buffaloes, cattle, pigs and poultry. Forests and grasslands could support many more animals and the expansion of livestock raising for export is an essential part of a plan to improve economic conditions throughout Thailand and particularly in the Northeast. At present the main buffalo and cattle raising area is the Northeast. The animals are generally used for draft buffaloes in the rice paddies and cattle on drier farms. Pigs are raised everywhere, some for sale in Bangkok and other urban markets. Most poultry is raised for family use except for some commercial duck farms around Bangkok. Fish is a popular food for most Thais. In 1972 the total catch of marine and freshwater fish was in excess of 3 million tons (37). Most of the fish marketed in Bangkok and other urban areas is sold fresh to the consumer; the remainder is smoked, dried, pickled or made into sauce or paste. The major varieties of marine fish include chub mackerel, shark, rays, cuttlefish, shrimps and crab, while the major fresh water varieties are serpent head fish, cat fish, climbing perch and carp.

1.1.6 Internal and external trade

For the most part Thailand's foreign trade policies are liberal. Most articles may be imported and exported freely with most nations.

In 1969, the value of exports was 14,890 million baht, an increase of 9 percent over 1968 (132). A steady increase in export returns has been experienced since World War II. From 1957 to 1967 exports almost doubled in value. Commodities exported are mainly of agricultural or mineral origin and are normally sold in either the raw material or slightly processed form. For the most part, the composition of exports has not changed since the early 1950's, although the relative values of the individual commodities have varied slightly. In 1969, seven major commodities, rice, rubber, maize, tin, tapioca products, kenaf and teak, accounted for 78.3 percent of the total export value in contrast to 80.7 percent in 1957. Other commodities exported include kapok fibre, castor beans, cattle, mungbeans, peanuts, shrimps, cement, hides and skins, tobacco leaves, stick lac, fresh eggs, sorghum and sugar.

Of Thailand's imports, approximately 40 percent of the value is in the form of food products and raw materials. In 1969, 5 percent of the value of imports was accounted for by dairy products. Other significant imports include fertilizers, pesticides, aircrafts, clothing and foot wear, textile fibres and paperboard.

Domestic trade is mostly carried out by private enterprise. According to the 1966 Census of business trade and services (79), 97 percent of the total of 290,487 commercial establishments in the whole Kingdom were individual proprietorships. Most establishments tended to be small in size of employment with only 98 establishments employing one hundred persons or more. Trade is carried out by a wide variety of commercial organizations, some devoted exclusively to wholesale trade, others exclusively to the retail trade and still others engaged in both forms of trade. Wholesale firms located in the Bangkok and Thonburi areas are agents for the sale of most imported goods while in some instances importing firms themselves act as wholesalers. Domestically, manufactured goods are usually distributed through wholesalers, although they may sometimes be marketed directly by the manufacturer. The collection of agricultural products from rural areas is normally conducted by middle men who send them to commission merchants in the urban centres where they are sold to exporters or processors. Retail goods are distributed by outlets that vary from highly sophisticated supermarkets to small general stores, itinerant peddlers and door-to-door traders selling food. Trade is encouraged and information concerning markets is spread by several means. Advertising is carried on through the press, radio, television, motion pictures and outdoor signs and is organized by any of the number of advertizing agencies based in Bangkok.

1.1.7 The Thai food processing industries

Food processing industries are increasing throughout Thailand in size, numbers and diversity. A wide range of industries exist including preparing and preserving meat, fruit and vegetable preservation, fish processing and sugar production.

In 1972 there were 291 registered slaughtering companies in Thailand. In addition there were 40 companies engaged primarily in preparing and preserving meat products. The majority of meat and meat products manufactured in Thailand is for local consumption, with only a small amount of frozen meat being exported. Each year Thailand imports about 5 million bahts worth of meat including beef and mutton, mainly from the USA.

Canning and other forms of fruit and vegetable preservation are carried on by about 300 factories throughout the country (6). Almost 200 of these, however, cannot properly be classified as operating on an industrial level. Rather, they are cottage-type operations run by a single person or family. Most of the processed fruit and vegetable production is dominated by 7 firms with a total registered capital of 207 million baht in 1972 (6). The main product is canned pineapple, which not only supplies the local market but also had an F.O.B. export value of over 55 million baht in 1971 (6). Other canned products include mushrooms, asparagus, tomatoes, papaya, baby corn, pickles and finger bananas.

The fishing industry in Thailand ranks next to agriculture both in extent and value and accounts for about 4 percent of G.N.P. It was estimated that 53,456 households were engaged in wharf operations related to the fishing industry in 1972 (6). Despite all this activity, the supply of fish and other seafoods is not yet sufficient to meet local demand. The considerable fish processing industry in Thailand is dominated by 5 large firms which are involved in the canning, drying, salting and smoking of fish and seafood. One of the most interesting branches of the fishing industry is the production of fish sauce (nam pla). Thais do not season their food with ordinary salt but rather use nam pla in cooking and also as a condiment. A total of 30 million litres of this extract of fish fermented in brine is consumed each year.

One of Thailand's largest food processing industries is the sugar industry. In 1970 there were 34 sugar mills, all of which were producing raw or so-called plantation white sugar (6). Most of the sugar is derived from cane, with a small amount from the flowers of the coconut and other palm trees. In 1972 it was estimated that 400,000 tonnes of sugar was exported at a value of about 1,000 million baht.

Other food industries include the production of vegetable and animal oils and fats; rice milling; soft drink and alcoholic beverage production; and the manufacture of confectionary.

1.1.8 The production and consumption of dairy products

Milk products prepared in Thailand are mainly based on imported skim milk powder and butter fat. Dairy farming is, however, increasing. The Thai-Danish dairy farm was one of the first large scale dairy farms in Thailand. It was established as a joint government venture in 1962 and produces bottled milk and cream for the Bangkok market. In 1969 it received 2272 litres of milk per day (6). The Thai-German dairy farm is a cooperative effort between the Thai Department of Livestock Development and the German government and was set up in Chieng Mai in 1967. In 1974 it received approximately 1300 litres of milk per day and produced liquid milk, cream, cottage cheese, butter and buttermilk, mainly for markets in Northern Thailand. Two groups of independent dairy farms also exist. One at Ayutthaya, with a total output of 5,000 litres per day, supplies the Bangkok Dairy Plant Co. Ltd. The second group at Ratchaburi produces about 1300 litres per day, mainly for the Kasetsart University Dairy Project.

The Foremost Dairy Company (Bangkok) Ltd. was the first company to start producing milk products on a large scale in Thailand in 1956. This factory has a capacity of 12 million gallons of plain and flavoured milk and 4 million gallons of ice cream per year. The Kasetsart University Dairy Project is primarily concerned with training and demonstration, but acts as a collecting, processing and distribution centre for bottled whole milk. In 1973 eight factories were producing canned milk. Six of these produced only sweetened condensed milk and only one utilized local fresh milk as the raw material. No milk powder is manufactured in Thailand except at a small plant set up by King Bhumibol.

The consumption of all kinds of milk and milk products has been increasing at an estimated rate of 15 percent per year and was predicted to reach 22,000 tonnes by 1974 (6). By far the greatest proportion of this consumption is condensed and evaporated milks. Of the other products, only butter is in much demand. Between 1962 and 1968 the demand for butter was increasing at a rate of 45 percent per year (6). Cheese, cream and yoghurt only appeal to the foreign community and hence the markets for these products are very small and supplied mostly by imports.

1.2 The model

The research discussed in this thesis formed part of a larger research programme of the Food Technology Department at Massey University. This programme aims at studying the application of mathematical techniques in an attempt to quantify what is largely the art of food product development. Work on the programme was initiated by Edwardson (41) with his study of the design of nutritional products for the Philippines. In designing such products, Edwardson considered the main criteria to be:

1. Low cost 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 system and channels.
6. Adaptability to existing manufacturing facilities for smooth introduction of the product into industrial production.

Edwardson further suggested that raw material selection was a central consideration in the product development method (see Figure 1.1). Such selection is dependent on the following properties:

Nutritional, e.g. protein, calories
Functional, e.g. viscosity, pH
Consumer acceptability, e.g. flavour, texture.

Although Edwardson studied all the criteria listed above, emphasis was placed on the selection of raw materials to provide a balanced nutritional diet at a low cost. The objective was then one of cost minimization, subject to specific restrictions on nutrients representing the nutritional requirements of the Filipino people.

Minimize the cost function

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

where c_j represents the cost per unit weight of each item or food raw material and x_j the weight of each of the n raw materials available for the formulation: subject to the restrictions

$$\sum_{j=1}^{n} a_{ij} x_j \geq b_i \qquad i = 1,2,\ldots k$$

where a_{ij} represents the content of each nutrient per unit weight of each raw material and b_i the minimum requirement for each nutrient in the mixture, for k nutrients.

Edwardson concluded that the problem description outlined above fitted the standard conditions of the linear programming model, and he applied this technique to the solution of the nutrition problem. It was the intention of the research discussed in this thesis to both complement and extend Edwardson's work.

The objective was to provide a quantitative basis for the selection of food raw materials in formulating nutritious food products with characteristics acceptable to the Thai consumer. The research was therefore divided into two areas. The first area was the application of the linear programming model to the selection of low cost raw material combinations with a balanced nutritional content for Thai consumers. To some extent this work overlapped that of Edwardson, in as much as the basic linear programming model used was the same. Emphasis was, however, placed on the value of supplementing indigenous raw materials with New Zealand dairy products. An adaption of the basic linear programming technique - goal programming - was also studied as a method for optimization of the nutritional balance from selected raw material combinations. The second area of the research aimed at the inclusion of organoleptic and cultural acceptability criteria into the basic linear programming model.

Hence, it was intended to set up a model for raw material selection, with the objective of minimization of the cost function:

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

subject to the two sets of restrictions:

$$(1) \qquad \sum_{j=1}^{n} a_{ij} x_j \geqslant b_i \qquad i = 1,2,\ldots k$$

where, as before, a_{ij} represents the content of each nutrient per unit weight of each item and b_i the minimum requirement for each nutrient in the mixture, for <u>k</u> nutrients

$$(2) \qquad \sum_{j=1}^{n} a_{ij} x_j \geqslant b_i \qquad i = k+1,\ldots m$$

where a_{ij} represents some factor related to consumer acceptability per unit weight input of each item and b_i the minimum requirement for this factor in the mixture, for (m-k) factors. The restriction on positive contribution of raw materials also remains:

$$x_j \geqslant 0 \qquad j = 1,2,\ldots n$$

1.3 Summary

The environment of Thailand was studied. Thailand is a country rich in natural resources, well capable of supporting its population. In spite of this, malnutrition still exists throughout most of the country and particularly in the rural areas of the North and Northeast. It was considered that through proper use of indigenous food raw materials and supplementation with imported materials, particularly dairy products, nutritionally adequate food products could be designed. Such products were to be not only nutritious but also inexpensive and generally acceptable to the consumer.

As the process of raw material selection is one of the central considerations in food product development, the objective chosen for the research was the development of a mathematical basis for selection of raw materials for input to nutritious food products acceptable to the Thai consumer. The relevance of this objective was discussed in the context of a larger research programme initiated by Edwardson (41), who proposed and used linear programming for selection of food raw materials as the basis of nutritious food formulations for the Philippines. The current research complements and extends Edwardson's work as it applies linear programming to the solution of raw material selection, firstly on the basis of nutritional needs and secondly on the basis of consumer requirements.

CHAPTER 2

LINEAR PROGRAMMING AND NUTRITION

The first area of research concerned the application of the linear programming model to the solution of the nutrition problem - that is the selection of low cost combinations of food raw materials with an acceptable nutritional balance. This chapter presents a brief review of previous applications of linear programming to the solutions of nutrition problems, showing their relationship to the current application.

The data for the model were collected, including raw material compositions and costs and Thai nutritional per capita requirements. The sources and derivations of these data are presented, together with the conversion of the original data to a suitable form for input to an IBM package linear programme.

2.1 A brief review of linear programming applications in the food industry.

Linear programming is a mathematical technique used to determine the optimum allocation of a limited supply of resources, to either maximize or minimize a specified objective. It is commonly believed that the first concepts of linear programming were laid by Von Neumann in 1928, with the mathematical theory being proposed by Danzig in 1949 (35). Danzig's work led to the definition of the Simplex method of solution, which is used as the basis for most hand and computer algorithms today. Since that time the subject has received widespread attention in such diverse fields as nutrition, engineering, economics and agriculture.

The first application of the technique in the food area was described by Stigler (192) in 1949, before the development of the solution method. His 'cost of subsistence' problem described the requirements for 9 nutrients of a moderately active man which were to be supplied by the cheapest mixture from a list of 77 foods. Solution was on a trial and error basis. Stigler's problem was solved, using the Simplex method, by Smith (180) in 1959. Edwardson (41) reviewed the literature pertaining to applications of linear programming to the solution of food formulation problems. He considered these applications as falling into three main areas.

Menu planning. Peryam (142) modified Smith's 'diet problem' to the 'menu planning problem'. Linear programming was used to select the optimum mixture of institutional meals, at low cost or possibly maximum acceptability, subject to restrictions on minimum nutritional composition, frequency of repetition of dishes, suitability of dishes for different meals and their acceptability ratings.

Planning of food supplies on national and global scales. Hruby (86) used linear programming to estimate least cost allowances of specific food groups to meet the nutritional requirements of the Czech people. Sukhatme (194) in 1961 calculated the required increase in the supply of 10 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.

Food formulation. This has been probably the most common area of application. The problem is to formulate a food product either at the lowest cost or to maximize profit, subject to specifications on both raw materials and the final product. Minimum cost formulations of bakery products were designed with required moisture, protein and raw materials (5); fruit salad and sausage formulations were designed based on legal regulations and organoleptic quality (177).

Edwardson (41) presented a summary of linear programming applications to the nutrition problem (see Table 2.1). No

Table 2.1 Summary of linear programming models in nutrition problems[a].

Year	Author	Area	Number of foods	Number of nutrients	Nutrients
1945	Stigler (192)	U.S.A.	77	9	calories, protein, Ca, Fe, vit A, thiamine, riboflavin, niacin, vit C
1959	Smith, V.E. (180)	U.S.A.	73 83 572	12 12 12	as Stigler plus carbohydrate, fat, P included restrictions on foods
1961	Smith, P.E. (178)	U.S.A.	400 30 40	8 8 8	as Stigler less calories; plus vit E
1961	Sukhatme (194)	World	10 food groups	3	calories, animal protein, vegetable protein
1964	Wirths et al.(222)	Germany	38+3 vitamin tablets	12	as Stigler plus total fat, vegetable fat and animal protein
1965	Wirths et al.(223)	Developing nations	10 food groups	8	calories, protein, animal protein, isoleucine, lysine, methionine, threonine and tryptophan
1966	de Moor et al.(125)	Belgium	n.a.	10	as Stigler plus fat
1969	Hruby (86)	Czechoslovakia	16 food groups	11	as Stigler plus animal protein and fat
1969	Inglett et al.(89)	general	6	7	protein, lysine, S-amino acids, isoleucine, threonine tryptophan, valine
1971	Patrick et al.(140)	Brazil	n.a.	n.a.	n.a.
1971	Pinto (156)	Brazil	n.a.	n.a.	included essential amino acids
1972	Cavins et al. (24)	general	6	11	protein and 10 essential amino acids

a. Taken from Edwardson (41)

further applications have been noted since the recording of this summary.

The work discussed in this thesis merged national food planning, menu planning and food formulation, as it aimed at the selection of low cost raw materials for input to nutritious food products acceptable to the Thai consumer.

In previous models for selection of raw materials of a specified combined nutritional composition, generally less than one hundred raw materials were included; the models by Smith (180), Smith (178), and Edwardson (41) being exceptions. In this project 151 raw materials were considered, including indigenous Thai foods and New Zealand dairy products. To provide a balanced diet, a wide spectrum of nutrients was considered. All nutrients regularly found in composition tables were included, totalling twenty six - calories, protein, fat, fibre, calcium, phosphorus, iron, vitamin A, vitamin C, thiamine, riboflavin, niacin, four trace vitamins and ten essential amino acids.

2.2 The data required

The general linear programming model as applied to the nutrition problem can be expressed as follows:

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

$$\begin{aligned}
\text{subject to} \quad & a_{11} x_1 + a_{12} x_2 + \cdots + a_{1n} x_n \lesseqgtr b_1 \\
& a_{21} x_1 + a_{22} x_2 + \cdots + a_{2n} x_n \lesseqgtr b_2 \\
& \vdots \\
& a_{k1} x_1 + a_{k2} x_2 + \cdots + a_{kn} x_n \lesseqgtr b_k
\end{aligned}$$

$$\text{and} \quad x_1 \geq 0, \quad x_2 \geq 0, \quad \ldots, \quad x_n \geq 0$$

where

k 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.

The data required for problem solution was then:

1. A complete list of available raw materials.
2. The cost of each raw material.
3. The composition of each raw material with respect to each nutrient.
4. A list of nutrients considered necessary in obtaining a balanced diet.
5. The required level of each nutrient.

2.3 The raw materials

FAO agricultural and fishery statistics publication (57,56) and information from the Thai Department of Statistics (119) provided a list of the major food raw materials indigenous to Thailand (see Appendix 3). This list included meats, fish, fruits, vegetables, spices and derivatives of these materials for example liver and kidney from meat animals or milk and cream from coconuts. Additional to this list of 144 indigenous raw materials were seven common New Zealand dairy products including butter, cheese, casein, lactalbumin, whole milk powder, skim milk powder and sterilized whole milk.

2.3.1 Costs

Market prices for each of the indigenous raw materials were supplied by a staff member of Chulalongkorn University, Bangkok (29). These 1972 costs could only be considered approximate but at the very least provided an ordered scaling of the materials with respect to their relative prices. Such prices are, of course, subject to variation from one market place to another and to seasonal fluctuations. The latter problem could be overcome by obtaining sets of prices for specific seasons. The problem of market place variation could be taken into account by including some estimate of the price ranges of each raw material. This would require quadratic programming for solution. In this project, it was considered reasonable to use average prices and linear programming for the following reasons:

1. If such a project was carried out by the Thai government or some private organization, quotations of costs for each raw material would be obtained. Such quotations would not be subject to either of the above variations.
2. The outputs from most computer algorithms of linear programming indicate the range of prices over which each material will remain part of a selected mix.

Prices for the dairy products were obtained from the New Zealand Dairy Board (134), expressed on a C.I.F. Thailand basis. All costs were converted to baht/100g to two significant figures, for input to the linear programming model.

2.3.2 Nutritional composition data

Data was sought on the compositions of the 151 raw materials for the 26 nutrients listed in Table 2.2. In all cases, edible portion compositions were used so that the solutions to the problem would give the nutritional composition of a mixture of raw materials prepared for processing.

The major source of the data was in a Thai Ministry of Health publication (120), which provided compositions of the local materials for proximate analyses, minerals and vitamins A, C, B1, B2, and niacin. USDA food composition tables (107, 137, 215) provided some data on vitamins B6, B12 and pantothenic acid and British tables provided folic acid data. Amino acid data were taken mainly from a recent FAO publication (54) and a Commonwealth

Table 2.2 The nutrients considered in the problem.

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

Agricultural Bureaux bulletin (78). The complete list of sources and their frequencies of use is shown in Table 2.3. After this model was set up, composition tables for Southeast Asia were published, but it was decided that little would be gained at that time by updating the data (58).

For approximately 7 percent of the composition matrix, data were assumed or calculated from compositional data of related materials. The bases for these assumptions were:

1. Was the material in question an obvious member of a wider class of raw materials? If so, did this material resemble other class members in other aspects of nutrient composition? If both criteria were reasonably met, then a minimum value of the compositional element was chosen from the documented data of other class members. For example, the folic acid content of red beans was assumed to have the minimum value recorded for all bean varieties.
2. If the other members of the raw material class differed markedly in composition from the material in question, then a minimum value was assumed from a broader grouping of materials - fruits, vegetables, meats or fish. For example, the cystine value of frog meat was assumed to be the lowest recorded value of all the meats considered in this project.
3. The majority of unrecorded fibre levels were for non-plant materials - eggs, meats, milk. Zero entries were recorded for these materials.

Table 2.3 Sources of raw material compositions.

Reference	Data included	Frequency of use	Percent of total matrix
Edwardson (41)	all 26 nutrients	1144	29.14
Thai composition tables (120)	protein, fat, calories calcium, phosphorus, iron, niacin, riboflavin, thiamine, vitamin C, vitamin A	959	24.42
FAO publication (54)	all amino acids	803	20.45
Commonwealth Agricultural Bureaux bulletin (78)	all amino acids	305	7.78
McCance and Widdowson (109)	folic acid	92	2.34
Orr (137)	pantothenic acid, vitamin B6, vitamin B12	79	2.01
Watt and Merrill (215)	protein, fat, calories, fibre, calcium, iron, phosphorus, riboflavin, niacin, thiamine, vitamin C, vitamin A	71	1.81
Bowes and Church (14)	protein, fat, calories, fibre, calcium, iron, phosphorus, riboflavin, niacin, thiamine, vitamin C, vitamin A	38	0.97
American Dairy Science Association (77)	vitamin A, thiamine, riboflavin, niacin, vitamin C, vitamin B6, vitamin B12, folic acid, pantothenic acid	32	0.82
Duckworth (39)	folic acid	30	0.76
N.Z. Dairy Board Export Purchase Handbook (133)	protein, fat, calories	14	0.35
N.Z. Dairy Research Institute (135)	calcium, phosphorus, iron, vitamin B6	8	0.20
Child (28)	folic acid, riboflavin	2	0.05
Jennes and Patton (94)	phosphorus	1	0.03
Data not available		69	1.76
Assumed and calculated data		279	7.11
		3926	100.00

4. Where materials were documented as containing traces of nutrients, and no further data was available, a zero level was recorded.
5. In a few cases data values were calculated. For example, the calorie levels of casein and lactalbumin were estimated by multiplying the fat levels by the factor 9kcal/g and protein and carbohydrate levels by the factor 4kcal/g.

Approximately 2 percent of the matrix elements were blank. The majority of these were for trace vitamins - vitamin B6, pantothenic and folic acids. In the computer solution, all missing elements were assigned zero values.

Nutrient units were expressed per 100g of food raw material. The accuracy of expression of these units and some description of the derivation of the nutrient compositional data is given below.

<u>Calories</u>:	nearest kilocalorie (kcal)	calculated using physiological energy factors for fat, protein and carbohydrate (9,4,4) where otherwise unknown
<u>Protein</u>:	nearest tenth of a gram(g) of nitrogen	where nitrogen was assumed to form 16 percent of protein in most foods. Other factors used for cereals, beans, nuts and milk
<u>Fat</u>:	nearest tenth of a gram(g)	by extraction estimation
<u>Fibre</u>:	nearest tenth of a gram(g)	by extraction estimation
<u>Calcium</u>:	nearest milligram (mg)	total (no correction for oxalate or phytate salts which make some of the mineral unavailable to the body)
<u>Phosphorus</u>:	nearest milligram (mg)	total (no correction for presence as combined phytic acid)
<u>Iron</u>:	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 0.6ug carotene = 1 iu 1.2ug other carotenes = 1iu 0.3ug 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 Thailand 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 microgram (µg)	generally total folate measured
Amino acids:	nearest milligram (mg)	average values of several independent assays for each amino acid; chromatographic estimations used where available

As in the case of costs, considerable variation exists in the raw material compositions due to seasonal effects, area of production, time of harvesting and varietal differences. The existence of these variations was recognized, but no account of them was taken. To have done this would have required specification of the variety of raw material to be used, the area of production and growing season. Accurate data would then have been required on the average compositions of each raw material and the natural variation of these averages. In this project, the use of what might be considered approximate data was justified because it made possible the development of the nutritional model. Although the combination of raw materials obtained from the model cannot be regarded as the lowest cost combination in Thailand at any one time, it can give low cost combinations of raw materials. The data can be updated easily to meet any particular raw material compositions in Thailand.

2.4 Nutritional constraints

It was considered more worthwhile initially to develop a food formulation for consumption by the whole family than for any particular age group. Raw material selection had then to be made to satisfy the nutritional requirements of all members of the family. Servings to each member would be made in proportion to his age and hence assumed to satisfy his nutritional requirements. This assumption relies on an increase in consumption with age proportional to the change in requirements for each nutrient. For example, a child in the 10-12 age group should consume more than a child in the 7-9 age group. This additional consumption is expected to supply the extra nutritional requirements of the older age group. With the exception of infants and very young children, there is a close to linear relationship between nutritional requirement and age, supporting the use of the weighted average approach to the development of constraints. In the first part of the project, that concerned solely with nutrition, all age groups have been included to provide a complete generalization of the model. It was recognized that greater accuracy would be obtained if more narrow age groupings were considered. This was done in the second part of the project where acceptance criteria for adults only were considered and hence only the nutritional requirements for this group were used.

Table 2.4 Weighted average daily per capita nutritional requirements.

Nutrient	Minimum weighted average requirement	Maximum weighted average requirement
Calories	2100	none
Protein (gN)	7.75	none
Fat (g)	20% of calories	35% of calories
Fibre (g)	6	15
Calcium (mg)	585	1500
Phosphorus (mg)	0.8 x calcium	1.5 x calcium
Iron (mg)	8.70	none
Vitamin C (mg)	28.0	none
Vitamin A (iu)	2100	none
Thiamine (mg)	0.4/1000kcals	none
Niacin (mg)	6.6/1000kcals	none
Riboflavin (mg)	0.55/1000kcals	none
Vitamin B12 (mg)	0.00185	none
Vitamin B6 (mg)	1.65	none
Folic acid (µg)	175	none
Pantothenic acid (mg)	6.80	none
Protein/calories	0.13	none
Amino acids	egg pattern values	
Isoleucine (mg/gN	415	
Leucine (mg/gN)	553	
Lysine (mg/gN)	403	
Phenylalanine (mg/gN)	365	
Tyrosine (mg/gN)	262	
Cystine (mg/gN)	149	
Methionine (mg/gN)	197	
Threonine (mg/gN)	317	
Tryptophan (mg/gN)	100	
Valine (mg/gN)	454	

Nutritional requirements for individual age groups were taken mainly from recommendations by the Thai Ministry of Health (121) and expert groups of FAO (46, 48, 49, 50, 55). The origins of the requirements for individual nutrients are discussed in the following section. In almost all cases only lower nutritional requirements were used due to the lack of information on the ill effects of overdoses of most nutrients.

Nutritional constraints were determined as weighted average requirements for each nutrient over the entire Thai population.

$$\text{Weighted average requirement, nutrient } \underline{j} = \sum_{i=1}^{n} P_i a_{ij}$$

where P_i is the proportion of the total population in age group $\underline{i}$.

a_{ij} is the requirement for nutrient $\underline{j}$ by age group $\underline{i}$.

$\underline{n}$ is the number of age groups.

The derivation of the population distribution is included in Section 2.5 and the final calculation of the weighted average requirements in Appendix 4. A summary of the weighted average requirements is given in Table 2.4

2.4.1 Energy requirements

The daily calorie allowances recommended by the Thai Ministry of Health (121) were used (see Appendix 2). These were found to be in agreement with the levels recommended by the Food and Agricultural Organization of the United Nations (55) when account was taken of the variable factors affecting energy requirements.

1. Physical activity. The FAO report (55) used an estimate of average activity based on the reference man and woman.
Reference man (65 kg in weight) requires 3200 kcal/day.
Reference woman (55 kg in weight) requires 2300 kcal/day.

2. Body size. A formula to estimate the energy requirements per unit of body weight was developed (55). A simplified version of this formula is:

$$\text{Men} \quad E = 152\ W^{0.73}$$

$$\text{Women} \quad E = 123.4\ W^{0.73}$$

where W is body weight in kg. and E is the daily calorie requirement.

3. Effect of age. The FAO group recommended a decrease in calorie intake of 3 percent for the decades 25-35 and 35-45 years, and 7.7 percent for each decade thereafter to 65 years. After 65 years the calorie intake should remain constant.

4. Climate. The group recommended a decrease in calorie intake of 5 percent for each 10°C above the base level of 10°C for the

reference man and woman. For each 10°C drop below this level, an increase of 3 percent is recommended.

These factors were used to calculate the requirements of the Thai people by age group and sex. For example the requirement for 20-29 year old men was calculated as follows:

1. No allowance was made for differing levels of activity. This was taken as that of the reference man with a requirement of 3200kcal/day.

2. Allowance for weight was made using the simplified formula.

$$E = 152\ W^{0.73}$$

$$E = 152 \times (54)^{0.73}$$

$$= 2850\ \text{kcal}$$

where the average weight of 20-29 year old men was 54kg.

3. The average temperature for Thailand is approximately 30°C which is 20°C above the base level. Hence the calorie requirement was reduced by 10 percent.

$$E = 2850 - 285$$

$$= 2535\ \text{kcal}$$

$$= 2550\ \text{kcal (rounded to the nearest 50kcal)}$$

This rounded figure of 2550kcal corresponds with the allowance recommended by the Thai Ministry of Health (121).

4. The requirement for 30-39 year old men was calculated by reducing the allowance for 20-29 year olds by 3 percent.

$$E = 2535 - (0.03 \times 2535)$$

$$= 2459\ \text{kcal}$$

$$= 2450\ \text{kcal (rounded to the nearest 50kcal)}$$

The requirements outlined by the FAO group (55) for infants and children are given in Table 2.5. In general there is agreement between these levels and those put forward by the Thai Department of Health. Slight variations exist in the allowances for children from 1-19 years. These are generally of the order of 100kcals and are probably due to small differences in body weight.

Table 2.5 Recommended daily calorie allowances for infants and children [a].

Age group	Daily allowance
1-3 months	120 kcal/kg
4-9 "	110 " "
10-12 "	100 " "
1-3 years	1300 kcal/day
4-6 "	1700 " "
7-9 "	2100 " "
10-12 "	2500 " "
13-15 years (male)	3100 " "
13-15 " (female)	2600 " "
16-19 " (male)	3600 " "
16-19 " (female)	2400 kcal/day

a. Recommended by the FAO committee on calories, 1957 (55).

Pregnancy. Extra energy is needed for growth of the foetus, the placenta and associated material tissues and for the increased cost of movement of the heavier mother. The FAO committee (55) recommended an allowance of 40,000kcals per pregnancy.

Lactation. Energy is required for milk production and for milk constituents. The FAO committee (55) recommended an extra 1000kcals/day for 6 months of lactation. These recommendations have been adopted by the Thai Ministry of Health. The calorie requirements for each age group are summarized in Appendix 2.

2.4.2 Protein requirements

Thai Health Ministry (121) and FAO/WHO recommendations (48) are not in complete agreement on daily protein requirements (see Table 2.6). The allowances for adults are almost the same on the basis of a protein utilization (NPU) of 60, while those for infants and children are higher in the Thai recommendations.

Pregnancy. The FAO/WHO group (48) estimated the extra amounts of protein laid down in the formulation of the foetus and foetal membranes. These increased demands were 6g/day in the second and third trimesters.

Lactation. An extra allowance of 15g/day is required (48).

The FAO/WHO recommendations were used and the protein requirement levels for each age group and special categories were calculated as grams nitrogen using the conversion factor 6.25 grams protein per gram nitrogen (see Appendix 2).

Table 2.6 Recommended daily protein allowances.

Age group		Thai Health Dept.[a] (g/kg body weight)	FAO/WHO[b] (g/kg body weight)
Men	20	1.00	0.98
Women	20	1.00	0.98
Infants	0-1	2.33	1.70[c]
Children	1-3	1.70	1.46
	4-6	1.31	1.34
	7-9	1.20	1.28
	10-12	1.28	1.20
Boys	13-15	1.11	1.16
	16-19	0.90	1.06
Girls	13-15	1.00	1.15
	16-19	0.81	1.06

a. Division of Nutrition, Ministry of Health, Thailand (121)
b. Report of joint FAO/WHO expert group (48)
c. Averaged over recommended allowances for four age groups between 0 and 1 year.

2.4.3 Fat requirements

Beaton and McHenry (11) maintained that the only human obligatory reason for including fat in the diet is to supply the essential fatty acids. They added, however, that fat was also desirable as a means of increasing palatability of food due to its lubricating function and slow absorption rate causing high satiety and as a possible source of fat soluble vitamins. The British Medical Association (118) were unaware of any evidence for a minimum daily intake of fat required to maintain the health and well being of the human body. Although no strict levels of fat intake are recommended in national nutrient requirement tables, desirable fat levels in terms of percentage of total calories as fat are suggested:

United Kingdom	25-35%
Canada	greater than 25%
Holland	less than 30%
South Africa	20-30%

Davidson and Passmore (36) in recommending fat intakes maintained that "any community which wishes to feed well in a civilized tradition (east or west) must obtain at least 20 percent 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 percent of total energy."

The fat contribution to total calories is generally much lower in Eastern countries than those recommended above (see Table 2.7).

Table 2.7 Calories from fat in Eastern countries[a].

Country	Fat available g/day	Calories available kcal/day	Percent[b] calories from fat	Year[c]
Ceylon	44	2150	18	1968 T
Taiwan	54	2510	19	1968 T
India	24	1900	11	1966/68/69 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 the nearest integer.
c. T is tentative, F is FAO estimate.

It was decided to limit the range of calories from fat to 20-35 percent, where fat contributes 9kcal/g. The lower limit provides enough fat for satiety and palatability factors, while the upper limit prevents possible health dangers due to excessive fat intake.

2.4.4 Fibre requirements

Fibre is recognized as an essential dietary constituent, giving bulk and consistency to faecal matter in the body to maintain laxation, but almost no data is available on recommended levels. In 1956 Robinson (160) reported that the daily requirement for crude fibre had been estimated in 1932 to be about 90-100mg/kg of body weight. Hutchinson (88) stated that approximately 40kcal/day from hemicelluloses and 20kcal/day from celluloses could be absorbed by intestinal organisms, after an allowance for material loss during fermentation. This is equivalent to 60kcal/day, which at the rate of 4kcal/g from carbohydrates would be available from 15g/day of mixed polysaccharides.

In this study, a crude fibre range of 6-15g/day was set for all age groups. It was recognized that specific components of crude fibre including celluloses, hemicelluloses and lignin, may have specific functions in the human body, but these could not be used because of the lack of compositional data in this area.

2.4.5 Calcium and phosphorus

Calcium and phosphorus are the chief elements in building skeletal structures of the body. Calcium also acts in blood clotting, absorption of vitamin B12 from the intestinal tract, regulates contractibility of muscle and helps maintain normal cell permeability essential to osmotic pressure control. Phosphorus is important in anabolic and catabolic reactions as ATP and ADP. In the inorganic form it helps regulate ion concentration of the body.

Recommended requirements for calcium vary considerably. Sherman (174) suggested the minimal requirement to be 680mg/day, while Mitchell and Curzon (122) found that 9.75mg/kg body weight per day was required to maintain equilibrium. The FAO/WHO expert committee on calcium (46) and the recommendations of the

Thai Ministry of Health (121) are shown in Table 2.8. The FAO/WHO group suggested a range to include the lowest acceptable intake of calcium because of the wide differences in requirements from area to area.

Table 2.8 Recommended daily calcium allowances.

Age group (years)	FAO/WHO[a] (mg/day)	Thai Health Dept.[b] (mg/day)
0-1	500-600	500
1-6	400-500	400
7-9	400-500	500
10-12	600-700	600
13-15 boys	600-700	700
16-19 boys	500-600	600
13-15 girls	600-700	600
16-19 girls	500-600	500
adult men	400-500	500
adult women	400-500	400

a. Joint FAO/WHO expert group on calcium, 1962 (46)
b. Division of Nutrition, Ministry of Health, Thailand, 1970 (121)

Additional intakes were recommended by the FAO/WHO group (46) during the third trimester of pregnancy to provide for growth of the foetus, and in the lactation period to compensate for losses in human milk. The suggested level of intake for both periods was between 1000 and 1200mg/day.

Although the group did not define an upper limit for calcium intake, it did suggest that levels in excess of 1500mg/day may lead to kidney stone formation.

In this project the upper level of the range of calcium allowances recommended by the FAO/WHO group were adopted as the acceptable minimum levels of intake. An upper limit of 1500mg/day was also defined for all age groups.

No allowances for phosphorus are recommended by the Thai Ministry of Health. The FAO/WHO group on calcium requirements (46) felt that variations in the calcium to phosphorus ratio in habitual diets are of no practical significance in relation to the utilization of the minerals. Sherman (174, 175), however, stated that when the ratio of the two minerals is greatly imbalanced, the mineral in the smaller amount is not well absorbed. Beaton and McHenry (11) believed that phosphorus levels up to 150 percent those of calcium were satisfactory for the American people.

It was considered that some restriction should be placed on the ratio of calcium to phosphorus. The range chosen was:

$$0.8 \leq Ca/P \leq 1.5$$

2.4.6 Iron requirements

Iron has a central function in oxygen transport in the blood and has a role in haemoglobin formation. On the basis of total body turnover studies, the FAO/WHO committee on iron requirements (49) calculated the total loss of iron per day to be 0.91mg for the average man (65kg in weight) and 2.8mg for the average woman (55kg in weight). The committee's recommendations for children from birth to 16 years were calculated on the assumption that girls began menstruation at the age of 13 years with an upper limit on menstrual loss of 1.4mg/day. To provide for the needs of the foetus and placenta an additional allowance of 1000mg was suggested for the first and second halves of pregnancy. During lactation an extra 2.4mg/day was suggested to account for blood losses, milk iron losses and basal losses. The FAO/WHO recommended allowances for iron are summarized in Table 2.9.

The requirements as set by the Thai Ministry of Health are close to the FAO/WHO recommended allowances for diets containing 10-25 percent calories from animal sources. Variation exists in the levels for pregnant and lactating women with the Thai figures being higher than those of the FAO/WHO group. In this project the Thai Ministry of Health allowances were used for all groups except pregnant and lactating women. In these cases FAO/WHO figures were considered more realistic in view of evidence presented in that report (49).

Table 2.9 Recommended daily allowances for iron.

Age group	Recommended intakes according to percentage calories from animal food			Thai Health Dept.[a]
	〈 10% (mg/day)	10-25% (mg/day)	〉 25% (mg/day)	(mg/day)
Infants 0-4 months	Supplied by breast feeding			kg x 1.0
5-12 months	10	7	5	kg x 1.0
Children 1-9 years	10	7	5	4
10-12	10	7	5	8
Boys 13-15	18	12	9	11
16-19	9	6	5	11
Girls 13-15	24	18	12	16
16-19	28	19	14	16
Men 20	9	6	5	6
Women 20-49	28	9	14	16
Women 50	NA[b]	NA	NA	6
Pregnant women				
1st half	an extra 0.8mg/day[c]			26
2nd half	an extra 3.0mg/day			26
Lactation	an extra 2.4mg/day			26

a. Division of Nutrition, Ministry of Health, Thailand, 1970 (121)
b. Not given in this report
c. Additional to each category

2.4.7 Vitamin C requirements

Recommendations of the joint FAO/WHO committee on vitamin C (49) and of the Thai Ministry of Health are in almost total agreement (see Table 2.10).

Work carried out by Baker et al (10) and Hodges et al (84) indicated that an adult can maintain health, as defined by the absence of scurvy, on 6.5mg/day. Baker (9) claimed that well fed young men metabolized on average 21.5mg vitamin C per day. On the basis of these and other studies, the FAO/WHO committee (49) decided that a level of 30mg/day should be sufficient to meet the requirements of adults of either sex. From information put forward by Martin et al (111) and Smith (179), the committee decided on a daily allowance of 50mg for pregnant and lactating women. It was considered that infants up to six months would obtain all their vitamin C requirements through breast feeding.

For this project, Thai Ministry of Health recommended levels were used (see Table 2.10).

Table 2.10 Recommended daily allowances for vitamin C.

Age group	FAO/WHO[a] (mg/day)	Thai Health Dept[b] (mg/day)
Infants 0-6 months	-[c]	20
6-12 "	20	20
Children 1-9 years	20	20
10-12 "	20	30
Males 12+	30	30
Females 12+	30	30
Pregnant women	50	50
Lactating women	50	50

a. Joint FAO/WHO expert group on ascorbic acid, vitamin D, vitamin B12, folate and iron, 1970 (49)
b. Nutrition Division, Ministry of Health, Thailand, 1970 (121)
c. Supplied through breast feeding.

2.4.8 Vitamin A requirements

Very little is known about the action of vitamin A other than its role in vision. An interministerial working group on nutrition guidelines for Thailand (91) indicated that vitamin deficiencies, especially vitamin A, was one of the five major nutrition problems. This claim was supported by Migasena (116) who suggested that low intake of this vitamin associated with protein-calorie malnutrition may retard growth of children.

In a report by the British Medical Research Council (113) it was found that 390µg of retinol was required to correct for defective dark adaption while 750µg was sufficient to maintain constant plasma levels. The joint FAO/WHO committee on vitamin A requirements (50) recommended 750µg/day of retinol for the normal adult. No extra allowance was considered necessary for pregnancy. To account for the 49µg/100ml of human milk, an intake of 1200µg/day of retinol was suggested during lactation. The recommended allowances of the Thai Ministry of Health (121) are given in international units of vitamin A. When converted to µg retinol these allowances are close to those of the FAO/WHO group (see Table 2.11).

1 iu vitamin A ≡ 0.3µg retinol

In this project, the Thai Ministry of Health allowances were used in the form international units of vitamin A. These units were chosen because most compositional tables record vitamin A levels in this form. In the case of data being given as β carotene the conversion to vitamin A was made as follows:

1 µg β carotene ≡ 0.167 µg retinol
1 iu vitamin A ≡ 0.3 µg retinol

Table 2.11 Recommended daily allowances for vitamin A.

Age group	FAO/WHO[a] µg retinol	Thai Health Department[b] µg retinol	Thai Health Department[b] iu vitamin A
Infants 0-6 months	-[c]	300	1000
6-12 "	300	300	1000
Children 1-3 years	250	255	850
4-6 "	300	300	1000
7-9 "	400	405	1350
10-12 "	575	570	1900
13-15 "	725	720	2400
Adults 16+ years	750	750	2500
Pregnant women	750	750	2500
Lactating women	1200	1200	4000

a. Joint FAO/WHO expert group on requirements for vitamin A, thiamine, riboflavin and niacin, 1967 (50).
b. Division of Nutrition, Ministry of Health, Thailand, 1970 (121).
c. Supplied by breast feeding.
d. Calculated from vitamin A requirements (iu), where 1 iu ≡ 0.3µg retinol.

2.4.9 Thiamine requirements

Considerable work has been done on the action of thiamine in the human body, particularly its role in the form of thiamine pyrophosphate as a coenzyme in carbohydrate metabolism. Thiamine deficiencies throughout Thailand were reported by the 1960 nutrition survey (90) and supported by more recent work in the North and Northeast (116, 202).

Although absolute daily requirements are included in several recommendations, including those of the Thai Ministry of Health, it is more common to relate thiamine intake to calorie levels. The FAO/WHO expert group on thiamine (50) suggested 0.33mg/1000 calories with a safety factor of 20 percent (for population variation) leading to 0.4mg per 1000kcals. This figure was considered adequate for all age groups including children and pregnant and lactating women. This recommended daily allowance was adopted.

2.4.10 Niacin requirements

Niacin is used by the body primarily in the form of nicotinamide adenine dinucleotide to form the prosthetic group of certain enzymes that take part in electron transfer reactions in the respiratory chain and in oxidative phosphorylation.

As with thiamine, it is common to link niacin requirements to calorie intake. The level recommended by the FAO/WHO expert group on niacin (50) was 6.6 niacin equivalent per 1000kcals, where 1 niacin equivalent is equal to 1mg niacin. This allowance was considered adequate for all age groups and pregnant and lactating women.

The term niacin equivalent is used to take account of tryptophan as a source of the vitamin:

1 niacin equivalent = 60mg tryptophan

The recommended allowances of 6.6mg/100kcals was adopted in this study. No account was taken of the possible contribution of tryptophan due to confusion in the literature over this conversion. Neglect of this source of niacin could only lead to an excess of the vitamin which has been shown to have no ill effects in large doses.

2.4.11 Riboflavin requirements

A deficit of riboflavin was reported by the 1960 nutrition survey (90). Much work has been done in the North and Northeast of Thailand to support this claim (116, 202, 203) although ariboflavinosis is not considered an important public health problem.

Riboflavin functions as part of a group of enzymatically active compounds called flavoproteins which contain either flavine mononucleotide or flavine adenine dinucleotide as prosthetic groups and are involved in the respiratory chain and oxidative phosphorylation. Because of this association with protein metabolism riboflavin requirements are sometimes linked with protein intake. It is now more common to specify riboflavin allowances in terms of calorie intake. The FAO/WHO expert group on riboflavin (50) recommended an allowance of 0.55mg per 1000kcals. This level was considered adequate for all age groups and for pregnant and lactating women.

2.4.12 Vitamin B12 requirements

Vitamin B12 is important in folate metabolism and may have a significant role in carbohydrate, fat and protein metabolism. In India and other parts of Southeast Asia low vitamin B12 intake, usually in association with folate deficiency, frequently causes complications in pregnancy and may lead to deficiency and anaemia in breast fed infants.

No recommendations are made by the Thai Ministry of Health for vitamin B12 intake. The FAO/WHO expert group (49) suggested a daily allowance of 2µg for adults. An allowance of 0.3µg/day was suggested for infants on the basis of this being the amount supplied by breast milk. Very little information is available on the requirements of children for the vitamin so the FAO/WHO group calculated levels in proportion to the calorie intake of the different age groups. To account for the drain of vitamin B12 to the foetus an intake of 3.0µg/day was recommended during pregnancy. For the lactation period a level of 2.5µg/day was suggested to make up for a loss of about 0.3µg/day in breast milk. These requirements were adopted for this project and are summarized in Table 2.12.

Table 2.12 Recommended daily allowances for vitamin B12[a].

Age group	Allowance (µg/day)
0-12 months	0.3
1-3 years	0.9
4-9 "	1.5
Adults over 10 years	2.0
Pregnant women	3.0
Lactating women	2.5

a. Joint FAO/WHO expert group on vitamin B12 (49).

2.4.13 Vitamin B6 requirements

Vitamin B6 has a role in the metabolism of nervous tissue. Deficiency of this vitamin is rare but can lead to increased irritability and convulsions.

Daily allowances adopted in this study are those recommended by the 1968 NRC report (128), in the absence of data in either FAO/WHO or Thai Ministry of Health sources (see Table 2.13).

Table 2.13 Recommended daily allowances for vitamin B6[a].

Age group	Allowance (mg/day)
0-1 year	0.4
1-3 "	0.6
4-6 "	0.9
7-9 "	1.2
10-12 "	1.4
13-15 "	1.6
16-19 "	1.8
Adults over 20 years	2.0
Pregnant women	2.5
Lactating women	2.5

a. NRC report, 1968 (128).

2.4.14 Folic acid requirements

Folic acid exists in two forms, 'free' folate and 'total' folate. It has been suggested that only 'free' folate is available for absorption in healthy individuals and that only 80 percent of this form is eventually absorbed (3, 93). The joint FAO/WHO committee on folic acid (49) considered this to be an over simplification as more needs to be known about the form of folates in foods and their action in the human body. There is a folic acid deficiency in Northeast Thailand which may be related to the malnutrition diseases in this area (211).

Work by Herbert (82) using pteroyloglutamic acid (PGA) suggested that between 50 and 100μg of folate per day was needed to produce a haemotalogical response in folate deficient patients. This evidence led the FAO/WHO group to recommend a daily allowance of 200μg of 'free' folate for normal adults. An allowance of 40μg/day was suggested for infants up to 6 months and 60μg/day between 6 and 12 months. In the absence of sufficient information an allowance of 100μg/day was suggested for children up to 12 years of age, this being a figure intermediate between infants and adults. These recommendations together with those for pregnant and lactating women are summarized in Table 2.14.

Table 2.14 Recommended daily allowances for 'free' folate[a].

Age group	Allowance (μg/day)
Infants 0-6 months	40
7-12 "	60
Children 1-12 years	100
Adults above 12 "	200
Pregnant women	400
Lactating women	300

a. Derived from recommendations by the FAO/WHO expert group on folic acid (49).

Compositional tables containing data on folate are frequently non-specific as to the form of this folate. In the absence of substantial evidence on the proportion of 'total' folate available to the human body and in consideration of the probable overstatement of the FAO/WHO recommended allowances the distinction between 'free' and 'total' folate was ignored in this project.

2.4.15 Pantothenic acid requirements

Pantothenic acid is a constituent of coenzyme A and is present in all living matter. Deficiencies are unlikely except where processed foods form a large part of the diet. It is probably for this reason that no recommended daily allowances are made by FAO/WHO or the Thai Ministry of Health. Since pantothenic acid deficiencies are still possible, although unlikely, daily allowances for the vitamin were included. The NRC report (128) indicates levels of intake in the United States of America which appear to be satisfactory. Children and adults obtain between 5 and 10mg/day and infants receive approximately 2mg/litre of breast milk. Williams (220) estimated that a typical diet containing both plant and animal foods, supplying 2500kcals/day provides 10mg pantothenic acid.

As no cases of pantothenic acid deficiency had been reported at levels of intake of 5mg/day, this level plus a 50 percent safety factor giving an allowance of 8mg/day was adopted in this study. An allowance of 2mg/day was used for weaned infants, with the level being increased gradually with age to 13 years, where adult status is achieved. On the basis of suggestions by Chaney and Ross (25), no extra allowances were made for pregnant and lactating women (see Table 2.15).

Table 2.15 Recommended daily allowances for pantothenic acid.

Age group	Allowance (mg/day)
0-1 years	2
1-3 "	3
4-6 "	4
7-9 "	5
10-13 "	6
Adults above 13 years	8

2.4.16 Amino acid requirements

Amino acids can be divided into two categories:

1. The essential amino acids which cannot be synthesized by the human body and must be obtained from the diet.
2. The non-essential amino acids which can be synthesized by the body given a source of nitrogen, either other amino acids or an inorganic source.

Recommendations on essential amino acids have been made either on the basis of absolute allowances for each acid or on a pattern of intake relating all essential amino acids. The 1965 FAO/WHO committee on protein requirements (48) stated that "when protein-containing foods are fed at the level needed to meet the total protein requirements, the over-all pattern of available amino acids is more important in determining quality than simply the absolute amount of each of the essentials". The 1957 FAO/WHO group on protein (47) suggested a provisional pattern for essential amino acids. This pattern was criticized for its high lysine, methionine, cystine and tryptophan levels and the 1965 committee considered that egg or milk protein presented more suitable patterns (see Table 2.16).

Table 2.16 Selected essential amino acid patterns [a].

	mg per g total nitrogen			
Amino acid	1957 FAO provisional pattern	Cow's milk	Human milk	Hen's egg (whole)
Isoleucine	270	407	411	415
Leucine	306	630	572	553
Lysine	270	496	402	403
Phenylalanine	180	311	297	365
Tyrosine	180	323	355	262
Cystine	126	57	134	149
Methionine	144	154	140	197
Threonine	180	292	290	317
Tryptophan	90	90	106	150
Valine	270	440	420	454

a. Taken from the joint FAO/WHO report on protein, 1965 (48).

Egg protein was used as the reference pattern for this study. Account was also taken of the ratio of essentials to total amino acids to prevent the selective conversion of excess essentials to non-essentials thus destroying the balance of essential amino acids. Requirements were expressed in terms of mg/g total nitrogen to ensure an acceptable ratio of essential to non-essential amino acids.

2.4.17 The ratio of protein to calories

Protein-calorie malnutrition has been recognized as one of the five major nutrition problems in Thailand (91). It was shown by Valyasevi et al (210) to be related to the high incidence rate of vesical calculi or bladder stone among the population of North and Northeast Thailand.

The FAO/WHO committee on protein requirements (48) considered that a diet providing less than 5 percent of calories in the form of utilizable protein is incapable of meeting the needs of adults and a diet supplying less than 8 percent of calories as utilizable protein is incapable of meeting the needs of young infants. To obtain a level of 8 percent calories from protein of NPU = 60 requires 1.67 times the intake of protein of NPU = 100 or a theoretical return of 13 percent of calories from the total protein intake of NPU = 60.

$$\text{Calories from protein} = N \times 6.25 \times 4$$

where N is g nitrogen and the metabolizable energy of protein is 4kcals.

$$\text{then protein calories percent} = \frac{N \times 6.25 \times 4 \times 100}{\text{Total cals.}} \geqslant 13 \text{ percent}$$

2.5 The weighted average per capita daily requirements

To calculate the weighted average daily requirements for each nutrient, the Thai population by age group was required. Unfortunately the age classifications used in the United Nations demographic yearbook (208) and in the nutritional recommendations were not in accord. The data from the demographic tables were modified to provide estimates of the population in each of the nutritional age groups during 1970 (see Appendix 4). These data were applied to the recommended daily allowances for each age group to obtain a weighted average population requirement for each of the following nutrients:

protein	vitamin C
calories	folic acid
iron	vitamin B12
calcium	vitamin B6
vitamin A	pantothenic acid

The remaining 16 nutrients were either related to calories as in the case of thiamine, riboflavin, niacin and fat; related to protein as for all the essential amino acids; related to another nutrient like phosphorus to calcium or fixed at one level for all age groups as for fibre.

Extra allowances for most nutrients were required during pregnancy and lactation. The nutrients in these categories are summarized in Table 2.17.

Table 2.17 Nutrients requiring extra allowances during pregnancy and lactaion.

	Pregnancy		Lactation
1st trimestre	2nd trimestre	3rd trimestre	
calories	calories	calories	calories
	protein	protein	protein
iron	iron	iron	iron
vitamin B6	vitamin B6	vitamin B6	vitamin B6
	folate	folate	folate
	vitamin B12	vitamin B12	vitamin B12
	vitamin C	vitamin C	vitamin C
			vitamin A
		calcium	calcium

Estimation of the numbers of pregnant and lactating women was made as in most FAO/WHO reports on nutrition:

1. When the number of pregnant women in a population is not known then it is assumed that there are 10 percent more pregnant women than infants from 0-12 months of age.

$$\text{pregnant women} = P + \frac{P \times 10}{100}$$

where P is the number of infants from 0-12 months.

2. The number of lactating women is related to the duration of lactation. This was assumed to be 8 months and the number of lactating women calculated as follows:

$$\text{lactating women} = \frac{P \times 8}{12}$$

where P is the number of infants from 0-12 months.

In the special case of infants up to 12 months of age, allowance was made for supply of nutrients from breast milk during the first 8 months. Therefore, account was only taken of one third of the infants in the 0-12 month category for the calculation of the weighted average requirements.

2.6 Setting up the data for computer solution

A description of the linear programming matrix is shown in Figure 2.1. This matrix, including raw material compositions, costs and nutritional constraints, was prepared as a card deck for input to the IBM Linear Programming System/1130 (LPS/1130) package programme, designed for use on the 1130 series of IBM computers. At Massey University, the 1130 computer had a single disk storage drive and was linked to a 1442 card reader punch and a 1132 line printer. Preparation of the data deck was according to the method described in the IBM LPS/1130 programme description manual (92) using 80 column cards.

2.6.1 The raw material compositions and costs

Each element of the composition matrix was expressed on separate cards displaying the raw material and relevant nutrient.

ANCHOVY	CAL	75.00
ANCHOVY	PROT	2.88
ANCHOVY	FAT	0.30

Cost data was similarly expressed.

ANCHOVY	COST	1.25

In all cases the column variable was punched first followed by the row variable and the data value. All variable names were restricted to eight alphanumeric symbols. In some cases an abbreviation of raw material or nutrient names was required. These abbreviated names are in the row and column summary shown in Figure 2.2.

2.6.2 The constraints

Restrictions on nutrient levels were either at an upper and/or lower limit, or a prespecified constant level. The options available to the LPS/1130 user are:

Columns / Rows	Raw materials (151 columns)	CAL	PROT	FAT	CA	P	THIA	NIA	RIBO	ISO	LEU	LYS	PHE	TYR	CYS	METH	THREO	TRYP	VAL	Constraints LB	Constraints UB
Objective, cost																					
CAL		1.0																		2100	∞
PROT			1.0																	7.75	∞
FAT				1.0																0	∞
FIB																				6.0	15
CA					1.0															585	1500
P						1.0														0	∞
FE																				8.70	∞
VITA																				2100	∞
VITC																				28.0	∞
THIA							1.0													0	∞
NIA								1.0												0	∞
RIBO	Nutrient composition matrix								1.0											0	∞
VITB.12																				0.00185	∞
VIT36																				1.65	∞
FOLIC																				1.75	∞
PANTCA																				6.6	∞
ISO										1.0										0	∞
LEU											1.0									0	∞
LYS												1.0								0	∞
PHE													1.0							0	∞
TYR														1.0						0	∞
CYS															1.0					0	∞
METH																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
LOCA/P				-1.0	0.8															-∞	0
HICA/P				-1.0	1.5															0	∞
LORIBO		-0.00055																		0	0
LONIA		-0.0066																		0	0
LOTHIA		-0.0004																		0	0
PROCAL		-0.1	1.0																	0	∞
CISO	Zero matrix		-415							1.0										0	0
CLEU			-553								1.0									0	0
CLYS			-403									1.0								0	0
CPHE			-365										1.0							0	0
CTYR			-262											1.0						0	0
CCYS			-149												1.0					0	0
CMETH			-197													1.0				0	0
CTHREO			-317														1.0			0	0
CTRYP			-100															1.0		0	0
CVAL			-154																1.0	0	0

Figure 2.1 Linear programming matrix for the Thai nutrition problem

COLUMN SUMMARY

28	ANCHOVY	11	PROT	2	FAT	7	CAL
1	FIB	1	CA	1	P	1	FE
1	VITB6	1	VITB12	1	FOLIC	1	PANTOA
1	NIA	1	RIBO	1	THIA	1	VITC
1	VITA	1	CYS	1	VAL	1	ISO
1	PHE	1	TYR	1	METH	1	TRYP
1	THREO	1	LYS	1	LEU	28	BAMSHOOT
28	BANANA	28	BEANBRD	28	BEANSNAP	28	BEANYDRD
28	BEEF	27	BFBLOOD	27	BFBRAIN	28	BFHEART
28	BFKIDNEY	25	BFLGINT	28	BFLIVER	27	BFLUNG
25	BFSMINT	28	BFSPLEEN	25	BFSTOM	27	BFTONGUE
28	BRDFRUIT	28	BUFFALO	27	BUBRAIN	28	BUHEART
28	BUKIDNEY	25	BULGINT	28	BULIVER	25	BUSMINT
28	BUSPLEEN	25	BUSTOM	28	CABCHI	28	CABCOM
28	CARP	28	CASHFRT	28	CASHNUT	28	CASSLVS
27	CASSAVA	28	CATFISH	28	CAULI	28	CELERY
28	CHICKEN	26	CHGIZZ	28	CHLIVER	28	COCOMEAT
28	COCOMILK	28	COCONUT	28	CORNWH	28	CORNY
28	CRAB	26	CUCUM	28	DUCK	28	DUCKT
28	EGGDUCK	28	EGGHEN	28	EGGPLANT	28	FROG
28	GARLIC	18	GINGER	28	GOOSE	28	GOOSET
28	GOURDB	28	GOURDWX	28	GRAPE	28	GUAVARD
28	GUAVAWH	28	HERRING	28	HORSE	28	JACKFRT
27	JACKFRTSD	28	KALE	28	LEEK	28	LEMON
28	LETTUCE	28	LIME	28	LOBSTER	28	MACKSP
28	MANGO	28	MELON	28	MILKBUFF	28	MILKFISH
28	MILKGOAT	28	MULLET	28	MUNGBEAN	28	MUSHROOM
28	OCTOPUS	28	OCTOPUS	28	ONIONB	28	ONIONGR
28	ORANGE	28	PAPAYA	28	PEACH	28	PEACHICK
28	PEANUT	28	PEAPIG	28	PEASWT	27	PEPPERGR
27	PEPPERRD	28	PERCH	28	PIG	27	PIGBLOOD
28	PIHEART	28	PIKIDNEY	25	PILGINT	28	PILIVER
27	PILUNG	25	PISMINT	28	PISPLEEN	28	PISTOM
28	PITONGUE	28	PINEAP	28	POMELO	28	POTATO
28	POTSTWH	28	POTSTY	28	PRAWN	28	PUMPKIN
28	RADISH	28	RICEBR	28	RICEGL	28	RICEWH
28	SARDINE	27	SESAME	28	SHALLOT	28	SHARK
28	SHRIMP	28	SNAPPER	28	SORGHUM	28	SOYBEAN
25	SUGAR	25	SUGCANEJ	27	SUNSEED	28	TAMALVS
28	TAMARIPE	28	TANG56	28	TANG57	28	TARO
28	TKBREAST	26	TKGIZZ	28	TKLIVER	28	TOMATO
28	WHEAT	28	WHEATBR	28	WHEATFL	28	WHEATGM
28	WTMELON	28	YAM	28	BUTTER	28	CASEIN
28	CHEESE	28	LACTALB	28	MILK	28	SMP
28	WMP						

ROW SUMMARY

151	COST	151	PROT	151	FAT	151	CAL
151	FIB	151	CA	151	P	150	FE
136	VITB6	151	VITB12	130	FOLIC	140	PANTOA
151	NIA	151	RIBO	151	THIA	151	VITC
149	VITA	150	CYS	150	VAL	150	ISO
150	PHE	150	TYR	150	METH	150	TRYP
150	THREO	150	LYS	150	LEU	151	WT
2	LONIA	2	LORIBO	2	LOTHIA	2	LOFAT
2	HIFAT	2	LOCA/P	2	HICA/P	2	CISO
2	CLEU	2	CLYS	2	CPHE	2	CTYR
2	CCYS	2	CMETH	2	CTHREO	2	CTRYP
2	CVAL	2	PROCAL				

Figure 2.2 Row and column summary for nutrition problem. Listed by the SUMMARY procedure LPS/1130

UB	-	upper bound
LB	-	lower bound
FR	-	free
FX	-	fixed or defined
GT	-	defined value to $+\infty$
LT	-	defined value to $-\infty$

1. Upper limits. These were rarely set in this project due to the lack of information on the ill effects of overdoses of specific nutrients. One exception was calcium where an upper limit of 1500mg/day was defined.

$$CA \leq 1500$$

or in card format,

UB   MIX1   CA   1500

where UB denoted the imposition of an upper limit of 1500mg/day for CA in MIX1.

2. Lower limits. Most nutrients were assigned a minimum acceptable daily allowance. For example calcium was not permitted to fall below 585mg/day.

$$CA \geq 585$$

or in card format,

LB   MIX1   CA   585

where LB denoted a lowest acceptable level of 585mg/day of CA in MIX1.

3. Equalities. The need to define the daily allowance of a nutrient at one specified level is rare. In the specification of an amino acid pattern identical to egg protein these constraints are required. The derivation of these constraints based on interrelationships with other nutrients is discussed below.

2.6.3 Interrelated variable expressions

Linear equations were set up to express the relationships between specific nutrients. A new variable name was assigned to the left hand side of the equation forming an additional row in the linear programming matrix (see Figure 2.1). For example, at least 20 percent of calories was to come from fat.

$$\frac{9 \times FAT}{CAL} \geq 0.2$$

$$LOFAT = \frac{9 \times FAT}{CAL} \geq 0.2$$

$$\text{or} \quad LOFAT = 9 \times FAT - 0.2 \times CAL$$

$$\text{where } LOFAT \geq 0$$

For expression of this linear equation two separate cards were used, the first showing the relationship of FAT to LOFAT and the second of CAL to LOFAT.

FAT	LOFAT	9.0
CAL	LOFAT	-0.2

The row variable LOFAT was required to be greater than zero.

LB	LOFAT	MIX1	0.0

A similar situation existed with the essential amino acids in their relationship to total protein intake. For example, exactly 119mg cystine per gram of nitrogen was required to duplicate the level of this amino acid in the egg pattern.

$$CYS = \frac{119mg}{g.N} \times PROT\ (gN)$$

$$CYS = 119 \times PROT$$

$$\text{then define} \quad CCYS = CYS - 119PROT$$

$$\text{where} \quad CCYS = 0$$

In card format this was written as follows:

	CYS	CCYS	1.0
	PROT	CCYS	-119.0
FX	CCYS	MIX1	0.0

2.6.4 Input for computer solution

The data was organized for computer solution. All data was stored on disk for quick access, and allowed for rapid modifications and revisions to both raw material compositions and nutrient requirements. When required, the complete linear programming matrix was moved from disk for computer solution. Chapter 3 includes a discussion of the solution to this problem and demonstrates some of the programming options available and their use.

2.7 Summary

A brief review of linear programming applications in the food industry showed that these applications fell into three main areas - menu planning, planning of food supplies on national and global scales and food formulation. It was concluded that the current research was an amalgamation of all three areas. The research was seen as both complementing and extending a model developed by Edwardson (41) for solution of nutrition problems in the Philippines, to solution of similar problems in Thailand.

The following data were collected for solution of the Thai nutrition problem using Edwardson's model:

1. Compositions and costs of 151 indigenous Thai food raw materials and New Zealand dairy products.
2. The requirements by age group for 26 selected nutrients.
3. The 1970 population distribution in Thailand.

Using the nutritional requirements by age group and the population distribution data, weighted average nutritional requirements were calculated for the Thai population. The raw data was converted to the form of a linear programming matrix with the compositional data forming the body of the matrix, the nutritional requirements as the constraints and cost as the objective function. This matrix was further converted to the card format required for solution by the IBM LPS/1130 computer programme. The solution to this problem is discussed in the next chapter together with solutions to specific modifications of the problem.

CHAPTER 3

SOLUTIONS TO THE NUTRITION PROBLEM

The linear programming matrix, including raw material costs and compositions and nutritional requirements, was used to find a least cost mix of raw materials to be used in formulation of a balanced nutritional food product for Thailand. Variations in the matrix were also made to find the effects on the composition and cost of the selected mixes. These variations were firstly, the inclusion of dairy products and secondly, changes in the amino acid pattern. Two specific solution methods were used, the conventional linear programming approach designed to satisfy nutritional requirements at the least cost and an adaption of this basic approach - goal programming. Goal programming was designed to 'optimize' the balance of nutrients in any selected combination of raw materials. Comparisons were made between the solutions obtained using each method, with and without the inclusion of dairy products in the list of available raw materials.

3.1 The linear programming approach

The basic linear programming model for the nutrition problem was solved using the LPS/1130 package programme. The amino acid requirements were varied to find the effect on cost of attaining the ideal egg pattern. In all cases solutions were obtained with and without dairy products.

3.1.1 Amino acids at egg pattern levels

The linear programming matrix as described in Figure 2.1 was input to the IPS/1130 programme but it was impossible to obtain a feasible solution. Several nutrients were at their lower limits including calories, pantothenic acid, thiamine, niacin and fat. Fibre and calcium were at their upper limits.

The amino acids had a strong effect on the computations because of the tight restriction of the egg pattern equality constraints and because they made up approximately one third of the total constraints. To remove this tight restriction on the amino acids and at the same time to evaluate the cost of improving their balance, solutions were obtained by systematically changing the desired amino acid pattern.

3.1.2 Stepwise variation in amino acid pattern

The parametric procedure of the LPS/1130 programme was used to systematically change the amino acid constraints. This was done by simultaneously increasing the required lower levels from 80 percent that of egg pattern and decreasing the upper levels from 120 percent that of egg pattern, each by steps of 5 percent. Solutions were then obtained at four ranges of amino acids:

80-120 percent egg pattern
85-115 " " "
90-110 " " "
95-105 " " "

All other nutrient requirements remained the same.

Feasible solutions were available at all four stages of improvement of the amino acid balance (see Appendix 5). The cost of the 95-105 percent solution was almost double that of the 80-120 percent solution. The cost increments in moving towards an improved balance grew progressively larger (see Figure 3.1).

Folic acid, pantothenic acid and calories remained at their lower limits of requirement through all four stages of amino acid balance. Protein remained constant at a level of 13 percent total calories. Fat remained at its lower limit in all but the 95-105 percent solution. The level of calcium increased progressively with improvement in the amino acid pattern taking phosphorus with it to maintain a Ca/P ratio of 0.8. Isoleucine and methionine were limiting in all four solutions and

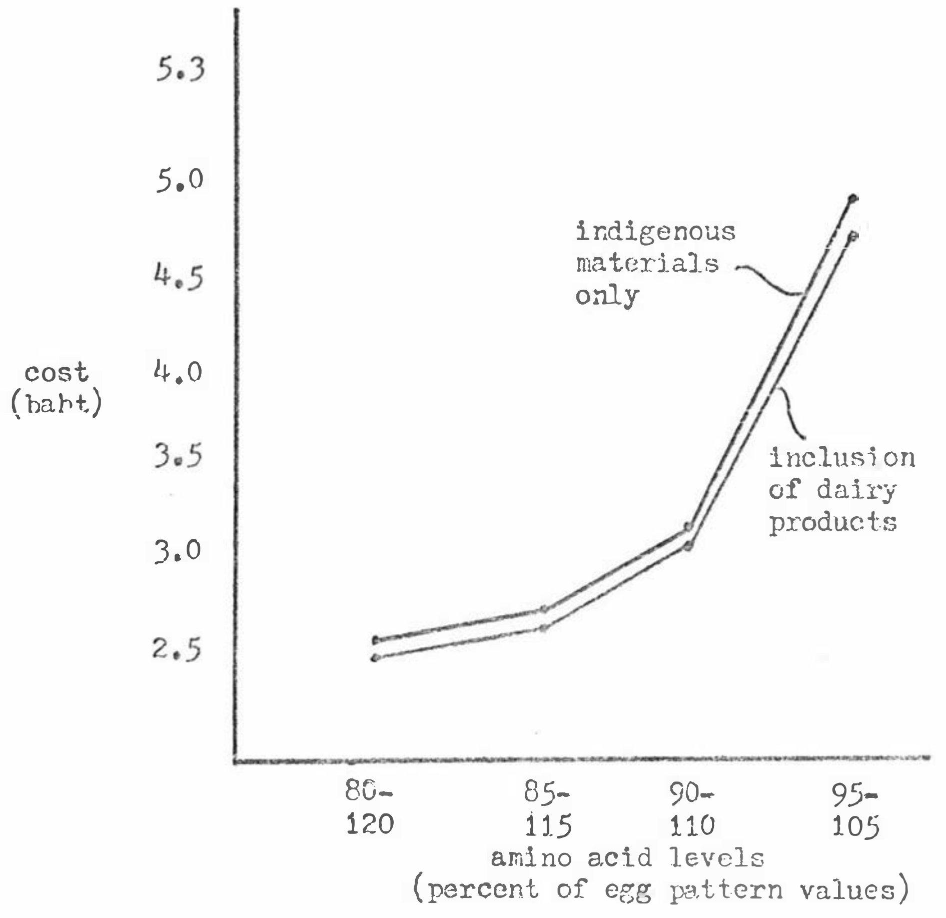

Figure 3.1 Effect of improvement in amino acid balance on cost

were the only two amino acids at the lower level of the 80-120 percent range. As the limits became tighter tyrosine and cystine joined them at the lower levels of the acceptable ranges. Leucine and tryptophan were in plentiful supply and generally at the upper limits of the specified ranges.

The weight of the selected mixture increased with improvement in the amino acid balance. This additional weight included a wider variety and a greater number of raw materials than solutions with poorer amino acid patterns. At the 80-120 percent level, there were 10 materials in the solution while at the 95-105 percent levels, there were 14 materials. The greater number of raw materials in a solution would provide obvious problems in the formulation of a single food product.

3.1.3 Addition of dairy products

The 7 New Zealand dairy products were added to the list of 144 indigenous Thai food raw materials. It was still impossible to achieve a feasible solution with the amino acids exactly equalling their ideal egg pattern values. The amino acid requirements were again varied parametrically to obtain feasible solutions at the four ranges as discussed in Section 3.1.2 (see Appendix 5).

Only skim milk powder was selected from the dairy products at levels ranging from around 2 percent of the total weight in the 80-120 percent solution to about 4 percent in the 95-105 percent solution. As would be expected, this addition to the mix did not have a marked effect on its composition. A slight drop of 0.1baht was recorded over all parametric solutions. Protein, fat, calories and pantothenic acid showed no change from the solutions using indigenous materials and were still at their lower limits. Folic acid ceased to be limiting at the 90-110 and 95-105 percent solutions. The trend of increased calcium with improved amino acid balance was again evident. Absolute levels of calcium were generally higher than in the indigenous raw material solutions with the difference becoming more marked with improved amino acid balance. This may be due to the increased levels of skim milk powder. Slight differences were also evident in vitamin levels. Niacin was generally at lower levels in all solutions using dairy products, while riboflavin and thiamine were slightly higher. Vitamin A showed a more marked difference and was at levels of 1000-2000iu lower in the solutions containing dairy products. There was little change in the ratios of essential amino acids, with isoleucine and methionine still limiting and leucine and tryptophan adequately supplied.

The addition of dairy products had little effect on weight at the first three levels of amino acid balance, but an increase of approximately 100g was recorded in the 95-105 percent solution.

The addition of dairy products to the list of available raw materials resulted in very little change in the solutions. It would be wrong, however, to conclude from the results of this study that dairy products are not suitable as nutritional supplements. The selection of only small amounts of these products does not indicate a relatively low overall nutritional value as compared with indigenous materials, but rather an inability to compete with these materials for the supply of limiting nutrients.

3.2 The application of goal programming

Goal programming is a modification and extension of linear programming. The goal programming approach allows for a simultaneous solution of a system of complex objectives rather than a single objective. Charnes and Cooper, who played a key role in introducing linear programming to industrial problems, first developed the concept of goal programming in 1961 (27).

The technique is a relatively new one and applications are scarce. Lee (106) reviewed the history of goal programming and applications to various functional areas including academic planning, financial planning, economic planning and hospital administration. No previous studies on the application to the solution of nutrition problems were found.

Linear programming solutions to nutrition problems often result in a gross imbalance of nutrients in selected mixes. This is particularly obvious in situations where only lower limits are imposed. For example, improvement of the amino acid balance as discussed in Section 3.1 resulted in marked increases in the levels of vitamin A, vitamin C and iron, far in excess of their lower levels of requirement. The 95-105 percent egg pattern solution using indigenous raw materials shows these high levels of certain nutrients.

Nutrient	Required level	Solution level
Vitamin A	2100	10,840
Vitamin C	28	229
Iron	8.7	22.7

Although considerable work has been done in the area of minimum satisfactory intakes of specific nutrients, little is known about the effects of many of these nutrients in excess. Hypervitaminosis D and excessive calcium intake have been associated with kidney stone formation (49), while high levels of vitamin A may cause serious injury to health with symptoms including loss of hair, pain in long bones and dry skin (123). One FAO/WHO expert group on nutrition has shown concern about the ill effects of nutrient overdoses in recommending further research on the effects of high and low levels of vitamins. Another FAO/WHO committee (45) suggested that the relatively newly developed research field of nutritional toxicology be adequately supported by government institutions, industries and international groups. As well as the effects of overdoses of individual nutrients, concern has been expressed about the interrelationship of nutrients and the need for a balanced intake. Pike and Brown (150) give examples of the relationship of protein and energy, niacin and tryptophan, and calcium and magnesium. They emphasize the change in the concept of the independent and relatively isolated nutrient function to the concept of interdependent and interrelated function and requirement.

> "If the metabolic machinery of the cell is visualized as a delicately balanced section of a large mobile, minor stress of one point might be compensated for at one or several other points, thus establishing a new balance: but a sustained and cumulative stress would be so disruptive that compensatory effects would be ineffective."

There is then, a need for diets to contain nutrients which are not only above their recommended levels of requirement but also well balanced. Goal programming, in its role as a modification of linear programming, was used to achieve a good balance of nutrients in selected combinations of raw materials. The technique was first applied to the problem of obtaining an ideal essential amino acid pattern and secondly to the achievement of a good balance of all 26 nutrients.

3.2.1 An example of goal programming

A simple example is used to show how goal programming can be applied as an extension of linear programming. For definitions of the basic linear programming terminology, reference should be made to standard texts on the subject (61, 62).

Consider the following problem:

$$\begin{aligned} &\text{Minimize} && x_1 + x_2 \\ &\text{subject to} && 2x_1 + 5x_2 \geq 10 \\ & && 3x_1 + x_2 \leq 6 \\ &\text{and} && x_1, x_2 \geq 0 \end{aligned}$$

The graphical representation of the problem and the feasible region for solution is shown in Figure 3.2.

As it stands, the problem could be solved by standard linear programming methods. But what if minimization of $(x_1 + x_2)$ ceases to be a priority and it becomes not only important to meet the two constraints, but also to ensure that the constraint values are exceeded by as little as possible? There are then two goals to aim for, subject to two constraints. A further goal is added to the problem to make it more realistic and to enable a discussion of all the situations which arose in the application of goal programming to the nutrition problem. The third goal is defined by the equation $4x_1 + 3x_2 = 12$. The overall objective is to minimize the total deviation from the three goals, subject to the two original constraints.

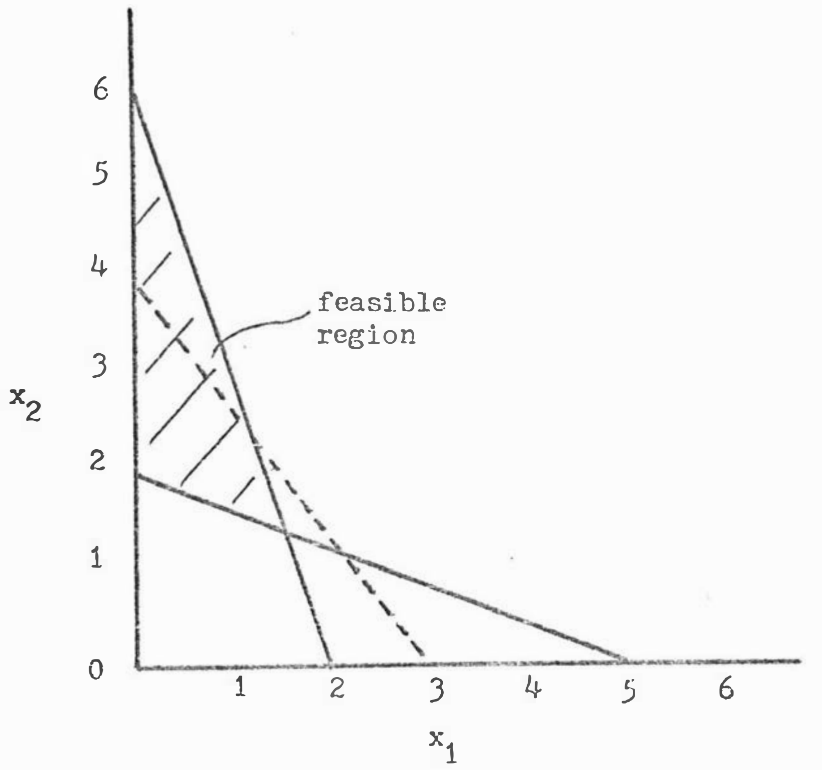

Figure 3.2 Graphical representation of an L.P. problem

Minimize $(|2x_1 + 5x_2 - 10| + |3x_1 + x_2 - 6| + |4x_1 + 3x_2 - 12|)$

subject to $2x_1 + 5x_2 \geq 10$

$3x_1 + x_2 \leq 6$

and $x_1 , x_2 \geq 0$

The problem now needs to be solved using goal programming, where the goals are defined as:

$$|2x_1 + 5x_2 - 10| = y_1$$

$$|3x_1 + x_2 - 6| = y_2$$

$$|4x_1 + 3x_2 - 12| = y_3^+ + y_3^-$$

where y_1, y_2, y_3^+ and y_3^- are slack variables. In the case of the first two goals, only one slack variable is required, whereas for the third goal two slack variables are needed to allow for both positive and negative deviations. The problem then becomes:

$$\text{Minimize} \quad y_1 + y_2 + y_3^+ + y_3^-$$

$$\begin{aligned} \text{subject to} \quad & 2x_1 + 5x_2 - y_1 = 10 \\ & 3x_1 + x_2 + y_2 = 6 \\ & 4x_1 + 3x_2 - y_3 + y_3^- = 12 \end{aligned}$$

$$\text{and} \quad x_1,\ x_2,\ y_1,\ y_2,\ y_3^+,\ y_3^- \geq 0$$

A solution can be obtained using conventional linear programming. The vectors associated with y_3^+ and y_3^- are linear dependent and as such only one will occur in a solution basis. The objective function will then serve to minimize the sum of y_1, y_2 and either y_3^+ or y_3^-.

This simple example demonstrates the use of goal programming in only one area and does not examine the great number of possible variations in application of the technique. Goal programming, as mentioned earlier, lends itself to the partial solution of problems infeasible to linear programming. It also allows for the weighting of individual goals according to relative levels of importance, permits the occurrence of non homogeneous units in an objective function and in more complex examples can even be used for the solution of problems requiring the establishment of a hierarchy of importance among incompatible goals. The example should, however, suffice as an introduction to the concepts of goal programming as it is used in this study.

3.3 Goal programming on the amino acids

One of the major aims of the nutrition problem was to obtain an essential amino acid pattern as close to that of egg protein as possible. This was done using goal programming where the objective was to minimize the deviation of solution levels for each amino acid from its corresponding egg pattern value.

$$\text{TOTDEV} = \sum_{i=1}^{10} D_i$$

where TOTDEV is the total deviation of the 10 amino acids from their egg pattern values and D_i is the deviation of the ith amino acid. For example:

$$D_1 = \text{ISO} - 415\text{PROT}$$

where D_1 is the difference between the actual level of isoleucine in the solution and the amount required to meet the egg pattern value of 415mg/gN.

The values of D_i were either positive or negative, which led to the possibility of cancelling of large differences with the total deviation still being small. It was therefore necessary to consider the differences as absolute values:

$$\text{TOTDEV} = \sum_{i=1}^{10} |D_i|$$

The use of absolute differences required the assignment of two slack variables to each constraint and reliance on the principle of selection of only linear independent variables in a solution basis, as discussed earlier.

$$\sum_{j=1}^{n} a_{ij}x_j - y_i^+ + y_i^- = b_i \qquad i = 1,2,....10$$

where a_{ij} is the amount of amino acid i per unit of raw material j.

x_j is the level of raw material j in the solution.

y_i^+ and y_i^- are the slack variables.

b_i is the required level of amino acid i.

For example in the case of isoleucine:

$$\text{ISO} - y_i^+ + y_1^- = 415\text{PROT}$$

$$\text{then } 415\text{PROT} - \text{ISO} + y_1^+ - y_1^- = 0$$

For input to the LPS/1130 programme, the slack variables were defined as GISO and FISO respectively. The isoleucine equation was then recorded as:

AA1 = 415PROT - ISO + GISO - FISO

where AA1 = 0

Cards for computer input were prepared as follows:

	PROT	AA1	415.0
	ISO	AA1	-1.0
	FISO	AA1	-1.0
	GISO	AA1	1.0
FX	THAIREQ	AA1	0.0

where AA1 is fixed at 0.0 in the bound set THAIREQ. Similar equations were required for the remaining 9 amino acids, and cards prepared for computer input as described above.

For solution of the goal programming problem, all data and constraints were as described in Figure 2.1, with the total deviation variable replacing cost in the objective function.

TOTDEV = FISO + GISO + FLEU + GLEU + ... + FVAL + GVAL

where the objective was to minimize TOTDEV. This objective served to minimize the deviation from the egg pattern but it did not account for the difference in magnitudes of the egg pattern values, ranging from 100mg/gN for tryptophan to 553mg/gN for leucine. The percentage deviation was considered more relevant in this case.

$$\text{Percent deviation } \underline{i} = \frac{D_i \times 100}{EP_i}$$

where D_i is the deviation if amino acid $\underline{i}$ from its egg pattern value and EP_i is the egg pattern value for amino acid $\underline{i}$.

The fraction $100/EP_i$ was used as a weighting factor for each deviation in the calculation of the TOTDEV variable of the objective function.

TOTDEV = 0.241FISO + 0.241GISO + 0.181FLEU + 0.181GLEU + ... + 0.221FVAL + 0.221GVAL

with the objective to minimize TOTDEV. The card input for this objective function is shown in Figure 3.3 indicating the percentage weightings for each amino acid deviation.

FISO	TOTDEV	0.241
GISO	TOTDEV	0.241
FLEU	TOTDEV	0.181
GLEU	TOTDEV	0.181
FLYS	TOTDEV	0.248
GLYS	TOTDEV	0.248
FPHE	TOTDEV	0.274
GPHE	TOTDEV	0.274
FTYR	TOTDEV	0.382
GTYR	TOTDEV	0.382
FCYS	TOTDEV	0.671
GCYS	TOTDEV	0.671
FMETH	TOTDEV	0.508
GMETH	TOTDEV	0.508
FTHREO	TOTDEV	0.315
GTHREO	TOTDEV	0.315
FTRYP	TOTDEV	1.000
GTRYP	TOTDEV	1.000
FVAL	TOTDEV	0.220
GVAL	TOTDEV	0.220
MINIMIZE	TOTDEV	

Figure 3.3 Card input for objective function of goal programme on amino acids

3.3.1 The solution using indigenous raw materials

The solution to the goal programming on the essential amino acids using indigenous food raw materials only is shown in Appendix 5. The total deviation of amino acids from the egg pattern was 6.2 percent as compared to about 46 percent in the final parametric solution (see Section 3.1.3). This total percentage deviation was accounted for entirely by a deficit of isoleucine, with all other amino acids at exactly their egg pattern values.

Protein, fat, calories, folic acid and pantothenic acid were at their lower limits of requirements. Vitamin C, vitamin A and iron levels showed a marked increase with the improvement in amino acid balance. Calcium continued to rise from its levels in the parametric solutions to the upper limit of 1500mg. Fibre was also at its upper level of 15g. The weight of the final mix also increased markedly to give a required level of intake of 1560g per day. Improvement in the amino acid balance continued to require a greater number of raw materials, sixteen in all, with a wide range of functional and organoleptic properties;

sugar	313.8g	Chinese cabbage	58.4g
hen's egg	243.8g	tangerine	50.1g
celery	234.2g	buffalo liver	46.6g
guava	138.0g	white sweet potato	39.8g
lime	108.3g	lemon	36.0g
red pepper	105.9g	peanut	5.8g
peach	88.1g	coconut	5.5g
leek	84.5g	sesame	1.7g

Although maybe not impossible, it would be extremely difficult to combine these materials into a single product or food dish. The high quantity of sugar, the mixing of fruits and vegetables and the use of high levels of ingredients uncommon in food dishes, such as lime and guava, would present problems in the formulation of an acceptable product.

The cost of this optimum balance of amino acids was 12.4baht or over twice that of the 95-105 percent parametric solution. This emphasizes the importance of setting sensible limits on amino acid requirements. Whenever possible, the value to the consumer's health in improving the amino acid balance of a diet should be weighed against the cost of achieving this improvement. For example, the cost of changing the amino acid balance from 80-120 percent to 95-105 percent that of egg protein, resulted in an almost twofold increase in cost. This cost may not be justifiable in terms of the improved health of the consumer.

3.3.2 The addition of dairy products

The addition of dairy products to the list of available raw materials resulted in a slight improvement of the amino acid pattern to give a total deviation of 5.78 percent (see Appendix 5). The only dairy product selected was butter, at a level of less than 0.1 percent. Once again the entire deviation from the ideal egg pattern was due to a deficit in isoleucine. Protein, fat, calories, pantothenic acid and folic acid were again at their lower limits, while fibre and calcium were at their upper limits. Vitamin C and vitamin A levels showed a further rise with the improvement in amino acid balance.

In this example, cost minimization was no longer the prime objective and hence there is no reason to attribute the low levels of dairy products to their high prices. The high levels of calcium in dairy products and the upper limit on this nutrient could be one reason for their rejection. A more likely reason, however, is simply the inability of these products to supply amino acids in proportions which would complement their supply from other sources, to achieve a pattern as close to that of egg pattern as possible.

As in the parametric solutions, there is no reason to discount dairy products as nutritious foods on the basis of their performances in this study. Their selection was determined not on the basis of their absolute nutrient value but rather on their ability to complement the supply of amino acids from other raw materials subject to the constraints imposed on this particular programme.

3.4 Goal programming on all nutrients

Goal programming was used to 'optimize' the balance of all 26 nutrients in the problem. The word optimize is used with some caution here as a mathematical objective only. Optimization implies only the achievement of the best possible balance of nutrients, subject to the levels of requirements defined in the programme. In this study, the objective of the goal programme was to minimize the total deviation of all nutrients from their lower levels of requirement, subject to these requirements being met and the amino acid pattern being between 90 and 110 percent that of egg protein. The constraints on all nutrients other than amino acids and protein were those described in Figure 2.1. The amino acids were within the 90-110 percent egg pattern range, while the lower limit for protein was set at 8.4gN/day, the lowest level which could be achieved with a constraint of 2100kcals and a required protein contribution to total calories of 13 percent. The problem was then:

$$\text{Minimize} \quad \sum_{i=1}^{16} y_i + \sum_{i=17}^{26} (y_i^+ + y_i^-)$$

$$\text{subject to} \quad \sum_{j=1}^{n} a_{ij} x_j + y_i = b_i \qquad i = 1,2,\ldots 16 \qquad (1)$$

$$\text{and} \quad \sum_{j=1}^{n} a_{ij} x_j - y_i^+ + y_i^- = b_i \qquad i = 17,18,\ldots 26 \qquad (2)$$

where equation set (1) represents the equations formed for all non-amino acid constraints by the addition of slack variables. Equation set (2) represents the equation formed for the amino acid constraints by addition of slack variables.

$\underline{n}$ is the number of food raw materials.

a_{ij} is the number of units of nutrient $\underline{i}$ in raw material $\underline{j}$.

b_i is the specified number of units of nutrient $\underline{i}$ required.

x_j is the number of units of raw material $\underline{j}$ in the solution.

y_i, y_i^+, and y_i^- are slack variables.

Two types of goals were used as represented by equation sets (1) and (2). The first sought to reduce the total deviation above the minimum requirement levels of sixteen nutrients and needed only one slack variable. The second set applied to the amino acids where deviations above or below the 100 percent egg pattern values were permitted, hence requiring two slack variables as discussed in Section 3.2.1.

As in the goal programming on amino acids, some consideration was needed of the wide variation in the magnitude of individual goals, ranging from 0.00185mg for vitamin B12 to 2100iu for vitamin A. Deviations were again calculated on a percentage basis, with the objective of minimizing the total percentage deviation.

$$\text{percent deviation} = \frac{100 y_i}{b_i}$$

$$\text{Minimize} \quad \sum_{i=1}^{16} \frac{100y_i}{b_i} + \sum_{i=17}^{26} \frac{(y_i^+ + y_i^-)x100}{b_i}$$

3.4.1 The solution using indigenous raw materials

The total percentage deviation from the 26 nutrient goals was 453 percent, at a cost of 8.3baht. Over half this total deviation came from vitamin C and iron, both at levels in excess of twice their requirements. Other nutrients showed smaller deviations and eleven were at exactly their requirement levels (see Table 3.1). Isoleucine and methionine were again the limiting amino acids at 90 percent egg pattern values.

The weight of the selected mix was not far in excess of the weights for the parametric solutions and showed a considerable drop from that of the goal programme on amino acids. Although there was still a large number of raw materials in the solution, fifteen in all, a far more acceptable selection was evident (see Appendix 5).

A comparison between the levels of certain nutrients in the 90-110 percent parametric solution, the goal programming solution to essential amino acid improvement and the goal programming solution to balancing all 26 nutrients, emphasizes the value of the goal programming approach.

Nutrient	Requirement level	90-110 percent parametric	Goal programme amino acid	Goal programme 26 nutrients
Vitamin C(mg)	28	282	464	68
Vitamin A(iu)	2100	10603	38755	2100
Iron(mg)	8.7	21.5	68.0	18.9
Fibre(g)	6.0	9.7	15.0	7.1
Cost (baht)		3.26	12.40	8.28

Table 3.1 Percent deviation of nutrients from goal programme on indigenous raw materials.

Nutrient	Required[a] amount in mix	Actual amount in mix	Percent deviation
Protein (gN)	8.40	8.40	0.0
Fat (g)	46.67	46.67	0.0
Calories	2100	2100	0.0
Fibre (g)	6.0	7.1	18.3
Calcium (mg)	585	733	25.3
Phosphorus (mg)	585	916	56.6
Iron (mg)	8.70	18.92	117.5
Vitamin B6 (mg)	1.65	1.65	0.0
Vitamin B12 (mg)	0.00185	0.00185	0.0
Folic acid (μg)	175	175	0.0
Pantothenic Acid (mg)	6.8	6.8	0.0
Niacin (mg)	13.9	13.9	0.0
Riboflavin (mg)	1.16	1.16	0.0
Thiamine (mg)	0.84	1.07	27.4
Vitamin C (mg)	28.0	68.1	143.2
Vitamin A (iu)	2100	2100	0.0
Cystine[b]	100.0	100.0	0.0
Valine	100.0	109.9	9.9
Isoleucine	100.0	90.0	10.0
Phenylalanine	100.0	96.5	3.5
Tyrosine	100.0	104.2	4.2
Methionine	100.0	90.0	10.0
Tryptophan	100.0	106.2	6.2
Threonine	100.0	100.7	0.7
Lysine	100.0	110.0	10.0
Leucine	100.0	110.0	10.0
	Total percentage deviation		452.9

a. Calculated as the minimum level of requirement for all nutrients except amino acids.
b. Amino acid levels presented as a percentage of the corresponding egg pattern values.

Table 3.2 Percent deviation of nutrients from goal programme using all raw materials[a].

Nutrient	Required amount in mix	Actual amount in mix	Percent deviation
Protein (gN)	8.40	8.40	0.0
Fat (g)	46.67	46.67	0.0
Calories	2100	2100	0.0
Fibre (g)	6.0	6.0	0.0
Calcium (mg)	585	802	37.1
Phosphorus (mg)	585	1002	71.3
Iron (mg)	8.70	13.2	51.7
Vitamin B6 (mg)	1.65	1.65	0.0
Vitamin B12 (mg)	0.00185	0.00185	0.0
Folic acid (μg)	175	175	0.0
Pantothenic acid (mg)	6.8	6.8	0.0
Niacin (mg)	13.9	13.9	0.0
Riboflavin (mg)	1.16	1.16	0.0
Thiamine (mg)	0.84	0.89	6.0
Vitamin C (mg)	28.0	69.3	147.5
Vitamin A (iu)	2100	2100	0.0
Cystine[c]	100.0	100.0	0.0
Valine	100.0	101.1	1.1
Isoleucine	100.0	90.0	10.0
Phenylalanine	100.0	100.0	0.0
Tyrosine	100.0	106.9	6.9
Methionine	100.0	90.0	10.0
Tryptophan	100.0	102.3	2.3
Threonine	100.0	92.0	8.0
Lysine	100.0	110.0	10.0
Leucine	100.0	110.0	10.0
	Total percentage deviation		371.9

a. Dairy products and indigenous Thai raw materials
b. Calculated as the minimum level of requirement for all nutrients except amino acids
c. Amino acid levels presented as a percentage of the corresponding egg pattern values.

The improvement of the overall nutritional balance was expensive. The cost of the solution to the goal programme on all 26 nutrients with amino acid levels at 90-110 percent those of egg protein, was over twice that of the equivalent 90-110 percent parametric solution. Once again, however, the high cost of improvement of the amino acid balance is shown. In the goal programming solution to the amino acid problem, a deviation from the egg pattern of 6.2 percent was obtained at a cost of 12.4baht as compared with a deviation of 64.8 percent at a cost of 8.3baht in the solution balancing all 26 nutrients. The total deviation from the target levels for all nutrients in the amino acid solution was over 5000 percent as compared with only 453 percent in the total goal programming solution. Hence, when achievement of nutritional balance is a priority, amino acids are very expensive nutrients.

3.4.2 The addition of dairy products

The addition of dairy products to the list of available raw materials in the goal programme for all nutrients, produced a total deviation of 372 percent, an improvement of 81 percent on the solution using only indigenous raw materials. The greatest part of this improvement was due to a decrease in the iron, fibre and thiamine levels (see Tables 3.1 and 3.2). Slight increases in the levels of calcium and phosphorus were recorded. Isoleucine and methionine were again limiting and the total deviation from egg pattern was 58.3 percent (see Table 3.2).

Improvement in the nutritional balance was accompanied by a decrease in weight, although a greater number of raw materials was included in the selected mix. Approximately 25 percent of this mix was dairy products, mostly sterilized whole milk.

Dairy product	Percent in mix
Sterilized whole milk	24.79
Skim milk powder	C.55
Lactalbumin	0.04

The cost of this improved mix was 9.7baht or 1.4baht more than the solution using only indigenous raw materials. The weight of the mix was, however, 324g less than the indigenous solution and was roughly equivalent to the weight of the 90-110 percent parametric solution.

The addition of dairy products helped to provide a more balanced diet. Their supply of an even balance of nutrients resulted in not only nutritional improvement, as defined by this problem, but also a selected mix with a weight much less than equivalent solutions using only indigenous materials. It should be stated once again, however, that the results from this study can only be used to draw conclusions about the contributions of individual raw materials within the context of this particular problem and as such, it would be unwise to make sweeping statements about the general value of dairy products from these results.

3.5 Summary and conclusions

Two basic approaches were used to the solution of the nutrition problem. Linear programming was applied to the problem with the object of cost minimization and improvement in the essential amino acid balance. Goal programming was presented as an extension to linear programming and used to 'optimize' the balance of firstly the amino acids and secondly all 26 nutrients in the problem. Both techniques are very complex and the inter-relationships of variables does not allow for a rigorous discussion of the results. Some conclusions from the solutions obtained are presented below. Again it should be emphasized that extreme caution should be exercized in the extension of these conclusions beyond the realm of these problems and their associated data and constraints.

1. Improvement in the nutritional value of a selected mix generally resulted in an increase in cost. This was particularly obvious for amino acids, where gradual improvement in the balance towards that of egg pattern resulted in a rapid increase in cost, a finding supported by Edwardson's work (41). Where cost minimization is an important criterion, the need for improvement in the amino acid pattern should always be weighed against the

cost of that improvement.

2. Protein, calories, vitamin B12, vitamin B6, folic acid and pantothenic acid were generally at their lower bounds in all solutions where cost minimization was an objective. They could, therefore, be considered expensive nutrients and a decrease in their requirement levels may result in a significant decrease in the cost of the solution.

3. Calcium and phosphorus levels tended to increase with improvement in the amino acid balance, as did vitamin A. At solutions nearing the egg pattern, vitamin A was present at nearly forty times its specified requirement.

4. Isoleucine and methionine were generally limiting. Even where cost was ignored and 'optimization' of the amino acid balance was a priority, it was impossible to bring the isoleucine level up to its corresponding egg pattern value.

5. An improvement in the nutritional value of a solution generally resulted in an increase in weight, a larger number and a greater variety of raw materials. These mixes were generally considered to have less acceptable functional and organoleptic properties.

6. Where cost minimization was an objective, dairy products usually proved too expensive as a source of nutrients when in competition with the less costly indigenous materials. Even where the objective was to improve the amino acid pattern, only small amounts of dairy products were selected, indicating an inability to complement other materials to achieve an amino acid pattern as close to egg protein as possible. Dairy products were shown to have great value in the achievement of a balanced nutritional diet. Here they supplied nutrients in proportions close to those required for 'optimum' balance as well as complementing other raw materials.

7. Both linear and goal programming have something to offer in the solution of the nutrition problem. Where optimization of some single variable, for example cost, is required, linear programming would be used. Generally, solutions obtained in this way would not contain balance of nutrients unless very strict upper and lower constraints are set, in which case solution infeasibilities are likely. If the balancing of all the nutrients, or some subset of them, is a priority, then goal programming would

prove useful. In this case cost may cease to be part of the objective function, but its relationship to nutrient balance could be obtained by setting an upper limit on cost and varying this using the parametric technique. Some optimum combination of cost and nutrient balance might then be chosen.

Linear programming was used to solve the nutrition problem, but in doing so, no regard was paid to the raw materials selected. Many solutions presented raw materials which would not be directly acceptable in combination. Acceptability may be achieved through extensive processing to transform the raw material properties. It was considered more reasonable to provide a basis for raw material selection, which would ensure acceptability with minimum processing. The remainder of this thesis considers this problem with the objective of adding cultural and organoleptic constraints to the existing nutrition problem and therefore to obtain nutritionally adequate raw material mixes which would be acceptable to the Thai consumer.

CHAPTER 4

FOOD CHARACTERISTICS AND CONSUMER ACCEPTABILITY

The aim of this thesis was to develop a quantitative model based on linear programming for the selection of food raw materials which in combination would form a nutritious and acceptable food product. The research was therefore divided into two stages. The first stage, that of inclusion of nutritional constraints in the linear programming model, has already been discussed. The objective of the second stage was to incorporate into the linear programming model a system for selection of raw materials which when combined together in a processed food product would be acceptable to the Thai consumer.

In Thailand only a small part of the population consumes commercially processed food products. Such processed products rarely form part of meals either at home or in the restaurant. Usually, food dishes are prepared directly from the raw materials with only a short cooking period so that the final dish retains much of the characteristics of the raw materials. Meal times are social occasions and involve the sharing of a number of small dishes. Any number of dishes may be served at one meal depending on the number of people present, the occasion, the wealth of the consumer and the time of day. It was therefore considered more relevant to the Thai situation to make the aim of the second stage of the research the development of nutritionally adequate food dishes. These food dishes would fit in with existing meal patterns with the least resistance.

A method was therefore required to supply data on the relative acceptance of various food dishes by Thai consumers and to relate this acceptance to the raw materials in the dishes. This data was needed in a form which could be used directly in the linear programming model to select combinations of raw materials which would be acceptable in a food dish. The literature was reviewed to find methods which might be used to obtain this data. The following areas were examined:

1. What is consumer acceptance?

2. The classification of sensory properties - taste, odour, appearance and texture.

3. The measurement of sensory properties of foods.

4. The measurement of consumer acceptance of foods.

A number of problems became evident from the literature review. There was a lack of adequate classification schemes for sensory properties and quantitative measures of these properties were difficult to obtain. Little work was reported on the interaction of sensory properties. Probably the most critical problem was the inability of conventional techniques to precisely define which sensory properties of raw materials are important to the consumer in his acceptance of a food product. This problem was largely due to the multiple relationships existing among the properties of the raw materials. A technique was therefore required to untangle these interrelationships and to define the dominant properties of the raw materials as they influence the acceptance of food dishes. A number of multivariate techniques were studied to estimate their potential to untangle the interaction of the raw material properties and to supply data in a reasonable form for the linear programming model, that is a linear function relating raw material properties and food dish acceptance. Nonmetric multidimensional scaling showed the greatest potential and a more extensive study of the theory and applications of this technique was made to ascertain its value to the second stage of the research.

4.1 What is consumer acceptance?

Consumer acceptance of food is the approval of and willingness to buy and eat that food. This definition may be extended to include degrees of acceptance, which may be thought of as degrees of liking or approval.

Interest in the reasons for acceptance or rejection of a food product generally leads the student to a study of consumer behaviour analysis. The aim of consumer behaviour analysis is to explain consumer behaviour. If a consumer decides to act in a certain way, what are the reasons behind his decision? Consumer behaviour analysis attempts to explain the 'why' of consumer behaviour and to answer such questions as "why are sales sensitive to advertizing?", "why is a product price elastic?", or "why is one product acceptable and another not?". Consumer behaviour analysis seeks to reveal the intellectual and emotional processes that underlie a purchase decision. Wentz (218) listed four uses of behavioural analysis:

1. To discover the pattern of purchase process, that is, to investigate the sequence of events leading to the eventual acceptance or rejection of a product.
2. To study psychogenic drives that may play a significant role in the behavioural process associated with a particular brand or product.
3. To search out attitudes that encourage or prevent the purchase of particular products or brands, or that encourage or prevent the acceptance of particular promotional messages.
4. To look for consumer needs that are not satisfied by present products.

Many interpretations of consumer behaviour have been put forward. Psychologists generally believe that consumer behaviour analysis should be based on psychogenic needs. These are learned needs that an individual acquires early in life by observation and interaction with his environment, such as the need for recognition, aggression and affiliation. These needs exist in addition to the basic human drives of hunger, thirst, pain avoidance and sex. A list of psychogenic needs was given by Hilgard and Atkinson (83). Freudian psychologists on the other hand believe that every individual has an Id, a Super Ego and an Ego. The Id is a bundle of instinctive needs of which sex is the greatest. The Super Ego is a collection of social values in conflict with the Id. The Ego is a mediating device that balances the Id and the Super Ego. Another common interpretation of consumer behaviour is based on sociology and social psychology. Here the consumer is perceived as a product of his environment, primarily his contact with other people. There are also economic models of consumer behaviour.

These theories and interpretations of consumer behaviour, although basic in concept, are difficult to apply to consumer acceptance of foods. Indeed in most cases, food is seen only as the factor which satisfies the basic drive of hunger, ignoring the possibility of choice between competing brands and product types in the consumer's selection of food. To help explain the complex nature of consumer behaviour in a more simplistic manner, a number of models have been presented in the literature (Howard (85), Nicosia (136), Wentz and Eyrich (219) and Engel et al (43)). Part of this complete model of consumer behaviour is shown in Figure 4.1.

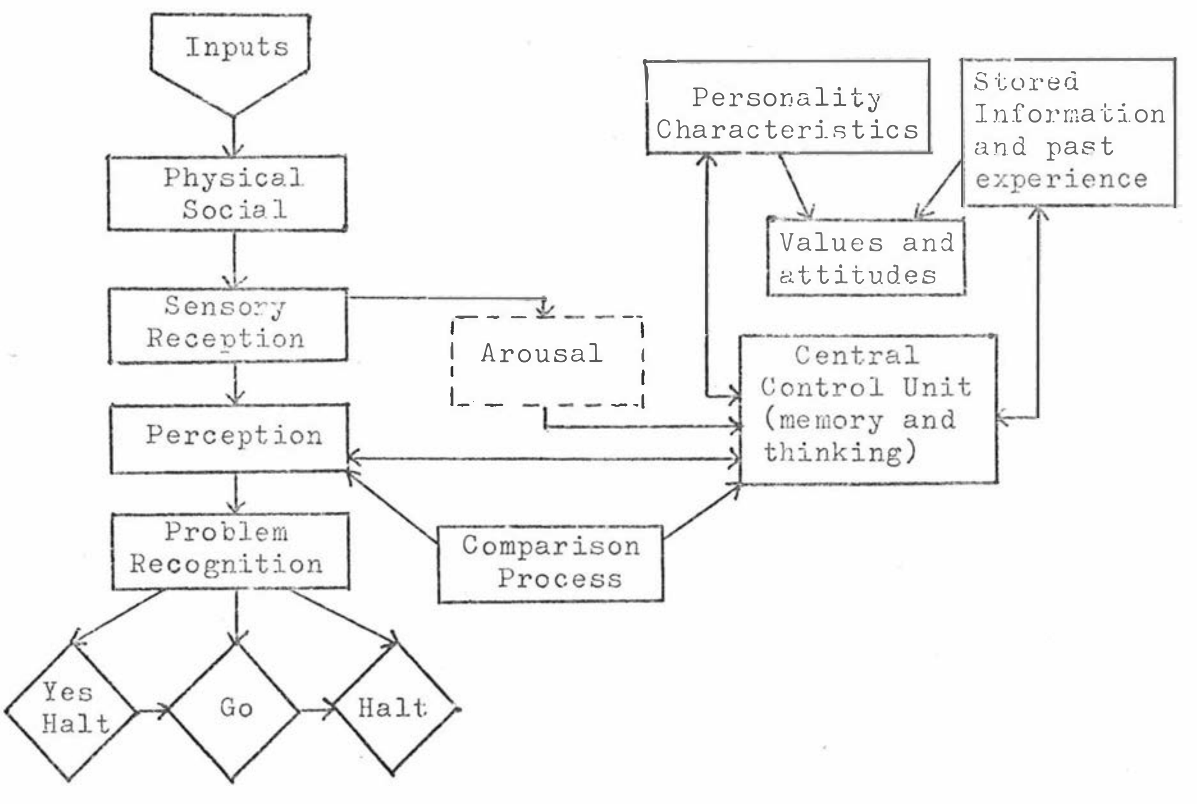

Figure 4.1 Part of a consumer behavioural model (Engel *et al* [43, p 46])

Each individual has certain ways of behaving and responding that characterize him in a unique way. These personality characteristics interact with stored information from past experience to form a set of values or attitudes which are stored in the central unit or brain. Values or attitudes stored in the central unit can be used to modify stored information and personality characteristics, and vice versa.

Everyone is continually bombarded with stimuli of all types from his environment. These stimuli or inputs are of two basic types, physical and social. One important stimulus input is the array of available products and services. Another is the demands of family members and behaviour of friends. Others are physical factors such as weather. These inputs are received by the 5 senses or sensory perceptors and can result in arousal of a need-satisfying action. Because the number of stimuli reaching the individual is so great, he cannot attend to each one on a conscious level. This implies that he perceives or 'sizes up' inputs selectively through a process of comparison, whereby inputs are compared with all that is stored in memory. If the individual is able to act (has the financial means etc.) then he is said to recognize the problem and does something about it. Otherwise the process halts at this point.

In the food marketing concept of the behavioural model, the inputs are food products with physical and social attributes which are received by the sensory perceptors. They in turn arouse the central control unit to make a comparison of the perceived sensory properties with acceptable criterion for the product, based on personality characteristics and stored information from past experience. The result of the comparison is acceptance or rejection of the product. Of immediate importance, therefore, is the result of food product-consumer interaction. Amerine et al. (1) listed the complex factors which combine to influence consumer acceptance of food.

Attributes of food product	Attribute of consumer
Availability	Regional preferences
Utility	Nationality, race
Convenience	Age and sex
Price	Religion
Uniformity, dependability	Education, socioeconomics
Stability, storage requirements	Psychological motivation
Safety, nutritional value	Physiological motivation
Sensory properties	

To simplify this problem of product-consumer interaction in the present research, the consumer attributes were considered constant and specified as being those of the Thai population. The only concern then was with the attributes of the food products and their effect on consumer acceptance. These are considered below, with reference to the proposed linear programming model for food product development.

Availability is a function of production, marketing and raw materials. The choice of raw materials in the development of a product may influence the product's availability due to the seasonality or the total production of the raw materials. Constraints can be placed on the limiting raw materials within the linear programming model.

Utility or usefulness is generally important as a function of a particular product or product class. Having defined the product, then unless the entire concept of the product is changed, its utility becomes a factor in the original choice of the product rather than the raw material input.

Convenience is also primarily a function of the product or product class chosen for development.

Price is dependent on raw materials, processing and marketing (where marketing includes physical distribution, storage and selling). In the present model, the effect of raw materials on price is dealt with in the objective of the linear programme. It is intended that compensation for the effects of the other factors be included in the model at a later date.

Stability is dependent on the raw materials, processing and storage.

Once a product or product class has been defined then normal storage conditions are also defined. Deviations from these normal storage conditions cannot be controlled easily and minimization of the effects of such deviations through choice of the best raw materials will not be considered here.

Nutritional value is a function of raw materials and processing. At present only the raw material contribution is being considered and it is intended that the effects of processing will be included at a later date.

Sensory properties are the properties of the food sensed by the consumer. It is these properties which play a major part in determining acceptance or rejection of a food product. Having specified a food product or product class, then a certain set of sensory properties should be defined for product acceptance. The properties of the product are dependent on the raw materials and processing. In this study external sensory properties, such as packaging, were ignored. Of greater concern was the effect of raw materials on the sensory properties of food products, which are in turn related to the consumer acceptance of these products.

There is some disagreement in the literature as to the relative importance of various sensory properties. Amerine et al (1) suggested that appearance probably has the greatest initial influence, since visual properties control consumer selection of a product. Foster (59) tested the importance of colour and appearance in food selection by asking women to wear tinted glasses when shopping in a supermarket. Shoppers were surprised at their selection of foods. Amerine et al (1) said that after food had been tasted, the colour and texture become secondary to flavour. Flavour is mentioned by an overwhelming proportion of consumers as the reason for overall preference and continued use of a product (Pangborn and Leonard (139), Valdes and Roessler (209)). A study by Hall and Hall (74) showed that the reason most often cited for disliking a food was that it "does not taste good". Word association tests carried out by Szczesniak and Kleyn (201) and Szczesniak (197) showed texture to be mentioned more often than flavour or colour in describing foods. These findings were supported by Yoshikawa et al (234, 235, 236).

Although lists of sensory properties, such as the one proposed by Amerine et al (1), can be made, it appears that clear definition of desirable properties may be difficult because of their interaction. The depth studies through word assocation do not necessarily agree with consumer opinion in evaluating the most important determinants of consumer acceptance or preference. It may well be that the consumer is incapable of clearly defining or separating out the attributes or properties which influence his liking for a food, because his opinion, and hence his ability to express this opinion in words is confused by the interaction of all the sensory properties, in and out of his mouth.

The basic problem in the study of the sensory properties of food is the definition and classification of these properties. A number of workers have attempted to resolve this problem and some methods of classification are outlined in the next section.

4.2 The classification of sensory properties of foods

4.2.1 Taste

Boring (13) has given a history of taste classification (see Table 4.1).

Table 4.1 A history of taste classification (Boring [13]).

Bravo (1952)	Linnaeus (1751)	Haller (1751)	Haller (1763)	Wundt (1910)
sweet	sweet	sweet	sweet	sweet
-	-	spiritous	spiritous	-
-	-	aromatic	-	-
acid	acid	acid	acid	acid
-	astringent	-	-	-
sharp	sharp	sharp	sharp	-
pungent	-	pungent	-	-
harsh	-	harsh	-	-
-	viscous	-	-	-
fatty	fatty	-	-	-
bitter	bitter	bitter	bitter	bitter
insipid	insipid	insipid	-	-
-	aqueous	-	-	-
saline	saline	saline	saline	saline
-	-	urinous	-	-
-	nauseous	putrid	-	-
-	-	-	-	alkaline
				metallic

Modern theories of taste are based on the four way classification system first shown by Henning (81) in his taste tetrahedrom (see Figure 4.2)

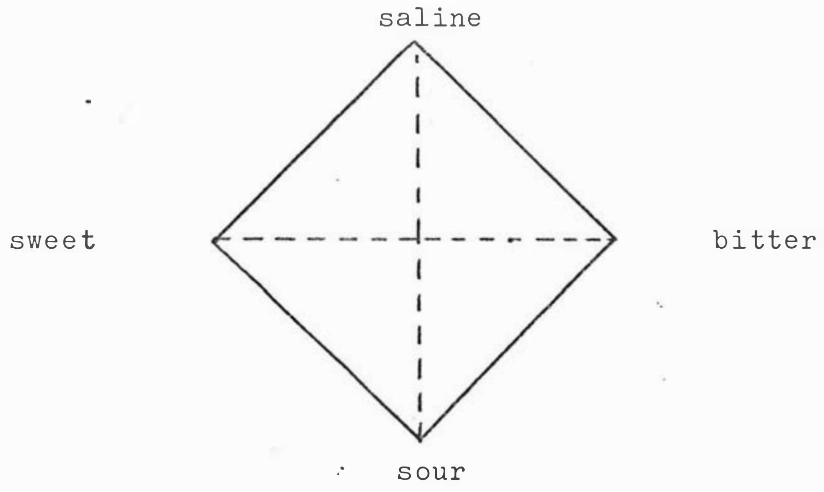

Figure 4.2 The taste tetrahedron (Henning [81])

The four basic tastes are shown at the extreme points of the tetrahedron, with intermediate qualities lying on the edges or on the surfaces.

Pfaffman (147, 148) has been responsible for most of the research into the theory of four basic tastes with his work on rats, cats and rabbits, involving the dissection of single taste nerve fibres and recording the electrical activity in response to various solutions dropped on the tongue.

Wenger et al (217) gave the following summary of data in favour of the four basic tastes:

1. Introspective evidence: the ability of normal individuals when deprived of a sense of smell to describe their gustatory sensations in terms of these four qualities.
2. Differential distribution of taste qualities on the surface of the tongue. This seems to indicate different sensory systems.
3. Differential effects of narcotics.
4. Fibres sensitive to certain tastes.
5. Interaction of tastes to change each others thresholds. A subliminal concentration of acid on one side of the tongue becomes intensely acid-tasting when the other side is coated with subliminal concentrations of sucrose.

4.2.2 Odour

Boring has given a history of odour classification (see Table 4.2).

Table 4.2 A history of odour classification (Boring [13]).

Linnaeus (1752)	Haller (1763)	Zwaardemaker (1895) Type	Zwaardemaker (1895) Example	Henning (1916) Type	Henning (1916) Example
aromatic	-	aromatic	camphor citral	spicy	clove anisaldehyde
fragrant	-	fragrant (balsamic)	vanillin	flowers fragrant	heliotrope coumarin
ambrosaic	sweet or ambrosaic	ambrosial	musk	resinous	pinene turpentine
alliaceous	-	alliaceous	onion mercaptan	-	
hircine	-	hircine	strong cheese	-	
-	-	(caprylic)	caprylic acid	-	
foul	stencher	foul (repulsive)	some night-shades bedbug	putrid (foul)	hydrogen sulphide mercaptan
nauseous	-	nauseous	faeces skatol	-	
-	inter-mediate	ethereal	fruit acetic acid amyl ether	fruit ethereal	fruit citral
-	-	empyreu-matic (burned)	phenol pyridine		

Henning (80) proposed a smell prism, showing six principle classes of odours (see Figure 4.3).

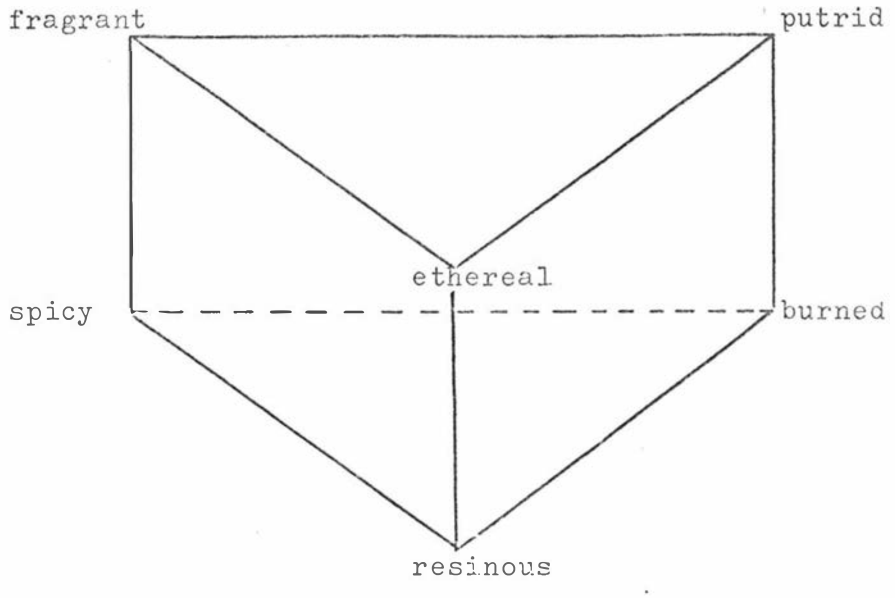

Figure 4.3 The smell prism (Henning [80])

The six basic smells are shown at the extreme points of the prism and intermediate qualities lie on the edges or the surfaces of the prism.

A four modular classification of odour, with eight degrees or intensities for each module, was proposed by Crocker and Henderson (33). A definite chemical compound was given for each intensity. Four examples of the basic types of odour and their representative chemical compounds are given below:

Basic odour	Example
fragrant	methyl salicylate
acid	20% acetic acid
burnt	guaiacol
caprylic	2,7 dimethyl octane

This system has been rejected because its reliability has not been established by intensive physiological or psychological experiments.

Wenger et al (217) concluded that there was no adequate classification of odours on the basis that we do not know how many separate odours can be perceived, how many classes or even whether there are classes or several broad bands. The problem of odour classification is still not resolved but much work is still being carried out with the emphasis on the use of factor analysis in the attempt to resolve the principle odour classes (Woskow (225), Wright (226)). The latest era in the search for odour classification was started in Japan by Yoshida (227-233) with an experimental examination of the representative theories of olfaction, for example those of Henning, Zwaardemaker and others. The results showed that none of the theories examined was satisfactory, so the classification scheme of Kainoshow (98) was applied in semantic differential scales for 25 bipolar and 20 monopolar odours, yielding factors of sensory pleasure, harshness and vividness (Yoshida (232)). Amoore (2) developed a stereo-chemical theory of olfaction. Briefly, this theory states that molecular size and shape are important determinants of the quality of an odour. There seems to be a distinct group of 'primary smells', of perhaps 20 or 30, that are the foundations of all odours known to man. These primary odours have molecular structures that exactly fit odour detectors in the olfactory region, thus producing the sensation of smell. When two or more primaries combine to stimulate several detectors at once, a blended sensation is produced. This mechanism gives rise to all non-primary smells.

Von Sydow (195) suggested that we still do not know how many different odour qualities there are or whether there are a discrete number at all. He believes that of the many odour classification systems that have been published probably none are foolproof, but suggests that one of the best is that of Harper et al (76) which is comprised of 44 basic odour descriptions such as aromatic, meaty and sickly.

The whole area of odour classification and olfactory study appears to be confused. The problems involved were well summarized by Tilgner when he said "the difficulties involved in investigations of this nature become apparent if we consider the fact that reactions arising on a psychological basis also differ and that interactions are different in different people. People are very much more than biochemical and electropsychological machines and sensory science, similar to food science, must include the study of ethnology and anthropology in addition to biochemistry, physiology and psychology" (204).

4.2.3 Appearance

Appearance may be defined as the integrated effect of all visual properties of a food including size, shape, colour, texture and conformation. Although all these factors contribute to overall appearance, the work of Foster (59) suggested that colour is the most significant.

Size and shape can be classified using conventional methods of measurement. Texture refers to the surface textural properties for example roughness, which as yet remain unclassified. The remainder of this section deals only with colour classification.

In specifying the colour of a food, we are most interested in the energy coming to the eye from the illuminated surface or, with transparent foods, through the material. The colour perceived by the eye from an illuminated object depends on the spectral composition of the light source, the nature of the background information and the spectral sensitivity of the eye viewing the object.

Kramer and Twigg (100) defined colour as "an appearance property attributable to the spectral distribution of light." Glossiness, transparency, haziness and turbidity are properties of materials attributable to the geometric manner in which the light is reflected and transmitted. Physically, colour is a characteristic of light, measurable in terms of intensity (radiant energy) and wavelength. It arises from the presence of light in greater intensities at some wavelengths than at others. Psychologically, it is further limited to the band of the spectrum from 380 to 770mμ, since the human eye is practically insensible to other wavelengths of radiant energy.

Colour can be classified by three items, lightness or value, hue and chroma. Lightness refers to the relationship of reflection to absorption with regard to specific wavelengths. If radiant energy is absorbed at certain wavelengths to a greater extent than at others then the human observer sees what is commonly termed 'colour', but what is more accurately referred to as the dominant wavelength or hue. The amount of reflection of light at a given wavelength is termed purity or strength, intensity or chroma.

When light is reflected from a surface at all angles then the surface appears dull or flat (diffuse reflectance), whereas if reflectance is directional then the surface appears glossy. Some of the physical and sensory terms used to denote different colour attributes are summarized below:

Physical measurement	Sensory term equivalent
radiant energy	light
reflectance	lightness, value
dominant wavelength	hue, colour
purity	chroma, intensity, strength
directional reflectance	gloss, sheen

The fact that a colour can be described by three numbers has been well established psychologically by Judd (97) who found that normal colour vision may be three dimensional. It therefore follows that any colour may be described by three numbers and that a spectrophotometric curve of percent reflectance against wavelength may be reduced to three numbers which adequately describe the colour of any substance. This is the basis of the standard tri-stimulus system set up by the International Commission on Illumination (CIE). The CIE system is based on a 'standard observer' which can be thought of as a stimulated eye, consisting of three primary colour filters, X, Y and Z, where X is essentially amber, Y is green and Z is blue. A spectrophotometric curve of reflectance obtained from the surface of an object can be integrated in terms of X, Y and Z, and chromaticity x and y obtained and plotted on a chromaticity diagram. The colour of a test object may thus be located in a colour space in terms of the internationally recognized colour specifications.

4.2.4 Texture

The most widely used system of texture classification is probably the one published by Szczesniak (198). This system classifies textural characteristics of food in mechanical and geometrical qualities, and into properties related to fat and moisture. Relationships to popular nomenclature are also given (see Table 4.3).

Table 4.3 A system of texture classification (Szczesniak [198]).

Primary Parameters	Secondary Parameters	Popular Terms
Mechanical Characteristics		
Hardness		Soft—〉firm—〉hard
Cohesiveness	Brittleness	Crumbly—〉crunchy—〉brittle
	Chewiness	Tender—〉chewy—〉tough
	Gumminess	Short—〉mealy—〉pasty—〉gummy
Viscosity		Thin—〉viscous
Elasticity		Plastic—〉elastic
Adhesiveness		Sticky—〉tacky—〉gooey
Geometrical Characteristics		
Particle size and shape		Gritty, grainy, coarse etc.
Particle size and orientation		Fibrous, cellular, crystalline etc.
Other Characteristics		
Moisture content		Dry—〉moist—〉wet—watery
Fat content	Oiliness	Oily
	Greasiness	Greasy

Kramer and Twigg (100) classified sensory characteristics relating to texture into two categories, finger feel and mouth feel.

Finger feel	Mouth feel
firmness	chewiness
softness or yielding quality	fibrousness
juiciness	grittiness
	mealiness
	stickiness
	oiliness

Yoshikawa et al (234-236) described a method of collection of words used to describe texture, based on work by Szczesniak and Kleyn (201) and Szczesniak (197). Forty of the most commonly used words were chosen for the development of texture profiles of number of foods. A correlation matrix was computed from the rating score matrix and multivariate analysis procedures used to yield eight orthogonal factors. They concluded that the most important dimensions of texture were: hard - soft, cold - warm, oily, juicy, elastic, flaky, heavy, viscous, smooth.

Brandt et al (15) designed a texture profile method based on the flavour profile described by Cairncross and Sjostrom (18) and using the classification system of Szczesniak and Kleyn (201) as "a logical and well defined basis on which to build a comprehensive sensory method for evaluating texture of a given food." Szczesniak and Kleyn gave a procedure for evaluating texture which is shown in Figure 4.4.

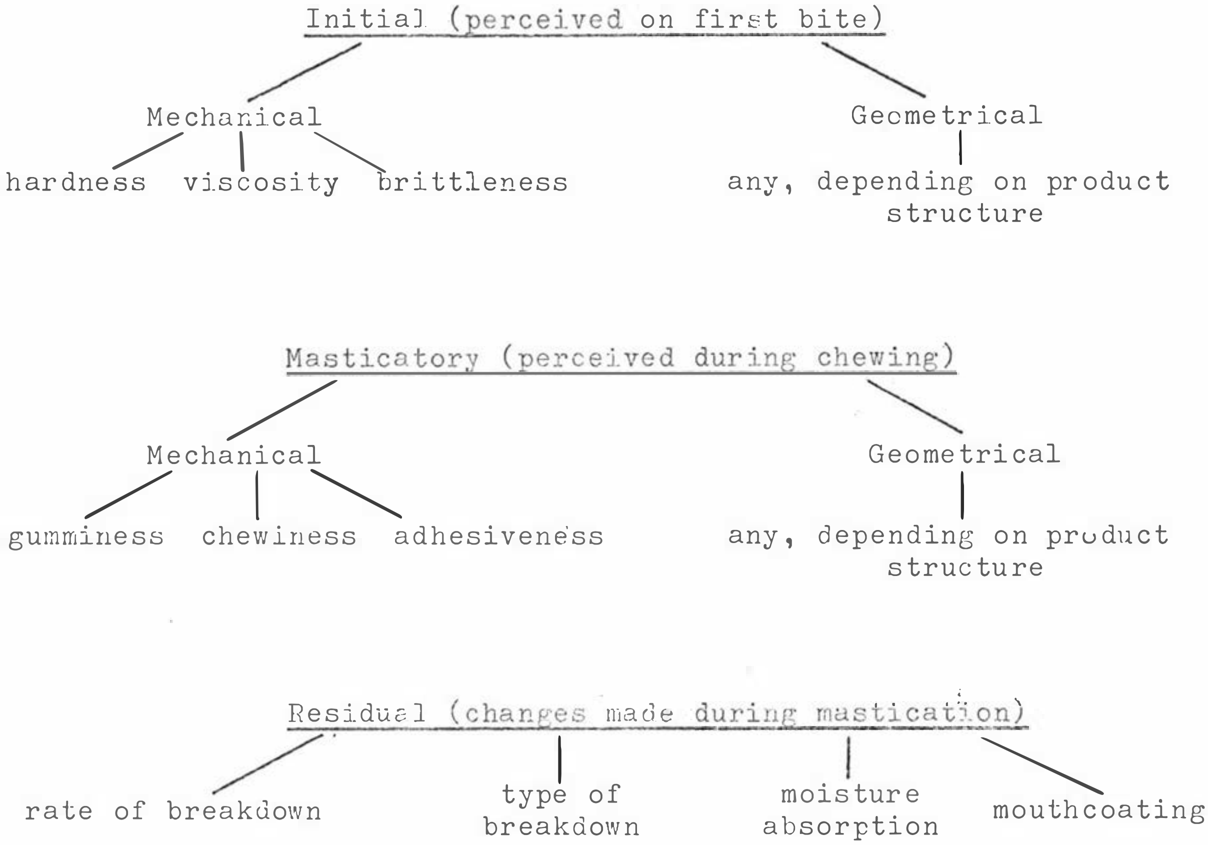

Figure 4.4 A procedure of evaluating texture (Szczesniak and Kleyn [201])

4.2.5 Temperature, pain and sound

These may be classed as minor sensory properties, both in so much as they appear to contribute little to the degree of acceptance of the average food, and little research has been done into their classifications and effects.

Temperature. Four effects of temperature are given by Amerine et al (1):

1. Its own effect, e.g. ice cream.
2. Our expectation of certain temperatures with certain foods.
3. Its effects on the volatility of odorous substances.
4. The change in sensitivity to the primary tastes with variation in temperature.

The temperature of food can be classified using the conventional scales of temperature measurement.

Pain. Pain is difficult to define. Is it strictly an unpleasant sensation? There is a wide variation in response to pain. Some people apparently derive pleasure from a certain degree of pain, as in the eating of excessively hot curries, drinking hot coffee or whisky 'straight'. A certain degree of adaption to these foods is involved, besides psychological differences in the degree of desirability of pain. Almost no work has been done on pain classification. Hardy et al (75) believed that trained observers could distinguish 21 different degrees of pain arising from radiant heat, whereas Armstrong et al (7), using a chemical excitant found 8 and possibly up to 16 levels of pain intensity.

Sound. Sound or audition as it may be referred to, appears not to have been classified. There is little doubt that certain sounds are associated with eating specific foods. For example the 'snap, crackle and pop' of rice bubbles, or the 'fizz' of champagne. Sound may also influence the acceptability of certain products, for example the snap of raw celery, the crackle of potato chips or the crispiness of lettuce. In some cases, a sound may cause rejection of a food, for example raw fish is said to be unattractive to Europeans because it 'squeaks' when chewed. In most cases, however, it would seem likely that sound or audition is largely determined by textural characteristics. Hence, adequate definition of product texture should also define to a large extent the sound characteristics of the product.

4.3 The measurement of the sensory properties of foods

4.3.1 Flavour

The concept of flavour embraces at least two phenomena, taste and aroma. When a person says a food tastes good, he actually means it has a good taste and a good aroma. Even though taste substances are important for the total flavour of a food, the aroma compounds distinguish one food from another and cause similar food items to taste so different (Von Sydow (195).

Two basic methods of flavour analysis have been used; chemical methods and descriptive sensory methods.

Chemical methods. Chemical analysis of aroma involves the following steps:

Concentration e.g. by extraction or distillation
Separation, generally by gas chromatography
Identification e.g. by mass spectrometry.

The first two steps must be nondestructive and cause no quantitative or qualitative changes, so that the results present the actual situation in and around the food. For this reason, it is desirable to carry out the complete analysis in one step. This is done using the HS-PCC-GC-MS procedure or Head Space - Pre Column Concentration - Gas Chromatography - Mass Spectrometry Procedure (Anderson and Von Sydow (4)). In this system the volatile compounds in a large head space gas sample are concentrated in a short pre-column or trap; separated by gas chromatography on a very long, open tubular column; and identified in a closed on-line system parallel to a FID standard detector.

Much work has been done on the chemical isolation and identification of flavour compounds. Work on chocolate aroma dates back to 1912 (Rohan (161)). Tilgner (204) suggested that the total number of possible flavour constituents for chocolate stood at over 200. In roast and ground coffee, 158 compounds were identified (Stoffelsna et al (193)). At the Campbell Soup Company, Camden, New Jersey, chicken flavours have been investigated since 1956. Not only are there more than 100 chicken flavour components, but flavour changes continually from the time the chicken is eviscerated, through processing, storage, cooling and serving. And so the list goes on, ever expanding with more and more new flavour compounds. Many of the same compounds occur in a variety of foods which, however, have no similarity (Tilgner (204)). For example, acetates and propionates have been found among the volatile constituents of bread, coffee, apples and milk.

As the search for more chemical compounds goes on we may tend to forget our ultimate aim - "to improve foods for humanity" (Caul (23)). Our aim should be to identify flavour components and correlate these with sensory data. Unfortunately there are very few examples of successful correlations between sensory and instrumental methods of evaluation of the flavour of foods. Two examples are tomato products and Coca Cola (Milutinovic et al (117); Young et al (241)). The problems associated with such correlations are:

1. The very large number of chemical compounds present.
2. The possibility of interactions of these compounds either chemically or through psychological stimulation of the olfactory receptors.
3. Even with modern and more sophisticated instrumentation, the inability in some cases to separate and identify extremely small quantities of flavour components, still detectable by sensory methods.
4. The fact that the chemical techniques are generally separators, whereas the taste and olfactory receptors are integrators of both aroma and taste.

Sensory methods. Pfaffman and Schalsberg (149) gave three general questions that sensory tests seek to answer. Firstly, is there a detectable difference between two food samples? Difference tests fall in this category and are closely related to psychophysics. Secondly, how well do people like the product? Two general approaches to this question are preference tests or ratings made by large consumer groups and quality ratings made by a small panel, selected and trained for evaluating the general acceptability of a class of foods. This group is closely related to psychometrics. Thirdly, what is flavour? The flavour profile falls into this group. Methods in this group are in the field of phenomenological description.

The best known method of descriptive sensory analysis is the flavour profile developed by the Arthur D. Little Co. and first described by Cairncross and Sjostrom (18). Caul (22) reviewed the profile method as well as outlining the history of descriptive analysis with applications, advantages and disadvantages of the major techniques. As the name implies, the flavour profile method is designed to give a profile of the overall flavour of a food, by describing and determining the relative magnitudes of its components. The technique involves the training of a panel, usually 4-6 people, presentation of the test product to each individual, definition of suitable odour and taste classifications and hence the description of 'character notes' (generally done through panel discussion, with reference to recognized classification systems). Each panel member is asked to grade the test product with reference to each character note, on a specified scale (usually 5 point). Classification by each individual is followed by a group discussion with one person acting as a moderator. The group attempts to reach agreement on each point under consideration. A rating for each character note is decided on, and hence the flavour profile for the product described. The flavour profile panel can be used to gather such information as perceptable aroma, taste and flavour, degree and intensity of each factor, the order in which factors are perceived, after-taste and overall impression of flavour and aroma.

The advantages and disadvantages of the profile method have been listed by Amerine et al (1). The advantages include its reproducibility and its ability to produce a breakdown of flavour and aroma contributors, even if only on a descriptive basis. Among the disadvantages are the time and expense involved in selection and training the panels, the danger in exclusive use of open discussion techniques and the difficulty in quantifying individual sensitivity to specific odours, tastes and flavours.

4.3.2 Colour and appearance

Scofield (164) listed four points which are applicable to most methods of colour measurement of foods:

1. The difficulty in relating what is normally seen to what the spectrophotometer measures.
2. The mental processes by which colour matches are made.
3. The visual spacing of standards on an empirical basis, without underlying theory.
4. The mental correction for depth.

The eye judges composite visual appearance, whereas instruments only record diffuse reflectance characteristics relative to a standard, and cannot detect colour differences when the same proportion of incident light is returned to the detector.

As discussed earlier under colour classification, three dimensions are necessary to specify colour precisely. There are basically two types of measurement techniques used to determine the colour of an object, precise methods measuring all three dimensions of colour and abridged methods which measure less than three dimensions. Examples of the precise methods are the reflectance spectrophotometer, the Munsell colour system and the Hunter colour system.

<u>The reflectance spectrophotometer</u> measures the amount of light reflected from the surface of an object at each wavelength in the visible range of approximately 380-770mμ. The instrument consists of one or more photosensitive cells which transform radiant energy into electrical energy, indicated on some form of millivoltmeter. In order to convert these data into more meaningful values, the spectrophotometric curve can be integrated by the weighted ordinate method, in terms of X, Y, and Z of the C.I.E. system and hence to chromaticity coordinates x, y, and z (Kramer and Twigg 100)).

<u>The Munsell colour system</u> is based on the use of three or four colour discs, each of which has been calibrated for hue, value and chroma. Each of these terms is expressed on a 10 point scale except for chroma which may exceed 10 in the case of strong colours. An example of the Munsell colour notation is 5G8/3. The 5G refers to the dimension of hue, which is midway between blue-green and yellow-green. The 8 refers to the value or lightness and means a light grey. The /3 refers to chroma or depth of colour, in this case rather weak. A notation of 2G3/9 would describe a green colour near to yellow-green, which is dark in value and strong in chroma. The Munsell colour system uses three or four colour discs, two of which cover the hue and chroma for the product to be examined, and the remaining one or two are grey, giving the

dimension of value. Rapid spinning of the discs blends them into one colour, which, through varying the fractions of each disc showing, can be made to match the colour of the test object. The hue, value and chroma of each disc, and the percentage of each disc showing are used to calculate the chromaticity coordinates.

The Hunter colour system consists of three separate circuits and carefully selected filters and photocells which provide approximations to the X, Y, and Z functions of the C.I.E. system. Hunter Rd (diffuse reflectance) or L (lightness) values are directly comparable with the Y of the C.I.E. system. Hunter a values are measures of redness or greenness and Hunter b values are measures of yellowness or blueness. The a values are functions of X and Y, while the b values are functions of Y and Z. Together a and b provide results equivalent to those obtained with the hue and chroma dimensions of the Munsell system. Hunter (87) gave equations for the conversion of Hunter values to C.I.E.

The abridged methods include firstly the extraction of the colour from a product by use of solvents and the measurement of the extract in a spectrophotometer in terms of percent transmittance of light at a specific wavelength. Other examples are the matching colour systems such as the use of coloured plastic blocks by the USDA in grading raw materials.

4.3.3 Texture

Measurement of texture can be divided into two categories - sensory tests and instrumental tests. Tilgner (204) considered that too many meaningless measurements of texture have been made because each branch of the food industry has tended to develop its own instrument or, more frequently, a multitude of instruments, in an attempt to measure certain properties. Szczesniak (199) divided instrumental measurements into fundamental or rheological, empirical and imitative. Mohsenin (124) used this classification and discussed instruments within each class.

Fundamental rheological tests measure the fundamental rheological properties of a material and relate the nature of the tested product to two basic rheological prototypes: a dashpot for a Newtonian liquid and a metal spring for a Hookean solid. Since most foods are complex, the final model will consist of several dashpots and springs connected in series and/or parallel. Because of their complexity and the necessity to relate the results to functional properties, the fundamental tests have only limited use. They can, however, serve to define the system and provide a more scientific basis for empirical and imitative tests. Mohsenin (124) cited examples of fundamental tests which had been correlated successfully with sensory measurement. The spreadability of butter has been shown to have a high degree of correlation with the force needed to extrude butter through an orifice at a standard rate. The 'body' of cheese can be evaluated using a constant creep test (Scott-Blair (165)).

Empirical tests measure characteristics related to the textural quality (Szczesniak (199)). Szczesniak believed that while such tests are very useful, caution must be taken in interpretation of the results. Examples of empirical tests are the penetrometer, which measures the force required to penetrate a material, or the depth of penetration after impact and shearing devices which record the force needed to shear the test material.

Imitative tests are performed under conditions simulating those to which the material is subjected in practice. Devices under this heading can be divided into two categories, those that imitate handling of food and those that imitate the properties of the food during consumption. In the first group are instruments such as butter spreaders, alveographs, amylographs and farinographs which measure the handling properties of flours, doughs and similar farinaceous materials. In the second group are instruments which attempt to imitate the chewing action of teeth. The first such instrument was described by Volodkevich (213). The MIT Denture Tenderometer and the G.F. Texturometer are refined versions of this general principle (Procter et al (157): Friedman et al (60)). Voisey (212) gave a review of recent texture measuring devices and listed five essential components of a texture measuring device: a mechanical mechanism for deforming the sample; a means of recording the force; a means of recording the deformation; a method of recording time during deformation; and a test cell to hold the sample.

The second category of texture measurements are the sensory tests. Szczesniak (196) commented that most of the work on sensory evaluation of food texture up to that time, used an arbitrary scoring system and was limited to one product or product class. She proceeded to describe the development of standard rating scales for hardness, brittleness, chewiness, gumminess, viscosity and adhesiveness. Each point on the rating scales was represented by a food product. The scales were claimed to be interval, and were set up by a panel trained in sensory testing and the definitions of Szczesniak's textural parameters. These scales were claimed "to offer a basis for quantitative organoleptic texture evaluation in a rational and relatively complete manner. The resulting set of numbers gives a texture profile".

A texture profile method was developed by Brandt et al (15), based on the Arthur D. Little flavour profile method. They defined a texture profile as "the organoleptic analysis of the texture complex of a food in terms of its mechanical, geometrical, fat and moisture characteristics, the degree of each present, and the manner in which they appear from the first bite through complete mastication." Examples of dry flake cereals, rice, whipped toppings and chemically levened biscuits were given.

One of the most recent applications of the flavour profile was by Yoshikawa et al (234-236). They described the construction of texture profiles using 40 texture describing words and 79 foods. The constant-sum method was employed, where subjects were requested to rate the degree of relationship between stimulus items and their attributes, as set by the researcher. Instructions were given to respondents as follows: "The words (attributes) listed in the left column 1-40 are fairly often used to describe the sensations in the mouth, on the tongue and on the teeth of the food given below.

Step 1, choose about 10 words which you think are most suitable for the foods printed in the top row and circle them. Step 2, allocate 100 points among them according to the degree of association between the word and the food". Texture profiles for all 79 foods were described by the average ratings over each of the 40 texture describing words. Unlike most profile methods, the 200 subjects used were untrained.

Two advantages of the texture profile method were given by Brandt et al (15). Firstly, its flexibility of application to any food product or textural characteristic and secondly, its objectivity through rigidly defined points of reference and nomenclature. The limitations of the method were seen as being related to the degree of proficiency of the panels applying the method.

The methods of classification and measurement of sensory properties are still confused in spite of the extensive research in the area. This indicates the extremely complex nature of food properties and the ways in which they are sensed, both individually and in combination, by human receptors. The lack of a universal classification and hence the lack of standard methods of measurement would provide problems in the definition of the overall properties of combinations of raw materials. Without the ability to clearly define these combined properties it would be almost impossible to predict consumer acceptance of a combination of raw materials.

4.4 The measurement of consumer acceptance of food

The measurement of consumer acceptance, like the measurement of sensory properties, has been studied extensively and a number of different methods have been proposed. To a large extent the method chosen for any particular consumer research depends on the form in which the results are required. Three broad classifications of the methods of measurement of consumer acceptance are discussed below - the historical approach, the observational approach and the questionnaire approach. By far the most widely used is the questionnaire approach.

4.4.1 The historical approach

Acceptance of food can be predicted through reference to statistics of food distribution, sales records and turnover rates. For example the sales of a food product which has been accepted by consumers, and has been on the market for a number of years, may be used to predict the sales of a new product with similar properties. Diary and pantry surveys may also be used to predict consumer acceptance of new products.

4.4.2 The observational approach

Hidden observers, people, cameras etc. may be placed in positions to record the behaviour of consumers in stores and supermarkets. Fleishman (53) used a combination of observation and questionnaires to establish consumer preferences for six brands of beer.

4.4.3 The questionnaire approach

Amerine et al (1) listed 7 methods used by the Market Research Corporation of America to gain insight into food habits: depth interviews, word associations, role playing, recorded group discussion, sentence completion and pretest questionnaire. They suggested that the most commonly used method was the questionnaire.

The selection of the questionnaire to be used when experimental food products are to be judged depends on the number of treatments, the sensory intensity of the food and the information required. Amerine et al (1) gave examples of presentation methods, suitable for consumer survey purposes.

Single-sample presentation including acceptable or unacceptable, degree of liking, description and numerical scoring.

Paired-sample presentation, for example the identified product paired comparison in which a sample of known quality is compared with a sample of unestablished quality, and the blind paired comparison in which the quality of neither sample has been established previously.

Three sample presentation such as the triangle test and the duo-trio. The samples can also be ranked or scored on the basis of quality.

More than three samples including ranking, scoring or scaling and degree of liking.

By far the most commonly used technique of measuring consumer acceptance over the past twenty years has been the hedonic scale, developed by Peryam and Girardot (143). The technique has received many applications (Weckel et al (216); Valdes and Roessler (209); Pangborn and Leonard (139)) to name a few. A brief history and outline of the technique was given by Peryam and Pilgrim (144), who considered the hedonic scale to be a special application of the rating scale, representing a direct approach to the measurement of psychological states.

Briefly, the hedonic scale is based on the assumption of a continuum of preference and the definitions of categories of response in terms of like and dislike along this continuum. The most widely used scale is the 9 point like extremely to dislike extremely scale, as shown in Figure 4.5.

- Like extremely
- Like very much
- Like moderately
- Like slightly
- Neither like nor dislike
- Dislike slightly
- Dislike moderately
- Dislike very much
- Dislike extremely

Figure 4.5 The 9–point Hedonic Scale

The subject is asked to state his opinion of the food in one of the 9 categories of response.

Jones et al (96) carried out an extensive study of the hedonic scaling technique and listed conclusions, believed to be the most pertinent to food technologists:

1. Descriptive phrases may differ greatly in ambiguity.
2. They also differ in the level of preference implied, and this cannot always be predicted on an a priori basis.
3. Increasing the length of a scale, up to 9 intervals, is related to only negligible increases in the time required for completion.
4. Test-retest reliability, within the range of 5 to 9 intervals, is relatively invariant.
5. Longer scales, up to 9 intervals, tend to be more sensitive to differences among foods.
6. Elimination of the 'neutral' category seems to be beneficial.
7. Balance, i.e. an equal number of positive and negative intervals is not an essential feature of a rating scale.

Peryam and Pilgrim (144) believed the hedonic scale to be useful in a broad range of situations and with any problem where evaluation on the criterion of human preference is required. They believed it to be equally useful for the consumer panel and trained taste panel alike. Cover (32) pointed out that the hedonic scale is useful for measuring consumer acceptance of foods, but it is not designed for following quantitative changes in foods. He noted, for example, that hedonic responses to meat will differ between judges who like rare and those who like well-done steaks. Quantitative scales of juiciness and tenderness, however, could be used by both groups of judges. Amerine et al (1) suggested that the method should be used to detect small differences in degree of liking for similar foods; to detect gross differences in degree of liking of foods, even when time, subjects and test conditions are allowed to vary; and to reveal differences in group preference attitudes towards foods in field questionnaire surveys. They felt that although the test had been used both by experts and by untrained consumers, it was more applicable to the latter. The variability in ratings from a group of observers tends to be high and this suggests that the scale is not suited for use with small panels. Seaton and Gardner (166) used hedonic scaling for determining the acceptability of new or unusual foods where there were no similar products for comparison.

For analysis of data obtained with the hedonic method, numbers 1 to 9 are assigned to the descriptive categories and the following can be calculated: means, standard deviation, standard errors of means and the significance of difference between means (Amerine et al (1)). Peryam and Pilgrim (144) said that one limitation must be recognized in applying ordinary statistics of variables, and that is the scale categories are known to be of unequal width psychologically. They suggested, however, that usually interval scales can be assumed without running into too much trouble. Chapman and Wigfield (26) believed that the assumption of equal interval was unwarranted. They gave two ways of overcoming error from this assumption. Firstly, non-parametric statistics can be used which do not make the assumption of equal interval scaling in the data (e.g. chi square analysis). Secondly, exact numerical values for the scale items can be determined and parametric statistics used on these. The technique described by Snell (182) was suggested for conversion of an ordinal scale to an interval scale.

The advantages and limitations of hedonic scaling have been outlined by Peryam and Pilgrim (144). Its advantages include its simplicity which makes it suitable for a wide range of populations, and allows subjects to respond meaningfully without previous experience. The data can be handled directly or indirectly by the statistics of variables. Finally, in contrast to other methods the results are meaningful for indicating general levels of preference. Among its limitations is its susceptability to a number of 'effects'. Firstly, the contrast effect where an average quality sample will tend to rate low when preceded by a good quality sample of the same type, and to rate high when preceded by a poor quality sample. Secondly, the contamination effect where the rating for an average quality sample will tend to move in the same direction as those with which it appears. Thirdly, the position effect where the first sample occupies the best position preference wise, and the later samples tend to be rated lower. Other limitations include the inequality of the scale intervals and the lack of a zero point. It also does not discriminate as finely between samples as paired comparisons.

4.5 The problems in using conventional sensory methods

The aim of this literature search was to find if product acceptability of Thai foods could be related to the characteristics of the raw materials used in these foods. The major part of the study was concerned with sensory properties - appearance, flavour and texture - as it was considered that these were the qualities in the raw materials most directly related to consumer acceptance of food products. It was hoped that a direct relationship between raw materials and food products might be found which could be used in the linear programming model.

The literature relating to sensory analysis is extensive, but it fails to offer any suggestions as to the results of combining sensory properties. Only two references to the addition and interaction of sensory properties were found. Eindhoven and Peryam (42) suggested that preferences for food combinations in the form of meals might not be predictable from any sum or weighted average of preferences of the components. Blended foods, such as stews, were excluded from their definition of a food combination. Fabian and Blum (44) studied the competitive and compensatory effects of some basic taste constituents. Their results indicated a high degree of interaction between the basic taste components of salt, sour, sweet and bitter. These interactions were difficult to generalize and were dependent not only on the basic tastes, but also on the compounds classified within each basic taste.

The methods of classification and measurement of sensory properties are not well defined. Some of the problems in adopting a quantitative approach in research involving sensory properties, their interaction and effect on the acceptance of foods are listed below:

1. The lack of adequate classification systems for sensory properties.

2. The difficulties in measuring sensory properties on an objective basis and of correlating these results with those from subjective or panel methods.

3. The complicated nature of the interaction of sensory properties. Such interactions can be both intra-property, that is combination of like properties, for example flavour, and inter-property, that is combinations of unlike properties such as flavour and texture.

4. The problem of defining the properties required for consumer acceptance of a food. There is disagreement among researchers on the relative importance of sensory properties. This disagreement is probably due to the consumer's inability to express, in words, his reasons for liking or disliking a food product.

5. The difficulties of measuring consumer acceptance using conventional hedonic scaling techniques. Not only are these techniques limited by their lack of a specified zero point, required for ratio scaling, but also the difficulty of defining a continuum for the judgement of acceptance. Without the definition of specific bases for acceptance, it would be difficult to relate raw material properties to final product characteristics and hence to consumer acceptance of this product.

6. The problems of predicting changes in raw material properties through processing, and hence the effect of these properties on the characteristics of the final product.

A surface view of the problem of selecting combinations of raw materials for acceptable food dishes might indicate a relatively simple solution. A set of attributes required for food dish acceptance would be defined, probably flavour, texture and appearance. The levels of each attribute in each raw material would be determined and raw material selection would be based on obtaining the optimum set of attributes required for food dish acceptance. The problems outlined above made this approach impossible. Not only is interval scale measurement of sensory properties difficult to obtain, but definition of these properties in raw materials, as they influence consumer acceptance of food dishes, is far from clear. A system was therefore required which firstly identified the raw material properties which influence the acceptance of food dishes. Secondly, the levels of each dominant property in each raw material was required, and finally a method for selection of combinations of raw materials was needed to achieve levels of these properties which were acceptable in a food dish.

The first problem was then to define the raw material properties which are important in the formation of food dish characteristics and in particular those characteristics which influence consumer acceptance of the food dish. A number of raw materials were therefore available, each with the potential of contributing to food dish characteristics. The multiple relationships existing among these raw materials and their properties in combination caused the main problem in defining the dominant properties. The methods often referred to collectively as 'multivariate analysis' is a growing set of statistical tools used to analyze simultaneously the relationships between two or more variables. Multivariate techniques have been developed to untangle the multiple relationships occurring in most behavioural problems. A number of these techniques were studied to ascertain their value with respect to the following criteria:

1. Their ability to indicate the dominant properties of raw materials as they influence food dish acceptance.
2. Their ability to accept nonmetric (ordinal) data, which is the most common form of consumer information, either about the sensory properties or the acceptance of foods.
3. Their potential to supply, either directly or indirectly, data for the linear programming model to enable the selection of raw material combinations to give an acceptable food dish. That is, it must lead to a linear function relating the acceptability of a food dish to its raw materials.

4.6 A study of multivariate techniques

A brief description of each multivariate technique is given below and their potential to meet the criteria listed above is summarized in Table 4.4.

Multiple regression involves the use of one criterion (dependent) variable and one or more predictor (independent) variables. The criterion variable is normally assumed to be either interval or ratio scaled, while the predictors need only be ordinal scaled. Multiple regression is used to find a linear combination of the predictors that 'best' accounts for the variation in the criterion variable.

Multiple discriminant analysis is an extension of multiple regression and is used to specify the relationship between a nonmetric criterion variable and one or more predictor variables. Both multiple discriminant analysis and multiple regression are generally considered to be unsatisfactory with large numbers of predictors (181).

Multivariate analysis of variance is used where two or more criterion variables are involved. It is only applicable when these variables are metric, and is useful in testing hypotheses concerning multivariate differences in group responses to experimental manipulations.

Canonical correlation is an extension of multiple regression analysis and is applicable to problems involving two or more metric or nonmetric criterion variables. It serves to specify the correlation between the criterion and predictor variables. It can also isolate the predictor variables contributing most significantly to the relationship between the two sets.

Factor analysis seeks to summarize metric data in a more compact form, while retaining its essential properties. Thus, an object or a phenomenon, described by a large number of variables, may be described by just a few synthetic variables, called factors, which retain the essence of the original data.

Cluster analysis seeks to identify mutually exclusive and exhaustive sets of objects and to assign the members of the population to the appropriate group. Cluster analysis normally uses the tools of factor analysis to reduce the data to a manageable number of factors. These factors become the data used in the actual classification procedure.

Multidimensional scaling methods bear a close relationship to factor analysis in the sense that they also seek to summarize the data in a more compact form. They reduce the number of variables (dimensions) required to define the original data. Two basic categories of the technique exist. Firstly, those requiring metric data and secondly those requiring only nonmetric data. The nonmetric group has the ability to produce a pictorial representation of items with a metric scale.

Table 4.4 Comparison of the suitability of various multivariate techniques for the second stage of the research.

	Ability to show dominant properties	Ability to use nonmetric data	Potential for the L.P. model
Multiple regression	Not directly	Only for the predictors	Yes, but only for small numbers of predictors
Multiple discriminant analysis	Not directly	Yes	Yes, but only for small numbers of predictors
Multivariate analysis of variance	No	No	No
Canonical analysis	No	Yes	No
Factor analysis	Yes	Yes, but only by assumption of interval data	No
Cluster analysis	Yes	Yes, but only by assumption of interval data	No
Multi-dimensional scaling	Yes	Yes	Yes

Of the 7 multivariate techniques studied, multiple regression, and particularly its nonmetric version of multiple discriminant analysis, showed obvious potential to produce a linear function relating the raw materials or raw material properties to the acceptance of a food dish. The main problem in the use of these techniques would have been their inaccuracy with the large number of raw materials (predictors) in this problem. Multidimensional scaling was the only technique which was able to meet all three criteria. It could accept simple nonmetric information about the raw materials and transform this into a spatial representation of the raw materials with metric scale values. These metric scale values, corresponding to the relative levels of the dominant raw material properties, might then be used in the linear programming model. Selection of an acceptable set of raw materials could be based on the derivation of some prespecified 'optimum' combination of the dominant properties.

4.7 Summary and conclusions

The aim of the second stage of the research was to include in the linear programming model a system for selection of raw materials which, when combined together in a food dish, would be acceptable to the Thai consumer. A review of the literature relating to the sensory properties and consumer acceptance of foods failed to find any conventional methods which could supply data in a suitable form to be used directly or indirectly in the linear programming model. A number of problems were found. There was a lack of adequate classification systems for sensory properties, and quantitative measures of these properties were difficult to obtain. Also, little work was reported on the interaction of sensory properties. Probably the most critical problem was the inability of most conventional techniques to precisely define which properties of the raw materials are important in the consumer's acceptance of a food dish.

The complexity of the problem of predicting consumer acceptance of a food dish from the properties of its raw materials was mainly due to the many interactions occurring among these properties. A number of multivariate techniques were studied to determine firstly their capacity to resolve the dominant properties of raw materials which influence consumer acceptance of a food dish; secondly, their ability to accept nonmetric data; and finally their potential to supply information about the raw materials which was suitable for the linear programming model. That is, a technique was required which could accept, from consumers, non-metric data about food raw materials and produce a metric output with potential to be used in a linear function relating the raw materials and food dish acceptance. The only technique which met all the requirements was nonmetric multidimensional scaling.

Nonmetric multidimensional scaling accepts relatively simple nonmetric information about items and transforms it into a spatial representation of these items, with a metric scale. The dimensions of the multidimensional space stand for the dominant properties of the items. Hence, a spatial model of the food raw materials could be derived from nonmetric information about these materials. The axes of the space would represent the dominant properties of the raw materials. The definition of some 'optimum' combination of these dominant properties required in a food dish might then lead to a linear function relating the raw materials to food dish acceptance. Such a function would then be in a suitable form for the linear programming model to select combinations of raw materials, acceptable in a food dish.

The theory and applications of multidimensional scaling were reviewed to provide a basis for the use of the technique in deriving a linear function relating raw material acceptance to the acceptance of Thai food dishes.

CHAPTER 5

MULTIDIMENSIONAL SCALING - THEORY AND APPLICATIONS

Multidimensional scaling, although dating back to 1938, has only received widespread recognition since the exposition of the nonmetric form of the technique by Shepard (167, 168) and Kruskal (102, 103) in the early 1960's. Nonmetric multidimensional scaling has received much attention from both the methodologist and the applied scientist. A great deal of work has produced improvements in the methods of computation with more efficient and versatile computer programmes. In spite of these computational improvements, several limitations still exist, including the problems of choice of dimensionality, axis definition and sub-optimal solutions.

The limitations of nonmetric multidimensional scaling have not prevented the behavioural scientist from applying it to a wide variety of problems. Its advent was particularly welcomed by market researchers because of its ability to produce a pictorial representation of items with a metric scale from ordinal information about the items. Particular emphasis has been placed on the location of product brands within a multidimensional space. Identification of 'holes' or 'gaps' in the space has then been used to identify potential for new brands. Although some workers (190) have reported successes in this form of new product development, most have been confronted with the problem of transforming the psychological scale values of a point in the product space into the physical properties of a new product. This thesis overcame this problem by positioning food raw materials in a multidimensional space and selecting raw material combinations, as a basis for new food dishes, according to the inherent attributes of the materials as they influence food dish characteristics. That is, raw materials were located in a multidimensional space according to the relative quantities of the dominant attributes (spatial dimensions) contained in each. A point was identified in the space representing the ideal combination of attributes as a basis for a food dish. Raw materials were then selected to give this required attribute combination.

5.1 What is multidimensional scaling?

The term multidimensional scaling is rather loose and includes a list of varied and powerful techniques for the analysis of data of several types collected in the behavioural sciences. Despite their diversity, these techniques share the dual purpose of deriving whatever pattern or structure exists in a matrix of empirical data, and of representing that structure in a form that is more acceptable to the human eye - namely a geometrical or pictorial model. The objects under study are represented as points in the spatial model in such a way as to reveal their dominant features through the geometrical relations among the points. The resulting spatial representation is in fact a 'scale' and resembles more traditional scales such as mass and temperature, in that it attempts to capture the fundamental properties of the objects by setting them within a spatial continuum. It is, in fact, an extension of these more simple unidimensional scales, as the points are allowed to assume positions within a two-dimensional plane or even within a three, four or higher dimensional space.

5.1.1 The problem of dimensionality and interpretation

In most cases, an attempt is made to find a representation of the lowest dimensionality, consistent with the data. A lower dimensional representation displays the same data by means of a smaller number of parameters and hence to the extent that fewer parameters are estimated from the same data, greater statistical reliability will be obtained. Perhaps the most important consideration in the achievement of a low dimensional configuration is the inability of the human eye to visualize past three dimensions. On the other hand, dimensionality cannot be decreased without some loss of information about the original data. The number of dimensions should always be sufficient to display the full complexity of the relations in the given data. Generally, no more than three dimensions have been adopted in previous practical applications.

The primary purpose of the representation is to enable the investigator to gain a better understanding of the total underlying pattern of interrelations in his data. The obtaining of a spatial configuration should not be considered an end in itself. Interpretation of the axes can lead to the definition of the dominant properties or characteristics of the objects which gave rise to the spatial model. Again, a lower dimensionality is more suitable as the procedure of finding interpretable axes becomes more difficult and uncertain when the number of dimensions exceeds what can normally be apprehended in a picture or model.

5.1.2 The development of multidimensional scaling

Multidimensional scaling dates back to 1938 when Young and Householder (240) laid some of the mathematical groundwork for the fully metric models. This work was extended in the early 1950's by Torgerson (205) and later by Messick and Abelson (115) who first achieved a generally workable method for multidimensional scaling proper. Torgerson (207) gives a comprehensive representation of this first phase of development. The requirements of these fully metric models for a metric input of ratio scaled data proved too severe for most social science applications and led to the development of the nonmetric varieties of multidimensional scaling. These fall into two categories. The first group was proposed by Coombs (31) for the spatial representation of ordinal or nonmetric data. These techniques have not been widely used. One reason for this may be that the methods lacked sufficient formalization to be converted into computer programmes and are not manageable, except with a relatively small number of objects. Another reason is their failure to extract substantial metric information contained in the ordinal data, a defect which has been largely overcome by the second group of nonmetric techniques. The basic concepts for these methods were presented by Shepard (167, 168) in 1962 and were closely followed by conceptual and computational improvements by Kruskal (102, 103) in 1964. These nonmetric forms of multidimensional scaling remove the restriction of a metric input and require only ordinal data for the derivation of a spatial representation of objects, where the space or 'scale' can be said to have metric properties.

5.2 Nonmetric multidimensional scaling

In behavioural studies, ordinal data is much easier to collect than interval data. As a result of this, all multidimensional scaling analyses in this thesis were carried out using fully nonmetric algorithms based on the concepts proposed by Shepard and Kruskal. These newer methods, unlike those described by Coombs (31), are able to yield tightly constrained metric representations. In spite of this, they are still referred to as nonmetric to indicate that in contrast to the earlier metric methods perfected by Torgerson (205), they are able to produce a metric output from a strictly nonmetric input. This ability of the newer methods is particularly attractive to workers in the social sciences, where data generally comes from human subjects who can reliably give only judgements or ratings with ordinal properties.

A second advantage of these nonmetric methods is the close relationship between the final result and the original data which gives an indication of how well the final spatial representation fits the initial data. The methods are designed to give stepwise improvements in this fit through an iterative procedure. The goodness of fit and derivation of a stress factor as a measure of the departure from the perfect fit was formalized by Kruskal (103) in 1964.

A third feature of the new approach includes the ability to overcome a number of problems, insurmountable by the original metric techniques. These include such problems as coping with ordinal information, missing data and cases where some non-Euclidean metric is desired for spatial representation. The formalization of the iterative approach by Kruskal (103) has led to its extension to many related multidimensional problems such as those of nonmetric factor analysis, conjoint measurement, unfolding analysis and cluster analysis. An overall taxonomy of the many types of data and methods for analysis is presented by Shepard (172).

5.2.1 The basis of nonmetric multidimensional scaling

The aim of these techniques is to transform nonmetric information about objects into a spatial representation of these objects, with metric properties. For every two objects (i and j) in some set n, data s_{ij} is obtained representing the similarity, substitutability, affinity, association, interaction, correlation or in general, the proximity between them. A configuration is sought where the n points are represented in the space of the smallest dimension, such that, to an acceptable degree of approximation, the resulting interpoint distances d_{ij} are monotonically related to the given proximity data in the sense that

$$d_{ij} < d_{kl} \quad \text{whenever} \quad s_{ij} > s_{kl}$$

where k and l represent two other objects.

The process of iterative improvement in the monotone relationship is by either the method of steepest descent or the method of gradients. Through adjustment of the coordinates at each iteration, the degree of monotonicity of interpoint distances and original proximities should be improved. The level to which a good fit is obtained may be assessed by computing the following residual sum of squares, proposed by Kruskal (103) and called 'stress'.

$$S = \frac{\sum_{ij} (d_{ij} - \hat{d}_{ij})^2}{d_{ij}^2}$$

where d_{ij} are the computed distances between all pairs of points in the configuration $\underline{X}$, and $\hat{d}_{ij}$ are a set of ratio scaled numbers, chosen to be as close to their respective d_{ij} as possible, subject to being monotone with the rank order of original proximities s_{ij}. That is

$$\hat{d}_{ij} \leq \hat{d}_{kl} \quad \text{whenever} \quad s_{ij} < s_{kl}$$

Iteration continues until the marginal improvement in stress is less than some pre-determined level.

The procedure described above can be carried out in any specified dimension. The starting configuration for the iterative procedure can be entirely arbitrary, randomly generated or constructed on the given data, for example by using a variant of the classical metric approach. Whatever method is used, the selection of a good starting configuration may have advantages in either reducing the number of iterations required or more importantly in avoiding the traps of local minima and sub-optimal solutions where small iterative changes will result in no further improvement in stress.

5.2.2 The number of dimensions and axis orientation

In most applications the appropriate number of dimensions is not known in advance. Best fitting configurations can be obtained in spaces of one, two, three or more dimensions and a choice made among the alternative representations to achieve a spatial model which is stable and easily visualized on the one hand, and has an overall goodness of fit to the data on the other. Shepard (170) gives four considerations as relevant to the choice of dimensionality:

1. The residual departure from monotonicity (i.e. stress) should

not be too large and should not drop too abruptly as further dimensions are added. Ideally, if stress is plotted against number of dimensions the number of dimensions chosen will correspond to an 'elbow' where the curve first steeply approaches the dimension axis and then declines only very slowly thereafter.

2. The representation should be statistically reliable. Solutions obtained separately from two independent sets of data, or from two independent subsets of the same data set should show good agreement. This agreement will break down if representations are permitted to have more dimensions and hence more degrees of freedom than the data will reasonably support.

3. The representation should be interpretable. If the axes can be interpreted then it is reasonable to conclude that the dimensions are real. If they cannot, then it may be because the parameters of the representation are too numerous and therefore dominated by error in the data. In this case a representation of a lower dimensionality should be tried.

4. Except in the case of special methods that do not require the rotation of axes for interpretation, the representation should be easily visualized, and so confined to two or at most three spatial dimensions.

Shepard concluded that of the four criteria the last two and particularly the very last have often been decisive. Not all researchers share Shepard's view that axis identification is an important criterion in the acceptance of a spatial model. Fenker (51) believes that it is time that the concept of a psychological space be accepted as a useful behavioural construct independent of whether or not the dimensions have clear cut physical interpretations. He concludes that the validity of the construct should be evaluated on the basis of whether the psychological spaces have potential in the prediction of behaviour.

A number of workers have placed considerable emphasis on the magnitude of stress values and particularly the rules of thumb proposed by Kruskal (103) for evaluating solutions: 0.025, excellent; 0.05, good; 0.10, fair; and 0.20 or over, poor. Young (238) concluded that stress should not be taken too seriously as a measure of indicating confidence in the results of an analysis, but should be used as a purely descriptive statistic. He proposed a measure of metric determinancy as an indicator of the confidence in a nonmetric scaling solution. Young further concluded that if the ratio of the degrees of freedom of the data to that of the coordinates is sufficiently large, then metric information is recovered even when random error is present. When the number of points being scaled increases, the stress of the solution increases, even though the degree of metric determinancy improves.

Spence and Ogilvie (188) developed a table of expected stress values for random rankings in nonmetric multidimensional scaling to assist workers to decide whether empirically obtained data sets are the result of a random process. The table covers 12-48 objects (points) for one to five dimensions. A Monte Carlo experiment by Spence and Graeff (186) led to a completely automatic procedure for determining the underlying dimensionality of an empirically obtained matrix of proximities. A programme called M-SPACE was developed by the same authors to determine the underlying dimensionality of empirical data and to give an indication of the error present in the data (187).

In spite of the attempts by many workers (186, 187, 188, 214) to provide a quantitative basis for choice of dimensionality, it would be unwise to use any one of these methods as the only criterion. Certainly as indicators and in association with the criteria proposed by Shepard (170), they provide a strong foundation for confidence in the choice of the dimensionality of nonmetric multidimensional scaling solutions.

Axis identification is a problem that faces most researchers developing spatial models. Generally, this is done subjectively by noting the changing properties of the objects along each axis. An attempt is made to identify a property, common to all objects, which changes by either increasing or decreasing in magnitude with movement along the axis. Attempts are sometimes made to correlate projections of the points or objects on a particular axis with known properties of the objects. These properties may be either physical and measured objectively or less tangible, in which case they may be measured along a prespecified unidimensional continuum using a human panel.

5.2.3 The distance metric

Most nonmetric multidimensional scaling algorithms have the capability to scale data in Minkowski metrics other than the familiar Euclidean. Almost all applied studies have, however, used the better known Euclidean metric. This may be partly due to the lack of familiarity of most users with other metrics but also to the increasing awareness of the robustness of the Euclidean metric in recovering structures under simulated conditions in which similarities were computed in some metric other than Euclidean (65). Shepard (171) reported on a study carried out with a random arrangement of 50 points in a square. All Euclidean interpoint distances were then changed to a type of six-lobed closed curve, rather than the circular isosimilarity contour of the Euclidean metric. These transformed distances were scaled using nonmetric multidimensional scaling with a Euclidean metric resulting in an almost perfect recovery of the original two-dimensional configuration.

Green (65) reported on exploration of Euclidean approximations to other Minkowski p-values, both with real and artificial data. On the basis of these studies, he concluded that unless one has strong theoretical reasons for selecting some other p-value, the Euclidean metric is not only well understood but also appears to recover solutions based on other Minkowski metric quite well (at least in the range $1 \leqslant p \leqslant 3$).

5.2.4 The ideal point and unfolding analysis

Coombs (30) first introduced the concept of a joint space of people and stimuli in 1950. Each individual's position can be interpreted as his ideal point, representing the particular combination of attribute scores that he would prefer above all other combinations. The individual's decreasing rank order of preferences for real stimuli would reflect the increasing psychological distance from his ideal point, i.e., real stimulus points nearer the ideal would be preferred to stimulus points further from the ideal. Coombs applied the concept in the unidimensional case and called it the 'unfolding' model because

> "...an individual's preference ordering would correspond to the ordering of stimuli obtained by picking up the plane as if it were a handkerchief at the ideal point and compressing the handkerchief into a line. The successive order of the stimulus points on this line corresponds to their successive order in distance from the ideal point in the plane" (30, p.141)

Bennett and Hays (12) generalized this model to the multidimensional case where both stimuli and individuals are represented in the same multidimensional space. The points for individuals represent ideal stimuli, or optimal sets of stimulus values, for those individuals. The further a stimulus is away from an individual's ideal point, the less that individual likes that stimulus. This leads to the development of 'isopreference contours' or concentric circles in two dimensions, concentric spheres in three dimensions and hyperspheres in higher dimensions indicating relative preference of an individual for stimuli located at various points through a multidimensional space.

The models proposed by Coombs (30) and extended by Bennett and Hays (12) form part of the group of fully nonmetric procedures. That is, they accept a nonmetric or ordinal input but produce only a rank order solution, i.e., only the rank order of the point projections on each dimension could be determined and not the configuration itself. These models were also specific for preference data. The more recent nonmetric algorithms are able to produce unfolding solutions with metric properties. Torgerson and Young (237) take advantage of the passive cell feature of their programme, TORSCA. Here an (mxn) rectangular matrix of <u>m</u> items (individuals) by <u>n</u> stimuli is expanded to an (n+m) by (m+n) square matrix. The original rectangular matrix forms one corner of the larger square matrix with the remaining submatrices treated as missing data. The (n+m) points are positioned in the multidimensional space by the normal iterative procedures as outlined previously, with m ideal (individual) points and n stimulus points. Kruskal's newest programmes, including KYST (105) and M-D-SCAL 5M (101) require only that within row comparisons of all stimuli be obtained for each person in turn.

The future for the newer forms of unfolding analysis remains a little uncertain. Past applications have see-sawed between success and failure. Percy (141) and Moskowitz (127) reported quite good solution while Green and Rao (70) and Green and Wind (72) obtained generally unsatisfactory results. Kruskal and Carroll (104) provided a good summary of modern unfolding analysis in saying that "the method may be good enough to be used successfully with some data in some cases."

5.2.5 The limitations of nonmetric multidimensional scaling

Since the introduction of nonmetric multidimensional scaling by Shepard (167, 169) and Kruskal (102, 103), much published work on the theory and application of the technique has appeared in the literature. This has probably been due to a large extent to the intuitive appeal of the method, but also to the highly successful attempts by various workers at Bell Laboratories to popularize the technique. Certainly the bulk of the research in the area has been theoretical and particularly the development of a great many computer programmes for the solution of scaling problems: Kruskal's M-D-SCAL (101), Guttman-Lingoes' SSA-1 (73), Young-Torgersons' TORSCA (237), McGee's EMD (110), Roskam and Lingoes' MINISSA-1 (163) and KYST by Kruskal et al (105) comprise some of the better known programmes. Although all these programmes are designed to accomplish essentially the same objective, they represent a number of approaches to overcome the complex computational problems. There has been little published information on the comparative performance of the different algorithms. Spence (183) compared the performance of M-D-SCAL, SSA-1 and TORSCA, while Lingoes and Roskam (108) examined in detail the SSA-1, MINISSA-1 and M-D-SCAL algorithms. Perhaps the most commonly used programmes are TORSCA and M-D-SCAL. More recently a new programme KYST, has been developed representing a merger of TORSCA 9 and M-D-SCAL 5M, which claims to include the best features of these algorithms as well as some new features of interest.

In spite of these numerous studies many problems still exist in the computational methods of nonmetric multidimensional scaling. Virtually all procedures are subject to their own particular type of degeneracy - configurations that can be markedly changed without affecting the rank order of the inter-point distances. Another problem concerns the robustness of solutions to noisy data. There is also the prospect of sub-optimal solution, i.e., local minima. Certain algorithms are better than others at overcoming this problem, which appears to be closely related to the quality of the starting configuration. Spence (183) claims that TORSCA is probably the most reliable programme and produces sub-optimal solutions less than 3 or 4 percent of the time. The newer KYST programme would also be relatively robust against local minima problems as it permits the user to take advantage of the TORSCA starting configuration.

The relative imbalance of theory and applications of non-metric scaling methods has led to many substantive problems, the major one being the location and identification of axes. Uniform expansions and contractions of a configuration are not of interest to the researcher as they will not change the rank order of inter-point distances. Rotations, however, are of substantive interest since the researcher may want to associate traits, attributes, dimensions or factors with the axes of the space. Certain programmes including KYST and TORSCA perform axis rotation according to the varimax criterion. This is only one way in which the position of the axes can be determined. Given a multi-dimensional scaling solution, there seems to be no universally accepted method of performing axis rotation. The orientation of the axes is a problem which the user of nonmetric multidimensional scaling must answer. His solution can be either to accept the rotated configuration as produced by his programme or to make some subjective rotation to align the axes with identifiable dimensions.

An attempt to overcome this problem has been made by Carroll and Chang (20) in the development of the INDSCAL programme which does not require axis rotation. The unrotated axes have turned out to be naturally and directly interpretable. Even after axis rotation, the researcher is faced with the problem of identification or labelling of the axes. The nature of the psychological dimension is determined subjectively either through prior knowledge of the researcher or the use of some type of open-ended response by the subject (19).

Even though multidimensional scaling has often been referred to as a conceptually simple technique, many fundamental problems still exist regarding the meanings of such terms as 'similarity' and 'preference'. Laboratory experiments by Shepard (169), Attneave (8) and Torgerson (206) indicated that different subjects may adopt different strategies in assessing overall similarity. Moreover, the criteria by which overall similarity judgements are made may interact with the stimuli. There is also the problem of handling cases of nonlinear data structures. Procedures are now being developed to recover such data structures (173).

The problems and limitations of nonmetric multidimensional scaling would, then, appear to preclude its application to practical problems with any chance of recovering a sensible spatial representation. In spite of these limitations or rather in the light of them, the technique has been put to good use to obtain information unobtainable by other methods. A review is now presented of the applications of nonmetric multidimensional scaling to marketing research problems and to problems related to the current area of research.

5.3 Applications of multidimensional scaling

In just over ten years since Shepard (167, 168) and Kruskal (102, 103) first proposed nonmetric multidimensional scaling the applications of the technique have been many and varied. Wish et al (224) looked at the ways different people conceive nations and the relationships between these nations. They studied the conditions which give rise to different types of conceptions. Mauser (112) considered the problems of predicting the effect that a new candidate would have on the election. Rosenberg and Sedlak (162) obtained co-occurrences among selected samples of personality trait terms and used multidimensional scaling to present these perceived trait co-occurrences as a structural representation. D'Andrade et al (34) investigated the conceptual organization of disease categories for English-speaking Americans and Spanish-speaking Mexicans with respect to a wide range of properties. Perhaps the most active single organization has been Bell Laboratories in the USA. Their interest in the formulation of different computer algorithms (101, 105) has been with a view to definition of consumer preferences and hence to the use of this information in the development of new products. Carroll and Wish (21) considered that the preferences of customers were more important in the Bell System than in many other industries - the enormous investments in research and development make it important that the customer gets what he wants.

The desire to produce and market goods according to consumer requirements and the apparent ability of multidimensional scaling to identify these requirements has made the technique appealing to the product designer and marketer. It is, therefore, not surprising that marketing researchers have been active in the development of methodology and the application of multidimensional scaling.

5.3.1 Marketing applications

Very few business applications of nonmetric multidimensional scaling have been published, possibly due to the newness of the technique and to the unwillingness of companies to widely publicize their marketing methods. Green (66) reports, however, that a number of consulting firms in the USA have started to offer such scaling services and that at least a score of large corporations are beginning to conduct multidimensional scaling studies - the DuPont Company has been using nonmetric scaling methods since 1963 in the measurement of buyer perceptions and preferences (38). A number of research workers have looked at the potential marketing applications of multidimensional scaling (64, 66, 68, 71). Green (68, 71) lists a number of such applications including product life-cycle analysis, market segmentation, vendor evaluations, test marketing, salesman and store image, and brand switching.

Most published work on the applications of the technique in the field of marketing have been with small samples, generally between 5 and 40 respondents, where the research has been concerned primarily with methodology. In most cases, perceptual and preference maps have been applied to a product class, often with one or more of the following questions in mind (64):

1. What are the major perceptual and evaluative dimensions of the product class?
2. What existing brands are perceived as similar to what other existing brands?
3. What are the major perceptual points of view among consumers?
4. What new brand possibilities are suggested by the configuration of existing brands?
5. How are respondent ideal points or preference vectors distributed in the various perceptual spaces?
6. How compatible are various advertizing messages, slogans or other types of promotional materials with brand perceptions?

Although some earlier studies (67, 70, 95) may have been performed with the sole objective of gaining insight to the major perceptual and evaluative dimensions of a product class, there has been a tendency in recent research to utilize this knowledge in the design of new products. Wind (221) used multidimensional scaling at the product concept testing level. Six new drink concepts were positioned in the same conceptual space as 28 existing drink products. The proximity of the new drinks to successful existing drinks was used as an indicator of their market potential. Johnson (95) used multiple discriminant analysis to determine a configuration of existing brands of beer and descriptions. Ideal product points were located according to consumer response on a set of prespecified scales.

Significant advances in the application of multidimensional scaling to product development were made by Stefflre (190) and Morgan and Purnell (126). Both suggested the identification of 'holes' or 'gaps' in a product attribute space as leading to the development of potentially successful new products. Stefflre is one of the few people who have claimed to have actually developed new ideas from an attribute space into marketable products (190, 191). His procedures involve the searching of product configuration to find 'holes' which identify the location of possible new products. New product descriptions are formulated by subjective consideration of the characteristics of surrounding products, rather than by a mathematical rationale.

More recently Shocker and Srinivasan (176) and Pessemier and Root (146) presented sophisticated models that employ multidimensional scaling procedures for new product design and evaluation. Shocker and Srinivasan (176) described a method based on multidimensional scaling and linear programming for the identification of new product ideas. The basis of this method is a LINMAP procedure (189) for searching a product space for the most acceptable combination of 'actionable' attributes, i.e. "those attributes which indicate specific actions the manufacturer must take to build such a product". Unfortunately no practical applications are given and no suggestions offered on how the transformation of psychological dimensions - actionable or not - into objective product dimensions could be carried out.

Percy (141) presented a new approach to the application of multidimensional scaling to product design or, more correctly, to menu planning. An unfolding analysis using M-D-SCAL 5M was performed on profile data relating the common usage of certain main dishes and potato side dishes. Percy suggested that the acceptability of main dish-side dish combinations was proportional to their interpoint distances in a 2-dimensional space.

Most studies employing multidimensional scaling have, then, tended to use perceptual maps in rather ad hoc ways to see what combinations of attributes might be useful for new product development. Green (64) suggested that although developed independently, the models for systematizing the process of new product generation and evaluation are similar in the following respects:

1. Emphasis on developing product-service spaces by the use of consumer ratings on prespecified attribute scales.
2. The general assumption of homogeneity of perceptual spaces across consumers.
3. Fitting of preference data into previously constructed perceptual spaces via external (regression-type) methods involving ideal point and/or vector representations of preferences.
4. Incorporation of some function for relating probability of choice to weighted distance from ideal point.

Many problems still exist with the use of these models. The testing of really new product ideas may involve new dimensions outside the consumer's experience. Concept testing as described by Wind (221), faces not only this problem but also the uncertainty of the consumer about the characteristics of the new product from a verbal description which forces him to consider the new product within the bounds of his knowledge of existing products of a similar type. Probably the most serious drawback in existing models is their inability to predict psychological response to physical changes in the stimuli (products). Even such sophisticated models as the one proposed by Shocker and Srinivasan (176) are more diagnostic than predictive. Although such models have led to successful product development (191), more research is required to overcome the problems encountered in their application, in particular the subjective nature of attribute definition for new products.

5.4 Summary and conclusions

Multidimensional scaling dates back to 1938 when Young and Householder (240) first laid the mathematical groundwork for fully metric models. Few applications of the technique were seen until 1962 when Shepard (167, 168) proposed the nonmetric form of multidimensional scaling requiring only an ordinal input of data to give a spatial model having ratio properties. Since 1962 a great wealth of work on the theory and application of the technique has been published. Emphasis has been placed largely on methodology with the development of many computer programmes and the testing of these programmes using small groups of respondents.

In spite of the extent of this research, problems still exist in the application of nonmetric multidimensional scaling. These include substantive problems e.g. axis rotation and labelling; conceptual problems e.g. the meanings of such terms as 'similarity' and 'preference'; computational problems e.g. degeneracy and local minima. The fact that these problems are not insurmountable is evidenced by the conviction of researchers in the validity and worthfulness of multidimensional scaling solutions.

The applications of the technique have been many and varied, by researchers in a number of disciplines. Not the least of these have been marketing researchers who have published numerous reports on the use of multidimensional scaling. Mostly these have studied methodology with small samples of respondents. There have been reports, however, of widespread use of nonmetric scaling techniques in businesses throughout the USA (66). A large proportion of the effort on the application of multidimensional scaling to marketing problems has been in the recognition and development of new products. Generally this work has utilized perceptual or evaluative maps of a product group to either find 'holes' or 'gaps' in these maps or to locate some point which represents an optimal combination of attributes which might be useful in new product development. Although useful as a diagnostic tool, these models have failed to be predictive due to their inability to relate psychological response to physical attributes of a product. They have proven successful in some cases (191) where subjective judgements were made on the physical changes to the product, hence indicating the potential of a fully objective and predictive model.

The aim of the research discussed in the second half of this thesis was to use multidimensional scaling as a tool for prediction of acceptable raw material combinations without the necessity for axis definition for any other purpose than to substantiate the model. Either the entire list or some subset of the list of raw materials used in the nutrition problem was to be located in a multidimensional space by the use of proximity measures of substitutability of the raw materials as ingredients in commonly used food dishes. An ideal point would then be located in the same perceptual space from data relating to the relative preferences for the raw materials as ingredients in either a specific food dish or food dishes in general. This ideal point would then represent the optimum combination of desirable food raw material attributes as defined by the axes of the spatial configuration. Correct selection of a mix of raw materials might lead to a combined set of attributes at or near the ideal point. The potential to select raw material mixes in order to maximize the acceptability of dishes based on these mixes, was to be used in the linear programming model in association with the nutrition data.

Surveys were carried out in Thailand to collect suitable data for the derivation of the raw material space and ideal point location. A number of surveys, employing different methods of data collections, were performed to provide supplementary information to support the claims and predictions of the general acceptability model. Multidimensional scaling analysis was performed using the nonmetric programme, KYST. This programme was chosen because of its flexibility and robustness against sub-optimal solutions. KYST is basically an amalgamation of TORSCA 9 and M-D-SCAL 5M, combining the well proven starting configuration of TORSCA 9 with the versatility of input and output of M-D-SCAL 5M.

CHAPTER 6

DATA COLLECTION FOR MULTIDIMENSIONAL SCALING ANALYSIS

The data for multidimensional scaling analysis was collected in Thailand during a 3 month visit to that country between March and June of 1975. A wide variety of surveys for data collection were designed to avoid the necessity of either a return visit to Thailand or further surveys by correspondence.

The surveys were designed and translated into Thai with the help of staff and students from Chulalongkorn University. The subjects were chosen from Chulalongkorn and Kasetsart Universities in Bangkok. The data collected from the surveys were intended to supply information about 40 commonly used food raw materials and 20 food dishes. The specific data collected were:

1. The general similarity or substitutability of all pairs of the 40 raw materials as ingredients in food dishes.
2. The acceptability of each raw material as an ingredient in specific categories of food dish.
3. The acceptability of paired combinations of the 40 raw materials as ingredients in the same food dishes.
4. The general similarity of all pairs of 20 commonly eaten Thai food dishes.
5. The relative acceptabilities for the 40 raw materials and the 20 food dishes.

The five sets of data were collected from samples of between 20 and 30 Thai students. In each survey the data were averaged over all subjects. The averaged data from the first 4 surveys were used to obtain spatial representations of the raw materials and the food dishes from the multidimensional scaling programme, KYST. The data from the fifth survey were used to locate ideal points in the raw material and food dish spaces.

6.1 General comments on the data collection

All sets of data had certain factors common to their collection and analysis. In all cases, the same 40 food raw materials were considered; the choice of subjects and the sample design were similar and the method of obtaining rank orderings of proximity measures across subjects was the same.

6.1.1 The food raw materials

A smaller sample of raw materials was considered than in the nutrition section. Only 40 raw materials were chosen, this being a number which gave sufficient representation of all categories of raw materials, whilst still remaining within the limits of data collection and of analysis using multidimensional scaling techniques. The 40 raw materials were chosen with the aid of a staff member from Chulalongkorn University. Selection was based firstly on the common use of the raw materials as ingredients in food dishes and secondly on obtaining a representation of all food categories including meats, vegetables, spices, fruits and dairy products. Almost all the 40 raw materials came from the original list used in the nutrition problem. New raw materials such as serpent head fish and swamp cabbage were added, as further research in Thailand showed these to be very common ingredients in food dishes. The complete list of raw materials is shown in Table 6.1.

Table 6.1 Raw materials used in the multidimensional scaling analyses.

Vegetables and cereals	Meat and fish	Fruit	Milk and eggs	Miscellaneous spices etc.
bamboo shoots	beef	banana	butter	chilli pepper
cabbage	chicken	mango (green)	cheese	coriander
Chinese cabbage	crab	papaya (green)	chicken egg	garlic
Chinese kale	duck	pineapple	coconut cream	sugar
cucumber	hog's liver	pumpkin	duck egg	
green gourd	pork	watermelon	milk	
mungbean curd	serpent head fish		sweetened condensed milk	
mungbean sprouts	shrimps			
peanut	striped mackerel			
rice				
rice noodle				
shallots				
string beans				
swamp cabbage				

6.1.2 The subjects and the samples

All surveys for collection of data for multidimensional scaling analysis were in Bangkok. The subjects were students from 18-25 years of age, selected from the technology departments of Chulalongkorn and Kasetsart Universities. For each survey, a sample of between 20 and 30 students was chosen. For the purpose of this exploratory research obtaining large samples was not considered worthwhile as it would have been impossible to select a statistically random sample with the facilities available and within the limits of the research budget. The 20-30 students chosen although not representative of the Thai population should, however, be sufficiently representative of the university population to allow for further studies on the same group to be correlated with the findings of this thesis.

6.1.3 Organization of the surveys

The problem of obtaining proximity data is common to all researchers who use multidimensional scaling techniques on large numbers of stimuli, and are faced with excessive labour and cost of obtaining n(n-1)/2 judgements for each subject. There is very little in the literature, however, to guide the user who wishes to reduce the number of judgements.

Rao and Katz (159) discussed and examined a number of methods which can be used to deal with large numbers of stimuli, but found that no method recovered the configurations perfectly. Fenker (51) suggested a method requiring proximity estimates between each of N 'experimental stimuli' and each of M standards, as well as between all possible combinations of the standards. The standards represent a collection of M stimuli, selected so as to comprehensively exhaust the underlying dimensionality of the multidimensional space. Spence and Domoney (185) looked at single subject incomplete designs for nonmetric multidimensional scaling, using the capability of most nonmetric scaling algorithms to deal with incomplete data matrices.

None of the methods suggested by these authors has been extensively tested and very little is known about the statistical ramifications of their effects on final configurations. The surveys in Thailand were designed to give all possible paired combinations of stimuli to each subject. In some cases a few pairs were missing due to errors in survey design and typing. The presentation of such long lists of pairs of stimuli (780 in some cases) ran the risk of dubious reliability of the results caused by subject fatigue and disinterest. This risk was minimized through selection of enthusiastic subjects, together with checks on the reliability and repeatability of judgements. The fact that many of the n(n-1)/2 judgements may be redundant (239) may have led to a degree of overdetermination and hence compensated for some error.

The questionnaires were designed and distributed with the aid of two research assistants from Chulalongkorn University. Four groups of students were used as subjects. The first group was given the raw material similarity, the raw material association and the raw material acceptability questionnaires. The second group was given the 'raw material by use in food dish' questionnaire. The third group was given the food dish similarity questionnaire and the final group was given the food dish acceptability questionnaire. The questionnaires were divided amongst four groups of respondents because answering all would have been too much work for one person. Each questionnaire was in Thai, introduced with explicit instructions followed by the list of pairs of stimuli (raw materials or food dishes). In most cases this list was carried on over a number of pages. These pages were randomly shuffled and presented in a different order to each subject in an attempt to compensate for systematic errors due to tiredness and disinterest of the subjects. The students were allowed to take the surveys home and were given 3 days to complete the questionnaires. In almost all cases they were returned the same day. A complete description of each survey is given in later sections of this chapter.

6.1.4 Organization for data analysis

The data from all surveys was prepared for multidimensional scaling analysis by calculating the average rank ordering of proximities across all subjects in the sample. To justify this calculation and the use of averaged data, two measures of subject agreement and reliability were used - the Kuder-Richardson reliability ratio (114) and Kendall's coefficient of concordance (99).

The reliability ratio (r) is a measure of the ratio of true score variance to total or observed score variance.

$$r = \frac{6_t^2}{6_o^2} = \frac{6_o^2 - 6_e^2}{6_o^2} = 1 - \frac{6_e^2}{6_o^2}$$

where 6_t^2 is the true score variance which is the difference between the total variance 6_o^2 and the estimate of error variance 6_e^2. The error variance is equal to the sum of the variances of the subjects' scores.

$$\sigma_e^2 = \sum_{i=1}^{m} \sigma_i^2 = \frac{1}{n}\sum_{i=1}^{m}\left(\sum_{j=1}^{n} x_{ij}^2\right) - \frac{1}{n^2}\sum_{i=1}^{m}\left(\sum_{j=1}^{n} x_{ij}\right)^2$$

where m is the number of subjects and n the number of stimuli being judged. The total variance σ_o^2 is calculated as follows:

$$\sigma_o^2 = \frac{1}{n}\sum_{j=1}^{n}\left(\sum_{i=1}^{m} x_{ij}\right)^2 - \frac{1}{n^2}\left(\sum_{j=1}^{n}\sum_{i=1}^{m} x_{ij}\right)^2$$

A high value of the reliability ratio r indicates a low error variance due to between subject variation, relative to the variance of the total scores, hence indicating reliable scoring and a high level of agreement among the judges.

The coefficient of concordance (W) was used to test the agreement among subjects' rank ordering of proximities.

$$W = \frac{12S}{m^2(n^3-n)}$$

where W is the coefficient of concordance, m is the number of subjects and n the number of objects (proximity ranks). S is the sum of the squares of the deviation of rank totals across all subjects, for each object, from the mean sum of ranks. The mean sum of ranks must always be m(n+1)/2.

Large numbers of tied rankings were observed in the data sets and a modified formula was used for calculation of the coefficient of concordance.

$$W = \frac{S}{\frac{1}{12}\quad m^2(n^3-n)-m\Sigma T'}$$

where $T' = \frac{1}{12}\sum_t (t^3-t)$ and t is the number of ranks in each tied set.

The significance of the value of W was tested using the chi square value.

$$\chi_w^2 = \frac{S}{\frac{1}{12}\, mn(n+1) - \frac{1}{n-1}\, \Sigma T'}$$

with (n-1) degrees of freedom. A significant coefficient of concordance served to reject the nul hypothesis of disagreement among the subjects, and to conclude that agreement existed.

As a further check on the reliability and consistency of scoring, repeat objects (pairs of stimuli) were included in most surveys. For example in the survey on the general similarity of the raw materials, the pair mungbean curd-pineapple was included twice throughout the list of raw material pairs. The rank ordering of scores across the subjects was determined for each repeat judgement and the Spearman rank correlation coefficient calculated.

$$\rho = \frac{\frac{1}{6}(m^3-m) - S(d^2) - T' - U'}{\sqrt{\left[\left\{\frac{1}{6}(m^3-m) - 2T'\right\}\left\{\frac{1}{6}(m^3-m) - 2U'\right\}\right]}}$$

where m is the number of rankings (subjects), $S(d^2)$ is the sum of the squares of rank differences and T' and U' relate to the number of ties in each list of ranks.

$$T' = \frac{1}{12} \sum_t (t^3-t)$$

$$U' = \frac{1}{12} \sum_u (u^3-u)$$

where t and u typify the sets of ties in the two rankings.

The significance of ρ was determined by calculating the number of standard errors included in the value of ρ. The standard error of ρ is calculated as follows:

$$SE_\rho = \sqrt{\frac{1}{m-1}}$$

Significant values of ρ indicated good repetition in scoring of the repeated objects by the subjects.

6.2 Raw material similarity data

The object of this first survey was to collect data which related to the similarity of the 40 raw materials as they are used in Thai food dishes. Similarity in this case was interpreted as a measure of substitutability of the raw materials in food dishes where these were defined as main meals, eaten generally at lunch-time or in the evening and providing a substantial contribution to the daily diet. A Thai phrase was available to provide a direct translation of this definition for use in the questionnaires.

A list of 769 of the possible 780 paired combinations of raw materials was presented to each of 28 subjects. They were asked to rate the similarity (substitutability) of each pair of raw materials on a scale from 0 to 10, where a larger score represented greater similarity. Each subject was given explicit instructions on how to complete the questionnaire and on the interpretation of the word 'similarity'. An English translation is given below:

> "You have been presented with a list of pairs of food raw materials. Look at each pair carefully and judge how well one could substitute the other as an ingredient in commonly eaten Thai food dishes. Make your judgement on a scale from 0 to 10. A score of 0 should indicate completely non-substitutable raw materials. Increasing scores from 0 to 10 should indicate an increasing acceptability of substitution of the raw materials".

A careful check was made by the Thai research assistants on each of the 28 subjects to ensure complete understanding of the questionnaire.

As a check on errors arising from fatigue and disinterest in completing the large number of judgements, 3 pairs of raw materials were included twice throughout the questionnaire. The repeatability of scoring was estimated by applying the calculation of Spearman rank correlation coefficient ρ to the subjects' scores for each duplicate.

Repeat pairs	ρ	ρ/SE_ρ
mungbean curd - pineapple	0.72	3.74
rice noodle - coriander	0.65	3.38
mungbean sprouts - sugar	0.68	3.53

The results show that there is no reason to assume inconsistency in the scoring by the 28 subjects.

The agreement in scoring among the 28 subjects was tested using the Kuder-Richardson reliability ratio r and Kendall's coefficient of concordance W.

$$r = 0.992$$
$$W = 0.459 \quad \text{with} \quad \chi^2_W = 9870$$

where the tabulated χ^2 value at the 0.01 percent significance level was 874. Both measures, therefore, point to a high level of agreement among subjects.

Average scores for each pair were calculated over the 28 subjects. These average scores, shown in Appendix 6, were used as input for the nonmetric multidimensional scaling programme, KYST.

6.3 Raw material association data

This second survey was carried out with the object of finding the relative affinities of the 40 raw materials as ingredients in food dishes. That is, to estimate the relative acceptabilities of the various materials in combination as part of the same dish. The term food dish retains the same definition as for the raw material similarity data.

The same sample of 28 students was used as for the similarity survey. Each subject was given a list of 771 of the possible 780 pairs of raw materials and asked to rate the acceptability of each pair as ingredients in the same food dish. The judgements were made on a scale of 0 to 10, where a larger score indicated a more acceptable combination. No mention was made of the levels of each material and the students were expected to judge the acceptability of combination based on the common levels of use of each raw material. All subjects performed the task without problems and all appeared to comprehend the task in the same way, as indicated by the measures of agreement given below. Instructions were given to each student in Thai according to the English translation below:

> "You have been presented with the same list of food raw materials as in the previous questionnaire. Look at each pair carefully and this time judge how acceptable the raw materials in that pair would be as ingredients in the same food dish. Make your judgement on a scale of 0 to 10. A score of 0 should indicate that the materials would be totally unacceptable in combination. Increasing scores from 0 to 10 should show an increasing acceptability of the raw materials as ingredients in the same food dish".

A careful check was again made to ensure that each subject was fully aware of the requirements of the survey.

Duplicate pairs were included to test the consistency of scoring by the subjects. The Spearman rank correlation coefficients ρ were calculated from the rank ordering of scores from the 28 subjects for the duplicate pairs.

Repeat pairs	ρ	ρ/SE_ρ
mungbean curd - pineapple	0.57	2.96
rice noodle - coriander	0.75	3.90
mungbean sprouts - sugar	0.73	3.79

The ratios of ρ/SE indicate a significant correlation at the 0.01 percent level, hence showing consistency in the scoring by the 28 subjects.

The results of the calculations of the Kuder-Richardson reliability ratio r and the coefficient of concordance W were as follows:

$$r = 0.993$$
$$W = 0.397 \quad \text{with} \quad \chi^2_w = 8559$$

where the tabulated χ^2 value at the 0.01 percent significance level was 872. A high level of agreement was again indicated among subjects.

The average scores for the 771 pairs were calculated across the 28 subjects. These average scores are shown in Appendix 6 and were used directly as input to the nonmetric multidimensional scaling programme, KYST.

6.4 'Raw material by use' data

Data were collected to relate the level of use and the acceptability of input of the 40 raw materials to each of 15 categories of Thai food dishes. The acceptability data were used to derive a set of proximity measures for the raw materials which were later analyzed using multidimensional scaling. The 'level of use' data were used to substantiate axis definition of multidimensional spaces for the raw materials in Chapter 7.

6.4.1 The acceptability of use

More specifically this data relates to the acceptability of input of each raw material to certain categories of food dishes. With the aid of a staff member from Chulalongkorn University, 15 categories of food dishes were defined to be representative of almost all commonly eaten Thai food dishes. Each of the 15 categories, then, represented a number of specific food dishes, e.g. the category meat curry encompassed all types of meat based curries. A list of the 15 categories of food dishes is shown in Table 6.2. Descriptions of food dishes from each of the 15 categories are given in Appendix 7. In some cases, no exact English translation was available and the listed name serves more as a description of the category of food dish rather than a direct translation of the Thai name.

Table 6.2 The 15 Thai food dish categories used in the 'raw material by use' survey.

meat balls	vegetables and sauce
meat curry	fried vegetables
chop-suey	soup
sour soup	Thai salad
omelette	stewed pork
sweet and sour	porridge
hot soup	noodles
fried meat	

Each of 24 subjects was asked to judge the acceptability of the 40 raw materials as ingredients in each of the 15 categories of food dishes. The acceptability was judged on a scale of 1 to 5, where a larger score represented a higher acceptability. An English translation of the instructions given to each subject is given below:

> "You have been given a number of forms, each divided into squares. Down the left hand side of each form you will notice a list of food raw materials and along the top a list of classes of food dishes. Please look at each raw material in turn and work from left to right along the food dishes, judging how acceptable that raw material would be as an ingredient in each class of dish. Make your judgement on a scale of 1 to 5. If a raw material would be totally unacceptable as an ingredient in a particular class of food dish then place 1 in the corresponding square. Increasing scores from 1 to 5 should indicate increasing acceptability".

The agreement among subjects was again estimated by calculation of the reliability ratio r and the coefficient of concordance W.

$$r = 0.756$$
$$W = 0.598 \quad \text{with} \quad \chi^2_w = 8590$$

where a χ^2 value of 663 was required for significance at the 0.01 percent level. Hence, although the reliability ratio is not as high as with previous data, the result in combination with the coefficient of concordance still indicates agreement among judges.

A proximity matrix was generated for the food raw materials based on their common acceptabilities of input to the 15 categories of food dishes. The derivation of this proximity matrix was based on a formula used by Stefflre (191).

$$s_{ij} = \frac{r_i r_j' + r_i' r_j}{r_i r_i' + r_j' r_j}$$

where s_{ij} is the measure of proximity between raw materials _i_ and _j_.

r_i is the row vector of input acceptability scores for raw material _i_.

r_j is the row vector of input acceptability scores for raw material _j_.

r_i' and r_j' are the transposes of r_i and r_j respectively to column vectors.

6.4.2 The level of use

The same 24 subjects were asked to judge the levels that each raw material would commonly be used in each of the categories of food dishes. The level of input was judged on a scale of 0 to 3, where a score of 0 indicated that a raw material was never used in a particular category of food dish. Increasing scores from 1 to 3 showed increasing amounts of raw material used. Hence condiments and spices were generally given low scores of 1, while meats and vegetables, forming a major part of food dishes were given higher scores of either 2 or 3.

Average scores for level of use of each raw material were calculated from the 24 subjects across the 15 categories of food dishes. These scores, indicating the average level of use of each raw material, are shown in Table 6.3.

Table 6.3 Average level of use in food dishes for 40 raw materials.

Raw material	Average level of use	Raw material	Average level of use
Bamboo shoots	1.11	Banana	0.04
Cabbage	1.10	Mango (green)	0.31
Chinese cabbage	1.20	Papaya (green)	0.36
Chinese kale	0.85	Pineapple	0.41
Cucumber	1.10	Pumpkin	0.41
Green gourd	0.57	Watermelon	0.12
Mungbean curd	0.60		
Mungbean sprouts	0.86	Butter	0.12
Peanut	0.47	Cheese	0.08
Rice	0.63	Chicken egg	0.96
Rice noodle	0.43	Coconut cream	0.46
Shallots	0.64	Duck egg	0.94
String beans	1.12	Milk	0.03
Swamp cabbage	1.06	Sweetened condensed milk	0.01
Beef	1.54		
Chicken	1.67	Chilli pepper	1.20
Crab	0.97	Coriander	0.90
Duck	1.03	Garlic	0.92
Hog's liver	1.26	Sugar	0.87
Pork	1.95		
Serpent head fish	1.07		
Shrimps	1.76		
Striped mackerel	0.81		

6.5 Food dish similarity data

Data showing the relative similarities of 20 food dishes was collected with the object of determining the most important dimensions of Thai food dishes. Similarity was interpreted as substitutability in the same way as for the raw material similarity survey. The food dishes, shown in Table 6.4, included representatives of all of the 15 categories listed in Table 6.2. A description of each dish is given in Appendix 7.

Table 6.4 The 20 food dishes used in the food dish similarity survey.

fish balls	fried beef with kale
beef curry	fried beef with oyster sauce
chicken curry	fish with green vegetables and sauce
chop suey	fried pork with green snap beans
shrimp sour soup	green gourd and pork soup
plain omelette	cucumber salad
sweet and sour fish	stewed pork with boiled egg and soy sauce
sweet and sour chicken	pork porridge
shrimp hot soup	pork noodles
fish hot soup	beef noodles

A list of 187 from the possible 190 pairs of food dishes was given to each of 27 subjects. The subjects were asked to judge the similarity of each pair of dishes on a scale from 0 to 10, where a larger score represented greater similarity. An English translation of the instructions for the questionnaire is given below:

> "You have been presented with a list of pairs of commonly eaten food dishes. Look at each pair carefully and judge how well one could substitute the other. Imagine yourself to be at a restaurant ordering one of the dishes. If this dish was not available then how suitable would the other dish in the pair be as a substitute. Make your judgement on a scale of 0 to 10. A score of 0 should indicate completely non-substitutable dishes. Increasing scores from 0 to 10 should indicate increasing acceptability of substitution of the dishes".

Once again, duplicate pairs were included in the list of pairs of dishes. The Spearman rank correlation coefficients as calculated from the scores of the duplicate pairs are shown below:

Repeat pair	ρ	ρ/SE_ρ
sweet and sour chicken - beef noodle	0.71	3.62
beef curry - fried beef with Chinese kale	0.65	3.31

This shows good repeatability.

The results of the calculations of the reliability ratio $\underline{r}$ and the coefficient of concordance $\underline{W}$ were as follows:

$$r = 0.988$$
$$W = 0.155 \quad \text{with} \quad \chi^2_w = 778$$

where a χ^2 value of 225 was required for significance at the 0.01 percent level. There was, therefore, agreement among the judges.

Average scores were calculated across the 27 subjects. These are shown in Appendix 6 and were used as input to the nonmetric multidimensional scaling programme, KYST.

6.6 Raw material and food dish acceptability

The relative acceptabilities of the 40 raw materials and the 20 food dishes were collected from two separate samples of students. The raw material data were obtained from the same sample of 28 subjects used in the raw material similarity and association surveys. The food dish data were collected from a separate sample of 30 students.

6.6.1 Raw material acceptability

The 28 subjects were asked to rate the acceptability of each of the 40 raw materials in food dishes in general. The judgement was made on a scale of 0 to 10, where a higher score represented greater acceptability. The agreement of the subjects was tested by calculation of the coefficient of concordance $\underline{W}$.

$$W = 0.232 \quad \text{with} \quad \chi^2_w = 253$$

where a χ^2 value of 46.9 was required for significance at the 0.01 percent level. There was, therefore, agreement among the subjects.

The acceptability scores were averaged over the 28 subjects. The rank order of acceptability of the raw materials, calculated from these average scores, is shown in Table 6.5. Lower ranks indicate greater acceptability.

Table 6.5 Rank order of raw material acceptability.

Raw material	Acceptability rank	Raw material	Acceptability rank
Shrimp	1	Mung bean curd	21
Chicken	2	Papaya (green)	22
Chicken egg	3	Pineapple	23
Crab	4	Bamboo shoots	24
Pork	5	Mung bean sprouts	25
Milk	6	Cabbage	26
Hog's liver	7	Sugar	27
Swamp cabbage	8½	Chilli pepper	28
Duck egg	8½	Cucumber	29
Chinese kale	10	Rice noodle	30
Striped mackerel	11	Serpent head fish	31½
Chinese cabbage	12½	Pumpkin	31½
Beef	12½	Banana	33
Green gourd	14	Peanut	34
Watermelon	15	Coriander	35
String bean	16	Sweetened condensed milk	36
Coconut cream	17	Garlic	37
Duck	18½	Shallots	38
Mango (green)	18½	Butter	39
Rice	20	Cheese	40

6.6.2 Food dish acceptability

The 30 subjects were asked to judge the acceptability of each of the 20 food dishes. The judgement was made on a scale of 0 to 10, where increasing scores showed increasing acceptability. The coefficient of concordance was calculated.

$$W = 0.221 \quad \text{with} \quad \chi^2_w = 126$$

where a χ^2 value of 49.6 was required for significance at the 0.01 percent level. There was, therefore, agreement among the subjects.

Average acceptability scores for each food dish were calculated across the 30 subjects. The rank order of acceptability of the dishes, derived from these scores, is shown in Table 6.6. Lower ranks indicate greater acceptability.

Table 6.6 Rank order of food dish acceptability.

Food dish	Acceptability rank	Food dish	Acceptability rank
Shrimp hot soup	1	Fried beef with oyster sauce	12
Beef noodles	2	Sweet and sour chicken	13
Fish with green vegetables and sauce	3	Fried pork with green snap beans	14
Fish balls	4	Sweet and sour fish	15
Chicken curry	5	Pork noodles	16
Stewed pork with boiled egg and soy sauce	6	Shrimp sour soup	17
Fried beef with kale	7	Chop suey	18
Beef curry	8	Pork porridge	19
Plain omelette	9	Cucumber salad	20
Fish hot soup	$10\frac{1}{2}$		
Green gourd and pork soup	$10\frac{1}{2}$		

6.7 Summary and conclusions

Data were collected in Thailand to relate raw materials and food dishes, using multidimensional scaling. A number of data collection methods were used to obtain differing measures of raw material and food dish proximity. Each survey was translated into Thai and administered with the help of Thai research assistants. Between 20 and 30 students from Bangkok universities were selected for each survey.

The surveys generally required each subject to make a judgement on the proximity (similarity or association) of pairs of stimuli, either raw materials or food dishes. Each survey was designed with the intention of obtaining judgements on all possible pairs of stimuli from each subject. In most cases some pairs were missing due to errors in design and typing. These were always less than 2 percent of the total number of possible pairs. Presentation of the full list of pairs of stimuli was considered preferable to some subset of pairs, due to the lack of information on the statistical ramifications of spatial configurations, resulting from the various methods for selections of such subsets. The requirement for a large number of judgements by each subject might have led to fatigue and disinterest but errors from these sources were reduced through selection of enthusiastic and willing students. Rank correlation coefficients were calculated from the scores for repeated pairs of stimuli, to estimate the level of repeatability of scoring and hence the errors arising from fatigue and disinterest. In all cases good repeatability was obtained.

The agreement among subjects was determined by calculation of Kendall's coefficient of concordance W and the Kuder-Richardson reliability ratio r. These measures indicated a high level of agreement in all surveys. The data from each survey were averaged across all subjects. The complete set of averaged data is shown in Appendix 6. These average scores were used to generate raw material and food dish spaces through the multidimensional scaling programme, KYST. These spaces firstly supplied information about the conceptions of the Thai consumer concerning the use of raw materials in food dishes. Secondly, metric data were derived from the spatial configurations for maximizing acceptability of food raw material combinations selected in the linear programming model.

CHAPTER 7

MULTIDIMENSIONAL SCALING ANALYSES

The objective of this stage of the research was to derive a linear function relating raw materials to food dish acceptability. Nonmetric multidimensional scaling was chosen as a technique to derive metric scale values for the raw materials and food dishes which might be used in this function. For this purpose a number of different methods of data collection were employed in Thailand to obtain proximity measures for both the raw materials and food dishes. These data were as follows:

1. Raw material similarities - showing the relative substitutabilities of pairs of the 40 raw materials.
2. Raw material association - showing the relative acceptabilities of pairs of the raw materials in association in the same food dish.
3. 'Raw material by use' in food dishes - showing the acceptability of each of the 40 raw materials as an ingredient in each of 15 categories of food dish.
4. Food dish similarities - showing the relative similarities of pairs of 20 Thai food dishes.

Each set of data was scaled in 5 through to 1 dimensions using the nonmetric multidimensional scaling programme, KYST. The point of 'elbowing' in the plot of stress versus dimension together with a graphical method described by Spence and Graef (187) were used to choose the underlying dimensionality of the data. Plots of the items (raw materials or food dishes) were obtained in the space of the chosen dimensionality.

In each case, attempts were made to identify the axes of the spatial configuration. Axis identification was done either objectively by correlation with external information or subjectively using the prior knowledge of the researcher. In all cases the configuration of items was sensible within the context of the collected data.

Although the separate spaces of raw materials and food dishes proved interesting in interpretation, there was no means of tying the two together into a single linear function as required for the linear programme. To this end, an unfolding analysis was performed on the 'raw material by use' data in an attempt to display the raw materials and food dishes in the same multidimensional space. Unfortunately the solution to this analysis was degenerate.

A further attempt was made to provide a common basis for the raw materials and food dishes by locating an ideal point in a raw material space. This point was defined as representing the optimum combination of raw material properties required in a food dish. Although three multidimensional spaces were derived, only the one obtained from the similarity measures showed spatial dimensions which were related solely to the raw material properties. The spaces derived from the association and 'raw material by use' data were related to both the properties of the raw materials and the characteristics of the food dishes in which the raw materials are commonly used. Hence, the space derived from the similarities measures was chosen as the basis for location of the ideal point. The averaged scores for the general use of the 40 raw materials in Thai food dishes provided the basis for ideal point location.

7.1 The application of multidimensional scaling

All multidimensional scaling analyses were performed using the computer programme, KYST (105), and the Burrough's B6700 computer. KYST was chosen because of its versatility in use and robustness against sub-optimal solutions. It is an amalgamation of two well known and proven programmes, TORSCA 9 and M-D-SCAL 5M. It gives the user a number of options, both in the input of data, its analysis and the output of results. Some of these options are described below:

1. It gives the choice of 5 methods for producing a starting configuration.
2. It has 2 separate formulae for stress calculation, depending on the form of the data and the type of analysis required.

3. It allows for splitting of the data into sublists and performs regressions on each list.
4. It performs unfolding analyses.
5. It permits the user to obtain solutions in a number of Minkowski metrics.
6. It gives several options on output including a history of calculations showing the progress of the iterative numerical calculation and a number of plots, such as the spatial configuration of points, distances and fitted distances versus data and stress versus dimension.

These are only a few of the great many options available. Fortunately, the user is not obliged to select from each option. Wherever several alternative possibilities are available, one is always selected to be the 'standard' or 'default' choice. In the absence of any indication from the user, the programme uses these standard choices. (Further description of KYST is given in the computer operations manual (105).)

Multidimensional scaling analyses were performed on the data obtained from the surveys in Thailand. These data were basically of two types. Firstly, proximity measures of the raw materials and food dishes including association, similarity and derived similarity. The derived similarities were calculated from the 'raw material by use' survey using Stefflre's method (191). The second type of data was a rectangular matrix showing the acceptability of the 40 raw materials in 15 classes of food dish. The method required to display the raw materials and classes of food dish in the same spatial configuration was unfolding analysis. Further description of this analysis is given in Section 7.7.

All scaling analyses of the proximity matrices were performed using the Minkowski-2 metric, i.e., in Euclidean space. The data were prepared on cards in the form of an upper triangular matrix with missing diagonal. Solutions were obtained in 5 through to 1 dimensions according to the control statements shown in Figure 7.1.

Card number	Card description
1	TORSCA
2	UPPERHALFMATRIX
3	DIAGONAL=ABSENT
4	PRE-ITERATIONS=3
5	DIMMAX=5,DIMMIN=1
6	COORDINATES=ROTATE
7	ITERATIONS=50
8	PLOT=SCATTER=NONE
9	PLOT=CONFIGURATION=NONE
10	DATA,REGRESSION=DESCENDING
11	RAW MATERIAL SIMILARITY
12	40 1 1
13	(5X,15F5.1,/,5X,15F5.1,/,5X,10F5.1)
	Data matrix
14	COMPUTE
15	STOP

Figure 7.1 KYST control cards for scaling solutions in 5 through to 1 dimensions

Card 1 indicates that the initial configuration was generated using the TORSCA procedure. Cards 2 and 3 show that the data was in the form of an upper half matrix with the diagonal absent. Card 4 states that a maximum of 3 iterations were used in the TORSCA procedure. Card 5 shows that the scaling was done from a 'dimension maximum' of 5 down to a 'dimension minimum' of 1. Card 6 specifies that the final configuration for each dimensionality was to be rotated to principal components. Card 7 states that no more than 50 iterations were to be performed in any single scaling solution. Cards 8 and 9 specify that no plots either of distances versus data or of the final spatial configuration were required. Card 10 indicates that the regression of distances on data values were to be 'monotone descending' regression. Card 11 is a title card.

Card 12 indicates the number of rows (and columns) of each matrix (namely, 40), the number of values provided for each matrix entry (namely, 1), and the number of such matrices included in the data deck (namely, 1). Card 13 describes the format of the input data. All other options available from KYST were chosen by the default procedure.

The stress values in each dimension, from 5 through to 1, were determined and a plot of stress versus dimension obtained. The point of 'elbowing' in this plot was used in the choice of dimensionality of the final configuration. To further substantiate the choice of dimensionality the method presented by Spence and Graef (187) was used. They described a graphical procedure for determining the underlying dimensionality of an empirically obtained matrix of proximities, which may be applied to matrices of order 12 to 36 inclusive. The procedure for 36 points was used as an approximation for the determination of the underlying dimensionality of the matrices of 40 raw materials.

A further scaling analysis was performed in the chosen dimensionality to obtain plots of distance and fitted distances versus data and of the spatial configuration of points. The control cards used for this procedure were the same as described in Figure 7.1, but with the deletion of cards 8 and 9.

7.2 Raw material similarities analysis

The averaged data of raw material similarities were analyzed using KYST. Scaled solutions were obtained in 5 through to 1 dimensions with a stress versus dimension plot as shown in Figure 7.2. An 'elbow' in this plot occurs at 3 dimensions. The choice of 3 dimensions for the final configuration was supported by Spence and Graef's (187) graphical method for determining underlying dimensionality. A 3-dimensional configuration of the 40 raw materials was therefore obtained. The scale values are shown in Table 7.1 and the plots shown in Figure 7.2.

Table 7.1 Scale values for the raw material similarity space.

Raw material	Scale values		
	Dimension 1	Dimension 2	Dimension 3
Bamboo shoots	0.476	-0.446	0.184
Cabbage	0.479	-0.490	0.085
Chinese cabbage	0.597	-0.351	-0.149
Chinese kale	0.518	0.532	-0.024
Cucumber	0.608	-0.349	0.159
Green gourd	0.635	-0.501	-0.236
Mungbean curd	-0.344	-0.097	-0.699
Mungbean sprouts	0.401	-0.382	-0.342
Peanut	0.112	0.264	-0.890
Rice	-0.390	0.370	0.901
Rice noodle	-0.478	0.240	1.169
Shallots	0.721	0.333	-0.915
Snap beans	0.500	-0.463	-0.189
Swamp cabbage	0.592	-0.385	-0.062
Banana	0.433	0.765	0.752
Mango (green)	0.898	0.528	0.477
Papaya (green)	0.799	-0.412	0.524
Pineapple	0.791	0.254	0.737
Pumpkin	0.455	-0.104	0.395
Watermelon	0.769	0.301	0.902
Beef	-0.779	-0.459	0.313
Chicken	-0.741	-0.453	-0.112
Crab	-0.762	-0.562	0.227
Duck	-0.735	-0.691	-0.247
Hogs liver	-0.706	-0.562	-0.233
Pork	-0.736	-0.452	-0.010
Serpent head fish	-0.676	-0.671	0.120
Shrimps	-0.611	-0.518	-0.043
Striped mackerel	-0.814	-0.707	0.118
Butter	-0.736	0.909	-0.224
Cheese	-0.717	0.883	-0.495
Chicken egg	-0.724	-0.101	0.009
Coconut cream	-0.411	1.157	-0.251
Duck egg	-0.815	-0.120	-0.053
Milk	-0.633	0.951	-0.323
Sweetened condensed milk	-0.593	1.151	-0.102
Chilli pepper	1.136	0.266	-0.521
Coriander	0.949	-0.167	-0.507
Garlic	0.835	0.604	-0.545
Sugar	-0.328	1.150	0.270
Ideal point	0.000	0.087	0.022

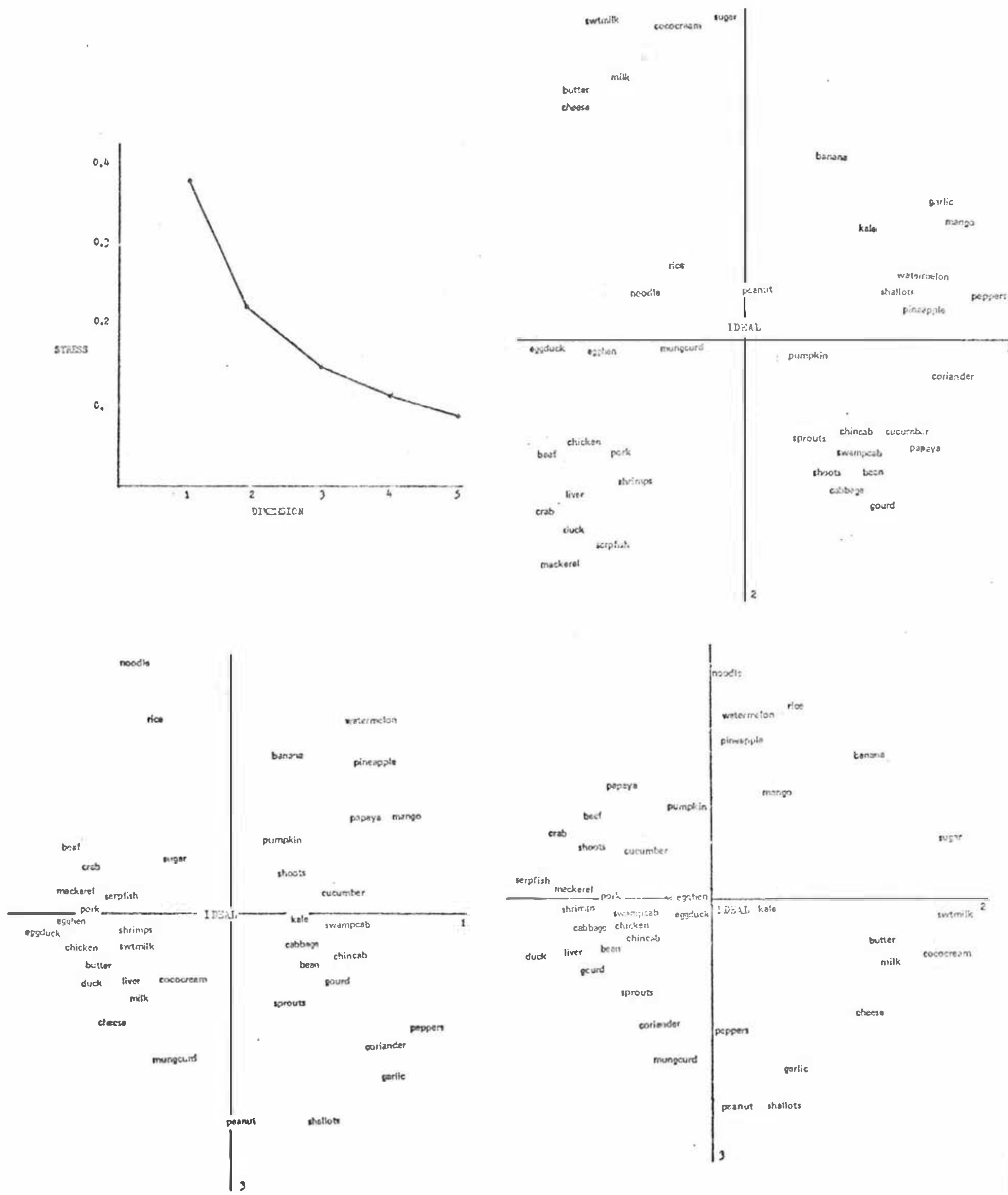

Figure 7.2 Plots for the raw material similarity space

7.2.1 Axis identification

Attempts were made to identify each of the 3 axes and to correlate the location of the raw materials on each axis with independent information.

The first axis was considered to be related to nutrition, ranging from low nutrition with chilli peppers to high nutrition with duck egg. The rank order of raw materials along this axis was correlated with the rank order of specific nutrients in these raw materials, namely protein, calories and the product of protein and calories. The Spearman rank correlation coefficients are shown below:

Correlation	ρ	ρ/SE
with protein	0.71	4.41
with calories	0.63	3.95
with protein x calories	0.75	4.70

All rank correlation coefficients are significant at the 0.01 percent level, hence indicating a relationship between axis 1 and nutrition or more specifically protein and calories.

The second axis was identified as 'level of use'. That is, the quantity of raw material which is normally used in food dishes. The rank order of the 'level of use' of the raw materials was determined from the averaged data from the 'raw material by use' survey. The rank order of the raw materials along axis 2 was determined and correlated against the 'level of use' ranks. The Spearman rank correlation coefficient was 0.68 or 4.27 times its standard error, i.e.,

$$\rho = 0.68 \quad \text{where} \quad \rho = 4.27 \text{ SE}$$

Axis 2 extends from low level of use with sweetened condensed milk and sugar to high level of use with striped mackerel and serpent head fish.

The third axis was less clear in its interpretation. It was labelled strength of flavour. Raw materials such as noodles, watermelon and rice contribute very little to the flavour of food dishes. Cheese, peanuts, mungbean curd, garlic and shallots at the other end of the scale have far more intense flavour, which carry over into dishes containing these raw materials. No independent scale of flavour strength was available for correlation with axis 3.

7.2.2 The clustering of raw materials

A number of clusters of raw materials exist in the spatial configuration. (For scale values see Table 7.1). Their existence helped to substantiate the model, both through the location of raw materials relative to each other within a single cluster and the relative locations of the different clusters throughout the space.

The first cluster comprises meat or meat-like raw materials. These can be divided into two groups.

Meat group 1	Meat group 2
mungbean curd	beef
chicken	crab
duck	serpent head fish
hog's liver	striped mackerel
pork	chicken eggs
shrimps	
duck eggs	

The main factor differentiating between the two groups is strength of flavour, with group 2 being generally stronger than group 1. The difference is not very distinct in some cases, for example chicken eggs and duck eggs. The cluster of raw materials as a whole is generally one of high nutrition, medium flavour and high on the scale of level of use.

The second cluster is one of dairy products and vegetable milks including butter, cheese, sweetened condensed milk, milk and coconut cream. Of particular note in this group is the proximity of cow's milk to coconut cream which might indicate the willingness of Thais to accept the substitution of coconut cream by cow's milk in certain dishes, for example in curries. The location of this group of dairy products in the 3-dimensional space indicates them to be particularly nutritious, high in flavour but used at very low levels.

A cluster of vegetable raw materials can also be divided into two groups as follows:

Vegetable group 1	Vegetable group 2
cabbage	bamboo shoots
Chinese cabbage	cucumber
green gourd	papaya
mungbean sprouts	pumpkin
snap beans	
swamp cabbage	
coriander	
Chinese kale	

The two groups differ mainly in their strength of flavour, with the materials in group 1 having slightly stronger flavours than group 2. Generally, the cluster of vegetables is medium to low on nutrition, medium flavour and tends to have a medium to high level of use.

The fourth cluster includes only fruits - banana, mango, pineapple and watermelon. The only other raw material which might have been classed as a fruit is papaya. In its green form papaya is often used in salads and hence has a higher level of use in food dishes than other fruits. It is therefore classed with the vegetables. The fruit cluster is low on nutrition, medium to low on flavour and has a low level of use in food dishes.

Condiments, spices and herbs, comprise the fifth cluster - peanuts, shallots, chilli pepper and garlic. This cluster is generally low on nutrition and has a very high level of flavour which probably accounts for the low level of use of its raw materials.

The final cluster includes rice, rice noodle and sugar. Rice and rice noodle exist very close to each other in the spatial configuration and are well removed from most other raw materials. This is probably due to their functions as bases for food dishes rather than ingredients in them. They are both regarded as medium to high on nutrition, low on flavour and at a medium level of use. Sugar is similar to rice and rice noodle with regard to nutrition, but is very much lower on level of use and stronger in flavour.

7.3 Raw material association analysis

The averaged data showing the relative acceptabilities of pairs of raw materials in combination, were analyzed using KYST. Solutions were derived in 5 through to 1 dimensions and a plot of stress versus dimensionality obtained as shown in Figure 7.3. The 'elbow' in this plot occurs at 3 dimensions, hence indicating that 3 dimensions are sufficient to display the raw materials. The choice of 3 dimensions was supported by Spence and Graef's (187) graphical method of determining underlying dimensionality. A 3-dimensional configuration of the 40 raw materials was obtained using KYST. The scale values are shown in Table 7.2 and the configuration in Figure 7.3.

7.3.1 Axis identification

In this space, the interpoint distances are proportional to the acceptability of two raw materials in association in the same food dishes. Hence, the axes of the space tend to be directly related to the types of food dishes made from the raw materials and only indirectly related to the raw material properties. In interpreting the axes, raw materials were related to the types of food dishes in which they are most commonly used. The axes were then identified according to the characteristics of these food dishes.

The first axis is related to the 'generality of use' of the raw materials. The axis ranges from raw materials such as garlic, Chinese kale and striped mackerel which are used in a wide variety of dishes, through mango, papaya, watermelon, coconut

Table 7.2 Scale values for the raw material association space.

Raw materials	Scale values		
	Dimension 1	Dimension 2	Dimension 3
Bamboo shoots	-0.442	0.008	0.523
Cabbage	-0.188	-0.220	-0.545
Chinese cabbage	-0.691	-0.319	-0.220
Chinese kale	-0.736	-0.303	-0.203
Cucumber	-0.334	0.105	-0.722
Green gourd	-0.706	-0.005	-0.742
Mungbean curd	-0.322	0.799	-0.461
Mungbean sprouts	-0.541	0.388	-0.536
Peanut	0.590	-0.116	0.758
Rice	-0.061	0.338	0.343
Rice noodle	-0.501	0.744	0.243
Shallots	-0.306	-0.202	1.036
Snap bean	-0.548	-0.403	-0.484
Swamp cabbage	-0.648	-0.163	-0.279
Banana	1.642	-0.618	0.025
Mango	0.257	-1.156	0.887
Papaya	-0.077	-1.145	-0.670
Pineapple	0.589	-1.075	0.136
Pumpkin	0.375	-0.195	-0.621
Watermelon	0.952	-1.393	-0.668
Beef	-0.173	-0.057	0.164
Chicken	-0.089	0.314	0.009
Crab	-0.688	0.259	0.218
Duck	-0.242	0.723	0.226
Hogs liver	-0.484	0.365	-0.208
Pork	-0.200	0.087	-0.115
Serpent head fish	-0.531	-0.607	0.114
Shrimps	-0.131	-0.081	-0.040
Striped mackerel	-0.746	-0.482	0.618
Butter	1.062	0.772	0.171
Cheese	1.259	0.719	-0.418
Chicken egg	0.058	0.455	-0.133
Coconut cream	0.563	0.195	0.459
Duck egg	0.075	0.576	-0.252
Milk	1.433	0.702	0.133
Sweetened condensed milk	1.706	0.509	-0.027
Chilli pepper	-0.432	-0.318	0.531
Coriander	-0.648	0.379	0.706
Garlic	-0.842	-0.082	0.053
Sugar	0.748	-0.100	0.003

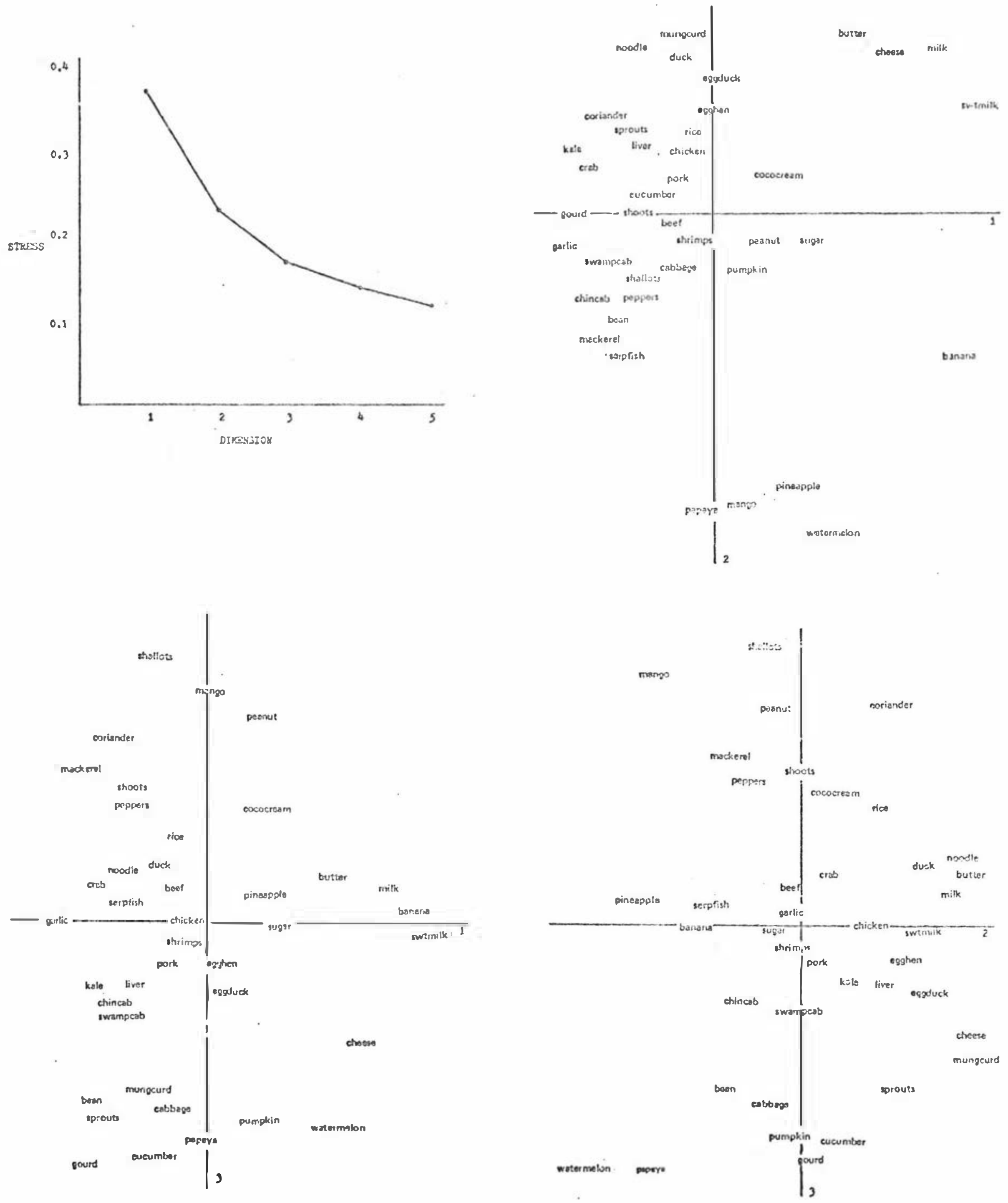

Figure 7.3 Plots for the raw material association space

cream, sugar, pineapple and pumpkin which are used in a more limited range of food dishes. Finally, at the far end of the axis are the dairy products and banana which are seldom, if ever, used in food dishes of any kind.

The bunching of 27 of the 40 raw materials at the widespread usage end of the axis, indicates the high level of acceptability of most raw materials in a wide variety of dishes. That is, there is a lack of specificity of most raw materials for food dishes. The results of the 'raw material by use' survey support this conclusion showing a large number of the raw materials to be highly acceptable in most of the 15 classes of food dish. For example, most meats and vegetables are acceptable as ingredients in a variety of dishes ranging from Thai salads to hot curries and sour soups. Included in the group of 13 raw materials which are not widely used are the fruits and dairy products. Fruits are seldom used in Thai food dishes and are quite specific to salads. Dairy products are seldom used in Thai cooking, mainly due to their unfamiliarity.

The second axis shows a gradation in the consistency of the dishes in which the raw materials are used. These range from liquid, soft textured or juicy, through to firm textured and dry dishes. Mungbean curd, noodles, duck eggs and chicken eggs are commonly used in soups and omelettes which are of a liquid or soft consistency. Towards the centre of the axis are the raw materials which are used in both soft and firm textured dishes, for example, beef, pork, green gourd and swamp cabbage. Fruits, including papaya, mango, watermelon and pineapple are quite specific to the more firm textured dishes, such as salads.

The third axis shows a relationship to the use of the raw materials in strong flavoured dishes. Raw materials such as shallots, mangoes, peanuts and coriander at one end of the axis are almost invariably associated with strong flavoured dishes, including Thai salads, curries and sour soups. The large group of raw materials in the centre of the axis includes most of the meats and the more commonly used vegetables. The meats follow a gradation from beef which is used mostly in strong flavoured dishes, through to chicken and pork which are used in strong and weak flavoured dishes. At the other end of the scale are papaya, watermelon, green gourd and cucumber which in themselves have weak flavours and are associated with bland flavoured food dishes.

7.3.2 Raw material clusters

The widespread usage of most Thai raw materials in a variety of food dishes is supported by this spatial configuration. A major cluster exists along the 'generality of use' axis, comprising 27 of the 40 raw materials. The 13 remaining raw materials, including most of the fruits, peanuts, sugar, coconut cream and the dairy products, represent those raw materials which have a more restricted use. Either they are used quite specifically in certain dishes such as the use of fruits in Thai salads or fried vegetables, or they are rarely, if ever used, as in the case of the dairy products.

The non-specificity of most raw materials could prove useful in the design of nutritional food dishes. Having defined a set of raw materials with acceptable combined properties, these raw materials could be used as the basis for most types of Thai food dishes without fear of rejection.

7.4 'Raw material by use' analysis

The matrix of proximities, derived using Stefflre's method (191), was analyzed by KYST. Scaled solutions were obtained in 5 through to 1 dimensions. The stress versus dimension plot is shown in Figure 7.4. The point of 'elbowing' in this plot, together with Spence and Graefs' graphical method again indicated 3 dimensions to be sufficient to display the raw materials. The scale values obtained from KYST are shown in Table 7.3 and the 3-dimensional plots in Figure 7.4.

Table 7.3 Scale values for the 'raw material by use' space.

Raw materials	Scale values		
	Dimension 1	Dimension 2	Dimension 3
Bamboo shoots	0.468	0.200	0.429
Cabbage	0.453	-0.107	0.469
Chinese cabbage	0.735	-0.172	0.494
Chinese kale	0.418	-0.686	0.524
Cucumber	0.577	0.464	-0.378
Green gourd	-0.180	-0.272	0.737
Mungbean curd	-0.483	-0.293	-0.135
Mungbean sprouts	0.352	-0.469	0.296
Peanut	-0.281	0.383	-0.549
Rice	-0.366	-0.065	-0.581
Rice noodle	-0.253	-1.104	-0.008
Shallots	0.156	0.708	-0.153
Snap bean	0.455	0.411	0.355
Swamp cabbage	0.357	0.041	0.507
Banana	-1.654	-0.104	-0.099
Mango	-0.773	0.758	-0.504
Papaya	-0.851	0.210	-0.090
Pineapple	-0.825	0.222	0.357
Pumpkin	-0.671	-0.137	0.459
Watermelon	-1.349	0.107	0.145
Beef	0.975	-0.023	0.025
Chicken	1.248	-0.123	-0.049
Crab	0.325	-0.182	-0.262
Duck	0.386	-0.375	0.001
Hogs liver	0.799	-0.397	-0.106
Pork	1.364	-0.198	-0.214
Serpent head fish	0.498	0.596	0.290
Shrimps	1.133	0.201	-0.032
Striped mackerel	-0.101	0.595	-0.092
Butter	-1.139	-0.226	0.021
Cheese	-1.467	-0.216	-0.034
Chicken egg	0.520	-0.607	-0.723
Coconut cream	-0.410	0.789	0.416
Duck egg	0.374	-0.547	-0.658
Milk	-1.592	-0.093	-0.061
Sweetened condensed milk	-1.685	-0.150	-0.083
Chilli pepper	0.964	0.640	-0.053
Coriander	0.590	-0.046	-0.477
Garlic	0.650	0.057	-0.007
Sugar	0.464	0.211	-0.176

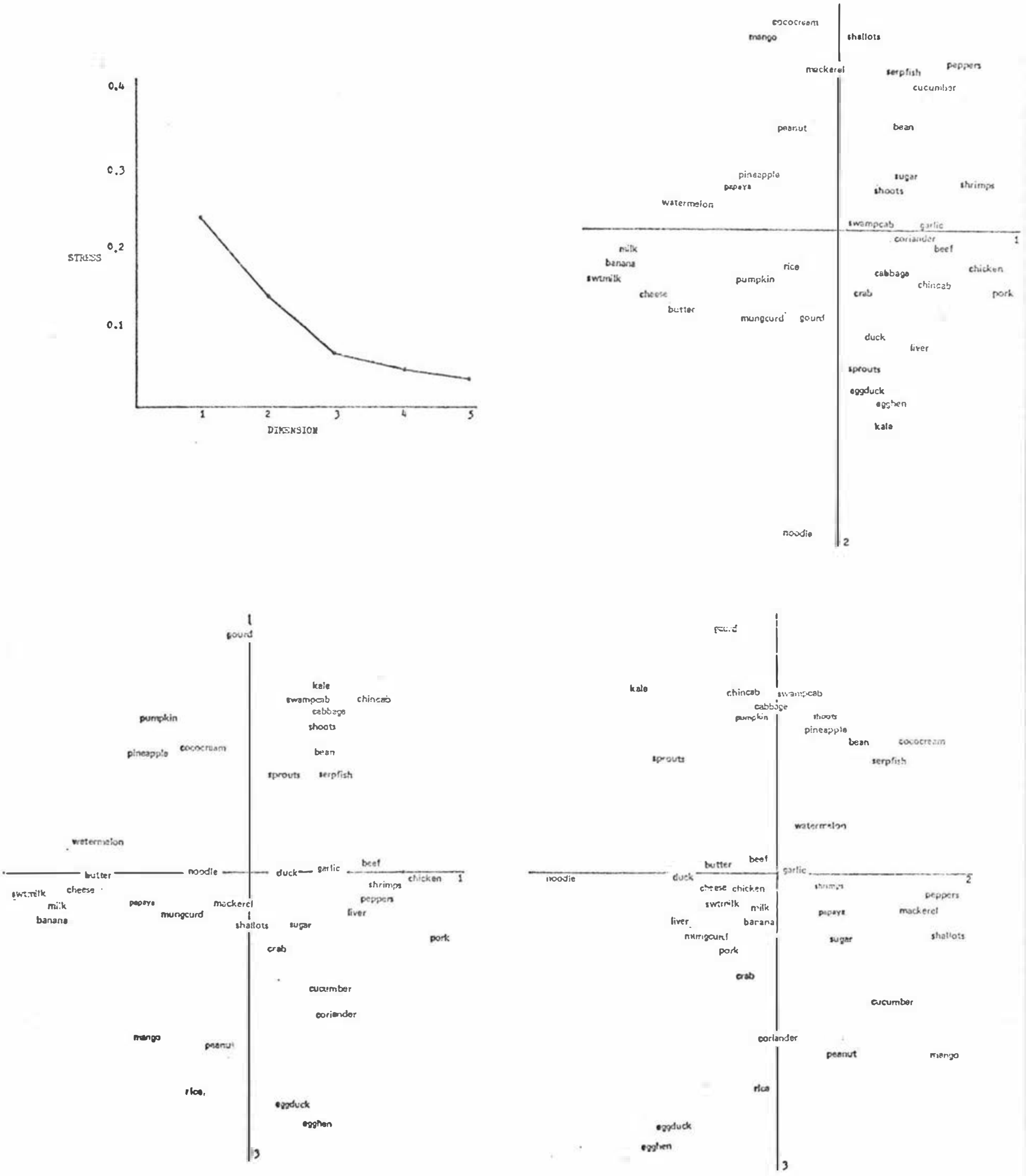

Figure 7.4 Plots for the 'raw material by use' space

7.4.1 Axis identification

The proximity measures were derived from the vectors of raw material acceptability in the 15 categories of food dish. The degree of similarity of these vectors is dependent on two factors, firstly the common usage of the raw materials and secondly the substitutability of the raw materials. On the one hand, two extremely dissimilar raw materials might be acceptable in the same food dishes and hence have similar acceptability vectors, and a high proximity measure. On the other hand, two raw materials which are almost identical, to the extent of being highly substitutable, would also have similar acceptability vectors and a high proximity measure. Axis identification is therefore slightly confused because of the dependence of raw material location on both the raw material properties and the characteristics of the dishes in which these materials are used.

Axis 1 shows a high correlation with the level of use of the raw materials. A Spearman rank correlation coefficient was calculated between the order of raw materials on axis 1 and the average level of use of these raw materials as shown in Table 6.3.

$$\rho = 0.95 \quad \text{with} \quad \rho/SE = 5.94$$

This axis ranges from pork, chicken and shrimps which have high levels of use, through to milk, banana, cheese and sweetened condensed milk which are seldom used in Thai food dishes.

The second axis shows a good relationship to the types of dishes in which the raw materials are used and in particular the strength of flavour of these dishes. At one end of the axis are coconut cream, mango, shallots and chilli peppers, all of which are used almost exclusively in stronger flavoured dishes such as curries and some Thai salads. Meats and most of the common vegetables are located midway along the axis, hence showing their versatility of use in weak and strong flavoured dishes. Eggs and noodles occur at the weak flavoured end of the axis and are used predominantly in soups and bland noodle based dishes.

Axis 3 appears to again be related to the food dishes in which the raw materials commonly occur and in particular whether these dishes are meat or vegetable based. At one end of the axis are most of the common vegetables including cabbage, green gourd, Chinese cabbage, swamp cabbage and Chinese kale. All of these raw materials are more commonly seen in dishes containing predominantly vegetables and hence having strongly vegetable characteristics, for example, fried vegetables and chop sueys. Progression along the axis goes from other vegetables such as snap beans and pumpkin, to fish, meats and finally eggs and rice.

7.5 Comparison of raw material spaces

The results of the three different methods used to derive spatial configurations of the 40 raw materials, emphasize the importance of the form of the raw data in the interpretation of the final configurations. Although all three spatial configurations were obtained from proximity measures of the raw materials, these measures of proximity were derived from different psychological spaces.

In the case of the similarities data, the subjects were asked directly to judge the similarity of the raw materials in terms of their relative substitutabilities in food dishes. The dimensions of the spatial configuration derived from these measures of proximity were clearly related to the properties of the raw materials which the subjects considered to be important in the choice of these raw materials as ingredients in food dishes. The axes of this space were identified as nutritive value, level of use and strength of flavour of the raw materials.

The second raw material space was obtained from proximity measures related to the degree of acceptability of pairs of raw materials in association in the same food dish. Here, there was a tendency for the subjects to judge the acceptability of the pairs of raw materials in terms of the food dishes in which they commonly occur together, rather than their individual properties. The dimensions of this spatial configuration therefore described the characteristics of the food dishes in which the raw materials are commonly used, rather than the raw material properties. The axes were identified as the 'generality of use' of the raw materials in food dishes, the strength of flavour of the food dishes and the consistency of the food dishes in which the raw materials are commonly used.

The proximity measures derived from the 'raw material by use' data were dependent on two factors. Firstly, the similarity of the raw materials and secondly, the extent to which the raw materials occur in the same food dishes. A high proximity measure could be obtained for two similar or highly substitutable raw materials and for two dissimilar or non-substitutable raw materials which occur frequently together in the same food dish. The spatial configuration of the raw materials was, therefore, a function of both similarity and association. The axes were identified as the level of use of the raw materials, the strength of flavour of the food dishes in which the raw materials are commonly used and the basis of the food dishes, either meat or vegetables.

The three different types of proximity measures for the 40 raw materials therefore resulted in spatial configurations with different interpretations. The spaces derived from the association and 'raw material by use' data resulted in spatial dimensions which were related to both the properties of the raw materials and to the characteristics of the food dishes in which the raw materials are commonly used. In these cases the interpretation of the axes was confused by this interaction. Only the space derived from the similarity measures was directly related to the raw material properties.

7.6 Food dish similarities analysis

The averaged food dish similarities were analyzed using KYST. Scaled solutions were obtained in 5 through to 1 dimensions. A plot of stress versus dimensionality is shown in Figure 7.5.

The point of 'elbowing' in this plot was again at 3 dimensions. The 3-dimensional scale values of the food dishes are shown in Table 7.4 and the plots in Figure 7.5.

7.6.1 Axis identification

An attempt was made to define the axes of the 3-dimensional spatial configuration in terms of obvious physical properties of the food dishes. The axis 1 was identified as 'level of meatiness', that is the predominance of meat components in the food dishes. At the 'non-meaty' end of the axis are beef noodles, pork noodles and chop suey, all of which may be described as more vegetable than meaty in character. On the other hand, fish balls, beef curry and fried beef with oyster sauce are obviously based on meat.

Axis 2 shows a gradation in the strength of flavour of the dishes from the weak flavour of porridge, chop suey and omelette, to the very strong flavours of shrimp hot soup, shrimp sour soup and sweet and sour fish.

Axis 3 was considered to be related to the consistency of the dishes, ranging from thin or runny through to solid or firm in texture. The thin or runny dishes include green gourd and pork soup, fish hot soup and pork noodles, all of which have a high proportion of water in them. The solid dishes are cucumber salad, fried beef with kale and fish with green vegetables and sauce.

The food dish space therefore has axes in common with those of the raw material spaces derived from the measures of association and 'raw material by use'. The raw material association space has two axes which are related to food dish characteristics - consistency and strength of flavour. The two axes of the 'raw material by use' space which are related to food dish characteristics are meatiness and strength of flavour.

Table 7.4 Scale values for the food dish space.

Food dish	Scale values		
	Dimension 1	Dimension 2	Dimension 3
Fish balls	-0.632	0.313	-0.089
Beef curry	-0.824	-0.493	0.123
Chicken curry	-0.438	-0.403	-0.040
Chop suey	0.524	0.780	0.142
Shrimp sour soup	-0.222	-0.720	-0.032
Plain omelette	-0.134	0.554	-0.343
Sweet and sour fish	0.713	-0.705	-0.180
Sweet and sour chicken	0.791	-0.487	-0.385
Shrimp hot soup	-0.155	-0.651	-0.261
Fish hot soup	0.240	-0.181	-0.769
Fried beef with kale	-0.242	0.233	1.152
Fried beef with oyster sauce	-2.011	-0.157	-0.176
Fish with green vegetables and sauce	-0.144	-0.127	0.932
Fried pork with green snap beans	0.271	0.193	0.365
Green gourd and pork soup	-0.055	0.357	-0.921
Cucumber salad	0.570	-0.560	0.642
Stewed pork with boiled egg and soy sauce	0.481	0.503	0.416
Pork porridge	-0.544	1.177	-0.226
Pork noodles	0.852	0.019	-0.379
Beef noodles	0.959	0.356	0.024
Ideal point	-0.087	0.042	0.027

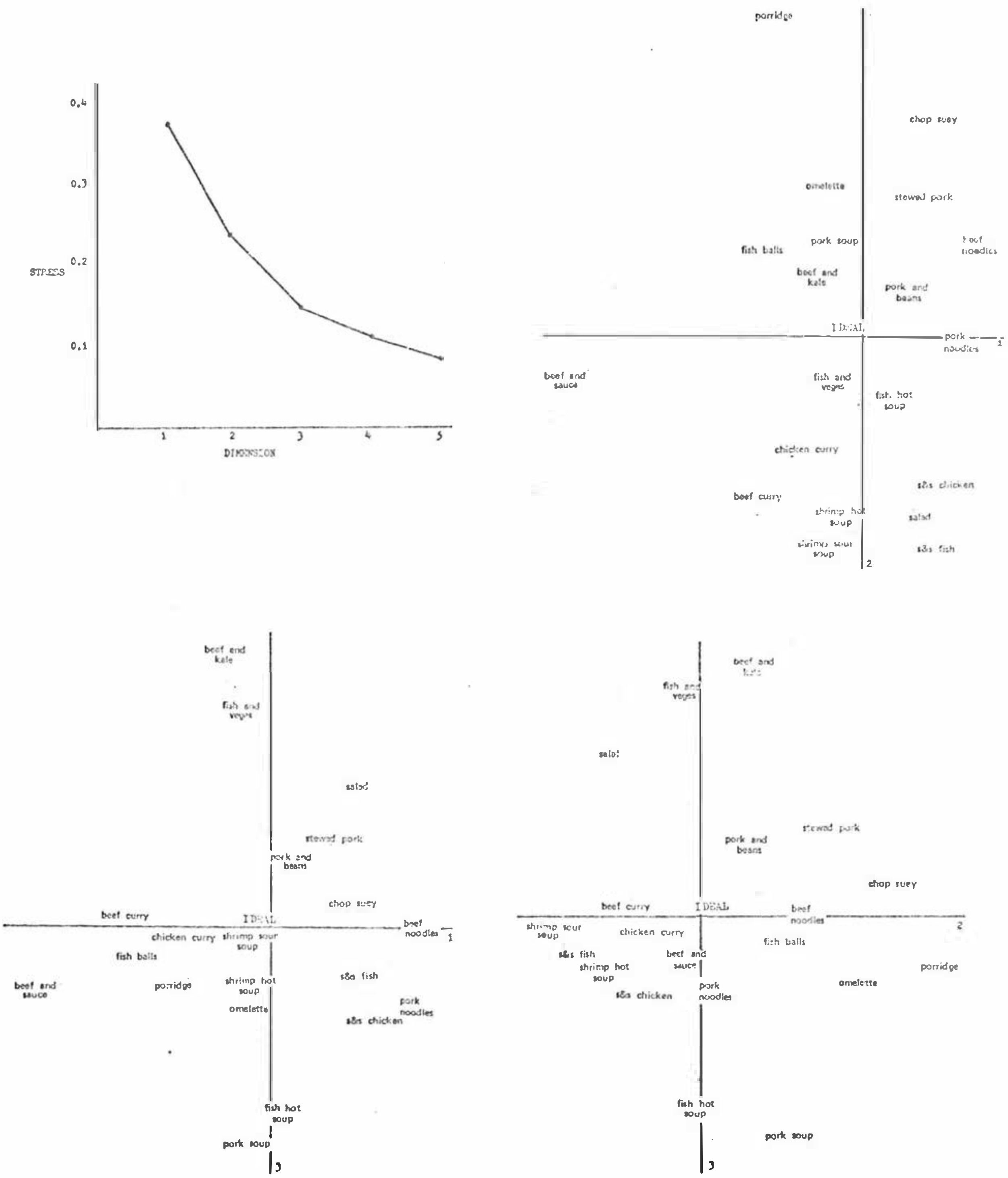

Figure 7.5 Plots for the food dish space

7.6.2 Food dish clusters

A number of small clusters of food dishes exist in the 3-dimensional spatial configuration. The existence of these clusters and the differences in food dishes between clusters can be explained in terms of the identified axes.

The first group consists of chicken curry, shrimp sour soup, shrimp hot soup and fried beef with oyster sauce. These dishes are all strong flavoured, with meaty characteristics. Slight differences occur in the consistency, with the sour soup and chicken curry being slightly thicker and bordering on the food dish pair of beef curry and fish with green vegetables and sauce.

Fish balls, pork porridge, green gourd and pork soup and omelette form another group which is quite meaty, weak flavoured and with a light or runny consistency. There is not a strong affinity between the members of this group. Fish balls have a firmer consistency while the soup has a far less meaty characteristic. The presence of omelette in this group, in spite of its lack of meat ingredients, is probably due to the high degree of association of eggs with meat which was found in the spatial configuration of raw materials based on their similarity measures.

Another group consists of fish hot soup, sweet and sour chicken and sweet and sour fish. These dishes are strong flavoured, non-meaty with a runny consistency. Pork noodles verges on this group but tends to be much weaker in flavour.

Cucumber salad and fried beef with Chinese kale exist separately in the spatial configuration and each is divorced from all other dishes, hence indicating quite unique characteristics. The cucumber salad is strong flavoured, non-meaty and with a solid consistency, unlike most other strong flavoured dishes which tend to be of a liquid consistency. Fried beef with Chinese kale is quite meaty, of a thick consistency with a fairly weak flavour. It is unlike most other meat dishes which are either strong flavoured and 'runny' such as curries, or weak flavoured and of a soft consistency, such as pork porridge and omelette.

The final group consists of chop suey, fried pork with green snap beans, stewed pork with boiled egg and soy sauce and beef noodles. These dishes are not very meaty, weak flavoured and are quite solid, except for beef noodles which is of a far more liquid consistency.

7.7 Unfolding analysis on the raw materials and food dishes

Separate raw material and food dish spaces were derived by various methods as described above. Although common axes existed in some of the raw material spaces and the food dish space there was no facility for a direct link between raw materials and food dishes. If a function relating the raw materials to food dish acceptability was to be derived then it was necessary to derive a joint multidimensional space of raw materials and food dishes. For this purpose, an unfolding analysis was performed on the averaged acceptability data from the 'raw material by use' survey, that is, the rectangular matrix showing the average acceptabilities of each of the 40 raw materials in each of the 15 categories of food dish (see Appendix 6). The KYST programme was again used for the unfolding analysis.

7.7.1 Organization for unfolding analysis

The complete input list required to perform an unfolding analysis on the matrix of raw materials by food dishes is shown in Figure 7.6.

Cards 1 to 4 have similar interpretations to those used for the normal multidimensional analysis (see Section 7.1). The analysis was performed using the TORSCA method to derive the initial configuration using 3 iterations. The solution was obtained in 3 spatial dimensions only, and the final configuration was rotated to principal components. Card 5 indicates that the

Card number	Card description
1	TORSCA
2	PRE-ITERATIONS=3
3	DIMMAX 3,DIMMIN 3
4	COORDINATES=ROTATE
5	SFORM2
6	SPLIT=BYROWS
7	REGRESSION=DESCENDING
8	CARDS
9	ITERATIONS=50
10	DATA,UPPERCORNERMATRIX
11	FOOD DISHES AND RAW MATERIALS
12	15 40 1 1
13	(5X,15F5.1,/,5X,15F5.1,/,5X,10F5.1)
	Data matrix
14	COMPUTE
15	STOP

Figure 7.6 KYST control cards for the unfolding analysis of raw materials and food dishes

stress formula 2 was used. KYST has two optional formulae for calculation of stress, where stress formula 1 is the default option used in most scaling analyses.

$$\text{STRESS} = \frac{\sum_{M=1}^{MM} (\text{DIST}(M) - \text{DHAT}(M))^2}{\sum_{M=1}^{MM} (\text{DIST}(M) - d_o)^2} \quad \ldots\ldots \quad (1)$$

Equation 1 shows the general formula for calculation of stress where d_o is equal to zero in stress formula 1 and the arithmetic average of the DIST values for stress formula 2. The writers of KYST (105) claim that if unfolding is to be done nonmetrically, it is in theory vital to use SFORM2 and to SPLIT BYROWS, as otherwise a meaningless zero-stress solution may be possible. Card 6 specifies that the data is to be split by rows and a separate regression performed on each row. Cards 7,8,9,10 and 11 have the same definitions as the equivalent cards in Figure 7.1. Card 12 specifies the number of rows (namely, 15), the number of columns (namely, 40), the number of values provided for each matrix entry (namely, 1) and the number of such matrices included in the data deck (namely, 1). Card 13 describes the format of the input data, followed by the card deck.

7.7.2 The unfolding solution

The present analysis failed to reach minimum stress after 50 iterations; the plots of distance and fitted distance versus the original data were flat; and a large number of points achieved the same coordinates in the 3-dimensional configuration. The problem was therefore considered to be degenerate. Hence, the final 3-dimensional configuration of raw materials and food dishes was meaningless, since random movement of the points would result in negligible changes in the value of stress.

Previous unfolding analysis by other workers have shown that the technique may not be entirely reliable. Green and Rao (70) and Green and Wind (72) reported unsatisfactory results,while Moskowitz (127) and Percy (141) reported quite good solutions. Kruskal has been quoted as suggesting that the seeming practical failure of unfolding analyses may be attributed to the need for many more points to be determined than in normal nonmetric multidimensional scaling and the lack of strength in the data to estimate this many parameters (141). Kruskal's explanation is supported in the present analysis where a matrix of 15 food dishes by 40 raw materials (or 600 data elements) was used to locate 55 points, as compared to the use of 780 data elements to locate 40 points in the corresponding multidimensional scaling analysis. It appears, therefore, that the extension from multidimensional scaling to unfolding analysis requires more research before it can be applied to practical problems with any certainty or confidence in the results.

7.8 Ideal point location

7.8.1 In raw material similarities space

The spatial configuration of raw materials, derived from the similarities data, was chosen as a basis for ideal point location firstly because of its greater validation through axis interpretation and secondly because of its direct relationship to the raw material properties. The other spatial configurations of raw materials were more confusing in their interpretation due to the combinations of the effects of raw material properties and of the characteristics of the food dishes in which they are commonly used.

The ideal point was located according to the method described by Fenker (51). The coordinates of the 40 raw materials, derived from the multidimensional scaling analysis on similarities, were fixed in the 3-dimensional space. The data matrix supplied to KYST included the similarities data (a 40 x 40 matrix) and the acceptance data (forming the 41st row and column). Fixing of the 40 raw material points allowed for adjustment in the 41st point (ideal) only to minimize stress and hence maximize the monotonic relationship between the rank order of acceptabilities (see Table 6.5) and the distances from the ideal point to the raw material points. The control statements required to locate the ideal point using KYST are shown in Figure 7.7.

The location of the ideal point in the 3-dimensional configuration of raw materials is shown in Figure 7.2.

The ideal point, although located in the raw material space, was interpreted as the ideal combination of raw material properties required in Thai food dishes. The reasons for this interpretation were as follows:

1. The raw materials were located in the 3-dimensional space according to data relating to the similarities of these raw materials as they are used in food dishes. The spatial dimensions are, therefore, representative of the raw material properties

Card number	Card description
1	TORSCA
2	PRE-ITERATIONS=3
3	DIMMAX=3,DIMMIN=3
4	REGRESSION=DESCENDING
5	FIX=40
6	COORDINATES=AS-IS
7	ITERATIONS=50
8	CARDS
9	CONFIGURATION
10	IDEAL POINT BY FENKER
11	41 3
12	(3X,3F6.3)
	Coordinates for 3 dimensional configuration
13	DATA
14	RAW MATERIAL SIMILARITIES
15	41 1 1
16	(5X,15F5.1,/,5X,15F5.1,/,5X,11F5.1)
	Data matrix
17	COMPUTE
18	STOP

Figure 7.7 KYST control cards for the ideal point location

which are important in food dishes.

2. The ideal point was located using data related to the acceptability of the raw materials in food dishes. The judgement of acceptability was assumed to be made using the same perceptual dimensions as for the judgement of raw material similarities.

The ideal point, in this case, represents the best combination of raw material properties for Thai food dishes in general. A similar procedure could be used in future research to locate an ideal point for a specific food dish in a raw material space. Here, the raw material space would be derived from similarity measures relating the substitutability of the raw materials in a particular dish. The ideal point would be located from the acceptability scores for the raw materials in that dish.

7.8.2 In the food dish space

An ideal point was located in the 3-dimensional spatial configuration of food dishes. The same procedure was used as described above for the raw materials. The location of the ideal point is shown in Figure 7.5. Although the location of the ideal food dish point was not used in this thesis it may, however, be useful in future research for the design of acceptable food dishes. This point represents the 'best' combination of food dish characteristics as defined by the axes of the spatial model. New and acceptable food dishes might be designed to have a set of characteristics defined by the ideal point. Such a design procedure would be similar to the one used by Stefflre (190) for the development of new products to fill 'gaps' or 'holes' in an existing product space. Stefflre used the existing products which were close to the 'gaps' or 'holes' as standards. He then developed new and improved products to fill the gaps by comparing their characteristics with those of the standards.

7.9 Summary and conclusions

Spatial configurations of the 40 raw materials and the 20 food dishes were obtained in the 'best' dimensionality and the axes of each space were identified. The configuration of food dishes was derived from similarity measures for pairs of the dishes. Three configurations of the raw materials were obtained using three different types of proximity measures:

1. Raw material similarity.
2. Raw material association.
3. Derived proximity measures from the raw material acceptability in food dish matrix.

The second and third set of proximity measures resulted in spatial configurations with axes related both to the raw material properties and to the characteristics of the food dishes in which the raw materials are commonly used. The configuration derived from the similarity measures resulted in axis interpretation in terms of solely the raw material properties.

Although the raw material and food dish spaces had some common axes, there was no method for providing a direct link between raw materials and food dishes for use in the linear programming model. Two methods were used to achieve this link, both relying on the location of the raw materials and food dishes in a common multidimensional space. The first method was an unfolding analysis, performed on the 'raw material by use' data. The solution to this analysis proved to be degenerate. A second method involved the location of an ideal point in the raw material similarities space. This point was defined as representing the 'optimum' combination of raw material properties required in a Thai food dish.

The ideal point provided the necessary link between the raw materials and food dishes. The metric scale values for the raw materials and the ideal point were used to develop a linear function relating the acceptability of a food dish to its raw material input. The development of this function and its use in the linear programming model are discussed in the next chapter.

CHAPTER 8

INCLUSION OF ACCEPTABILITY FACTORS IN THE L.P. MODEL

The raw material space obtained from the similarity measures was chosen as the basis for the derivation of acceptability factors to be used in the linear programme. The location of the ideal point and its relationship to the raw material points in the 3-dimensional space was used to derive two factors which contribute to the total acceptability of a combination of raw materials in a Thai food dish. The first factor, the compensatory factor (COMPFAC), accounted for the requirement for a balanced raw material content in a food dish. The second factor, the preference factor (PREFAC), recognized the need for the selection of raw materials which were not only acceptable in combination, but were also acceptable individually. That is, a balanced combination of acceptable raw materials was required. A total acceptability function (ACCEPT), was defined as a linear combination of PREFAC and COMPFAC

$$\text{ACCEPT} = a(\text{PREFAC}) + b(\text{COMPFAC})$$

This linear function of acceptability was used in the linear programming model in association with nutritional requirements. The requirements were calculated as the weighted average daily requirements for men and women in the 20-29 year age group, this being the age group of the subjects used in the surveys for the multidimensional scaling analysis.

The relative contribution of PREFAC and COMPFAC to the total acceptability function was varied using the parametric procedure available in the LPS/1130 programme, by changing the values of <u>a</u> and <u>b</u>. This procedure pointed to the ease of achieving a zero value for COMPFAC and suggested that optimization of acceptability be performed by minimization of PREFAC subject to COMPFAC = 0.0. A final linear programming model was proposed combining both nutritional constraints and acceptability factors. This model required the minimization of PREFAC subject to certain specified nutritional constraints at COMPFAC = 0.0.

Two methods were used to substantiate the acceptability function. Firstly, parametric changes were made in each of the acceptability factors separately, while holding the other constant. The nature of the raw material mixes obtained by this procedure was examined and was found to be consistent with the values of PREFAC and COMPFAC. The second method involved the use of taste panels in Thailand to determine the rank order of acceptability of 21 combinations of raw materials, prepared to simulate a Thai food dish. This rank order of acceptability was correlated with the predicted rank orders from COMPFAC and PREFAC. No correlation existed with either factor. These taste panels were organized to coincide with a Massey University staff member's visit to Thailand and preceded the proposal of the final model. They were, therefore, not entirely satisfactory as a validation procedure for the model but did suggest the format for future experiments which might be used to support or refute the model.

The model is extremely adaptable and may be subjected to a number of extensions and variations, in particular, to a total menu planning system. Such a system would allow for a choice of food dishes to be made by the consumer, where specific combinations would ensure a varied, nutritious and acceptable diet.

8.1 The derivation of a linear function of acceptability

The ideal point in the raw material space was defined as representing the optimum combination of raw material properties for a Thai food dish. The distance from the ideal point to each raw material is proportional to the acceptability of that raw material in a food dish. The ideal point therefore links raw materials and food dishes in two ways. Firstly, through the choice of suitable combinations to achieve a good balance of raw materials in a food dish and secondly, through the selection of raw materials which are individually more acceptable than others in a food dish. These two relationships of the raw materials to the ideal point were used to derive a linear function relating the raw materials to the acceptability of food dishes.

8.1.1 The balance of raw materials

The requirement for a food dish containing a balance of ingredients was satisfied through the selection of raw materials with combined properties at or near those of the ideal point.

$$I_i = \sum_{j=1}^{n} v_{ij} x_j \qquad i = 1,2,\ldots p$$

where I_i is the scale value of the ideal point on axis $\underline{i}$.
v_{ij} is the scale value of raw material $\underline{j}$ on axis $\underline{i}$.
x_j is the amount of raw material $\underline{j}$ in the solution.
$\underline{n}$ is the number of raw materials.
$\underline{p}$ is the number of dimensions of the multidimensional space of raw materials.

Now if
$$D_i = \left| I_i - \sum_{j=1}^{n} v_{ij} x_j \right| \qquad i = 1,2\ldots p$$

where D_i is the absolute difference of the ideal scale value from the sum of the weighted raw material scale values on axis $\underline{i}$

and
$$\text{COMPFAC} = \sum_{i=1}^{p} D_i$$

the COMPFAC (compensatory factor) is equal to the sum of the absolute differences of the ideal point scale values from the weighted raw material scale values on each of $\underline{p}$ axes. To optimize the balance of raw materials, the objective was to minimize COMPFAC.

In deriving this function for COMPFAC, two assumptions were made. Firstly, that the raw material properties defined by the multidimensional scaling model are linearly additive and secondly, that each of these properties is of equal importance in the choice of raw materials for a food dish.

8.1.2 The acceptability of individual raw materials

The requirement for a food dish to contain the most acceptable raw materials was achieved by minimizing the total weighted distance of the raw materials from the ideal point.

$$\text{PREFAC} = \sum_{j=1}^{n} d_j x_j$$

where PREFAC is defined as the preference factor.

d_j is the distance of raw material j from the ideal point.

x_j is the amount of raw material j in the solution.

Selection of the combination of most preferred raw materials was therefore achieved by minimizing PREFAC.

8.1.3 The linear acceptability function

A linear function of acceptability was defined as the sum of PREFAC and COMPFAC.

$$\text{ACCEPT} = a(\text{PREFAC}) + b(\text{COMPFAC})$$

where ACCEPT is the total acceptability factor

a and b are the coefficients of PREFAC and COMPFAC respectively in the linear function.

To optimize the acceptability of a combination of raw materials the objective was to minimize ACCEPT. In doing this it was necessary to account for the relative importance of PREFAC and COMPFAC in determining the overall acceptance of a raw material combination. That is, values for a and b were required. The effects of a and b on the choice of raw materials in a solution were examined by parametrically changing their values.

8.2 Data organization for acceptability optimization using L.P.

Data were organized for the linear programme to select combinations of raw materials which would not only meet specific nutritional requirements, but which would also maximize the acceptability of a food dish in which these materials were used.

8.2.1 The nutritional requirements

Weighted average daily nutritional requirements were calculated for the 20-29 year old age group. This group was chosen to be consistent with acceptability factors which were obtained from subjects within this age classification.

$$R_i = P_w a_{wi} + P_m a_{mi}$$

where R_i is the weighted average daily requirement for nutrient $\underline{i}$.
P_w is the proportion of women in the 20-29 age group.
P_m is the proportion of men in the 20-29 age group.
a_{wi} is the requirement of the women in the 20-29 age group for nutrient $\underline{i}$.
a_{mi} is the requirement of the men in the 20-29 age group for nutrient $\underline{i}$.

Weighted average daily nutritional requirements were calculated for all the nutrients described in Chapter 2, using the daily per capita requirements for 20-29 year old males and females as shown in Appendix.2. These weighted requirements are shown in Table 8.1.

Table 8.1 Weighted average daily nutritional requirements for 20 – 29 year old Thais.

Nutrient	Minimum weighted average requirements	Maximum weighted average requirements
Calories	2200	none
Protein (g.N)	9.53	none
Fat (g)	20% of calories	35% of calories
Fibre (g)	6.00	15.00
Calcium (mg)	500	1500
Phosphorus (mg)	0.8 x calcium	1.5 x calcium
Iron (mg)	11.0	none
Vitamin C (mg)	30.0	none
Vitamin A (iu)	2500	none
Thiamine (mg)	0.4/1000kcals	none
Niacin (mg)	6.6/1000kcals	none
Riboflavin (mg)	0.55/1000kcals	none
Vitamin B12 (mg)	0.002	none
Vitamin B6 (mg)	2.00	none
Folic acid (µg)	200	none
Pantothenic acid (mg)	8.00	none
Protein/calories	0.10	none
Amino acids	egg pattern values (see Table 2.4)	

8.2.2 The acceptability factors

The two factors COMPFAC and PREFAC, comprising the total acceptability function ACCEPT, were prepared for the linear programme as follows:

1. The compensatory factor (COMPFAC). The 3 scale values for the spatial configuration of raw materials, obtained from the multi-dimensional analysis, were punched as data values for each raw material.

e.g., MILK DIM1 -0.633

This shows that the scale value of MILK on dimension 1 is -0.633. Since the sum of the scale values in any single dimension could be positive or negative, a procedure was required to convert this sum to an absolute value. The procedure used was similar to that used in Chapter 3 for the goal programming on nutrients. This procedure required the addition of two slack variables for each dimension.

e.g.,

$$\text{DIFF1} = \left| I_1 - \sum_{j=1}^{n} v_{1j} x_j \right| - y_1^- + y_1^+$$

$$= D_1 - y_1^- + y_1^+$$

where y_1^+ and y_1^- are the slack variables. For input to the LPS/1130 computer programme, the slack variables y_1^- and y_1^+ were defined as FDIM1 and GDIM1 respectively. Therefore:

DIFF1 = D1 - FDIM1 + GDIM1

and DIFF1 = 0.0

The cards were prepared for dimension 1 as follows:

	D1	DIFF1	1.0
	FDIM1	DIFF1	-1.0
	GDIM1	DIFF1	1.0
FX	THAIREQ	DIFF1	0.0

with similar cards for dimensions 2 and 3.

Then COMPFAC = FDIM1+GDIM1+FDIM2+GDIM2+FDIM3+GDIM3

2. The preference factor (PREFAC). The distances from each raw material to the ideal point were calculated and punched on cards as follows:

MILK	PREFAC	1.125

shows that the value of PREFAC for MILK is 1.125.

8.3 Linear programming solutions

A number of solutions were obtained from the linear programme, including cost minimization subject to nutritional constraints only and optimization of acceptability by minimization of ACCEPT. Minimization of ACCEPT was performed parametrically by varying the coefficients of COMPFAC and PREFAC. The nutritional requirements used in all computer runs were those listed in Table 8.1, with the amino acid levels set at 80-120 percent of the egg pattern values. A summary of the nutrient composition of each solution is given in Appendix 8.

8.3.1 Cost minimization subject to nutritional constraints only

A feasible solution was obtained at a cost of 4.20 baht. The mix of raw materials is listed below.

banana	646.8
Chinese cabbage	259.3
bamboo shoots	205.2
rice noodles	175.8
peanuts	84.0
milk	66.7
pineapple	55.7
mungbean curd	33.9
sweetened condensed milk	3.2
Total weight of mix	1530.6

The nutrient composition of this mix is shown in Appendix 8. The limiting nutrients were protein, vitamin B6, pantothenic acid and calories, all at their lower limits of daily requirement. The limiting amino acid was methionine at 80 percent of its egg pattern requirement.

The combination of raw materials obtained from cost minimization subject only to nutritional constraints was extremely varied. The high level of fruit and in particular banana, was not consistent with Thai eating habits for main meal food dishes. The mix is predominantly of vegetable character with no meat or meat substitute raw materials. This lack of balance and unacceptability of the raw material mix was supported by the high values of PREFAC and COMPFAC obtained for the solution.

PREFAC = 15.16
COMPFAC = 13.46

8.3.2 Optimization of acceptability

A total acceptability factor was defined as:

$$ACCEPT = a(PREFAC) + b(COMPFAC)$$

The lack of information on the relative importance of PREFAC and COMPFAC on the value of ACCEPT presented a problem in the definition of values for a and b. To judge the effects of differing levels of these coefficients, a parametric run was made by varying the values of a and b. The values chosen for a and b were as follows:

Run	a	b
1	1.00	0.00
2	0.75	0.25
3	0.50	0.50
4	0.25	0.75
5	0.00	1.00

At each computer run the objective set for the linear programme was to minimize ACCEPT. As the importance of COMPFAC in the ACCEPT function increased through runs 1, 2 and 3 its value declined to zero. The further increases in b in runs 4 and 5 were therefore unable to reduce the value of COMPFAC and as a result were unable to reduce the level of ACCEPT. Runs 4 and 5 therefore produced the same solutions as run 3. The values for COMPFAC and PREFAC for the 3 runs are shown below.

Run	COMPFAC	PREFAC
1	5.61	10.10
2	0.04	10.67
3	0.00	10.68

The solutions to runs 1, 2 and 3 are shown in Table 8.2.

Although the solutions to the parametric runs summarized above do not conclusively prove the predictive powers of the ACCEPT function, the nature of the raw material combinations does help to substantiate this function. The following observations were made from these solutions:

Table 8.2 Solutions from the parametric runs optimizing ACCEPT.

Run 1 a=1.00, b=0.00		Run 2 a=0.75, b=0.25		Run 3 a=0.50, b=0.50	
White rice	236.7[a]	Chinese cabbage	238.2	Chinese cabbage	235.8
Banana	221.6	Duck egg	200.9	Duck egg	203.6
Chinese kale	207.9	White rice	137.8	White rice	132.1
Duck egg	172.7	Mungbean sprouts	130.1	Mungbean sprouts	130.1
Chinese cabbage	114.6	Banana	128.5	Banana	128.8
Butter	71.2	Snap beans	94.2	Snap beans	97.3
Pumpkin	56.0	Milk	89.5	Milk	87.3
Hog's liver	28.4	Butter	60.7	Butter	60.4
Mungbean sprouts	19.8	Garlic	57.9	Garlic	58.2
		Hog's liver	37.7	Hog's liver	38.6
				Sugar	4.8
Total weight	1128.9	Total weight	1175.5	Total weight	1177.0
Cost (baht)	8.21	Cost (baht)	10.80	Cost (baht)	10.87

a. All weights of raw materials are given in grams.

1. There is a definite improvement in the choice of raw materials when the ACCEPT function is minimized. Minimization of PREFAC in the first parametric run reduced the level of fruits in the solution by deleting pineapple and reducing the level of banana from 42.1 percent in the solution to the nutrition problem to 19.6 percent. Decreases in the level of COMPFAC in runs 2 and 3 brought further reductions in the amount of fruit in the solution.
2. The solution obtained from cost minimization subject to nutritional constraints only contained no meat or meat-like raw materials. Optimization of ACCEPT brought an increase in the level of these raw materials, in particular duck eggs and hog's liver. Reduction of COMPFAC increased the levels of these ingredients.
3. Reduction in COMPFAC brought increased levels of stronger flavoured ingredients into the solution, to provide a balance in flavour. Garlic was not present in either the solution to the nutrition problem or the solution to PREFAC minimization. As

COMPFAC became part of the total ACCEPT function, garlic was chosen for the solution at a level of about 7 percent. Sugar was also selected in the third parametric run at a level of 0.4 percent.

4. The choice of milk and butter for the solutions optimizing acceptability was interesting. These were found to be the most acceptable dairy products from previous studies. They were selected in small quantities (milk at about 8 percent and butter at about 5 percent) and were directly compatible with the other ingredients in the solution, in particular eggs for the production of an omelette.

5. Optimization of acceptability resulted in a decrease in the weight of the selected mix from 1530.6g in the nutrition problem to just under 1200g in the parametric runs, minimizing ACCEPT. This feature of the minimization of ACCEPT procedure would prove useful where a non-bulky, nutritious and acceptable diet was required.

6. As would be expected, improvement in the acceptability of the mixes was accompanied by an increase in cost, from 4.20 baht in the nutrition problem to just under 11 baht for the parametric solutions.

7. The parametric procedure, varying the relative contributions of PREFAC and COMPFAC to the total ACCEPT function, showed the ease of obtaining a zero value for COMPFAC and the small effect on PREFAC in doing this. Hence it was suggested that rather than define values for the coefficients a and b that COMPFAC be set at zero and the process of acceptability optimization be performed by minimizing PREFAC. In effect this procedure would achieve the most acceptable mix of raw materials by selecting those materials which are most preferred in food dishes in order to obtain an optimum balance at COMPFAC=0.0.

8.4 A summary of the total model

The linear programming model designed to meet nutritional requirements and to maximize consumer acceptability is summarized as follows:

$$\text{Minimize} \quad \sum_{j=1}^{n} d_j x_j$$

$$\text{subject to} \quad \sum_{j=1}^{n} a_{ij} x_j \quad \gtrless \quad b_i \quad \text{for } i = 1,2,\ldots m \qquad (1)$$

$$\text{and} \quad \sum_{i=1}^{p} \left| I_i - \sum_{j=1}^{n} v_{ij} x_j \right| = 0 \qquad (2)$$

That is, the object of the model is to minimize PREFAC subject to two sets of constraints. The first set represents the nutritional requirements where:

- a_{ij} is the content of nutrient _i_ in raw material _j_.
- x_j is the amount of raw material _j_ in the solution.
- b_i is the daily per capita requirement of nutrient _i_.
- _m_ is the number of nutrients.
- _n_ is the number of raw materials.

The second set of constraints represents the compensatory factor (COMPFAC), which must equal zero.

- I_i is the scale value of the ideal point in dimension _i_.
- v_{ij} is the scale value of raw material _j_ in dimension _i_.
- _p_ is the number of dimensions chosen from the multi-dimensional scaling analysis.

8.5 Validation of the model

The model described above for the selection of acceptable combinations of raw materials for food dishes and the assumptions made in the development of this model have not been completely proven. Two methods were used to obtain evidence which would support the model. Firstly, variations on the levels of COMPFAC and PREFAC were performed using the parametric procedure and the solutions were compared. Secondly, the acceptability of various combinations of raw materials obtained from taste panels in Thailand, were compared with the predicted acceptability from the model.

8.5.1 Variations in COMPFAC and PREFAC

Solutions were obtained from the linear programming model by varying the level of one of the acceptability factors (either COMPFAC or PREFAC) and holding the other factor at a fixed level. The objective in all cases was to minimize cost.

PREFAC was varied parametrically from 10.679 to 14.679 in steps of 2 units, while holding COMPFAC at zero. This procedure had the effect of maintaining balance in the raw material mix by choosing increasingly less acceptable raw materials. The solutions are shown in Table 8.3.

Table 8.3 Solutions to parametric changes in PREFAC with COMPFAC at zero.

PREFAC=10.679		PREFAC=12.679		PREFAC=14.679	
Chinese cabbage	235.8[a]	Cabbage	332.8	Cabbage	493.2
Duck egg	203.6	Milk	295.1	Milk	344.2
White rice	132.1	Bamboo shoots	150.8	Bamboo shoots	258.2
Mungbean sprouts	130.1	White rice	136.7	Rice noodle	176.0
Banana	128.8	Mungbean sprouts	85.0	Sugar	88.3
Snap bean	97.3	Chinese cabbage	75.7	Peanut	66.2
Milk	87.3	Duck egg	72.4	Duck egg	48.7
Butter	60.4	Rice noodle	61.6	Green gourd	38.7
Garlic	58.2	Banana	47.3	Butter	34.8
Hog's liver	38.6	Peanut	45.1	Mungbean curd	15.3
Sugar	4.8	Butter	44.4	Mungbean sprouts	1.1
		Green gourd	31.5		
		Mungbean curd	4.0		
Total weight	1177.0	Total weight	1382.4	Total weight	1564.7
Cost (baht)	10.87	Cost (baht)	7.52	Cost (baht)	6.73

a. All weights of raw materials are given in grams.

The increase in PREFAC brought about a replacement of the more expensive and more acceptable raw materials by the less expensive and less acceptable raw materials such as milk. Milk increased from 7.4 percent of the solution at the lowest PREFAC value to 22 percent at the highest PREFAC value. Duck egg, on the other hand, decreased its contribution from 19.5 percent to 3.1 percent of the solution in a corresponding increase in the value of PREFAC. The increase in the preference factor also brought about a replacement of rice, a widely accepted ingredient as the basis for food dishes, by the less used rice noodle. Overall, there was an increase in the weight of the raw material mix required to achieve the nutritional requirements and a corresponding decrease in cost. This was in keeping with the traditional form of nutritional food products which were generally inexpensive, but bulky and unacceptable.

COMPFAC was varied parametrically in steps of 5 units from 0 to 10 while holding PREFAC at 10.679. This procedure had the effect of decreasing the balance of raw materials but maintaining the same level of acceptance of the individual raw materials in the solution. The raw material mixes are shown in Table 8.4.

Table 8.4 Solutions to parametric changes in COMPFAC with PREFAC at 10.679.

COMPFAC 0.0		COMPFAC 5.0		COMPFAC 10.0	
Chinese cabbage	235.8[a]	Banana	242.6	Banana	315.3
Duck egg	203.6	Chinese cabbage	208.8	Chinese kale	285.4
White rice	132.1	Duck egg	174.5	Rice noodle	149.0
Mungbean sprouts	130.1	Rice noodle	137.8	Duck egg	145.9
Banana	128.8	White rice	110.0	White rice	74.8
Snap bean	97.3	Chinese kale	101.2	Butter	60.4
Milk	87.3	Butter	57.1	Pumpkin	42.0
Butter	60.4	Bamboo shoots	34.5	Hog's liver	26.7
Garlic	58.2	Peanut	26.9	Peanut	26.6
Hog's liver	38.6	Hog's liver	20.5		
Sugar	4.8	Pumpkin	18.2		
Total weight	1177.0	Total weight	1132.1	Total weight	1126.1
Cost (baht)	10.87	Cost (baht)	7.34	Cost (baht)	7.24

a. All weights of raw materials are given in grams.

The scale values on each dimension which made up the total value of COMPFAC in the parametric solutions were as follows:

		Dim.1	Dim.2	Dim.3
COMPFAC	0.0	0.000	0.000	0.000
COMPFAC	5.0	0.024	1.507	3.469
COMPFAC	10.0	0.238	3.836	4.125

The solution to COMPFAC=0.0 resulted in a 'perfect' balance of all three dimensions. In dimension 3 the weak flavours of rice and banana were compensated for by the strong flavour of garlic. In dimension 2 the raw materials which are normally used in small quantities (milk, butter, banana, garlic and sugar) were balanced with raw materials which are normally used in larger quantities in food dishes (Chinese cabbage, hog's liver and snap beans). In dimension 1 the balance of nutritional properties in the raw material mix was brought about by the inclusion of some raw materials which are considered as nutritious, e.g., milk, butter, hog's liver and duck egg, and some raw materials which are not high on nutrition and are normally used as fillers e.g., Chinese cabbage, snap beans and mungbean sprouts.

As the value of COMPFAC increased, dimensions 2 and 3 became increasingly out of balance and contributed most to the value of COMPFAC. These dimensions were identified as 'level of use' and strength of flavour, respectively. Dimension 1 (nutritional value) contributed only a small amount to the level of COMPFAC. As the value of COMPFAC increased, the flavour of the solution mix became more bland through the addition of greater quantities of banana, Chinese cabbage and rice noodles and reduction in the levels of garlic and milk. There was also an increase in the imbalance of the raw materials from the point of view of their levels of use. This came about through the addition of extra quantities of banana, Chinese kale and rice noodles.

The variations in PREFAC and COMPFAC resulted in solutions which, to a large extent, substantiated the total linear programming model. Further validation is, however, required through selection of a greater number of raw material mixes using similar parametric procedures to those employed above and testing of these mixes by a statistically designed method based on the procedure outlined in Section 8.5.2.

8.5.2 Validation through taste panels

Twenty one combinations, each containing 3 raw materials, were selected to give a representation of most of the 40 available raw materials. The 21 combinations and the percentage of each raw material in these combinations are shown in Table 8.5. Each combination was prepared to simulate a Thai food dish, by cooking the raw materials for a short period of time in a small amount of water containing fish sauce. No other garnishings were used and in all cases, other than butter and cheese, the raw materials retained their identities in the final dish. A rank ordering of the acceptabilities of the 21 raw material combinations was obtained using a panel of 84 students at Kasetsart and Chulalongkorn Universities in Bangkok.

Due to the inability of human subjects to rank 21 items, a Youden array was used to obtain a set of incomplete rankings (99). In a Youden array, n objects are presented k at a time and each is ranked m times in the experiment. The number of blocks of objects is mn/k. Within each block there are $\frac{1}{2}k(k-1)$ comparisons between pairs and hence the total number of comparisons is $\frac{1}{2}mn(k-1)$. The number of blocks in which a given comparison occurs is termed λ where

$$\lambda = \frac{m(k-1)}{n-1}$$

The description of the Youden array design used to obtain a set of incomplete rankings of the raw material combinations is as follows:

$$n = 21$$
$$m = 20$$
$$\lambda = 3$$
$$k = 5$$

The raw material combinations were presented to each subject 5 at time and the subject was asked to rank them in order of

Table 8.5 Raw material combinations used in Thai taste panels.

A.		B.		C.	
Beef	33.3[a]	Crab	45.0	Chinese cabbage	33.3
Chicken	33.3	Striped mackerel	45.0	Chinese kale	33.3
Pork	33.3	Chicken egg	10.0	Green gourd	33.3
D.		E.		F.	
Mungbean sprouts	15.0	Chicken	25.0	Pork	20.0
String beans	80.0	Rice noodle	70.0	Banana	40.0
Chilli pepper	5.0	Sugar	5.0	Pineapple	40.0
G.		H.		I.	
Shrimps	40.0	Beef	20.0	Pork	50.0
Peanuts	30.0	Chinese kale	40.0	Cheese	30.0
Shallots	30.0	Chinese cabbage	40.0	Milk	20.0
J.		K.		L.	
Milk	20.0	Cheese	40.0	Rice	60.0
Condensed milk	40.0	Coconut cream	20.0	Chinese cabbage	20.0
String beans	40.0	Green gourd	40.0	Chinese kale	20.0
M.		N.		O.	
Rice	60.0	Rice	60.0	Rice	60.0
Mango (green)	20.0	Crab	20.0	Crab	20.0
Watermelon	20.0	Duck	20.0	Mango (green)	20.0
P.		Q.		R.	
Rice	60.0	Rice	60.0	Pork	30.0
Serpent hd. fish	25.0	Chinese kale	20.0	Banana	40.0
Milk	15.0	Beef	20.0	Chinese kale	30.0
S.		T.		U.	
Pork	20.0	Pork	40.0	Pork	47.5
Banana	60.0	Banana	20.0	Banana	5.0
Chinese kale	20.0	Chinese kale	40.0	Chinese kale	47.5

a. The composition of each raw material in the combination expressed as a percentage.

acceptability. Each of the 21 combinations was ranked 20 times in the experiment. The number of blocks was 84 and 84 subjects were used. A total of 840 paired comparisons were made and each comparison occurred in 3 blocks. The rank order of the 21 combinations was derived from the sums of ranks obtained in the experiment (see Table 8.6).

Table 8.6 The actual and predicted acceptabilities for 21 raw material mixes.

Dish	Taste panel rank[a]	COMPFAC rank[a]	PREFAC rank[a]	COMPFAC score	PREFAC score
A	1	20	6½	1.49	0.92
N	2	14	11	1.21	0.99
L	3	4	5	0.46	0.91
F	4	16	19	1.25	1.08
H	5	11	2	1.06	0.87
Q	6	5	9	0.70	0.96
B	7	21	16	1.60	1.04
E	8	17	21	1.30	1.15
T	9	2	6½	0.25	0.92
U	10	1	3½	0.06	0.88
G	11	7	8	0.73	0.94
R	12	3	10	0.41	0.97
J	13	8	17½	0.77	1.06
C	15	18	3½	1.33	0.88
O	15	9	13½	0.81	1.02
S	15	12	13½	1.08	1.02
M	17½	15	17½	1.24	1.06
P	17½	10	13½	1.02	1.02
D	19	19	1	1.35	0.83
K	20	6	20	0.72	1.12
I	21	13	13½	1.09	1.02

a. A lower rank indicates greater acceptability.

The coefficient of concordance W was calculated to be 0.521. The significance of this value was tested by comparison of the calculated χ^2 statistic with the tabulated value (see Kendall (99)).

$$\chi^2 = 114.6 \text{ with 20 degrees of freedom}$$

which shows significance of W at the 0.01 percent level hence showing agreement among the subjects.

The values of the compensatory factor (COMPFAC) and the preference factor (PREFAC) were calculated for each of the 21 combinations of raw materials (see Table 8.6). The rank orders for each of these factors were correlated with the acceptability rankings obtained from the taste panel. The Spearman rank correlation coefficients were as follows:

Correlation	ρ
Taste panel - PREFAC	0.194
Taste panel - COMPFAC	-0.031

No significant correlation existed with either PREFAC or COMPFAC.

This taste panel was planned to coincide with a Massey University staff member's visit to Bangkok to enable her to supervise the organization of the tasting sessions. Unfortunately the panels preceded the application of the acceptability data to the linear programme and the selection of the raw material combinations was therefore made before the proposal of the final model. The results of the taste panels show that no correlation exists between the actual acceptability of food raw material combinations and the values of either PREFAC or COMPFAC. It is still possible and more likely that a combination of the two factors, rather than either one or the other, is capable of predicting acceptability.

Figure 8.1 shows the relationship between COMPFAC, PREFAC and taste panel acceptability ranks. This figure indicates a trend for taste panel acceptability to decrease with an increasing PREFAC, over restricted ranges of COMPFAC. The problem of the interaction of COMPFAC and PREFAC and their combined effect on consumer acceptability of raw material combinations prevented further conclusions from the data. It is suggested therefore, that further taste panel experiments are required to validate the model. In these experiments raw material combinations should be chosen with a constant COMPFAC (probably zero) and over a wide range of PREFAC. The consumer acceptability of the raw material combinations as simulated Thai food dishes could then be correlated with the levels of PREFAC. An outline of the proposed procedure is as follows:

1. Derive various raw material mixes by varying the levels of PREFAC and fixing the level of COMPFAC at zero. These mixes should be selected to meet the nutritional requirements of a specific age group.

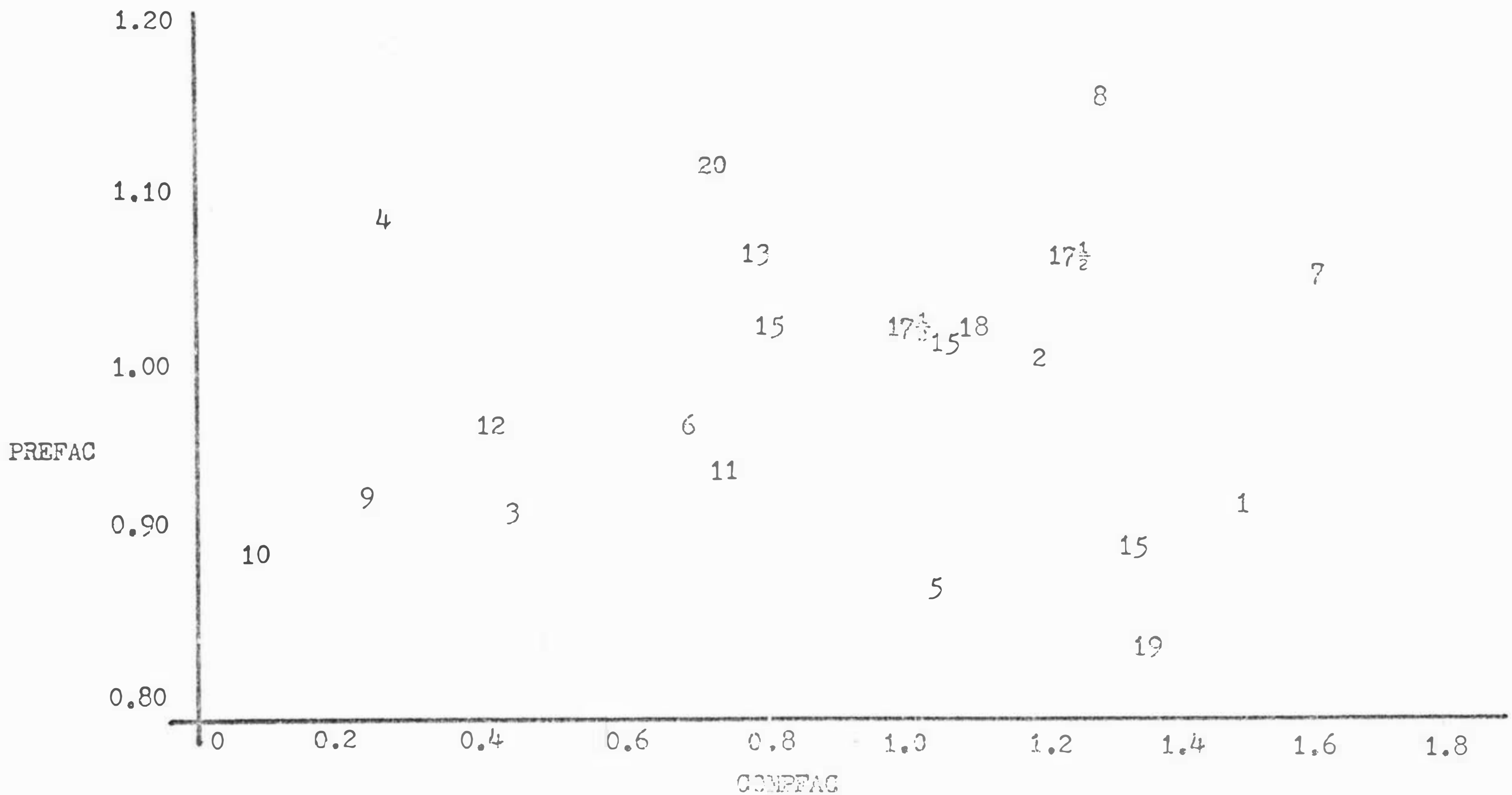

Figure 8.1 Plot of PREFAC against COMPFAC for 21 raw material combinations

The points for PREFAC and COMPFAC are represented by the corresponding taste panel rank.

2. Develop these mixes into food dishes which resemble as closely as possible the presentation of normal Thai food dishes.
3. Design an experiment to obtain the relative acceptabilities of these food dishes. Such an experiment should allow for the consumer to choose and eat the dishes within a normal meal time environment e.g., a restaurant or cafeteria.
4. The actual acceptability ratings obtained from this experiment would then be compared with the predicted acceptabilities from the values of PREFAC.

8.6 The flexibility of the model

The model for selection of acceptable and nutritious raw material combinations is extremely flexible. It allows for a number of variations to be made depending on the emphasis required in the solution. Some of these variations are outlined below:
1. Goal programming could be performed to achieve a raw material mix of 'optimum' nutritional balance. The cost and/or acceptability factors could then be varied parametrically and the effect on nutritional balance observed.
2. The effects of increases or reductions in the nutritional requirements on the acceptability of the solution could be tested.
3. One or more raw materials could be fixed at a specific level in the solution and the other raw materials selected by the linear programming model e.g., a level of 200g of beef could be specified for the solution mix.
4. The effects of cost changes on the level of acceptability, as described by COMPFAC and PREFAC, could be determined.

The model, as described above, was used to select raw material mixes which would be acceptable in a general type of Thai food dish. A single dish only was considered and the raw materials were selected to give an acceptable mix which would meet the daily nutritional requirements of 20-29 year old Thais. Although a single food dish might be accepted and liked once, twice or even three times in a row, it is unlikely that it would be accepted as the sole source of nutritional requirements. Rather, it is more logical that a menu planning system be adopted where a choice of dishes is available from which specific combinations could be selected to meet daily nutritional requirements. Such a system could be envisaged using the linear programming model, where the model was extended to the selection of raw materials for specific food dishes.

It would be possible to derive a raw material space which related to a specific food dish. This could be achieved by obtaining measures of raw material substitutability for that food dish. An ideal point could be located in this space from the relative acceptabilities of the raw materials in the food dish. A number of such spaces could be derived for separate food dishes and a system devised whereby specific combinations of these dishes satisfied the daily nutritional requirements of the Thai consumer. This would allow for a variety of dishes to be presented and a choice to be made by the consumer. Such a system would provide an acceptable, nutritious and varied diet.

8.7 Summary and conclusions

A linear function, relating the raw material properties to the acceptability of a food dish, was derived from the metric scale values obtained from the multidimensional analysis of raw material similarities. Two factors contributed to this acceptability function. Firstly, a factor which accounted for the preference of raw materials in food dishes (PREFAC) and secondly, a factor which recognized the need for a balance of raw materials in food dishes (COMPFAC). The total acceptability function was used in the linear programming model, in association with nutritional constraints, to select raw material combinations which are nutritious and acceptable.

Two attempts were made to substantiate the linear function of acceptability. Firstly, a number of variations to the linear function were made to evaluate the effects on the solution. The raw material content of these solutions was, to a large extent, predictable from the values of PREFAC and COMPFAC. Secondly, taste panels were used to obtain a rank order of acceptability of 21 combinations of raw materials which was correlated with the values of PREFAC and COMPFAC. No significant correlation existed with either factor. It was concluded that acceptability is a function of both factors, rather than each acting separately. Further experiments were suggested to validate the model.

A total linear programming model was therefore presented which would select raw material combinations for a nutritious and acceptable food dish. This model was specific to the selection of raw materials for a general type of Thai food dish and hence allowed for no variation in the diet of the consumer. A menu planning system, based on the linear programming model, was presented. This system would permit the consumer to select from a menu of available dishes and hence provide an acceptable, nutritious and varied diet.

CHAPTER 9

QUANTITATIVE PRODUCT DESIGN IN PERSPECTIVE

Food product development has been more of an art than a science, where experience and intuition have taken precedence over logical and quantitative thought. The formulation of new products has been largely on a trial and error basis where raw materials are selected, developed into a product and tested for acceptability by a particular segment of consumers. After several modifications to the product and more consumer tests, the product is finally marketed. This thesis formed part of a larger research programme aimed at quantifying the process of food product development. In particular, the aim of this thesis was to develop a quantitative procedure for the selection of raw materials for nutritious and acceptable food dishes. The basis of the quantitative model was linear programming and the consumer group chosen was the Thai population.

The inclusion of nutritional constraints in a linear programming model for raw material selection has been well tried and proven by a number of researchers. Generally, however, these applications have used only small numbers of raw materials and nutrients. In the application of linear programming to the selection of raw materials to satisfy the nutritional requirements of the Thai population, 151 raw materials were considered and 26 nutrients provided the constraints for the model. Almost all nutrients in the problem were constrained at their lower levels of daily requirements, with very few having specific upper levels.

Although the traditional linear programming approach satisfies the specific lower levels of requirements, some nutrients can be present in the solution at levels far in excess of the levels required for adequate nutrition. There is a growing feeling among nutritionists that such a diet, comprised of a gross imbalance of nutrients, is unsatisfactory. Rather, it is suggested that a balance of all nutrients at or near their lower levels of requirement may result in better health. It is possible to set range constraints on all nutrients to ensure a balanced diet, but previous studies have shown that this procedure may result in infeasible solutions. Even if a feasible solution is achieved by this method it will not necessarily contain the 'optimum' balance of nutrients.

Goal programming was introduced as a technique for selection of raw materials to achieve a balanced nutritional diet. Goal programming is an extension of linear programming, where the objective is one of minimizing the deviation from a set of pre-specified goals. In the nutrition problem the goals are the lower levels of requirement for the nutrients. The technique can be used to provide a balance of all nutrients in the diet or of some subset of these nutrients. In this thesis, the essential amino acid balance was 'optimized' by achieving levels as close to those of egg protein as possible. A selection of raw materials was also made to achieve a balance of all 26 nutrients. Both procedures resulted in a large increase in the cost of the solution. In future research the necessity to balance any nutrient should be based on sound information and the need for a balanced diet should be weighed against the cost of that diet.

Both goal programming and linear programming may provide solutions of raw materials with incompatible properties, both from the point of view of processing into a food dish and the consumer acceptability of that dish. The problems of developing a product from raw materials selected solely on nutritional criteria have been established in previous research. Edwardson (41) found it difficult to develop a product from raw materials selected by linear programming with only nutritional constraints. His procedure of development of a food product from these raw materials relied more on technologists' ingenuity and the ready availability of flavouring compounds than the inherent characteristics of the raw materials. A filtering procedure is required in the linear programming model which selects raw materials on the basis of their predicted acceptability in combination in a food dish.

A function relating raw materials and food dish acceptability for the linear programme requires not only the definition of the important sensory properties of the raw materials and their interactions in food dishes, but also requires that the variables in the linear function have metric scale values. The conventional methods used by food technologists to evaluate sensory properties and to predict consumer acceptance are not readily applied to the solution of this problem. Not only are the methods of classification and measurement of sensory properties unresolved but there is almost no recorded research on the interaction of these properties. A technique was required which could untangle the multiple relationships existing among the sensory properties of raw materials and to provide data in an acceptable form for the linear programming model.

Nonmetric multidimensional scaling showed the greatest potential of a number of multivariate techniques to resolve the problems of sensory property definition and interaction in food dishes. It also has the capability to supply metric data on the raw materials which can be used in the linear programming model. Nonmetric multidimensional scaling has been applied to food product development in the past. These applications have employed the technique mainly as a 'diagnostic' rather than a 'predictive' tool through the location of 'holes' or 'gaps' in existing product spaces and the formulation of new products which filled these holes. No use has been made of the metric information contained in the scale values of the existing products in the formulation of new products.

Nonmetric multidimensional scaling was used in this thesis as a totally predictive tool. Simple questionnaires on the relative similarity and acceptability of raw materials provided data which were transformed into a multidimensional space containing the raw materials and an ideal point. The dimensions of this space represent the important properties of the raw materials in determining food dish acceptability and the ideal point is defined as the 'optimum' combination of these raw material properties required in a food dish. The metric scale values for the raw materials and the ideal point provided the basis for a linear function relating raw material properties to food dish acceptability. This function was used in the linear programming model in association with nutritional constraints for the selection of raw materials which in combination would provide nutritious and acceptable food dishes. This total model is described below:

$$\text{Minimize} \quad \sum_{j=1}^{n} d_j x_j$$

$$\text{subject to} \quad \sum_{j=1}^{n} a_{ij} x_j \gtrless b_i \qquad \text{for } i = 1,2,\ldots m$$

$$\text{and} \quad \sum_{i=1}^{p} \left| I_i - \sum_{j=1}^{n} v_{ij} x_j \right| = 0$$

where d_j is the distance from raw material j to the ideal point.
x_j is the amount of raw material j in the solution.
a_{ij} is the level of nutrient i in raw material j.
b_i is the requirement for nutrient i.
I_i is the scale value of the ideal point in dimension i.
v_{ij} is the scale value of raw material j in dimension i.
n is the number of raw materials.
m is the number of nutrients.
p is the number of dimensions required to display the raw materials and the ideal point in a multidimensional space.

The model, therefore, seeks to select raw materials so as to maximize the combined acceptability of these raw materials i.e., by minimizing their combined weighted distances from the ideal point. Optimization of acceptability is achieved subject to specific nutritional constraints and to the selection of an optimum balance of raw material properties, equal to those of the ideal point.

Although the model was applied to the selection of raw materials for a general type of Thai food dish, its real value lies in the extension to a system of menu planning. Under such a system a menu, consisting of a number of different types of dishes, could be generated using the linear programming model. The consumer could then choose his own meals for the day and hence obtain a diet which would be nutritious, acceptable and varied.

The overall model provides a systematic and objective approach to the design of food dishes for the Thais. The selection of the raw materials to be used in these dishes is made on the basis of nutritional and consumer acceptance criteria. The resultant food dishes could be seen as fulfilling the need for a more nutritious diet without upsetting normal eating habits.

The structure of the model allows for its complete generalization to other developing countries through revision of the list of available raw materials, the nutritional requirements and the raw material scale values based on consumer acceptance. Although it was the object of this thesis to develop a model for the design of nutritious and acceptable foods for developing countries, the resultant model might easily be applied in the broader area of product design in developed countries. In almost all societies, malnutrition is becoming a problem. It is the responsibility of the food processor, and hence the product developer, to offer processed food products which provide a balanced diet for the consumer. The need for an objective system of product design based on nutrition and consumer acceptance is becoming greater. Already some food companies are using linear programming for raw material selection in food formulation, both in original product design and on a day by day basis. The inclusion of constraints based on the predicted consumer acceptability of raw material combinations, as described in the research, would prove invaluable.

A more complete study of certain problem areas is required before commercial application of the linear programming model. Although the model is quite robust against raw material compositional variations, a more complete study of the effects of such variations on selected raw material mixes is required. A further problem exists in the definition of nutritional requirements. Should these be weighted average requirements, should upper limits be specified to prevent oversupply of nutrients, is a balance of nutrients necessary to the well-being of the consumer? There are also problems to be solved in using the nonmetric multidimensional scaling, for example the location and definition of the ideal point; the identification of axes, the requirement for extensive judgements by consumers and the difficulties in reducing the number of judgements required. The thesis has, however, provided a basis for further research into the use of quantitative procedures for the selection of raw materials in food product design.

During the application of the quantitative methods to food product design certain observations were made on the state of knowledge in food science, nutrition, sensory evaluation and consumer acceptance of foods. There was found to be a definite lack of reliable information on the composition of food raw materials and on the variability of composition. The recently published compositional tables, which collected together compositional data from various countries, have provided useful information but more specific data are required from individual countries. Nutritional requirements are generally well documented for minimum levels but even these levels are subject to controversy for some nutrients, for example, fat and crude fibre. Very little information is available on the effects of overdoses of most nutrients, although concern about overdoses of nutrients such as calcium and vitamin A has been stated by individual nutritionists and FAO/WHO committees. Similar concern has been shown over the requirement for a balanced diet, but very little research has been done to demonstrate the effects of nutritional imbalance in the human diet. Before there can be extensive use of the linear programming model in the design of human foods, there must be more knowledge of nutritional requirements. There is also a need for more information on the relationship between sensory and other properties of raw materials and consumer acceptance of foods. The major problems in the linear programming model were the definition of the important raw material properties and the interrelationships of these properties influencing the consumer's acceptance of foods. In addition to these extremely complex interrelationships of the dominant sensory properties, there is the problem of differing importance of individual properties in different foods. Nonmetric multidimensional scaling was shown to be on technique which could identify the dominant raw material properties. It is also able to provide information relating these properties to the consumer acceptance of foods.

This study has used Thai information and a theoretical model has been developed for the selection of raw materials to be used in Thai food dishes. Although the model described in this thesis considered only the rather hypothetical general food dish it might be preferable in future research to use the model for selection of raw materials for a specific food dish, for example a meat curry. The generalization of the model has brought together the composition of raw materials, indigenous to Thailand and also the nutrient requirements for different age groups in Thailand. It has provided the basis for more specific models catering for the requirements of individual age groups and market segments.

The model for selection of nutritious and acceptable combinations of raw materials for Thai food dishes requires further validation before it is applied on the industrial scale. Completion of the model will, however, provide a much needed quantitative basis for the selection of indigenous raw materials to be used in food dishes not only for Thailand but for all other developing countries. The model is seen as identifying the most important raw materials in the design of nutritious and acceptable food dishes. A direction might then be provided in farm production to provide an overall plan for optimal land use in the provision of the most desirable food raw materials. It can also be used to evaluate the use of imported foods, as can be seen by the study of dairy products.

This thesis has sought to provide a more quantitative basis for food product design. It took three operations research and social science techniques and applied these in an integrated model for the selection of nutritious and acceptable raw materials for Thai food dishes. The continuing evaluation of such techniques will eventually result in the total concept of food product development being based on processes of objective decision making rather than subjective judgement.

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APPENDIX 1

RAW MATERIAL COMPOSITION TABLES

A complete list of the nutrient composition data used for the linear programming application to the nutrition problem is given. Compositional data on each of 26 nutrients is included for 151 raw materials.

The compositional data is divided into 3 parts as follows:

1. Cost, proximate analysis and minerals.
2. Vitamins.
3. Essential amino acids.

Within each part a complete listing of the 144 indigenous raw materials is given in alphabetical order. The 7 dairy products are included at the end of the list of indigenous raw materials.

PART 1.

FOOD	COST	WEIGHT	CALORIES	PROTEIN	FAT	FIBRE	CALCIUM	PHOSPHORUS	IRON
	BHAT/100G	100G	KCAL/100G	G/100G	G/100G	G/100G	MG/100G	MG/100G	MG/100G
ANCHOVY	1.2500	1.0000	75.0000	2.8800	0.3000	0.1000	218.0000	211.0000	1.7000
BAMSHOOT	0.3000	1.0000	27.0000	0.3200	0.7000	0.7000	19.0000	26.0000	0.2000
BANANA	0.2000	1.0000	119.0000	0.1600	0.4000	0.6000	11.0000	24.0000	0.7000
BEANSRD	0.3000	1.0000	46.0000	0.5600	1.0000	0.8000	34.0000	157.0000	2.0000
BEANSNAP	0.2500	1.0000	34.0000	0.3200	0.1000	1.0000	72.0000	38.0000	0.8000
BEANYDRD	0.1000	1.0000	36.0000	0.5300	0.2000	2.0000	60.0000	57.0000	0.4000
BEEF	1.7000	1.0000	242.0000	2.9800	18.0000	0.0000	11.0000	172.0000	2.6000
BFBLOOD	1.5000	1.0000	103.0000	3.5000	1.1000	0.0000	7.0000	24.0000	1.3000
BFBRAIN	1.5000	1.0000	120.0000	1.6500	9.4000	0.0000	11.0000	208.0000	2.4000
BFHEART	1.5000	1.0000	133.0000	3.0100	5.9000	0.0000	11.0000	170.0000	4.1000
BFKIDNEY	1.5000	1.0000	86.0000	2.4500	1.7000	0.0000	24.0000	158.0000	2.1000
BFLGINT	1.5000	1.0000	128.0000	1.9600	8.0000	0.0000	15.0000	59.0000	3.6000
BFLIVER	1.5000	1.0000	127.0000	3.5500	2.8000	0.0000	130.0000	312.0000	9.2000
BFLUNG	1.5000	1.0000	99.0000	2.7400	1.9000	0.0000	22.0000	138.0000	1.6000
BFSMINT	1.5000	1.0000	130.0000	2.2400	7.2000	0.0000	14.0000	115.0000	4.0000
BFSPLEEN	1.5000	1.0000	96.0000	2.7500	1.7000	0.0000	11.0000	201.0000	9.7000
BFSTOM	1.5000	1.0000	116.0000	2.4200	5.6000	0.0000	53.0000	51.0000	0.4000
BFTONGUE	1.5000	1.0000	218.0000	2.3700	15.2000	0.0000	42.0000	154.0000	0.0000
BRDFRUIT	0.6500	1.0000	56.0000	0.3850	0.5000	1.4000	40.0000	36.0000	1.3000
BUFFALO	1.7000	1.0000	106.0000	3.1300	1.6000	0.0000	11.0000	187.0000	2.9000
BUBRAIN	1.5000	1.0000	138.0000	3.1100	10.1000	0.0000	14.0000	254.0000	4.0000
BUHEART	1.5000	1.0000	120.0000	2.7800	4.6000	0.0000	10.0000	156.0000	2.5000
BUKIDNEY	1.5000	1.0000	80.0000	2.2400	1.8000	0.0000	14.0000	309.0000	2.9000
BULGINT	1.5000	1.0000	169.0000	1.4900	11.9000	0.0000	17.0000	61.0000	0.9000
BULIVER	1.5000	1.0000	111.0000	2.4800	1.7000	0.0000	16.0000	207.0000	6.8000
BUSMINT	1.5000	1.0000	151.0000	1.5700	9.7000	0.0000	16.0000	142.0000	1.7000
BUSPLEEN	1.5000	1.0000	104.0000	3.4000	1.5000	0.0000	13.0000	103.0000	5.4000
BUSTOM	1.5000	1.0000	86.0000	2.9900	0.7000	0.0000	53.0000	55.0000	0.4000
CABCHI	0.3500	1.0000	21.0000	0.2880	0.3000	0.7000	147.0000	33.0000	4.4000
CABCOM	0.3500	1.0000	24.0000	0.2080	0.2000	0.8000	49.0000	29.0000	0.4000
CARP	0.8000	1.0000	115.0000	2.8800	4.2000	0.0000	50.0000	253.0000	0.9000
CASHFRT	3.2500	1.0000	57.0000	0.1120	0.6000	0.3000	4.0000	13.0000	0.5000
CASHNUT	2.5000	1.0000	551.0001	3.2000	46.4000	2.6000	32.0000	425.0000	4.5000
CASSLVS	0.3000	1.0000	60.0000	1.1500	1.4000	2.2000	100.0000	106.0000	3.5000
CASSAVA	0.2000	1.0000	141.0000	0.1100	0.1000	1.0000	24.0000	37.0000	1.5000
CATFISH	1.5000	1.0000	256.0000	2.4800	21.5000	0.1000	30.0000	132.0000	2.5000
CAULI	0.3500	1.0000	27.0000	0.4320	0.2000	1.0000	25.0000	56.0000	1.1000
CELERY	0.6500	1.0000	27.0000	0.3500	0.6000	1.4000	326.0000	51.0000	15.3000
CHICKEN	3.2500	1.0000	200.0000	3.2300	12.6000	0.0000	14.0000	200.0000	1.5000
CHGIZZ	1.8000	1.0000	111.0000	1.5000	1.0000	0.0000	18.0000	72.0000	0.6000
CHLIVER	1.8000	1.0000	129.0000	2.9000	3.9000	0.0000	14.0000	152.0000	3.5000
COCOMEAT	0.2000	1.0000	45.0000	0.6600	35.3000	4.0000	13.0000	95.0000	1.7000
COCOMILK	0.2000	1.0000	252.0000	0.6050	24.9000	0.0000	15.0000	100.0000	1.6000
COCONUT	0.2000	1.0000	300.0000	0.7400	26.1000	2.1000	28.0000	95.0000	1.9000
CORNWH	0.2000	1.0000	128.0000	0.7050	0.8000	2.2000	9.0000	119.0000	0.7000
CORNY	0.2000	1.0000	188.0000	0.7850	1.9000	1.0000	4.0000	116.0000	0.4000
CRAB	1.5000	1.0000	121.0000	3.1600	4.0000	0.0000	93.0000	157.0000	1.0000
CUCUM	0.3500	1.0000	15.0000	0.1440	0.1000	0.6000	25.0000	27.0000	1.1000
DUCK	1.9000	1.0000	127.0000	3.4400	3.9000	0.0000	9.0000	184.0000	28.0000
DUCKT	1.9000	1.0000	326.0000	2.5600	28.6000	0.0000	10.0000	176.0000	1.6000
EGGDUCK	0.8350	1.0000	180.0000	1.8700	12.6000	0.0000	71.0000	174.0000	2.8000

FOOD	COST BHAT/100G	WEIGHT 100G	CALORIES KCAL/100G	PROTEIN G/100G	FAT G/100G	FIBRE G/100G	CALCIUM MG/100G	PHOSPHORUS MG/100G	IRON MG/100G
EGGHEN	1.0700	1.0000	169.0000	2.0300	11.9000	0.0000	76.0000	186.0000	3.5000
EGGPLANT	0.2000	1.0000	24.0000	0.1600	0.2000	0.8000	30.0000	27.0000	0.5000
FROG	2.2500	1.0000	95.0000	3.3500	0.6000	0.0000	46.0000	168.0000	1.8000
GARLIC	1.6000	1.0000	68.0000	0.4200	0.6000	2.0000	94.0000	53.0000	2.2000
GINGER	0.5500	1.0000	37.0000	0.1760	0.9000	1.0000	32.0000	29.0000	3.0000
GOOSE	1.5000	1.0000	131.0000	2.6200	3.5000	0.0000	9.0000	144.0000	2.0000
GOOSET	3.5000	1.0000	354.0000	2.6200	31.5000	0.0000	10.0000	176.0000	1.6000
GOURDB	0.2000	1.0000	17.0000	0.0960	0.1000	0.4000	19.0000	16.0000	0.4000
GOURDWX	0.2000	1.0000	15.0000	0.0640	0.2000	0.7000	18.0000	17.0000	0.2000
GRAPE	1.2500	1.0000	76.0000	0.0640	0.4000	2.3000	5.0000	19.0000	0.5000
GUAVARD	0.5000	1.0000	124.0000	0.1600	0.4000	5.7000	33.0000	28.0000	0.6000
GUAVAWH	0.5000	1.0000	99.0000	0.1900	4.4000	5.0000	22.0000	34.0000	0.6000
HERRING	1.0000	1.0000	101.0000	3.3500	1.3000	0.0000	191.0000	225.0000	1.4000
HORSE	1.7000	1.0000	125.0000	3.2100	4.1000	0.0000	10.0000	150.0000	2.7000
JACKFRT	0.8000	1.0000	100.0000	0.1900	0.4000	0.8000	22.0000	20.0000	1.0000
JCKFRTSD	0.4000	1.0000	143.0000	0.8900	0.6000	1.4000	23.0000	80.0000	0.8000
KALE	0.3500	1.0000	38.0000	0.6750	0.8000	1.3000	179.0000	73.0000	2.2000
LEEK	0.9000	1.0000	29.0000	0.3200	0.7000	1.4000	70.0000	53.0000	7.5000
LEMON	0.7500	1.0000	32.0000	0.0640	1.0000	0.1000	18.0000	12.0000	0.8000
LETTUCE	0.5000	1.0000	23.0000	0.1920	0.4000	0.5000	83.0000	34.0000	5.4000
LIME	0.7500	1.0000	40.0000	0.1280	2.4000	0.3000	17.0000	11.0000	0.1000
LOBSTER	4.7500	1.0000	91.0000	2.7000	1.9000	0.0000	29.0000	183.0000	0.6000
MACKSP	0.9000	1.0000	85.0000	2.8100	1.1000	0.0000	23.0000	236.0000	1.0000
MANGO	1.5000	1.0000	57.0000	0.0800	0.2000	0.4000	8.0000	17.0000	0.5000
MELON	0.3000	1.0000	21.0000	0.0480	0.4000	0.9000	30.0000	18.0000	0.4000
MILKBUFF	2.3000	1.0000	106.0000	0.7300	7.9000	0.0000	164.0000	99.0000	0.2000
MILKFISH	2.5000	1.0000	126.0000	2.8100	5.7000	0.0000	51.0000	161.0000	1.0000
MILKGOAT	0.5800	1.0000	76.0000	0.6150	4.3000	0.0000	98.0000	78.0000	2.7000
MULLET	2.2500	1.0000	94.0000	3.2000	1.0000	0.0000	43.0000	190.0000	0.5000
MUNGBEAN	0.4500	1.0000	356.0000	3.9000	1.0000	4.3000	125.0000	340.0000	5.7000
MUSHROOM	1.1500	1.0000	16.0000	0.3840	0.3000	0.9000	9.0000	115.0000	1.0000
MUSSEL	0.2000	1.0000	52.0000	1.2900	0.9000	0.1000	26.0000	184.0000	15.6000
OCTOPUS	0.7500	1.0000	62.0000	2.1300	0.6000	0.0000	42.0000	103.0000	1.6000
ONIONBU	0.9000	1.0000	45.0000	0.1760	0.2000	1.0000	40.0000	39.0000	0.6000
ONIONGR	0.9000	1.0000	27.0000	0.2560	1.4000	1.3000	56.0000	39.0000	2.2000
ORANGE	0.9000	1.0000	45.0000	0.1440	0.2000	0.6000	33.0000	23.0000	0.4000
PAPAYA	0.3000	1.0000	48.0000	0.0960	0.2000	0.6000	23.0000	10.0000	0.7000
PEACH	3.5000	1.0000	38.0000	0.0960	0.1000	0.6000	9.0000	19.0000	0.5000
PEACHICK	0.6500	1.0000	366.0000	3.2000	6.4000	2.6000	106.0000	340.0000	3.8000
PEANUT	0.5000	1.0000	564.0001	4.7700	47.5000	2.4000	69.0000	401.0000	2.1000
PEAPIG	0.3000	1.0000	119.0000	1.2100	0.7000	5.0000	77.0000	198.0000	1.7000
PEASWT	1.5000	1.0000	57.0000	0.5290	0.3000	1.2000	76.0000	45.0000	1.4000
PEPPERGR	0.3500	1.0000	23.0000	0.1120	0.2000	1.5000	12.0000	18.0000	0.4000
PEPPERRD	0.3500	1.0000	32.0000	0.0800	0.3000	1.6000	29.0000	45.0000	0.5000
PERCH	0.8000	1.0000	76.0000	2.7800	0.2000	0.0000	130.0000	156.0000	0.6000
PIG	2.1000	1.0000	457.0000	1.9000	45.0000	0.0000	7.0000	117.0000	1.8000
PIBLOOD	0.4000	1.0000	57.0000	1.8700	0.1000	0.0000	8.0000	30.0000	1.1000
PI-EART	2.3500	1.0000	120.0000	2.6200	5.3000	0.0000	6.0000	139.0000	1.5000
PIKIDNEY	2.3500	1.0000	114.0000	2.4600	4.3000	0.0000	13.0000	198.0000	5.1000
PILGINT	2.3500	1.0000	83.0000	1.5300	2.2000	0.0000	12.0000	89.0000	1.1000
PILIVER	2.3500	1.0000	131.0000	3.3000	3.7000	0.0000	10.0000	356.0000	19.2000

FOOD	COST BHAT/100G	WEIGHT 100G	CALORIES KCAL/100G	PROTEIN G/100G	FAT G/100G	FIBRE G/100G	CALCIUM MG/100G	PHOSPHORUS MG/100G	IRON MG/100G
PILUNG	2.3500	1.0000	76.0000	1.9600	1.8000	0.0000	14.0000	159.0000	3.1000
PISMINT	2.3500	1.0000	74.0000	2.0200	2.3000	0.0000	9.0000	150.0000	2.4000
PISPLEEN	2.3500	1.0000	91.0000	2.5700	2.5000	0.0000	13.0000	206.0000	6.9000
PISTOM	2.3500	1.0000	125.0000	2.0900	6.5000	0.0000	11.0000	106.0000	1.0000
PITONGUE	2.3500	1.0000	274.0000	2.2200	23.8000	0.0000	17.0000	116.0000	1.1000
PINEAP	0.1500	1.0000	54.0000	0.0640	0.3000	0.5000	22.0000	8.0000	0.4000
POMELO	0.5000	1.0000	67.0000	0.0800	0.2000	0.6000	21.0000	18.0000	0.5000
POTATO	0.5000	1.0000	76.0000	0.3360	0.1000	0.5000	7.0000	53.0000	0.6000
POTSTWH	0.5000	1.0000	113.0000	0.2960	0.4000	0.6000	64.0000	42.0000	1.0000
POTSWY	0.5000	1.0000	136.0000	1.7600	0.4000	0.7000	57.0000	52.0000	0.7000
PRAWN	2.1500	1.0000	101.0000	3.1400	0.8000	0.0000	146.0000	215.0000	1.1000
PUMPKIN	0.1500	1.0000	25.0000	0.1920	0.1000	0.9000	43.0000	19.4000	0.5000
RADISH	0.2500	1.0000	21.0000	0.0960	0.1000	0.6000	32.0000	21.0000	0.6000
RICEBR	0.2000	1.0000	364.0000	1.4800	2.0000	0.8000	28.0000	252.0000	2.2000
RICEGL	0.1500	1.0000	366.0000	1.1600	1.0000	0.2000	16.0000	95.0000	1.1000
RICEAH	0.3500	1.0000	368.0000	1.2400	0.5000	0.4000	8.0000	108.0000	1.2000
SARDINE	1.0000	1.0000	110.0000	2.9200	3.6000	0.0000	90.0000	245.0000	1.7000
SESAME	1.7500	1.0000	588.0001	3.2000	49.3000	3.2000	1100.0002	570.0001	16.0000
SHALLOT	0.4500	1.0000	67.0000	0.3050	0.3000	0.7000	35.0000	45.0000	0.8000
SHARK	0.3000	1.0000	103.0000	3.8200	0.1000	0.5000	14.0000	204.0000	1.1000
SHRIMP	4.2500	1.0000	57.0000	1.9200	1.0000	1.1000	1.0000	205.0000	3.4000
SNAPPER	0.9000	1.0000	68.0000	2.5000	0.2000	0.0000	37.0000	134.0000	0.6000
SORGHUM	0.2000	1.0000	332.0000	1.7600	3.3000	1.7000	28.0000	287.0000	4.4000
SOYBEAN	0.2000	1.0000	403.0000	5.9600	17.7000	4.9000	225.0000	554.0001	8.4000
SUGAR	0.3000	1.0000	370.0000	0.0000	0.0000	0.0000	75.0000	37.0000	2.6000
SUGCANEJ	0.7500	1.0000	55.0000	0.0320	0.2000	2.5000	12.0000	9.0000	0.6000
SUNSEED	1.7500	1.0000	560.0001	4.5200	47.3000	3.8000	120.0000	837.0001	7.1000
TAMALVS	0.3000	1.0000	64.0000	0.5400	1.0000	2.0000	39.0000	71.0000	1.1000
TAMARIPE	0.7000	1.0000	233.0000	0.3200	0.6000	2.9000	94.0000	78.0000	0.9000
TANG56	0.3500	1.0000	24.0000	0.0640	0.1000	0.2000	33.0000	17.0000	0.2000
TANG57	0.3500	1.0000	44.0000	0.1280	0.3000	1.0000	33.0000	23.0000	0.4000
TARO	0.2000	1.0000	85.0000	0.3840	0.2000	0.4000	32.0000	64.0000	0.8000
TKBREAST	3.2500	1.0000	162.0000	3.8400	6.6000	0.0000	8.0000	212.0000	1.5000
TKGIZZ	1.8000	1.0000	157.0000	3.3600	7.3000	0.0000	6.0000	117.0000	1.3000
TKLIVER	1.8000	1.0000	138.0000	2.7700	4.0000	0.0000	9.0000	185.0000	2.3000
TOMATO	0.6500	1.0000	22.0000	0.1760	0.2000	0.5000	13.0000	27.0000	0.5000
WHEAT	0.5750	1.0000	348.0000	2.0300	1.5000	1.2000	50.0000	320.0000	5.3000
WHEATBR	1.3000	1.0000	213.0000	2.5400	4.6000	9.1000	119.0000	1276.0002	14.9000
WHEATFL	1.0000	1.0000	365.0000	2.1000	1.3000	0.5000	24.0000	[illegible]	1.3000
WHEATGM	2.0000	1.0000	363.0000	4.5700	10.9000	2.5000	72.0000	1118.0002	9.4000
WTMELON	0.1500	1.0000	28.0000	0.0900	0.2000	0.5000	10.0000	10.0000	0.5000
YAM	0.2000	1.0000	94.0000	0.3510	0.3000	0.7000	22.0000	30.0000	1.2000
BUTTER	2.1800	1.0000	739.0001	0.1600	81.8000	0.0000	15.0000	16.0000	0.1000
CASEIN	2.4700	1.0000	354.0000	13.3000	1.5000	0.0000	100.0000	800.0001	0.7500
CHEESE	1.7200	1.0000	426.0000	3.7800	36.5000	0.0000	810.0001	478.0000	0.6000
LACTALB	2.2300	1.0000	394.0000	12.6000	6.0000	0.0000	6.0000	20.0000	0.7500
MILK	1.2400	1.0000	78.0000	0.5510	4.7500	0.0000	123.0000	93.0000	0.0300
SMP	1.1900	1.0000	350.0000	5.9500	1.0000	0.0000	1371.0002	1016.0001	0.3000
WMP	1.6300	1.0000	500.0000	4.4000	26.5000	0.0000	992.0001	708.0001	0.2000

FOOD	VIT.A IU/100G	THIAMINE MG/100G	RIBOFLAVIN MG/100G	NIACIN MG/100G	VIT.C MG/100G	VITB6 MG/100G	VITB12 MG/100G	PANTO.ACID MG/100G	FOLIC ACID µG/100G
ANCHOVY	137.0000	0.0200	0.0400	0.6000	3.0000	0.1440	0.0062	1.0000	50.0000
BAMSHOOT	0.0000	0.0300	0.0500	0.2000	3.0000	0.1530	0.0000	0.6200	100.0000
BANANA	540.0001	0.0200	0.2300	0.1000	12.0000	0.5100	0.0000	0.2600	10.0000
BEANBRD	[illegible]	0.3200	0.1400	3.0000	26.0000	0.0800	0.0000	5.4000	12.0000
BEANSNAP	525.0001	0.0700	0.1000	0.7000	15.0000	0.0800	0.0000	0.1900	20.0000
BEANYDRD	375.0000	0.1300	0.1000	1.1000	20.0000	0.4410	0.0000	0.5000	12.0000
BEEF	40.0000	0.0800	0.1700	4.5000	0.0000	0.3300	0.0014	0.4700	10.0000
BFBLOOD	108.0000	0.0050	0.0300	1.2000	0.5000	0.0000	0.0000	0.1820	2.0000
BFBRAIN	0.0000	0.1300	0.1600	3.8000	18.0000	0.1500	0.0043	2.6000	0.0000
BFHEART	30.0000	0.4800	0.8700	6.8000	14.0000	0.2500	0.0133	2.5000	3.0000
BFKIDNEY	660.0001	0.2300	3.3000	6.2000	15.0000	0.4300	0.0163	3.8500	60.0000
BFLGINT	30.0000	0.0500	0.3200	1.7000	4.0000	0.0000	0.0062	0.0000	0.0000
BFLIVER	24940.0039	0.1700	0.7600	6.4000	31.0000	0.8400	0.0526	7.7000	300.0000
BFLUNG	40.0000	0.1000	0.2700	3.5000	10.0000	0.0000	0.0047	1.0000	3.0000
BFSMINT	30.0000	0.0800	0.1900	2.6000	16.0000	0.0000	0.0040	0.0000	0.0000
BFSPLEEN	195.0000	0.1500	0.4400	4.7000	29.0000	0.1200	0.0068	1.2500	3.0000
BFSTOM	55.0000	0.0400	0.1700	1.6000	3.4000	0.0000	0.0024	0.0000	0.0000
BFTONGUE	5.0000	0.0900	0.1800	3.6000	0.0000	0.1250	0.0017	2.0000	3.0000
BRDFRUIT	55.0000	0.0900	0.0500	1.5000	45.0000	0.0200	0.0000	0.4570	0.0000
BUFFALO	40.0000	0.0800	0.1700	4.7000	0.0000	0.3300	0.0014	0.4700	10.0000
BUBRAIN	0.0000	0.1600	0.2000	2.7000	12.0000	0.1500	0.0069	2.6000	0.0000
BUHEART	30.0000	0.2400	1.2000	6.9000	6.0000	0.2500	0.0074	2.5000	3.0000
BUKIDNEY	335.0000	0.2200	2.6700	6.2000	15.0000	0.4300	0.0271	3.8500	60.0000
BULGINT	30.0000	0.0300	0.1000	1.2000	4.0000	0.0000	0.0011	0.0000	0.0000
BULIVER	49735.0079	0.1700	1.5400	11.2000	22.0000	0.8400	0.0286	7.7000	300.0000
BUSMINT	30.0000	0.0700	0.1800	3.0000	16.0000	0.0000	0.0042	0.0000	0.0000
BUSPLEEN	95.0000	0.1200	0.4600	4.9000	30.0000	0.1200	0.0036	1.2500	3.0000
BUSTOM	40.0000	0.0200	0.1200	3.5000	0.5000	0.0000	0.0019	0.0000	0.0000
CABCHI	3600.0004	0.0700	0.1300	1.0000	74.0000	0.1600	0.0000	0.2050	20.0000
CABCOM	130.0000	0.0500	0.0500	0.3000	47.0000	0.1600	0.0000	0.2050	20.0000
CARP	170.0000	0.0100	0.0400	1.5000	1.0000	0.2000	0.0002	0.1500	50.0000
CASHFRT	25.0000	0.0200	0.0100	0.4000	197.0000	0.0200	0.0000	0.0760	2.0000
CASHNUT	100.0000	0.4900	0.2100	1.7000	0.0000	0.0600	0.0000	1.3000	4.0000
CASSLVS	18155.0039	0.2500	0.4300	2.0000	127.0000	0.0700	0.0000	0.1000	20.0000
CASSAVA	250.0000	0.0400	0.0100	0.6000	41.0000	0.1100	0.0000	0.5210	0.0000
CATFISH	1245.0002	0.0300	0.0800	0.8000	0.0000	0.2000	0.0025	0.2000	50.0000
CAULI	60.0000	0.1100	0.1000	0.7000	78.0000	0.2100	0.0000	1.0000	30.0000
CELERY	2685.0004	0.0800	0.1200	0.6000	49.0000	0.0600	0.0000	0.4290	7.0000
CHICKEN	410.0000	0.0800	0.1600	8.0000	0.0000	0.5000	0.0004	0.9000	3.0000
CHGIZZ	0.0000	0.0600	0.2500	4.8000	4.0000	0.0300	0.0019	0.7500	0.0000
CHLIVER	32200.0039	0.3100	4.4900	11.2000	35.0000	0.7500	0.0270	6.0000	270.0000
COCOMEAT	0.0000	0.0500	0.0200	0.5000	3.0000	0.0440	0.0000	0.2000	28.0000
COCOMILK	0.0000	0.0300	0.0020	0.8000	2.0000	0.0320	0.0000	0.0500	0.3000
COCONUT	0.0000	0.0400	0.0300	0.4000	3.0000	0.0440	0.0000	0.2000	28.0000
CORNWH	5.0000	0.2200	0.1000	1.9000	6.0000	0.2500	0.0000	0.5800	35.0000
CORNY	435.0000	0.2600	0.1500	1.5000	10.0000	0.2500	0.0000	0.5800	35.0000
CRAB	300.0000	0.0700	0.1500	2.1000	2.0000	0.3000	0.0100	0.6000	50.0000
CUCUM	250.0000	0.0300	0.0400	0.2000	11.0000	0.0420	0.0000	0.2500	6.0000
DUCK	0.0000	0.1600	0.3800	8.0000	0.0000	0.5000	0.0004	0.9000	3.0000
DUCKT	0.0000	0.0800	0.1900	6.7000	0.0000	0.5000	0.0004	0.9000	3.0000
EGGDUCK	2845.0004	0.2700	0.5600	0.1000	0.5000	0.1100	0.0047	1.6000	8.0000

FOOD	VIT.A	THIAMINE	RIBOFLAVIN	NIACIN	VIT.C	VITB6	VITB12	PANTO.ACID	FOLIC ACID
	IU/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	μG/100G
EGGHEN	1140.0002	0.0800	0.4800	0.1000	1.0000	0.1100	0.0040	1.6000	[illegible].0000
EGGPLANT	130.0000	0.1000	0.0500	0.6000	5.0000	0.0810	0.0000	0.2200	10.0000
FROG	0.0000	0.0600	0.1200	5.0000	0.0000	0.1200	0.0020	0.3700	10.0000
GARLIC	1430.0002	0.0900	0.1000	0.8000	33.0000	0.1300	0.0000	0.1300	10.0000
GINGER	0.0000	0.0400	0.0500	0.6000	4.0000	0.0750	0.0000	0.2030	10.0000
GOOSE	0.0000	0.1100	0.3700	9.5000	0.0000	0.5000	0.0004	0.9000	3.0000
GOOSET	0.0000	0.0800	0.1900	6.7000	0.0000	0.5000	0.0004	0.9000	3.0000
GOURDB	20.0000	0.0400	0.0300	0.4000	10.0000	0.0680	0.0000	0.3000	2.0000
GOURDWX	0.0000	0.0500	0.0600	0.3000	22.0000	0.0680	0.0000	0.3000	2.0000
GRAPE	100.0000	0.0600	0.0200	0.2000	3.0000	0.0800	0.0000	0.0750	6.0000
GUAVARD	105.0000	0.0600	0.0400	2.1000	126.0000	0.0170	0.0000	0.1500	2.0000
GUAVAWH	65.0000	0.0700	0.0400	1.6000	104.0000	0.0170	0.0000	0.1500	2.0000
HERRING	90.0000	0.0100	0.0700	7.5000	3.0000	0.3700	0.0100	0.9700	50.0000
HORSE	0.0000	0.0700	0.1200	4.3000	0.0000	0.3300	0.0014	0.4700	10.0000
JACKFRT	175.0000	0.0900	0.0500	0.9000	4.0000	0.0200	0.0000	0.4570	2.0000
JCKFRTSD	0.0000	0.2200	0.0600	0.6000	10.0000	1.2500	0.0000	1.4000	0.0000
KALE	2750.0004	0.1000	0.7600	1.0000	120.0000	0.3500	0.0000	0.3000	50.0000
LEEK	3045.0004	0.0700	0.1100	0.8000	25.0000	0.2000	0.0000	0.1200	10.0000
LEMON	0.0000	0.0200	0.0100	0.2000	45.0000	0.0800	0.0000	0.1900	7.0000
LETTUCE	2855.0004	0.0600	0.1200	0.4000	21.0000	0.0550	0.0000	0.2000	20.0000
LIME	30.0000	0.0200	0.0200	0.2000	52.0000	0.0430	0.0000	0.1380	7.0000
LOBSTER	0.0000	0.4000	0.0500	1.5000	0.0000	0.2100	0.0005	1.5000	2.0000
MACKSP	70.0000	0.0300	0.0800	5.7000	0.5000	0.5000	0.0023	0.2400	50.0000
MANGO	2590.0004	0.0900	0.0500	0.7000	47.0000	0.0200	0.0000	0.1600	2.0000
MELON	370.0000	0.0200	0.0200	0.3000	21.0000	0.0400	0.0000	0.2300	6.0000
MILKBUFF	130.0000	0.0400	0.1800	0.1000	1.0000	0.0400	0.0004	0.3400	0.3000
MILKFISH	675.0001	0.0100	0.0400	6.9000	0.5000	0.2000	0.0034	0.2000	50.0000
MILKGOAT	110.0000	0.0500	0.2700	0.1000	1.3000	0.0450	0.0001	0.3200	0.3000
MULLET	105.0000	0.0100	0.1000	5.7000	0.0000	0.4200	0.0086	0.7500	50.0000
MUNGBEAN	130.0000	0.6600	0.2200	2.4000	10.0000	0.5800	0.0000	0.9750	20.0000
MUSHROOM	0.0000	0.1000	0.4400	4.9000	5.0000	0.1250	0.0000	2.2000	20.0000
MUSSEL	162.0000	0.0200	0.1800	1.9000	0.0000	0.0300	0.0012	0.1320	2.0000
OCTOPUS	0.0000	0.0100	0.0900	2.0000	0.0000	0.3600	0.0020	0.2000	10.0000
ONIONBU	0.0000	0.0500	0.0400	0.4000	25.0000	0.1000	0.0000	0.1000	10.0000
ONIONGR	4000.0004	0.0700	0.1000	0.6000	51.0000	0.1000	0.0000	0.1000	10.0000
ORANGE	190.0000	0.0800	0.0300	0.2000	49.0000	0.0600	0.0000	0.2500	5.0000
PAPAYA	425.0000	0.0300	0.0300	0.4000	89.0000	0.0200	0.0000	0.2180	20.0000
PEACH	1330.0002	0.0200	0.0500	1.0000	7.0000	0.0240	0.0000	0.1700	2.0000
PEACHICK	15.0000	0.1300	0.1600	1.2000	0.5000	0.5400	0.0000	1.2500	20.0000
PEANUT	35.0000	1.1400	0.1300	17.2000	11.0000	0.4000	0.0000	2.8000	55.0000
PEAPIG	0.0000	0.4200	0.1600	1.4000	28.0000	0.3000	0.0000	1.5000	20.0000
PEASWT	305.0000	0.1400	0.0900	0.9000	77.0000	0.1600	0.0000	0.[illegible]00	27.0000
PEPPERGR	260.0000	0.0500	0.0300	0.5000	84.0000	0.2600	0.0000	0.2300	0.0000
PEPPERRD	470.0000	0.0500	0.0600	0.9000	18.0000	0.2600	0.0000	0.2710	0.0000
PERCH	0.0000	0.0200	0.3100	3.7000	0.0000	0.2000	0.0010	0.2000	50.0000
PIG	0.0000	0.5400	0.1300	2.9000	0.0000	0.3500	0.0005	0.6000	3.0000
PIBLOOD	87.0000	0.0100	0.0100	0.3000	0.3600	0.0000	0.0000	0.0320	2.5000
PIHEART	35.0000	0.2200	1.5600	5.2000	4.0000	0.3900	0.00[illegible]2	2.5000	3.0000
PIKIDNEY	121.0000	0.3800	1.7100	9.7000	12.0000	0.4500	0.0121	3.2000	60.0000
PILGINT	30.0000	0.0800	0.2400	1.7000	4.0000	0.0000	0.0008	0.0000	0.0000
PILIVER	10900.0019	0.3000	3.0300	16.4000	23.0000	0.6500	0.0651	6.4000	220.0000

FOOD	VIT.A	THIAMINE	RIBOFLAVIN	NIACIN	VIT.C	VITB6	VITB12	PANTO.ACID	FOLIC ACID
	IU/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	µG/100G
PILUNG	71.0000	0.1100	0.4100	3.1000	10.0000	0.0000	0.0007	1.0000	3.0000
PISMINT	30.0000	0.1700	0.3300	2.9000	14.0000	0.0000	0.0007	0.0000	0.0000
PISPLEEN	195.0000	0.2100	0.4100	4.4000	29.0000	0.1200	0.0055	1.2500	3.0000
PISTOM	40.0000	0.0900	0.2900	2.4000	2.0000	0.0000	0.0009	0.0000	0.0000
PITONGUE	5.0000	0.1700	0.2100	3.4000	0.0000	0.2800	0.0028	2.0000	3.0000
PINEAP	15.0000	0.0900	0.0400	0.2000	17.0000	0.0880	0.0000	0.1600	5.0000
POMELO	10.0000	0.0200	0.0100	0.2000	58.0000	0.0600	0.0000	0.2500	3.0000
POTATO	0.0000	0.1000	0.0400	1.5000	20.0000	0.2500	0.0000	0.3800	6.0000
POTSTWH	60.0000	0.0900	0.0400	0.5000	53.0000	0.2800	0.0000	0.8200	10.0000
POTSWY	900.0001	0.1000	0.0400	0.6000	35.0000	0.2180	0.0000	0.8200	10.0000
PRAWN	250.0000	0.0700	0.0400	3.6000	0.0000	0.0300	0.0012	0.1320	2.0000
PUMPKIN	1650.0002	0.0400	0.0500	0.6000	12.0000	0.0560	0.0000	0.4000	6.0000
RADISH	0.0000	0.0200	0.0300	0.3000	25.0000	0.1000	0.0000	0.1800	10.0000
RICEBR	0.0000	0.3800	0.1800	6.6000	0.0000	0.5500	0.0000	1.1000	10.0000
RICEGL	0.0000	0.1200	0.0400	2.6000	0.0000	0.1700	0.0000	0.5500	10.0000
RICEWH	0.0000	0.1000	0.0500	2.4000	0.0000	0.1700	0.0000	0.5500	10.0000
SARDINE	50.0000	0.0100	0.1000	8.1000	0.5000	0.2400	0.0018	1.0000	50.0000
SESAME	35.0000	0.5000	0.1000	4.5000	0.0000	1.2500	0.0000	2.7600	0.0000
SHALLOT	5.0000	0.0400	0.0200	0.3000	2.0000	0.1000	0.0000	0.1000	10.0000
SHARK	0.0000	0.0200	0.0300	6.6000	0.0000	0.2000	0.0010	0.2000	50.0000
SHRIMP	36.0000	0.0500	0.1400	3.1000	0.0000	0.1000	0.0080	0.2800	2.0000
SNAPPER	5.0000	0.0500	0.0800	3.7000	21.0000	0.2000	0.1000	0.2000	50.0000
SORGHUM	0.0000	0.3800	0.1500	3.9000	0.0000	0.3000	0.0000	1.1000	10.0000
SOYBEAN	80.0000	1.1000	0.3100	2.2000	0.5000	0.8100	0.0000	1.7000	55.0000
SUGAR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SUGCANEJ	0.0000	0.0100	0.0100	0.1000	0.0000	0.0000	0.0000	0.0000	0.0000
SUNSEED	50.0000	1.9600	0.2300	5.4000	0.0000	1.2500	0.0000	1.4000	0.0000
TAMALVS	2715.0004	0.1800	0.1500	1.7000	9.0000	0.0700	0.0000	0.1000	20.0000
TAMARIPE	0.0000	0.3300	0.1000	1.0000	4.0000	0.0200	0.0000	0.1430	0.0000
TANG56	50.0000	0.1100	0.0200	0.2000	20.0000	0.0670	0.0000	0.2000	0.0000
TANG57	420.0000	0.0700	0.0300	0.2000	31.0000	0.0670	0.0000	0.2000	0.0000
TARO	5.0000	0.1800	0.0400	0.9000	10.0000	0.1100	0.0000	0.5210	10.0000
TKBREAST	0.0000	0.0800	0.1400	8.0000	0.0000	0.3250	0.0004	0.7480	3.0000
TKGIZZ	0.0000	0.0700	0.2400	5.9000	4.0000	0.0300	0.0019	0.9090	0.0000
TKLIVER	17700.0039	0.2400	2.4600	15.6000	35.0000	0.7500	0.0279	6.0000	220.0000
TOMATO	900.0001	0.0600	0.0400	0.7000	23.0000	0.1000	0.0000	0.3300	5.0000
WHEAT	106.0000	0.5400	0.1200	5.0000	0.0000	0.3400	0.0000	1.1000	35.0000
WHEATBR	0.0000	0.7200	0.3500	21.0000	0.0000	0.6200	0.0000	2.9000	14.0000
WHEATFL	0.0000	0.2600	0.0700	2.0000	0.0000	0.1000	0.0000	0.8000	14.0000
WHEATGM	0.0000	2.0100	0.6800	4.2000	0.0000	1.1500	0.0000	1.2000	14.0000
WTMELON	360.0000	0.0300	0.0300	0.2000	6.0000	0.0680	0.0000	0.3000	2.0000
YAM	140.0000	0.0400	0.0200	0.5000	22.0000	0.1100	0.0000	0.6290	2.0000
BUTTER	2900.0004	0.0000	0.0100	0.1000	0.0000	0.0040	0.0000	0.2300	0.0000
CASEIN	0.0000	0.0820	0.2600	0.2400	0.0000	0.2700	0.0071	0.3600	34.0000
CHEESE	1300.0002	0.0300	0.4200	0.0500	0.0000	0.0750	0.0013	0.2700	9.5000
LACTALB	0.0000	0.0700	0.8500	0.2000	0.0000	0.1200	0.0050	0.7300	27.0000
MILK	180.0000	0.0410	0.1700	0.1000	1.0000	0.0640	0.0004	0.3460	0.2800
SMP	50.0000	0.4170	1.9700	1.1000	0.0000	0.4500	0.0034	3.8800	4.4000
AMP	1220.0002	0.2980	1.4100	0.8000	0.0000	0.3900	0.0026	2.7300	1.6000

FOOD	ISOLEUCINE MG/G N.	LEUCINE MG/G N.	LYSINE MG/G N.	METHIONINE MG/G N.	CYSTINE MG/G N.	PH/ALANINE MG/G N.	TYROSINE MG/G N.	THREONINE MG/G N.	TRYPTOPHAN MG/G N.	VALINE MG/G N.
ANCHOVY	330.0000	551.0001	563.0001	194.0000	76.0000	289.0000	242.0000	321.0000	67.0000	354.0000
BAMSHOOT	162.0000	281.0000	281.0000	81.0000	56.0000	162.0000	131.0000	175.0000	74.0000	231.0000
BANANA	181.0000	294.0000	256.0000	125.0000	169.0000	244.0000	163.0000	213.0000	74.0000	250.0000
BEANBRD	250.0000	443.0000	404.0000	46.0000	50.0000	270.0000	200.0000	210.0000	50.0000	275.0000
BEANSNAP	271.0000	488.0000	465.0000	69.0000	55.0000	337.0000	163.0000	256.0000	63.0000	296.0000
BEANYORD	144.0000	218.0000	32.0000	68.0000	19.0000	387.0000	81.0000	34.0000	75.0000	194.0000
BEEF	301.0000	507.0000	556.0001	169.0000	80.0000	275.0000	225.0000	287.0000	70.0000	313.0000
BFBLCOD	79.0000	1110.0002	770.0001	97.0000	136.0000	590.0001	350.0000	455.0000	146.0000	750.0001
BFBRAIN	297.0000	543.0001	454.0000	225.0000	98.0000	282.0000	194.0000	250.0000	94.0000	398.0000
BFHEART	297.0000	543.0001	454.0000	114.0000	98.0000	252.0000	194.0000	250.0000	86.0000	398.0000
BFKIDNEY	297.0000	543.0001	454.0000	225.0000	98.0000	282.0000	194.0000	250.0000	88.0000	398.0000
BFLGINT	297.0000	543.0001	454.0000	114.0000	98.0000	252.0000	194.0000	250.0000	86.0000	398.0000
BFLIVER	297.0000	543.0001	454.0000	300.0000	98.0000	263.0000	194.0000	250.0000	100.0000	398.0000
BFLUNG	297.0000	543.0001	454.0000	114.0000	98.0000	252.0000	194.0000	250.0000	86.0000	398.0000
BFSMINT	297.0000	543.0001	454.0000	181.0000	98.0000	237.0000	194.0000	250.0000	69.0000	398.0000
BFSPLEEN	297.0000	543.0001	454.0000	114.0000	98.0000	252.0000	194.0000	250.0000	86.0000	398.0000
BFSTOM	312.0000	549.0001	410.0000	162.0000	23.0000	274.0000	255.0000	300.0000	0.0000	356.0000
BFTONGUE	297.0000	543.0001	454.0000	250.0000	98.0000	213.0000	194.0000	250.0000	82.0000	398.0000
BRDFRUIT	419.0000	463.0000	363.0000	75.0000	54.0000	519.0001	45.0000	425.0000	111.0000	488.0000
BUFFALO	253.0000	425.0000	465.0000	141.0000	67.0000	230.0000	188.0000	241.0000	59.0000	262.0000
BUBRAIN	297.0000	543.0001	454.0000	225.0000	98.0000	282.0000	194.0000	250.0000	94.0000	398.0000
BUHEART	297.0000	543.0001	454.0000	114.0000	98.0000	252.0000	194.0000	250.0000	86.0000	398.0000
BUKIDNEY	297.0000	543.0001	454.0000	225.0000	98.0000	282.0000	194.0000	250.0000	94.0000	398.0000
BULGINT	297.0000	543.0001	454.0000	182.0000	98.0000	237.0000	194.0000	250.0000	69.0000	398.0000
BULIVER	297.0000	543.0001	454.0000	300.0000	98.0000	264.0000	194.0000	250.0000	100.0000	398.0000
BUSMINT	297.0000	543.0001	454.0000	182.0000	98.0000	236.0000	194.0000	250.0000	69.0000	398.0000
BUSPLEEN	297.0000	543.0001	454.0000	114.0000	98.0000	252.0000	194.0000	250.0000	86.0000	398.0000
BUSTOM	312.0000	549.0001	410.0000	162.0000	23.0000	274.0000	255.0000	300.0000	0.0000	356.0000
CABCHI	350.0000	362.0000	369.0000	37.0000	70.0000	187.0000	115.0000	206.0000	63.0000	275.0000
CABCOM	193 0000	331.0000	194.0000	65.0000	70.0000	189.0000	115.0000	235.0000	66.0000	263.0000
CARP	289.0000	499.0000	552.0001	231.0000	77.0000	224.0000	207.0000	274.0000	64.0000	404.0000
CASHFRT	54.0000	125.0000	116.0000	0.0000	36.0000	89.0000	36.0000	107.0000	18.0000	134.0000
CASHNUT	322.0000	513.0001	287.0000	94.0000	150.0000	266.0000	140.0000	203.0000	115.0000	362.0000
CASSLVS	303.0000	536.0001	390.0000	105.0000	69.0000	345.0000	245.0000	292.0000	91.0000	358.0000
CASSAVA	175.0000	247.0000	259.0000	83.0000	90.0000	156.0000	100.0000	165.0000	72.0000	209.0000
CATFISH	289.0000	499.0000	552.0001	231.0000	77.0000	224.0000	207.0000	274.0000	64.0000	404.0000
CAULI	302.0000	436.0000	356.0000	99.0000	500.0000	225.0000	88.0000	264.0000	86.0000	347.0000
CELERY	244.0000	425.0000	150.0000	138.0000	6.0000	281.0000	81.0000	213.0000	81.0000	300.0000
CHICKEN	334.0000	460.0000	497.0000	157.0000	82.0000	250.0000	209.0000	248.0000	64.0000	318.0000
CHGIZZ	320.0000	540.0001	475.0000	137.0000	63.0000	327.0000	188.0000	302.0000	63.0000	371.0000
CHLIVER	300.0000	592.0001	510.0000	156.0000	125.0000	281.0000	205.0000	370.0000	68.0000	370.0000
COCOMEAT	244.0000	419.0000	220.0000	120.0000	76.0000	283.0000	167.0000	212.0000	68.0000	339.0000
COCOMILK	131.0000	435.0000	230.0000	75.0000	110.0000	280.0000	167.0000	106.0000	69.0000	275.0000
COCONUT	280.0000	450.0000	220.0000	110.0000	110.0000	260.0000	167.0000	190.0000	130.0000	350.0000
CORNMH	327.0000	745.0001	313.0000	142.0000	39.0000	318.0000	107.0000	370.0000	37.0000	387.0000
CORNY	230.0000	783.0001	167.0000	120.0000	97.0000	305.0000	239.0000	225.0000	44.0000	303.0000
CRAB	291.0000	542.0001	493.0000	182.0000	79.0000	252.0000	227.0000	285.0000	72.0000	299.0000
CUCUM	194.0000	263.0000	273.0000	58.0000	6.0000	144.0000	81.0000	163.0000	48.0000	213.0000
DUCK	418.0000	575.0001	621.0001	196.0000	102.0000	313.0000	261.0000	311.0000	80.0000	396.0000
DUCKT	417.0000	575.0001	620.0001	196.0000	103.0000	313.0000	262.0000	310.0000	80.0000	392.0000
EGGDUCK	350.0000	605.0001	485.0000	301.0000	106.0000	388.0000	336.0000	438.0000	81.0000	467.0000

FOOD	ISOLEUCINE MG/G N.	LEUCINE MG/G N.	LYSINE MG/G N.	METHIONINE MG/G N.	CYSTINE MG/G N.	PH/ALANINE MG/G N.	TYROSINE MG/G N.	THREONINE MG/G N.	TRYPTOPHAN MG/G N.	VALINE MG/G N.
EGGHEN	393.0000	551.0001	436.0000	210.0000	152.0000	358.0000	260.0000	320.0000	93.0000	428.0000
EGGPLANT	270.0000	380.0000	332.0000	71.0000	33.0000	260.0000	240.0000	230.0000	64.0000	320.0000
FROG	319.0000	489.0000	620.0001	207.0000	54.0000	244.0000	375.0000	257.0000	63.0000	306.0000
GARLIC	93.0000	169.0000	288.0000	74.0000	400.0000	175.0000	200.0000	93.0000	93.0000	138.0000
GINGER	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
GOOSE	339.0000	460.0000	497.0000	157.0000	82.0000	250.0000	209.0000	248.0000	64.0000	318.0000
GOOSET	417.0000	575.0001	620.0001	196.0000	103.0000	313.0000	262.0000	310.0000	80.0000	392.0000
GOURDB	50.0000	130.0000	137.0000	50.0000	600.0001	100.0000	300.0000	300.0000	38.0000	300.0000
GOURDWX	50.0000	130.0000	137.0000	50.0000	600.0001	100.0000	300.0000	300.0000	38.0000	300.0000
GRAPE	50.0000	130.0000	140.0000	210.0000	100.0000	130.0000	110.0000	170.0000	25.0000	170.0000
GUAVARD	180.0000	250.0000	188.0000	60.0000	54.0000	150.0000	240.0000	51.0000	60.0000	250.0000
GUAVAWH	180.0000	250.0000	188.0000	60.0000	54.0000	150.0000	240.0000	51.0000	60.0000	250.0000
HERRING	330.0000	551.0001	563.0001	194.0000	76.0000	299.0000	242.0000	321.0000	67.0000	384.0000
HORSE	406.0000	594.0001	625.0001	175.0000	81.0000	238.0000	231.0000	244.0000	63.0000	313.0000
JACKFRT	27.0000	63.0000	63.0000	9.0000	18.0000	45.0000	18.0000	54.0000	13.0000	67.0000
JCKFRTSD	300.0000	331.0000	363.0000	50.0000	63.0000	256.0000	118.0000	269.0000	69.0000	413.0000
KALE	375.0000	413.0000	387.0000	56.0000	6.0000	356.0000	81.0000	287.0000	75.0000	325.0000
LEEK	406.0000	375.0000	400.0000	100.0000	406.0000	200.0000	155.0000	194.0000	56.0000	294.0000
LEMON	188.0000	328.0000	219.0000	94.0000	157.0000	188.0000	265.0000	188.0000	63.0000	265.0000
LETTUCE	238.0000	394.0000	238.0000	112.0000	6.0000	319.0000	169.0000	256.0000	50.0000	338.0000
LIME	195.0000	328.0000	117.0000	16.0000	78.0000	195.0000	133.0000	196.0000	23.0000	265.0000
LOBSTER	256.0000	535.0001	591.0001	200.0000	144.0000	293.0000	381.0000	275.0000	56.0000	280.0000
MACKSP	277.0000	425.0000	539.0001	152.0000	68.0000	212.0000	224.0000	247.0000	74.0000	413.0000
MANGO	75.0000	175.0000	651.0001	63.0000	50.0000	125.0000	50.0000	150.0000	119.0000	187.0000
MELON	50.0000	130.0000	169.0000	12.0000	54.0000	100.0000	48.0000	94.0000	25.0000	147.0000
MILKBUFF	334.0000	631.0001	489.0000	167.0000	84.0000	281.0000	313.0000	308.0000	92.0000	380.0000
MILKFISH	330.0000	551.0001	563.0001	194.0000	76.0000	299.0000	242.0000	321.0000	67.0000	384.0000
MILKGOAT	328.0000	589.0001	327.0000	84.0000	45.0000	236.0000	201.0000	274.0000	75.0000	404.0000
MULLET	293.0000	446.0000	590.0001	178.0000	74.0000	235.0000	229.0000	264.0000	68.0000	405.0000
MUNGBEAN	287.0000	450.0000	456.0000	69.0000	38.0000	369.0000	106.0000	213.0000	37.0000	320.0000
MUSHROOM	140.0000	230.0000	280.0000	29.0000	33.0000	130.0000	120.0000	170.0000	64.0000	160.0000
MUSSEL	295.0000	483.0000	498.0000	171.0000	99.0000	259.0000	260.0000	293.0000	81.0000	391.0000
OCTOPUS	231.0000	270.0000	530.0001	150.0000	52.0000	162.0000	188.0000	194.0000	69.0000	640.0001
ONIONBU	93.0000	169.0000	288.0000	74.0000	400.0000	175.0000	200.0000	93.0000	93.0000	138.0000
ONIONGR	93.0000	169.0000	223.0000	74.0000	300.0000	56.0000	156.0000	155.0000	93.0000	925.0001
ORANGE	180.0000	170.0000	330.0000	94.0000	75.0000	230.0000	130.0000	94.0000	44.0000	240.0000
PAPAYA	63.0000	146.0000	292.0000	10.0000	42.0000	104.0000	42.0000	125.0000	83.0000	156.0000
PEACH	100.0000	220.0000	230.0000	240.0000	69.0000	140.0000	160.0000	210.0000	29.0000	310.0000
PEACHICK	277.0000	468.0000	428.0000	65.0000	74.0000	358.0000	183.0000	235.0000	54.0000	284.0000
PEANUT	211.0000	400.0000	221.0000	72.0000	78.0000	311.0000	244.0000	163.0000	65.0000	261.0000
PEAPIG	194.0000	394.0000	481.0000	33.0000	61.0000	517.0001	126.0000	182.0000	35.0000	225.0000
PEASNT	260.0000	435.0000	456.0000	58.0000	60.0000	275.0000	194.0000	235.0000	63.0000	296.0000
PEPPERGR	239.0000	239.0000	260.0000	83.0000	88.0000	285.0000	238.0000	260.0000	42.0000	166.0000
PEPPERRD	239.0000	239.0000	260.0000	83.0000	88.0000	285.0000	238.0000	260.0000	42.0000	165.0000
PERCH	293.0000	446.0000	590.0001	178.0000	74.0000	235.0000	229.0000	264.0000	68.0000	405.0000
PIG	356.0000	563.0001	625.0001	188.0000	88.0000	288.0000	247.0000	319.0000	85.0000	388.0000
PIBLOOD	56.0000	1140.0002	743.0001	93.0000	113.0000	592.0001	315.0000	418.0000	136.0000	735.0001
PIHEART	300.0000	500.0000	555.0001	144.0000	63.0000	288.0000	181.0000	257.0000	56.0000	362.0000
PIKIDNEY	275.0000	520.0001	438.0000	144.0000	63.0000	288.0000	162.0000	269.0000	88.0000	414.0000
PILGINT	225.0000	331.0000	468.0000	144.0000	81.0000	262.0000	169.0000	287.0000	69.0000	338.0000
PILIVER	325.0000	600.0001	425.0000	150.0000	69.0000	288.0000	205.0000	306.0000	69.0000	387.0000

FOOD	ISOLEUCINE	LEUCINE	LYSINE	METHIONINE	CYSTINE	PH/ALANINE	TYROSINE	THREONINE	TRYPTOPHAN	VALINE
	MG/G N.	MG/G N.	MG/G N.	MG/G N.	MG/G N.	MG/G N.	MG/G N.	MG/G N.	MG/G N.	MG/G N.
PILUNG	378.0000	520.0001	529.0001	159.0000	85.0000	302.0000	215.0000	282.0000	81.0000	372.0000
PISMINT	225.0000	331.0000	488.0000	146.0000	81.0000	262.0000	169.0000	387.0000	69.0000	338.0000
PISPLEEN	378.0000	520.0001	529.0001	159.0000	85.0000	302.0000	215.0000	282.0000	31.0000	372.0000
PISTOM	378.0000	520.0001	529.0001	159.0000	85.0000	302.0000	215.0000	282.0000	81.0000	372.0000
PITONGUE	312.0000	462.0000	638.0001	119.0000	94.0000	288.0000	194.0000	306.0000	87.0000	350.0000
PINEAP	94.0000	218.0000	225.0000	47.0000	63.0000	156.0000	63.0000	187.0000	78.0000	234.0000
POMELO	200.0000	337.0000	212.0000	87.0000	125.0000	200.0000	212.0000	200.0000	62.0000	274.0000
POTATO	236.0000	377.0000	299.0000	81.0000	37.0000	251.0000	171.0000	235.0000	103.0000	292.0000
POTSTWH	230.0000	340.0000	214.0000	106.0000	69.0000	241.0000	146.0000	236.0000	107.0000	283.0000
POTSWY	230.0000	340.0000	214.0000	106.0000	69.0000	241.0000	146.0000	236.0000	107.0000	283.0000
PRAWN	200.0000	420.0000	505.0000	188.0000	75.0000	388.0000	150.0000	270.0000	112.0000	250.0000
PUMPKIN	251.0000	325.0000	270.0000	54.0000	330.0000	206.0000	81.0000	169.0000	70.0000	300.0000
RADISH	300.0000	419.0000	269.0000	54.0000	1160.0002	269.0000	125.0000	231.0000	23.0000	394.0000
RICEBR	238.0000	514.0001	237.0000	145.0000	67.0000	322.0000	218.0000	244.0000	78.0000	344.0000
RICEGL	232.0000	544.0001	243.0000	137.0000	75.0000	337.0000	212.0000	243.0000	81.0000	337.0000
RICEWH	262.0000	514.0001	226.0000	133.0000	96.0000	303.0000	200.0000	207.0000	84.0000	361.0000
SARDINE	361.0000	606.0001	618.0001	213.0000	83.0000	317.0000	265.0000	352.0000	73.0000	420.0000
SESAME	226.0000	419.0000	171.0000	176.0000	113.0000	277.0000	195.0000	223.0000	84.0000	288.0000
SHALLOT	93.0000	169.0000	288.0000	74.0000	400.0000	175.0000	200.0000	93.0000	93.0000	138.0000
SHARK	434.0000	534.0001	603.0001	178.0000	57.0000	258.0000	231.0000	257.0000	70.0000	344.0000
SHRIMP	200.0000	418.0000	393.0000	187.0000	175.0000	237.0000	231.0000	263.0000	44.0000	250.0000
SNAPPER	293.0000	446.0000	590.0001	178.0000	74.0000	235.0000	229.0000	264.0000	68.0000	405.0000
SORGHUM	245.0000	832.0001	126.0000	87.0000	94.0000	306.0000	167.0000	189.0000	76.0000	313.0000
SOYBEAN	284.0000	486.0000	359.0000	79.0000	83.0000	309.0000	196.0000	241.0000	80.0000	300.0000
SUGAR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SUGCANEJ	63.0000	63.0000	63.0000	0.0000	0.0000	63.0000	63.0000	125.0000	0.0000	125.0000
SUNSEED	267.0000	401.0000	225.0000	119.0000	93.0000	278.0000	118.0000	230.0000	85.0000	317.0000
TAMALVS	331.0000	581.0001	369.0000	44.0000	56.0000	388.0000	219.0000	288.0000	91.0000	362.0000
TAMARIPE	56.0000	130.0000	312.0000	31.0000	54.0000	100.0000	48.0000	94.0000	37.0000	147.0000
TANG56	160.0000	140.0000	300.0000	170.0000	56.0000	180.0000	81.0000	110.0000	75.0000	290.0000
TANG57	160.0000	140.0000	300.0000	170.0000	56.0000	180.0000	81.0000	110.0000	75.0000	290.0000
TARO	219.0000	460.0000	241.0000	84.0000	163.0000	316.0000	226.0000	257.0000	88.0000	382.0000
TKBREAST	319.0000	475.0000	570.0001	163.0000	63.0000	226.0000	94.0000	256.0000	56.0000	319.0000
TKGIZZ	318.0000	538.0001	475.0000	137.0000	63.0000	324.0000	187.0000	300.0000	63.0000	368.0000
TKLIVER	300.0000	595.0001	505.0000	156.0000	125.0000	280.0000	206.0000	368.0000	88.0000	368.0000
TOMATO	112.0000	169.0000	175.0000	37.0000	37.0000	11[illegible].0000	81.0000	138.0000	52.0000	131.0000
WHEAT	204.0000	417.0000	179.0000	94.0000	159.0000	281.0000	187.0000	183.0000	68.0000	276.0000
WHEATBR	209.0000	415.0000	270.0000	102.0000	168.0000	263.0000	197.0000	223.0000	80.0000	315.0000
WHEATFL	228.0000	440.0000	130.0000	91.0000	159.0000	304.0000	145.0000	168.0000	57.0000	258.0000
WHEATGM	225.0000	433.0000	407.0000	122.0000	130.0000	257.0000	194.0000	265.0000	66.0000	314.0000
WTMELON	75.0000	175.0000	25.0000	0.0000	50.0000	125.0000	50.0000	150.0000	12.0000	187.0000
YAM	234.0000	404.0000	255.0000	100.0000	72.0000	300.0000	201.0000	225.0000	30.0000	291.0000
BUTTER	370.0000	706.0001	502.0000	214.0000	64.0000	396.0000	400.0000	269.0000	76.0000	511.0000
CASEIN	345.0000	607.0001	518.0001	178.0000	23.0000	334.0000	371.0000	297.0000	103.0000	430.0000
CHEESE	339.0000	661.0001	553.0001	188.0000	27.0000	337.0000	345.0000	[illegible]57.0000	77.0000	494.0000
LACTALB	450.0000	732.0001	512.0001	156.0000	237.0000	350.0000	320.0000	338.0000	156.0000	431.0000
MILK	368.0000	678.0001	435.0000	143.0000	43.0000	350.0000	318.0000	269.0000	92.0000	447.0000
SMP	388.0000	590.0001	445.0000	169.0000	69.0000	307.0000	282.0000	275.0000	88.0000	388.0000
WMP	350.0000	619.0001	453.0000	161.0000	59.0000	303.0000	311.0000	263.0000	89.0000	402.0000

APPENDIX 2

DAILY NUTRITIONAL REQUIREMENTS

The nutritional requirements of the Thai population for each of 26 nutrients are given in Table A.1. The requirements are given by sex and age group.

The weighted average nutritional requirements for each nutrient were calculated from the daily requirements quoted in Table A.1 and the 1970 population data shown in Table A.3 (see Appendix 4).

Table A.1. Nutritional Requirements by Age Group

Nutrient	Unit	Children					Males								Females									
		0-1	1-3	4-6	7-9	10-12	13-15	16-19	20-29	30-39	40-49	50-59	60-69	70+	13-15	16-19	20-29	30-39	40-49	50-59	60-69	70+	pregnant	lactating
Protein	g	10.2	17.5	25.8	30.8	36.0	50.0	63.5			← 63.7 →				52.8	58.4			← 55.5 →				10[a]	25
Calories	Kcal	660	1200	1500	1900	2300	2800	3300	2550	2450	2350	2200	200	1750	2355	2200	1800	1700	1650	1500	1450	1250	200[c]	1000
Calcium	mg	600	500	500	500	700	700	500			← 500 →				700	500			← 500 →				700[b]	700
Iron	mg	6	4	4	4	8	11	11			← 6 →				16	16		← 16			6 →		2[c]	3
Vitamin A	iu	1000	850	1000	1350	1900	2400				← 2500 →				2400			← 2500 →					d	1500
Vitamin C	mg	20	20	20	20	20					← 30 →							← 30 →					20[a]	20
Vitamin B6	mg	0.4	0.6	0.9	1.2	1.4	1.6	1.8			← 2.0 →				1.6	1.8			← 2.0 →				0.5[c]	0.5
Vitamin B12	mg	0.3	0.9	1.5	1.5	2.0					← 2.0 →								← 2.0 →				1.0[a]	0.5
Pantothenic acid	mg	2	3	4	5	6					← 3 →								← 8 →				d	d
Folic acid	μg	50	100	100	100	100					← 200 →								← 200 →				200[a]	100
Fat[e]	g									0.2 ≤ 9 FAT/CAL ≤ 0.35													d	d
Fibre[e]	g									6 ≤ Fibre ≤ 15													d	d
Riboflavin[e]	mg									greater than 0.4/1000 Kcals													d	d
Thiamine[e]	mg									greater than 0.55/1000 Kcals													d	d
Niacin[e]	mg									greater than 6.6/1000 Kcals													d	d
Phosphorus[e]	mg									0.8 ≤ CA/P ≤ 1.5													d	d
Amino acids[e]	mg/g.N									egg pattern values													d	d

a. extra allowance for 2nd and 3rd trimestres only.
b. extra allowance for 3rd trimestre only.
c. extra allowance for total pregnancy.
d. no extra allowance.
e. standard allowance for all age groups.

APPENDIX 3

RAW MATERIALS USED IN THE NUTRITION PROBLEM

A complete listing of the 151 raw materials used in the linear programming application to the nutrition problem is given in Table A.2.

The order of the raw materials in Table A.2 is the same as the order used for the compositional tables shown in Appendix 1.

Table A.2. Complete listing of Indigenous Thai food raw materials and N.Z. milk products used in nutrition problem.

Anchovy
Bamboo shoots
Banana
Broad bean
Snap bean
Yard long bean
Beef
Beef blood
Beef brain
Beef heart
Beef kidney
Beef large intestine
Beef liver
Beef lung
Beef small intestine
Beef spleen
Beef stomach
Beef tongue
Breadfruit
Buffalo
Buffalo brain
Buffalo heart
Buffalo kidney
Buffalo large intestine
Buffalo liver
Buffalo small intestine
Buffalo spleen
Buffalo stomach
Chinese cabbage
Common cabbage
Carp
Cashew fruit
Cashew nut
Cassava leaves
Cassava
Catfish
Cauliflower
Celery
Chicken
Chicken gizzard
Chicken liver
Coconut meat
Coconut milk
Coconut (whole)
Corn (white)
Corn (yellow)
Crab
Cucumber
Duck (meat)
Duck (whole)
Egg (duck)
Egg (hen)
Eggplant
Frog
Garlic
Ginger
Goose (meat)
Goose (total)
Gourd (wax)
Gourd (bottle)
Grape
Guava (red)
Guava (white)
Herring
Horse
Jackfruit
Jack fruit seed
Kale
Leek
Lemon
Lettuce
Lime
Lobster
Mackerel (spanish)
Mango
Melon
Buffalo milk
Milk fish
Goat's milk
Mullet
Mungbean
Mushroom
Mussel
Octopus
Onion (bulb)
Onion (green)
Orange
Papaya
Peach
Chick pea
Peanut
Sweet peas
Pig peas
Green pepper
Red pepper
Perch
Pig
Pig blood
Pig heart
Pig kidney
Pig large intestine
Pig liver
Pig lung
Pig small intestine
Pig spleen
Pig stomach
Pig tongue
Pineapple
Pomelo
Potato
Sweet potato (white)
Sweet potato (yellow)
Prawn
Pumpkin
Radish
Rice (brown)
Rice (glutinous)
Rice (white)
Sardine
Sesame
Shallot
Shark
Shrimp
Snapper
Sorghum
Soybean
Sugar
Sugar cane juice
Sunflower seed
Tamarind leaves
Tamarind
Tangerine 56
Tangerine 57
Taro
Turkey breast
Turkey gizzard
Turkey liver
Tomato
Wheat
Wheat bran
Wheat flour
Wheat germ
Watermelon
Yam
Butter
Casein
Cheese
Lactalbumin
Milk
Skim milk powder
Whole milk powder

APPENDIX 4

DISTRIBUTION OF THE THAI POPULATION (1970)

The age groups used in nutritional requirement tables and demographic tables were not in agreement. The population numbers within each nutrition age group (see Appendix 2) were derived from the population distribution given in the U.N. Demographic Yearbook (1970).

The derived estimated 1970 population distribution is given in Table A.3 together with the method used to obtain these estimates.

Table A.3. Demographic data - the calculation of the population distribution of Thailand.

Age Group (years)	Derivation from age group in U.N. Demographic Yearbook (1970)	Estimated 1970 population x 1000
0-1	no change	796
1-3	0.75(1-4y)	3545
4-6	0.25(1-4y) + 0.4(5-9y)	6807
7-9	0.6(5-9y)	3120
10-12	0.5(10-14y)	2012
13-15 male	0.5(10-14y)males + 0.2(15-19y)males	1018
13-15 female	0.5(10-14y)females + 0.2(15-19y)females	994
16-19 male	0.8(15-19y)male	1317
16-19 female	0.8(15-19y)female	1290
20-29 male	(20-24y)male + (25-29y)male	2913
30-39 male	(30-34y)male + (35-39y)male	2053
40-49 male	(40-44y)male + (45-49y)male	1383
50-59 male	(50-54y)male + (55-59y)male	943
60-69 male	(60-64y)male + (65-69y)male	492
70+ male	no change	232
20-29 female	(20-24)female + (25-29y)female	2930
30-39 female	(30-34y)female + (35-39y)female	2018
40-49 female	(40-44y)female + (45-49y)female	1363
50-59 female	(50-54y)female + (55-59y)female	967
60-69 female	(60-69y)female + (65-69y)female	529
70+ female	no change	321
Pregnant women	$(796 + \frac{796 \times 10}{1000}) \times 1000$	438
Lactating women	$(\frac{796 \times 8}{12}) \times 1000$	531

APPENDIX 5

SOLUTIONS TO THE LINEAR AND GOAL PROGRAMMING APPLICATIONS TO THE NUTRITION PROBLEM

The levels of raw materials and nutrients in each solution from the linear and goal programming runs are given (see Chapter 3 for a full description of these computer runs).

The solutions are given in 4 tables as described below:
Table A.4 gives the levels of raw materials in the solutions to the linear and goal programming runs using only indigenous raw materials.
Table A.5 gives the levels of raw materials in the solutions to the linear and goal programming runs using indigenous raw materials and N.Z. dairy products.
Table A.6 shows the levels of all nutrients except amino acids in the solutions to the linear and goal programming runs.
Table A.7 shows the levels of the essential amino acids in the solutions to the linear and goal programming runs.

Table A.4. Food Raw Materials in Solution (grams)

Indigenous Thai Food Raw Materials Only											
Amino Acid Bounds				(% of Egg Pattern)				Goal Program on amino acids		Goal Program on whole problem	
80-120%		85-115%		90-110%		95-105%					
Glutinous rice	471.2	Glutinous Rice	449.6	Glutinous Rice	449.1	Tangerine 56	216.7	Sugar	313.8	Egg plant	284.4
Pumpkin	230.1	Pumpkin	198.7	Chinese cabbage	220.6	Red pepper	215.7	Hen's eggs	243.5	White rice	229.8
Banana	154.6	Banana	169.3	Tangerine 56	214.1	Coconut	171.5	Celery	234.2	Goat milk	188.3
Coconut meat	112.1	Coconut meat	108.1	Banana	135.7	White rice	154.2	Guava white	138.0	Sugar	124.2
Celery	101.2	Celery	95.4	Coconut meat	98.2	Chinese cabbage	119.8	Lime	103.3	Tangerine 56	115.5
Kale	53.8	Kale	81.0	Broad beans	38.5	Duck egg	73.3	Red pepper	105.9	Bamboo shoots	98.4
Broad beans	31.6	Tangerine 56	42.8	Kale	33.5	Sugar	58.2	Peach	88.1	Beef tongues	93.4
Bamboo shoots	13.7	Broad beans	35.2	White corn	30.0	Guava red	27.1	Leek	84.5	Peach	71.1
Shank	11.8	White corn	34.9	Pumpkin	25.2	Glutinous rice	20.7	Chinese cabbage	58.4	Coconut	47.4
Beef liver	3.3	Shark	10.2	Shark	11.4	Radish	20.2	Tangerine 56	30.1	Radish	37.3
		Coconut	4.7	Sesame	10.4	Sesame	14.7	Buffalo liver	46.6	Jackfruit seed	20.2
		Snapper	1.7	Beef liver	1.6	Shark	14.7	White sweet potato	39.8	Sesame	18.3
				Snapper	0.9	Broad beans	12.6	Lemon	36.0	Leek	14.5
						Buffalo liver	6.5	Peanut	5.8	Red pepper	11.5
								Coconut	5.5	Broad beans	6.5
								Sesame	1.7		

Table A.5. Food Raw Materials in Solution (grams)

Inclusion of Dairy Products											
Amino Acid Bounds (% of Egg Pattern)								Goal Program on amino acids		Goal Program on whole problem	
80-120%		85-115%		90-110%		95-105%					
Glutinous rice	391.8	Glutinous rice	364.7	Glutinous Rice	409.7	Tengerine 56	279.9	Sugar	307.9	Sterilized whole milk	306.3
Banana	333.2	Banana	285.7	Chinese cabbage	207.8	Red pepper	229.8	Hen eggs	243.1	White rice	263.2
Pumpkin	155.1	Pumpkin	142.7	Tangerine 57	202.1	White corn	197.9	Celery	208.8	Bamboo shoots	126.6
Kale	106.7	Coconut meat	94.0	Banana	185.6	Coconut	172.2	Guava white	139.4	Tangerine 56	123.6
Coconut meat	100.3	Kale	71.5	Coconut meat	97.5	White rice	161.7	Lime	110.3	Sugar	103.0
Broad beans	31.3	White corn	64.6	White corn	46.8	Sugar	98.9	Peach	99.0	Goose (total)	62.2
Celery	27.1	Celery	58.5	Kale	39.1	Egg plant	54.7	Red pepper	98.2	Red pepper	54.2
Skim milk powder	20.5	Coconut	24.8	Broad beans	37.8	Skim milk powder	46.3	Leek	84.0	Grape	47.8
Coconut	16.6	Broad beans	22.6	Coconut	19.1	Leek	40.0	Chinese cabbage	63.9	Leek	36.3
Snapper	1.2	Skim milk powder	17.9	Skim milk powder	14.2	Bottle gourd	26.6	White sweet potato	60.7	Broad beans	33.6
		Snapper	1.2	Radish	8.7	Chinese cabbage	18.8	Buffalo liver	51.6	Radish	31.4
				Snapper	1.4	Guava red	15.1	Tangerine 56	33.8	Coconut	18.8
				Shark	0.4	Buffalo liver	10.2	Lemon	25.9	Sesame	8.0
						Broad beans	6.4	Yard long red bean	12.8	Sugar cane juice	7.4
						Radish	0.1	Sesame	7.5	Skim milk powder	6.8
								Butter	1.7	Jackfruit seed	3.2
										Beef tongue	1.6
										Lactalbumin	0.5

Table A.6. Nutrient Levels in Solutions

Nutrient	Indigenous Foods only						Inclusion of Dairy Products					
	Amino Acids				goal on (amino acids)	goal on whole problem	Amino Acids				goal on amino acids	goal on whole problem
	80-120%	85-115%	90-110%	95-105%			80-120%	85-115%	90-110%	95-105%		
Cost (baht)	2.652	2.807	3.258	4.887	12.405	8.275	2.618	2.776	3.202	4.774	12.81	9.672
Protein (gN)	8.40	8.40	8.40	8.40	8.40	8.40	8.40	8.40	8.40	8.40	8.40	8.40
Fat (g)	46.67	46.67	46.67	74.86	46.67	46.67	46.67	46.67	46.67	49.54	46.67	46.67
Calories	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100
Fibre (g)	10.95	11.73	9.67	15.00	15.00	7.121	10.554	11.902	11.602	15.00	15.0	6.0
Calcium (mg)	651.4	674.2	701.7	888.7	1500.0	732.8	755.3	765.0	761.7	1035.9	1500.0	801.8
Phosphorus (mg)	814.2	842.8	877.1	1110.8	1040.7	915.9	944.1	956.3	952.2	1292.3	1008.8	1002.2
Iron (mg)	27.1	27.1	21.5	22.7	68.0	18.9	16.6	21.1	19.8	15.5	65.7	13.2
Vitamin B6 (mg)	2.114	2.440	2.407	2.253	1.65	1.65	3.013	2.842	2.523	2.025	1.65	1.65
Vitamin B12 (ug)	1.85	1.85	1.85	6.00	23.0	1.85	1.85	1.85	1.85	4.00	2.40	1.85
Folic Acid (ug)	175.0	175.0	175.0	175.0	219.13	175.0	175.0	175.0	176.52	181.01	232.87	175.0
Pantothenic acid (mg)	6.8	6.8	6.8	6.8	10.22	6.8	6.8	6.8	6.8	6.8	10.68	6.8
Niacin (mg)	17.45	17.29	18.49	15.35	13.86	13.86	14.45	14.73	16.51	13.86	13.86	13.86
Riboflavin (mg)	1.29	1.54	1.22	1.19	2.56	1.16	2.32	1.98	1.63	1.71	2.63	1.16
Thiamine (mg)	1.04	1.10	1.34	1.43	0.93	1.07	1.01	1.08	1.24	1.44	0.89	0.89
Vitamin C (mg)	173.3	204.5	282.7	228.7	464.9	68.1	211.8	196.8	304.2	166.6	468.4	69.3
Vitamin A (iu)	9716	9227.8	10603	10840	38755	2100	8097	7606	10497	8305	41115	2100
Weight (Diet) (g)	1183.4	1237.5	1275.6	1285.3	1560.3	1366.6	1183.7	1225.6	1270.1	1358.7	1553.9	1234.4
Total Percent difference	-	-	-	-	6.20	452.97	-	-	-	-	5.78	371.89

Table A.7. Amino Acid Levels in Solutions

Nutrient	Indigenous Foods Only						Inclusion of Dairy Products					
	Amino Acids				goal program on (amino acids)	goal program of whole problem	Amino Acids				goal on amino acids	goal on whole problem
	80-120%	85-115%	90-110%	95-105%			80-120%	85-115%	90-110%	95-105%		
Cystine	119.9	115.00	90.0	95.0	100.0	100.0	120.0	115.0	90.0	95.0	110.0	100.0
Valine	96.9	101.37	102.9	99.2	100.0	109.94	94.8	99.6	102.5	100.9	100.0	101.1
Isoleucine	80.0	85.00	90.0	95.0	93.8	90.0	80.0	85.0	90.0	95.0	94.22	90.0
Phenylalanine	110.2	115.00	110.0	105.0	100.0	96.5	110.43	115.0	110.0	105.0	100.0	100.0
Tyrosine	84.7	85.94	90.0	95.0	100.0	104.2	87.5	90.0	90.0	95.0	100.0	106.9
Methionine	80.0	85.00	90.0	95.0	100.0	90.0	80.0	85.0	90.0	95.0	100.0	90.0
Tryptophan	106.3	109.19	110.0	105.0	100.0	106.2	106.9	109.2	110.0	105.0	100.0	102.3
Threonine	97.6	103.05	100.7	105.0	100.0	100.7	99.8	106.2	101.9	103.0	100.0	92.0
Lysine	89.2	95.09	108.5	105.0	100.0	110.0	93.3	94.8	107.8	105.0	100.0	110.0
Leucine	110.8	115.00	110.0	105.0	100.0	110.0	106.1	115.0	110.0	105.0	110.0	110.0

APPENDIX 6

THE DATA FOR MULTIDIMENSIONAL SCALING ANALYSIS

Five sets of data were collected from surveys in Thailand in 1974. Each set of data was analyzed using the nonmetric multidimensional scaling programme, KYST.

The sets of data are shown in 5 tables as follows:

Table A.8. Averaged raw material similarities data.

Table A.9. Averaged raw material association data.

Table A.10. Derived proximity measures from the 'raw material by use' survey.

Table A.11. Averaged food dish similarities data.

Table A.12. The matrix of raw material acceptability in 15 categories of food dish.

Table A.8. Averaged raw materials similarities 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	36	37	38	39
2	4.7																																						
3	5.7	8.1																																					
4	6.0	6.6	7.6																																				
5	5.3	5.8	6.8	6.2																																			
6	4.5	5.9	7.5	7.6	5.8																																		
7	2.5	3.1	3.2	2.2	2.2	2.9																																	
8	4.6	6.6	6.3	6.2	5.5	6.8	3.6																																
9	2.3	2.7	2.1	2.3	2.5	2.4	2.7	4.2																															
10	2.1	1.7	1.8	1.8	1.8	1.5	2.7	2.1	2.8																														
11	2.0	1.3	1.4	1.8	1.3	1.0	2.8	1.7	1.0	7.5																													
12	2.6	2.7	3.3	2.2	0.0	2.1	1.3	2.5	2.1	1.2	1.1																												
13	5.2	6.8	6.8	7.5	7.0	6.4	3.0	6.2	4.7	1.6	0.0	2.6																											
14	5.3	7.7	7.5	8.0	6.0	7.9	2.9	6.3	2.7	1.6	1.7	2.5	7.3																										
15	1.7	2.1	1.5	1.5	1.7	1.6	1.3	1.8	1.9	3.7	1.1	1.4	1.6	1.9																									
16	2.5	2.7	2.1	2.8	4.0	2.7	1.0	2.1	1.3	1.3	1.2	1.7	2.6	2.5	3.5																								
17	4.1	4.2	3.6	3.9	5.0	4.5	1.4	2.2	2.5	1.5	1.5	1.5	4.9	4.1	2.8	0.0																							
18	3.2	2.7	2.7	2.1	3.1	2.1	1.1	2.3	1.2	1.3	1.1	1.5	2.1	2.8	4.6	5.5	4.6																						
19	4.6	4.6	4.0	5.0	5.2	3.7	2.5	3.2	2.6	2.1	1.7	2.6	4.4	4.8	4.3	3.0	4.0	3.6																					
20	1.6	2.1	2.7	1.8	3.8	1.8	1.0	1.9	2.1	1.1	1.0	1.3	2.5	2.1	4.6	3.3	4.0	5.6	3.1																				
21	1.6	2.0	2.0	2.8	2.1	1.7	2.0	1.8	1.4	1.9	1.5	1.2	2.2	1.9	1.0	1.0	1.1	1.2	2.4	1.0																			
22	2.2	1.7	2.4	2.6	2.0	2.1	3.1	1.7	1.4	1.3	1.3	1.5	2.3	2.3	1.1	1.4	1.2	1.6	1.8	1.2	8.7																		
23	2.2	2.0	1.7	2.2	2.0	1.3	2.0	1.8	1.6	2.6	2.0	1.0	1.8	1.4	1.1	1.2	1.3	1.3	1.9	1.1	6.6	6.8																	
24	1.3	2.3	1.2	1.8	1.6	1.9	1.8	2.2	1.5	1.5	1.3	1.2	2.0	2.1	1.2	1.3	1.2	1.2	2.0	1.2	0.0	9.8	6.3																
25	2.2	2.7	1.5	1.7	2.3	1.8	3.0	3.0	2.0	1.6	1.2	1.6	2.2	2.3	1.0	1.2	1.2	0.0	2.2	[illegible]	6.3	6.5	5.5	6.4															
26	2.2	1.6	2.4	2.5	2.1	1.6	2.5	2.5	1.5	2.0	1.9	1.1	2.1	2.0	1.2	1.2	1.3	1.5	2.5	1.2	9.9	9.2	6.4	9.7	8.4														
27	2.0	2.0	2.6	2.0	1.6	2.0	2.3	1.6	1.1	1.7	1.3	1.1	2.0	2.1	1.1	1.2	1.8	1.6	1.6	1.0	5.3	6.7	5.8	6.2	5.1	6.2													
28	2.1	2.1	2.2	2.5	2.0	2.3	2.5	2.5	1.8	2.4	1.6	1.7	2.4	2.1	1.2	2.0	1.8	1.1	2.2	1.0	7.3	8.1	9.0	7.2	7.1	7.6	6.7												
29	1.6	2.2	2.1	2.0	1.9	1.7	1.6	1.7	1.6	1.8	1.1	1.2	1.5	2.0	1.0	1.0	1.3	0.0	1.2	1.2	5.0	5.3	7.0	4.7	4.8	5.6	7.8	6.6											
30	1.2	1.3	1.4	1.2	1.1	1.0	2.5	1.2	2.2	1.6	1.4	1.0	1.0	1.1	1.9	1.1	1.0	1.4	1.6	1.2	1.7	2.1	1.5	1.4	2.1	1.9	1.4	1.7	1.2										
31	1.3	1.3	1.1	1.2	1.2	1.1	2.8	1.5	1.8	1.3	1.2	1.4	1.0	1.3	1.6	1.2	1.2	1.6	1.7	1.1	1.6	1.7	1.4	1.1	1.7	2.2	1.1	1.8	1.5	8.0									
32	2.2	2.3	2.3	2.3	1.8	2.2	2.8	2.2	1.3	2.5	2.4	1.5	2.3	1.8	1.8	1.3	1.5	1.5	2.4	1.2	4.7	5.8	4.9	5.5	5.1	4.7	4.1	5.1	3.5	3.1	2.7								
33	1.7	1.2	1.2	1.3	1.6	1.7	2.2	1.4	1.3	1.7	1.4	1.2	1.1	1.2	1.8	1.3	1.1	1.2	1.2	1.1	1.5	1.8	1.2	1.1	1.2	2.1	1.2	1.5	1.8	4.2	3.0	1.7							
34	1.5	2.2	[illegible]	2.0	2.5	2.3	2.4	2.3	1.8	2.8	1.6	1.5	2.4	2.1	1.2	1.1	1.3	1.7	2.3	1.5	4.1	4.8	3.7	5.5	5.0	5.0	3.3	5.1	3.7	2.1	2.3	10.5	1.3						
35	1.1	1.3	1.7	1.0	1.1	1.0	2.1	1.2	3.1	1.8	1.7	1.3	1.3	1.1	1.5	1.1	1.2	1.1	1.1	1.3	1.7	2.8	1.2	1.4	1.2	2.0	1.1	1.5	1.4	6.3	5.8	3.9	6.2	3.1					
36	1.1	1.1	1.2	1.2	1.1	1.0	2.1	1.1	1.7	1.5	1.5	1.2	1.1	1.2	2.0	1.2	1.1	1.2	1.3	1.3	1.2	1.3	1.5	1.5	1.1	1.1	1.1	1.3	1.1	6.0	5.5	2.6	4.1	2.3	8.6				
37	2.2	2.6	2.3	2.2	2.1	2.2	1.1	2.5	1.7	1.0	1.0	2.5	2.6	2.2	1.2	1.9	1.7	1.8	2.0	1.5	1.2	1.5	1.1	1.0	1.2	1.2	1.0	1.8	1.1	1.1	1.0	1.1	1.1	1.1	1.1	1.0			
38	2.9	3.7	5.2	5.5	4.6	5.1	1.3	3.8	1.8	1.3	1.6	4.3	3.8	5.2	1.5	2.5	1.8	1.9	2.0	1.2	1.0	1.1	1.1	1.1	1.1	1.5	1.1	1.2	1.2	1.1	1.0	1.4	1.3	1.2	1.3	1.0	3.6		
39	2.4	1.9	2.2	1.8	2.3	2.1	1.3	2.1	1.0	1.9	1.5	6.8	2.1	2.9	1.7	2.1	1.8	1.8	1.7	1.1	1.4	1.5	1.2	1.3	1.2	1.5	1.1	1.6	1.0	1.4	1.0	1.4	1.2	1.4	1.4	1.0	2.1	3.1	
40	1.6	1.3	1.3	1.0	1.3	1.0	1.7	1.3	1.6	2.1	1.0	1.1	0.0	1.3	2.0	1.3	1.5	1.9	1.6	2.0	1.6	1.3	1.1	1.6	1.3	1.0	1.4	1.3	1.6	3.4	2.3	1.9	2.9	1.6	3.0	6.6	1.4	1.2	1.1

Table A. 9. Averaged raw material association data.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2	4.6																			
3	4.8	6.9																		
4	5.1	6.8	7.2																	
5	4.8	5.4	6.3	5.3																
6	4.3	5.1	6.1	5.7	5.7															
7	4.3	4.6	6.6	4.6	5.0	5.3														
8	5.1	5.6	5.9	6.0	6.1	6.3	7.7													
9	3.7	3.2	3.6	2.7	3.8	2.6	4.7	4.0												
10	5.3	5.0	5.3	6.6	4.5	5.3	5.6	4.6	4.5											
11	4.6	4.4	5.5	6.1	4.0	3.6	6.2	7.8	5.5	6.1										
12	3.6	3.4	4.1	4.0	0.0	3.0	2.4	3.6	4.2	3.4	4.1									
13	5.5	6.4	6.3	7.2	6.8	5.6	4.7	6.8	3.8	5.2	0.0	3.7								
14	5.0	6.3	7.2	5.9	5.6	6.7	5.2	6.1	4.0	5.1	6.3	3.6	6.5							
15	1.5	1.7	1.3	1.3	1.2	1.2	1.5	1.4	2.0	3.3	1.1	1.3	1.3	1.8						
16	3.2	2.6	2.0	2.1	3.2	2.6	1.2	2.1	3.2	2.3	1.9	4.8	2.6	2.6	2.7					
17	3.1	3.9	4.0	3.0	3.8	3.1	2.0	2.6	5.1	2.6	1.4	2.4	4.8	4.6	2.0	0.0				
18	3.4	2.9	3.3	2.3	2.3	2.3	1.7	3.0	3.0	4.2	1.7	2.2	3.0	2.9	4.1	5.4	3.6			
19	3.5	5.6	4.5	4.3	4.8	4.8	4.0	4.2	4.0	4.2	2.1	3.1	4.6	4.6	4.2	2.7	3.1	3.2		
20	1.5	2.2	2.2	1.4	2.2	1.9	1.3	1.7	1.9	1.9	1.3	1.6	2.1	1.8	3.5	2.8	3.5	4.0	2.7	
21	7.6	7.4	6.7	6.2	6.5	4.7	4.7	7.1	3.6	7.6	6.1	5.7	6.9	7.3	1.1	2.5	2.8	4.3	5.0	1.2
22	7.6	7.1	7.3	8.1	6.6	6.7	6.8	7.1	4.1	7.6	8.1	5.3	6.5	6.9	1.5	2.1	3.6	5.4	5.9	1.5
23	6.1	6.6	5.9	6.7	6.0	4.8	4.7	5.2	3.2	7.8	7.8	4.2	6.3	5.0	1.2	2.3	2.9	3.7	4.3	1.3
24	6.3	5.4	7.0	6.4	6.8	4.7	5.0	5.1	3.7	7.3	7.8	5.0	5.6	6.8	1.1	2.0	1.7	2.5	4.2	1.5
25	6.1	9.0	7.6	7.7	7.2	6.8	6.3	7.7	4.1	6.6	8.3	4.8	7.3	6.8	1.2	2.2	3.2	0.0	5.4	1.3
26	5.0	6.2	8.2	8.4	7.4	8.7	7.5	8.4	5.2	7.6	8.6	5.2	8.2	7.6	1.2	3.6	4.3	6.2	7.4	1.6
27	6.0	5.8	7.3	5.3	4.3	4.2	4.1	4.3	3.1	6.4	4.3	3.6	5.7	5.6	1.4	2.5	3.8	3.1	3.6	2.1
28	8.2	7.7	7.8	8.0	5.0	6.3	6.6	6.8	5.2	8.0	6.2	5.8	7.6	6.4	1.1	4.8	5.4	5.5	6.9	2.1
29	4.7	3.5	5.2	3.9	5.5	4.1	2.7	3.6	3.4	6.9	2.5	5.0	5.2	5.2	1.2	2.5	3.2	0.0	2.5	1.8
30	2.0	3.0	2.6	2.3	1.9	1.6	2.5	1.7	5.2	3.8	2.2	1.8	2.3	1.8	3.4	1.4	1.3	2.1	2.3	1.2
31	2.0	2.0	1.8	1.9	2.0	1.5	2.4	2.0	4.0	1.9	2.2	1.7	1.6	2.0	4.0	1.5	1.5	2.1	2.4	1.3
32	6.3	5.7	6.6	6.6	7.1	5.6	5.7	6.0	2.4	8.2	7.6	6.6	6.2	5.2	2.3	2.1	2.6	2.3	6.7	1.2
33	6.7	3.2	3.2	2.5	2.5	3.5	2.3	3.5	3.9	4.3	4.0	3.2	4.6	4.6	5.5	1.6	2.0	2.7	6.9	1.3
34	4.4	5.7	6.6	5.6	7.2	4.3	5.9	6.1	3.6	6.6	6.8	5.5	6.3	6.1	1.5	1.4	7.7	2.8	5.5	1.6
35	1.3	2.0	1.8	1.2	1.4	1.2	2.2	1.6	3.4	2.8	1.5	1.4	1.3	1.5	3.3	1.3	1.4	1.8	2.0	1.3
36	1.3	1.2	1.4	1.6	1.5	1.0	1.8	1.2	2.6	1.6	1.0	1.3	1.2	1.5	2.5	1.4	1.2	1.5	2.1	1.8
37	6.2	3.5	4.6	5.2	5.3	3.1	4.8	4.5	4.6	4.7	6.4	6.1	4.8	6.0	1.1	5.0	4.2	3.4	3.1	1.6
38	4.2	4.1	5.2	5.2	7.0	5.2	4.8	3.9	4.2	4.0	6.0	5.5	3.7	4.5	1.2	3.3	1.7	2.6	2.5	1.2
39	5.6	6.2	6.9	6.6	4.6	4.5	5.1	6.6	0.0	5.4	6.3	6.5	6.0	6.7	1.1	2.6	3.7	3.5	5.1	1.5
40	3.6	4.6	4.2	5.0	3.7	2.7	4.4	4.1	5.5	3.7	5.8	3.8	0.0	3.7	6.8	5.6	4.2	6.1	7.5	6.0

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
22	7.3																		
23	6.0	7.7																	
24	0.0	6.8	5.1																
25	6.6	7.6	6.3	6.7															
26	8.9	8.5	6.9	8.0	9.0														
27	4.6	5.2	5.5	5.2	5.0	6.3													
28	7.4	8.4	8.7	6.3	8.0	9.0	6.7												
29	4.2	4.0	4.8	3.1	3.7	5.3	6.1	6.0											
30	5.1	6.8	2.1	4.6	4.1	4.8	2.2	4.1	1.7										
31	3.5	4.2	1.5	2.9	3.1	3.4	1.7	4.0	1.8	7.3									
32	7.3	8.0	7.2	7.1	7.3	9.1	4.6	8.5	5.4	5.1	3.7								
33	6.6	7.3	4.2	4.7	4.0	6.2	5.7	5.6	4.9	3.6	3.3	3.8							
34	6.7	7.5	6.1	6.7	5.5	8.1	4.7	8.1	5.9	3.5	3.3	9.8	3.7						
35	2.7	4.2	1.6	2.1	1.6	2.5	1.6	2.4	1.3	7.4	6.6	6.7	5.2	5.3					
36	1.2	2.1	1.4	1.6	1.6	1.5	1.0	1.9	1.1	6.5	5.9	3.1	4.1	2.6	7.8				
37	7.4	6.8	6.5	6.6	6.4	6.5	7.1	7.1	6.2	1.8	1.6	4.5	4.9	4.5	1.3	1.0			
38	5.6	6.4	5.0	5.8	6.2	6.2	4.6	5.5	5.7	2.2	1.3	5.3	4.7	4.5	1.3	1.0	5.6		
39	6.1	6.6	6.2	6.9	6.2	7.2	6.2	7.5	5.3	2.1	2.3	5.2	3.2	5.4	1.5	1.0	6.4	5.3	
40	4.8	4.3	4.0	4.9	4.0	5.1	3.9	5.6	3.7	6.4	4.0	6.9	7.7	5.7	8.0	7.8	4.7	2.8	3.5

Table A.10. Proximity measures from 'raw material by use' survey.

	1	2	3	4	5	6	7	8	9	10	11	12	13
2	0.72												
3	0.60	0.82											
4	0.75	0.75	0.86										
5	0.60	0.87	0.84	0.77									
6	0.72	0.75	0.72	0.84	0.84								
7	0.94	0.79	0.64	0.77	0.71	0.74							
8	0.62	0.85	0.69	0.77	0.83	0.65	0.87						
9	0.65	0.81	0.92	0.86	0.85	0.77	0.69	0.80					
10	0.65	0.84	0.91	0.64	0.88	0.79	0.68	0.79	0.93				
11	0.56	0.80	0.92	0.75	0.86	0.68	0.60	0.72	0.92	0.95			
12	0.61	0.87	0.85	0.80	0.92	0.83	0.71	0.75	0.86	0.86	0.82		
13	0.77	0.75	0.75	0.89	0.72	0.76	0.84	0.77	0.75	0.70	0.64	0.70	
14	0.80	0.82	0.80	0.67	0.40	0.83	0.81	0.59	0.82	0.87	0.79	0.76	0.80
15	0.63	0.75	0.72	0.60	0.77	0.83	0.83	0.89	0.80	0.78	0.72	0.71	0.82
16	0.56	0.79	0.72	0.67	0.77	0.86	0.89	0.91	0.81	0.78	0.69	0.75	0.91
17	0.98	0.74	0.62	0.76	0.64	0.74	0.94	0.87	0.69	0.68	0.59	0.63	0.78
18	0.95	0.75	0.64	0.77	0.67	0.77	0.93	0.90	0.72	0.71	0.62	0.66	0.79
19	0.99	0.72	0.60	0.75	0.62	0.74	0.94	0.64	0.66	0.66	0.56	0.62	0.78
20	0.99	0.71	0.59	0.73	0.60	0.71	0.94	0.82	0.64	0.64	0.55	0.60	0.77
21	0.76	0.77	0.81	0.83	0.21	0.87	0.77	0.65	0.84	0.84	0.80	0.61	0.79
22	0.72	0.81	0.65	0.90	0.97	0.86	0.80	0.61	0.86	0.83	0.76	0.92	0.89
23	0.62	0.81	0.91	0.79	0.78	0.66	0.66	0.72	0.91	0.87	0.89	0.75	0.70
24	0.61	0.84	0.81	0.79	0.95	0.87	0.71	0.86	0.86	0.89	0.85	0.89	0.72
25	0.62	0.89	0.87	0.81	0.58	0.74	0.69	0.63	0.92	0.93	0.90	0.92	0.71
26	0.59	0.78	0.91	0.76	0.76	0.64	0.62	0.65	0.93	0.86	0.59	0.74	0.60
27	0.60	0.81	0.79	0.73	0.84	0.70	0.65	0.82	0.84	0.92	0.88	0.75	0.63
28	0.63	0.79	0.93	0.89	0.91	0.84	0.69	0.77	0.72	0.51	0.89	0.89	0.78
29	0.47	0.71	0.89	0.68	0.85	0.68	0.51	0.64	0.67	0.85	0.95	0.84	0.56
30	0.51	0.72	0.88	0.75	0.90	0.76	0.57	0.71	0.91	0.91	0.93	0.86	0.64
31	0.58	0.80	0.92	0.82	0.94	0.79	0.65	0.77	0.91	0.92	0.92	0.90	0.69
32	0.44	0.67	0.87	0.66	0.83	0.63	0.44	0.61	0.84	0.65	0.92	0.79	0.54
33	0.55	0.87	0.86	0.73	0.94	0.70	0.65	0.77	0.85	0.90	0.91	0.87	0.67
34	0.60	0.79	0.82	0.81	0.93	0.81	0.69	0.92	0.67	[illegible]	0.82	0.92	0.74
35	0.55	0.61	0.69	0.63	0.87	0.72	0.64	0.74	0.65	0.82	0.85	0.61	0.78
36	0.70	0.72	0.76	0.81	0.71	0.71	0.71	0.77	0.85	0.87	0.78	0.69	0.68
37	0.50	0.66	0.87	0.79	0.87	0.76	0.57	0.56	0.65	0.80	0.61	0.89	0.68
38	0.60	0.90	0.36	0.76	0.95	0.74	0.70	0.53	0.86	0.89	0.84	0.87	0.72
39	0.64	0.77	0.85	0.68	0.85	0.80	0.73	0.76	0.60	0.79	0.74	0.88	0.85
40	0.49	0.73	0.39	0.72	0.85	0.59	[illegible]	0.60	0.69	0.66	0.90	[illegible]	0.62

	14	15	16	17	18	19	20	21	22	23	24	25	26
15	0.84												
16	0.83	0.90											
17	0.83	0.86	0.89										
18	0.85	0.83	0.91	0.99									
19	0.81	0.84	0.88	0.99	0.97								
20	0.79	0.83	0.87	0.98	0.96	0.99							
21	0.91	0.84	0.86	0.79	0.81	0.77	0.75						
22	0.82	0.81	0.87	0.74	0.75	0.72	0.71	0.84					
23	0.83	0.71	0.72	0.67	0.69	0.64	0.62	0.83	0.76				
24	0.53	0.76	0.79	0.66	0.69	0.63	0.61	0.79	0.83	0.76			
25	0.81	0.75	0.77	0.67	0.71	0.64	0.62	0.74	0.80	0.84	0.92		
26	0.60	0.67	0.68	0.63	0.66	0.60	0.58	0.82	0.73	0.99	0.74	0.82	
27	0.84	0.73	0.73	0.65	0.69	0.61	0.59	0.73	0.71	0.79	0.92	0.93	0.77
28	0.84	0.81	0.79	0.66	0.69	0.64	0.62	0.82	0.89	0.85	0.89	0.87	0.83
29	0.70	0.64	0.62	0.50	0.57	0.49	0.46	0.73	0.74	0.80	0.81	0.87	0.81
30	0.74	0.71	0.70	0.55	0.58	0.53	0.51	0.76	0.81	0.81	0.37	0.67	0.60
31	0.62	0.74	0.72	0.62	0.65	0.59	0.57	0.62	0.83	0.88	0.92	0.89	0.67
32	0.69	0.60	0.54	0.48	0.50	0.45	0.44	0.70	0.70	0.34	0.79	0.79	0.84
33	0.77	0.69	0.70	0.59	0.62	0.55	0.55	0.73	0.81	0.80	0.74	0.92	0.79
34	0.81	0.75	0.77	0.64	0.67	0.61	0.59	0.80	0.87	0.77	0.75	0.85	0.75
35	0.75	0.78	0.74	0.61	0.64	0.58	0.57	0.75	0.84	0.81	0.85	0.65	0.73
36	0.80	0.79	0.77	0.74	0.77	0.71	0.70	0.71	0.71	0.73	0.79	0.88	0.74
37	0.69	0.58	0.66	0.53	0.56	0.51	0.49	0.73	0.94	0.72	0.85	0.78	0.72
38	0.82	0.75	0.79	0.65	0.65	0.61	0.60	0.77	0.83	0.82	0.55	0.93	0.80
39	0.50	0.77	0.82	0.68	0.71	0.66	0.64	0.83	0.93	0.80	0.86	0.79	0.78
40	[illegible]	0.65	0.64	0.52	0.54	0.50	0.48	0.72	0.81	0.80	0.85	0.83	0.80

	27	28	29	30	31	32	33	34	35	36	37	38	39
28	0.33												
29	0.79	0.88											
30	0.65	0.51	0.96										
31	0.84	0.95	0.91	0.94									
32	0.77	0.86	0.97	0.94	0.91								
33	0.91	0.87	0.88	0.89	0.91	0.85							
34	0.54	0.91	0.81	0.87	0.93	0.80	0.90						
35	0.79	0.93	0.81	0.65	0.89	0.79	0.86	0.89					
36	0.84	0.78	0.67	0.74	0.77	0.64	0.72	0.70	0.68				
37	0.72	0.94	0.37	0.91	0.93	0.35	0.82	0.90	0.66	0.68			
38	0.92	0.86	0.84	0.87	0.91	0.82	0.98	0.92	0.69	0.73	0.80		
39	0.71	0.91	0.74	0.82	0.88	0.74	0.80	0.70	0.85	0.71	0.89	0.83	
40	0.76	0.91	0.95	0.94	0.54	0.93	0.89	0.18	0.87	0.66	0.93	0.86	0.82

Table A.11. Averaged food dish similarities data.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
2	5.8																		
3	6.0	9.9																	
4	5.9	3.8	4.8																
5	5.7	6.6	7.7	4.3															
6	6.4	0.0	6.2	4.0	5.5														
7	6.1	5.9	7.6	4.8	6.5	5.5													
8	7.0	7.4	7.2	4.3	6.2	5.9	7.5												
9	5.5	4.6	5.0	6.6	4.8	4.6	5.6	0.0											
10	6.3	5.8	6.4	5.0	6.3	6.1	5.3	6.3	6.1										
11	5.9	5.3	6.4	5.5	6.1	6.6	6.1	6.3	5.8	6.5									
12	5.1	5.5	6.5	3.9	7.0	6.1	5.5	5.8	4.3	5.7	6.3								
13	5.6	5.4	5.0	4.6	5.2	5.5	4.8	6.5	5.3	6.1	7.0	4.3							
14	6.6	6.5	7.9	4.5	7.8	5.5	9.2	7.0	6.4	6.6	8.1	7.1	6.7						
15	5.6	5.1	6.4	3.9	6.0	4.9	6.1	6.2	5.4	6.0	6.0	5.2	6.5	6.5					
16	5.4	5.5	6.7	4.9	5.5	6.8	5.8	5.9	5.7	8.0	6.4	5.3	5.0	5.1	6.2				
17	5.6	4.7	5.2	5.3	4.6	4.0	5.6	3.8	8.3	4.3	6.3	4.7	4.8	4.8	4.1	0.0			
18	7.5	7.0	6.4	6.0	6.0	5.5	6.5	6.6	5.4	7.4	7.0	6.1	6.6	6.6	5.2	6.4	6.0		
19	5.8	5.5	5.0	4.4	6.0	7.4	5.9	5.5	5.3	6.3	6.5	5.8	5.6	6.9	5.4	5.3	4.3	7.2	
20	7.3	5.9	7.1	4.7	4.6	6.5	4.7	6.1	6.1	6.4	6.5	4.9	5.0	4.7	5.1	7.8	4.8	7.2	6.0

Table A.12. Raw material acceptability in 15 categories of food dish.

Raw material	Omelette	Salad	Fried meat	Meat balls	Stewed pork	Porridge	Chop suey	Sweet and sour	Curry	Sour soup	Hot soup	Fried vegetables	Vegetables and sauce	Soup	Noodles
Bamboo shoots	1.3	2.6	3.4	1.1	1.8	1.3	2.3	2.3	4.2	4.1	1.9	3.6	2.3	3.7	1.8
Cabbage	1.6	2.5	3.5	1.3	1.8	1.2	3.7	2.0	1.9	3.4	1.8	4.5	2.3	4.1	1.8
Chinese cabbage	1.3	2.8	3.8	1.2	1.6	1.6	4.3	1.7	2.0	3.8	2.5	4.7	2.2	4.8	2.7
Chinese kale	1.5	1.3	3.8	1.2	1.5	1.2	4.3	1.4	1.2	1.6	1.2	4.8	1.6	2.1	3.8
Cucumber	1.6	4.4	3.3	3.2	1.5	1.1	1.7	4.3	1.2	2.0	1.7	3.6	1.1	3.6	1.7
Green gourd	1.2	1.3	1.5	1.3	1.2	1.2	2.1	1.1	1.5	2.0	1.4	2.6	2.1	4.8	1.3
Mungbean curd	1.4	1.5	1.8	1.5	3.1	1.9	2.6	1.0	2.0	1.1	1.0	2.3	1.9	1.2	1.8
Mungbean sprouts	1.6	2.3	3.2	1.3	1.1	1.2	1.8	1.2	1.4	1.8	1.9	4.3	2.0	4.0	4.2
Peanut	1.0	3.2	1.3	3.0	2.0	1.1	1.3	1.1	2.0	1.1	1.8	1.2	3.2	1.5	2.9
Rice	1.6	1.9	2.0	1.6	1.7	3.9	1.5	1.5	3.0	1.2	1.2	1.8	1.9	1.2	1.0
Rice noodle	1.6	1.3	2.6	1.0	1.1	1.0	1.2	1.2	1.0	1.0	1.5	1.9	1.0	1.3	5.0
Shallots	3.3	4.1	1.9	1.9	1.4	1.2	1.2	1.4	3.6	3.4	2.2	1.8	3.5	1.5	1.8
String beans	1.8	3.3	3.7	3.3	1.4	1.4	2.5	1.8	3.3	4.1	1.7	4.4	2.7	1.8	1.5
Swamp cabbage	1.3	2.0	3.5	1.5	1.3	1.2	2.6	1.4	3.0	4.0	1.4	4.8	2.6	2.1	3.0
Beef	1.0	1.0	1.0	1.3	1.0	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Chicken	1.0	3.9	1.2	1.0	1.1	1.0	1.0	1.2	1.1	1.7	1.2	1.0	3.0	1.1	1.1
Crab	1.2	2.8	1.3	1.1	1.0	1.0	1.2	1.1	2.1	1.0	1.0	2.2	1.3	1.0	1.4
Duck	1.1	1.8	2.5	1.0	1.0	1.0	1.0	3.2	1.6	1.0	1.1	1.7	1.5	1.0	1.3
Hog's liver	1.4	1.1	2.3	1.1	1.1	1.0	1.3	1.2	2.0	1.7	1.0	3.4	[illegible]	1.4	1.0
Pork	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.3	1.0	1.3	1.1	1.3	1.0
Serpent head fish	1.9	4.6	4.9	1.8	2.3	2.6	2.5	3.3	4.9	1.8	3.5	4.2	1.3	3.3	4.4
Shrimps	2.0	3.8	4.1	1.9	2.5	4.8	4.0	4.5	4.8	1.9	4.5	4.6	1.3	4.6	4.5
Striped mackerel	2.8	3.6	2.3	2.5	1.1	2.7	1.2	2.5	2.2	1.3	2.3	3.5	1.2	2.7	3.9
Banana	1.2	2.1	2.6	1.8	1.9	2.7	3.2	2.0	2.7	1.2	2.5	3.0	1.3	3.0	4.4
Mango	1.5	2.9	3.3	1.4	2.5	4.3	3.3	3.5	2.2	1.3	2.4	4.0	1.3	4.3	4.3
Papaya	4.4	4.3	4.5	2.0	4.8	4.9	4.3	4.3	4.7	2.5	3.6	4.8	1.6	4.8	4.9
Pineapple	1.2	2.5	2.0	3.2	1.1	2.2	1.7	1.5	4.0	4.3	4.2	3.0	1.5	2.9	1.8
Pumpkin	2.7	4.5	3.3	3.5	1.6	3.6	2.1	4.4	4.0	4.3	4.8	4.7	1.9	4.5	3.7
Watermelon	1.3	3.9	1.7	2.2	1.2	1.3	1.5	1.3	2.6	2.7	3.4	1.6	2.1	1.8	1.2
Butter	1.6	1.1	1.7	1.2	1.1	1.0	1.0	1.0	1.1	1.0	1.0	1.6	1.1	1.0	1.1
Cheese	1.4	1.1	1.3	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.0	1.0	1.0
Chicken egg	5.0	2.5	2.0	1.9	3.1	4.4	2.0	1.8	1.2	1.2	1.1	2.1	1.6	3.9	3.3
Coconut cream	1.1	1.5	2.3	1.8	1.0	1.0	1.1	1.0	4.8	1.2	1.8	1.8	2.4	1.1	1.5
Duck egg	4.1	2.6	1.9	1.8	3.2	3.7	2.0	1.9	1.1	1.2	1.1	2.2	1.7	3.8	3.0
Milk	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.1	1.0	1.0
Sweetened condensed milk	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Chilli peppers	2.2	4.5	3.8	3.8	1.5	2.1	1.5	3.7	4.8	4.5	4.6	2.9	4.1	1.2	4.0
Coriander	2.6	3.5	2.3	2.4	2.5	3.7	2.3	2.6	1.6	1.5	3.7	1.9	3.8	4.0	3.6
Garlic	2.8	2.3	3.8	2.8	2.8	2.8	2.3	2.9	3.8	3.4	2.3	3.8	3.2	3.2	3.8
Sugar	2.0	3.4	2.6	2.6	2.8	1.6	2.0	3.8	2.8	2.8	3.1	2.8	3.4	2.0	3.4

APPENDIX 7

DESCRIPTION OF 20 FOOD DISHES USED IN THE FOOD DISH SIMILARITY SURVEY

A list of the 20 food dishes used in the food dish similarity survey are given below. The dishes are divided into 15 categories used as the basis of the 'raw material by use' survey.

1. Meat balls

Fish balls. A fried product containing minced fish, onion spices and herbs, with a delicate flavour. They are normally served with rice but can be eaten as a snack.

2. Meat curries

Beef curry. Contains mainly beef with possibly some egg-plant, chillies and onion. The dish has a hot flavour mainly derived from the small chilli peppers. It is generally served with rice or noodles.

Chicken curry. Much the same as beef curry but based on chicken, either on or off the bone. It is usually more expensive than beef curry and as such is considered a better dish.

3. Chop suey

Chop suey. Contains a variety of vegetables, cabbage, celery, kale and bamboo shoots with small amounts of meat, usually pork. It has a mild and predominantly vegetable flavour.

4. Sour soup

Shrimp sour soup. This dish is similar to shrimp hot soup but often contains mushrooms. It still has a very strong flavour which is a combination of hot, spicy and sour.

5. Omelette

Plain omelette. A plain omelette resembles scrambled eggs. It is made from eggs with no added milk and has a very mild flavour.

6. Sweet and sour

Sweet and sour fish. This dish is based on fish with a sweet and sour sauce made from sugar and vinegar. The fish may be either whole or in battered pieces. It usually contains cucumber, spring onions, tomatoes and chillies.

Sweet and sour chicken. This dish is based on chicken with a sauce similar to that used for sweet and sour fish. Cucumber, tomato and onion are often added and the dish is served with rice.

7. Hot soup

Shrimp hot soup. Contains shrimps and long green beans, flavoured with ground chillies, onion and garlic. The flavour is a combination of hot and sour.

Fish hot soup. Similar to shrimp hot soup but with more of a sour flavour and containing more meat. Chillies, dried pepper and possibly mushrooms are added to fish and boiled in water.

8. Fried meat

Fried Chinese kale. Contains beef with added Chinese kale, fried in oil. Garlic is normally added to give the dish a mild and beefy flavour.

Fried beef with oyster sauce. Beef and oyster sauce are fried with garlic and spring onions. The dish has a mild and oily flavour.

9. Fried vegetables and sauce

Fish with green vegetables and sauce. Contains whole fish (usually striped mackerel) which is fried in oil. A sauce made from shrimp paste, garlic and chillies is added to the fish with green vegetables such as cucumber, green beans and cabbage.

10. Fried vegetables

Fried pork with green snap beans. Contains pork with green snap beans, fried in oil. The dish is normally flavoured with garlic and served with rice.

11. Soup

Green gourd and pork soup. Contains minced pork in the form of balls, green gourd, Chinese cabbage and frequently other green vegetables. All the ingredients are boiled in water to form a thin and bland soup.

12. Thai salad

Cucumber salad. This dish contains mainly sliced cucumber with some sliced pork, Chinese cabbage and chillies. Usually it has a dressing made from lemon juice, sugar and salt. The Thai cucumber salad has a very strong hot and sour flavour.

13. Stewed pork

Stewed pork with boiled egg and soy sauce. This dish is made from pork, boiled egg with soy sauce and mixed spice. It has a liquid consistency with a fairly bland flavour and is served with rice.

14. Porridge

Pork porridge. Normally served in the morning or throughout the day to sick or elderly people. The dish is based on broken rice and is slightly thinner than Scottish porridge. Some stock is added, together with pork and possibly liver. Small amounts of ginger and spring onions may be used but the overall flavour is bland.

15. Noodle dishes

Pork noodles. This dish is based on rice noodles with added pork, onions, bean sprouts and Chinese cabbage. Garlic is usually added to give the dish a mild flavour. It may be served either wet or dry, that is either in the form of a soup based on water or without the water.

Beef noodles. This is similar to pork noodles containing rice noodles, beef, onions and bean sprouts. It usually contains a little more meat than pork noodles.

APPENDIX 8

L.P. SOLUTIONS WITH NUTRITIONAL AND ACCEPTABILITY CONSTRAINTS

Table A.13 shows the levels of nutrients in the solutions to the L.P. problem with the inclusion of COMPFAC and PREFAC.

The first solution was obtained subject to only nutritional constraints. These constraints were the weighted average daily requirements of 20-29 year old Thais. The other three solutions show the effect of parametric changes in COMPFAC and PREFAC.

COMPFAC	PREFAC
0.00	1.00
0.25	0.75
0.50	0.50

Table A.13. Solutions to the L.P. problem with inclusion of COMPFAC and PREFAC

	Nutritional constraints only	PREFAC =1.0 COMPFAC=0.0	PREFAC =0.75 COMPFAC=0.25	PREFAC =0.5 COMPFAC=0.5
Cost (baht)	4.201	8.210	10.795	10.866
Protein (gN)	9.53	9.53	9.53	9.53
Fat (g)	48.89	85.56	85.56	85.56
Calories	2200	2200	2200	2200
Fibre (g)	11.24	6.43	6.00	6.00
Calcium (mg)	705.3	747.8	787.9	789.4
Phosphorus (mg)	881.7	934.7	984.9	986.7
Iron (mg)	23.7	24.9	29.7	29.9
Bitamin B6 (mg)	2.00	2.87	2.08	2.08
Vitamin B12 (ug)	2.00	27.0	35.0	35.0
Folic acid (ug)	429.5	276.2	355.7	357.4
Pantothenic acid (mg)	8.00	8.00	9.87	9.92
Niacin (mg)	19.28	14.52	14.52	14.52
Riboflavin (mg)	2.28	4.25	3.42	3.46
Thiamine (mg)	1.63	1.17	1.31	1.31
Vitamin C (mg)	298.5	378.7	260.2	259.2
Vitamin A (iu)	13046	22036	22365	22458
Calcium/ Phosphorus	0.80	0.80	0.80	0.80
Protein/calories	0.11	0.11	0.11	0.11
Weight (g)	1530.6	1128.9	1175.5	1177.0
Cystine[a]	119.9	80.0	82.6	82.5
Valine	96.8	90.1	91.6	91.4
Isoleucine	82.2	84.3	86.6	99.9
Phenylalanine	104.2	98.4	98.7	98.6
Tyrosine	99.7	85.5	100.6	100.4
Methionine	80.0	80.0	80.0	80.0
Tryptophan	119.9	91.0	99.2	98.8
Threonine	103.8	98.6	100.2	100.2
Lysine	113.8	101.4	120.0	120.0
Leucine	102.5	97.3	105.4	105.1

a. amino acids expressed as percent of egg pattern values.