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A QUANTITATIVE MODEL FOR THE DESIGN OF
A PROCESSED INFANT FOOD
PRODUCT FOR THAILAND

A thesis presented in partial fulfilment
of the requirements for the degree of Ph.D.
in Product Development at Massey University

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ABSTRACT

A quantitative model was developed to design a processed infant food product for Thailand. Linear programming was used as a basis for the model. The model can select not only the raw materials but also the process, taking into consideration the nutritional requirements of infants and the product acceptability. Furthermore, any changes in the raw materials, process and product quality can be easily studied with the model.

The model was developed in three consecutive steps. Firstly, the Thai infant's nutritional requirements, and the compositions and costs of suitable indigenous Thai raw materials were included in the linear programming model. Secondly, the effect of heat processing on the destruction of the required nutrients was considered for different processes and the nutritional constraints in the model were modified to allow for the losses during processing. A mixture of raw materials was chosen by the model for each process and the most suitable combination of process and raw materials was selected. Finally, eating qualities were included in the model which enabled the model to select the raw materials not only subject to the modified nutritional constraints but also to the required eating quality.

To include the losses of nutrients during heat processing, data on the destruction of nutrients by heat

processing were collected from the literature to predict the reaction rate constants at different temperatures. First order reaction kinetics were assumed. The Arrhenius relationship between the reaction rate constant and the reciprocal of the absolute temperature was found to be generally true for the destruction of all vitamins and essential amino acids. The losses of vitamins and amino acids during a process were thus calculated from the Arrhenius relationship using the time and temperature history of the process.

By including these losses of nutrients into the nutritional constraints in the model, their effects on the nutritional composition and cost of the formulation were compared for different processes and a choice was made of the most suitable process. Several cooking and dehydration processes which could be used for infant food processing in Thailand were compared and batch cooking followed by drum drying was found to be best.

Consumer evaluation of the drum dried product suggested a need for improvement in the taste and colour of the product. Constraints restricting the selection of sugar and of raw materials with strong colours were included in the model, and a more acceptable product was obtained.

This model can be used not only to formulate an acceptable mixture of raw materials for any process but also to compare different processes for the production of an acceptable and cheap infant food.

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CHAPTER 1

THE NEED FOR AN INFANT FOOD IN THAILAND

The aim of this study is to design a nutritionally balanced processed infant food for general use throughout Thailand. As far as possible, indigenous raw materials and simple processing methods are to be used.

The first problem was to identify the need for an infant food in Thailand. The present infant feeding pattern was studied in order to discover any nutritional deficiencies and to find the most suitable infant food to introduce.

In this first chapter, the problems of infant malnutrition in Thailand and in particular the present feeding patterns are discussed. The qualitative characteristics needed in an infant food and the type of products available in Thailand for infant feeding are identified.

1.1 Relevant information on Thailand

Thailand is an agricultural country, 83 percent of the population work in farming and/or fishing. The population was estimated to be 38 million in 1971, with the rural population as 84 percent of the total population (180).

The country can be divided into 4 major regions. The Central plain, stretching 400 km north from Bangkok, contains approximately one-third of the population. The Northeast, centering around Nakorn Rasjasima contains about one-third. The Northern region centering around Chiangmai

and the Southern region, covering the Thai portions of the Indo-China Peninsula, contain the remaining one-third of the country. The area and population by region is shown in Table 1.1

Table 1.1 Area and Population by Region (180)
(Area: square kilometers; Population: thousand)

Region	Area	Population	
		1960	1970
Central	103,579	8,347	11,332
Northeast	170,226	9,078	12,499
North	170,006	5,777	7,763
South	70,189	3,302	4,438
Total	514,000	26,504	36,032

Income per capita differs markedly from region to region and also between the rural and urban areas as shown in Table 1.2. Income per capita over the whole country is about 3600 baht, the highest figure is in the Central region, followed by the South, the North and the Northeast.

Table 1.2 Income Per Capita by Region (180)

Region	Income per capita, Baht			
	1968	1969	1970	1971
Whole Kingdom	3196	3440	3480	3692
Northeast	1600	1668	1694	1766
North	2200	2370	2380	2520
South	3098	3376	3430	3482
Central	5692	6158	6304	6702

Even though there are some differences in the income per capita by different regions, the highest portion of income in all regions is spent on food with little difference in urban and rural areas as shown in Appendix 1.

For the general food habits of the Thai people, the main diet is rice, constituting about 40 percent of the total expenditure on food. The protein foods such as meat, pork, poultry and fish account for 27 percent, vegetable and fruit 11 percent and milk and eggs only 4 percent (179). The nutritional survey conducted in 1960 by the Interdepartmental Committee on Nutrition for National Defence, ICNND, established deficient intakes of vitamin A, thiamine, riboflavin, while in general calorie and protein intakes were rather low but adequate. In 1966, the Ministry of Public Health conducting a nutritional survey of 10 villages in the province of Ubol of the Northeast region found a similar result to the one conducted in 1960.

Dietary habits during pregnancy and lactation are observed to be markedly different among individuals (108). The custom of food restriction during the pregnant and lactating period is practised in many parts of the country, in particular rural areas. The restricted foods are nutritional foods such as meat, eggs and fat (179). A case study in the Northeast revealed that the food intake of a pregnant woman was short in calorie, protein and almost all nutrients except phosphorus, thiamine and niacin; this could be the consequence of the food restriction (179). Therefore it is likely that protein calorie malnutrition and nutrient deficiency already exists in some of the pregnant women.

1.2 Nutritional status of infant in Thailand

The first year of life is a very important period, the new born baby must triple his weight and increase his length by half. Therefore, the food intake at an early age of life is very important, it must be adequate in terms of quality as well as quantity.

Within the Thai population of 34.15 million in 1970, 5.6 million were children aged from 0-4 years. The vital statistics of Thailand 1970 (171) showed the number of deaths of children in 0-4 year period as high as 22.6 percent of the total deaths with the following age distribution:-

Under	1 year	12.1
	1 year	3.7
	2 years	2.7
	3 years	2.2
	4 years	1.9
Total	0-4 years	22.6

The mortality rate is high compared to that found in countries such as U.S.A. and Denmark as shown in Table 1.3

Table 1.3 The Mortality Rate of Children 1-4 Years of Age in Selected Countries Compared to Thailand (171).

Country	Mortality rate per 1000 children
U.S.A.	1.1
Denmark	1.1
Columbia	18.6
Mexico	19.3
Thailand	22.6
El Salvador	26.6

Statistical data on malnutrition of children in Thailand is scarce and those available are rather out of date. The survey on the number of malnutrition cases admitted and the deaths at all of the hospitals in the country in 1968 by the Ministry of Public Health, Table 1.4, revealed that the major nutrient deficiencies were thiamine, protein, calorie and iron.

Table 1.4 Cases Admitted and Deaths of Infants by Malnutrition (Number and Percentage)

	Whole Kingdom				Bangkok				Provincial			
	Admission		Death		Admission		Death		Admission		Death	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Total	111	100	20	100	43	100	8	100	68	100	12	100
Avitaminosis and other deficiency	96	86.5	18	90.0	32	74.4	6	75.0	64	94.1	12	100.0
Beri beri	39	25.3	6	30.0	17	39.5	4	50.0	22	32.4	2	16.7
Vitamin A	7	6.2	4	20.0	3	7.0	-	-	4	5.9	4	33.3
Malnutrition	21	18.9	3	15.0	5	11.6	1	12.5	16	23.5	2	16.7
Kwashiokor	15	13.5	5	25.0	3	7.0	1	12.5	12	17.6	4	13.3
Others	14	12.6	-	-	4	9.3	-	-	10	14.7	-	-
Iron-deficiency anaemia	15	13.5	2	10.0	11	25.6	2	25.0	4	5.9	-	-

In 1968, Dhanamitta and Vallyasevi (61) studied the nutritional status of more than a thousand infants in the Northeast and found the percent prevalence of malnutrition based on weight and height ranged from 50 percent of the subjects on the main road to 95 percent in the remote areas. In 1974 a study was carried out in the same province, it was found that 50 to 65 percent of the total number suffered from malnutrition. This means that there is very little improvement in overall nutritional status in that area in the last 7 years. In 1973, the interministerial

working group for the development of national food and nutrition policy guidelines for Thailand reported the problem of malnutrition in Thailand especially in the preschool children. Approximately 50 percent of children under 5 years old suffered from malnutrition. Khanjanstithi and Wray (140) in 1974, looking for evidence of protein calorie malnutrition (PCM) in 4 slum areas of Bangkok municipality in children aged from birth to 72 months, found that the rate of PCM was strikingly high, 83.63 percent. The highest percentage was found at the age of 12-17 months but PCM was found starting from the beginning of life as shown in Table 1.5.

Table 1.5 Percent of PCM in Preschool Children in Various Categories, by Age in Months in 4 Districts

	Age in months							
	0-5	6-11	12-17	18-23	24-35	36-47	48-59	60-72
1 ^o PCM	23.0	16.0	28.25	40.75	27.75	32.5	45.25	29.0
2 ^o PCM	28.0	31.5	45.5	27.0	35.5	38.25	25.75	45.5
3 ^o PCM	7.75	15.5	10.5	3.75	5.75	4.25	2.25	7.0
Total								
PCM	58.75	63.0	84.25	71.5	69.0	75.0	73.25	81.5

At Ramathibodi Hospital in Bangkok and Ubol Hospital in the Northeast, Valyasevi et al. 1974 (240) studied anaemia in pregnant women, infants and preschool children and reported a high incidence as one-third of the number of infants up to the age of 2 years suffered from anaemia. Therefore, it can be concluded from the literature available that PCM, vitamin deficiency and anaemia are the major

nutritional deficiencies facing infants in Thailand.

A study under the rice fortification project by Tantivonse 1969, investigated 1500 preschool children aged from 6 months to 5 years in the farmer families of 26 villages in Chiangmai, found that the growth performance of Thai children could match with the Harvard standard (123) up to the age of 6 months as long as they are fully breast fed. It was confirmed by the work of Kanjanasthiti et al. 1973 who conducted studies on the growth of Thai infants and school children selected from the middle class families of Bangkok and found that the growth of Thai children at the start was comparable to those of the North American standard and became slower after 6 months. This evidence indicates the need for nutritional solid food. Kanjanasthiti et al. 1974 suggested that nutritionally adequate foods for weaning periods were urgently needed.

1.3 Reviews on infant feeding practices in Thailand

Generally the infant is started on breast feeding, the duration for breast feeding ranging from less than 6 months to more than 2 years. From the survey by the National Economic and Social Development Board, NESDB (Appendix 2) only a few mothers stopped breast feeding when the infant was between 6 months to 1 year old. About half continued breast feeding until the infant was between 1-2 years old. The number of mothers continuing breast feeding until the infant was more than 2 years was quite high. There were differences in the duration of breast feeding between urban and rural mothers (179).

The breast feeding is supplemented by other foods. The supplementary food varies greatly from region to region

(242). In Central regions, most mothers feed the infant first on banana then after 6 months on a mixture of mashed, boiled rice and banana. Fifty percent of the infants in Bangkok are introduced to solid foods such as cooked egg yolk or mashed rice with vegetable or meat soup at the age of 6 months or older (179). For the urban poor area, one-third of the children are introduced to canned milk and started on carbohydrates as early as 1 to 2 months. In the Northeast, mothers start with a mixture of chewed glutinous rice, banana and few drops of human milk wrapped in banana leaf and cooked over a charcoal fire. This supplementary feeding is introduced as early as 2-3 days after birth. In the North, the supplementary feeding begins after the first month, the mother chews cooked glutinous rice and sometimes banana is added. The change to the use of mashed boiled rice was reported in some villages in the study by Halstead et al. 1967 (103). In the South, supplementary feeding starts around the age of 3 months with a mixture of mashed cooked rice and banana. Table 1.6 shows the type of food fed to infants aged from birth to 1 year is in general human milk supplemented with banana and mashed rice.

Table 1.6 Type of Food Fed to Infant (0-1 year)

	Food for Infant (0-1 year)				
	(percentage)				
	All Areas	Bangkok		Other	
	Middle Income	Low Income	Urban	Rural	
	100.0	100.0	100.0	100.0	100.0
Breast feeding	34.7	10.0	35.2	36.1	35.0
Powdered milk	8.6	40.0	18.9	14.4	3.9
Sweetened milk	7.3	20.0	8.1	5.4	7.4
Breast feeding and powdered milk	3.2	10.0	5.4	2.7	2.8
Breast feeding and sweetened milk	1.4	16.7	2.7	2.7	1.4
Breast feeding, banana and mashed rice	34.7	-	16.2	28.8	39.9
Powdered milk, banana and mashed rice	1.8	10.0	10.8	-	1.1
Sweetened milk, banana and mashed rice	2.9	-	2.7	0.9	1.8
Breast feeding, and vitamin	1.8	-	-	4.5	2.8
No answer	3.6	-	-	-	3.9

It can be concluded from the literature review that breast feeding is commonly practised and there are cases where it has been used for too long a period. Mashed rice and banana are widely used as supplementary food. In the rural and urban poor areas, the solid food is mainly based on carbohydrate and is introduced rather early. This leads to poor nutritional status for infants. The investigation is needed for an up to date information on the feeding practices which in consequence will give a confirmative understanding of the nutritional status of

infant and identify what are the need of the infant.

1.4 Investigation on feeding patterns

To find the more detailed information needed to design an infant food, a survey was made to find what is fed to infants from birth up to 1 year. Two hundred mothers with children aged up to 1 year were interviewed from 4 regions. As it was too costly and time consuming to do random sampling in each region; 4 towns, one from each region, were chosen - Bangkok for the Central, Khon Kaen for the Northeast, Chiangmai for the North and Pukhet for the South. These mothers with varying socio-economic backgrounds were interviewed in child clinics or their own homes. The number of mothers interviewed in each town was proportional to the number of households in that region (182), as shown in Table 1.7. The questions used in the interview are given in Appendix 3.

Table 1.7 The Distribution of the Number of Households in Thailand and the Number of Mothers Interviewed in Each Region

	Total population	Number of households	Percentage of distribution of household	Number of mothers interviewed
Whole Kingdom	34,397,374	5,908,473	100.0	200
Central	10,611,877	1,821,558	30.5	62
Northeast	12,025.140	1,952,653	32.5	67
North	7,488,683	1,363,041	22.5	45
South	4,271,674	771,221	14.5	26

The facts investigated in the survey were:

1. Number of mothers breast feeding.
2. Type of other milk used with human milk.
3. The duration the infants were on milk feeding, both human and other types of milk.
4. Age of infant when solid food was introduced.
5. Types of commonly used solid food.

The result of the survey is discussed with particular reference to the pattern of milk feeding and introduction of solid food.

1.4.1 Milk feeding patterns

The use of human milk, dried milk and canned milk is shown in Table 1.8.

Table 1.8 Milk Feeding Pattern

Feeding pattern	Number of Mothers Region				Total for all Regions	Percentage for all Regions
	Central	Northeast	North	South		
Breast milk alone	10	43	5	3	61	30.5
Breast milk and milk powder	26	12	24	3	65	32.5
Breast milk, milk powder and canned milk	6	3	9	9	27	13.5
Number and percentage ^(a) of mother breast milk feeding	42 (67.7)	58 (86.6)	38 (84.4)	15 (57.7)	153	76.5
Dry milk powder alone	20	6	7	8	41	20.5
Dry milk powder and canned milk	-	3	-	3	6	3.0

(a) Percentage given in brackets.

Human milk is commonly used by 76.5 percent of the mothers in all regions, with the highest percentage of breast feeding alone in the Northeast. But 23.5 percent of

the mothers feed their children with some other kind of milk such as milk powder and canned milk. The figure for breast feeding in this investigation is slightly less than reported by NESDB (179) (Appendix 2), nevertheless it similarly indicates breast feeding as common practice.

The next consideration was how long has breast feeding been used and Table 1.9 shows the distribution of different durations of breast feeding.

Table 1.9 Duration of Breast Feeding.

Region	Percentage of mothers with different duration of breast feeding			Percentage of mothers did not answer
	1	2 - 6	7 - 12 (month)	
Central	53.3	35.6	11.1	27.4
Northeast	20.9	4.7	74.4	35.8
North	22.9	65.7	11.4	22.2
South	23.5	35.3	41.1	34.6
Average for all regions	32.1	33.6	34.3	30.0

A high proportion of infants in the Central, approximately 50 percent, are stopped in the first month and another one-third are stopped between the second and sixth month. In the Northeast, approximately 25 percent within the sixth month and a higher percentage of 74.4 percent are still on breast feeding up to 12 months. In the North, half of the mothers stop within the first 6 months and the other half between 7 to 12 months. In the South, the majority of mothers, 89 percent, stop breast

feeding within 6 months and only 11 percent breast feed during 7 to 12 months.

About one-third of mothers were breast feeding at the time of investigation and could not answer when they would stop. Only the mothers who gave an answer are tabulated for the duration of breast feeding.

1.4.2 Patterns for the introduction of solid food

Two important points were considered: types of solid food commonly used and age of infant when different solid foods are introduced. From the investigation, there are 3 categories of solid foods: carbohydrates mainly as rice and glutinous rice; protein as egg, meat, meat soup and fish; and vegetable as cooked vegetable and vegetable soup.

Table 1.10 gives the profile of food material types commonly used in home preparation. It is only a qualitative indication of the food material types, and not related to the quantity given.

Table 1.10 Percentage Distribution of Different types of Solid Food Introduced to Infants in 4 Regions.

Region	Percentage of Mothers using Foods									
	Carbohydrates			Protein				Vegetable		
	Rice	Glutinous rice	Total	Egg	Meat	Fish	Total	Vege- table	Vegetable soup	Total
Central	58.5	-	58.5	15.1	12.2	-	27.3	11.3	2.8	14.1
Northeast	16.7	39.7	56.4	5.7	12.1	18.4	36.2	5.1	2.3	7.4
North	0.9	66.1	67.0	9.2	11.9	0.9	22.0	5.5	5.5	11.0
South	60.0	-	60.0	5.0	-	5.0	10.0	5.0	25.0	30.0
Average for all regions	34.0	26.5	60.5	8.7	9.1	6.1	23.9	6.7	8.9	15.6

The age of infant when different solid foods is introduced, is shown in Table 1.11.

Table 1.11 Age of Infant when Different Solid Foods are Introduced in Various Regions

Region	Age in months				
	Type of solid Food				
	Carbohydrate	Egg	Fish	Meat or meat soup	Vegetable or vegetable soup
Central	3	3	-	3	3
Northeast	Within first month	12	12	12	12
North	Within first month	3	12	6	6
South	6	12	12	6	6

In the Central, solid food is introduced in the third month and covers quite a combination of food materials. In the Northeast, carbohydrate is introduced very early within the first month and other types of food material are not used until after one year. In the North, carbohydrate is introduced very early as in the Northeast, egg is introduced in the third month, meat and vegetable in the sixth month. Different from other regions is the South where solid food is introduced in the sixth month as a combination of carbohydrate, meat and vegetable soup. Egg and fish are given later at the age of one year.

From the established fact that an adequate intake of all essential nutrients can be provided from milk within the first 6 months (81), the practice in the Central, South and North as far as age of infant when solid food is

introduced can be regarded as an adequate practice provided that the actual combination of solid food gives adequate nutrients. But the mother in the Northeast introduces the solid food based on glutinous rice very early within the first month, and does not introduce other food materials at all until the infant is one year old.

In the Central area, the infant nutritional status depends on the quality of milk used in combination with human milk as half of these mothers stop breast feeding within the first month, and also depends on the nutritional value of the solid food given. In the South, approximately 59 percent keep breast feeding up to 6 months and solid food is introduced later than other regions. In the North, approximately 84 percent of mothers breast feed their infant. Solid food is introduced within the first month, mainly from glutinous rice. Within 6 months, a good combination of raw materials are given. The nutritional status of infant in this region does not only depend on the nutritional value of solid food given but also on the replacement of the glutinous rice given within the first month.

In the Northeast, the highest percentage of mothers, 86.6 percent, use breast feeding. The infants in this region are the most vulnerable group of all regions considering that 74 percent keep on breast feeding after 6 months. A combination of food sources is only given at the age of one year, while carbohydrate food mainly glutinous rice is given in the first month. Obviously, the infant in this group does need a nutritional food to replace carbohydrate in the first month and to replace or

supplement mother milk after 6 months.

Thus, the present feeding pattern reveals a potential need for a nutritional infant food. The categories of infants where nutritional food is seriously needed are: group where breast milk is kept on after 6 months, group where breast milk is given up very early, group where only carbohydrate is introduced. Even with the less vulnerable groups, there is the question of whether the home-prepared solid food gives nutrients to the requirements of the infant.

1.5 The types of infant food available in Thailand

In order to consider the best food to design, it was pertinent to observe the types of manufactured products in Thailand that can be used for infant feeding. The investigation was planned to determine the type of infant foods available in the market together with the information on prices and sizes, and whether it is locally manufactured or imported. The investigation was performed by interviewing the retailers in the Bangkok market on the type of infant food available in the urban area and the retailers in the Northeast, Khon Kaen, for the semi-rural area. It involved 10 supermarkets and 15 groceries in Bangkok and 15 groceries in Khon Kaen. The interview form is shown in Appendix 4.

From the result of the investigation, similar types of products are found in the Bangkok and Khon Kaen markets. This indicates the unrestricted product distribution, even in a province far from Bangkok. It was presumed that the types of products found are well distributed throughout the country.

The types of available infant food observed from the investigation can be divided into 2 categories.

1.5.1 Dairy products

The dairy products available are a combination of imported and locally manufactured products. Table 1.12 lists the available dairy products in the market.

Table 1.12 Dairy Products Available in the Market

Brand	Description of Products	Type of Package	Size of Container g	Price in Baht	Brand	Description of Products	Type of Package	Size of Container g	Price in Baht
Locally Manufactured Product					Imported Manufactured Product				
Alaska	Evaporated liquid milk	can	400	3.50	Bear brand	Infant milk powder	tin	454	34
Mali	Sweetened condensed milk	can	400	3.50	Lactogen	Infant milk powder	tin	454	30
Milk maid	Sweetened condensed milk	can	400	3.50	Nan	Infant milk powder	tin	454	30
Carnation	Evaporated liquid milk	can	400	5.5	Molly	Infant milk powder	tin	454	30
Suen-jit	Milk powder	tin	454	27.0	S - 26	Infant milk powder	tin	454	44
Imported Manufactured Product					Imported Manufactured Product				
Bear brand	Sweetened condensed milk	can	400	5.0	Klim	Infant milk powder	tin	400	25
Hawaii	Evaporated liquid milk	can	400	3.0	Enfamil	Infant milk powder	tin	454	43
Dunmilk	Sweetened milk powder	tin	128	5.0	Masnex	Infant milk powder	tin	454	35
					Pelargon	Infant milk powder	tin	454	37
					Dumex	Infant milk powder	tin	1135	75
					Snow	Infant milk powder	tin	450	33
					Lactogen	Infant milk powder	tin	454	30
					Similac	Infant milk powder	tin	454	49
					Cerelac	Wheat and milk	tin	400	33

1.5.2 Infant foods other than dairy products

All of the non dairy infant foods available in the market are imported as listed in Table 1.13.

It is worth noting that there is an experimental infant food developed by the Institute of Food Research and Product Development, Kasetsart University, for infants older than 3 months (30). It is a dry product consisting mainly of rice flour; other minor ingredients are full fat soy flour, sesame and brown sugar. It is an experimental product with only a limited number of the nutrients as specified by Thai Notification for infants older than 3

months, some of the vitamins and minerals are supplemented.

Table 1.13 Types of Infant Food other than Dairy Products Available in the Market.

Brand	Description of products	Type of package	Size of container g	Price in Baht
Aurora	Instant baby cereal	Paper package	227	23.50
Heinz	Paste (carrots, chicken soup, vegetable soup, egg noodle and chicken, apple and pear)	Pottle	128- 135	12.50- 16.50
Heinz	Teething biscuit	Paper package	114	13.0
Nestum	Mixed cereal	Tin	283	15.0
Gerber	Paste (vegetable and lamb, green beans, oatmeal, cream corn, mixed cereal, apple sauce with pineapple, cereal and egg yolk)	Bottle	128- 135	11.50

In considering the type of products available for infants in Thailand, it can be concluded that dairy products are the only type of product in general use for feeding infants. Other foods, though available are all imported, except for the experimental infant food. The frequency of using imported infant food was not found in the conducted survey of infant feeding pattern but it is considered to be very small. There is a need for locally produced infant foods and this is only partially met by Kasetart infant food. There is a need for a nutritionally balanced food which would supply all of the infant's

nutritional requirements and which could be manufactured in Thailand using only indigenous raw materials.

It can be concluded that, apart from the dairy products, there is no locally manufactured product for infants available in the market, despite the need for a nutritional infant food.

1.6 The need for nutritional infant food

Considering the need for a nutritional solid food for Thai infants, it is pertinent to consider the necessity of having solid food and also the age of the infant at which it should be introduced.

Fomon 1974 stated that a breast fed infant from a healthy, well nourished mother with adequate calorie intake obtained most of the specific nutrients except iron and vitamin D. This is true for infants fed on cow milk as well because the content of these 2 nutrients are approximately the same in both human and cow milk. Therefore, it is desirable to feed solid food in order to obtain these nutrients not adequately available from milk. This answers the question when should the solid food be introduced. As far as iron and vitamin D are concerned, an infant born from a well nourished mother is likely to have adequate storage of iron for almost 3 months. In the industrialized countries where cow milk is widely used, most of the evaporated milk, commercially prepared formulae for infants and most fresh whole milk are fortified with vitamin D. In these circumstances, solid food should be given preferably after 3 months. In an early study, Marriot 1935 suggested that 6 months was the proper age for introduction of solid foods. Butler and Wolman 1954 did a

survey among pediatricians and found that 88 percent recommended feeding solids before 3 months, 66 percent before 2 months. This shows the trend in early introduction of solid food. It appears that feeding solid food between 2 and 3 months is preferable and is recommended. An investigation on how the infant tolerated the extremely early introduction of cereal and strained foods was studied by Sackett 1956. Cereal was fed on the second or third day of life, vegetable at age of 10 days, strained meat at age 14 days and fruit at age 17 days, and the infant was found to tolerate them well. However, there is no advantageous evidence to such early introduction of solid foods (81).

In consideration of Thai infants, literature reviews on the nutritional status pointed to the evidence of malnutrition in particular of protein calorie malnutrition, iron deficiency and vitamin deficiency in the poor urban and rural areas. Reviews on the feeding practices reflected a large number of breast fed infants and evidence that human milk did not provide an adequate supply of nutrients, especially after 6 months (228, 139, 235). The information from the present investigation confirmed the feeding practices reported in the literature. Though the practices are different from region to region, it can be concluded that the practice in the Central and in the South could supply adequate nutrients provided that the prepared solid food and milk given in combination with human milk are adequate both in quality and quantity. The practice in the North and the Northeast indicated the evidence of prolonged breast feeding, leaving the introduction of other

nutritional foods very late, though solid food based only on carbohydrate is introduced in the first month.

All this information leads to the suggestion that having nutritional infant food available to mothers in different regions will help in solving the problems of malnutrition facing infants in Thailand. This fact has already been emphasized by the research workers in the area of infant nutrition (139). The infants aged from 6 months to 1 year are the group that needs this kind of nutritional food more than other groups (139, 235). The suggestion of a solid food will also not upset the good practice of feeding human milk during the early months, as the infant can only slowly be weaned onto the solid food. It is equally important that this infant food must become available in such a way that it will get used by most mothers i.e., it must be as cheap as possible, convenient to use and in the form preferred or required by the mothers. This infant food must provide balanced nutrients according to the infant requirements so that it can either be used as a supplement to milk or as a sole source of nutrients.

Therefore, it can be finally concluded that there is a need for nutritional solid food that can either be used by itself as a sole source of food or supplementary to milk. The age group of infant in most need is from 6 months to one year, but the mothers might introduce solid food earlier. Therefore, the infant food should be designed for infants over 3 months. This infant food must be as cheap as possible, derive as much of the required nutrients from the local indigenous raw materials and in the form required and preferred by the mothers.

CHAPTER 2

DETERMINATION OF QUANTITATIVE AND QUALITATIVE
CHARACTERISTICS OF INFANT FOOD

It has been discussed that the Thai infant should have a balanced nutritional food, at the latest by the sixth month. Therefore it was decided to design a nutritional food for infants aged from 6 months up to one year. With the consideration that the infant food might be needed for infants from 3 months, the quantitative and qualitative characteristics of infant food were determined for both groups of infants i.e. for 3 - 5 months and 6 - 12 months. The aim was to design a combination of indigenous Thai food raw materials to be processed as an infant food that provided a daily requirement of each nutrient and complied with the Thai food regulations. What needed to be considered was firstly, the quantitative characteristics of the infant food, i.e. the daily requirement of the nutrients known to have an important role in the growth of infants between 3 months and one year old; and secondly, the qualitative characteristics with particular reference to the mothers' attitudes towards food raw materials, processing, product and the market feasibility. This chapter discusses the infant nutritional requirements and also describes the survey to discover the attitudes of Thai mothers towards infant foods. From this study, the quantitative and qualitative specifications for the infant food were defined.

2.1 Infant nutritional requirement

According to Fomon 1974, "The requirement of an individual for specific nutrients may be defined as the least amount of that nutrient, that will promote an optimal state of health." The requirement is known to vary with age, size, rate of growth and level of activity. Furthermore, the nutrients are known to interact; for example, the requirement for an individual amino acid depends on the total consumption of protein, requirements of various vitamins depend on intake of total calorie, protein, fat, carbohydrate, specific amino acid and other vitamins. The interrelation between minerals and other dietary components are also known to be complex. Because of the uncertainty in the estimation of the requirements for various nutrients, it is desirable to recommend intake in excess of the estimated requirement. Consequently, the margin between the estimated requirement and the advisable intake depends on the degree of confidence in the assigned value and the possible danger in having an excess. Therefore, advisable intakes, when the nutrient requirements are well defined, are set at a value slightly greater than the estimated requirement. When there is less confidence, the advisable intake is generous and when the estimate of nutrient requirement is highly uncertain, the advisable intake can be as high as 3 times the estimated requirement (81).

Therefore, to specify the quantitative characteristics of an infant food, the nutritional requirement of the infant, with particular reference to the Thai infant, were considered. However, whatever was specified had also to comply with the

Thai Notification by the Ministry of Public Health (167) on the standard for an infant food.

A wide range of nutrients known to have important roles in infant nutrition was considered. Many literature sources on infant nutrition and also personal communication with both New Zealand and Thai paediatricians (111, 241) were used in defining the requirements of the Thai infant. The important references were the Thai Notification (Appendix 5), the drafted infant food standard by Codex Alimentarius (Appendix 6), relevant report by joint FAO/WHO expert groups (125, 126, 127) and the text book on infant nutrition by Fomon 1974.

It was important to specify the amount of nutrients necessary to maintain growth and normal health of the Thai infant.

A number of nutrients are important to the infant (39, 56, 81). Most of these nutrients are recommended by Codex Alimentarius and the Thai Notification. Nevertheless, there are other trace elements such as sulphur, chromium, cobalt, selenium and molybdenum which are discussed as important trace elements (81) but are not specified by either Codex Alimentarius or the Thai Notification. Very little is known on their metabolism and their exact requirement by the infant. Furthermore, very limited information is available on the analysis of these elements in food materials. Accordingly, it was decided not to include these elements in this study until more quantitative evidence for the infant's requirements is available. The other nutrients that are recommended by the literature and by Codex Alimentarius were considered in this study; the

list of these nutrients is given in Table 2.1.

Table 2.1 The Nutrients Specified in the Design of Infant Food.

Proximate Analysis	Minerals	Vitamins	Amino Acids
Calorie	Sodium	Vitamin A	Histidine
Protein	Potassium	Vitamin D	Isoleucine
Fat	Chloride	Vitamin E	Leucine
Fibre	Calcium	Vitamin K	Lysine
Sugar	Phosphorus	Ascorbic acid	Methionine
Linoleic acid	Magnesium	Thiamine	Cystine
Carbohydrate	Iron	Riboflavin	Phenylalanine
	Iodine	Niacin	Tyrosine
	Copper	Vitamin B6	Threonine
	Zinc	Pantothenic acid	Tryptophan
	Manganese	Folic acid	Valine
		Biotin	
		Vitamin B12	
		Choline	

It is worth noting that among all these nutrients, less is known about the methods of absorption, deposition and excretion of copper, zinc and manganese. Cuthbertson 1973 commented that the addition of these nutrients to infant food should not be encouraged unless more information is available. As they were specified by Codex Alimentarius and only indigenous food raw materials would be used, these elements were specified in this study.

The Thai Notification divides infant foods into 2 categories, for infants younger than 3 months and for

infants older than 3 months, while Codex Alimentarius recommends for infants all in one group from birth to 12 months. It is questionable whether a single dietary recommendation would satisfy the nutritional requirements for infants for the whole 12 months. However, the differences in the specifications by the Thai Notification are that with the older group of infants less nutrients and a different relationship of sugar and carbohydrate are specified. It is questionable whether those unspecified nutrients are not important during that age of 4 to 12 months. Therefore, more nutrients were specified in this study than were specified by the Thai Notification, based on the knowledge of infant nutrition and the recommended standard by Codex Alimentarius.

Both Codex Alimentarius and Thai Notification specify most of the nutrients as related to energy per unit of 100 kcal. To achieve the daily requirement for each nutrient, the expression of each nutrient related to energy will have no meaning in this design unless the minimum energy intake is also specified. To comply with the Thai Notification where the nutrient is specified per unit of 100 kcal, it was specified likewise in this study. The first consideration was to estimate the energy requirement of the Thai infant. Once the energy requirement was estimated, the nutrients related to energy were defined so that taking the recommended energy the infant would obtain the daily requirement of each nutrient. To define the minimum level for each nutrient, the following steps were considered:

1. For the nutrient specified by the Thai Notification, the adequacy in providing for the daily nutritional requirement was checked. The Thai Notification was used in this design only when it met the advisable daily intake. In cases where it did not, it was increased so that at the required energy level, it gave the advisable daily intake.
2. For the nutrient not specified by the Thai Notification but where the advisable daily intake had been established, it was specified as a daily requirement.
3. When the nutrient is not specified by the Thai Notification and the advisable daily intake has not been established in the literature despite its significance, the infant food standard recommended by Codex Alimentarius was used.

Likewise, the maximum level specified by the Thai regulation was studied to ensure that it would not lead to an adverse effect. In cases where a maximum level is not specified by Thai Notification, it was defined according to the available information on infant nutrition. In cases where such information had not been established, the recommendation by Codex Alimentarius was used. However, where it was neither specified by Codex Alimentarius nor available elsewhere, the composition of human milk was used to derive the maximum limit at selected energy intakes.

The following sections give the detail on the extent to which each nutrient was specified.

2.1.1 Energy requirement

According to the report of a Joint FAO/WHO Expert Group (127), the energy requirement is defined as the energy intake that is considered adequate to meet the energy needs of the average healthy infant and recommends that the energy intake is based on body weight. The requirement per kg of body weight is highest in the first 3 months and lower in the second 3 months. During the first 3 months, energy requirement can be estimated from the observed intakes of the breast fed infant growing normally. After 3 months, the infant is unable to obtain his full energy needs from human milk alone and the energy requirement depends largely on the infant's activity.

The average requirement during the first year given by FAO/WHO Expert Group (127) is shown in Table 2.2.

Table 2.2 Energy Requirement for Infants

Age	Kcal per kg
< 3 months	120
3-5 months	115
6-8 months	110
9-11 months	105
Average during first year	112

The recommended intake by the Ministry of Health, Thailand (168) for energy requirement from birth to 12 months is 660 kcal per day. However it was felt that the energy requirement of the Thai infant should be based on body weight rather than being fixed at one value for the whole group of infants from birth to one year. Therefore

the available standard of Thai infant body weights as shown in Appendix 7 (139) was used with energy intakes suggested by FAO/WHO Expert Group (127). The calculated daily recommended energy for the Thai infant is shown in Table 2.3.

Table 2.3 Recommended Daily Energy Intake for Thai Infant

Age month	Average weight kg	Recommended daily ^a kcal ^b
<3	4.35	530
3-5	6.56	760
6-8	7.83	870
9-12	8.38	880

^aThe recommended daily intake is given to the nearest figure of 10.

^b1 kcal is equivalent to 4.184 kilojoules.

After 3 months, the calculated daily intake is higher than the Thai recommendation at 660 kcal. The consequence of decreasing energy requirement with age and increasing body weight of the Thai infant gives rise to approximately the same calorie intake for the infant groups of 6 to 8 months and 9 to 12 months, but approximately 100 kcal different to the age 3 to 5 months. Because of the small differences in calculated intakes, it is not worthwhile to sub-divide the energy requirement for infants aged 6 to 12 months. The daily energy requirement for infants aged 6 to 12 months was estimated at 880 kcal. Therefore, the model for the design of infant food considered 2 categories of estimated daily energy requirements i.e. at 760 kcal for infants 3 to 5 months and 880 kcal for infants 6 to 12 months.

2.1.2 Protein requirement

The FAO/WHO committee on protein requirement (127) suggests that, "the most useful criterion of an adequate protein intake is a growth rate that meets accepted paediatric standards". The safe level of protein intake for infants aged 3-6, 6-9 and 9-12 months are given as 1.85, 1.62 and 1.44 g of protein per kg of body weight respectively. Based on the average weight of Thai infants and recommended daily energy intakes (Table 2.3), the equivalence of safe level intakes of protein per 100 kcal at different ages are 1.60, 1.46 and 1.36 g respectively as shown in Table 2.4.

Table 2.4 Safe Level of Protein Intake for Different Age Groups of Infants

Age month	Weight of Thai infant kg	Safe level of protein intake per kg	Calculated protein intake per day	Recommended daily energy intake, kcal	Safe level of protein intake per 100 kcal
3-5	6.56	1.85	12.14	760	1.60
6-8	7.83	1.62	12.68	870	1.46
9-12	8.38	1.44	12.07	880	1.37

For the concept of advisable intake, Fomon 1974 observed that 1.6 g of protein per 100 kcal from a milk based formula appeared adequate to support normal growth for the first 6 weeks of life and estimated that 1.4 g per 100 kcal would be adequate during the remainder of life. It is worth noting that human milk ratio of protein to calorie is 1.5 g per 100 kcal. In setting the advisable intakes of protein, Fomon 1974 increased the estimated

requirement by 20 percent to allow for any uncertainty in the estimation. Therefore, his advisable intake is 1.7 g per 100 kcal from age of 4 months to one year.

It is specified in the Thai Notification per 100 kcal that "the infant food must contain not less than 1.8 g and not more than 3.5 g of reference protein; as for other proteins either whole or part those proteins shall have consumable value not less than 70 percent of the protein of egg." Codex Alimentarius recommends slightly different by using casein as reference protein and specifies not less than 1.8 g and not more than 4 g per 100 kcal and quality of protein must not be less than 85 percent of casein.

Therefore in specifying protein, it is necessary to not only give minimum levels, but also to define the protein quality. The protein quality can be defined by its amino acid composition as well as by other biological evaluations such as protein efficiency ratio (PER), biological value (BV) and net protein utilization (NPU). Amongst these factors, amino acid composition is well established and readily available. It was impossible to find biological values for all the raw materials. It was realized that digestibility should be included with amino acid pattern to give a more accurate estimation of the biological values, but these figures were not available. Therefore, the protein quality was considered only in terms

Carmel, J. (The prediction of diets of high energy and protein value by linear programming. Ecology of Food and Nutrition 2:101-177, 1976.) used ND_p Cal %, an index specifying the nutritional relationships between protein quantity, protein quality and energy. Protein quality was based on the A/E ratio i.e. the ratio of each individual essential amino acid to the total essential amino acids. This is basically the same presentation of protein quality as in this thesis, and does not include the digestibility.

of the amino acid composition. As the Thai Notification refers consumable value to egg protein, it was therefore decided to use egg protein as reference protein.

Specification at 1.8 g per 100 kcal by Thai Notification and Codex Alimentarius covers the safe level of protein intake suggested by FAO/WHO (127) as in Table 2.4 and Fomon suggested only 1.7 g per 100 kcal at the age of 4 months to one year. Therefore, the specification by the Thai Notification was used at 1.8 g per 100 kcal, using egg protein as the reference protein.

The next consideration was how to obtain the minimum amount of reference protein, i.e. egg protein, when different food materials were to be used in the design. They were chosen to give an amino acid mixture as similar to egg protein as possible. The question was the amount of the other proteins needed as compared to the amount of reference protein. For the amount of mixed proteins, the correction factor can be applied (127) if the protein quality of the designed food is known. For example, if the protein quality is at 70 percent egg protein, the correction factor at $\frac{100}{70}$ will make minimum value at 1.8 equivalent to 2.6 and the maximum value 3.5 equivalent to 5.0.

Logically, one would go for the best quality of protein as much as possible. The problems arise in obtaining high levels of amino acids as well as maintaining other nutrients at their satisfactory levels. Edwardson 1974 found that the cost of a food mix increased with increasing amino acid levels. Whether the increasing levels will create difficulty in maintaining the requirement of other nutrients in this infant food model will have to be

confirmed. But from Edwardson's work and from the Thai Notification, the 70 percent level of egg protein could be used as the minimum limit. The actual level of amino acids to be used in the infant food will be obtained by experimentation with the model. Once this is known, the amount of protein needed can be adjusted according to the quality of protein.

However, it is known that a high percentage of calorie from protein, at 20 percent or more, results in renal disease especially with infants of low birth weight (81). In applying the correction factor, the upper level of protein at 5.0 g per 100 kcal is equivalent to 20 percent. Though correction should be applied to both upper and lower levels, it should be within limits and not lead to high loading on the kidney. Thus, the minimum and maximum protein contents per 100 kcal were set temporarily at 1.8 g and 3.5 g until more information would be obtained from the experiments with the model.

Therefore, the minimum and maximum protein content per 100 kcal were specified at 1.8 and 3.5 g respectively. The protein quality was expressed by its amino acid composition as compared with egg protein.

2.1.3 Essential amino acids requirement

There are 11 essential amino acids known to be necessary for infants (81, 127). Suggested pattern of essential amino acids for infant feeding is given by FAO/WHO report as shown in Table 2.5. Human milk composition is also given in Table 2.5. It is suggested by the Thai Notification that protein quality provided by infant food

must all together not be lower than 70 percent of the quality of egg protein.

Therefore, the essential amino acids pattern in egg is used as standard and the minimum value of essential amino acids derived from all the food materials must not be less than the value at 70 percent of amino acids in egg, expressed in mg per g of protein as shown in Table 2.5.

Table 2.5 Comparison of amino acids in egg, human milk and FAO pattern

Essential amino acid	Egg	Human milk	FAO/WHO suggested pattern	70 percent of egg amino acid
mg of amino acid per g of protein				
Histidine	22	20	14	15.4
Isoleucine	54	62	35	37.8
Leucine	86	91	80	60.2
Lysine	70	66	52	49.0
Methionine and Cystine	57	43	29	39.9
Phenylalanine and Tyrosine	93	99	63	65.1
Threonine	47	45	44	32.9
Tryptophan	17	16	8.5	11.9
Valine	66	64	47	46.2

2.1.4 Fat requirement

It is known that with the exception of essential fatty acids, linoleic and arachidonic acid, in small amount, it is not absolutely necessary to include fat in the diet (81). However, a diet exceptionally high in protein and

carbohydrate may give rise to diarrhoea and dehydration in some infants. The high calorie density of fat appears to be a particular asset during the early months of life when energy requirement per unit of body weight is high. On the contrary, a diet extremely high in fat and low in carbohydrate content may give rise to ketosis (81). Nevertheless, little evidence is known to define the term "extremely high". Fomon 1974 found from his clinical experience that the infant diet often provided 30 to 55 percent of calories from fat.

The Thai Notification specifies the minimum and maximum fat per 100 kcal at 2 g and 4 g which are equivalent to 18 percent and 36 percent of calories from fat respectively. Codex Alimentarius recommends higher at 3.3 g and 6 g per 100 kcal, equivalent to 30 and 54 percent of calories from fat. The Thai Notification is considerably lower than Codex Alimentarius and Fomon's observation. The maximum fat per 100 kcal will have to be defined according to the Thai Notification at 4 g per 100 kcal but the minimum fat content can possibly be modified, provided it is not less than 2 g per 100 kcal. It is an area where experimentation can be designed to investigate the feasibility and benefit of increasing the fat lower limit. However, to use as a basis for further study, the Thai Notification was temporarily specified.

Therefore, the minimum and maximum contents of fat per 100 kcal were specified at 2 g and 4 g respectively.

Linoleic acid is known to be responsible for growth promotion and integrity of the skin (2, 81). When linoleic acid accounts for 1 percent of calorie intake

i.e. 111 mg per 100 kcal, health appears normal. In the Thai Notification, linoleic acid is specified at 200 mg per 100 kcal which is equivalent to 1.8 percent. It is notable that the linoleic acid recommended by Codex Alimentarius, 300 mg per 100 kcal, is higher than the infant appears to need. As what is required by the Thai Notification covers the infant nutritional requirement, it was used in this study.

Therefore, the minimum content of linoleic acid per 100 kcal was specified at 200 mg.

2.1.5 Vitamin A requirement

In the review by Rodriquez and Irwin 1972 , an infant receiving 25 to 35 I.U. of vitamin A per kg of body weight per day developed normal weight gain and normal dark adaptation. Using Thai reference body weight (139), the estimation of vitamin A daily requirements for infants at age of 3-5, 6-8 and 9-12 months were 199, 235 and 248 I.U. respectively. Fomon 1974 estimated the requirement of vitamin A to be 30 I.U. per kg of body weight per day. He estimated the daily requirement during the first year to be 250 I.U. and set the advisable intake at 500 I.U. per day. This is equivalent to 57 and 66 I.U. per 100 kcal based on recommended energy intake, Table 2.3. The Thai Notification and Codex Alimentarius specify the minimum vitamin A per 100 kcal at 250 I.U. which well covers the requirement of an infant during the first year as discussed earlier, so it was used in this study.

Therefore the minimum vitamin A per 100 kcal was specified at 250 I.U..

However, the maximum limit of vitamin A, which is

not specified by the Notification but is 750 I.U. by Codex Alimentarius, was brought into consideration because of the hazards of vitamin A over-dosage. Persson et al. 1965 reported five cases of vitamin A toxicity developing in infants less than 6 months of age. In one instance, 18,000 I.U. of vitamin A were taken daily for 3 months and in 3 instances, 22,500 I.U. of vitamin A daily for one to one and a half months. Therefore, a particular value must be set for the maximum limit for vitamin A. In this circumstance where no exact value is established for the ceiling intake of vitamin A, the value recommended by Codex Alimentarius was used.

Therefore, the maximum vitamin A per 100 kcal was specified at 750 I.U..

2.1.6 Vitamin D requirement

The requirement for vitamin D during infancy is known to be between 100 and 200 I.U. per day (49). Regular intake of the advisable amount of vitamin D is important because little vitamin D is stored in the body. Though the Thai Notification does not specify vitamin D, it was considered important to include it in this study as only 22 I.U. is provided from a litre of human milk. An intake of 400 I.U. which is twice as much of the requirement is suggested as the advisable daily intake (81). This is equivalent to 45 - 53 I.U. per 100 kcal based on recommended energy intakes, Table 2.3. Codex Alimentarius recommends vitamin D at 40 I.U. per 100 kcal, slightly less than given as advisable intake by Fomon 1974. Therefore, the advisable daily intake suggested by Fomon at 400 I.U. was specified for the minimum

vitamin D requirement.

Apart from the importance of trying to reach a certain level of vitamin D, it is also important that the intake of vitamin D must not be too high because of evidence of toxicity. It was found that vitamin D daily intakes of 3000 to 4000 I.U. resulted in cases of hypercalcemia (26). Fomon 1974 recommended to avoid intake greater than 1000 I.U. per day. Codex Alimentarius recommended the maximum at 100 I.U. per 100 kcal. As for vitamin A, recommended maximum limit by Codex Alimentarius was specified for vitamin D i.e. at 100 I.U. per 100 kcal.

Therefore, the minimum vitamin D was specified at 400 I.U. daily and maximum limit was at 100 I.U. per 100 kcal.

2.1.7 Vitamin E requirement

The amount required by infant is uncertain, though infants receiving low intake of vitamin E or failing to absorb vitamin E demonstrated the same symptoms to those seen in experimentally produced vitamin E deficiency in animals (81). It is found that the infant maintains satisfactorily a concentration of α -tocopherol in plasma with a diet with vitamin E to polyunsaturated acid ratio of 0.4 mg per g or 0.54 I.U. per g (151), taking 0.74 mg of natural form of D α -tocopheryl acetate equal to 1 I.U.. In human milk, the ratio of vitamin E to linoleic acid is in the range of 0.32 - 0.48 I.U. per g. The Thai Notification and Codex Alimentarius specify the requirement of vitamin E related to intake of linoleic acid at 1 I.U. per g which covers the ratio in the diet discussed earlier and twice as much as the ratio in human milk. This ratio

was considered adequate for the nutritional requirement of an infant and was used for this study.

Therefore, the minimum amount of vitamin E was specified related to intake of linoleic acid at 1 I.U. per g of linoleic acid.

2.1.8 Vitamin K requirement

The requirement of vitamin K is believed to be not greater than 5 mcg daily (48). Fomon 1974 suggested 15 mcg as advisable daily intake. Human milk generally provides less vitamin K than cows milk i.e. 2 mcg compared to 8.7 mcg per 100 kcal respectively. Vitamin K deficiency in new born period is more common in breast fed than in formula fed infant (232). The United State Committee on Nutrition (50) recommended strongly that new born infant should receive a parenteral dose of phytylmenaquinone soon after birth. Though the Thai Notification does not require vitamin K for infants older than 3 months, it was considered beneficial to include vitamin K in this study because breast feeding is common in Thailand. Furthermore, vitamin K deficiency has been reported when unsupplemented formula such as soy isolate formula has been used (174). Codex Alimentarius recommends vitamin K per 100 kcal at 4.0 mcg which is approximately 35 mcg per day. However, the daily requirement is suggested as 5 mcg per day and the advisable daily intake as 15 mcg, so the advisable daily intake was used.

Therefore, the minimum daily intake of vitamin K was specified at 15 mcg.

2.1.9 Ascorbic acid requirement

Requirement for the infant is estimated to be 10 mg

daily (109, 257). The Thai Notification specifies the requirement of ascorbic acid at 10 mg per 100 kcal, which in effect will provide approximately 7 to 9 times of the estimated daily requirement. Slightly less ascorbic acid is recommended by Codex Alimentarius i.e. 8 mg per 100 kcal. Though the Thai Notification is higher than the requirement, there is no evidence of toxicity of large doses in human (144, 222). As it is the minimum level that one has to comply with, the Thai Notification for ascorbic acid was used in this study.

Therefore, the minimum ascorbic acid per 100 kcal was specified at 10 mg.

2.1.10 Thiamine requirement

Requirement of thiamine is known to relate to the metabolism of carbohydrate. On the basis of human and animal studies, the requirement for thiamine is estimated at 0.02 mg per 100 kcal (81). Human milk can provide adequate thiamine, it contains 0.021 mg per 100 kcal. The Thai Notification specifies the minimum requirement of thiamine at 0.05 mg per 100 kcal which will provide approximately twice as much of the requirement per 100 kcal. Codex Alimentarius recommends slightly less at 0.04 mg per 100 kcal. The higher value in the Thai Notification is likely the consequence of vitamin deficiency in Thai infants as discussed earlier.

Therefore, the minimum thiamine per 100 kcal was specified at 0.05 mg.

2.1.11 Riboflavin requirement

The requirement of riboflavin is found to depend on

energy metabolism (29). Fomon 1974 (81) estimated the requirement from the riboflavin content in human milk (0.05 mg per 100 kcal) to be 0.34 mg per day during the first year of life and hence suggested the advisable intake to be 0.4 mg per day. The Thai Notification specifies minimum requirement of riboflavin at 0.07 mg per 100 kcal which will provide approximately 0.53 to 0.62 mg daily, based on recommended calorie intakes (Table 2.3). Codex Alimentarius recommends slightly less at 0.06 mg per 100 kcal. It is noticable that ascorbic acid, thiamine and riboflavin are specified by the Thai Notification at higher values than Codex Alimentarius and higher than the known advisable intakes. This may be the consequence of the vitamin deficiencies evident during infancy in Thailand (Table 1.4). As riboflavin specified by the Thai Notification well covers the nutritional requirement, it was also specified for this study.

Therefore, the minimum riboflavin per 100 kcal was specified at 0.07 mg.

2.1.12 Niacin, Vitamin B6 and Vitamin B12

These vitamins are not specified by the Thai Notification for infants older than 3 months. Because of their important role in infant nutrition, they are all considered in this study.

Niacin. Niacin requirement is related to energy metabolism as is thiamine and riboflavin. Under suitable conditions, niacin can be synthesized from tryptophan in mammalian tissues (39). Approximately 60 mg of tryptophan is required for the synthesis of 1 mg of niacin. However, the synthesis of niacin from tryptophan in this study was ignored because

tryptophan was defined related to protein quality as already discussed in 2.1.3. The minimum amount of niacin that will prevent pellagra in the adult is reported at 0.44 mg per 100 kcal (39). Fomon 1974 estimated the niacin requirement for infants to be 4.1 mg per day at age of 6 months and hence listed the advisable intake of niacin from birth to 3 years at 5 mg per day. Based on recommended energy intakes (Table 2.3) this advisable intake of niacin expressed per 100 kcal is at 0.57 mg and 0.66 mg for 3-6 months and 6-12 months respectively. Codex Alimentarius recommended at 0.25 mg per 100 kcal, less than advisable intake. As discussed earlier in 2.1, when the advisable intake has been established, it was used in this study.

Therefore, the minimum daily intake of niacin was specified at 5 mg per day.

Vitamin B6 requirement. The requirement of vitamin B6 is known to relate more to protein content than to calorie content of the diet. Fomon 1974 presumed that the concentration of vitamin B6 in mature human milk was adequate for infants during the first year of life and suggested an intake of 9 mcg per g of protein as an approximation of the requirement. He suggested 0.4 mg as advisable daily intake. Using this daily intake with the recommended energy intakes (Table 2.3), the advisable vitamin B6 per 100 kcal for 3-6 and 6-12 months were 0.045mg and 0.053 mg respectively. Codex Alimentarius recommends vitamin B6 at 0.035 mg per 100 kcal. Therefore, the daily advisable intake was used in this study.

The minimum daily intake of vitamin B6 was specified at 0.4 mg.

Vitamin B12 requirement. Despite being known to be involved in methylation of choline, serine, methionine and in the pyrimidine and purine metabolism, there is little evidence available for the infant requirement for vitamin B12. The breast fed infant is estimated to have approximately 0.3 mcg of vitamin B12 daily (125). The daily intake of vitamin B12 is recommended by the Joint FAO/WHO Expert Group (125) to be 0.3 mcg for infant during the first year of life. Based on the recommended energy intakes (Table 2.3), the required intake per 100 kcal is at 0.034 mcg and 0.039 mcg respectively. Though Codex Alimentarius recommends at a higher value i.e. at 0.15 mcg per 100 kcal, the requirement of vitamin B12 is expected to be less than 0.3 mcg daily (81). As for niacin and vitamin B6, the estimated daily requirement was used in this study.

Therefore, the minimum daily intake of vitamin B12 was specified at 0.3 mcg.

2.1.13 Pantothenic acid, folic acid, choline and biotin requirements

There is less information for the specific needs during infancy for these vitamins. Although pantothenic acid and biotin are important as catalysts, they are not known to be essential for infants (39). In fact, these 4 vitamins are not specified by the Thai Notification for infants older than 3 months. As it is uncertain that the infant does not require these vitamins, it was decided to include them in this study.

The infant requirement for folic acid has been estimated at 20 to 50 mcg per day (231), and 50 mcg per day

is equivalent to 5.7 to 6.6 mcg per 100 kcal respectively based on the recommended energy intakes (Table 2.3). Codex Alimentarius recommends pantothenic acid, choline, biotin and folic acid at 300 mcg, 7 mg, 1.5 mcg and 4 mcg per 100 kcal respectively. It is worth noting that, the composition of human milk expressed per 100 kcal for pantothenic acid is 245.3 mcg (81), 12.7 mg for choline (39), 0.56 mcg for biotin (39) and 6.93 mcg for folic acid respectively (81). The recommended standard by Codex Alimentarius compares very well with human milk in the composition of pantothenic acid, but slightly higher in biotin and considerably less in choline and folic acid. As discussed earlier in 2.1, when the exact requirement of infant has not been established, the recommended value by Codex Alimentarius was used. Therefore, the pantothenic acid, choline and biotin were specified as recommended by Codex Alimentarius; Sullivan's (231) suggestion at 50 mcg per day was used for folic acid.

Therefore, the minimum pantothenic acid, choline and biotin per 100 kcal were specified at 300 mcg, 7 mg and 1.5 mcg and folic acid was specified as minimum daily requirement at 50 mcg (0.05 mg).

2.1.14 Sodium, chloride, potassium, calcium, phosphorus and magnesium requirements

Fomon 1974 estimated the requirement for these elements and listed the advisable intakes as shown in Table 2.6.

Table 2.6 Estimated Requirements and Advisable Intakes of Major Minerals at the Age of 4 to 12 Months

Minerals		Estimated requirement	Advisable intake
Sodium	mg	48.3	138.0
Chloride	mg	74.6	213.0
Potassium	mg	78.0	234.0
Calcium	mg	289.0	350.0
Phosphorus	mg	110.0	130.0
Magnesium	mg	13.5	20.0

Sodium, Chloride, Potassium requirements. As shown in Table 2.6, Fomon 1974 suggested the advisable daily intake for sodium, chloride and potassium to be 138, 213 and 234 mg for infants from 4 to 12 months respectively. There has been an incidence of development of hypertension caused by high intakes of sodium chloride (105). The toxic effect of chloride and potassium have been well discussed in various literature (39, 193, 56). Therefore, not only the minimum intake but the maximum intake should be specified.

The Thai Notification specifies only the maximum limits per 100 kcal for sodium and chloride at 80 mg and 150 mg respectively. Though the minimum contents of sodium, chloride and potassium are not specified, they were considered necessary because of their significance as discussed earlier. Based on the recommended energy intakes (Table 2.3), the advisable intakes by Fomon 1974 per 100 kcal of sodium is at 16 to 18 mg, chloride at 24 to 28 and potassium at 27 to 31 mg respectively. It is noticeable

that Codex Alimentarius recommends for sodium, chloride and potassium higher than the advisable intake, i.e. at 20, 55 and 80 mg per 100 kcal respectively.

For defining the minimum contents of these 3 elements, the advisable daily intakes were used in this study.

Therefore, the minimum daily requirements were specified for sodium at 138 mg, chloride at 213 mg and potassium at 234 mg respectively.

For the maximum limits, the Thai Notification specifies only sodium and chloride as mentioned earlier, the Codex Alimentarius recommends the maximum limits per 100 kcal for all 3 elements at 60 mg for sodium, 150 mg for chloride and 200 mg for potassium respectively. It is worth noting that maximum limit of sodium is less than that specified by the Thai Notification. According to the discussion in 2.1, the maximum limits of sodium and chloride by Thai Notification and Maximum limit of potassium by Codex Alimentarius were used.

However, the excess of these electrolytes are excreted by the kidney and is referred to as the renal solute load. The importance in infant feeding is given by Fomon 1974. Renal solute load is derived from the amount of protein, sodium, potassium and chloride in the diet. It is known that each g of protein yields 4 mosmol and each meq of sodium, potassium and chloride contributes 1 mosmol (81). Using Fomon's composition of human and cow's milk, the solute per 100 kcal from human milk was 10 mosmol and 34 mosmol for cow's milk. The renal solute load of the specified levels of sodium, chloride and potassium was 32

mosmol per 100 kcal. It is noticeable that this value was higher than human milk but less than cow's milk.

The next consideration was to evaluate the repercussion of having protein, sodium, potassium and chloride at these maximum limits on the ability of infants to concentrate these solutes in urine. The amount of liquid taken by infants in terms of milk or liquid food less the losses through skin and faeces is the liquid left for renal excretion. There is variation in the ability of normal infants to concentrate urine above a certain value. Some normal infants are not able to concentrate urine above 600 or 700 mosmol per litre (81).

With the assumption of losses through skin and faeces of 600 ml and calorie concentration in food of 67 kcal per 100 ml, the concentration of solute to be excreted in urine based on recommended energy intakes in Table 2.3 can be estimated. It was found to be in the range of 396 to 455 mosmol per litre as shown in Table 2.7 respectively. As these values were less than 600 mosmol per litre, it was considered safe to set the maximum limits of these elements, i.e. for sodium and chloride, as by the Thai Notification and potassium as by the Codex Alimentarius.

Therefore, the maximum limits for these elements per 100 kcal were specified at 80 mg for sodium, 150 mg for chloride and 200 mg for potassium.

Table 2.7 Renal Solutes Load of Proposed Specification.

Recommended energy intakes	Liquid intakes based on 67 kcal per 100 ml	Liquid less the loss of 600 ml	Total mosmol based on 32 mosmol per 100 kcal	Estimated renal solutes load, mosmol per litre
760	1134	534	243	455
880	1313	713	282	396

Calcium, Phosphorus and Magnesium requirements. As suggested by Fomon 1974 in Table 2.6, the daily advisable intakes for calcium, phosphorus and magnesium are 350, 130 and 20 mg respectively.

The Thai Notification specifies the minimum requirement per 100 kcal for only calcium at 50 mg. Based on recommended energy intakes (Table 2.3), the daily intake of calcium is in the range of 380 to 440 mg, which meets the advisable intake by Fomon 1974. Therefore the Thai specification at 50 mg per 100 kcal was used. Though phosphorus and magnesium are not specified by the Thai Notification, they are known as important minerals (39, 56) and were considered in this study. As discussed in 2.1, advisable intakes for phosphorus and magnesium by Fomon 1974 were specified as the minimum requirements. Based on the recommended energy intakes (Table 2.3), the advisable intakes of phosphorus and magnesium per 100 kcal were at 15 to 17 mg and 2.3 to 2.6 mg. It is noticeable that Codex Alimentarius recommends these minerals higher than the advisable intakes. As the advisable intakes of these elements are known, they were used in this study.

Therefore, the minimum calcium per 100 kcal was

specified at 50 mg. For phosphorus and magnesium, the minimum daily intakes were specified at 130 mg and 20 mg.

However, a high intake of calcium together with a high intake of vitamin D can lead to infant disorder, hypercalcemia (221). The British paediatric committee (26) on hypercalcemia, calculated the diet of the infant showing disorder as providing approximately 400 I.U. of vitamin D and 1200 mg of calcium. Because of this evidence, the maximum limit of calcium was included in this study. Since neither the Thai Notification nor the Codex Alimentarius clearly specify the acceptable upper limit for calcium, the upper level normally obtained from human milk was used.

To set the maximum limit based on human milk composition, the energy intake in excess of the energy requirement of infant age one year must be chosen as a yardstick. The minimum energy requirement was increased by 50 percent i.e. from 880 kcal to 1400 kcal and the calcium content from 1400 kcal of human milk was used as calcium upper limit. Fomon 1974 observed the 90th percentile of normal American male infant aged 12 - 15 months to be 1430 kcal. Therefore, taking an energy intake of 1400 kcal as a criterion to derive the maximum limit of nutrient should be quite generous for the Thai infant. On this basis the amount of calcium in 1400 kcal of human milk is 635 mg (81) so 630 mg was used as daily maximum limit for calcium. It is notable that this calcium maximum limit is well below the calcium content found in the diet of disordered infant (81).

Therefore, the maximum daily intake of calcium was specified at 630 mg.

Regarding the calcium and phosphorus ratio, it is

specified by both Thai Notification and Codex Alimentarius to be at the minimum of 1.2 and maximum of 2.0. Though calcium and phosphorus ratio was once believed to be important and that higher intake of phosphorus depressed the absorption of calcium, subsequent experiments on the human have shown that total phosphate intake has little or no influence on calcium absorption (56, 81). For infants, the ratio of calcium to phosphorus in human milk (approximately 2.0 - 2.4) was believed to be effective in promoting the absorption of calcium; but Widdowson et al. 1963 demonstrated that addition of moderate amounts of phosphate to the diet of 5 to 8 day old breast fed infants improved the absorption of calcium and magnesium. However, in further experiments with artificial milk where calcium and phosphorus ratio was considerably lower than breast milk, i.e. 1.31 to 2.0, Widdowson 1965 found that calcium was less absorbed by infants aged 5 to 7 days and absorption was improved when the infant became 4 to 6 weeks old. She found with infants 4 to 6 weeks old that the ratio of calcium to phosphorus at 1.37 did not impair calcium absorption compared to human milk; while at ratio 1.31, the absorption of calcium was found lower than the estimated need for tissue increment (81). However, the absorption of calcium is not just simply related to phosphorus, it is also found to be influenced by the absorption of vitamin D and fat (254). Being aware of the problem, it was felt that the minimum ratio of calcium to phosphorus must be adjusted at least to the ratio of 1.37 as discussed earlier, which is near enough to 1.4. The ratio at 2.0 is not found to present any problem in calcium absorption.

Therefore, the minimum ratio of calcium phosphorus in this study was specified at 1.4 to 1.0 and the maximum at 2.0 to 1.0.

2.1.15 Iron, iodine, manganese, copper and zinc requirements

Iron. It was estimated by Fomon 1974 that the net increment of body content by iron, during the first year of greatest need infant, is 214 mg. The extent of absorption is found to vary widely. Though Schulz and Smith 1958 suggested that more than 10 percent of dietary iron was absorbed by most infants, Fomon 1974 based his estimated requirement for iron on 10 percent absorption. He recommended that a normal infant should receive a cumulative intake of iron at least 2140 mg during the first year or 7 mg per day. The Thai Notification specifies iron at 1 mg per 100 kcal. Codex Alimentarius specifies iron at two levels - at 0.15 mg per 100 kcal and also 1 mg per 100 kcal, with the condition that product must be specified as infant formula with iron. It is worth noting that, addition of iron to food has been observed to remove the ability of human milk to inhibit the growth of Escherichia coli in the intestine (31, 53). Hence, for the young child during the first 3 months where there is an adequate iron storage, having iron added to food can be advantageous or disadvantageous depending on the hygiene of the feeding environment. However, with infants from 4 months to 12 months, it is necessary to provide adequate iron from food. As a minimum of 1 mg of iron per 100 kcal is required by the Thai Notification and it covers the estimated iron requirement (81) based on the recommended calorie intakes (Table 2.3), it was used in this study.

Therefore, the minimum iron was specified per 100 kcal at 1 mg.

Iodine. Though iodine is an essential component of thyroid hormone, the difficulty in the analytical method and the wide variability in concentration in foodstuff make it very difficult to establish the requirement (81). As an example, iodine in human milk is given by Fomon 1974 at 30 mcg per litre and Salter 1950 reported it to be in the range of 40 to 80 mcg per litre. However the American Food and Nutrition Board (181) recommended 5 mcg per 100 kcal for an infant aged up to 6 months. The Thai Notification as well as Codex Alimentarius specify iodine per 100 kcal at 5 mcg, this value was used in this study.

Therefore, the minimum iodine per 100 kcal was specified at 5 mcg.

Manganese. Though manganese deficiency has been demonstrated in experimental animals, the deficiency syndromes in human beings have not been identified and therefore it is impossible to estimate the requirement (81). Codex Alimentarius recommends manganese at 5 mcg per 100 kcal. Nevertheless, the intake of a normal one year old child has been reported to be approximately 0.8 mg per day (216) or 91 to 105 mcg per 100 kcal based on the recommended energy intakes (Table 2.3). Human milk contains 7 - 15 mcg of manganese per litre. Taking 15 mcg of manganese and 750 kcal per litre of human milk, the manganese per 100 kcal is approximately 2.0 mcg. It is noticeable that observed intake of manganese is considerably higher than what is available in human milk and as recommended by Codex Alimentarius. Cuthbertson 1973 commented that the addition of manganese

in any form to the infant diet is unwise until positive identifiable benefits can be shown. Nevertheless, little manganese is found in the body of new born infant (255) and it is known that manganese is important to human nutrition (81). As discussed in 2.1, the recommended value by Codex Alimentarius was used in this study.

Therefore, the minimum manganese per 100 kcal is specified at 5 mcg.

Copper. Copper is known to have nutritional significance from the fact that it is a component in the structure of many important enzymes (239). Nevertheless, the requirement for copper during infancy has not been determined (81). Price et al. 1970 estimated the copper requirement of 7 to 9 year old girl to be about 60 mcg per kg per day and Fomon 1974 accepted this value as the requirement for infants and preschool children, which is equivalent to 52 to 57 mcg per 100 kcal. Human milk and cow's milk provide approximately 53 to 45 mcg per 100 kcal respectively. It is worth noting that suggestion by Fomon 1974 and Codex Alimentarius are approximately the same as provided by human milk. As discussed in 2.1, the recommended value by Codex Alimentarius was used in this study.

Therefore, the minimum copper per 100 kcal was specified at 60 mcg.

Though a certain minimum content must be suggested for infant food, it was also felt that a maximum limit must also be defined due to its toxic effect. As discussed in 2.1, when the exact information is not available, the human milk composition was used. Using the same criteria as for calcium in 2.1.14, the amount of copper in 1400 kcal was

742 mcg and 740 mcg was used as a maximum limit.

Therefore, the maximum daily intake of copper was specified at 740 mcg.

Zinc. Though it is an essential nutrient (39, 56), there is no satisfactory method for estimating the requirement during infancy (81). The requirement of zinc for growth is calculated to be 0.32 mg daily by Fomon 1974, but the retention during the first 4 months is found to be less than 0.3 mg daily. However, zinc balance study with older infants has not been reported. Human milk contains 3 to 5 mg of zinc per litre. Taking 5 mg of zinc and 750 kcal per litre of human milk, the zinc per 100 kcal is approximately 0.66 mg. Zinc is not specified by the Thai Notification but is recommended by Codex Alimentarius at 0.5 mg per 100 kcal. As discussed in 2.1, the zinc recommended by Codex Alimentarius was used in this study.

The maximum limit had to be considered for the same reason as for copper. Using the same criteria as for copper, the value of zinc derived from 1400 kcal of human milk is 9.2 mg and 9.0 mg was used in this study.

Therefore, the minimum zinc per 100 kcal was specified at 0.5 mg and the maximum daily intake was specified at 9.0 mg.

2.1.16 Other requirements by the Thai Notification

Apart from the nutrients required by infants, there are 2 other specifications set by the Thai Notification.

Energy related to weight of infant food. It is defined that the energy per 100 g of dry weight of infant food must not be less than 350 kcal, and if food is liquid for drinking, the energy must not be less than 65 kcal and not more than

70 kcal per 100 g of liquid food. Therefore, in designing an infant food, the energy per unit weight must be taken into account. In food composition table, the moisture content is given and hence the energy per unit of dry weight could be easily obtained. For inclusion in the linear programming model, it is preferable to base energy on dry solids. According to Table 2.3, the amount of dry weight required to give 760 and 330 kcal are 217 g and 251 g respectively. The question was whether the infants aged 3 - 5 and 6 - 12 months are able to take these amounts of dry weight. Observation by Fomon 1974 found the median intake of American infants to be 189 ml per kg per day. No such information is available for Thai infant. In application of this observation to the weight of Thai infant, the volume expected for infant 3 - 5 and 6 - 12 months are 1240 ml and 1570 ml respectively. Therefore, the approximate ratio of dry food and water would be 1 to 5.7 for infants 3 - 5 months and 1 to 6.32 for 6 - 12 months respectively. Anderson and Fomon 1971 reported the average ratio of dry cereal and diluent to be 1 to 7.1 for infants less than 6 months and 1 to 5.5 for infants 5 to 10 months. Seemingly, the estimated dilution to use with the energy of 350 kcal from 100 g of dry weight is in the range reported by Anderson and Fomon 1971.

Therefore, the minimum energy per 100 g dry weight was specified at 350 kcal.

Sugar related to carbohydrate. It is also defined that sugar content must not be less than 20 percent of all carbohydrate. There is no information on how much sugar should be taken by infants. It is known that infants

usually obtain 35 to 55 percent of calorie from carbohydrate (81). In normal diet of adult in United Kingdom, it is found that 350 g of carbohydrate is taken daily of which 60 percent is starch, 30 percent as sucrose and 10 percent as lactose (101). In our specification, taking protein, fat and carbohydrate as major contributors to energy, the likelihood of energy derived from carbohydrate is 54 to 71 percent. Therefore, on the basis of 20 percent of carbohydrate as sugar, the percentage of energy from sugar is 9.2 to 14.3 percent. How the infant would manage this amount of sugar is not known exactly. Most of the information available on sugar tends to concentrate on lactose intolerance (134, 135). The available data revealed the normal sucrose metabolism of Thai children aged 1 - 24 months, where 2 g of sucrose and lactose per kg of body were given (135).

Sucrose and dextrose have been reported to be added in commercial infant foods such as fruit juices, creamed vegetable and dessert. A consumer report on baby food, New Zealand (224), revealed percentage of sucrose in two instant baby foods at 21.3 and 28.3 percent. This is equivalent to 24.1 and 27.3 percent of energy derived from sucrose and approximately 30 to 32 percent of carbohydrate are in the form of sucrose. Therefore, it seems that the specification by the Thai Notification is in the practical range.

As this sugar/carbohydrate relationship required by the Thai Notification is in the practical range and there is no evidence against this specified value, it was used in this study.

Therefore, the minimum sucrose content was specified at 20 percent of all carbohydrate.

It is worth noting that lactose intolerance has been reported in adults in Thailand (136). However, it has been found that during infancy there is adequate enzymes to digest lactose (135). Keusch et al. 1969^a found that though the abnormality did not manifest itself during infancy, by the age of 2 years all studied children revealed lactose malabsorption or lactose deficiency. As this study deals with infants from 4 to 12 months, it was considered not necessary to specify for lactose.

2.1.17 Fibre allowance

Introduction of solid food to infant is in a trend towards an early age as discussed in 1.6. However, the solid foods have been suggested to be strained up to about 4 to 5 months (39, 81). Fibre had never been recognized as an important nutrient until the last 20 years. Suggestion for the fibre intake was by Robinson in 1956 (207), with an intake of 90 - 100 mg of cellulose per kg of body weight. The significance of fibre is known in the laxative quality and the biochemical effect on the absorption and reabsorption of cholesterol and bile acids (215). How important is this biochemical effect to the infant cannot be discussed due to lack of information. The common practice is that most food given to infant is either strained, mashed or low in fibre. For instance, fibre found in commercial strained food such as strained vegetable is 1.55 g per 100 kcal and strained soup dinner at 0.34 g per 100 kcal (81). Fibre found in instant baby food is 6.7 percent by weight or 1.95 g per 100 kcal (224).

In the design for infant food, one must be aware that in the selection of raw material, the food will not come up with a large amount of fibre. Nevertheless, there is not adequate evidence to define for maximum limit of fibre. It is an aspect which will have to be considered during the design.

2.1.18 The specifications for studied nutrients

The specifications are summarized in Table 2.8.

Table 2.8 Specification Set for Infant Food

Nutrients	Expressed per 100 kcal		Expressed per day		Other expressions
	Minimum value	Maximum value	Minimum value	Maximum value	
Energy kcal					760 daily for 3-5 months and 880 for 6-12 months
Protein g	1.8	3.5			
Essential amino acids					Pattern of essential amino acids must not be less than 70 percent of egg protein
Fat g	2.0	4.0			
Linoleic acid mg	200.0				
Vitamin A I.U.	250.0	750.0			
Vitamin D I.U.		100.0	400.0		
Vitamin E I.U.					1 I.U. per g of linoleic acid
Vitamin K mcg			15.0		
Ascorbic acid mg	10.0				

Table 2.8 cont'd

Nutrients	Expressed per 100 kcal		Expressed per day		Other expressions
	Minimum	Maximum	Minimum	Maximum	
	value	value	value	value	
Thiamine mg	0.05				
Riboflavin mg	0.07				
Niacin mg			5.0		
Vitamin B6 mg			0.4		
Vitamin B12 mcg			0.3		
Pantothenic acid mcg	300.0				
Folic acid mg			0.05		
Choline mg	7.0				
Biotin mcg	1.5				
Sodium mg		80.0	138.0		
Chloride mg		150.0	213.0		
Potassium mg		200.0	234.0		
Calcium mg	50.0			630	
Phosphorus mg			130.0		
Calcium phosphorus ratio					1.4 as minimum and 2.0 as maximum
Magnesium mg			20		
Iron mg	1.0				
Iodine mcg	5.0				
Manganese mcg	5.0				
Copper mcg	60			740	
Zinc mg	0.5			9.0	
Calorie per g of dry weight					minimum at 3.5
Sucrose as percentage of carbohydrate					minimum at 20 percent

2.2 Qualitative characteristics of the infant food

It is important that the infant food does not only provide the required nutrients for the infant but also provides the quality preferred by the mother and infant. Though the infant is the ultimate consumer, the mother or caretaker is the person who will choose, buy and feed the food to an infant. Usually where the infant is looked after by a helper, servant or caretaker, the decision on food is under the mother's supervision. Therefore, the opinions and attitude of the mother towards infant food were investigated.

The attitudes of the Thai mother considered important in the designing of infant foods were related to types of Thai food raw materials acceptable in infant feeding, desirable characteristics of infant foods, methods of preparation and handling of infant foods, existing marketing channels and acceptable prices of infant food. An investigation was carried out together with the investigation on feeding patterns, the survey form is shown in Appendix 3. The discussion on the results of the investigation is given below.

2.2.1 Type of Thai food raw materials acceptable in infant feeding

The purpose was to find the acceptable types of food materials for use in the preparation of foods for infants. As discussed earlier in 1.4.2 and shown in Table 1.10, the types of food materials used by the mothers are rice and glutinous rice; egg, meat, fish, vegetable and fruit. For fish and vegetables, it was not possible to obtain the specific varieties because they were referred

to by mothers in general as fish and vegetables rather than by giving the specific names. Fruits also are used to a considerable extent as shown in Table 2.9 , 118 out of 200 mothers gave fruits to their infants. The most commonly used fruit was banana, and to a lesser extent orange. Other fruits used were pineapple and watermelon.

Table 2.9 Number and Percentage of Different Types of Fruits given to Infants in 4 Regions

Region	Number of mothers giving different types of fruit				Number of mothers giving fruits
	Banana	Orange	Both banana and orange	Other fruits	
Central	14	11	9	1	35
Northeast	32	4	1	3	40
North	17	10	5	3	35
South	5	2	1	-	8
Total	68	27	16	7	118
Percentage	57.6	22.9	13.6	5.9	100.0

Therefore, it can be concluded that there is no restriction in using various types of foods. Rice and glutinous rice are used as basic food materials. Meat, egg and fish are used together with rice and so are the vegetables, but to a lesser extent. Fruits are commonly used especially banana and orange.

2.2.2 Desirable characteristics of infant food by Thai mothers

Having known that different types of food could be used for infant, the further consideration was to find the preferable forms and the perception towards taste, colour

and consistency of infant food. The preferable forms were investigated in order that the most acceptable process could be designed. Only dehydration, canning and bottling as methods of processing were considered in this study. Freezing was not considered for two reasons, firstly frozen storage is not widespread in Thailand and secondly infant food has seldom been processed as frozen food. As the general feeding practice is to give mashed rice and banana which is a little sweet or rice with vegetable and meat soup which is a little salty, the perception of taste was asked related to sweetness and saltiness. The colour was asked related to colour of foods generally used such as creamy colour, light brown or light greenish. The consistency of the designed infant food would be governed to an extent by the specification of calorie to dry weight so that the dry infant food once mixed with water was not too thick.

However, the general feeding practice ranges from mashed rice with banana or egg which is a thick paste, rice with soup which can be regarded as medium and liquid milk which can be regarded as thin. Therefore, the consistency was asked whether the mothers preferred thick, medium and thin consistency. It must be noted that these words are merely an English translation, the interview was in Thai in which this required meaning can be expressed without difficulty.

As shown in Table 2.10 most mothers preferred the dry form, next was a ready to use mix in which canning was preferred slightly higher than bottling. It is suspected that this is caused by the widespread use of canned products in Thailand. Obviously, dry infant food was found to be the most acceptable form.

Table 2.10 Number and Percentage of Mothers Preferring Different Forms of Infant Food

Region	Number of mothers			
	Dry powder	Ready to use bottle	Ready to use can	Do not know
Central	33	16	5	8
Northeast	29	7	24	7
North	23	9	12	1
South	16	4	2	4
Total number	101	36	43	20
Percentage	50.5	18.0	21.5	10.0

In the perception of mother towards infant food, the taste, colour and consistency of infant foods were investigated. Table 2.11 shows the perception of mothers towards different tastes. By far, a slightly sweet flavour was most preferred and next was a bland flavour. It is noticeable that mothers in the Central and in the South preferred slightly salty flavour. This is due to the common practice of giving meat and vegetable soup stock to infant which is slightly salty. Comments for other flavours were mild flavour, salty and sour and nutty flavour.

Table 2.11 Number and Percentage of Mothers Preferring Different Flavours

Region	Number of mothers					
	Bland	Little sweet	Soup flavour	Little salty	Others	Do not know
Central	11	24	4	13	10	-
Northeast	18	35	4	1	8	1
North	5	26	9	-	5	-
South	9	10	-	4	3	-
Total	43	95	17	18	26	1
Percentage	21.5	47.5	8.5	9.0	13.0	0.5

For the acceptable colour, Table 2.12 shows the range of acceptable colours. Obviously, light creamy colour is correlated with infant food by the majority of mothers.

Table 2.12 Number and Percentage of Mothers Preferring Different Colours

Region	Number of Mothers				
	Light cream	Any colour	Light brown	Others	Do not know
Central	33	11	7	7	4
Northeast	38	10	8	9	2
North	34	1	1	9	-
South	22	1	1	1	1
Total	127	23	17	26	7
Percentage	63.5	11.5	8.5	13.0	3.5

For the acceptable consistency, Table 2.13 shows that the acceptable consistency of infant food before feeding is in the range of thick to medium consistency.

Table 2.13 Number and Percentage of Mothers Preferring Different Consistencies

Region	Thick	Medium	Thin	Do not know
Central	26	18	15	3
Northeast	33	29	1	4
North	19	23	3	-
South	8	16	1	1
Total	86	86	20	8
Percentage	43.0	43.0	10.0	4.0

As far as the acceptable characteristics of the finished infant food product are concerned, it can be

concluded that Thai mothers prefer a dry product with slightly sweet flavour, creamy colour and medium to thick consistency before feeding.

2.2.3 Method of preparation and handling of infant food

The purposes were to investigate the mothers' need of a processed infant food and the methods that the processed infant food would be handled when it is available.

For the preparation of infant food, Table 2.14 shows that 45 percent of the mothers prepared food especially for their infant and 40 percent divided it from the family food. Some 15 percent did not answer because their infants were younger than 3 months and solid foods were not given. For the quantity prepared, 29 percent of mothers prepared for one feeding at the time, while 15.5 percent prepared more than one feeding and 55.5 percent did not answer. Seemingly, mothers who did not answer either fed their infants from the food prepared for the whole family or their infants were too young to introduce solid foods.

Table 2.14 Number and Percentage of Mothers With Different Methods of Preparing Food for Infant

Region	Number of mothers					
	Preparing food Specially	Taken from family food	Do not answer	Quantity prepared For one feeding	More than one feeding	Do not answer
Central	30	16	16	18	11	33
Northeast	20	40	7	13	7	47
North	26	15	4	17	9	19
South	14	9	3	10	4	12
Total	90	80	30	58	31	111
Percentage	45.0	40.0	15.0	29.0	15.5	55.5

In discussing whether it is convenient for mothers to prepare food for infant, the mothers' occupation was observed. Table 2.15 shows that as high as 72 percent were working mothers, either farming or office work. Statistically 83 percent of the population is reported to work in farming (183).

Table 2.15 Number and Percentage Distribution of Mothers' Occupation

Region	Working mothers			
	Housewife	Farming	Government office	Office and factory work
Central	24	-	20	18
Northeast	14	27	17	9
North	3	1	32	9
South	15	-	1	10
Total	56	28	70	46
Percentage	28.0	14.0	35.0	23.0

In this survey, 14 percent of mothers were found to engage in farming. This may be the consequence of the selection of mothers from the urban area more than the rural area. Also, statistical figures included men and women whereas in this survey only women with young children were selected. With this high percentage of working mothers, it was expected that processed infant food would assist in the home preparation for infant food.

For the opinions towards having to prepare food for infant, Table 2.16 shows that 45 percent of mothers found it convenient, 14 percent found it inconvenient and 38.5 percent did not answer the question. The majority of the

mothers not giving an answer were in the Northeast. It is suspected to be the consequence of not having to prepare food for their infant specially, most of the mothers fed their infants with human milk and glutinous rice. A small number of mothers in other regions did not answer this question, they had infants younger than 3 months old. Despite the high number of working mothers, most of them did not find it inconvenient to prepare food for their infants.

Table 2.16 Number and Percentage of Mothers with Different Opinions in Preparing Infant Food

Region	Number of mothers			
	Convenient	Inconvenient	Not sure	Did not know
Central	47	5	3	7
Northeast	2	7	1	57
North	29	15	-	1
South	12	1	1	12
Total	90	28	5	77
Percentage	45.0	14.0	2.5	38.5

In the investigation for the methods by which the processed infant food will be handled, the available facilities in the home were observed. It is common in Thailand that each household in the rural area has an open charcoal stove and in the urban area has either charcoal stove or gas stove. In cases where a charcoal stove is used, boiled hot water is kept in a thermos to save time in getting the charcoal stove going. In realizing that if a dry infant food is used, it may need dissolving in hot water; and if canned or bottled infant food, a refrigerator may be needed because of the higher susceptibility to

microbial spoilage of the contents of an opened can in the tropical environment. Therefore, the investigation was also made on the availability of refrigerators and thermos flasks in the houses.

Table 2.17 Number and Percentage of Facilities

Region	Having both Refrigerator and thermos	Having only thermos	Not having either
Central	33 53.22%	28 45.16%	1 1.61%
Northeast	13 19.40%	41 61.19%	13 19.40%
North	29 64.44%	13 28.88%	3 6.66%
South	3 11.53%	22 84.62%	1 3.85%
Total	78	104	18
Percentage	39.0	52.0	9.0

As shown in Table 2.17, most households possessed thermos flasks i.e. 91 percent whereas only 39 percent possessed refrigerator as well and 9 percent did not possess either of these items. In the circumstances where hot water can be easily obtained, dry infant food will be convenient to handle by the majority of the mothers. Though bottled or canned product is convenient to use, a higher degree of sanitation during handling is required in comparison to dry form. The product can be designed to be used for one feeding but some mothers may not use the whole container at the time. Once the container is opened, it will be difficult for the 61 percent of mothers without

refrigerators to keep it away from the spoilage in the average temperature of 28°C (184). Though refrigerator does not prevent microbiological spoilage, it makes it possible to keep the opened container for a few days.

Because of the hygiene and convenience during handling, dry infant food will fit in with the widespread use of thermos flasks in the home better than the canned or bottled infant food.

2.2.4 The existing marketing channels

The dairy based infant foods, the nearest product to the processed infant food, was investigated for the market distribution. The purpose was to determine the marketing channels which would have to be used for the processed infant food. As the normal marketing channels in Thailand may be different to other countries, a brief description is given. It is common in Thailand for a district, either in the rural or urban areas to have a so called fresh market, where fresh commodities as well as processed commodities are sold. Apart from this type of market, there is a grocery type shop scattered around the country. In the big city, there are supermarkets as well as fresh markets and grocery shops. These are the normal channels where food commodities are sold.

It was found as shown in Table 2.18 that the main distributing channel for milk based infant food was through the fresh market i.e. 34 percent and 29 percent through the grocery, the rest were through health-centre and supermarket.

Table 2.18 Number and Percentage of Mothers with Different Market Channels for Milk-based Infant Food Distribution

Region	Market	Number of mothers				
		Grocery	Super-market	Health centre and hospital	Others	Do not answer
Central	6	21	9	19	1	6
Northeast	29	15	3	6	2	12
North	12	18	7	3	1	4
South	21	1	-	3	-	1
Total	68	55	19	31	4	23
Percentage	34.0	27.5	9.5	15.5	2.0	11.5

According to the existing channels, the processed infant food is expected to be sold through fresh market and grocery shop. It was also found that 15.5 percent was sold through the health centre and hospital. Difficulty is not expected in the distribution of processed infant food along the channels of dairy based infant food. However, the exact marketing distribution can be further investigated once the product is launched in the market.

2.2.5 Acceptable prices for infant food in relation to incomes

The purpose was to find the most acceptable price and the effect of different incomes upon the acceptable price. First, the incomes of mothers in different regions were considered. Table 2.19 shows the highest number of mothers having in the Central an income of 2000 baht per month, while in the Northeast having 500 baht and in the

North and South having 2000 baht and 1000 baht respectively. On the whole, the highest number was in the income group of 2000 baht. The average income of interviewed mothers calculated from Table 2.19 was 1892 baht or approximately 1900 baht.

Table 2.19 The Distribution of Mothers Incomes by Different Regions, Comparing to the National Distribution

Regions	Number of mothers						
	Monthly income, baht						
	500	1000	2000	3000	4000	5000	>5000
Central	3	8	28	11	5	2	5
Northeast	28	13	15	7	1	2	1
North	3	8	21	2	8	-	3
South	1	14	8	-	2	-	1
Total	35	43	72	20	16	4	10
Percentage	17.5	21.5	36.0	10.0	8.0	2.0	5.0
Percentage national distribution	29.0	23.0	25.0	12.0	5.0	2.0	4.0

Comparing the percentage distribution of interviewed mothers with the national distribution (183), the percentage of interviewed mothers was less in the income category of 500 baht but more in the category of 2000 baht. In other categories, the percentage of national distribution and the interviewed mothers were approximately the same. The average monthly income calculated from the national distribution was 1753 or 1800 baht. The average income of interviewed mothers was only slightly higher than the national average. On the whole, the income distribution of interviewed mothers compared quite well with the national distribution. It is

expected that the information on prices given by this group of mothers should reasonably point to the acceptable prices of infant food.

However, in asking for the prices acceptable for daily infant feeding, 60 percent of mothers could not answer this question for the reason of not having any experience in buying processed infant food (Table 2.21). The number of mothers answering this question was found to increase with the incomes i.e. from 20 to 26, 42 and 64 percent when monthly incomes increased from 500 to 1000, 2000 and greater than 2000 respectively. The acceptable prices also increased with monthly incomes as shown in Table 2.20.

Table 2.20 Number and Percentage^a of Mothers with Different Acceptable Prices for Daily Feeding by Income Categories

Monthly income categories, baht	Number of mothers			Number and percentage of mothers answering the question	Total interviewed mothers
	Acceptable prices, baht				
	1 - 3	4 - 6	8 - 15		
500	2 (28.6)	4 (57.0)	1 (14.3)	7 (20.0)	35
500-1000	4 (36.4)	6 (54.5)	1 (9.1)	11 (25.6)	43
1000-2000	6 (20.0)	14 (46.7)	10 (33.3)	30 (41.7)	72
>2000	11 (34.4)	7 (21.8)	14 (43.7)	32 (64.0)	50

^aPercentage given in bracket.

The percentages of mothers accepting price of 8-15 baht increased from approximately 10 percent in the income of 500 and 1000 baht to 33 percent in the income of 2000 baht and 44 percent in the income greater than 2000 baht. About one-third of mothers in all income categories accepted the price of 1 - 3 baht. Taking into account that only 20 and 26 percent of mothers in income groups of 500 and 1000 baht answered the question, only mothers with income greater than 1000 baht were able to accept prices of 8 - 15 baht. The majority of mothers in the monthly incomes of 500, 1000 and 2000 baht accepted the price of 4 - 6 baht, while mothers with incomes greater than 2000 baht accepted the price of 8 - 15 baht. Considering the acceptable prices by all the mothers answering this question, Table 2.21 shows that 28.75 percent were prepared to pay up to 3 baht per day, 38.75 percent for 4 - 6 baht, and 32.5 percent for 8 - 15 baht.

Table 2.21 Number and Percentage of Mothers With Different Acceptable Prices for Daily Feeding

Regions	Number of mothers			Number and percentage of mothers answering the question	Total interviewed mothers
	Acceptable prices, for daily feeding, baht				
	1 - 3	4 - 6	8 - 15		
Central	12	3	10	25	62
Northeast	1	8	2	11	67
North	9	18	9	36	45
South	1	2	5	8	26
Total	23	31	26	80	200
Percentage	28.75	38.75	32.5	40.0	100.0

Many alternatives may be concluded, the 60 percent not answering the question either may not afford it or may be prepared to buy if it is cheap. There is a question on how cheap. It is doubtful if the mothers with monthly incomes less than 1000 baht can afford processed food as the income is comparatively low and only 20 percent in this group were able to give the acceptable prices. Certainly, with 40 percent of mothers answering the question, the cheapest product was most accepted. If it was 1 - 3 baht, it would be accepted by all, while if it was 4 - 6 baht two-third of the mothers would accept and only one-third would accept at the price of 8 - 15 baht.

2.3 Conclusion

The requirement of an infant with particular reference to Thai infant has been discussed and specified not only to comply with the Thai Notification but also with the available information on infant nutrition and the drafted standard by Codex Alimentarius (46). Infants were divided into 2 groups according to different energy requirements, i.e. 3 - 5 month old where energy requirement was estimated at 760 kcal per day and 6 - 12 month old at 880 kcal per day. The nutrients, consisting of 14 vitamins, 11 minerals, 11 essential amino acids and 6 other general nutrients were defined. Most of the infant requirements were defined related to energy per unit of 100 kcal as specified by Thai Notification and recommended by Codex Alimentarius. Nutrients that were considered in this study but not required by the Thai Notification were expressed as minimum daily requirement. The minimum requirements were specified for all the nutrients. Nevertheless, for a number

of nutrients it was considered necessary to define for their maximum limits as well. In the specification for protein, fat and fibre, because of indefinite requirements further consideration is needed during the design.

From the survey with mothers in different regions, the investigation certainly revealed the perception of mothers towards infant food. There was no restriction to the use of general types of food raw materials. The perception of mothers of an infant food was a dry product in a creamy colour with slightly sweet flavour and medium to thick consistency. Furthermore, dry product will fit in better with the facilities available in the homes. There was a high number of working mothers. Most of mothers have to prepare food for infant specially but they do not find it inconvenient. Whether convenient infant food would be an asset to mothers, is difficult to decide. Most mothers are used to preparing food for infant and do not have experience in buying already made infant food. This area needs more investigation once there is such a product available for the market.

The other difficult aspect to decide is the acceptable price. Seemingly, 4 - 6 baht can be concluded as the most acceptable price as it is accepted by two-thirds of mothers answering that question. One certain emphasis is that the designed infant food should be as cheap as possible. The cheaper the product is, the wider the product is expected to be used.

Having determined both quantitative and qualitative characteristics of the infant food, the next consideration is finding the method to design the infant food to provide

all the specified nutrients from Thai raw materials and at the same time to give the cheapest product with the other qualities as perceived by mothers.

CHAPTER 3

SETTING UP THE LINEAR PROGRAMMING MODEL FOR AN INFANT FOOD

To arrive at a product with the specified quantitative and qualitative characteristics, the first step is to find a suitable blend of the raw materials available. Raw materials to give the specified quantitative characteristics are needed first as a basis, before modification for the qualitative characteristics can be made.

The cheapest product can only be derived from the cheapest formulation. To give this, the raw materials will have to be formulated to provide the specified quantities of nutrients at the lowest possible cost i.e. the formulation has an objective of minimizing the cost and at the same time providing all the specified nutrients. This problem description fits with linear programming conditions, where the limited resources are allocated to meet the specified objective. Hence, to select the food raw materials for the low cost infant foods with required nutrients, the linear programming model was applied. This chapter discusses the setting up of a linear programming model for selection of raw materials to satisfy the nutritional requirements of the Thai infant, the organisation for solution by computer and the possibility of achieving the best solution in accordance with the restriction on the nutrients.

3.1 The general linear programming model

This was first developed and applied in 1947 by Dantzig to investigate the feasibility of applying mathematical technique to military programming and planning problems, and the Simplex method as a systematic procedure was given for solving the problem (93). The first application of the linear programming technique in the design of nutritional foods was by Stigler in 1949. Edwardson 1974 reviewed the literature on the application of linear programming and summarized the application to nutrition problems as in Appendix 8. In the literature, no reference has been found on the application of linear programming to the design of an infant food which will provide the full daily nutrient requirement for infants under one year. The nearest investigation was by Inglett et al. 1969. Realising the increasing importance of cereal in feeding preschool children in the developing countries, they used linear programming to optimize only the protein quality in a cereal-based food. The technique may have been used in the food industry for the design of infant foods but published information on this is not available.

The general mathematical statement of linear programming related to the nutritional problem involves: minimize the cost function

$$c_1 x_1 + c_2 x_2 + \dots\dots\dots c_n x_n$$

subject to the conditions

$$\begin{array}{rcl} a_{11} x_1 + a_{12} x_2 + \dots\dots\dots a_{1n} x_n & \begin{array}{l} \leq \\ \geq \end{array} & b_1 \\ a_{21} x_1 + a_{22} x_2 + \dots\dots\dots a_{2n} x_n & \begin{array}{l} \leq \\ \geq \end{array} & b_2 \\ a_{m1} x_1 + a_{m2} x_2 + \dots\dots\dots a_{mn} x_n & \begin{array}{l} \leq \\ \geq \end{array} & b_m \end{array}$$

and

$$\begin{array}{rcl} x_1 & & \geq 0 \\ & x_2 & \geq 0 \\ & & x_n \geq 0 \end{array}$$

where m represents the number of nutrients or rows

n represents the number of food raw materials or columns

a_{ij} represents the number of weight units of the i^{th} nutrient in one unit weight of the j^{th} food raw material.

x_j represents the number of weight units of the j^{th} food raw material in the solution.

c_j represents the cost per unit weight of the j^{th} food raw material.

b_i represents the number of unit weights of the required i^{th} nutrient.

Therefore, the data required in setting up the linear programming model for the infant nutritional requirements are:

1. The list of nutrients as specified for infant nutritional requirements.
2. The required level of each nutrient and the inter-relationship of nutrients in the infant food.
3. The list of food materials which can be used for infant food.
4. The nutrient composition of each food raw material.
5. The cost per unit weight of each food raw material.

The list of nutrients, their levels and the inter-relationship of nutrients required by an infant has already been given in 2.1. The list of food raw materials, its cost and compositional data are the pertinent issues to consider.

3.2 The Thai food raw materials

3.2.1 Selection of food raw materials

The list of Thai food materials is given in the Table of Thai Food Compositions by the Nutrition and Health Department, Public Health Ministry, Thailand (170). The selection of Thai food raw materials was aimed to cover as many raw materials as possible, to allow the linear programming technique to work with plenty of flexibility for the cheapest mix. But it was necessary that the food raw materials once selected must be available commercially in quantities sufficient for the industrial process. Also, the raw materials must be appropriate for infant food in general terms i.e. do not possess any strong flavours such as bitterness, tartness and spicyness. Therefore, from the available list, the food raw materials without strong flavour were selected. These raw materials were then investigated for their availabilities. The food raw materials production data was either recorded by the government statistical tables (164) or available from observation of the Bangkok markets. It is worth noting that statistical figures in Thailand are very scarce. The production of only a limited number of food raw materials were reported. For this reason, it was necessary to determine approximately the amounts available in the Bangkok market by observing the quantities for sale in the market. Out of 113 raw materials first selected from the Thai list, 96 food raw materials were available commercially and hence used in this study. The recorded and estimated production of these raw materials is given in Appendix 9.

3.2.2 The costs

Average costs through out the year given by Monthly Agricultural Economics News (156), Weekly Report of Price, Market Situation of Agricultural Products (166) and Fish Market News (164) were used. There were 46 raw materials where prices were not documented and average market wholesale prices were taken.

It is realized that cost is subject to seasonal fluctuation. In tropical countries like Thailand, commodities likely to be most affected by season such as fruits and vegetables are grown almost all year round. Though the price varies from season to season, the variation is not expected to be great. Also the value of linear programming is that it can study the effects of price changes. In fact, it is how linear programming model is used to select the lowest cost mix at a certain set of costs. It is simply achieved by obtaining the computer solution to the linear programming model subjected to changed cost data. It is important to note that, in a given optimum solution to a linear programming model, prices can vary within a certain range without interfering with the optimum solution. This range can be obtained from LPANALYSIS (121) output of computer algorithms of the linear programming model. In practice, the changes in cost are checked regularly and new solutions can be obtained. Therefore, the average prices taken from available publications and from the market price survey were considered reasonable to use in this study.

The food material in this study is referred to as edible portion, it is the form that will be used in the

mix prior to processing. The cost is expressed in Thai currency, baht per 100 g of edible portion. The list of raw materials with cost per 100 g of edible portion is shown in Table 3.1.

Table 3.1 Food Raw Materials and Their Costs, Paht per 100g Edible Portion, used in the Linear Programming Model

Raw Materials	Cost	Raw Materials	Cost	Raw Materials	Cost	Raw Materials	Cost
1. Cereals; starchy roots, tubers; legumes; nuts and seeds				3. Fruit			
Cashew nut	7.0000	Cassava starch	0.4000	Banana, common variety	0.4760	Banana	0.9060
Cowpea, dry	0.5000	Coconut	0.6000	Grape	1.9231	Guava	0.4082
Mungbean, whole	0.4700	Mungbean, starch	0.6500	Lemon	0.7463	Orange	0.9375
Peanut, raw, with shell	0.3846	Peanut, dry and shelled	0.7000	Orange, mandarin	0.8571	Papaya	0.2778
Pigeon pea	0.6294	Rice, black, glutinous	0.3500	Pineapple	0.3636	Water melon	0.2542
Rice, brown	0.4000	Rice flour	0.6000	4. Meats and poultry			
Rice, glutinous flour	0.7000	Rice, glutinous milled	0.3500	Beef	3.5294	Buffalo	3.0000
Rice, milled and polished, 5 %	0.3470	Rice, parboiled	0.4204	Chicken, matured	2.6250	Chicken, young	2.8000
Sesame	1.0660	Soybean	0.4400	Duck	2.5000	Liver, beef	3.2908
Soybean curd	1.2000	Soybean flour	0.7500	Liver, chicken	3.6082	Liver, duck	3.6082
Sweet potato, white	0.1724	Sweet potato, yellow	0.1724	Liver, bog	3.9175	Pork, lean	3.9024
2. Vegetables				Heart, beef	2.6804	Heart, hog	4.1237
Bamboo	0.7143	Beans, snap	0.3158	Gizzard, duck	3.6082	Gizzard, chicken	3.6082
Cabbage	0.4070	Cabbage, chinese	0.4069	5. Eggs and milks			
Cauliflower	0.9167	Collard	0.3378	Egg, hen	1.9318	Egg, duck	1.4848
Cowpea, yard long	0.2273	Goabean	0.3158	Whole cow milk	1.1110	Milk, dry	5.0000
Ivygourd	0.6000	Peas	2.1053	Skim, fluid	1.1110	Skim, dry	5.0000
Mustard, green	0.6667	Sprouted mungbean	0.2151	6. Fish and Shellfish			
Swamp cabbage	0.1467	Bottle gourd	0.3353	Anchovy	2.4658	Catfish, fresh water	2.6322
Carrot	2.6506	Corn	0.5405	Catfish, sea water	2.4490	Carp	1.9300
Cucumber	0.3346	Eggplant	0.3240	Dorab	1.5405	Eel	2.8571
Mushroom	1.6484	Pumpkin	0.2989	Gouramy	2.1054	Hardtail	1.7391
Radish	0.2409	Snake gourd	0.2222	Spanish mackerel	2.9231	Stripe mackerel	2.1930
Sponge gourd	0.2532	Wax gourd	0.2111	Milkfish	2.1739	Mullet	3.3077
Tomato	0.3723			Prawn, river	9.3910	Prawn, sea	12.0000
				Perch	2.0816	Snapper	2.0816
				Serpenthead	2.7272	Squid	1.6130
				7. Miscellaneous			
				Sugar	0.5000		

3.2.3 Food raw material compositional data

The composition of the 96 raw materials had to be found for the 43 nutrients listed in Table 2.1. The various

sources used as references for these compositions are given in the Appendix 10. The Thai food compositional tables (170) were not used because they are a compilation of the available published data, mostly from the Philippine and U.S.A. composition tables, related to the particular type of raw materials available in Thailand, not the results of analysis done on Thai food raw materials. In addition, only a limited number of nutrients were tabulated. Therefore, it was decided to refer to the original data from which the collection of Thai food compositional data was taken. Among these various sources, the Food Composition Tables for use in East Asia by the Food Policy and Nutrition Division, FAO (82), offering the composition of 38 nutrients, was most used in this study. Six nutrients not included in these tables are chloride, choline, biotin, vitamins D, E and K. The compositions for most of these nutrients were taken from the study of Dam and Glavind (54), the vitamin E from Booth and Bradford (21), choline from the Encyclopedia of Chemical Technology (142), biotin from Biochemists' Handbook (152).

Approximately 90 percent of the nutritional compositions were defined from these sources in Appendix 10. An attempt was made to fill in the nutrient compositions as completely as possible. In order to estimate the missing compositional data, assumptions were made as following:

1. For the raw materials of the same food group, the missing data was taken from the data available for other members of the group, e.g. for gourd type raw materials (wax-gourd, snakegourd and spongegourd), the data for amino acids, rare vitamins and minerals

were taken from the data for bottlegourd and marrow; amino acids of swamp cabbage and mustard green were taken from chinese cabbage data. In this way, amino acid compositions for 9 raw materials and some vitamins, and minor minerals for 10 raw materials were assumed. This assumption accounted for 8.5 percent of all data.

2. For the linoleic acid composition of the raw materials with low fat content such as collard, watermelon, and mushroom, the content of linoleic acid was set at zero. This was approximately 0.5 percent of all data.

Approximately one percent of the data could not be estimated and was set at zero. This data was for vitamin E, vitamin K, biotin, choline and minor minerals such as zinc, manganese and magnesium.

Nutrient units were expressed per 100 g of food raw material, edible portion. The compositions of the raw materials used are shown in Appendix 11. The accuracy of expression of these units and some description of the derivation of the nutrient compositional data is given below.

Calories:	nearest kilo calorie (kcal)	calculated using physiological energy factors for fat, protein and carbohydrate where otherwise unknown
Protein:	nearest tenth of a gram (g)	calculated from estimated nitrogen content of food assuming 16 percent nitrogen in protein. Other factors used for cereals, beans, nuts and milk (82)

Fat:	nearest tenth of a gram (g)	by extraction estimation
Linoleic acid:	nearest tenth of a milligram (mg)	by gas liquid chromatography
Vitamin A:	expressed in term of "retinol" and "beta-carotene equivalent" as recommended by the Joint FAO/WHO Expert Group (123)	chemical method I.U. = 0.3 mcg retinol = 0.5 mcg beta-carotene = 1.2 mcg other total mixed carotenoids
Retinol	nearest microgram (mcg)	
B-carotene	nearest microgram (mcg)	
Vitamin D:	nearest tenth of an international unit (I.U.)	chemical method
Vitamin E:	nearest one hundredth international unit (I.U.)	by colorimetric method or gas chromatography
Vitamin K:	nearest tenth of a microgram (mcg)	chemical and biological methods
Vitamin C:	nearest tenth of a milligram (mg)	total ascorbic acid
Thiamine:	nearest one hundredth of a milligram (mg)	determined by methods adopted by AOAC (9)
Riboflavin:	nearest one hundredth of a milligram (mg)	determined by methods adopted by AOAC (9)
Niacin:	nearest tenth of a milligram (mg)	1mg niacin = 1 niacin equivalent, tryptophan contribution not considered
Vitamin B6:	nearest one hundredth of a milligram (mg)	total pyridoxine activity is contributed by pyridoxine, pyridoxal, pyridoxamine and conjugated forms, figures expressed as pyridoxine

Vitamin B12:	nearest tenth of a microgram (mcg)	microbiological method
Pantothenic acid:	nearest one hundredth of a milligram (mg)	pantothenate estimations corrected to pantothenic acid
Choline:	nearest one hundredth of a milligram (mg)	chemical and microbiological methods
Biotin:	nearest one hundredth of a microgram (mcg)	microbiological method
Folic acid:	nearest one thousandth of a milligram (mg)	microbiological method
Sodium ^a :	nearest tenth of a milligram (mg)	
Chloride ^a :	nearest tenth of a milligram (mg)	
Potassium ^a :	nearest tenth of a milligram (mg)	
Calcium ^a :	nearest tenth of a milligram (mg)	total (no correction for oxalate or phylate salts which make some of the mineral unavailable to the body)
Phosphorus ^a :	nearest tenth of a milligram (mg)	total (no correction for presence as combined phytic acid)
Magnesium ^a :	nearest tenth of a milligram (mg)	
Iron ^a :	nearest tenth of a milligram (mg)	total (no correction for phytate unavailability or absorption)
Iodine ^a :	nearest one hundredth of a microgram (mcg)	

^aFor the determination of minerals, atomic absorption spectrophotometry is the method of choice. However, volumetric, gravimetric and spectrophotometric methods were also used.

Manganese ^a :	nearest tenth of a milligram (mg)	
Copper ^a :	Nearest tenth of a microgram (mcg)	
Zinc ^a :	nearest tenth of a milligram (mg)	
Dry weight:	nearest tenth of a gram (g)	moisture content subtracted from 100
Carbohydrate:	nearest tenth of a gram (g)	total carbohydrate by difference including fibre, the sum of moisture, protein, fat and ash is subtracted from 100
Sugar:	nearest hundredth of a gram (g)	as sucrose
Fibre:	nearest tenth of a gram (g)	by extraction estimation
Amino acid:	nearest milligram (mg)	average values of several independent assays for each amino acid, chromatographic estimation used where available

^aFor the determination of minerals, atomic absorption spectrophotometry is the method of choice. However, volumetric, gravimetric and spectrophotometric methods were also used.

3.2.4 Nutritional constraints

The list of nutrients and the required levels have already been discussed in Chapter 2 and summarized as in Table 2.8.

3.3 Linear programming model for infant food

The composition of 43 nutrients and the cost data of

96 food raw materials form a matrix of 96 columns and 43 rows of nutrients and one row of costs. The interrelated constraints also form a matrix of additional rows and columns as in Figure 3.1.

The problem matrix is derived from the expression of linear relationships of cost, compositional data and nutritional constraints as follows:

3.3.1 Costs

Cost data provide one row of the matrix which forms an objective for the problem, i.e. to minimize

$$c_1 x_1 + c_2 x_2 + \dots + c_n x_n \quad \text{or} \quad \sum_{i=1}^n c_i x_i$$

where c_i is the cost per 100 g of edible portion of the i th food material.

3.3.2 Compositional data

Data for the content of the 43 nutrients of the 96 food raw materials form another 96 columns and 43 rows in the matrix e.g. in the row of calorie, it is derived from

$$a_{11} x_1 + a_{12} x_2 + \dots + a_{1n} x_n$$

where x_1 to x_n represent the weight of the 96 raw materials and a_{11} to a_{1n} represent the calorie level per 100 g of edible portion of x_1 to x_n raw materials.

3.3.3 Nutritional constraints

Nutritional constraints are the set of bounds, defining the limits on the problem variables. There are direct constraints and interrelated constraints. The direct constraint is a restriction on nutrient level either at an upper and/or lower limit, or at a specified constant level. The interrelated constraint is the restriction

derived from the linear relationships between specific nutrients. In this case, a variable name is assigned to the left hand side of the equation forming an additional row in the problem matrix. Examples of relevant constraints are given as follows

1. Direct constraint. Calorie at lower limit of 760 kcal can be expressed in the linear relationship as

$$CAL = a_{11} x_1 + a_{12} x_2 + \dots + a_{1n} x_n \geq 760$$

and copper upper limit at 740 mcg can be expressed as

$$CU = a_{21} x_1 + a_{22} x_2 + \dots + a_{2n} x_n \leq 740$$

where CAL and CU represent calorie and copper in the mix to be not less than 760 kcal and not more than 740 mcg respectively. The expression of direct constraints is given in Table 3.2

Table 3.2 Direct Nutritional Constraints

Nutrient	Row variables	Restriction	
		Lower	Upper
Calorie	CAL	760 ^a	∞
		880 ^b	∞
Vitamin D	VITD	400.0	∞
Vitamin K	VITK	15.0	∞
Niacin	NIA	5.0	∞
Vitamin B6	VITB6	0.4	∞
Vitamin B12	VITB12	0.3	∞
Folic acid	FOLIC	0.05	∞
Sodium	NA	138.0	∞

^aFor infant aged 3 - 5 months

^bFor infant aged 6 - 12 months

Table 3.2 cont'd

Nutrient	Row variables	Restriction	
		Lower	Upper
Chloride	CL	213.0	∞
Potassium	K	234.0	∞
Calcium	CA	$-\infty$	630.0
Phosphorus	P	130.0	∞
Magnesium	MG	20.0	∞
Copper	CU	$-\infty$	740.0
Zinc	ZN	$-\infty$	9.0

2. Interrelated constraints. The lower and upper limits of protein, expressed related to 100 kcal to be not less than 1.8 g and not more than 3.5 g, can be expressed as:

$$\text{calorie protein lower limit, i.e. } \frac{\text{protein}}{\text{calorie}} \geq \frac{1.8}{100}$$

$$\text{or protein} - .018 \text{ calorie} \geq 0$$

$$\text{calorie protein upper limit, i.e. } \frac{\text{protein}}{\text{calorie}} \leq \frac{3.5}{100}$$

$$\text{or protein} - 0.035 \text{ calorie} \leq 0$$

CALPROTL and CALPROTH are the names assigned for the lower and upper limits of protein related to calorie. Hence, CALPROTL and CALPROTH form another 2 row variables corresponding to the columns of protein and calorie. CALPROTL is limited to be greater or equal to zero, while CALPROTH is less or equal to zero. The expressions are

$$\text{CALPROTH} = \text{protein} - 0.035 \text{ calorie} \leq 0$$

$$\text{CALPROTL} = \text{protein} - 0.018 \text{ calorie} \geq 0$$

The expression of interrelated constraints is given in Table 3.3.

Table 3.3 Nutritional Constraint Requiring Linear Expression of Interrelationship Between Nutrients.

Nutrients inter-relationship	Row variables	Column elements	Restriction lower	Restriction upper
<u>NUTRIENTS EXPRESSED PER 100 KCAL</u>				
<u>Minimum values</u>				
Protein	CALPROTL	1.0 PROT - 0.018 CAL	0	∞
Fat	CALFATL	1.0 FAT - 0.02 CAL	0	∞
Linoleic acid	CALLINCL	1.0 LINOA - 2.0 CAL	0	∞
Vitamin A	CALVITAL	1.0 VITA - 2.5 CAL	0	∞
Ascorbic acid	CALVITCL	1.0 VITC - 0.1 CAL	0	∞
Thiamine	CALTHIAL	1.0 THIA - 0.0005 CAL	0	∞
Riboflavin	CALRIEOL	1.0 RIPO - 0.0007 CAL	0	∞
Pantothenic acid	CALPATOL	1.0 PANTO - 0.003 CAL	0	∞
Choline	CALCHOL	1.0 CHOLINE - 0.07 CAL	0	∞
Piotin	CALEIOTL	1.0 PIOTIN - 0.015 CAL	0	∞
Calcium	CALCAL	1.0 CA - 0.5 CAL	0	∞
Iron	CALFEL	1.0 FE - 0.01 CAL	0	∞
Iodine	CALIL	1.0 I - 0.05 CAL	0	∞
Manganese	CALMNL	100.0 MN - 0.005 CAL	0	∞
Copper	CALCUL	1.0 CU - 0.6 CAL	0	∞
Zinc	CALZNL	1.0 ZN - 0.005 CAL	0	∞
<u>Maximum values</u>				
Protein	CALPROTH	1.0 PROT - 0.035 CAL	$-\infty$	0
Fat	CALFATH	1.0 FAT - 0.04 CAL	$-\infty$	0
Vitamin A	CALVITAH	1.0 VITA - 7.5 CAL	$-\infty$	0
Vitamin D	CALVITDH	1.0 VITD - 1.0 CAL	$-\infty$	0
Sodium	CALNAH	1.0 NA - 0.8 CAL	$-\infty$	0

Table 3.3 cont'd

Nutrients inter- relationship	Row variables	Column elements	Restriction	
			lower	upper
<u>Maximum values cont'd</u>				
Potassium	CALKH	1.0 K - 2.0 CAL	$-\infty$	0
Chloride	CALCLH	1.0 CL - 1.5 CAL	$-\infty$	0
<u>NUTRIENT EXPRESSED PER G OF PROTEIN</u>				
<u>Minimum values</u>				
Histidine	CHIST	1.0 HIST - 15.4 PROT	0	∞
Isoleucine	CISO	1.0 ISO - 37.8 PROT	0	∞
Leucine	CLEU	1.0 LEU - 60.2 PROT	0	∞
Lysine	CLYS	1.0 LYS - 49.0 PROT	0	∞
Sulphur amino acids, (Methionine + Cystine)	CSULAA	1.0 METH + 1.0 CYS - 39.9 PROT	0	∞
(Phenylalanine + Tyrosine)	CAROMAA	1.0 PHE + 1.0 TYR - 65.1 PROT	0	∞
Threonine	CTHREO	1.0 THREO - 32.9 PROT	0	∞
Tryptophan	CTRYP	1.0 TRYP - 11.9 PROT	0	∞
Valine	CVAL	1.0 VAL - 46.2 PROT	0	∞
<u>Maximum values</u>				
Histidine	DHIST	1.0 HIST - 22.0 PROT	$-\infty$	0
Isoleucine	DISO	1.0 ISO - 54.0 PROT	$-\infty$	0
Leucine	DLEU	1.0 LEU - 86.0 PROT	$-\infty$	0
Lysine	DLYS	1.0 LYS - 70.0 PROT	$-\infty$	0
Sulphur amino acids, (Methionine + Cystine)	DSULAA	1.0 METH + 1.0 CYS - 57.0 PROT	$-\infty$	0
Aromatic amino acids (Phenylalanine + Tyrosine)	DAROMAA	1.0 PHE + 1.0 TYR - 93.0 PROT	$-\infty$	0

Table 3.3 cont'd

Nutrients inter- relationship	Row variables	Column elements	Restriction	
			lower	upper

Maximum values cont'd

Threonine	DTHREO	1.0 THREO - 47.0 PROT	$-\infty$	0
Tryptophan	DTRYF	1.0 TRYF - 17.0 PROT	$-\infty$	0
Valine	DVAL	1.0 VAL - 66.0 PROT	$-\infty$	0

OTHER EXPRESSIONS OF NUTRIENTS

Conversion of

E-carotene and
retinol to
vitamin A

VITA 3.3 RETINOL +
 1.6 B-CARO

Minimum values

Vitamin E per g
of Linoleic
acid

VIELINOL 1.0 VITE - 0.001 LINOA 0 ∞

Ratio of calcium
to phosphorus

CAPL 1.0 CA - 1.4 P 0 ∞

Sucrose as
percentage of
carbohydrate

CHOSUL 1.0 SUGAR - 0.2 CHO 0 ∞

Calorie per g of
dry weight

CALDWT 1.0 CAL - 3.5 DWT 0 ∞

Maximum values

Ratio of
calcium to
phosphorus

CAPH 1.0 CA - 2.0 P $-\infty$ 0

3.4 Setting up the data for solving the problem by computer

The matrix of cost, compositional data and nutritional constraints were prepared as a card deck to input to the IBM linear programming system/1130 (LPS/1130) package programme, designed for use on the 1130 series of

IBM computers. The preparation was according to the method described in the IBM/1130 programme description manual (121) using 80 column cards.

3.4.1 The cost and compositional data

The problem equation expressing the linear relationship of raw materials with costs and compositions were input by card in element format. For example, cost and calorie data for the raw material anchovy were prepared as:

ANCHOVY	COST	2.4658
ANCHOVY	CAL	99.0

The column variable was punched first followed by the row variable and the data value. All variable names were restricted to 8 alphanumeric symbols. Abbreviation was required for some raw materials and nutrients. These abbreviated names are in the row and column summary as shown in Appendix 12.

3.4.2 The nutritional constraints

The nutritional constraints were prepared as a card deck by element cards defining the upper and lower bounds on each bounded variable. The bound was input with a defined name. The bounds types used were:

UB	upper bound
LB	lower bound
FR	free
GT	defined value to ∞
LT	defined value to $-\infty$

Each bound element card was defined for bound type, name of bound set, name of variable and bound value. The name of bound set used in this study is INFANT. The nutritional constraints, either direct or interrelated

constraints were prepared as follows

1. Upper limits. An example of a direct constraint is the upper limit on zinc of 9.0 mg per day, the expression is

$$ZN \leq 9.0$$

card is prepared in format,

```
UE INFANT ZN 9.0
```

Example of interrelated constraint as for protein per 100 kcal at 3.5 g, the expression is

$$CALPROTH = PROT - 0.035 CAL \leq 0.0$$

card is prepared for the bounded value of CALPROTH as

```
UE INFANT CALPROTH 0.0
```

the expression of linear equation showing the relationship of CALPROTH to PROT (protein) and CAL (calorie) is prepared as:

$$PROT \quad CALPROTH \quad 1.0$$

$$CAL \quad CALPROTH - 0.035$$

2. Lower limits. Example of direct constraint as for vitamin D lower limit at 400 I.U. per day, the expression is

$$VITD \geq 400.0$$

card is prepared in format

```
LB INFANT VITD 400.0
```

Example for interrelated constraint as for proteins per 100 kcal at 1.3 g, the expression is

$$CALPROTL = PROT - 0.018 CAL \geq 0$$

card is prepared as

```
LB INFANT CALPROTL 0.0
```

The expression of linear equation showing the relationship of CALPROTL to PROT (protein) and CAL (calorie) is prepared as:

$$\begin{array}{rcl} \text{PROT} & \text{CALPROTL} & 1.0 \\ \text{CAL} & \text{CALPROTL} & - 0.018 \end{array}$$

3.4.3 Loading the problem data onto the computer

The procedure to input all data to store on the disk was as follows. The problem file was named. The procedure control card "INPUT" was used, followed by problem file name "LPINFANT", next were the cards for all the data and data deck was concluded by the indicator card "ENDATA".

3.5 Obtaining solution by computer

The initial problem had one infeasibility, the value of column variable "RICERO" (brown rice) was in negativity. This meant that there were a number of artificial variables associated with a certain number of inequality constraints, which could not be removed. Indication of the restricted inequality constraints was observed in the output of the infeasible solution given by computer as these constraints were at the bounded values. These were the direct constraints and interrelated constraints as shown in Table 3.4.

In order to obtain a feasible solution, modification of the initial problem was considered. The constraints at bounds could be made less restricting either by removal or slackening of the bounds. Removal of the bound meant no restriction on that particular nutrient, the value could be from zero up to infinity. This was undesirable in this design because the purpose was to provide as near as

possible to the minimum requirements of the infant. Hence, trying to reach as near as possible to the required nutrient was more desirable. Therefore, consideration was given to the slackening of these restricted bounds.

Table 3.4 Nutritional Constraints at Bounds Found With Initial Problem File

Nutritional constraints	At lower bound	At upper bound
Direct constraints:	Calorie	Calcium
	Niacin	Copper
	Chloride	
	Vitamin D	
Interrelated constraints:	Fat related to calorie	Potassium related to calorie
	Vitamin A related to calorie	
	Vitamin E related to linoleic acid	Histidine related to protein
	Zinc related to calorie	
	Calcium related to phosphorus, (Calcium phosphorus ratio)	
	Sulphur amino acid related to protein	

An upper limit was specified in order to prevent some of the nutrients coming into the mix at more than specified level and lower limit was specified according to the minimum requirement. It was wiser to slacken the upper limits first and maintain the lower limits to the initial problem. These upper limits were for calcium and copper,

potassium as related to calorie and the amino acid histidine related to protein. Among these upper limits, potassium and copper should not be increased. Potassium is related to the renal solute load and limited information is available for the maximum limit of copper. Of the other two upper limits, histidine and calcium, histidine could be increased without having much effect on the requirement of an infant, except that the histidine would be wasted. For calcium, the level found to have an adverse effect on infant nutrition is 1200 mg per day (26) yet it was specified in this study at 630 mg. It was possible to increase calcium upper limit, though only a small increment was desirable.

It is worth noting that the only lower limit at bound associated with upper limit at bound is calcium phosphorus ratio, "CAPL" at 1.4. It is possible that to keep calcium greater than phosphorus by 1.4 times, calcium upper limit at 630 mg is very difficult to maintain due to different ratio of calcium to phosphorus coming in from food materials. Two alternatives could be investigated to ease this difficulty, i.e. either releasing calcium upper limit or allowing the problem to bring in calcium independent of phosphorus. The latter could be achieved by the addition of calcium salt such as calcium carbonate.

3.5.1 Modification of the problem by increasing calcium upper bound

It was found possible to obtain the feasible solution by releasing calcium upper limit to 682 mg for infant aged 3 - 5 months where minimum calorie requirement was at 760 kcal and calcium upper limit of 700 mg for

infant aged 6 - 12 months where minimum calorie requirement was at 880 kcal. The cost of the solutions, the raw material and the nutrient compositions are given in Table 3.5, for requirement I (3-5 months) and II (6-12 months).

Table 3.5 Nutritional and Raw Material Compositions and Cost of Feasible Solutions

Raw Material and Nutrient Contents	Calcium Upper Limit Released		Calcium Carbonate Added		Raw Material and Nutrient Contents	Calcium Upper Limit Released		Calcium Carbonate Added	
	Requirement	Requirement	Requirement	Requirement		Requirement	Requirement	Requirement	Requirement
	I	II	I	II		I	II	I	II
Raw material content, g					Nutrient contents				
Anchovy	33.3	18.1	37.7	42.2	Vitamin E mcg	6957.1	9221.1	529.4	524.7
Buffalo, meat	-	-	0.2	0.2	Ascorbic acid mg	153.5	190.2	76.0	88.0
Cassava starch	-	-	19.3	42.6	Thiamine mg	0.77	0.90	0.64	0.70
Coconut	-	3.6	15.7	26.9	Riboflavin mg	0.53	0.62	0.53	0.62
Collard	149.9	199.6	-	-	Niacin mg	5.0	5.0	5.72	5.34
Egg duck	32.1	39.1	11.9	12.8	Vitamin B6 mg	1.37	1.49	1.26	1.22
Guava	-	-	11.7	18.4	Vitamin B12 mg	0.004	0.004	0.003	0.004
Ivy gourd	24.4	3.3	-	-	Pantothenic acid mg	2.69	2.80	2.79	2.83
Milk fish	15.7	16.1	16.7	12.1	Folic acid mg	0.79	1.00	0.13	0.14
Mungbean, starch	50.1	50.5	-	-	Choline mg	377.50	411.41	182.81	184.51
Radish	2.4	4.3	-	-	Biotin mcg	15.98	17.69	11.66	10.37
Rice, brown	-	-	21.5	16.9	Sodium mg	224.4	245.1	176.4	187.6
Rice, parboiled	-	7.8	12.7	-	Chloride mg	222.1	231.3	223.5	235.7
Stripe mackerel	3.5	18.1	-	-	Potassium mg	1520.0	1760.0	1414.4	1760.0
Sesame	19.5	15.0	11.4	10.1	Calcium mg	681.8	700.0	630.0	630.0
Soybean curd	12.0	3.5	-	-	Phosphorus mg	487.1	500.0	450.0	450.0
Sponge gourd	2.8	-	18.1	24.7	Magnesium mg	198.0	211.9	461.7	468.7
Sugar	72.3	94.7	36.1	33.4	Iron mg	13.3	14.3	7.6	8.8
Calcium carbonate	-	-	0.86	0.84	Iodine mcg	38.00	46.19	38.00	44.00
					Manganese mg	1.5	1.7	789.6	844.0
Nutrient contents					Copper mcg	740.0	740.0	740.0	740.0
Weight g	418.2	473.6	404.4	455.2	Zinc mg	3.8	4.4	6.1	6.5
Dry weight g	173.6	203.3	175.9	203.4	Isoleucine mg	1258.0	1307.0	897.0	890.0
Calorie kcal	760.0	880.0	760.0	880.0	Leucine mg	1884.0	1877.0	1484.0	1461.0
Protein g	25.8	26.7	20.1	19.6	Lysine mg	1677.0	1718.0	1208.0	1255.0
Fat g	18.1	17.6	15.2	17.6	Methionine mg	787.0	806.0	589.0	580.0
Carbohydrate g	124.1	153.0	135.2	160.3	Cytanine mg	243.0	206.0	211.0	203.0
Fibre g	3.2	3.4	3.7	4.3	Phenylalanine mg	1194.0	1209.0	854.0	830.0
Linoleic acid mg	4091.7	3437.7	2437.8	2323.7	Threonine mg	1069.0	1074.0	843.0	833.0
Retinol mcg	139.0	156.0	64.0	66.0	Tryptophan mg	384.0	399.0	298.0	286.0
B-carotene mcg	3139.1	989.5	3286.3	3822.3	Tyrosine mg	775.0	768.0	731.0	707.0
Vitamin D I.U.	400.0	400.0	400.0	400.0	Valine mg	1351.0	1447.0	1074.0	1044.0
Vitamin E I.U.	4.01	3.43	2.44	2.52	Histidine mg	568.0	588.0	441.0	432.0
					Cost baht	3.45	3.56	2.52	2.78

3.5.2 Modification of the problem by addition of calcium

The addition of calcium as another column of raw material can be included. It was considered reasonable because there is a number of calcium salts allowed for addition to food for infant (47). Calcium carbonate, being available in Thailand, was chosen as source of calcium. Cost and compositional data were added to the problem file.

The feasible solution was obtained after this modification without having to release calcium upper limit for both groups of infants, i.e. aged 3 - 5 months and 6 - 12 months. The costs of solution, the raw materials and the nutrient compositions are given in Table 3.5.

3.6 Conclusion

The linear programming technique was used in the raw materials formulation. The model consisted of cost and compositional data of 96 indigenous Thai food raw materials and a set of nutritional constraints as specified according to discussion in Chapter 2. The problem was analysed by the IBM linear programming system/1130 package programme with the 1130 series of IBM computer but the solution was infeasible. It was found that a feasible solution could be obtained by slackening the restriction on the calcium upper limit. It was found for the requirement of infant aged 3 - 5 months (requirement I), calcium upper limit had to be increased to 682 mg and for the requirement of infant aged 6 - 12 months (requirement II), had to be increased to 700 mg in order to obtain feasible solution. As an alternative to increasing the calcium upper limit, addition of calcium as calcium carbonate made it possible to obtain the feasible solution at the original constraints.

To decide which is the better approach, the effect of increasing the calcium upper limit or the addition of calcium salt, the costs and compositions of the two solutions were compared. However, these two solutions only take into account the composition of the raw materials and do not include the effects of processing on the nutrients

in the raw materials. The raw materials have to be processed to give the final infant food and consideration of the changes in nutrients during processing is necessary.

It has been shown that linear programming can be set up to design an infant food and obtain the least cost mixture of raw materials giving specified quantities of 43 nutrients. However, this model will not be realistic until the losses during processing are included in order that the processed infant food will provide the nutrients at the levels as required by the infant.

CHAPTER 4

THE DESTRUCTION OF NUTRIENTS WITH HEAT PROCESSING

Having set up the model to select the raw material mixture that suits the nutrient requirements, the next consideration was how to modify the model in order that any changes to the nutrients during processing could also be included. This chapter first reviews the losses in nutrients during heat processing which are reported in the literature. Unfortunately there is a lack of quantitative data, but wherever possible the kinetics of the reactions causing loss of nutrients were determined. The reaction rate constants at various temperatures were predicted from the data collected for each nutrient.

4.1 Nutrient losses in food processing

What had to be considered was the extent to which the required nutrients change or lose their biological activities when the mixture is subjected to certain types of processing. To predict the extent of the loss in nutrients, it was necessary first to predict the rate of change in the nutrients when subjected to certain processing conditions. The most important variables in food processing which affect the rates of reactions are concentration and temperature.

According to the law of mass action, the velocity of reaction at a given temperature was proportional to the product of the concentration of the reacting substances (1).

For example, the rate of the disappearance of reactant A can be written as

$$\frac{dC_A}{dt} = -k C_A^a C_B^b \dots\dots\dots C_N^n \quad (4.1)$$

where $\frac{dC_A}{dt}$ is the rate of disappearance of reactant A; $C_A, C_B, \dots\dots\dots C_N$ are the concentrations of reactants A, B, $\dots\dots\dots N$ involved and k is the reaction rate constant. The order of the reaction is defined as the sum of the powers to which the concentration of all reactants are raised.

Other variables can be added to this reaction rate equation and in food processing the most important is temperature, although pressure and radiant energy as sunlight or U.V. light can also affect reaction rates. An overall equation can then be:

$$\frac{dC_A}{dt} = -k C_A^a C_B^b \dots\dots T \quad (4.2)$$

In the destruction of nutrients, the concentrations of water, oxygen, acids, alkalis, reducing sugars are often important, as are the concentrations of metal catalysts and enzymes. But the most important factor in the food processing reactions is the concentration of the reacting substance, C_A , and the reaction rate equation at a given temperature is:

$$\frac{dC_A}{dt} = -k C_A^n \quad (4.3)$$

where in this study, C_A is the concentration of the nutrient A, k is the reaction rate constant and n is the order of the reaction.

4.2 The order of the reactions involved in the destruction of nutrients

It was pertinent to this research to consider the order of reactions involved in the destruction of the nutrients in the food mixture; and a short literature review was done so as to decide on the order of the reactions in the nutrient destruction. The two nutrients whose reaction kinetics have been studied in most detail were ascorbic acid and thiamine.

4.2.1 Ascorbic acid

Earlier studies on the order of the destruction reaction were conflicting. It was reported as either zero, first order or pseudo! (253, 192, 13). However, Joslyn and Miller in 1949 studied the autoxidation of ascorbic acid in buffered solution under continuous supply of oxygen and confirmed the validity of first order. Freed et al. 1949, confirmed that ascorbic acid and thiamine in miscellaneous food materials stored at constant temperature followed first order reaction kinetics. Vojnovich and Pfeifer 1970 studied the rate of ascorbic acid destruction in wheat flour, corn soya milk, infant cereal and found that the data could be treated as first order reaction and the effect of temperature followed Arrhenius equation. In the review by Labuza 1972, first order reaction kinetics was assumed for the destruction of vitamin C in various food products, such as dried carrot flakes and cabbage, wheat flour and orange juice powder. However, deviation from first order rate of reaction has also been reported. Under limited oxygen supply, Joslyn and Miller 1949 found that the initial rate of reaction was reduced. Singh et al. 1976, studying the

kinetics of ascorbic acid oxidation in infant formulae in special plexiglass cells during storage at 72°C, concluded that under limited supply of oxygen the degradation of ascorbic acid with dissolved oxygen uptake could be described as a second order reaction. It is unlikely that processing of the infant food will take place under limited oxygen supply, so that it can be assumed that first order rate of reaction would be true for the degradation of ascorbic acid during processing.

4.2.2 Thiamine destruction

For thiamine, the order of reaction involved in thermal destruction was studied as early as 1939; Watanabe showed that the thermal destruction of pure thiamine in aqueous solution proceeded according to first order. Later in 1944, Greenwood et al., studying the destruction of thiamine in pork luncheon meat, reported that in the range of 99°C to 121°C, data could be interpreted on the basis of first order. Rice and Beuk 1945 studied thiamine loss in lean pork muscle at temperatures from 49 to 121°C and found that the data obeyed the first order reaction better at temperatures higher than 77°C. Bendix et al. 1951 studied thiamine stability in peas, corn, limabeans and tomato juice over the temperature range of 110 to 132°C and found only in peas that thermal destruction data could be interpreted as a first order reaction. However, Felicotti et al. 1957 in their investigation in low acid foods and in buffered solution at pH 4.5 to 7.0 over the temperature range of 109 to 149°C found the thermal destruction followed first order. Farrer in his extensive review in 1955 found that the data collected from various

studies fitted first order reaction kinetics remarkably well. The recent work by Mulley et al. 1975a gave strong evidence of first order reactions of thiamine in a food system at buffered pH of 6. The failure of the earlier workers to obtain the straight line fitting of first order reactions could have been due to the incapability of the equipment used at that time to operate accurately at the required temperature. It was not until the availability of the thermoresistometer by Stumbo in 1948 that reproducible data could be obtained. It was therefore assumed that first order reaction kinetics could be taken for destruction of thiamine in the processing of the infant food.

4.2.3 Destruction of other nutrients

Very little information is available on the order of reaction in destruction of other nutrients. Carotene oxidation in dehydrated carrot studied by Falconer et al. 1964 was analysed using first order reaction. Garret 1956, in a study to predict the thermal stability of a complex vitamin mixture, found that vitamin A destruction had an initial zero order degradation which subsequently became pseudo first order. It was explained that beyond the concentration of solubility of the nutrient, the degradation rate was constant because it depended on concentration which was constant. However, this concentration of nutrient does not occur in food systems and it is unlikely that this initial zero order degradation will occur, and from Garret's work it can be assumed that vitamin A destruction is a first order reaction in foods. For tocopherol, Frankel et al. in 1959 found that the initial rates of tocopherol

loss in lard was first order and this was also shown in Garret's work. In the review by Labuza in 1972, he assumed that carotene and tocopherol destruction followed first order reaction kinetics.

For vitamins B12 and B6, and pantothenic acid in the vitamin mix, Garret 1956 found that first order reaction kinetics could be applied to their destruction rates, but that destruction of folic acid was similar to vitamin A and the order depended on the concentration - zero at high concentration, pseudo first order at lower concentrations. Singh et al. in 1975 showed that the destruction of riboflavin in liquid milk was found to be in the manner of first order reaction. It can be assumed that first order reaction kinetics are a description of the destruction of these vitamins.

Very little is known on the destruction rate of other vitamins, such as niacin, biotin, choline, vitamin D, vitamin K. These vitamins are either stable to heat processing or the losses are very small.

The present knowledge on the destruction of amino acids does not lead to any clear indication on the order of the reaction. The lack of information on the order of reaction involved in destruction of amino acid is undoubtedly due to the complex nature of this reaction. Reeves 1977 found that the destruction of lysine in liquid milk could not be fitted in with any order, however the pseudo first order was assumed. In the reviews by Labuza 1972 and Lund 1975, nevertheless, first order reaction was assumed applicable for destruction of lysine.

As there is no information suggesting the destruction

of amino acids in other manners, the first order rate of destruction was assumed to hold for all the essential amino acids studied.

4.2.4 Prediction of order of reaction

In this study, an attempt had to be made to predict the loss of nutrients in processing so that the designed mixture after processing contains nutrients according to the requirements of the infant. To do this, it was assumed that the destruction reactions of all the nutrients were first order reactions as regards concentration of the nutrient. This is an assumption based on little information in the literature, but it was considered a valid one to make in order to have the linear programming model include the effect of processing on nutrients. As more information becomes available on nutrient destruction, it can be used to improve the predictions of processing losses.

4.3 Reaction rate kinetics for nutrient destruction

In general, a first order reaction of disintegration of A can be described as

$$-\frac{dC_A}{dt} = k C_A \dots\dots\dots (4.4)$$

If C_0 is the initial concentration of nutrient A at zero time and C is the concentration at subsequent time t,

$$-\int_{C_0}^C \frac{dC_A}{C_A} = k \int_0^t dt \dots\dots\dots (4.5)$$

which can be written as

$$-\ln \frac{C}{C_0} = kt \dots\dots\dots (4.6)$$

$$\text{or} \quad - 2.303 \log \frac{C}{C_0} = kt \dots \dots \dots (4.7)$$

Thus a plot of the logarithms of the retention against time yields a straight line with slope $-\frac{k}{2.303}$.

The rate of reaction has long been known to be temperature dependent (1). The reaction rate constant, k , increases with temperature and the relationship is:

$$k = Ae^{-E/RT} \dots \dots \dots (4.8)$$

where A is called the frequency factor, E is the energy of activation, R is the gas constant and T is the absolute temperature.

Taking logarithms, the equation can be written as:

$$\log k = \log A - \frac{E}{2.303 RT} \dots \dots (4.9)$$

Therefore the plot of $\log k$ against $1/T$ yields a straight line with slope equal to $-\frac{E}{2.303 R}$.

The constant, E , is characteristic of the reaction and determines the influence of temperature on the reaction rate. Thus, the relationship of k and temperature can be established from fitting a straight line to data of $\log k$ and $1/T$. The rates of reaction at other temperatures can be predicted from this relationship.

Besides depending on the temperature, the rates of the reaction are affected by other variables - pH, water activity, concentration of oxygen and concentration of minor components such as trace metals and enzymes (146, 251). Wanninger 1972 postulated a mathematical model for the effect of moisture content on the rate of reaction; but data is not available to generalise the effects of any of these

variables on nutrient destruction.

In this study, it was assumed that oxygen was abundant, the pH was near neutral and water activity was high when processing started but would decrease during drying. It was assumed that there would be no great variation in pH or in oxygen level during processing.

To sum up, a first order reaction was assumed for the destruction of nutrients during heat processing and the two variables considered were concentration of the nutrient and temperature.

4.4 Review on stability of nutrients during heat processing

The data on the destruction of the nutrients was collected from the literature. Wherever possible the destruction rate in high moisture foods was collected rather than the destruction rate in dry products during storage, because it will be more relevant to the mixture of indigenous food materials during processing. An attempt was made to include data on foods with pH near neutral as it was assumed that the infant food would have near neutral pH. An attempt was made not to include data from very high or very low pH foods.

The data was collected either as already expressed rates of reaction or as a series of concentrations at certain temperatures and times. With the latter type of data, the log of retention fraction (C/C_0) was plotted against time; the straight line was fitted to the data by the least squares method and the reaction rate was calculated from the slope as shown in Equation 4.7. When the data only consisted of 3 or 4 points, the straight line was fitted manually.

The following sections review the literature on the losses of nutrients in heat processing of foods. The data for each nutrient were collected and k values at different temperatures and in different food products are presented.

4.5 Protein and essential amino acids

Generally, the nutritive value of protein is defined by its essential amino acid composition, taking that the amount of non-essential amino acids must be sufficient to minimise the metabolic diversion of the essential amino acids (157). In other words, the quality of protein depends on its ability to supply essential amino acids in sufficient amount to fulfill all the requirements for maintenance and growth (81).

There can be loss of nutritional value on heating. Reviewed by Bender 1970, Burger et al. 1973, the three types of reactions responsible for the nutritional changes are firstly maillard reactions i.e. amino groups especially of lysine react with either aldehyde groups of reducing sugars or carbonyl groups from oxidised fats (237); secondly, cross linkage reactions between protein molecules; and thirdly the damage to sulphur amino acids by oxidation and sulphydration. In relation to protein-protein cross linkages, Ford 1973 suggested several possibilities: an ester link of carbonyl group to a hydroxyl group of amino acid, thioester link between the carbonyl and thiol group and lastly an amide link between carbonyl group and amide group. As a result of these reactions, the new linkages found within or between peptide chains are suggested to have resistance to hydrolysis by the proteases of the gut and also impair the digestibility of adjacent peptide bonds due

to stearic hindrance to the access of proteolytic enzymes. Therefore, loss in nutritional value of protein means that a proportion of the amino acids are destroyed or made unavailable nutritionally.

The rate of amino acids destruction during heat processing can be determined by the decrease in the total amount of the individual amino acid in the food. There are problems in estimating the amino acid which is not destroyed but made unavailable nutritionally.

4.5.1 Methods of determining total and available amino acids

Total amino acids in a food can be determined by acid hydrolysis of the protein followed by either microbiological assays or by chromatography and colometric measurement of the individual amino acid . The availability of specific amino acids can be determined chemically, microbiologically and by bioassays. In determining the availability of specific amino acids, the results relate to the conditions of the test. For example, in comparing the results from rat growth assays and in vitro digests using proteolytic enzymes, Ford and Salter in 1966 found that 71 percent of the methionine, 81 percent isoleucine and 28 percent lysine were measured as available in the in vitro digests as against 42, 39 and 18 percent measured in the rat growth tests. Miller et al. 1965 found that the determination of available methionine by the organism Streptococcus zymogenes was lower than determined by the chick bioassay, unless the concentration of papain used in the enzyme predigestion was increased. In the enzymic determination of available lysine by the chemical method using fluorodinitrobenzene (FDNB) and by the chick bioassay,

Miller et al. in 1965 found that available lysine determined by the FDNB method was 93 percent while by chick bioassay it was 81 percent of the total lysine. Therefore, in studying the literature for data to use in the kinetics, attention was given to the total amino acids and the available amino acids, and also to the methods used in the determinations. This variability in methods of analysis makes it very difficult to use data from different papers in a generalised study such as this.

4.5.2 The effect of conditions on the kinetic rate constants

In compiling these data, the disparity in the estimated k values for each amino acid was found to be quite marked. Undoubtedly, this disparity was due to the differences in the conditions of the experiments such as moisture content, pH, duration of heat treatment and type of food products. With respect to moisture content, earlier work such as by Lea and Hannan in 1949 suggested that the maximum destruction occurred at moisture contents between 10 and 14 percent. Carpenter et al. 1962 heated defatted herring pressed cake at 130°C for 27 hours over the region of 0 to 50 percent moisture and found the maximum amino acid binding from 4 to 12 percent moisture for lysine, methionine and tryptophan. Miller et al. 1965 heating cod muscle at 85°C and 115°C for 27 hours over the region of 0 to 50 percent moisture content found the greatest loss in lysine at 14 percent moisture but methionine, tryptophan and leucine had increased losses at higher moisture contents. However, when chick assays were used instead of Streptococcus zymogenes, the destruction did not change with increased

moisture content. From the available data, it is not possible to relate the rate of destruction of amino acids with moisture content. But losses at very low moisture contents are possibly not relevant to the present study as they will be lower than can be expected during the processing of the infant food. Unfortunately, some of the papers did not state the moisture content of the foods, but generally foods with moisture contents below 4 percent were not used.

Duration of heat treatment in the experiments certainly has an effect on reaction rates. The accuracy in the analysis decreases as the concentration gets smaller. It is worth noting that most of the experiments done on protein are quite severe i.e. long holding times such as 18 or 24 hours at temperatures above 100°C . The difference in holding time will play an important role in the estimation of the k value. The k values derived from the shorter holding times will be markedly higher than those from longer holding times. In studying the situation where the reaction rate constant will be used to predict the loss during processing, which occurs for a short holding time, the initial stage of the reaction whenever possible was taken in the estimation.

Other factors which tend to affect the loss of amino acids and the availability of amino acids such as the amount of reducing sugars and pH were reviewed by Bender 1972 and Osner and Johnson 1968. The effect of reducing substances is found in the maillard reaction, a major cause of protein destruction and in particular of lysine. There is a great deal of evidence for the fall in nutritive value resulting

from the presence of reducing substances in heated protein (107, 195). Unfortunately, in the collection of the kinetic data, it was not possible to take this into account. With respect to pH, there is evidence that increasing pH causes the decomposition of sulphur amino acids (189). Schroeder et al. 1961 indicated that more of the amino acids are bound at higher pH.

Heat can have both beneficial and detrimental effects on protein. Beneficial effects have been reported; in particular all legumes (16) and some cereals such as wheat, rye, buckwheat, rice, oats and maize contain trypsin inhibitors and heating helps in destroying these.

Therefore, although heat must be applied adequately to certain raw materials such as legumes and cereals to improve its nutritional value, the further heating required in processing will certainly impair the amino acids and hence the protein quality. In order to find the effect of temperature on the destruction of the amino acids, data was collected from the literature on the retention of each essential amino acid related to time and temperature of processing. The other variables - type of product, pH, moisture content, method of analysis - were noted wherever possible but they were not used in calculating the reaction rate constants for each amino acid. The data was all treated as first order reaction and the reaction rate constants, related to temperature, of different amino acids were calculated.

4.5.3 The reaction rate constants for the destruction of the essential amino acids

As many data as possible related to known

temperatures and times were collected. In cases where the amino acid retention during different periods of heating were given, k values were estimated from the slope of the retention/heating time relationship graphed on semilog paper. Because of the lack of suitable data, single readings at the end of the heating time were also used. Both total and available amino acid data were collected. The data is shown in Tables 4.1 to 4.11. This data was compiled from various sources with differences in the experimental conditions, and disparity in the estimated values would be expected. It was felt that all the available information should be noted, and then the data examined to determine the most suitable for the kinetic studies.

Although it is difficult to generalize because of the wide variation in the data, the reaction rate constants for the available amino acid destruction was higher than for the total amino acid destruction. It was felt that the available amino acid data should be used wherever possible as this would give the greater predicted losses. However, in deciding which data to use consideration had to be given to the availability of the data, in particular the range of temperature available for each amino acid. The data had also to be in a form where it was possible to apply the Arrhenius equation. For these reasons, it was decided that data on total amino acids were used for histidine, threonine, phenylalanine, tyrosine, and valine. Data on available amino acids were used for lysine, leucine, methionine, isoleucine, cystine and tryptophan. For histidine, threonine, phenylalanine and valine, total amino acid data were used because it covered a wider range of

temperature than the available amino acids. For tyrosine, data on available tyrosine was not found. For lysine and methionine, there were more data on the available amino acid.

With available lysine, fluctuations due to moisture content were eliminated by using only data of higher moisture content. However, with the other amino acids there was not sufficient data available to do this.

With available methionine, data determined by Miller et al. 1965 using the chick assay were not included as it reflected a slower rate than the microbiological method. Otherwise, no attempt was made to exclude data because of the method of amino acid determination. Most of the available lysine were by the FDNE method and were comparable, but there was variation in the methods used for other amino acids.

For cystine and isoleucine, it was very difficult to decide on the data to use due to their disparity and scarcity. For both amino acids, the rate was higher with the available amino acid especially with the pork slurry at 113°C (19). To reflect this higher rate of reaction and yet allow the assumption of the validity of the Arrhenius equation, only some of the data on available cystine and isoleucine were selected to find the relationship between k and temperature. The data not included in the prediction of the k/temperature relationship are shown in brackets in the tables.

Table 4.1 Reaction Rate Constants for Histidine

Temp. °C	k X10 ⁻³ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Histidine</u>						
105.0	3.47	11.5	-	Chromatography + colorimetric	Cod fillet	Ellinger and Boyne 1965 (69)
110.0	3.48	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
120.0	8.22	-	-	Acid hydrolysis + <u>S. zymogenes</u>	Skim milk powder	Ford 1962 (83)
120.0	3.89	-	-	" "	Fish meal	" " (83)
121.0	43.60	-	-	Acid hydrolysis + <u>S. faecalis</u>	Soybean protein	Evans and Putts 1949 (72)
121.0	3.02	-	-	Acid hydrolysis + <u>S. lactis</u>	Cured pork	Beuk et al. 1948 (18)
150.0	194.23	9.9	-	Amino acid analysis	Coconut meal	Samson 1971 (214)
<u>Available Histidine</u>						
113.0	32.62	-	-	<u>S. lactis</u>	Fresh pork slurry	Beuk et al. 1948 (18)
116.0	36.93	-	-	<u>S. zymogenes</u>	Chicken muscle	Varnish et al. 1975 (246)
121.0	110.77	-	6.2	<u>L. mesenteroides</u>	Canned sword fish	Lopez - Matas Fellers 1948(153)
121.0	26.46	-	-	Enzyme hydrolysis + <u>S. lactis</u>	Fresh pork	Beuk et al. 1948 (18)
121.0	19.25	-	-	" "	Cured pork	" " (18)

Table 4.2 Reaction Rate Constants for Isoleucine

Temp. °C	k X10 ⁻³ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Isoleucine</u>						
110.0	3.02	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
116.0	2.91	-	-	" "	Chicken muscle	Varnish et al. 1975 (246)
120.0	2.70	-	-	Acid hydrolysis + <u>S. zymogenes</u>	Fish meal	Ford, 1962 (83)
120.0	13.25	-	-	" "	Skim milk powder	" " (83)
121.0	20.85	-	-	Acid hydrolysis + <u>L. arabinosus</u>	Soybean protein	Evans and Butts 1949 (72)
<u>Available Isoleucine</u>						
113.0	(65.97)	-	-	<u>L. arabinosus</u>	Fresh pork slurry	Beuk et al. 1949 (19)
114.0	20.63	6.0	-	<u>S. zymogenes</u>	Groundnut flour	Anantharaman and Carpenter 1971 (3)
116.0	43.99	-	-	<u>S. zymogenes</u>	Chicken muscle	Varnish et al. 1975 (246)
121.0	46.43	6.0	-	<u>S. zymogenes</u>	Groundnut flour	Anantharaman and Carpenter 1971 (3)
121.0	(29.73)	-	-	Enzyme hydrolysis + <u>L. arabinosus</u>	Fresh pork	Beuk et al. 1948 (18)
121.0	(17.95)	-	-	" "	Cured pork	" " (18)

Table 4.3 Reaction Rate Constants for Leucine

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Leucine</u>						
110.0	9.30	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
116.0	5.27	-	-	" "	Chicken muscle	Varnish et al. 1975 (246)
120.0	20.79	-	-	Acid hydrolysis + <u>S. zymogenes</u>	Skim milk powder	Ford 1962 (83)
120.0	3.17	-	-	" "	Fish meat	" " (83)
121.0	20.85	-	-	Acid hydrolysis + <u>L. arabinosus</u>	Soybean protein	Evans and Butts 1949 (72)
<u>Available Leucine</u>						
113.0	(54.83)	-	-	<u>L. arabinosus</u>	Fresh pork slurry	Beuk et al. 1949 (19)
114.0	(54.18)	6.0	-	<u>S. zymogenes</u>	Groundnut flour	Anantharaman and Carpenter 1971 (3)
116.0	30.39	-	-	<u>S. zymogenes</u>	Chicken muscle	Varnish et al. 1975 (246)
121.0	24.16	-	-	Enzyme hydrolysis + <u>L. arabinosus</u>	Fresh pork	Feuk et al. 1948 (18)
121.0	23.23	-	-	" "	Cured pork	" " (18)
121.0	58.13	6.0	-	<u>S. zymogenes</u>	Soybean protein	Anantharaman and Carpenter 1971 (3)
121.0	110.51	50.0	-	Enzyme hydrolysis + <u>L. mesenteroides</u>	Sesame meal	Villegas et al. 1968 (247)

Table 4.4 Reaction Rate Constants for Lysine

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Lysine</u>						
90.0	0.55	-	-	Acid hydrolysis + chromatography	Meat meal	Atkinson and Carpenter 1970 (10)
102.5	2.47	14.0	6.95	Ion exchange chromatography	Cod muscle protein	Miller et al. 1965 (162)
105.0	3.22	11.5	-	Chromatography + colorimetric	Cod fillet	Ellinger and Boyne 1965 (69)
110.0	9.30	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
116.0	3.99	14.0	6.95	Ion exchange chromatography	Cod muscle protein	Miller et al. 1965 (162)
120.0	8.32	-	-	Acid hydrolysis + <u>P. cerevisiae</u>	Skim milk powder	Ford 1962 (83)
120.0	21.99	9.9	-	Amino acid analyser	Coconut meal	Samson 1971 (214)
121.0	1.70	-	-	Acid hydrolysis + <u>L. mesenteroides</u>	Cured pork	Beuk et al. 1948 (18)
121.0	2.14	-	-	" "	Fresh pork	" " (18)
121.0	37.71	50.0	-	Acid hydrolysis	Sesame meal	Villegas et al. 1968 (247)
121.0	89.18	-	-	Acid hydrolysis + <u>L. mesenteroides</u>	Soybean protein	Evans and Futts 1948 (70)
130.0	287.74	-	-	-	Canned peas	Armbruster and Murray 1951 (8)
150.0	772.34	9.9	-	Amino acid analyser	Coconut meal	Samson 1971 (214)
<u>Available Lysine</u>						
23.0	0.0046	14.0	-	FDNB	Groundnut flours	Anantharaman and Carpenter 1971 (3)
23.0	(0.0092)	6.0	-	FDNB	" "	" " (3)
37.0	0.0186	14.0	-	FDNB	" "	" " (3)
37.0	(0.0092)	6.0	-	FDNB	" "	" " (3)
37.0	(3.41)	15.0	6.3	FDNB	Casein glucose mixture	Rao et al. 1963 (200)
56.0	0.144	14.0	-	FDNB	Groundnut flours	Anantharaman and Carpenter 1971 (3)
56.0	(0.0798)	6.0	-	FDNB	" "	" " (3)
70.0	43.02	-	-	FDNB	Beef fillet slurry	Dvorak and Vogmarova 1965 (65)
75.0	1.77	14.0	-	FDNB	Groundnut flours	Anantharaman and Carpenter 1971 (3)
75.0	(0.1256)	6.0	-	FDNB	" "	" " (3)
85.0	2.62	14.0	6.95	FDNB	Cod muscle protein	Miller et al. 1965 (162)
85.0	3.47	14.0	6.95	Chick	" "	" " (162)
90.0	3.50	-	-	FDNB	Meat meal	Atkinson and Carpenter 1970 (10)

Table 4.4 cont'd

Temp.	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Available Lysine cont'd</u>						
93.0	3.46	-	-	FDNB	Soybean milk - dried	Van Puren et al. 1964 (244)
100.0	20.00	50.0	-	-	Soybean meal	Labuza 1972 (146)
100.0	64.53	-	7.6	FDNB	Fish protein concentrate	Dubrow and Stillings 1970 (64)
107.0	(20.11)	6.0	-	FDNB	Groundnut flours	Anantharaman and Carpenter 1971 (3)
110.0	17.32	50.0	-	FDNB	Fork	Donoso et al. 1962 (63)
113.0	64.71	-	-	<u>L. mesenteroides</u>	Fresh pork slurry	Peuk et al. 1949 (19)
114.0	(50.28)	6.0	-	FDNB	Groundnut flours	Anantharaman and Carpenter 1971 (3)
115.0	46.00	50.0	-	-	Soybean meal	Labuza 1972 (146)
116.0	14.81	14.0	6.95	FDNB	Cod muscle protein	Miller et al. 1965 (162)
116.0	24.37	14.0	6.95	Chick	" "	" " (162)
121.0	31.47	-	-	Enzyme digestion + <u>L. mesenteroides</u>	Fresh pork	Beuk et al. 1948 (18)
121.0	39.24	-	-	" "	Cured pork	" " (18)
121.0	24.15	-	6.2	<u>L. mesenteroides</u>	Canned sword fish	Lopez - Matas and Fellers 1948 (153)
121.0	93.99	-	-	FDNB	Raw beef fillet slurry	Dvorak and Vognarova 1965 (65)
121.0	74.13	-	-	FDNB	Soybean milk - dried	Van Buren et al. 1964 (244)
121.0	(109.52)	6.0	-	FDNB	Groundnut flour	Anantharaman and Carpenter 1971 (3)
121.0	89.18	-	-	Enzyme digestion	Soybean protein	Evans and Eutts 1948 (70)
121.0	203.28	High	-	FDNB	Black beans in water	Pressani et al. 1963 (25)
121.0	212.86	50.0	-	FDNB	Sesame meal	Villegas et al. 1968 (247)
121.0	119.53	14.0	-	FDNB	Groundnut flour	Anantharaman and Carpenter 1971 (3)
121.0	235.44	-	-	Enzyme hydrolysis + <u>L. mesenteroides</u>	Soybean meal	Evans and Eutts 1948 (70)
126.0	166.00	50.0	-	-	Soybean meal	Labuza 1972 (146)
130.0	287.74	-	-	Enzyme digestion + microorganisms	Canned peas	Armbruster and Murray 1951 (8)
130.0	624.85	-	-	Enzyme digestion + <u>S. faecalis</u>	Dried peas	Evans and St. John 1948 (74)
140.0	221.97	-	-	FDNB	Beef fillet slurry	Dvorak and Vognarova 1965 (65)
150.0	91.67	-	7.5	FDNB	Fish protein concentrate	Dubrow and Stillings 1970 (64)

Table 4.5 Reaction Rate Constants for Methionine

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Methionine</u>						
110.0	7.26	50.0	-	Amino acid analyser	Perk	Donoso et al. 1962 (63)
116.0	7.40	-	-	Amino acid analyser	Chicken muscle	Varnich et al. 1975 (246)
120.0	12.57	-	-	Acid hydrolysis + <u>S. zymogenes</u>	Skim milk powder	Ford 1962 (83)
120.0	3.17	-	-	" "	Fish meal	" " (83)
121.0	15.47	-	-	Acid hydrolysis + <u>L. mesenteroides</u>	Soybean protein	Evans and Putts 1949 (72)
140.0	336.93	9.7	-	-	Casein solution	Takeo and Takatoshi 1967 (234)
150.0	407.06	9.9	-	Amino acid analyser	Coconut meal	Samson 1971 (214)
<u>Available Methionine</u>						
37.0	(0.576)	15.0	6.3	Enzyme hydrolysis + <u>S. zymogenes</u>	Casein glucose mixture	Rao et al. 1963 (200)
85.0	3.23	14.0	6.95	<u>S. zymogenes</u>	Cod muscle protein	Miller et al. 1965 (162)
85.0	12.06	50.0	6.95	" "	" "	" " (162)
85.0	(4.37)	14.0	6.95	Chick	" "	" " (162)
85.0	(4.37)	50.0	6.95	"	" "	" " (162)
90.0	6.28	-	-	<u>S. zymogenes</u>	Meat meal	Atkinson and Carpenter 1970 (10)
90.0	(4.47)	-	-	Chick	" "	" " (10)
102.5	8.01	14.0	6.95	<u>S. zymogenes</u>	Cod muscle protein	Miller et al. 1965 (162)
102.5	(8.01)	14.0	6.95	Chick	" "	" " (162)
102.5	23.68	50.0	6.95	<u>S. zymogenes</u>	" "	" " (162)
102.5	(9.31)	50.0	6.95	Chick	" "	" " (162)
110.0	174.20	-	-	Enzyme hydrolysis + <u>L. arabinosus</u>	Dry peas	Evans and St. Johns 1948 (74)
113.0	99.01	-	-	<u>L. mesenteroides</u>	Fresh pork slurry	Euik et al. 1949 (19)
116.0	35.25	-	-	<u>S. zymogenes</u>	Chicken muscle	Varnish et al. 1975 (246)
116.0	(13.88)	14.0	6.95	Chick	Cod muscle protein	Miller et al. 1965 (162)
116.0	21.77	14.0	6.95	<u>S. zymogenes</u>	Cod muscle protein	" " (162)
121.0	29.73	-	-	Enzyme hydrolysis + <u>L. mesenteroides</u>	Cured pork	Euik et al. 1948 (18)
121.0	30.59	-	-	" "	Fresh pork	" " (18)
121.0	43.60	-	-	<u>L. mesenteroides</u>	Soybean meal	Evans and Putts 1949 (72)
121.0	202.65	-	6.2	<u>L. arabinosus</u>	Canned sword fish	Lopez - Matos and Fellers, 1948 (153)
121.0	(42.62)	6.0	-	<u>S. zymogenes</u>	Groundnut flour	Anantharaman and Carpenter 1971 (3)
130.0	405.49	-	-	Enzyme hydrolysis + <u>L. arabinosus</u>	Dry peas	Evans and St. Johns 1948 (74)

Table 4.6 Reaction Rate Constants for Cystine

Temp. °C	k X10 ⁻³ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Cystine</u>						
85.0	6.75	14.0	6.95	Chromatography as cysteic acid	Cod muscle protein	Miller et al. 1965 (162)
102.5	15.02	14.0	6.65	" "	" "	" " (162)
105.0	28.56	11.5	-	Chromatography colorimetric	Cod fillet	Ellinger and Boyne 1965 (69)
110.0	24.16	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
116.0	40.69	14.0	6.95	Chromatography as cysteic acid	Cod muscle protein	Miller et al. 1965 (162)
120.0	95.15	-	7.5	Chromatography as cysteic acid	Fish protein concentrate	Dubrow and Stillings 1970 (64)
121.0	24.16	-	-	Acid hydrolyser + <u>L. mesenteroides</u>	Fresh pork	Beuk et al. 1948 (18)
121.0	24.16	-	-	" "	Cured pork	" " (18)
121.0	37.71	-	-	Acid hydrolysis + <u>L. mesenteroides</u>	Soybean protein	Evans and Butts 1949 (72)
<u>Available Cystine</u>						
113.0	(374.56)	-	-	<u>L. mesenteroides</u>	Fresh pork slurry	Beuk et al. 1949 (19)
121.0	46.20	-	-	Enzyme hydrolysis + <u>L. mesenteroides</u>	Cured pork	Beuk et al. 1948 (18)
121.0	54.57	-	-	" "	Fresh pork	" " (18)
121.0	71.93	-	-	" "	Soybean meal	Evans et al. 1951 (73)
130.0	209.16	-	-	Enzyme hydrolysis + <u>L. mesenteroides</u>	Dry peas	Evans and St. Johns 1948 (74)
130.0	274.48	-	-	-	Canned peas	Armbruster and Murray 1951 (8)

Table 4.7 Reaction Rate Constants for Phenylalanine

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Phenylalanine</u>						
110.0	4.40	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
120.0	23.58	9.9	-	" "	Coconut meal	Samson 1971 (214)
120.0	23.58	-	-	Acid hydrolysis + <u>L. arabinosus</u>	Soybean protein	Evans and Butts 1949 (72)
121.0	143.20	50.0	-	<u>L. mesenteroides</u>	Sesame meal	Villegas et al. 1968 (247)
140.0	103.16	97.0	-	-	Casein solution	Takeo and Takatoshi 1967 (234)
150.0	47.62	9.9	-	Amino acid analyser	Coconut meal	Samson 1971 (214)
<u>Available Phenylalanine</u>						
113.0	58.17	-	-	<u>L. arabinosus</u>	Fresh pork slurry	Beuk et al. 1949 (19)
121.0	25.68	-	-	Enzyme hydrolysis + <u>L. arabinosus</u>	Cured pork	Beuk et al. 1948 (18)
121.0	31.47	-	-	" "	Fresh pork	" " (18)

Table 4.8 Reaction Rate Constants for Tyrosine

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Tyrosine</u>						
110.0	4.86	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
120.0	156.34	9.9	-	" "	Coconut meal	Samson 1971 (214)
140.0	176.77	97.0	-	-	Casein solution	Takeo and Takatoshi. 1967 (234)
150.0	330.63	9.9	-	Amino acid analyser	Coconut meal	Samson 1971 (214)

Table 4.9 Reaction Rate Constants for Threonine

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Threonine</u>						
105.0	0.76	11.5	-	Chromatography + colorimetric	Cod fillet	Ellinger and Boyne 1965 (69)
110.0	5.81	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
140.0	73.66	97.0	-	-	Casein solution	Takeo and Takatoshi 1967 (234)
150.0	90.32	9.9	-	Amino acid analyser	Coconut meal	Samson 1971 (214)
<u>Available Threonine</u>						
113.0	71.39			<u>S. lactis</u>	Fresh pork slurry	Beuk et al. 1949 (19)
121.0	37.16	-	-	Enzyme hydrolysis + <u>L. arabinosus</u>	Fresh pork	Beuk et al. 1948 (18)
121.0	43.75	-	-	" "	Cured pork	" " (18)
121.0	183.09	-	6.2	<u>L. arabinosus</u>	Canned sword fish	Lopez - Matas and Fellers 1948 (153)
121.0	199.10	50.0	-	Enzyme hydrolysis + <u>S. faecalis</u>	Sesame meal	Villegas et al. 1968 (247)

Table 4.10 Reaction Rate Constants for Tryptophan

Temp. °C	k X10 ⁻³ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Tryptophan</u>						
90.0	0.37	-	-	Chemical	Meat meal	Atkinson and Carpenter 1970 (10)
110.0	2.14	50.0	-	Amino acid analyser	Pork	Donoso et al. 1962 (63)
120.0	2.83	-	-	Acid hydrolysis + <u>S. zymogenes</u>	Fish meal	Ford 1962 (83)
120.0	29.90	-	-	" "	Skim milk powder	Ford 1962 (83)
121.0	35.13	6.0	-	-	Groundnut flour	Anantharaman and Carpenter 1971 (3)
<u>Available Tryptophan</u>						
85.0	6.76	14.0	6.95	<u>S. zymogenes</u>	Cod muscle protein	Miller et al. 1965 (162)
85.0	25.68	50.0	6.95	" "	" "	" " (162)
90.0	11.61	-	-	" "	Meat meal	Atkinson and Carpenter 1970 (10)
90.0	2.29	-	-	Chick	Meat meal	" " (10)
102.5	19.96	14.0	6.95	<u>S. zymogenes</u>	Cod muscle protein	Miller et al. 1965 (162)
102.5	40.70	50.0	6.95	" "	" "	" " (162)
113.0	80.80	-	-	<u>L. arabinosus</u>	Fresh pork slurry	Beuk et al. 1949 (19)
116.0	46.06	-	-	<u>S. zymogenes</u>	Chicken muscle	Varnish et al. 1975 (246)
116.0	32.43	14.0	6.95	<u>S. zymogenes</u>	Cod muscle protein	Miller et al. 1965 (162)
121.0	40.32	-	-	Enzyme hydrolysis + <u>L. arabinosus</u>	Cured pork	Beuk et al. 1948 (18)
121.0	43.75	-	-	" "	Fresh pork	" " (18)
121.0	143.22	-	6.2	<u>L. arabinosus</u>	Canned sword fish	Lopez-Matas and Fellers 1948 (153)
121.0	(35.13)	6.0	-	<u>S. zymogenes</u>	Groundnut flour	Anantharaman and Carpenter 1971 (3)

Table 4.11 Reaction Rate Constants for Valine

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Method of analysis	Type of product	Reference
<u>Total Valine</u>						
105.0	164.92	9.9	-	Amino acid analyser	Coconut meal	Samson 1971 (214)
110.0	4.86	50.0	-	Amino acid analyser	Pork protein	Donoso et al. 1962 (63)
120.0	117.90	9.9	-	" "	Coconut meal	Samson 1971 (214)
120.0	39.47	-	-	Acid hydrolysis + <u>S. zymogenes</u>	Skim milk powder	Ford 1962 (83)
121.0	20.85	-	-	Acid hydrolysis + <u>L. arabinosus</u>	Soybean protein	Evans and Putts 1949 (72)
140.0	123.3	97.0	-	-	Casein solution	Takeo and Takatoshi 1967 (234)
150.0	252.36	9.9	-	Amino acid analyser	Coconut meal	Samson 1971 (214)
<u>Available Valine</u>						
113.0	62.83	-	-	<u>L. arabinosus</u>	Fresh pork slurry	Beuk et al. 1949 (19)
121.0	159.96	-	6.2	" "	Canned sword fish	Lopez-Matas and Fellers 1948 (153)
121.0	22.70	-	-	Enzyme hydrolysis + <u>L. arabinosus</u>	Cured pork	Beuk et al. 1948 (18)
121.0	25.68	-	-	" "	Fresh pork	" " (18)

4.6 Fat and Linoleic acid

It is generally known that fat and fatty acid are subject to oxidative deterioration (114). Labuza 1971 extensively reviewed the mechanism of fat oxidation in relation to fat rancidity during storage. It was summarized that it involves 3 periods i.e., induction period, monomolecular period and bimolecular period. The unsaturated acids are involved and three types of reaction generally occur i.e., initiation where a free radicle is formed, propagation where free radicle is propagated and the termination where the free radicles react and form non radicle products. The rate of this oxidative reaction of unsaturated acids is related to temperature (145). However in most heat processing in industry, there is not a significant breakdown of linoleic and linolenic acids until heating has been both prolonged and at a high temperature.

There is unlikely to be loss of saturated fats and fatty acids in processing unless hydrolysis of the fats occur and the fatty acids are leached out. As reviewed by Nesheim 1974, industrial processing did not have a significant effect on fats and fatty acids. Giddings and Hill 1975 found only slight losses in the lipid fraction and fatty acids of blue crab in autoclaving at 121⁰C for 10 minutes. Kinsella and Weihrauch 1976 found that processing such as degumming, refining, bleaching, deodorizing and winterizing did not alter the fatty acid composition of vegetable oils and fats and animal fats. Chow and Draper 1969 found that drying corn from ambient temperature to 143⁰C did not affect the fatty acids.

Because heat processing and drying has not been

reported to change the composition of fats and fatty acids in foods to any great extent and because the induction period of the oxidative reaction is known to take sometime, it was assumed that the reactions occurring during processing would not go beyond this induction period and there would be little loss of the unsaturated fatty acids.

From what information was available, it was decided to assume that fat and linoleic acid did not change during processing and therefore, they were not considered in the modification of the infant food model.

4.7 Vitamin A

As recommended by Joint FAO/WHO Expert Group on requirement of vitamin A (128), vitamin A values are expressed in terms of B-carotene equivalent and retinol. Food composition tables commonly use B-carotene and retinol, but the destruction of vitamin A is reported as loss of carotene. Therefore, the data collected and calculated was in terms of carotene.

Vitamin A and its precursor, B-carotene are stable to high temperature under an inert atmosphere (23, 12). It is easily oxidised in the presence of oxygen especially at high temperature and it is sensitive to ultraviolet light (114). In a review by Lang 1970, it was suggested that home cooking and industrial processing had little detrimental effect on carotene and retinol. Earlier investigations on the loss during cooking of vegetables reported the losses to be in the range of 0-10 percent (96, 177). Unfortunately these data cannot be interpreted kinetically. With milk products, Ford et al. 1969 found no loss of vitamin A using UHT processing. Henry et al. 1944 also found no loss of

vitamin A during evaporation of milk. Harris and Von Loesecke 1960, discussed that canning had little effect on the destruction of vitamin A; however, if it is exposed to atmospheric oxygen, loss can be high. In the review by Furger et al. 1973, loss of vitamin A in frying meat at 200°C can be as high as 40 percent after 5 minutes and 60 percent after 10 minutes. Not as high a loss was reported by Hannukainen 1974, in cooking of liver, the highest loss was found to be 16 percent. In another instance with exposure to atmospheric oxygen, Denton et al. 1944 gave an average retention of vitamin A in spray-dried egg under normal commercial practice to be 90-100 percent. Labuza 1972 summarized the average retention of carotene in drying carrots by tray drying to be 74 percent and by explosion puff drying to be 31 percent.

Although a number of investigations were studied on the destruction of vitamin A during processing, very little available data were kinetically meaningful. Most of the data interpreted were from storage tests on animal products. The only data at high temperatures was the work of Cook and Sundaram 1963 where food was heated by the household method of cooking. It was likely that the rate of reaction would be higher than actually occurred during the heating due to leaching and to the slow cooling down process. However, the data was used because of the shortage of data in particular of data for fresh food systems.

It was realised that moisture content has a marked effect, particularly in the vicinity of the monolayer moisture content, and that the rate of reaction was higher at very low moisture contents (156). However this effect is not

known in the high moisture foods such as fresh foods. The data on the very low moisture content foods were not included as they were not relevant to this study.

The effect of oxygen present was not considered in this study, but foods at reasonable levels of oxygen were used whenever possible.

The data in Table 4.12 is therefore mostly for canned foods stored at different temperatures.

Table 4.12 Reaction Rate Constants for Carotene

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
5.6	.046	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
5.6	.114	-	-	Canned green lima beans	" " (104)
5.6	.074	-	-	Canned whole kernel corn	" " (104)
17.0	.032	-	-	U.H.T. sterilised milk	Ford et al. 1969 (86)
29.4	.058	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
29.4	.151	-	-	Canned green lima beans	" " (104)
29.4	.044	-	-	Canned whole kernel corn	" " (104)
30.3	.006	-	6.3	Canned evaporated milk	Brenner et al. 1948 (24)
30.3	.004	-	6.3	Canned fruit and vegetable	" " (24)
30.3	.013	-	6.3	Canned whole kernel corn	" " (24)
30.3	.028	-	6.3	Canned orange juice	" " (24)
43.3	.064	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
43.3	.201	-	-	Canned green lima beans	" " (104)
43.3	.125	-	-	Canned whole kernel corn	" " (104)
100.0	185.58	In water	-	Boiled artichokes	Cook and Sundaram 1963 (51)
121.0	1137.84	In water	-	Boiled artichokes in pressure cooker	" " (51)

4.8 Vitamin D and Vitamin K

Vitamin D is quite stable to heat, acid and oxygen but slowly destroyed in alkali (114). Klose et al. 1943 found no loss of vitamin D in spray drying of egg. In milk, Henry et al. 1944 found that fat soluble vitamins were unaffected during processing. In canned fish, Nielands et al. 1947 found insignificant loss of vitamin D.

Vitamin K is stable to heat and reducing agents but sensitive to light and oxidation (114, 148). Due to its stability to heat and the ability of the intestinal flora to synthesize vitamin K, little information is available on the effect of heat on the stability of vitamin K. Richardson et al. 1961 found canning of vegetables had no influence on vitamin K.

As both vitamin D and vitamin K are known as stable vitamins to heat, the data available did not reveal any significant loss during heat processing. It does seem that the rate of the destruction reaction is very slow and does not change with temperature. Therefore, vitamin D and vitamin K were assumed not to change to any significant extent during heat processing.

4.9 Vitamin E

It is known that different forms of tocopherol differ considerably in their vitamin E activity. According to Sebrell and Harris 1971, 4 tocopherols and 4 tocotrienols are known to occur in nature; these are alpha, beta, gamma, delta, tocopherol and tocotrienols. Most plant sources are rich in α tocopherols such as wheat germ, corn, cotton seed. Two distinct patterns of tocopherol are found in cereal grains, i.e. the α , γ and δ pattern found in higher plants

such as soybean, linseed, peanut and α , β tocopherols as well as α and β tocotrienols in the staple cereals such as wheat, barley, rye and rice. Harris 1962 gave the conversion factors of various forms of tocopherol to α -tocopherol as

alpha - tocopherol	1.0
beta - tocopherol	0.5
gamma - tocopherol	0.2
delta - tocopherol	0.1

The unit of vitamin E is expressed in term of I.U. which is based on the following equivalents.

1 mg dl α tocopherol	= 1.1 I.U.
1 mg dl α tocopheryl acetate	= 1.0 I.U.

Therefore, various types of tocopherol can be related to vitamin E activity. However, the general term tocopherol was used in the data available on the destruction of vitamin E. Therefore the reaction rate constant was used in term of tocopherol.

Vitamin E is known as a vitamin sensitive to oxidation by atmospheric oxygen. In the absence of air, it is stable to heat treatment up to about 200°C. In the presence of strong acids, it can resist heat to 100°C and in the absence of oxygen is relatively stable to alkali (221). Oxidation of vitamin E is catalyzed by light and accelerated by the presence of unsaturated fatty acid. When oils are oxidized in the presence of air, peroxides are formed and tocopherol is destroyed (88). Most of the studies on tocopherol stability during processing have been in the area of milling, bleaching and storage of cereal grain (114). Loss of vitamin E during milling is expected through the

loss of germ and bran which are sources of vitamin E. During baking, Moore et al. 1957 found that 47 percent of the tocopherols in ordinary unbleached flour were destroyed in the baking of bread. The change during heating and storage of oils was studied by Ramanujan and Anantakrishnan 1958, and the loss of tocopherol was found in the range of 3-36 percent when various types of oil were heated at 175°C for 30 minutes. Ford et al. 1969 found that the UHT processing of milk at 138°C and 142°C for few seconds did not effect the content of tocopherol even after 90 days storage at 17°C. Chow et al. 1969 found that drying corn from ambient to 143°C had no effect on vitamin E. In overnight drying of seaweed at 40°C in a drying cabinet, Jensen 1969 found loss was approximately 20 percent. In canning, Hellendoorn et al. 1971 found sterilization had no effect on the vitamin E content. Studies on the effect of heat processing on the retention of vitamin E in food are limited and the data which can be interpreted kinetically are very scarce. The data available were on the storage of seaweed meal (124), the storage of potato chips (32) and the storage and processing of different oils (113). The effects of factors such as moisture content and pH were not available. The effect of oxygen was presumed to be included in the collected data due to the nature of the deterioration. The summarised data is shown in Table 4.13.

Table 4.13 Reaction Rate Constants of Vitamin E.

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content	pH	Type of product	Reference
4.0	.144	33.3	-	Seaweed meal	Labuza 1972 (146)
4.0	(.083)	17.6	-	" "	" " (146)
4.0	(.074)	11.1	-	" "	" " (146)
10.0	.242	-	-	" "	" " (146)
15.0	.416	33.3	-	" "	" " (146)
15.0	(.160)	17.6	-	" "	" " (146)
15.0	(.115)	11.1	-	" "	" " (146)
17.0	1.825	-	-	Potato chip	Bunnell et al. 1965 (32)
25.0	.583	33.3	-	Seaweed meal	Labuza 1972 (146)
25.0	(.361)	17.6	-	" "	" " (146)
25.0	(.175)	11.1	-	" "	" " (146)
37.0	.418	-	-	Coconut oil	Harris 1962 (113)
37.0	.781	-	-	Peanut oil	" " (113)
37.0	.757	-	-	Sesame oil	" " (113)
37.0	.495	-	-	Ghee	" " (113)
175.0	471.53	-	-	Coconut oil	" " (113)
175.0	724.26	-	-	Peanut oil	" " (113)
175.0	892.74	-	-	Sesame oil	" " (113)
175.0	60.928	-	-	Ghee	" " (113)

4.10 Ascorbic acid

Ascorbic acid is known as one of the most heat labile vitamins as reviewed up to 1960 by Harris and Von Loesecke and thereafter by Lang in 1970 and De Ritter in 1976. The oxidation reaction in foodstuff is dependent upon many factors such as oxidation reduction potential of the system, pH, oxygen, moisture content and trace metals especially copper and iron (14). Khan and Martell 1967 found that in the pH range of 2-5, destruction of ascorbic acid increased with increasing pH and decomposition rate was strongly accelerated by temperature. It was also found that alcohol

and sugar might be either prooxidants or antioxidants depending on their concentrations and the presence of natural substances in food such as anthocyanin or other phenolic compounds. The detail of pathways and reactions involved in oxidation of ascorbic acid was given by Bauernfeind and Finkert 1970.

In collecting data, it was found that moisture content plays an important role especially in the dry product. Gooding 1962 reported significantly increasing rate of destruction (5 times) when moisture content in the dried cabbage increased from 3 to 5 percent. Vojnovich and Pfeifer 1970 studied the destruction of ascorbic acid in wheat flour at different moisture contents and found that destruction rate of ascorbic acid increased as moisture content or temperature increased. However, effect of moisture content at given temperature depends on type of raw material; for example, ascorbic acid in wheat flour stored at 13.7 percent moisture was reasonably stable, whereas for similar stability the moisture content of corn soya milk had to be no more than 9 percent and of infant cereal no more than 10 percent.

Regarding losses during food processing, destruction of ascorbic acid in canning of vegetables reviewed by Cain 1967 was from 67 to 95 percent. In dehydration, losses varied widely from 10 percent to complete destruction (114) due to the different structures of raw materials, their susceptibility to oxidation and leaching during blanching. For UHT processing of milk, loss was approximately 20 percent (86) but in bottle sterilization of milk, loss was as high as 60 percent.

In the present study, most of the data used were for different types of food at their normal pHs and with high moisture contents, except for wheat flour and corn soya milk. With the latter products, the reaction rate constants at the highest moisture content - 14.6 and 11.8 percent - were considered reasonable to use. Unfortunately, although a great number of investigations have been carried out on the stability of ascorbic acid, only a limited number can be interpreted kinetically. The reaction rates calculated are shown in Table 4.14.

Table 4.14 Reaction Rate Constants for Ascorbic Acid

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
5.6	.095	-	-	Canned whole kernel corn	Guerrant et al. 1945 (104)
5.6	.103	-	-	Canned green lima beans	" " (104)
5.6	.085	-	-	Canned tomato juice	" " (104)
9.1	.007	-	-	Canned orange juice	Ross 1944 (210)
17.0	5.958	-	-	U.H.T. sterilised milk in aluminium foil carton	Ford et al. 1969 (86)
21.0	.035	73.3	4.32	Canned tomato paste	Lamb et al. 1951 (147)
21.0	.011	94.2	4.23	Canned tomato juice	" " (147)
21.1	.030	-	3.90	Canned apricot	Brenner et al. 1948 (24)
21.1	.018	-	3.56	Canned orange juice	" " (24)
21.1	.017	-	5.40	Canned spinach	" " (24)
21.1	.006	-	4.35	Canned tomato juice	" " (24)
21.1	.615	-	6.30	Canned peas	" " (24)
24.2	.035	-	-	Canned orange juice	Ross 1944 (210)
26.0	.018	14.6	-	Wheat flour	Vojnovich and Pfeifer 1970 (248)
26.0	(.012)	13.7	-	Wheat flour	" " (248)
26.0	(.006)	12.9	-	Wheat flour	" " (248)
26.0	.125	11.8	-	Corn soya milk	" " (248)
26.0	(.054)	10.4	-	Corn soya milk	" " (248)
26.0	(.012)	8.0	-	Corn soya milk	" " (248)
29.4	.110	73.3	4.32	Canned tomato paste	Lamb et al. 1951 (147)
29.4	.245	-	-	Canned whole kernel corn	Guerrant et al. 1945 (104)
29.4	.148	-	-	Canned green lima beans	" " (104)
29.4	.339	-	-	Canned tomato juice	" " (104)
32.1	.098	-	3.90	Canned apricot	Brenner et al. 1948 (24)
32.1	.089	-	3.56	Canned orange juice	" " (24)
32.1	.033	-	5.40	Canned spinach	" " (24)
32.1	.031	-	4.35	Canned tomato juice	" " (24)
32.1	.019	-	6.30	Canned peas	" " (24)

Table 4.14 cont'd

Temp. °C	k X10 ⁻³ hr ⁻¹	Moisture content %	pH	Type of product	Reference
37.0	.077	14.6	-	Wheat flour	Vojnovich and Pfeifer 1970 (248)
37.0	(.054)	13.7	-	Wheat flour	" " (248)
37.0	(.024)	12.9	-	Wheat flour	" " (248)
37.0	1.333	11.8	-	Corn soya milk	" " (248)
37.0	(.345)	10.4	-	Corn soya milk	" " (248)
37.0	(.036)	8.0	-	Corn soya milk	" " (248)
37.0	.210	-	-	Canned orange juice	Ross 1944 (210)
37.8	.298	-	4.32	Canned tomato paste	Lamb et al. (147) 1951
37.8	.168	-	3.90	Canned apricot	Brenner et al. 1948 (24)
37.8	.183	-	3.56	Canned orange juice	" " (24)
37.8	.097	-	5.40	Canned spinach	" " (24)
37.8	.064	-	4.35	Canned tomato juice	" " (24)
37.8	.028	-	6.30	Canned peas	" " (24)
43.3	.323	-	-	Canned whole kernel corn	Guerrant et al. 1945 (104)
43.3	.425	-	-	Canned green lima beans	" " (104)
43.3	.148	-	-	Canned tomato juice	" " (104)
45.0	.815	14.6	-	Wheat flour	Vojnovich and Pfeifer 1970 (248)
45.0	(.292)	13.7	-	Wheat flour	" " (248)
45.0	(.089)	12.9	-	Wheat flour	" " (248)
45.0	3.642	11.8	-	Corn soya milk	" " (248)
45.0	(1.220)	10.4	-	Corn soya milk	" " (248)
45.0	(0.077)	8.0	-	Corn soya milk	" " (248)
50.0	81.9	-6.0-6.2	-	Squash puree	Sistrunk and Cash 1970 (227)
50.0	(.678)	-	3.2	Mixture of vitamins in 36 percent sugar	Garrett 1956 (92)
60.0	(1.99)	-	3.2	" "	" " (92)
70.0	(5.55)	-	3.2	" "	" " (92)
82.5	445.8	-6.4-6.8	-	Heating spinach in steam kettle	Clydesdale et al. 1971 (45)
100.0	1340.908	89.2	-	Steam-boiled artichokes	Cook and Sundaram 1963 (51)
121.0	3307.334	81.1	-	Pressure cooked artichokes	" " (51)

4.11 Thiamine

Thiamine is a vitamin that has been extensively studied by many research workers. The destruction of thiamine is reported to be thermal and not oxidative (78). The extent of thermal degradation and the nature of the products formed was discussed in detail by Dwivedi and Arnold 1973. Two possible reactions are suggested: the breaking of the CH bridge, freeing the moities of pyrimidine and thiazole, and the breaking down of the thiazole ring to produce hydrogen sulphide. The type of breakdown is controlled by the pH of the food.

In collecting data to estimate the k value, thiamine was found to be the only vitamin where extensive work had been done on the kinetic reaction such as Feliciotti et al. 1957 and Mulley et al. 1975a, and 1975b. A number of data were already given as the reaction rate constant. Only data from the work of Guerrant et al. 1945 and Greenwood et al. 1944 were calculated. Data collected demonstrated the effects of moisture content, pH and the form of thiamine as co-carboxylase.

It was found that with the low moisture content foods that increasing moisture content increased the rate of thiamine destruction (204, 188). The reaction rate constants calculated from the study on storage of dehydrated pork at 0,2,4,6 and 9 percent moisture for 7 days at 49°C by Rice et al. 1944 were 0.56, 3.04, 9.58, 13.71 and 13.14 $\times 10^{-3}\text{hr}^{-1}$ respectively. However, the high moisture food or "wet" foods appeared to have lower reaction rate constants than dried foods, for example at 27°C dehydrated pork had k value of $0.4583 \times 10^{-3}\text{hr}^{-1}$ and canned tomato

juice at 29°C had $0.0179 \times 10^{-3} \text{hr}^{-1}$. There is inadequate data to establish the rate of loss over the wide range of moisture content in the processing of any particular product. In this study, only the data from the high moisture foods were selected.

With the effect of pH, it was found that the rate increased with increasing pH from 4.5 to 7, and changed sharply at pH 6.0 - 6.5 (79, 175). The pH in the foods studied for destruction of thiamine varied throughout this range, from the acid foods such as canned tomato juice to the near neutral foods such as canned pork, and there is some variation in k values due to this variation. Unfortunately, very few of the foods had the pH recorded and it was not possible to separate them according to pH. All foods at their natural pHs were used.

For the form of thiamine, Feliciotti et al. 1957 found a slight increase in the rate of reaction with higher amounts of combined thiamine, as shown in Table 4.15. The form of thiamine in food varies quite considerably e.g. 88 percent of combined thiamine in lamb to 13 percent in pork. However, the reaction rate constants did not vary very much. In addition, the rate of reaction was found to be less when thiamine was present as co-carboxylase (175). However, Mulley et al. 1975b found that the presence of co-carboxylase up to one third of the thiamine, as generally occurred in foods, did not affect the kinetics of the thermal destruction.

Other factors reported to affect the thermal destruction of thiamine were the presence of ions such as copper, of oxygen and of oxidizing agents (78, 59). The

presence of copper ion has long been recognized to have an influence on accelerating the rate of destruction of thiamine (175). However, as only data from processing or storage of food products were collected, the effect of these factors are expected to be included. The reaction rate constants as collected and calculated are shown in Table 4.15.

Table 4.15 Reaction Rate Constants for Thiamine

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
5.6	.005	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
5.6	.01	-	-	Canned whole kernel corn	" " (104)
27.0	(.458)	-	-	Dehydrated pork	Labuza 1972 (146)
29.4	.018	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
29.4	.030	-	-	Canned green lima beans	" " (104)
29.4	.057	-	-	Canned whole kernel corn	" " (104)
37.0	(1.792)	-	-	Dehydrated pork	Labuza 1972 (146)
43.3	0.122	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
43.3	0.170	-	-	Canned green lima beans	" " (104)
43.3	0.237	-	-	Canned whole kernel corn	" " (104)
49.0	(9.000)	-	-	Dehydrated pork	Labuza 1972 (146)
63.0	(24.083)	-	-	" "	" " (146)
89.0	150.000	-	-	Fresh pork	" " (146)
99.0	150.000	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)
100.0	126.000	-	6.5	Peas, puree	Farrer 1953 (77)
100.0	132.000	-	5.7	Carrot, puree	" " (77)
100.0	162.000	-	5.5	Cabbage, puree	" " (77)
100.0	156.000	-	5.9	Potato, puree	" " (77)
104.0	348.000	-	-	Canned peas, brine packed	Bendix et al. 1951 (17)
104.0	276.000	-	-	Canned peas, vacuum packed	" " (17)
110.0	336.000	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)
110.0	340.00	-	-	Fresh pork	Labuza 1972 (146)
118.3	732.00	-	-	Canned peas, brine packed	Bendix et al. 1951 (17)
118.3	852.00	-	-	Canned peas, vacuum packed	" " (17)
118.3	414.00	-	-	Canned peas, puree	" " (17)
118.3	648.00	-	-	Canned peas, pureed in buffer solution	" " (17)
118.5	660.00	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)

Table 4.15 cont'd

Temp.	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
120.0	(372.00)	-	3.5	Thiamine in buffer solution	Feliciotti and Esselen 1957 (79)
120.0	(348.00)	-	4.53	" "	" " (79)
120.0	(396.00)	-	5.0	" "	" " (79)
120.0	(456.00)	-	5.5	" "	" " (79)
120.0	(756.00)	-	6.0	" "	" " (79)
120.0	(1968.00)	-	6.5	" "	" " (79)
120.0	(9060.00)	-	7.0	" "	" " (79)
120.0	720.00	90.7	6.13	Carrot, puree (46.0) ^a	" " (79)
120.0	732.00	93.2	5.83	Green beans, puree (44.0) ^a	" " (79)
120.0	684.00	84.4	6.75	Peas, puree (19.0) ^a	" " (79)
120.0	774.00	77.2	6.18	Pork, puree (13.0) ^a	" " (79)
120.0	858.00	93.5	6.7	Spinach, puree (76.0) ^a	" " (79)
120.0	942.00	82.7	6.1	Beef heart, puree (58.0) ^a	Feliciotti and Esselen 1957 (79)
120.0	882.00	79.2	6.07	Beef liver, puree (55.0) ^a	" " (79)
120.0	828.00	80.3	6.18	Lamb, puree (88.0) ^a	" " (79)
121.0	(880.80)	-	6.0	Phosphate-buffered Thiamine	Mulley et al. 1975a (175)
121.0	559.20	85.0	6.0	Peas, puree	" " (175)
121.0	543.53	85.0	6.0	Beef, puree	" " (175)
121.0	609.00	85.0	6.0	Peas, in brine	" " (175)
126.5	1320.00	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)
126.5	1320.0	-	-	Fresh pork	Labuza 1972 (146)
127.0	1716.00	-	-	Peas, brine packed	Bendix et al. 1951 (17)
127.0	1356.00	-	-	Peas, vacuum packed	Bendix et al. 1951 (17)
127.0	(1482.00)	-	6.0	Thiamine in buffer solution	Mulley et al. 1975a (175)
127.0	697.80	85.0	6.0	Peas, puree	" " (175)
127.0	863.40	85.0	6.0	Beef, puree	" " (175)
127.0	949.80	85.0	6.0	Peas, in brine	" " (175)
129.0	1710.00	90.7	6.13	Carrot, puree	Feliciotti and Esselen 1957 (79)
129.0	1866.00	93.2	5.83	Green beans, puree	" " (79)
129.0	1656.00	84.4	6.75	Peas, puree	" " (79)
129.0	1728.00	77.2	6.18	Pork, puree	" " (79)
129.0	2016.00	93.5	6.7	Spinach, puree	" " (79)
129.0	2352.00	82.7	6.1	Beef heart, puree	Feliciotti and Esselen 1957 (79)
129.0	2184.00	79.2	6.07	Beef liver, puree	" " (79)
129.0	2262.00	80.3	6.18	Lamb, puree	" " (79)

Table 4.15 cont'd

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
129.5	(1368.00)	-	4.5	Thiamine hydrochloride + 35 percent Coccarboxylase	Mulley et al. 1975b (176)
129.5	(1206.00)	-	5.0	" "	" " (176)
129.5	(1428.00)	-	5.5	" "	" " (176)
129.5	(1372.00)	-	6.0	" "	" " (176)
129.5	(4212.00)	-	6.5	" "	" " (176)
129.5	(1392.00)	-	4.5	Thiamine hydrochloride	" " (176)
129.5	(1290.00)	-	5.0	" "	" " (176)
129.5	(1284.00)	-	5.5	" "	" " (176)
129.5	(1818.00)	-	6.0	" "	" " (176)
129.5	(3834.00)	-	6.5	" "	" " (176)
132.0	(2556.00)	-	6.0	Thiamine in buffer solution	Mulley et al. 1975a (175)
132.0	1320.00	85.0	6.0	Peas, puree	" " (175)
132.0	1504.80	85.0	6.0	Beef, puree	" " (175)
132.0	1815.60	85.0	6.0	Peas, in brine	" " (175)
132.0	2106.00	-	-	Peas, brine packed	Eendix et al. 1951 (17)
132.0	2106.00	-	-	Peas, vacuum packed	" " (17)
138.0	(4026.00)	-	6.0	Thiamine in buffer solution	Mulley et al. 1975a (175)
138.0	2250.00	85.0	6.0	Peas, puree	" " (175)
138.0	2203.80	85.0	6.0	Beef, puree	" " (175)
138.0	2463.00	85.00	6.0	Peas, in brine	Mulley et al. 1975a (175)
138.0	4260.00	90.7	6.13	Carrot, puree	Felicetti and Esselen 1959 (79)
138.0	4302.00	93.2	5.83	Green beans, puree	" " (79)
138.0	4248.00	84.4	6.75	Peas, puree	" " (79)
138.0	4302.00	77.2	6.18	Fork, puree	" " (79)
138.0	4950.0	93.2	6.7	Spinach, puree	" " (79)
138.0	6366.00	82.7	6.1	Beef heart, puree	" " (79)
138.0	5352.00	79.7	6.07	Beef liver, puree	" " (79)
138.0	4884.00	20.3	6.18	Lamb, puree	" " (79)
149.0	10014.00	90.7	6.13	Carrot, puree	" " (79)
149.0	10464.00	93.2	5.83	Green beans, puree	" " (79)
149.0	9942.00	84.4	6.75	Peas, puree	" " (79)
149.0	10158.00	77.2	6.18	Pork, puree	" " (79)
149.0	13680.00	93.5	6.7	Spinach, puree	" " (79)
149.0	13020.00	82.7	6.1	Beef heart, puree	" " (79)
149.0	13956.00	79.2	6.07	Beef liver, puree	" " (79)
149.0	11610.00	20.3	6.18	Lamb, puree	" " (79)

()^a Percent combined thiamine

4.12 Riboflavin

Riboflavin is comparatively stable to heat but unstable to light. The sensitivity to light increases with temperature and pH (114). Cain 1967 reviewed that dehydrated beef and sweet potatoes retained all their riboflavin while canned asparagus and spinach retained only 88 to 90 percent. Ford et al. 1969 found no loss of riboflavin by UHT processing of milk. The stability of riboflavin towards heat was reviewed by Rolls and Porter 1973 who concluded that heat treatment had little significant effect on the riboflavin in milk. However, loss can be significant if exposed to sunlight. Singh et al. 1975 found the destruction rate of riboflavin increased four fold when milk was stored in glass containers instead of paperboard at 10°C for 72 hours ($11.02 \times 10^{-4} \text{hr}^{-1}$ compared to $2.72 \times 10^{-4} \text{hr}^{-1}$). Loss during cooking and boiling was also reviewed by Lang 1970 to be in the range of 10 to 20 percent, and during roasting and frying to be in the range of 15 - 20 percent.

Most of the data collected were from canned food where the effect of light would not be included. The data with high heating temperatures were from cooking artichokes and fish either by boiling or in a pressure cooker. It was obvious that if light was screened off, heat did not have much effect as revealed by the rates of reaction calculated from the work of Greenwood et al. 1944 over the temperature range of 99 to 126.5°C, during storage of different canned food and milk in glass bottle (226). Therefore the data on the heating and storage of canned food were not included in this study in order that the predicted loss would include

loss due to light as in general heat processing. Data were not available to take into account the effect of pH, but as previously discussed the data taken from a variety of food systems were used so as to give at least a variation of pH in the natural range of foods. Although meaningful data on the effect of heat on riboflavin are limited, the data on the destruction of riboflavin that could be interpreted kinetically were collected and the reaction rate constants were calculated and are presented in Table 4.16.

Table 4.16 Reaction Rate Constants for Riboflavin

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
1.7	.777	-	-	Milk	Singh et al. 1975 (226)
4.4	.875	-	-	Milk	" " (226)
5.6	(.012)	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
5.6	(.012)	-	-	Canned green lima beans	" " (104)
5.6	(.014)	-	-	Canned whole kernel corn	" " (104)
10.0	1.102	-	-	Storage of milk	Singh et al. 1975 (226)
29.4	(.024)	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
29.4	(.024)	-	-	Canned green lima beans	" " (104)
29.4	(.019)	-	-	Canned whole kernel corn	" " (104)
43.3	(.063)	-	-	Canned tomato juice	" " (104)
43.3	(.033)	-	-	Canned green lima beans	" " (104)
43.3	(.032)	-	-	Canned whole kernel corn	" " (104)
99.0	(17.14)	55.0	-	Canned luncheon pork	Greenwood et al. 1944 (102)
100.0	9.626	In water	-	Boiled artichokes	Cook and Sundaram 1963 (51)
110.0	(5.08)	55.0	-	Canned luncheon pork	Greenwood et al. 1944 (102)
118.5	(2.67)	55.0	-	Canned luncheon pork	" " (102)
126.5	(7.74)	55.0	-	Canned luncheon pork	" " (102)
121.0	857.06	In water	-	Boiled artichokes	Cook and Sundaram 1963 (51)
121.0	1414.93	-	-	Fish in pressure cooker	Kennedy and Ley 1971 (133)

4.13 Niacin

Niacin, a vitamin in the form of nicotinic acid and nicotinamide, is heat stable in both acid and alkaline media. It is quite stable to air and light (114). In the review by Cain 1967, loss of niacin during canning of fruit and vegetable was 6.9 percent and during dehydration was 8 percent. Rice et al. 1947 studying the cooking of ham found niacin loss was 10 percent. Miller et al. 1973, studying retention of niacin in bean products found the niacin loss only occurred in discarded cooking water; retorting at 121°C for 45-90 minutes did not cause significant breakdown, the loss was only 7.2 percent. Morgan et al. 1944 found niacin loss in dehydrated carrot and potatoes to be 7 and 6 percent respectively. In UHT processing of milk, the loss was found to be very small i.e. 2 percent in direct heating at 138°C for 2 seconds (86).

The collected kinetic data were from the storage and processing of canned food and the cooking of fish and artichokes. The rates of reaction at 121°C varied a great deal. It is likely that the high losses reported by Kennedy and Ley 1971 and Cook and Sundaram 1963 on domestic cooking of fish and artichokes included the drip and leaching losses while the lower losses in canned lima beans did not. As niacin is known to be quite stable to air and light, the data on canned food was assumed to be representative of general heat processing. The data from cooking fish and artichokes were not used because it was not possible to predict how much of the loss was due to leaching and how much to heat processing.

All the data used were for high moisture content

foods such as canned peas and luncheon pork as shown in Table 4.17.

Table 4.17 Reaction Rate Constants for Niacin

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
22.0	.009	76.0	-	Canned army ration	Hellendoorn et al. 1971 (116)
31.6	.004	-	-	Canned peas	Brenner et al. 1948 (24)
99.0	6.06	50.0	-	Luncheon pork	Greenwood et al. 1944 (102)
100.0	(66.713)	-	-	Boiled artichokes	Cook and Sundaram 1963 (51)
110.0	14.16	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)
115.0	320.39	-	-	Canned corn	Charlampowicz and Sobiech 1965 (40)
118.5	127.2	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)
121.0	49.93	-	-	Canned lima beans	Miller et al. 1973 (161)
121.0	(612.45)	-	-	Fish in pressure cooker	Kennedy and Ley 1971 (133)
121.0	(846.384)	-	-	Artichokes in pressure cooker	Cook and Sundaram 1963 (51)
126.5	282.6	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)

4.14 Vitamin B6

Vitamin B6 is a group of compounds consisting of pyridoxine, pyridoxal and pyridoxamine. Pyridoxine is stable to heat, strong acid and alkali but sensitive to light; while pyridoxal and pyridoxamine are sensitive to heat, light and oxygen (114). Polanski et al. 1969 found pyridoxal and pyridoxamine are the predominant forms of vitamin B6 in animal products. During the heating process, transamination occurred and pyridoxal was converted to pyridoxamine. Schroeder 1971, analysed vitamin B6 in a large variety of foods and found losses in canned vegetables ranged from 57 to 77 percent; in fish and seafood canning

the loss was approximately 49 percent. A wider range of losses is expected in canned vegetable because of variation in the losses occurring during blanching. When only losses during canning were considered, Miller et al. 1973 found that when retorting canned beans at 121°C for 90 minutes; the loss was only 2.5 percent. Hellendoorn et al. 1971 found no loss of vitamin B6 during sterilization of canned army rations. In heating milk, loss due to UHT processing was slightly less than 10 percent (86) and loss in bottle sterilization of milk was approximately 20 percent (209).

Data collected for vitamin B6 were mostly from the storage or the processing of bottled or canned products except for some data from the cooking of artichokes by Cook and Sundaram 1963. The rates of reaction were higher in cooking of artichokes compared to the rates calculated from heating of the canned products, and this increased rate might be due to leaching and exposing to light. However, the rates of reaction calculated from the storage of canned and bottled products at 20°C and 30°C did not reveal any significant difference. Though it is realized that data from Cook and Sundaram probably included losses due to leaching, it was used in order that the data included cooking food in air as well as in cans. The calculated rates of reaction is shown in Table 4.18.

Table 4.18 Reaction Rate Constants for Vitamin B6

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
17.0	.486	-	-	Storage of milk	Ford et al. 1969 (86)
20.0	.073	81.9	-	Bottled strained beef	Everson et al. 1964 (75)
20.0	.089	81.8	-	Canned strained beef	" " (75)
20.0	.055	86.3	-	Bottled lima beans	" " (75)
20.0	.063	85.7	-	Canned lima beans	" " (75)
30.0	.076	81.9	-	Bottled strained beef	" " (75)
30.0	.098	81.8	-	Canned strained beef	" " (75)
30.0	.074	86.3	-	Bottled lima beans	" " (75)
30.0	.062	85.7	-	Canned lima beans	" " (75)
100.0	589.92	In water	-	Boiling artichokes	Cook and Sundaram 1963 (51)
115.0	206.32	-	-	Canned corn	Charlampowicz and Sobiech 1965 (40)
116.0	21.06	-	-	Canned lima beans	Raab et al. 1973 (197)
116.0	54.82	-	-	" "	" " (197)
121.0	16.87	-	-	" "	Miller et al. 1973 (161)
121.0	2482.60	In water	-	Artichokes in pressure cooker	Cook and Sundaram 1963 (51)

4.15 Vitamin B12

Vitamin B12, or cyanocobalamin, is stable to heat in the pH range of 4 to 7 but unstable when heated in alkaline or strong acid media and when exposed to sunlight (114, 43, 23). However, the pH in food is generally 4 to 7 where vitamin B12 is stable.

Reviewed by Rolls and Porter 1973, vitamin B12 loss in bottle sterilization of milk at 110 and 112°C for 15 to 20 minutes was only 20 percent. Ford et al. 1969 found UHT processing of milk at 138°C and 145°C to be 13 to 17 percent respectively. Investigation on the destruction of vitamin B12

in milk suggested that it was the consequence of the oxidative destruction of ascorbic acid, dissolved oxygen in milk would hasten the reaction (84). However, in heat sterilization of other canned products such as canned army rations where the processing times and temperatures were generally greater, the average loss was only 12 percent. Approximately the same loss was found by Charlampowicz and Sobiech 1965 in the canning of corn at 115°C for 30 minutes, i.e. the loss was 14.8 percent.

Unfortunately, very little of the data on the destruction of vitamin B12 in foods can be interpreted kinetically. The rates of reaction from the study of Garrett 1956 on the heating of a vitamin mixture, though not in the food system, fitted with the other two calculated rates of reaction on milk and canned corn and hence, were used in this study. The rates of reaction of vitamin B12, shown in Table 4.19 are obviously not a reliable indication of the reaction rate constants for vitamin B12 destruction but had to be used in this study because of the lack of data.

Table 4.19 Reaction Rate Constants for Vitamin B12

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
17.0	.010	-	-	Storage of milk	Ford et al. 1969 (86)
50.0	.392	-	3.2	Mixture of vitamin in 36 percent sugar	Garrett 1956 (92)
60.0	1.255	-	3.2	" "	" " (92)
70.0	3.186	-	3.2	" "	" " (92)
115.0	320.39	-	-	Canned corn	Charlampowicz and Sobiech 1965 (40)

4.16 Pantothenic acid

According to an extensive review by Harris and Von Loesecke 1960, pantothenic acid is stable in neutral pH in the range of 5.5 to 7. In alkaline pH, it is hydrolyzed to pantoic acid which forms lactone upon heating, and in acid pH, it is hydrolyzed to pantolactone. It is a moderately heat labile vitamin but stable to light and oxygen.

Schroeder 1971 reviewed the losses of pantothenic acid in canned foods; in canned animal foods, losses ranged from 20 to 35 percent, in canned fruit juice 50.5 percent and in canned vegetables from 46 to 78 percent. It is most likely that the large variations found in canned vegetables is due to differences in structure and susceptibility to leaching during blanching. In dehydration, Morgan et al. 1944 found losses of pantothenic acid in dehydrated carrot to be 6 percent and no loss was found in dehydrated potatoes. In dehydrated beef, higher loss was found, 32 percent, by Rice et al. 1944. In UHT processing of milk at 127 - 140°C for 3 - 15 seconds, Ford et al. 1969 found no loss of pantothenic acid. The effect of processing on milk was reviewed by Rolls and Porter 1973 and they concluded that heat treatment did not affect pantothenic acid. In experiments with cooking beef, Meyer et al. 1969 found that roasted loin retained 89 percent and recovery in drip was 11 percent. In braised meat, average retention was 56 percent with 44 percent recovered in the drip. Seemingly, loss of pantothenic acid due to heat is very small.

The collected data were from the storage and processing of canned products and from the cooking of

artichokes. Data from the study of Garrett 1956, with the mixture of vitamins in syrup, seemed to fit in well with the food data, and it was therefore decided to use it in this study. It was obvious that the rates of reaction calculated from the losses during boiling and pressure cooking of artichokes was considerably higher than the rates of reaction calculated from the data on heating canned products. Therefore only data from the canned products and for closed containers (92) were used in this study for the same reason as for niacin. The data collected were from high moisture content foods. The pH did not seem to affect the rate of reaction to any great extent, comparing the work of Garrett 1956 at low pH to other canned foods where pHs were generally in the range of 5 to 6. The rates of reaction for pantothenic acid are shown in Table 4.20.

Table 4.20 Reaction Rate Constants for Pantothenic acid

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
5.6	.060	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
5.6	.019	-	-	Canned green lima beans	" " (104)
5.6	.019	-	-	Canned whole kernel corn	" " (104)
22.0	.021	76.0	-	Canned army ration	Hellendoorn et al. 1971 (116)
29.4	.099	-	-	Canned tomato juice	Guerrant et al. 1945 (104)
29.4	.035	-	-	Canned green lima beans	" " (104)
29.4	.041	-	-	Canned whole kernel corn	" " (104)
43.3	.160	-	-	Canned tomato juice	" " (104)
43.3	.107	-	-	Canned green lima beans	" " (104)
43.3	.064	-	-	Canned whole kernel corn	" " (104)
50.0	.307	-	3.2	Mixture of vitamin in 36 percent sugar	Garrett 1956 (92)
60.0	.854	-	3.2	" "	" " (92)
70.0	2.072	-	3.2	" "	" " (92)
99.0	37.68	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)
100.0	357.60	-	-	Boiled artichokes	Cook and Sundaram 1963 (51)
110.0	47.76	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)
118.5	117.6	55.0	-	" "	" " (102)
121.0	1385.61	In water	-	Artichokes in pressure cooker	Cook and Sundaram 1963 (51)
126.0	304.8	55.0	-	Luncheon pork	Greenwood et al. 1944 (102)

4.17 Folic acid

Folic acid is a vitamin that is sensitive to heat, light and presence of oxygen (84, 34). It is stable at pH 8 but largely destroyed during autoclaving in acids and alkalis (114). The type of micro-organism used in the

analysis of folic acid plays an important role on the result. Karlin et al. 1969 found the loss of folic acid in UHT processing of milk assayed by Lactobacillus casei was 75 percent, while by Streptococcus faecalis and Pediococcus cerevisiae was 50 percent and 83 percent respectively.

Despite the difficulty in the determination of folic acid, losses due to effect of heat, light and presence of oxygen were reported. Rolls and Porter 1973 reviewing the destruction of water soluble vitamins in liquid milk showed that in bottle sterilization at 110 - 112°C for 20 - 30 minutes, loss of folic acid was 30 percent. Residual oxygen in milk was also found to have a marked effect on folic acid destruction in milk. There are a number of papers on the retention of folic acid in milk, but the data cannot be treated kinetically. With other canned products, Miller et al. 1973 found loss of folic acid on retorting of canned pinto beans at 121°C for 90 minutes was only 16 percent. Hellendoorn et al. 1971 did not find any loss of folic acid in canning sterilization of canned army rations.

As light and oxygen are known to have an effect on the folic acid destruction, the data on the cooking of artichokes and the frying of meat and vegetables were used. It was realized that part of the folic acid loss would be due to leaching and dripping, but it could be presumed that they would include the effect of light and oxygen. The data on storage of canned foods would not do this. The rate constants shown in Table 4.21 may be higher than those encountered in normal industrial heat processing, but the predicted losses using this data will at least cover the actual losses.

Table 4.21 Reaction Rate Constants for Folic Acid

Temp. °C	k $\times 10^{-3}$ hr ⁻¹	Moisture content %	pH	Type of product	Reference
17.0	.219	-	-	Storage of milk	Ford et al. 1969 (86)
20.0	.064	-	-	Fish meal	Tadeusz 1971 (233)
22.0	.008	-	-	Canned army ration	Hellendoorn et al. 1971 (116)
50.0	(2.303)	-	3.2	Mixture of vitamin in 36 percent sugar	Garrett 1956 (92)
60.0	(5.114)	-	3.2	" "	" " (92)
70.0	(10.564)	-	3.2	" "	" " (92)
100.0	369.12	-	-	Boiled artichokes	Cook and Sundaram 1963 (51)
115.0	2281.82	-	-	Fried vegetables	Banerjee and Chatterjea 1964 (11)
115.0	3742.4	-	-	Fried leafy vegetables	" " (11)
115.0	3379.33	-	-	Fried fish	" " (11)
115.0	4550.13	-	-	Fried meat	" " (11)
121.0	114.58	-	-	Canned lima beans	Miller et al. 1973 (161)
121.0	2316.95	In water	-	Boiled artichokes pressure cooker	Cook and Sundaram 1963 (51)

4.18 Choline and Biotin

Choline is fairly stable to heat, light, acid, alkaline and is slightly unstable in the presence of oxygen (114). In regarding to losses during processing, Hodson 1945 found little loss occurred in the preparation of dried milk. Hellendoorn et al. 1971 found no loss of choline after sterilization of canned army rations. Harris and Von Loesecke 1960 estimated the cooking loss of choline to be in the range of 0 to 5 percent.

Biotin is sensitive to heat but stable to light, oxygen, acid and alkali. Data compiled by Schroeder 1971

showed the differences of biotin content in fresh and canned vegetables to be from 22 to 34 percent in green peas, to 60 percent in canned carrot. Of course, these differences included the blanching losses and the variations in raw materials. In the UHT processing of milk, a small loss of 5 to 10 percent was reported (86, 131). In cooked meat, loss was 23 percent (220).

For both biotin and choline, studies on losses during processing are very scarce and it is not possible to set up the relationship of the reaction rate constant and temperature. From the available data, it is known that there are some losses of biotin and choline during processing but these are seemingly small. It was therefore decided to predict the losses for biotin and choline from data of vitamins known to have higher losses during processing. Porter and Rolls 1973 reviewed that biotin was less destroyed than vitamin B6 and B12. Ford et al. 1969 studied UHT processing of milk and found biotin was destroyed more than vitamin B6 but less than B12 and Karlin et al. 1969 found similar destruction in heating milk. Therefore, it was decided to take the relationship of reaction rate constant with temperature of vitamin B12 to predict for the losses of choline and biotin.

4.19 Minerals

Minerals are known to be stable to heat processing. Losses are due to leaching into the water during cutting, washing and blanching. This loss depends on the size, shape, cell structure of the raw material and condition of the process. As compiled by Schroeder 1971, the differences in fresh and canned food were quite large. For

example, 82 percent of manganese was lost in canned spinach, while for zinc, 40 percent loss was found in spinach and 89 percent for green beans. In canned meat, phosphorus and iron were found to be less by 29 and 13 percent compared to fresh meat respectively (37). However, when the cooking liquid is retained during canning process, there is no loss of minerals (37). As the loss of minerals is due to their solubility in water, keeping this loss to the minimum is to retain cooking water. In this study, the indigenous food raw materials are selected and processed into a dry powder, and it is likely that the food mixture will be cooked as a paste before drying. It is possible and sensible to eliminate this loss by retaining cooking water. Therefore the loss due to leaching can be ignored. The minerals during heat processing were taken as being stable and were not modified in this study.

4.20 Prediction of the reaction rate constant

In order to predict the loss at a known condition of processing, the reaction rate constant at the temperature of processing is required. Once it is known, the nutrient loss can be predicted from Equation 4.7.

$$- 2.303 \log \frac{C}{C_0} = kt \quad (4.7)$$

For example, for a drum drying process consisting of cooking the mixture at 100°C for 30 minutes, milling to a fine slurry at 85°C, mixing at 20°C for 60 minutes, drying at 100°C for 15 seconds and 160°C for 15 seconds, the reaction rate constants of that particular nutrient at 20°C, 85°C, 100°C and 160°C are required.

Having collected the reaction rate constants at some

temperatures, the reaction rate constant at any temperature can be predicted. In this section, the Arrhenius plot from the Equation 4.9 was applied to the collected data from the previous sections. The logarithm of the reaction rate constant for each nutrient was plotted against the reciprocal of absolute temperature, $1/T$. A straight line was fitted to the data by the least squares method. Once the straight line was obtained, the reaction rate constant at any temperature could be determined either by reading from the established curve or by applying Equation 4.8

$$k = Ae^{-E/RT} \quad (4.8)$$

from which the activation energy E and frequency factor, A were first determined from the expression of:

$$\frac{k_1}{k_2} = \exp \frac{-E (T_2 - T_1)}{RT_1T_2} \quad (4.10)$$

From a set of known reaction rate constants and temperature readings from the graph, E can be calculated and hence A can be determined from Equation 4.8. For any nutrient, if E and A values are then known, k value can be determined from the Equation 4.8 for any required temperature.

4.20.1 The prediction of amino acids reaction rate constants

The reaction rate constant for each amino acid was plotted against the reciprocal of absolute temperature. The straight lines fitted by least squares method are shown for cystine, isoleucine, threonine, histidine in Figure 4.1, tyrosine, methionine, leucine and lysine in Figure 4.2 and tryptophan, phenylalanine and valine in Figure 4.3.

Reaction
rate constant
 $\times 10^{-3} \text{ hr}^{-1}$

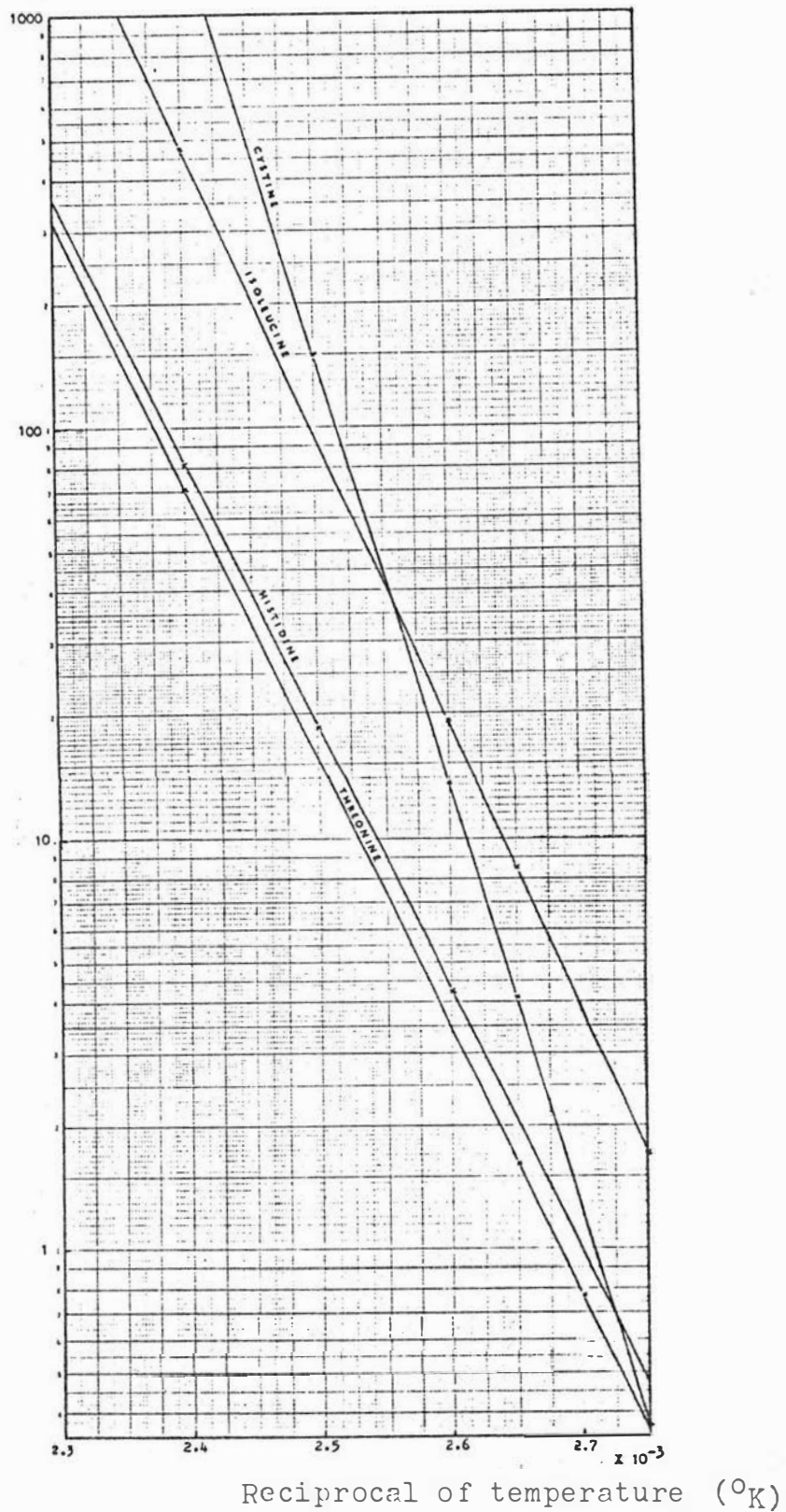
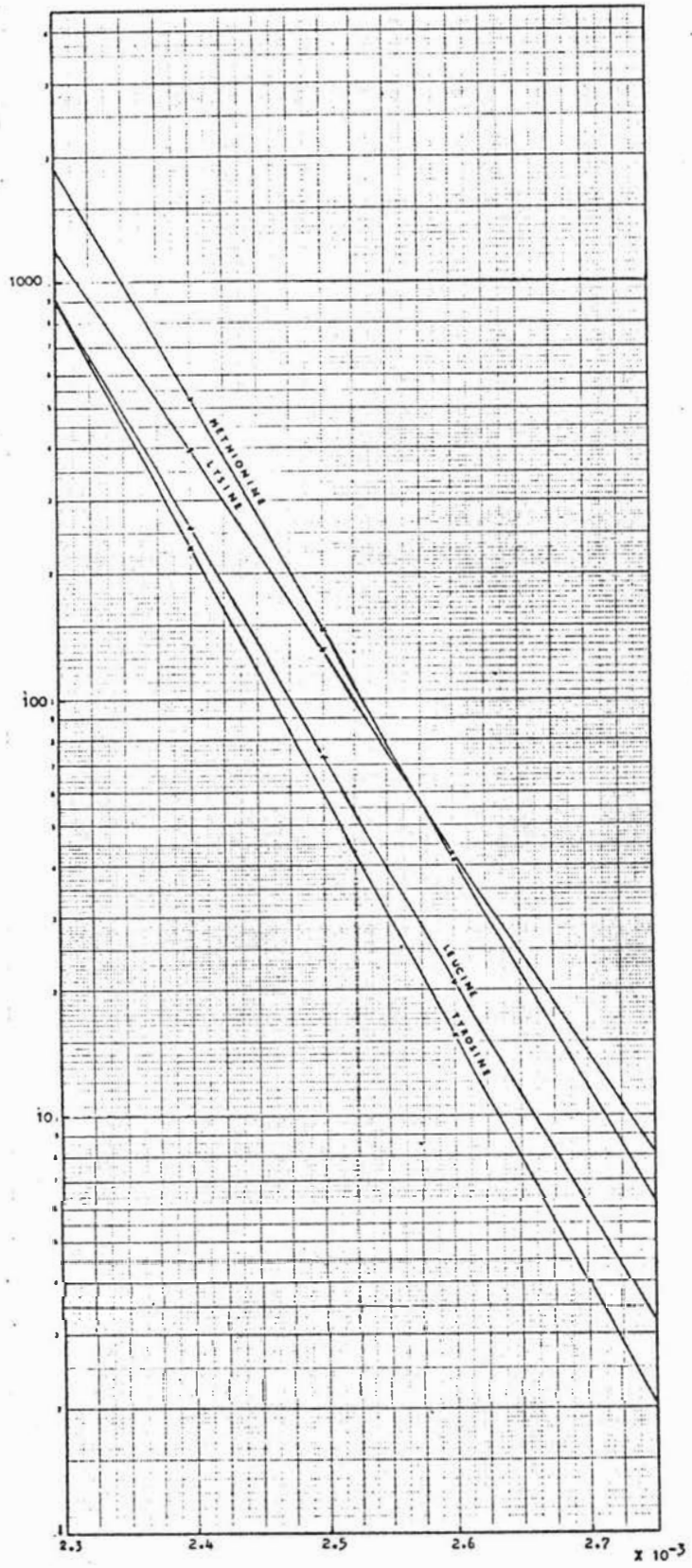


Figure 4.1 Relationship of Reaction Rate and Temperature for Isoleucine, Cystine, Threonine and Histidine

Reaction
rate constant
 $\times 10^{-3} \text{ hr}^{-1}$



Reciprocal of temperature ($^{\circ}\text{K}$)

Figure 4.2 Relationship of Reaction Rate and Temperature for Leucine, Lysine, Methionine and Tyrosine

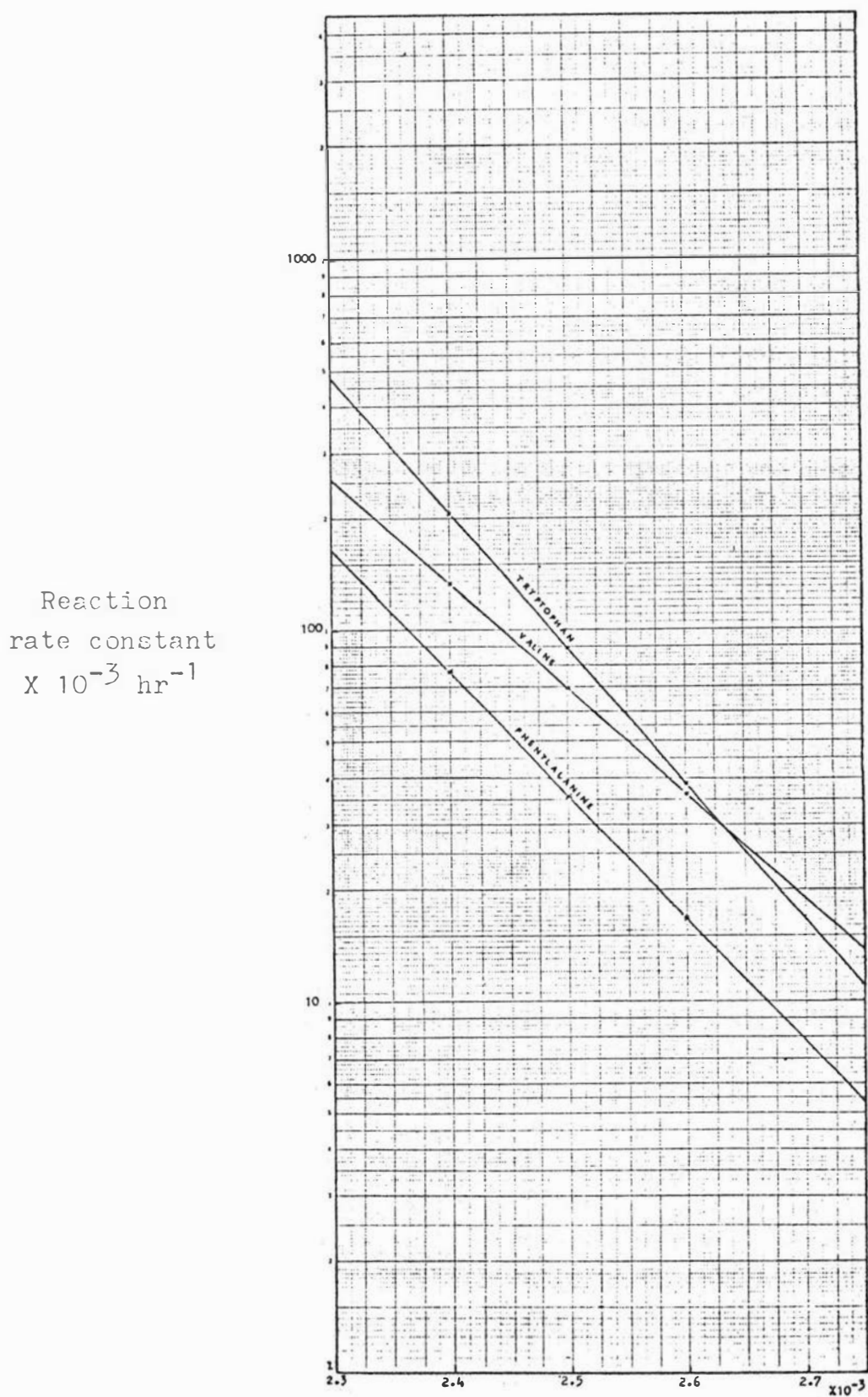


Figure 4.3 Relationship of Reaction Rate and Temperature for Phenylalanine, Tryptophan and Valine

From these straight lines, the activation energy for each amino acid was calculated from the expression

$$\text{Slope} = - \frac{E}{2.303 R}$$

and shown in Table 4.22.

Table 4.22 The Estimated Activation Energy for Amino Acids and Vitamins

Amino acids		Vitamins	
Activation energy (kcal/mole)			
Cystine	48	Thiamine	26
Isoleucine	32	Niacin	24
Threonine	31	Folic acid	24
Histidine	30	Vitamin B12	24
Tyrosine	27	Ascorbic acid	21
Methionine	25	Pantothenic acid	20
Leucine	25	Carotene	19
Lysine	22	Vitamin B6	18
Tryptophan	17	Tocopherol	11
Phenylalanine	15	Riboflavin	11
Valine	13		

In order to compare the variations in the destruction rates of the amino acids in the range of general processing temperatures, the reaction rate constants of each amino acid, read at temperatures of 90°C to 130°C at an interval of 10°C is shown in Table 4.23.

Table 4.23 The Reaction Rate Constants Predicted at Temperatures of 90°C to 130°C for Amino Acids and Vitamins

		Temperature °C							
		90	100	110	120	130			
		Reaction rate constants ($\times 10^{-3}$ hr $^{-1}$)							
<u>Amino acids</u>									
Valine	12.7	Valine	21.0	Lysine	37.5	Methionine	73.0	Cystine	240.0
Tryptophan	10.5	Tryptophan	19.5	Methionine	36.0	Lysine	69.0	Methionine	190.0
Lysine	7.7	Lysine	17.3	Tryptophan	35.0	Tryptophan	56.0	Lysine	156.0
Methionine	5.8	Methionine	15.0	Valine	33.5	Valine	48.0	Isoleucine	128.0
Phenyl-alanine	5.1	Phenyl-alanine	9.0	Leucine	18.0	Cystine	39.0	Tryptophan	105.0
Leucine	3.0	Leucine	7.6	Isoleucine	15.7	Isoleucine	38.0	Leucine	92.0
Tyrosine	1.9	Isoleucine	5.3	Phenyl-alanine	15.4	Leucine	36.0	Valine	78.0
Isoleucine	1.55	Tyrosine	5.2	Tyrosine	13.5	Tyrosine	28.0	Tyrosine	76.0
Histidine	0.42	Cystine	1.9	Cystine	10.5	Phenyl-alanine	23.0	Phenyl-alanine	41.0
Cystine	0.35	Histidine	1.3	Histidine	3.6	Histidine	8.3	Histidine	25.0
Threonine	0.30	Threonine	0.95	Threonine	2.77	Threonine	6.5	Threonine	20.0
<u>Vitamins</u>									
Folic acid	157.0	Folic acid	420.0	Folic acid	990.0	Folic acid	2200.0	Folic acid	4900.0
Riboflavin	98.0	Thiamine	150.0	Thiamine	365.0	Thiamine	840.0	Thiamine	1950.0
Thiamine	57.5	Riboflavin	150.0	Ascorbic acid	235.0	Ascorbic acid	470.0	Ascorbic acid	930.0
Ascorbic acid	51.0	Ascorbic acid	112.0	Riboflavin	222.0	Vitamin B12	340.0	Vitamin B12	740.0
Vitamin B12	28.0	Vitamin B12	68.0	Vitamin B12	155.0	Riboflavin	320.0	Riboflavin	470.0
Vitamin B6	23.5	Vitamin B6	46.5	Vitamin B6	87.0	Pantothenic acid	162.0	Pantothenic acid	310.0
Pantothenic acid	20.0	Pantothenic acid	42.5	Pantothenic acid	84.0	Vitamin B6	157.0	Vitamin B6	285.0
Tocopherol	16.7	Carotene	34.0	Carotene	67.0	Carotene	126.0	Carotene	240.0
Carotene	16.3	Tocopherol	25.5	Niacin	41.0	Niacin	90.0	Niacin	205.0
Niacin	7.1	Niacin	17.4	Tocopherol	38.0	Tocopherol	54.4	Tocopherol	79.0

The important issues in predicting the reaction rate constant and the activation energy of an amino acid can be summarized as

1. The reaction rate constants of amino acids are generally low at temperature lower than 100°C. However, at

higher temperature the rate increases significantly.

2. The differences in the reaction rate constants among different amino acids are higher at lower temperature, i.e. approximately forty two fold at 90°C . However, when the temperature is increased, the differences are smaller. It is twenty two fold at 100°C and only eleven to thirteen fold at temperatures of $110\text{-}130^{\circ}\text{C}$.

3. The influence of temperature on the reaction rate varies with different amino acids as can be seen from the characteristic of the reaction, the activation energy as shown in Table 4.22. According to the extent at which the rate of reaction increases with temperature, the amino acids can be categorized into 4 groups. The most rapid is cystine; the second group where the rates change quite considerably are in the order of isoleucine, threonine, histidine; the third group tyrosine, methionine, leucine and lysine; in the last group where the rates only change slightly with temperature are tryptophan, phenylalanine and valine. The activation energies range from 13 kcal/mole to 48 kcal/mole but seven amino acids have reaction rates between 22 and 32 kcal/mole. Few data have been given in the literature on the activation energies of amino acids. Labuza 1972 calculated it for available lysine, in heating dry cod muscle to be 28 kcal/mole. Brockman 1966 assumed 25 kcal/mole as activation energy required for deterioration in food nutrients. Among activation energies of other nutrients given by Lund 1975, the only amino acid given was lysine at 30 kcal/mole. This available information is quite relevant to the predicted activation energies for isoleucine, threonine, histidine, tyrosine, methionine, leucine and

lysine. However, the predicted activation energy is considerably higher for cystine and slightly lower for tryptophan, phenylalanine and valine. The activation energy value predicted for lysine is also slightly lower than given by Labuza 1972 and Lund 1975. This could be due to the fact that the data used in this prediction were derived from various types of foods and under various conditions of treatment while the data referred to by Lund 1975 and Labuza 1972 referred to one particular food and treatment. However, more data is needed for other amino acids before any further comment can be made.

4. As the consequence of the influence of temperature on the rates of destruction, the most affected amino acid, i.e. the amino acid with the highest rate of reaction constant, changes as the temperature is increased. For example, at 100°C the order of amino acids most affected by heat processing is valine, tryptophan, lysine, methionine, but at 110°C it is lysine, methionine, tryptophan, valine, at 120°C methionine, lysine, tryptophan, valine and at 130°C cystine, methionine and lysine as shown in Table 4.23.

This collection of data reveals that at temperatures higher than 110°C, the most affected amino acids are the group of lysine, methionine, tryptophan, valine and cystine. Although these graphs in Figure 4.1, 4.2, 4.3 are derived from very scattered information, the most affected amino acids predicted are similar to those reported elsewhere in the literature. Dubrow et al. 1970 found in heating dried fish proteins at 120°C and 150°C that among histidine, tryptophan, lysine and cystine, lysine was most affected and cystine was the next affected amino acid. Yanez et al. 1970,

drying fish protein at 105°C and 170°C found lysine was most affected and there was an indication of damage of the sulphur amino acids. In canning of chicken meat at 117°C, Grabowski et al. 1969 investigated isoleucine, leucine, methionine, tryptophan, valine, histidine and found tryptophan as the most affected amino acid. In prolonged heating of raw and cured pork at 112°C, Beuk et al. 1943 found cystine was most affected among histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. In dairy products, most work has been done on lysine because of its highly reactive nature and the abundance of reducing sugar, lactose. Mauron et al. 1955 found lysine was most affected in the evaporation of milk among methionine, tyrosine and tryptophan. For plant protein, tryptophan was most affected in roasted soybean and next were lysine and cystine (146). Lysine as the most affected amino acid was also reported by Varela et al. 1970 in roasted peanut protein and by Samson 1971 in heating fresh coconut at 110°C and 120°C. In canned turnip, Meredith et al. 1974 found highest loss in isoleucine, next group were lysine, phenylalanine, leucine and the least affected was histidine.

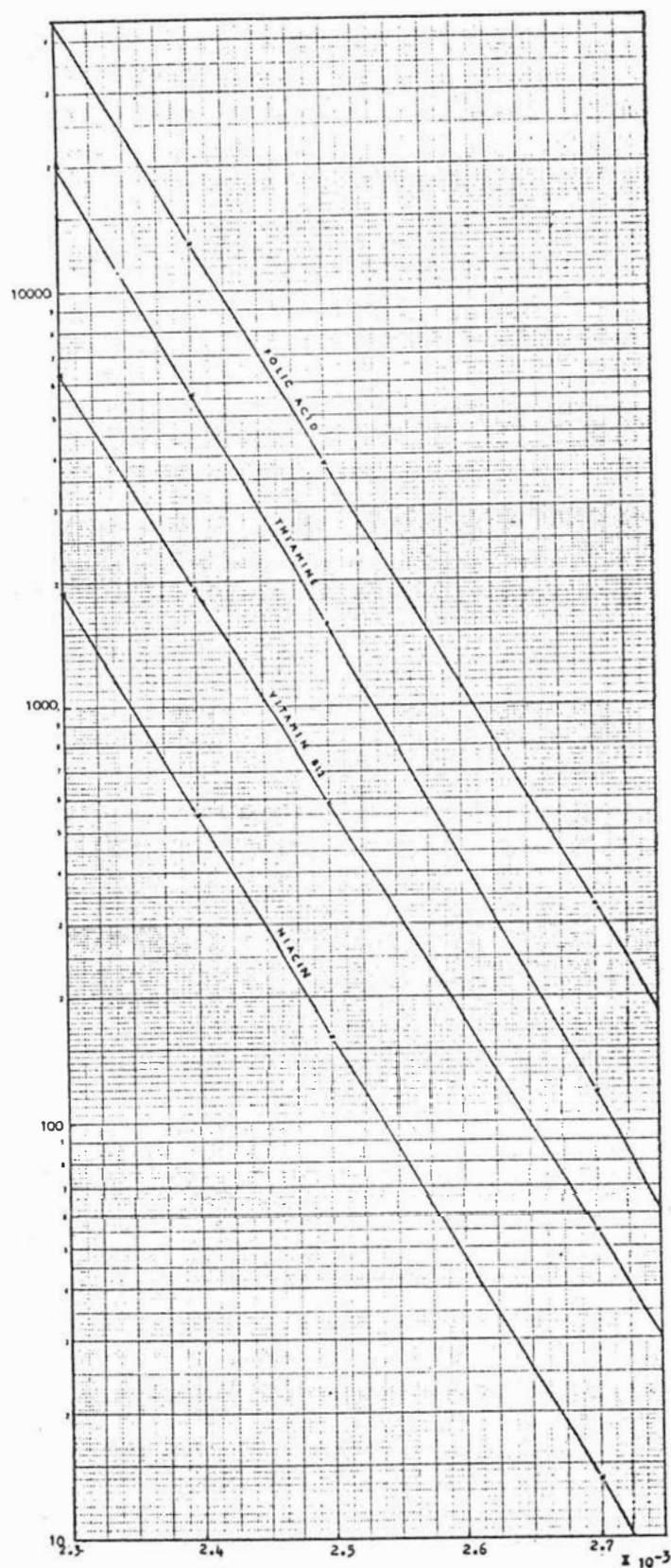
On the whole, it can be concluded that the prediction of amino acid rate of reaction constants, although they cannot be expected to be very accurate due to disparity in the methods of analysis and the scarcity of the data, does indicate the trend of the reactions and is the most appropriate method to use as a quantitative approach in this controversial area of processing loss prediction.

4.20.2 The prediction of vitamins' reaction rate constants

The data for vitamins were treated in the same manner as for amino acids. The straight lines of the Arrhenius plot for folic acid, thiamine, vitamin B12 and niacin are shown in Figure 4.4 and for ascorbic acid, riboflavin, vitamin B6, pantothenic acid, carotene and tocopherol in Figure 4.5. The activation energies calculated from the slope of the Arrhenius plot is shown in Table 4.22 and the reaction rate constants of each vitamin read at temperatures from 90°C to 130°C are shown in Table 4.23. In predicting the reaction rate constant of vitamins, the important issues can be summarized as:

1. The reaction rate constants of vitamins are considerably higher than amino acids.
2. The differences in reaction rate constants of vitamins are quite marked and are found to increase with increasing temperature. The differences are approximately twenty two fold at 90°C and increase to twenty four, twenty six, forty and sixty two fold when temperature increases to 100, 110, 120 and 130°C respectively. However, if the folic acid is excluded, the differences increase but to a lesser extent, i.e. only fourteen, nine, ten, sixteen and twenty five fold respectively.
3. The reaction rate constants of different vitamins are also found to increase differently with increasing temperature. The vitamins can be categorized into 3 groups according to the extent at which the rate of reaction increases with temperature. Thiamine, niacin, folic acid and

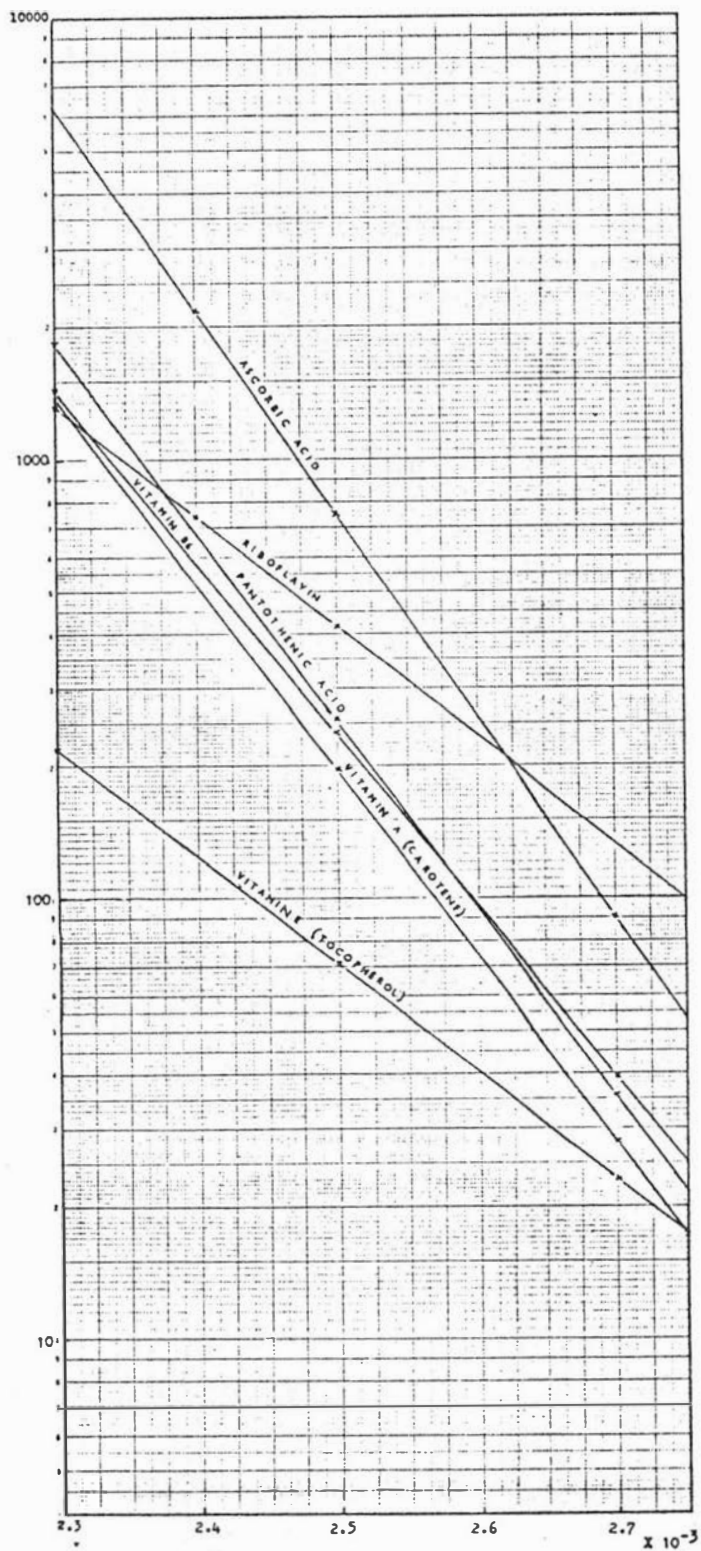
Reaction
rate constant
 $\times 10^{-3} \text{ hr}^{-1}$



Reciprocal of temperature ($^{\circ}\text{K}$)

Figure 4.4 Relationship of Reaction Rate and Temperature for Thiamine, Niacin, Folic Acid and Vitamin B12

Reaction
rate constant
 $\times 10^{-3} \text{ hr}^{-1}$



Reciprocal of temperature ($^{\circ}\text{K}$)

Figure 4.5 Relationship of Reaction Rate and Temperature for Vitamin A, Vitamin E, Ascorbic Acid, Riboflavin, Vitamin B6 and Pantothenic Acid

vitamin B12 are found to increase their rates of reaction rapidly with temperature while ascorbic acid, pantothenic acid, carotene, vitamin B6 increase their rates only moderately and riboflavin, tocopherol increase their rates to the least extent. The activation energies range from 11 to 26 kcal/mole. Except for tocopherol and riboflavin, the activation energies for the vitamins compare very well with the assumptions given by Brockman 1966. The activation energies given by Lund 1975 for thiamine at 20 - 27.5 kcal/mole, pantothenic acid at 20, ascorbic acid at 23 and vitamin B12 at 23 kcal/mole are very close to the values predicted in this study. However, the predicted values are higher than what were given by Lund for folic acid and lower for riboflavin.

4. As for amino acids, it is also found that the vitamins with the highest rates of reaction vary with temperatures. As shown in Table 4.23, the order of highest rates are folic acid, thiamine, riboflavin, ascorbic acid at 100°C and folic acid, thiamine, ascorbic acid, vitamin B12 at 120°C.

From this collection of data, folic acid is the most unstable vitamin. At temperatures from 100°C, thiamine is the vitamin that is unstable next to folic acid. The unstable vitamins next to thiamine are riboflavin, ascorbic acid and vitamin B12. However, with increasing temperature vitamin B12 and ascorbic acid are close in their rates and at a very high temperature such as 162°C, vitamin B12 is more unstable than ascorbic acid.

However, vitamin B6, pantothenic acid and carotene are found not quite as labile and niacin, tocopherol are in the group of the least unstable among these vitamins. This prediction reveals similar vitamin stability as stated in the recent reviews. Rolls and Porter 1973 stated that ascorbic acid, thiamine, vitamin B6, vitamin B12 and folic acid were destroyed more than other vitamins in processing of milk. De Ritter 1975 stated that vitamin B12 was quite labile at higher temperatures. Miller et al. 1973 found in retorting of pinto beans at 121°C that thiamine was most affected, next was folic acid while vitamin B6 and niacin were destroyed only slightly. Morgan et al. 1944 compared the loss of thiamine, riboflavin, niacin and pantothenic acid in the dehydration of carrot and potatoes, found considerable loss in thiamine and only slight losses were found with other vitamins. Cain 1967 reviewing losses of thiamine, riboflavin, niacin and ascorbic acid in canned asparagus and spinach stated thiamine and ascorbic acid as the most affected vitamins.

The predicted rate of reaction for folic acid in this study as the highest of all vitamins is not unexpected, the marked loss of folic acid was found in processing of milk as reported by Burton et al. 1967 and Karlin et al. 1969. It is possible that the rate of folic acid in this study was over estimated as discussed previously. More data on the effect of heat processing on folic acid is needed before any further clarification can be made. On the whole it is felt that the predicted data resemble the information available on the effect of heat processing on the stability of vitamins.

To sum up, it can be concluded that the collection

and presentation of the available data in term of their kinetic expressions does indicate comparatively the rates of destruction of different amino acids and vitamins and clearly shows how the rates change with temperatures. It is felt that by this approach, the effect of temperature and time of heating can be integrated into one presentation. Hence, it can be both quantitative and qualitative in predicting the loss of any nutrient during processing.

4.21 Conclusion

In order to predict the nutrient losses during processing, the law of mass action was applied and first order of reaction was found to be approximately true for most of the nutrients studied. Therefore, the first order of reaction was assumed to hold for all the nutrients unstable to heat. Arrhenius equation was also used to express the temperature dependence of the reaction rate constant.

Among many factors affecting the destruction of nutrients, moisture and pH have been reported to play important roles in affecting the reaction rate constant. Being aware of these effects, an attempt was made to collect data relevant to the mixture of indigenous food materials during processing i.e. data of high moisture content food with pH in the vicinity of neutral rather than at the extreme ends of the scale. The reaction rate constants were calculated from concentration losses reported in various papers. Unfortunately the initial concentration varied and the times of heating at a certain temperature were not always controlled and concentrations were not always taken at small time intervals. This led to inaccuracy in calculating

the reaction rate constant from the C/C_0 ratio.

The scatter of the data from the fitted straight line in the Arrhenius plots resulted from several factors - the variation in the nutrient content of food materials, the methods of analysis, the interaction of factors affecting the stability of the nutrients, the differences in the stability of food materials and the differences in the experimentation accuracy from various sources. The data were more scattered and limited in the amino acids than with the vitamins. Nevertheless, there are some nutrients such as pantothenic acid, niacin and in particular thiamine for which the data from various papers in the literature fitted the straight line remarkably well.

The data in the literature that could be treated kinetically were generally limited. Nevertheless an attempt was made to include as many data as possible for various types of products. The reaction rate constants at different temperatures were collected and/or calculated from the available data. These data once available, enabled the prediction of the reaction rate constants at any temperature using the Arrhenius equation. Among the studied nutrients, vitamin D, vitamin K and minerals were treated as being stable to heat and were assumed to have no significant change during the processing. Pictin and choline, reported to be slightly affected by heat, had very limited kinetic data so that it was not possible to predict the relationship of the reaction rate constant to temperature. In this circumstance, vitamin B12, reported to be slightly more affected by heat, was taken for the prediction of reaction rate constants of biotin and choline.

The prediction of reaction rate constants at different temperatures was established for 11 amino acids and 10 vitamins. The amino acids and vitamins predicted to be the most affected by heat processing were similar to those given in the recent literature and reviews. This use of the Arrhenius plot was chosen to be the most appropriate method to present quantitatively the nutrient losses reported by different workers, taking into account the effect of time and temperature and to the lesser extent the other factors affecting the rate of destruction such as moisture content and pH.

Once the processing conditions are selected for infant food, the reaction rates at the processing temperatures can be read from the Arrhenius plot and the nutrient losses predicted. In order to design an infant food to provide the required nutrients after processing, these losses of nutrients can be included in the linear programming model.

CHAPTER 5

PREDICTION OF THE NUTRIENT LOSSES
DURING PROCESSING

The design of the infant food has considered the qualitative and quantitative characteristics required in the product. To make the linear programming model more realistic, the losses in nutrients during processing needed to be included. A suitable process had to be selected, the processing conditions defined, the nutrient losses predicted, and then the linear programming model changed to allow for the effect of processing.

The processing method is the first thing to be considered. The processing method must give a product with the required qualitative characteristics and at the same time it must provide the lowest cost product which satisfies the nutritional constraints. From the survey on feeding practices, an infant food in the form of dry powder was most preferred. Therefore, a dehydration process had to be used. However, there are many dehydration techniques that one can employ such as pan drying, vacuum drying, freeze drying and spray drying (115, 243) and their suitability for the infant food had to be compared.

To convert a mixture of different raw materials into a dry powder, the general steps in the process are preparation of raw materials, such as washing, peeling, cutting; a predrying process such as blanching, cooking

and mixing; and finally the actual drying. To design a suitable processing method, these three major steps of processing were considered.

5.1 Preparation of raw materials

The majority of the raw materials considered in this study were fresh raw materials such as tubers and some grains, fruits, vegetables, meat, fish, egg and milk. Only a few of the raw materials were in dry form e.g. rice, soybean, sesame and peanut. The only pretreated raw materials considered in this study were cereal flours and dried milk powder. The mixture of raw materials used will vary from time to time according to the prices and the availability of the raw materials. As the linear programming model can be changed quickly to allow for changes in price and availability, the least cost mixtures of raw materials obtained from the model can change either from day to day or week to week according to the seasonal fluctuations.

The preparation stage must therefore be adaptable and able to cope with a variety of raw materials. Those fresh raw materials will have to go through general preparation such as washing, peeling and cutting; the method of preparation is determined by the type of raw material - vegetables and fruit will be peeled, fish gutted and filleted, meat deboned, nuts shelled, tubers peeled, rice and other cereals dehusked.

The losses in nutrients during this process were already accounted for in the linear programming model as only the cost and composition of the edible portion of all raw materials were used. There must be of course no excessive washing during this preparation as there would be

some leaching of nutrients which is not allowed for in the model.

5.2 Predrying process

What is needed during predrying is determined by the properties of the raw materials and the required product quality. Mostly fresh raw materials are used which make preheating and cooking before drying necessary. From the nature of the raw materials, the desirable changes during preheating are firstly the improving of digestibility by gelatinization of starch, denaturation of protein, softening of the fibrous tissue and secondly the destruction of those naturally present hazardous materials (154). The mixture of the raw materials has to be converted to a homogenous paste or fluid before drying because the infant food must have a uniform composition. It is important to mix the raw materials well before drying. Therefore, the suggested steps in the predrying are heating, mixing and milling.

There must be adequate heating of the raw materials during processing to improve digestibility and destroy hazardous materials, and although some of this heating can take place during the drying process, it is preferable to do it during the predrying stage. It is necessary to quickly preheat the mixture of raw materials to inactivate enzymes that are detrimental to food nutrients such as ascorbic acid oxidase, thiaminase and avidin, and to flavour and colour such as peroxidase. Also trypsin inhibitors and other anti-nutritional factors should be destroyed as quickly as possible.

The heat treatment required for the destruction of these hazardous compounds and the improvement of

digestibility of the raw materials had to be determined before a suitable predrying process could be designed.

5.2.1 Destruction of hazardous materials

The natural hazardous materials are the substances depressing the utilization of proteins and the substances inactivating vitamins (249). The improvement of the nutritive value of proteins by mild heat is well established (114, 148, 16, 206). In egg white, there is a heat labile antiproteinase which can be destroyed by heating at 100°C for 3 minutes. However, this proteinase inhibitor in egg white was found to have a limited effect on protein absorption in human. Egg white, either raw or heated in the presence of added ovomucoid of known antitrypsin activity had no effect on nitrogen retention of human (206). In raw milk, there is also a trypsin inhibitor. Boiling for short time is known not to completely inactivate the inhibitor (249). The pronounced effect of trypsin inhibitor is found in the leguminosae such as soybean. The components found in soybean, trypsin inhibitor, haemagglutinin and saponin, are heat labile and of these trypsin inhibitor is found to be most stable to heat. Therefore, among the enzyme inhibitors in soybeans, the level of trypsin inhibitor can be used as an index of adequacy of heat treatment (244). Different sets of time and temperature have been reported for soybeans, e.g. Fritz et al. 1947 reported the best biological value of ground soybeans was achieved by autoclaving at 121°C for 20-30 minutes. Rackis 1966 found soybean flake required only 20-30 minutes at 100°C by steaming. Gontzea and Sutzescu 1968 found soy products with maximum protein value by autoclaving at 115°C

for 20 minutes or at 107-108°C for 40 minutes and with some varieties of soybeans it required up to 30 minutes at 121°C. Certainly, the differences in the temperature and time could be related to the differences in the size and shape of heated materials and hence the efficiency of heat transfer within that material. Most of these experiments were carried out at neutral pH. It was found that from pH 6.8 to 9.9, less heating time was required with increasing pH (137). However, increasing pH from neutral would not be useful for the processing of infant food. Khaleque 1971 found that at pH 6.8, the complete destruction of trypsin inhibitors in soy milk was 76 minutes at 98°C or 15 minutes at 115°C.

In the previous discussion, the destruction of amino acids and vitamins were assumed to follow first order reaction. It is difficult to decide whether the same assumption should be made for destruction of trypsin inhibitors due to the lack of information on the kinetics of the reaction. Khaleque 1971 found in his experiment that, the reaction only followed first order at higher pH i.e., over the range of 7 - 9.9 which is not likely the pH of infant food. Nevertheless, the assumption of first order rate of reaction has been extended to destruction of trypsin inhibitor by Labuza 1972 and Lund 1975. Both authors calculated the reaction rate constant and the activation energy from the same experiment by Hackle et al. 1965. Labuza 1972 gave the reaction rate constant at both 93°C and 121°C to be $1680 \times 10^{-3} \text{hr}^{-1}$ and $10380 \times 10^{-3} \text{hr}^{-1}$ and Lund 1975 at the range of 93°C - 121°C to be $10389 \times 10^{-3} \text{hr}^{-1}$ respectively. Whether the Arrhenius equation can be assumed

is the question. It is established that the inactivation of the enzyme is reversible at low temperature and only from 90°C that the reaction is irreversible (206).

Therefore, if Arrhenius equation is to be applied, the temperature must be over 90°C.

In order to define the time and temperature of the predrying process, it was decided to assume first order reaction. With this assumption, the reaction rate constants for destruction of trypsin inhibitor from various data were calculated as shown in Table 5.1.

Table 5.1 The Reaction Rate Constant For Destruction of Trypsin Inhibitor

Temp. °C	k x10 ⁻³ hr ⁻¹	Type of product	Reference
93	1680	Soy milk	Labuza 1972 (146) Lund 1975 (154)
98	5454	Soy milk	Khaleque 1971 (137)
100	13818	Soybean flake	Rackis 1966 (198)
103	10368	Soy product	Gontzea and Sutzescu 1968 (97)
115	24384	Soy milk	Khaleque 1971 (137)
115	20727	Soy product	Gontzea and Sutzescu 1968 (97)
121	10380	Soy milk	Labuza 1972 (146) Lund 1975 (154)
121	13818	Soy product	Gontzea and Sutzescu 1968 (97)
121	13818	Ground soybeans	Fritz et al. 1949 (91)
121	20727	Soybean product	Richardson 1976 (206)

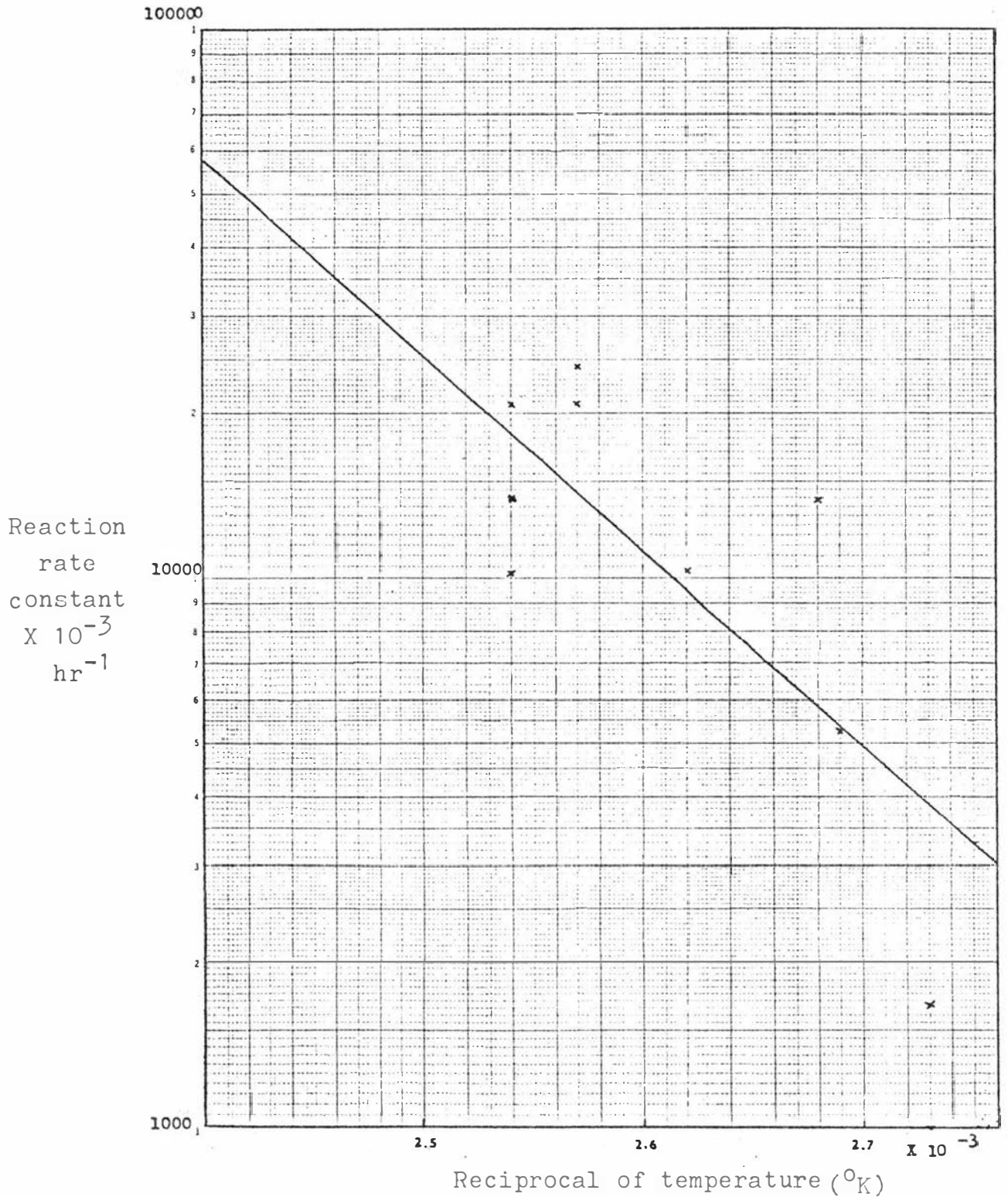


Figure 5.1 Relationship of Reaction Rate and Temperature for Destruction of Trypsin Inhibitor

In order to use data from complete destruction to calculate the reaction rate constant, the destruction was taken as 99.9 percent. As soybean needs more severe heat treatment than other raw materials (249), only data on soybean were collected. The straight line fitted to the data in Table 5.1 is shown in Figure 5.1.

For the predrying process, it was decided to study the two temperatures at the limits of the temperature range i.e. 98°C and 121°C . Taking the reaction rate constant from the graph, the required holding time was calculated on 99.9 percent destruction and found to be 81 minutes at 98°C and 23 minutes at 121°C respectively. In effect, these 2 sets of temperatures and times represented a high temperature short holding time and a low temperature long holding time and were used in this study as criteria for inactivation of trypsin inhibitors.

Apart from trypsin inhibitors, there are substances responsible for inactivating vitamins. The important substances in this category are ascorbic acid oxidase, widely occurs in vegetables, avidin or antibiotin found in egg white, thiaminase found in raw fish and shellfish and a substance reacting with niacin found in maize. Ascorbic acid oxidase inactivates ascorbic acid and thiaminase inactivates thiamine. However, these substances seem to be heat labile. Information available shows that ordinary home cooking is sufficient to destroy these enzymes. For example, ascorbic acid oxidase is inactivated by blanching at 100°C for one minute, avidin is inactivated by boiling for 3 - 5 minutes (206).

Among these natural hazardous substances, trypsin

inhibitors seems to be more stable to heat than others.

It can be concluded that processing required for destruction of the natural hazardous substances is adequately covered by the conditions required by soybean which is 81 minutes at 98°C or 23 minutes at 121°C.

5.2.2 Improving the raw material digestibility

The three major constituents in food raw materials are proteins, carbohydrate and fat. Mild heat treatment is known to have beneficial effects on proteins and carbohydrates. Digestibility of proteins and availability of sulphur amino acids are improved by heat treatment (6) and gelatinization of starch improves its digestibility. With infant, it is known that digestion of starch is slow with very young infants and increases gradually with increasing age (81). Therefore, it is important to have starch well gelatinized. Different types of starches have slightly different temperature ranges where gelatinization occurs. Gelatinization ranges of temperature for various starches given by Hodge and Osman 1976 is shown in Table 5.2.

Table 5.2 Gelatinization Ranges of Temperature for Various Starches

Source	Temperature °C
Corn	62.0 - 70.0
Rice	68.0 - 78.0
Pea (green garden)	57.0 - 70.0
Potato	58.0 - 66.0
Tapioca	52.0 - 64.0

For fat, there is more of a detrimental effect than beneficial effect in heating, especially at high temperature.

It may be said that among the major components of food raw materials, only protein and carbohydrates are known to have improved digestibilities by heat treatment. With the time and temperature required to inactivate trypsin inhibitor, it is almost certain that protein will be denatured and starches will be gelatinized. Therefore, the temperature and time required for destruction of trypsin inhibitors can be taken as criteria for this predrying stage.

5.2.3 Design of cooking process

Consideration was now given to the processes to accomplish this required time and temperature. The raw materials after being prepared would be cut into small pieces to hasten the heat transfer during heating. The mixture would be heated in a batch cooker with stirring or in a continuous process.

To determine the total time required for heating up and cooling down assuming agitation of the mixture, the equation given by Heldman 1975 was used

$$\frac{T - T_m}{T_o - T_m} = \exp \left(- \frac{UA t}{Wc_p} \right) \text{ or } - t = \frac{Wc_p}{UA} \ln \left(\frac{T - T_m}{T_o - T_m} \right)$$

where

- T = temperature at any time t
- T_m = temperature of heating or cooling media
- T_o = original temperature
- U = overall heat transfer coefficient
- t = time
- W = mass
- c_p = specific heat
- A = Area

From the equation, it is obvious that to reach any required temperature, the important variable is the ratio of W/A . This ratio is generally high in batch process and low in continuous process. As expected, the type of process plays an important role in the temperature and time distribution.

In order to estimate the distribution of time and temperature, assumptions were made on:

Type of cooker Jacketed pan with agitator was assumed for the batch process and scraped surface heat exchanger (67) was assumed for the continuous process. A typical capacity and surface area of 300 lb and 10 ft^2 were taken for jacketed pan and 5 inches in diameter for heating cylinder and 3 inches diameter for the blade rotator were taken for the continuous process. The volume of the blade is usually small and hence was ignored.

Overall heat transfer coefficient For jacketed pan typical values range from 50 for cream (115) to 125 - 150 for paste (190) and $154 \text{ BTU/ft}^2\text{h } ^\circ\text{F}$ for fruit slurry (190). In this estimation a value at $100 \text{ BTU/ft}^2\text{h } ^\circ\text{F}$ was taken as an average value. However, for the scraped surface heat exchangers, heat transfer coefficients vary with speeds of rotation (67) and are found to be in the order of 150 - $650 \text{ BTU/ft}^2\text{h } ^\circ\text{F}$ and an average of $350 \text{ BTU/ft}^2\text{h } ^\circ\text{F}$ was used in this study.

Specific heat The specific heat for high moisture content food can be estimated from the expression given by Siebel 1892 as $C_p = 0.2 + 0.008$ (moisture content, percent) or by Dickerson 1965 as $C_p = 0.4 + 0.006$ (moisture content, percent) which gives approximately the same estimation. Therefore one of the expressions i.e. Dickerson's was chosen

in this study. From the previous formulation (Table 3.5) the moisture content of the mixed fresh raw materials was approximately 55 - 60 percent. Allowing for water necessary for cooking, the moisture content of the mixture was taken as 75 percent. Therefore, the c_p of the paste from Dickerson's expression was 0.85 FTU/lb °F.

The required temperatures and times It was discussed earlier that the required temperatures and times were 81 minutes at 98°C and 23 minutes at 121°C.

The temperatures of heating and cooling media The steam was assumed to be the heating medium with a pressure of 10 psi for heating the mixture to 98°C and 20 psi for heating the mixture to 121°C. It was also assumed that the mixture once being heated to the required temperature and time was put through the mill quickly before cooling and this milling time was not counted. For cooling down to 30°C water at 25°C was assumed to be used.

Having assumed all the required variables, the distribution of temperature and time in selected batch and continuous processes were determined and are shown in Table 5.3.

Table 5.3 Temperature and Time Distribution
During Heating and Cooling for Selected Batch and
Continuous Processes

I. USING STEAM AT 10 PSI TO RAISE TEMPERATURE TO 98°C

	<u>Batch process</u>	<u>Continuous process</u>
Heating up time	17 minutes	63 seconds
Cooling down time	30 minutes	109 seconds
Holding time	81 minutes	81 minutes

Distribution of temperature during heating up

At 5 minutes	60°C	At 20 seconds	62°C
At 10 minutes	81°C	At 40 seconds	84°C
At 15 minutes	94°C	At 60 seconds	96°C
At 17 minutes	98°C	At 63 seconds	98°C

Distribution of temperature during cooling down

At 5 minutes	80°C	At 20 seconds	78°C
At 10 minutes	59°C	At 40 seconds	56°C
At 15 minutes	46°C	At 60 seconds	43°C
At 20 minutes	38°C	At 80 seconds	36°C
At 30 minutes	30°C	At 109 seconds	30°C

II. USING STEAM AT 20 PSI TO RAISE TEMPERATURE TO 121°C

	<u>Batch process</u>	<u>Continuous process</u>
Heating up time	31 minutes	114 seconds
Cooling down time	31 minutes	114 seconds
Holding time	23 minutes	23 minutes

Distribution of temperature during heating up

At 5 minutes	64°C	At 20 seconds	67°C
At 10 minutes	88°C	At 40 seconds	91°C
At 15 minutes	103°C	At 60 seconds	106°C
At 20 minutes	112°C	At 80 seconds	113°C
At 25 minutes	117°C	At 100 seconds	119°C
At 31 minutes	121°C	At 114 seconds	121°C

Distribution of temperature during cooling down

At 5 minutes	82°C	At 20 seconds	84°C
At 10 minutes	63°C	At 40 seconds	60°C
At 15 minutes	48°C	At 60 seconds	46°C
At 20 minutes	39°C	At 80 seconds	37°C
At 25 minutes	34°C	At 100 seconds	32°C
At 31 minutes	30°C	At 114 seconds	30°C

5.3 Drying process

Drying processes were screened firstly according to their technical feasibility as a process for infant food and secondly for the costs involved.

5.3.1 Selection of drying process

For drying liquid puree and paste, the suitable methods are pan drying, vacuum drying, freeze-drying, foam-mat drying, spray drying and drum drying (243). It is possible to use an extrusion process when gelatinization, mixing, puffing and drying are required (211). However, the extrusion process is more suitable for doughs than pastes as low moisture contents are required for successful extrusion. The paste will have considerably higher moisture content, 70 to 75 percent, compared to the optimal range for extrusion which is 15 to 30 percent (178). As discussed previously, for this infant food mixture, cooking the paste is necessary before actual drying, and it was thought that it would be difficult to ensure adequate cooking in the extrusion process.

Therefore, the extrusion process was considered not suitable for this product. Pan drying is a process yielding a hard dense product difficult to dissolve, and hence was considered not suitable. For foam mat drying, it was realized that foaming agents, such as glyceryl monostearate, soya proteins, cellulose ether, are used to produce stable foam. This type of drying was considered suitable only when it was possible to produce stable foam with the raw material mixture, because firstly the aim was to use only indigenous raw materials and secondly the addition of other substances would upset the nutritional balance of the mixture.

Therefore, drying methods to be considered further were vacuum drying, freeze drying, foam mat drying, spray drying and drum drying. For selection of the drying method, it was pertinent to consider the cost of the different methods.

Cost involved in drying can be considered as capital investment and manufacturing cost. Capital investment is directly related to purchased equipment cost (7). Data given by Aries and Newton 1955 were used to compare the purchased equipment cost for the different methods. It was realized that these data were out of date and could not be taken as actual costs but it was regarded reasonable to use them for a comparative cost study. Taking an arbitrary figure of drying area of 50 square feet, the purchased cost data for different types of driers were:

	<u>Drying method</u>	<u>Purchased cost,</u> <u>U.S. \$</u>
Drum drying	vacuum, single	25,000
	atmospheric, single	9,500
Tray drying	vacuum, stainless steel	5,000
Spray drying	10 ft. diameter, 2300 lb per hour evaporating capacity.	46,000

The capacity of spray drying was chosen in equivalent to drum drying of 50 square feet area, drum speed at 2 rounds per minute, thickness on drum at 0.1" and density at 63 lb per cubic foot. Information on cost of foam mat drying was limited, it was regarded to be in the same category as drum drying (149). Freeze-drying requires a more expensive

capital cost (243).

In addition to capital investment was manufacturing cost. Van Arsdel 1973 gave the following comparative costs:

<u>Drying method</u>	<u>Cost per lb of water evaporated (U.S. cents)</u>
Forced air drying	0.7
Foam mat drying	0.7
Drum drying	0.8
Spray drying	1.0
Vacuum drying	2.0
Freeze drying	4.0

From the estimated purchased equipment cost, vacuum tray drying was the cheapest, followed by atmospheric drum drying. Both spray drying and vacuum drum drying were more expensive than the other two types already mentioned. The most expensive method was freeze-drying. When considering the operating cost, foam mat drying, drum drying and spray drying were the cheapest while vacuum drying was twice as much and freeze drying was considerably higher and was the most expensive. Logically, in selecting for the processing method, one would select the cheapest method that will give the best required product. Before any further consideration on the effect of processing on the nutrients, it was felt that some of the very expensive processes should be screened out. When considering both purchased equipment cost and operating cost, freeze drying was by far the most expensive method in both capital and operating costs. Though it was realized that in freeze drying there is less loss of nutrients, colour and flavour, it was far too expensive to

consider for a cheap infant product for Thailand. The next expensive capital and operating costs were for vacuum drum drying. For the same reason as freeze drying, it was considered not suitable to include in this study. It was obvious that the capital cost for spray drying was very high compared to drum drying and vacuum drying. Though it is a very common method of drying, its high capital cost could make it difficult to implement in Thailand. Also there would be some difficulties in preparing the raw material mixture for spray drying. It would need to be concentrated and if this was not possible, drying cost would be high because of the amount of water to be removed (57). At the present time, spray drying did not appear to be a suitable process. Therefore, the most suitable methods were atmospheric drum drying, vacuum drying and foam mat drying. These were the drying methods with the cheapest capital investment and operating costs. The operating cost for vacuum drying was notably higher than drum and foam mat drying but the estimated equipment cost was considerably lower. Therefore, these 3 methods of drying were considered economically suitable for processing of the required infant food and were considered in studying the nutrient losses during drying.

5.3.2 Setting the time and temperature for each drying process

Firstly, it was necessary to define the times and temperatures generally employed in each drying method. The temperatures considered were the material temperatures during drying not the air or shelf temperatures.

The temperature and time that can be employed for

any particular type of drying depends on the characteristics of the drying materials and their sensitivities towards heat. However, only a certain range of temperature and time can be used for each type of drying. For instance, high temperature and short time such as 104-160°C for 20 seconds are generally used for drum drying while considerably lower temperature and time such as 66-82°C for 2 hours are used in vacuum drying (187).

According to the differences in rate of drying, the drying process can be divided into a constant rate period and a falling rate period. If the critical moisture content, the final moisture content, and the operating temperature and humidity are known, the time involved in each period can be calculated from the general expression as given by Heldman 1975, Charn 1971 and Karel 1975. Nevertheless, there are some difficulties in calculating drying times based on the moisture to be removed. First of all, there are parameters that must be known such as the gas film coefficient of mass transfer (K_g), overall internal liquid diffusivity (D) and convective heat transfer coefficient (h) (41, 115). It must be noted these parameters, K_g , D and h are not available for most food materials. They can only be predicted by experimentation (41, 115). Therefore, it was not possible to calculate the drying times and temperatures before some experimental data could be obtained using the food mixture. Secondly, the general expression to calculate drying time during constant rate and falling rate assume ideal conditions (130) but disparity from such conditions is known to exist in food systems. Thirdly, within a particular type of drying

process, drying time and temperature can be varied by variation in the drying operation such as drum speed and drum clearance in drum drying, air velocity, bulk density and layer thickness in foam mat drying and solid content and layer thickness in vacuum drying.

Therefore, it was felt that the general times and temperatures reported in the literature should be used first to study the effect of processing conditions on the infant food model. Once the effects of the range of conditions related to a particular type of drying on the final raw material mixture are determined, the most suitable time and temperature can be studied experimentally and if necessary further adjustments made to the model.

The drying conditions are dependant very much on the properties of the raw materials. The mixture used for the infant food was based on various combination of food materials such as cereal, fruit, vegetable, egg, meat, fish and dairy product. As there was no publication on drying of such a combination of raw materials, the conditions for drying food products in thick liquid and paste were taken as being relevant. Therefore, the temperatures and times in each type of drying for thick liquid or paste were collected as shown in Appendix 13.

With vacuum drying, the only relevant type of food products for which drying conditions could be found was fruit juice. The range of product temperature was from 52°C to 77°C and drying time was from one to two hours. With cereals present, this time could be increased.

With foam mat drying, application was to a wider variety of products such as potato, banana and fruit juices.

(Appendix 13). The range of product temperatures was from 60°C to 82°C and drying time was generally from 10 to 60 minutes. Though the air temperature varied up to 104°C , the product temperature was generally 60°C to 82°C .

Drum drying was used with wider varieties of paste and liquid mixtures than the two other drying methods (Appendix 13). Drying conditions for pastes such as potato with fish and fruit cereal baby food, were available. The range of steam pressure in the drum was from 30 to 90 psi with the temperature on the drum of 138°C to 166°C . Though the time was as short as 8 seconds and as long as $2\frac{1}{2}$ minutes depending on other operating variables, drying time was generally between 10 to 30 seconds.

In conclusion, the range of temperatures and times for these 3 methods of drying can be grouped into 3 categories i.e. very high temperature and short time drying as for drum drying, a moderate drying temperature and time as in foam mat drying and a considerably lower temperature and longer time as in vacuum drying. Therefore, the drying time and temperature for each type of drying were decided from the general range of drying times and temperatures used with liquid and paste as collected in Appendix 13. It was found that the range of material temperature was greatest in drum drying, i.e. from $104-160^{\circ}\text{C}$, next was foam mat drying of $60-82^{\circ}\text{C}$ and vacuum drying was the smallest at 52 to 77°C . The drying times for each type of drying were found to range from 10 to 60 seconds for drum drying, 15 to 60 minutes for foam mat drying and one to $2\frac{1}{4}$ hours for vacuum drying. Within the range of times and temperatures used in each type of drying, 2 temperatures at each end of the range were

chosen for study. In any particular mix, when drying temperature is higher, the drying time is generally shorter. Therefore, the conditions could be taken as high temperature with short drying time and vice versa. Accordingly, the drying time and temperature in each type of drying were specified as shown in Table 5.4. These times and temperatures are at this stage theoretical and would have to be confirmed during actual drying tests.

Table 5.4 Product Temperatures and Drying Times Selected for Vacuum, Foam Mat and Drum Drying

Type of drying	Temperature and time
Vacuum drying	52°C for 2 hours
	77°C for 1 hour
Foam mat drying	71°C for 1 hour
	89°C for 8 minutes
Drum drying	104°C for 60 seconds
	160°C for 30 seconds

A further factor taken into consideration was the range of product temperature during the drying cycle. At the early stage of drying, the product temperature is well below the air temperature and gradually increases from feed temperature to a certain temperature and may be, as in vacuum drying, reduced during the later stages of drying (95, 132). For drum drying, steam at certain pressure is generally used and the product temperature increases from the feed temperature to the drum temperature just before it is scraped off (90). In realizing that the time required to bring the product to the referred drying temperature could be as long as half of the total drying time as in

vacuum and drum drying (90, 132) and to the lesser extent in foam mat drying (95), consideration of the distribution of this time and temperature must be taken into account. Therefore, the typical distributions of product temperature and time in the 3 drying methods were studied.

For vacuum drying, the temperature measured at various times in vacuum puffing drying of tomato juice in the experiment by Kaufman et al. 1955 showed that the product temperature dropped gradually to very low temperature as the juice froze and then came up slowly as the moisture was removed as shown in Appendix 14. It took a considerably long time to raise the product temperature to the range of the drying temperature at 56 to 80°C. Data given in vacuum drying of tomato juice at lower vacuum pressures by Hoyer 1969 showed higher product temperatures as the material did not freeze (Appendix 14). It took a third of the drying time to raise the product from 15.6°C to 48°C and half of the drying time to 68°C where the product was kept around 62-68°C for the rest of drying time which was in total 2 hours. Because vacuum drying was generally operated at low temperature, the rising of product temperature was very slow.

The other important issue was that the reaction rate constants were quite low at lower temperatures, approximately below 56°C for vitamins and below 80°C for amino acids. It was found with vacuum drying that the loss of nutrients calculated from the reaction rate kinetics was only significant when the product was in the higher range of drying temperatures. For example, the loss of riboflavin, the nutrient with the highest rate of reaction up to the

temperature of 80°C , was calculated based on the data of Kaufman et al. 1955, was found to be only 0.1 percent lower when the calculated loss excluded the loss during drying at temperatures lower than 56°C . With Noyes 1969 data it was found that the difference was approximately 1 percent when the loss at temperatures lower than 68°C was not included. It could be assumed with vacuum drying that the loss during raising the temperature to the top drying temperature was very small and could be regarded as insignificant compared to the loss during the whole drying process. Therefore, the losses of nutrients during vacuum drying was based on the product temperature of 52°C for 2 hours and 77°C for 1 hour; the losses during raising the product to these temperatures were so small they were not included in this study.

For foam mat drying, the product temperatures were taken from the experiment on tomato paste by Ginette et al. 1963. Because of the higher air temperature used in foam mat drying, the product temperature was raised very quickly to the range of drying temperature. In this particular case, it took only 1.25 minutes. The loss during this period would be insignificant compared to the loss during subsequent drying. Therefore, the losses of nutrients during foam mat drying was based on the product temperature of 71°C for 60 minutes and 89°C for 8 minutes. It was realised that the temperature during the later drying period might vary depending on the manipulation of pressure during vacuum drying and air temperature in foam mat drying. In this study, the product temperatures in these 2 methods were taken to be at top drying temperature until the drying was complete.

For drum drying, the product temperature during

drying was not available in the literature as in the two previous drying methods. However, in the industrial drying of infant food it was found that approximately half of the drying time was at 100°C and the other half was at the final product temperature (42). Therefore, these generalised product temperatures were used in this study and the conditions of drum drying used in this study were at (a) 30 seconds at 100°C, 30 seconds at 104°C and (b) 15 seconds at 100°C and 15 seconds at 160°C.

5.4 Prediction of the nutrient losses during the processing

Nutrient losses during predrying and drying processes were predicted. First of all, the rates of reaction at the required temperatures were taken from the Arrhenius plots of reaction rate constants. Then the percentage destruction of each nutrient during predrying and drying processes were determined from the Equation (4.7)

$$- 2.303 \log \frac{C}{C_0} = kt \quad (4.7)$$

which is equivalent to

$$\frac{C}{C_0} = e^{-kt} \quad (5.1)$$

C_0 was the original concentration of nutrient, C was the concentration of nutrient after heating for a certain time. For the set of temperatures at different times in the predrying and drying processes, the percentage retention at the end of process was calculated from the expression of

$$C_1 = C_0 e^{-k_1 t_1} \quad (5.2)$$

$$C_2 = C_1 e^{-k_2 t_2} = C_0 e^{-(k_1 t_1 + k_2 t_2)} \quad (5.3)$$

and hence

$$C_n = C_0 e^{-(k_1 t_1 + k_2 t_2 + \dots + k_n t_n)} \quad (5.4)$$

where C_1 was the concentration of nutrient after time t_1 and reaction rate constant k_1 and C_n the concentration at the end of process after time t_n and at rate k_n . C_0 was set at 100, and C_n represented the percentage retention of nutrient at the end of the process. Therefore, reaction rate constants k at different intervals of time and temperature were taken to calculate the percentage retention of a process at a set of times and temperatures.

5.4.1 Nutrient losses during predrying process

The losses during the predrying process occur during the period of heating up, holding and cooling down. In this study, the heating up and cooling temperatures were calculated at intervals of 5 minutes in the batch process and 20 seconds in the continuous process. It was realized that the division of time into smaller intervals such as $1/8$ of minute would predict the losses more accurately (236). However to compare processing loss and product formulation, for the relevant processes, it was felt that dividing the heating up and cooling down time into 5 or 6 intervals was adequate. The destruction of each nutrient was calculated as discussed previously in 5.4. Table 5.5 gives the percentage destruction of nutrients after different predrying processes. Comparison of the predicted values for the different processes showed 4 significant aspects of nutrient destruction during processing.

Table 5.5 The Predicted Nutrient Losses During Predrying Process at 98°C and 121°C, Batch and Continuous Process

	At 98°C			At 121°C		
	Batch	Contin- uous	Holding for 81 mins.	Batch	Contin- uous	Holding for 23 mins.
	Percentage loss					
Histidine	0.15	0.13	0.12	0.61	0.40	0.38
Isoleucine	0.58	0.51	0.49	2.91	1.96	1.90
Leucine	0.91	0.82	0.77	2.67	1.72	1.67
Lysine	2.15	1.90	1.80	5.01	3.21	3.09
Methionine	1.8	1.56	1.50	5.32	3.47	3.35
Cystine	0.18	0.17	0.16	3.19	2.26	2.20
Phenylalanine	1.23	1.05	1.01	1.72	1.04	1.00
Tyrosine	0.58	0.54	0.52	2.04	1.34	1.29
Threonine	0.11	0.10	0.09	0.49	0.32	0.31
Tryptophan	2.60	2.23	2.15	4.13	2.53	2.40
Valine	2.92	2.50	2.38	3.61	2.12	2.01
Folic acid	38.52	36.19	36.01	76.82	60.54	59.20
Pantothenic acid	5.22	4.74	4.71	10.55	6.64	6.38
Vitamin B12	7.76	7.19	7.14	20.53	13.57	13.12
Vitamin B6	5.80	5.22	5.18	10.40	6.44	6.18
Niacin	2.03	1.86	1.85	5.93	3.82	3.70
Riboflavin	16.71	14.35	14.16	21.54	12.61	11.90
Thiamine	15.92	14.69	14.61	43.29	30.52	29.64
Ascorbic acid	12.68	11.57	11.49	27.08	17.82	17.20
Tocopherol	3.58	3.09	3.06	4.05	2.27	2.15
Carotene	4.16	3.76	3.74	8.32	5.18	4.98

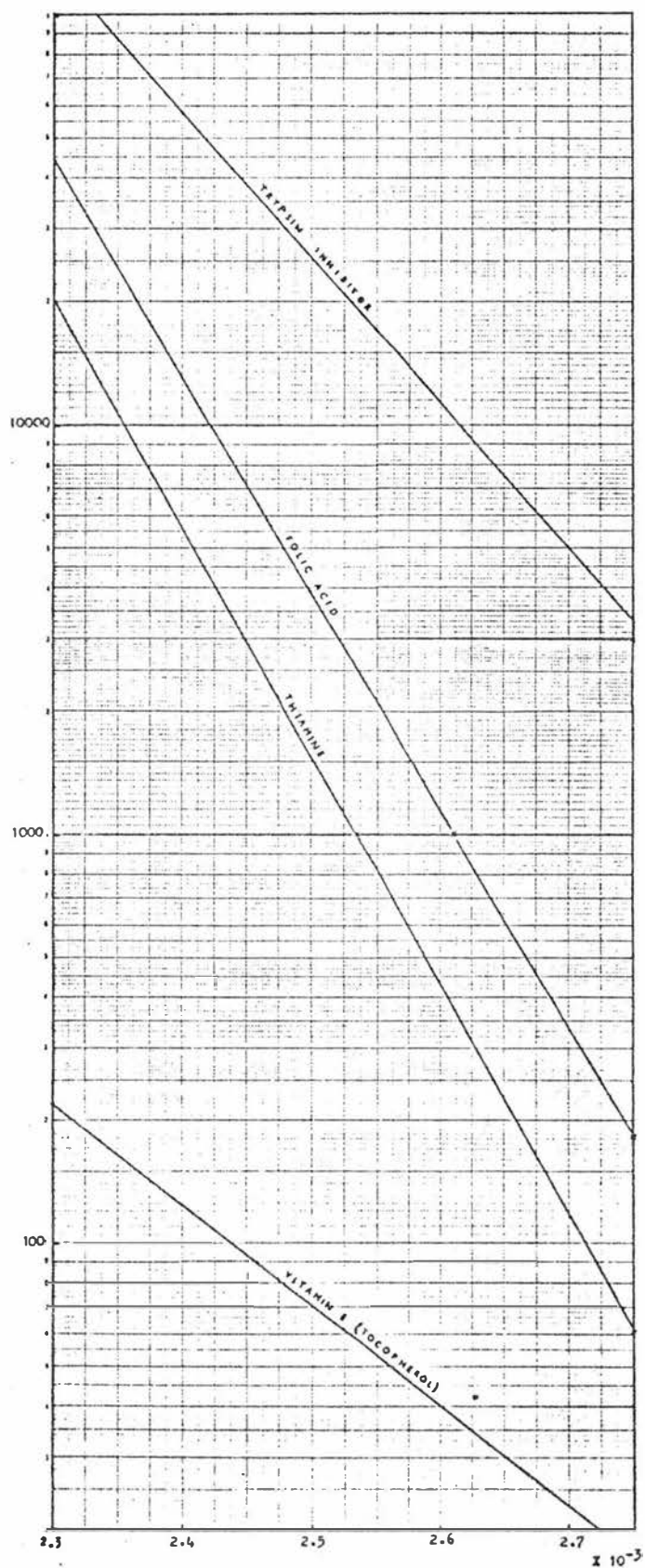
Firstly, the losses of amino acids were considerably lower than of vitamins. The differences in losses at the selected 2 temperatures of processing were not much with amino acids but were markedly so with vitamins.

Secondly, the order of the amino acids with the highest loss changed markedly when the temperature was raised from 98°C to 121°C in both batch and continuous processes. The order of vitamins changed to a smaller extent. This was due to the greater differences in the activation energies of amino acids than of vitamins.

Thirdly, the nutrient losses were higher at high temperature and short time than at low temperature and long time. This was due to the lower activation energy of the trypsin inhibitor in comparison to the activation energies of all the nutrients except riboflavin and tocopherol. Arrhenius plot of trypsin inhibitor was compared with some of the vitamins with high activation energies and high rates of reaction such as thiamine, folic acid and with low activation energies and low rates of reaction such as tocopherol as shown in Figure 5.2.

Despite the comparatively high rate of reaction in the destruction of trypsin inhibitor, the rate did not increase to any great extent with increasing temperature. On the contrary, all nutrients except tocopherol and riboflavin increased their rates of reaction more rapidly than the trypsin inhibitor. Therefore, the time needed to inactivate trypsin inhibitor at high temperatures would be more detrimental to all studied nutrients except tocopherol, riboflavin and phenylalanine than the time at low temperatures.

Reaction
rate constant
 $\times 10^{-3} \text{ hr}^{-1}$



Reciprocal of temperature ($^{\circ}\text{K}$)

Figure 5.2 Relationship of Reaction Rate and Temperature for Trypsin Inhibitor, Thiamine, Folic Acid and Vitamin E

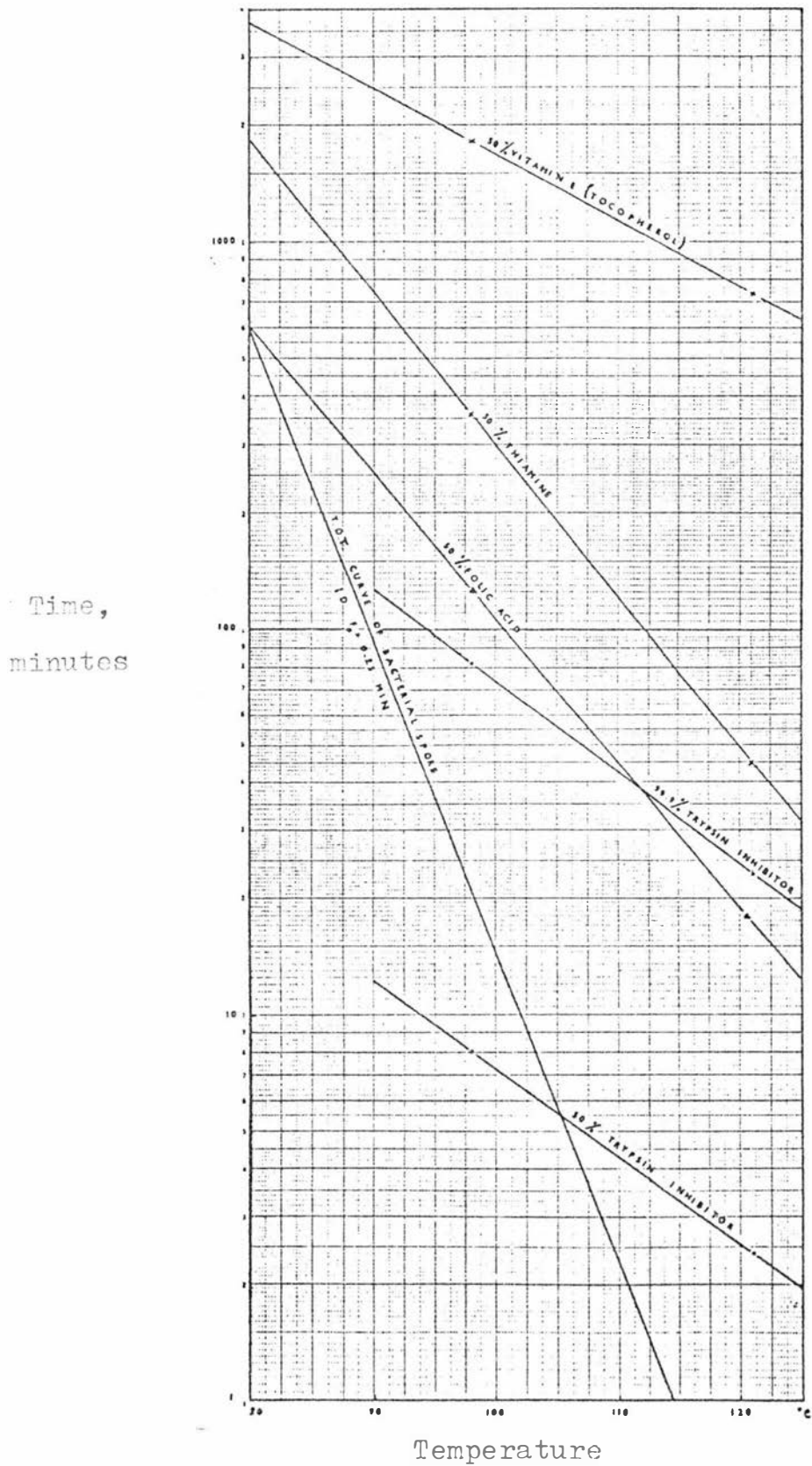


Figure 5.3 Comparison of the Destruction of Trypsin Inhibitor, Vitamins and Bacteria

The kinetic rate of reaction in the destruction of trypsin inhibitor in comparison to destruction of vitamins was contrary to the destruction of microorganisms compared to vitamins. Figure 5.3 shows the typical thermal death time (1 D) curve of bacterial spore (22) compared to 50 percent destruction of trypsin inhibitor, thiamine, folic acid and tocopherol. For trypsin inhibitor, the times required for 50 and 99.9 percent destruction did not decrease with increasing temperature as fast as for 50 percent destruction of folic acid and thiamine. The time required to destroy the bacterial spore changed very fast with temperature. Tocopherol, having the same activation energy as trypsin inhibitor, the rate at which the time changed with temperature was approximately the same. As can be seen from the intersection of the lines of 50 percent destruction of folic acid and 99.9 percent destruction of trypsin inhibitor, the inactivation of trypsin inhibitor at the temperature lower than 112°C will destroy less than 50 percent of folic acid and at temperature higher than 112°C the destruction of folic acid will be more than 50 percent. Regarding the time and temperature required to destroy trypsin inhibitor, it was obvious that high temperature and short time did not benefit the retention of all the vitamins and amino acids with the exception of tocopherol, riboflavin and phenylalanine. However, the increases in the retention of the exceptional nutrients were so small that high temperature/short time could not be regarded as a significant benefit.

Therefore, the low temperature and long time was more beneficial to use for the destruction of trypsin inhibitor.

Nevertheless, one must be aware that there is a limit in using the low temperature because of the reversibility in the destruction of trypsin inhibitor at temperatures of 90°C and lower. Temperatures above 90°C should be used.

Finally, losses of nutrients were generally less in the continuous process than in batch process. However, at the low temperature i.e. 98°C, the losses in the continuous process were only slightly less than by batch process. Once the higher temperature, 121°C was used, the losses were quite considerably higher in the batch process than by the continuous process. This was due to the fact that, the reaction rates at lower temperatures were not so great for most nutrients and became more significant at higher temperatures. Certainly at the high temperature, the nutrient with high activation energy would result in greater differences in nutrient losses between the batch and continuous process than the nutrient with lower activation energy.

5.4.2 Nutrient losses during drying process

The losses of nutrients were calculated as discussed in 5.4 for each of the specified times and temperatures in the 3 drying methods. The predicted losses are shown in Table 5.6.

In vacuum drying, there was not any significant change in the amino acids. With vitamins, the loss of riboflavin was highest at 52°C/2 hours i.e. 3.5 percent, while the losses in others were less than 1.0 percent. However, once the temperature was at 77°C/1 hour; the loss in riboflavin increased only slightly to 5.5 percent but losses in folic acid and ascorbic acid increased to 5.0

Table 5.6 The Predicted Nutrient Losses During Different Methods of Drying

	Vacuum drying		Foam mat drying		Drum drying	
	52°C/ 2hr	77°C/ 1hr	71°C/ 1hr	89°C/ 8min	104°C/ 60sec	160°C/ 30sec
	Percentage loss					
Histidine	0.001	0.009	0.004	0.005	0.003	0.140
Isoleucine	0.002	0.030	0.010	0.020	0.011	0.700
Leucine	0.001	0.080	0.040	0.040	0.016	0.340
Lysine	0.040	0.230	0.130	0.100	0.034	0.450
Methionine	0.020	0.150	0.080	0.070	0.031	0.700
Cystine	0.001	0.003	0.001	0.002	0.005	6.060
Phenylalanine	0.080	0.220	0.150	0.065	0.020	0.070
Tyrosine	0.005	0.050	0.023	0.020	0.010	0.320
Threonine	0.001	0.006	0.003	0.004	0.002	0.065
Tryptophan	0.140	0.420	0.280	0.130	0.040	0.190
Valine	0.300	0.620	0.470	0.170	0.040	0.112
Folic acid	0.69	4.64	2.58	2.07	0.85	14.97
Pantothenic acid	0.16	0.72	0.44	0.19	0.08	0.69
Vitamin B12	0.12	0.83	0.45	0.34	0.14	2.29
Vitamin B6	0.27	0.95	0.61	0.30	0.09	0.56
Niacin	0.03	0.2	0.11	0.09	0.04	0.68
Riboflavin	3.10	5.26	3.98	1.27	0.27	0.58
Thiamine	0.20	1.05	0.84	0.72	0.31	7.05
Ascorbic acid	0.36	1.73	1.03	0.65	0.22	2.27
Tocopherol	0.55	0.95	0.72	0.22	0.05	0.10
Carotene	0.14	0.61	0.38	0.21	0.07	0.53
Choline	0.12	0.83	0.45	0.34	0.14	2.29
Biotin	0.12	0.83	0.45	0.34	0.14	2.29

percent and 2.0 percent respectively, much higher than the other vitamin losses.

With foam mat drying, the losses in amino acids were not significant in both conditions of time and temperature; the losses were only from 0.5 to 1.0 percent. With vitamins, losses in riboflavin and ascorbic acid were higher than losses of other vitamins. At the conditions of 89°C/8 minutes, the losses in all vitamins were less than at 71°C/1 hour.

With drum drying, the losses of amino acids at drum temperature 104°C/60 seconds were not significant i.e. less than 0.1 percent. At conditions of 160°C/30 seconds, loss in cystine was highest at 6 percent while other amino acids were from 0.1 to 1.0 percent. With vitamins, the losses were not significant at the lower temperature. At 160°C/30 seconds, loss in folic acid was highest at 15 percent, next were thiamine at 7.5 percent, ascorbic acid and vitamin B12, biotin and choline at 2.5 percent, the others were less than 1.0 percent.

The losses of vitamins and amino acids in the 3 selected methods were generally small except when high temperatures were used with drum drying. It was notable that riboflavin with its comparatively high rate of reaction at low temperature was most affected at condition with low temperature. Once a higher temperature was used, the most affected vitamins were folic acid, thiamine, vitamin B12, biotin, choline and ascorbic acid, as these vitamins with higher activation energies increased their rates of reaction more rapidly with increasing temperature.

This calculation shows the importance of calculating

the losses in all vitamins when comparing different drying processes and conditions. Comparing the processes giving the highest losses of vitamins - drum drying at 160°C and vacuum drying at 77°C - folic acid, vitamin B12, biotin, choline, niacin, thiamine and ascorbic acid had the highest losses with drum drying at 160°C; but pantothenic acid, vitamin B6, riboflavin, tocopherol and carotene had the highest losses with vacuum drying at 77°C. Similarly, most amino acids had the greatest loss with drum drying at 160°C but phenylalanine, tryptophan and valine had the greatest loss with vacuum drying at 77°C. Therefore in choosing a process to give only a small loss of nutritional value, all the vitamins and amino acids need to be studied.

Comparing these drying methods to find the process giving the lowest loss of nutrients, drum drying at the lower temperature (104°C) gave the smallest losses for seven vitamins but vacuum drying at 52°C gave the smallest losses for folic acid, niacin and thiamine. However, the losses were not very different - 0.69 and 0.85, 0.03 and 0.04, 0.20 and 0.31 percent. Drum drying at 104°C for 60 seconds was the best method for drying infant food amongst the methods studied.

5.4.3 Nutrient losses in combined heating and drying process

The losses in vitamins and amino acids after batch heating at 98°C and then drying are shown in Table 5.7. The very much greater losses during the predrying stage overshadow the losses during drying. For example, the loss in folic acid after heating and drum drying at 104°C was 39.04 percent as compared with 0.85 percent with drying alone.

Drum drying at 104°C is still the method of drying

fixwage

Table 5.7 The Predicted Nutrient Losses During Different Methods of Drying with Batch Predrying at 98°C

	Vacuum drying		Foam mat drying		Drum drying	
	52°C/ 2hr	77°C/ 1hr	71°C/ 1hr	89°C/ 8min	104°C/ 60sec	160°C/ 30sec
Histidine	0.15	0.15	0.15	0.15	0.15	0.16
Isoleucine	0.58	0.61	0.59	0.60	0.60	1.27
Leucine	0.92	0.99	0.96	0.95	0.93	1.25
Lysine	2.19	2.39	2.28	2.24	2.18	2.59
Methionine	1.79	1.92	1.85	1.84	1.80	2.46
Cystine	0.18	0.19	0.18	0.18	0.19	6.23
Phenylalanine	1.31	1.45	1.38	1.30	1.25	1.30
Tyrosine	0.59	0.63	0.61	0.61	0.59	0.92
Threonine	0.11	0.11	0.11	0.11	0.11	0.17
Tryptophan	2.73	3.01	2.87	2.72	2.63	2.78
Valine	3.22	3.53	3.38	3.09	2.99	3.04
Folic acid	38.94	41.37	40.10	39.79	39.04	47.72
Pantothenic acid	5.38	5.90	5.64	5.40	5.30	5.88
Vitamin E12	7.88	8.53	8.18	8.08	7.89	9.88
Vitamin B6	6.05	6.69	6.37	6.08	5.88	6.32
Niacin	2.06	2.23	2.13	2.12	2.06	2.90
Riboflavin	19.28	21.08	20.02	17.75	16.93	17.19
Thiamine	16.09	16.80	16.62	16.53	16.18	21.85
Ascorbic acid	12.98	14.19	13.57	13.24	12.87	14.66
Tocopherol	4.11	4.49	4.27	3.79	3.62	3.66
Carotene	4.30	4.75	4.53	4.36	4.23	4.67
Choline	7.88	8.53	8.18	8.08	7.89	9.88
Biotin	7.88	8.53	8.18	8.08	7.89	9.88

giving the smallest loss in nutritional value.

5.5 Conclusion

Processing for an infant food was divided into predrying and drying processes. Cooking times and temperatures in the predrying process were designed to inactivate trypsin inhibitor because these times and temperatures would be adequate for the other processing purposes, i.e. gelatinization of starch and improvement of digestibility.

Though it was reported that first order reaction was not completely valid near neutral pH for destruction of trypsin inhibitor, it was felt that assuming first order over the short range of temperature and presenting the available data in such manner was more representative than taking one particular time and temperature for destruction. In fact, the temperatures and times defined by using the kinetics of the reaction were in the range reported by different investigators.

Only three methods of drying were selected as being suitable for processing infant food in Thailand. Though the drying times and temperatures could be calculated from the moisture needed to be removed from the product, it was not possible in this study without experimental data because of the unavailability of the required parameters, in particular for food materials. Therefore, general times and temperatures reported for different methods of drying were used in this study.

For predrying processes, the losses of vitamins and amino acids were higher at 121°C for 23 minutes than at 98°C for 81 minutes. This was due to the lower activation energy

of trypsin inhibitor, the rate of reaction does not increase with temperature as much as the rates of reaction of the nutrients except for tocopherol, riboflavin and phenylalanine. For these latter nutrients, the losses at these two temperatures were approximately the same. Therefore, it would be less detrimental to the nutrients to inactivate trypsin inhibitor at lower temperature and longer holding time, i.e. at 98°C for 81 minutes.

With different drying methods, there were only little differences in the losses of vitamins and amino acids except higher losses were found when high temperature was used in drum drying. Tryptophan and valine were affected more than the other amino acids in vacuum and foam mat drying. However, with the high temperature drum drying, cystine was most affected and folic acid was the most affected vitamin and next were the group of thiamine, vitamin B12, biotin, choline and ascorbic acid.

For both predrying and drying processes, the losses during predrying process overshadowed the losses during drying. The most affected nutrient was folic acid, next were the group of riboflavin, thiamine and ascorbic acid. Among all the studied times and temperatures, drum drying at 104°C/60 seconds resulted in the smallest losses of all nutrients.

From this study, it can be seen that kinetic data can be used to compare processes which are to produce foods to a certain nutritional standard. This approach in estimating the nutrient loss based on its kinetic property does give the profile in the losses of different nutrients at a certain time and temperature. These profiles can then

be compared for the different processes and a choice can be made for the process most suitable for the nutritional requirements.

The differences in the activation energies and the reaction rate constants of the vitamins and the amino acids illustrate why different nutrients were reported as being "the most unstable nutrient". Because of the marked differences in the activation energies, the order of nutrients, from the most affected to least affected changes with increase of temperature. There is a real need for more extensive kinetic data on nutrient destruction so that comparison of nutrient losses can be made on a systematic basis.

CHAPTER 6

INCLUSION OF THE PROCESSING LOSSES
INTO THE LINEAR PROGRAMING MODEL

Having defined the times and temperatures during the heating and drying processes, the next step was to investigate how the losses of nutrients during processing would affect the selection of raw materials, the nutritional value and the cost of the formulation. Only the model for infant aged from 6 - 12 months was studied.

The minimum requirements of the nutrients were increased according to the predicted losses and the nutritional constraints of the model were modified accordingly. The predrying process was first selected based on the nutritional value, the cost of the formulation and the cost of processing. Having selected the predrying process, the model was modified according to the nutrient losses during different drying methods. Finally a suitable drying method was selected.

This chapter discusses the difficulty in obtaining a nutritionally balanced and low cost formulation when the losses during processing were included.

6.1 Modification of the model according to the losses during the predrying process

The constraints on amino acids and vitamins were modified according to the predicted losses during the predrying processes. The minimum specifications for amino

acids and vitamins were increased by the amount predicted to be lost during the predrying process. As each amino acid was related to protein, the modification was in the coefficient of the column "PROT" (Table 3.3) corresponding to the row variables specifying the amino acids interrelated constraint i.e. CHIST, CISO, CLEU, CLYS, CSULAA, CAROMAA, CTHREO, CTRYF and CVAL. For vitamins, those specified by interrelated constraints were modified in the coefficient of the column CAL and LINOA corresponding to the row variables specifying the interrelated constraints such as CALRIBOL, CALVITCL (Table 3.3). For those vitamins specified by direct constraints, the lower limits were increased as in the case of folic acid, vitamin B12, vitamin B6 and niacin. The modified constraints for amino acids and vitamins are shown in Table 6.1. As discussed earlier in 3.5, a feasible solution could only be obtained either by releasing calcium upper bound to 700 mg per day or by the addition of calcium carbonate. Therefore, an attempt to obtain a solution was first made with the calcium upper bound at 700 mg.

Table 6.1 The Modified Constraints of Amino Acids and Vitamins for the Predrying Process

<u>Interrelated constraints</u>					
Column variable	Row variable	Coefficients at different temperatures of predrying process			
		98°C Patch	98°C Continuous	121°C Patch	121°C Continuous
PROT	CHIST	-15.50	-15.50	-15.60	-15.50
	CISO	-38.18	-38.18	-38.97	-38.57
	CLEU	-60.8	-60.8	-62.06	-61.43
	CLYS	-50.26	-50.0	-51.85	-50.78
	CSULAA	-40.71	-40.71	-42.22	-40.92
	CAROMAA	-66.09	-66.09	-66.77	-66.09
	CTHREO	-33.07	-33.07	-33.07	-33.07
	CTRYP	-12.27	-12.21	-12.46	-12.27
	CVAL	-47.63	-47.39	-48.13	-47.39
CAL	CALPATOL	-.00320	-.00320	-.00340	-.00320
	CALRIBOL	-.00084	-.00082	-.00090	-.00081
	CALTHIAL	-.00060	-.00059	-.00090	-.00073
	CALVITCL	-.120	-.114	-.140	-.120
	CALVITAL	-2.62	-2.60	-2.73	-2.65
	CALCHOL	-.076	-.076	-.089	-.081
	CALBIOTL	-.0160	-.0160	-.0190	-.0170
LINOA	VIELINOL	-.00105	-.00104	-.00105	-.00103
<u>Direct constraints</u>					
	FOLIC	.082	.079	.217	.128
	VITB12	.330	.330	.400	.350
	VITB6	.430	.420	.450	.428
	NIA	5.13	5.13	5.32	5.21

6.1.1 Obtaining the solution for the predrying process at 98°C

One infeasibility was obtained for both batch and continuous processes at 98°C, associated with the calcium upper bound. It was not possible to keep calcium at the limit of 700 mg. The other restricted constraints at bounds were found at the following upper and lower limits:

Upper limit	Lower limit
CU	CAL
CALKH	NIA
DHIST	VITD
	CAIVITAL
	CALIL
	CALZNL
	CSULAA

It was decided to release calcium upper limit rather than modify any of the other lower and upper limits, as discussed in 3.5 that calcium upper limit up to 1000 mg was regarded as not being harmful (26). It was found that by releasing calcium upper limit to 760 mg, feasible solutions were obtained for both batch and continuous processes. The nutritional and raw materials compositions of the solutions and their costs are shown in Table 6.2.

Table 6.2 Nutritional and Raw Material Compositions for Batch and Continuous Process at 98°C and 121°C

Raw Material Content (g)	Batch	Continuous	Batch	Continuous	Nutrient Content	Batch	Continuous	Batch	Continuous
	Process	Process	Process	Process		Process	Process	Process	Process
	98°C		121°C			98°C		121°C	
Anchovy	28.5	27.0	35.6	33.0	Ascorbic acid mg	196.9	198.1	185.5	200.2
Buffalo meat	-	0.1	0.1	0.1	Thiamine mg	0.95	0.96	0.94	0.99
Chicken liver	-	-	2.9	-	Riboflavin mg	0.64	0.75	0.79	0.75
Collard	205.9	207.2	195.3	209.2	Niacin mg	5.13	5.13	5.32	5.21
Duck egg	41.5	42.1	34.3	41.3	Vitamin B6 mg	1.55	1.56	1.42	1.59
Duck gizzard	8.0	7.3	-	8.1	Vitamin B12 mg	0.100	0.086	0.216	0.162
Ivy gourd	3.9	3.8	-	4.3	Pantothenic acid mg	2.96	2.95	2.99	2.96
Milk fish	13.1	13.2	-	13.8	Folic acid mg	1.03	1.04	1.01	1.04
Mungbean starch	51.2	51.1	49.7	48.8	Choline mg	424.06	425.73	409.27	425.38
Peanut, dried	-	-	1.8	-	Biotin mcg	18.15	18.28	19.30	18.76
Radish	5.6	5.7	4.9	5.8	Sodium mg	263.7	264.4	258.8	270.8
Serpent head fish	6.3	5.3	14.1	10.4	Chloride mg	253.0	250.9	246.9	268.7
Seean	16.7	16.8	16.8	19.6	Potassium mg	1811.4	1823.5	1760.0	1852.1
Soybean curd	8.4	7.8	10.8	9.8	Calcium mg	760.0	760.0	750.5	800.0
Sponge gourd	-	-	0.7	-	Phosphorus mg	542.9	542.9	536.1	571.4
Stripe mackerel	9.9	11.2	16.1	4.2	Magnesium mg	209.9	209.5	208.7	206.1
Sucrose	102.6	104.1	100.0	104.3	Iron mg	15.7	15.8	14.9	16.2
<u>Nutrient content</u>					Iodine mcg	45.3	45.6	44.0	46.3
Weight g	501.6	502.8	483.0	512.9	Manganese mg	1.7	1.7	1.7	1.7
Dried weight g	209.4	210.8	203.9	212.9	Copper mcg	740.0	740.0	740.0	740.0
Calorie kcal	905.7	911.7	880.0	926.1	Zinc mg	4.5	4.6	4.4	4.6
Protein g	29.9	29.7	28.9	31.2	Isoleucine mg	1512.0	1498.0	1539.0	1586.0
Fat g	18.1	18.2	17.6	19.8	Leucine mg	2212.0	2186.0	2259.0	2340.0
Carbohydrate g	155.0	156.4	150.8	155.3	Lysine mg	2040.0	2015.0	2136.0	2131.0
Fiber g	3.5	3.5	3.4	3.7	Methionine mg	924.0	918.0	925.0	973.0
Linoleic acid mg	3706.9	3731.2	3942.1	4185.0	Cytine mg	292.0	290.0	299.0	305.0
Retinol mcg	172.6	175.1	397.6	171.7	Phenylalanine mg	1407.0	1393.0	1405.0	1485.0
B-carotene mcg	1079.8	1073.4	652.9	1130.2	Threonine mg	1260.0	1246.0	1283.0	1333.0
Vitamin A I.U.	2373.0	2370.5	2402.4	2454.0	Tryptophan mg	428.0	427.0	396.0	444.0
Vitamin D I.U.	400.0	400.0	400.0	400.0	Tyrosine mg	887.0	878.0	926.0	937.0
Vitamin E I.U.	3.89	3.88	4.14	4.15	Valine mg	1630.0	1621.0	1658.0	1693.0
Vitamin K mcg	9514.7	9573.1	9031.7	9662.1	Histidine mg	656.0	653.0	722.0	687.0
					Cost baht	4.164	4.123	4.075	4.337

The raw material compositions for both processes were almost the same, the continuous process having one extra raw material, buffalo meat. There were no significant differences in the nutrient contents of the two solutions. The cost was slightly less for the continuous process. The differences in cost could be explained by considering the constraints at bounds.

Generally, cost of the solution will be reduced if the constraints at lower bounds are made lower and upper bounds are made higher (121). As the constraints for niacin, carotene and tocopherol were higher in batch process than in continuous process, (Table 6.1), the cost of batch process was higher than continuous process. Because of the small differences in the modified constraints of these nutrients, the difference in the costs was only small.

6.1.2 Obtaining the solutions for predrying processes at 121°C

It was not possible to obtain a feasible solution at calcium upper limit of 760 mg as for the predrying process at 98°C. Four infeasibilities were obtained associated with the negativity in column variable, MACKST (stripe mackerel); and the artificial variables associated with the inequality constraints of the row variables CAL, CALFROTH and DLYS could not be removed. These were lower limits of calorie, (CAL) upper limit of protein (CALFROTH) and upper limit lysine (DLYS). The restricted constraints at bounds were found in the following upper and lower limits:

Upper limit	Lower limit
CA	NIA
CU	VITD
CALKH	CALFATL
DHIST	CALVITAL
	VIELINOL
	CALRIBOL
	CALIL
	CALZNL
	CAPL
	CSULAA

As discussed earlier, calcium upper limit was considered before other upper limits at bounds. It was found possible to obtain a feasible solution when the calcium upper limit was at 800 mg per day for the continuous process. For batch process, it was not possible to obtain a solution by increasing calcium upper limit even at the value of 1000 mg per day. One infeasibility was obtained in the negativity of the column variable, RICEPAPO (parboiled rice). The restricted constraints at bounds were found in the following upper and lower limits:

Upper limit	Lower limit
CU	NIA
CALPROTH	VITD
CALKH	CALVITAL
DIYS	VIELINOL
DHIST	CALRIEOL
	CALPATOL
	CALIL
	CALZNL
	CAPL
	CSULAA

Obviously, calcium upper limit at 1000 mg did not restrict the obtaining of the feasible solution anymore though it was still difficult to maintain the minimum ratio of calcium to phosphorus (CAPL) at 1.4. It was more the effect of the other listed constraints. Among the restricted upper limits, protein (CALPROTH) could not be modified because it was the maximum limit allowed by the Thai Notification. Copper, potassium and amino acids were not specified by the Thai Notification. It was preferable not to modify copper

and potassium upper limits because of their potential adverse effects. Therefore, only upper limits on lysine and histidine were freed. As the consequence, a feasible solution was obtained. Table 6.2 shows the nutritional and raw material compositions and the costs of the solutions for both batch and continuous processes at 121°C. Differences in the two solutions were found in raw material compositions, nutritional compositions and costs.

For the raw material compositions, the differences were extra raw materials such as duck gizzard, ivy gourd, milk fish in continuous process and chicken liver, sponge gourd, dried peanut in batch process. In addition, the solution for the batch process contained higher content of serpent head fish.

For the nutritional composition, the contents of lysine and histidine exceeded their maximum limits by 4 and 3 mg per g of protein. Though lysine and histidine exceeded the upper limit only slightly, it was not desirable because the purpose was to have amino acids as near as possible to the pattern of egg amino acids.

For the cost, one must take into account that additional modification was made to the model for batch process. Hence, the costs of the two solutions could not be compared directly. The cost of the continuous process was higher than the batch process.

6.1.3 The effect of adding calcium carbonate to the model

It was found in the preliminary study (3.5) that a feasible solution could be obtained at the original value of calcium upper bound, 630 mg, by providing calcium independent of phosphorus. Therefore, the addition of

calcium carbonate was also studied. The calcium upper limits were at the levels found feasible to obtain the solutions for the process at 98°C, 760 mg and for the process at 121°C, 800 mg.

Feasible solutions were obtained for both processes at 98°C and 121°C. The nutritional and raw material compositions and the costs of the solutions are shown in Table 6.3.

Table 6.3 Nutritional and Raw Material Compositions for Batch and Continuous Process at 98°C and 121°C with Calcium Carbonate Added

Raw Material Content (g)	98°C		121°C		Nutrient Content	98°C		121°C	
	Batch Process	Continuous Process	Batch Process	Continuous Process		Batch Process	Continuous Process	Batch Process	Continuous Process
Anchovy	41.4	41.2	39.4	42.1	Vitamin K mcg	466.8	469.1	1417.7	454.8
Buffalo	0.2	0.3	0.3	0.2	Ascorbic acid mg	105.6	100.3	123.2	105.6
Cabbage	-	-	3.6	-	Thiamine mg	0.71	0.71	0.79	0.71
Cassava starch	53.3	55.0	46.2	52.7	Riboflavin mg	0.71	0.72	0.79	0.71
Coconut	5.1	4.2	-	1.3	Niacin mg	6.96	6.93	7.30	7.52
Collard	-	-	18.6	0.3	Vitamin B6 mg	1.39	1.39	1.64	1.41
Duck egg	13.9	14.0	23.9	14.0	Vitamin B12 mg	0.004	0.004	0.004	0.004
Guava	46.8	42.7	45.3	48.1	Pantothenic acid mg	2.82	2.82	3.11	2.82
Milk fish	12.8	13.0	13.9	12.1	Folic acid mg	0.13	0.13	0.22	0.13
Peanut	-	-	-	1.3	Choline mg	228.52	228.78	265.89	242.80
Rice, brown	14.6	14.8	30.7	14.0	Biotin mcg	14.08	14.08	16.72	15.31
Rice, parboiled	6.9	5.6	-	11.5	Sodium mg	234.9	235.1	240.8	252.6
Sesame	19.9	20.4	19.7	21.2	Chloride mg	270.5	269.4	284.13	286.6
Sponge gourd	18.2	18.1	17.5	16.4	Potassium mg	1760.0	1760.0	1760.0	1760.0
Squid	32.9	32.8	21.5	44.2	Calcium mg	760.0	760.0	800.0	800.0
Soybean	3.0	3.0	2.4	3.1	Phosphorus mg	542.9	542.9	571.4	571.4
Sweet potato, white	101.0	102.4	113.2	90.5	Magnesium mg	410.2	409.8	424.8	393.9
Sweet potato, yellow	64.7	64.1	59.0	65.7	Iron mg	8.8	8.8	9.5	8.8
Sucrose	36.6	36.4	34.0	33.5	Iodine mcg	44.0	44.0	44.0	44.0
Calcium carbonate	1.03	1.03	1.03	1.10	Manganese mg	782.4	790.0	788.9	743.9
<u>Nutrient content</u>					Copper mcg	740.0	740.0	740.0	740.0
Weight g	472.2	469.0	490.2	473.3	Zinc mg	6.4	6.3	6.2	6.3
Dried weight g	205.0	204.9	205.5	205.1	Isoleucine mg	1253.0	1252.0	1286.0	1372.0
Calorie kcal	880.0	880.0	880.0	880.0	Leucine mg	1990.0	1987.0	2039.0	2136.0
Protein g	26.5	26.5	26.9	28.7	Lysine mg	1754.0	1750.0	1743.0	1918.0
Fat g	17.6	17.6	17.6	17.6	Methionine mg	784.0	783.0	836.0	848.0
Carbohydrate g	154.3	154.3	154.2	152.0	Cystine mg	296.0	295.0	300.0	328.0
Fiber g	5.6	5.4	5.7	5.6	Phenylalanine mg	1150.0	1149.0	1202.0	1250.0
Linoleic acid mg	3760.5	3831.2	3802.5	4029.5	Threonine mg	1106.0	1106.0	1132.0	1195.0
Retinol mcg	74.9	75.4	110.7	76.8	Tryptophan mg	356.0	356.0	375.0	376.0
B-carotene mcg	1232.5	1221.1	1219.8	1244.7	Tyrosine mg	953.0	952.0	972.0	1040.0
Vitamin A I.U.	2305.0	2288.0	2402.4	2332.0	Valine mg	1488.0	1486.0	1517.0	1640.0
Vitamin D I.U.	400.0	400.0	400.0	400.0	Histidine mg	584.0	583.0	592.0	632.0
Vitamin E I.U.	3.95	3.98	3.99	4.15	Cost baht	2.839	2.826	2.983	2.843

The differences in the solutions with and without calcium carbonate were found in raw material and nutritional compositions and the costs of the solution. The major raw materials in the solution without calcium carbonate were found to be collard, sugar, mungbean starch, duck egg and anchovy, while the major raw materials with addition of calcium carbonate were sweet potato, cassava starch, guava, anchovy and squid.

For the nutritional compositions, significant differences were found in the levels of vitamin K and ascorbic acid. The solutions without the addition of calcium carbonate contained a high level of vitamin K, approximately 9500 mcg, compared to 470 mcg in the other solution. It must be noted that the minimum requirement was specified only at 15 mcg (81). For ascorbic acid, the solution without calcium carbonate contained approximately twice as much as the solution with addition of calcium carbonate.

For the cost, the solutions with the addition of calcium carbonate were considerably cheaper. Table 6.4 summarizes the costs and modification of predrying processes with and without addition of calcium carbonate.

Table 6.4 The Cost of the Solutions and the Modifications for Predrying Process, with and without Calcium Carbonate

Type of predrying process	With calcium carbonate		Without calcium carbonate	
	Cost, baht	Modified constraints	Cost, baht	Modified constraints
98°C, batch	2.839	Calcium upper limit at 760 mg	4.164	Calcium upper limit at 760 mg
98°C, continuous	2.825	" "	4.122	" "
121°C, batch	2.983	Calcium upper limit at 800 mg	4.074	Calcium upper limit at 800 mg; lysine, histidine upper limit freed
121°C, continuous	2.843	Calcium upper limit at 800 mg	4.337	Calcium upper limit at 800 mg
98°C, batch	2.832	Calcium upper limit at 800 mg	-	-
98°C, continuous	2.818	" "	-	-

At 98°C, the costs of the solutions were reduced by approximately 31 percent for both batch and continuous processes. The same was found for the continuous process at 121°C. For the batch process, the cost could not be directly compared because the upper limits for lysine and histidine were freed to obtain the feasible solution. Nevertheless, the costs were cheaper with the addition of calcium carbonate for both processes at 121°C. The costs of the solutions were also cheaper when calcium upper limit was increased from 760 to 800 mg.

6.2 Selection of predrying process

To select for the predrying process, consideration

was given to the nutritional value of the solution, the cost of the solution and the cost of the process.

6.2.1 The nutritional value of the solution

With only indigenous raw materials, it was found that the nutritional values of the solutions for both processes at 98°C were approximately the same. The only modification to the original problem was in calcium upper limit at 760 mg. At 121°C, the calcium upper limit had to be at 800 mg to obtain the solution for continuous process and lysine and histidine must be allowed to exceed their upper limits for the batch process. Though having lysine and histidine exceed their upper limits did not create any hazard to infant, it was not desirable because of the required amino acids being near to the egg pattern. Obviously, the solutions for both batch and continuous processes at 98°C were closer to the specified nutritional requirement than at 121°C.

With addition of calcium carbonate as raw material, there was little difference in the nutritional values of the solutions for all processes. It was possible to obtain solutions without having to modify any of the constraints, the calcium upper limit being at 630 mg. Nevertheless, the studied levels were at 760 mg and 800 mg to make them comparable with the solutions without the addition of calcium carbonate.

6.2.2. The cost of the solutions for different predrying processes

As shown in Table 6.4, the cost of the continuous process at 121°C was higher than both processes at 98°C. For batch process at 121°C, it was not possible to compare

the cost of solution directly because of the difference in the nutritional modification. With addition of calcium carbonate, the costs of the solutions for different predrying processes increased when processing conditions at 121°C were used. At the same nutritional constraints, it could be concluded that the cost of the solution for the process at 98°C was cheaper than at 121°C . Considering both nutritional value and cost of the solution, it was obvious that the process at 98°C was more desirable than at 121°C . Therefore, it was decided to use the predrying process at 98°C . However to consider whether the batch or continuous process should be used, the cost of processing and the cost of the raw materials in solutions were considered.

6.2.3 The cost of the processing and the cost of the raw materials for the batch and continuous processes

The cost of the raw materials in the solution for the continuous process was found to be approximately 1 - 2 percent cheaper than for the batch process. However the equipment required for the batch process would be considerably cheaper than continuous process due to its simplicity (7). To decide on the process does depend on the size of the production, the reduction in the cost of raw material could compensate for the increase in the cost of the equipment with large scale production. It was felt that simple and versatile equipment such as a jacketed pan as required for the batch process would make the starting of the new product easier, in particular for Thailand. Therefore, it was decided to use the batch process at 98°C for further studying on the effect of drying.

6.3.1 Obtaining the solutions for different drying methods

The feasible solutions were obtained for both temperatures and times of vacuum drying and foam mat drying. For drum drying, it was feasible only for the drying at 104°C. At 160°C, there were 2 infeasibilities associated with the negativity in the column variable RICEPAFO (parboiled rice) and the artificial value associated with the inequality constraint of calcium upper limit could not be removed. Even with the upper limit of calcium at 1000 mg, one infeasibility was obtained in the negativity of column variable RICEPAFO, the restricted constraints at bounds were found in the following upper and lower limits:

Upper limit	Lower limit
CU	NIA
CALPROTH	VITD
CALKH	CALVITAL
DIYS	VIELINOL
DUIST	CALRIPOL
	CALPATOL
	CALIL
	CALZNL
	CAPL
	CSULAA

These restricted constraints were the same as encountered in obtaining the solution for batch predrying process at 121°C. As discussed earlier in 6.1.2, it was decided to first modify the upper limits of lysine and histidine. By freeing these upper limits, a feasible solution was obtained for drum drying at 160°C. The solutions for different drying methods are shown in Table 6.6.

Raw Material Content (g)	Vacuum Drying		Foam mat Drying		Drum drying		Vacuum Drying		Foam mat Drying		Drum Drying		
	52°C/2 hr	77°C/1 hr	71°C/1 hr	89°C/8 min	104°C/60 sec	160°C/30 sec	52°C/2 hr	77°C/1 hr	71°C/1 hr	89°C/8 min	104°C/60 sec	160°C/30 sec	
Anchovy	30.6	30.9	30.8	27.4	26.2	24.3	<u>Nutrient Content</u>						
Buffalo	0.1	0.1	0.1	0.1	-	0.1	Thiamine mg	0.94	9.94	0.94	0.96	0.97	0.92
Coconut	-	-	-	-	-	0.5	Riboflavin mg	0.78	0.80	0.79	0.77	0.69	0.75
Collard	204.5	204.2	204.3	206.8	207.7	191.7	Niacin mg	5.13	5.13	5.13	5.13	5.13	5.16
Duck egg	40.6	40.4	40.5	41.9	42.5	40.2	Vitamin B6 mg	1.54	1.53	1.50	1.60	1.60	1.50
Gizzard duck	9.0	9.1	9.0	7.4	6.7	-	Vitamin B12 mg	0.124	0.124	0.123	0.090	0.078	0.004
Ivy gourd	3.9	4.0	4.0	3.9	4.0	4.2	Pantothenic acid	2.96	2.96	3.00	2.95	2.94	2.80
Milk fish	12.9	12.8	12.8	13.2	13.3	-	Folic acid mg	1.02	1.02	1.02	1.03	1.04	0.97
Mungbean starch	51.2	51.2	51.2	51.1	51.0	51.4	Choline mg	421.3	420.8	421.0	425.2	426.9	414.4
Peanut dried	-	-	-	-	-	1.2	Biotin mg	17.96	17.92	17.90	18.20	18.40	17.70
Radish	5.4	5.3	5.3	5.7	5.8	5.1	Sodium mg	262.8	262.7	262.8	264.3	264.9	253.9
Serpent head fish	7.6	7.9	7.8	5.6	4.8	-	Chloride mg	255.9	256.4	256.3	251.7	249.9	214.2
Sesame	16.6	16.6	16.6	16.8	16.8	16.1	Potassium mg	1796.1	1793.7	1794.7	1820.8	1830.6	1760.0
Soybean curd	8.5	8.5	8.5	7.8	7.8	8.7	Calcium mg	760.0	760.0	760.0	760.0	760.0	719.9
Sponge gourd	-	-	-	-	-	3.5	Phosphorus mg	542.9	542.9	542.9	542.9	542.9	514.2
Stripe mackerel	8.0	7.6	7.8	10.8	12.0	28.2	Magnesium mg	210.3	210.3	210.2	209.5	209.2	208.9
Sucrose	100.8	100.5	100.6	103.8	105.0	100.9	Iron mg	15.6	15.5	15.6	15.7	15.8	14.8
<u>Nutrient Content</u>							Iodine mg	44.9	44.8	44.9	45.5	45.8	44.0
Weight g	499.5	499.2	499.3	502.4	503.8	476.1	Manganese mg	1.7	1.7	1.7	1.7	1.7	1.7
Dried weight g	207.7	207.4	207.5	210.5	211.6	203.6	Copper mcg	740.0	740.0	740.0	740.0	740.0	740.0
Calorie kcal	898.0	896.9	897.4	910.4	915.3	880.0	Zinc mg	4.5	4.5	4.5	4.6	4.6	4.4
Protein g	30.1	30.1	30.1	29.7	29.6	26.8	Isoleucine mg	1527.0	1530.0	1529.0	1501.0	1491.0	1400.0
Fat g	17.9	17.9	17.9	18.2	18.3	17.6	Leucine mg	2244.0	2249.0	2247.0	2192.0	2171.0	2024.0
Carbohydrate g	153.3	153.0	153.1	156.1	157.2	152.9	Lysine mg	2071.0	2075.0	2073.0	2020.0	2001.0	1911.0
Fibre g	3.5	3.4	3.5	3.5	3.5	3.3	Methionine mg	931.0	932.0	931.0	919.0	915.0	864.0
Linoleic acid mg	3686.4	3683.7	3685.0	3727.9	3741.3	3765.2	Cystine mg	294.0	294.0	294.0	290.0	289.0	279.0
Retinol mcg	168.9	168.3	168.5	174.4	176.8	164.7	Phenylalanine mg	1423.0	1425.0	1424.0	1396.0	1386.0	1284.0
B-carotene mcg	1073.9	1080.8	1081.1	1082.4	1093.0	1061.4	Threonine mg	1278.0	1281.0	1280.0	1249.0	1238.0	1153.0
Vitamin A I.U.	2350.8	2360.2	2361.5	2383.2	2408.6	2315.8	Tryptophan mg	429.0	428.0	428.0	427.0	427.0	382.0
Vitamin D I.U.	400.0	400.0	400.0	400.0	400.0	400.0	Tyrosine mg	898.0	900.0	899.0	880.0	873.0	843.0
Vitamin E I.U.	3.87	3.87	3.90	3.90	3.90	3.90	Valine mg	1641.0	1642.0	1641.0	1522.0	1615.0	1571.0
Vitamin K mcg	9448.70	9434.90	9439.16	9556.35	9594.70	8865.90	Histidine mg	662.0	663.0	662.0	654.0	651.0	667.0
Ascorbic acid mg	195.5	195.2	195.3	197.8	198.7	184.4	Cost baht	4.214	4.221	4.219	4.131	4.099	3.662

Table 6.6 Nutritional and Raw Material Compositions of the Solutions for Different Methods of Drying

Differences in the solutions for different drying methods were found in the raw material compositions, the nutritional compositions and the costs.

The raw material compositions. There was not much difference in the raw material compositions for the selected times and temperatures of vacuum and foam mat drying. However, for drum drying at 104°C, there were slight increased amounts of stripe mackerel, duck egg, while the amounts of duck gizzard and serpent head fish were reduced. Drum drying at 160°C, the solution did not have serpent head fish but the content of stripe mackerel increased markedly. The other differences were in the extra raw materials - coconut, dried peanut and spongegourd.

The nutritional compositions. There was not much difference in the solutions for vacuum, foam mat and drum drying at 104°C as the same modification was on calcium upper limit at 760 mg. For drum drying at 160°C, lysine and histidine exceeded their upper limits by 2 mg and 3 mg per g of protein respectively. Though this modification did not create any hazard, it was not desirable as discussed earlier.

Considering whether the lower limit of protein needed to be adjusted as discussed earlier in 2.1.2, the level of protein per 100 kcal from the solutions for different processing methods were found at the following level:

Vacuum drying	at 52°C for 2 hours	was at 3.35
Vacuum drying	at 77°C for 1 hour	was at 3.36
Foam mat drying	at 71°C for 1 hour	was at 3.35
Foam mat drying	at 89°C for 8 minutes	was at 3.26
Drum drying	at 104°C for 60 seconds	was at 3.23
Drum drying	at 160°C for 30 seconds	was at 3.05

All the solutions had sulphur amino acids as limiting amino acids at the level of 70 percent of egg amino acids. To allow for the use of lower protein quality at the level of 70 percent of egg amino acids, the protein per 100 kcal would require to be at 2.57 g. It was obvious that the actual protein content in these solutions well covered the corrected value. Therefore, the solutions could be regarded as having adequate protein and amino acids as specified for infant requirement.

Regarding the fat content - as discussed in 2.1.4, fat lower limit could be increased if it would either benefit the obtaining of a solution or reduce cost. However, fat was at the lower limit and was found in the restricted constraint CALFATL. It means that the increase in fat requirement will increase the cost of the solution. It was obvious that the modification for fat lower limit was not desirable. Therefore, the minimum requirement for fat was used at its original value i.e. 2 g per 100 kcal.

Regarding fibre as discussed in 2.1.17, there was not adequate evidence to specify the requirement for fibre. The fibre in the solution should not be much greater than what is found in commercial infant food. The fibre in the solutions for different processes were found at the following levels:

Vacuum drying	at 52 ^o C for 2 hours	was at 0.39g/100 kcal
Vacuum drying	at 77 ^o C for 1 hour	was at 0.38g/100 kcal
Foam mat drying	at 71 ^o C for 1 hour	was at 0.39g/100 kcal
Foam mat drying	at 89 ^o C for 8 minutes	was at 0.38g/100 kcal
Drum drying	at 104 ^o C for 60 seconds	was at 0.38g/100 kcal
Drum drying	at 160 ^o C for 30 seconds	was at 0.38g/100 kcal

These contents for fibre were comparable to the range of fibre found in commercial infant food as discussed earlier i.e. between 0.34 to 1.55 g per 100 kcal (81). These values of fibre could be regarded as acceptable. Therefore it was not necessary to specify for fibre maximum limit for these solutions.

The costs. The highest cost was found in the solution for vacuum drying at 77°C/1 hour, next were at 71°C/1 hour, 52°C/2 hours, 39°C/8 minutes, 104°C/60 seconds and 160°C/30 seconds. As discussed earlier in 6.1.1, the differences in the costs of the solutions could be explained by observing the restricted constraints at bounds during drying. Table 6.7 shows the restricted constraints of different solutions. The restricted constraints of the solutions for vacuum drying, foam mat drying and drum drying at 104°C were the same. Among the nutrients associated with restricted constraints, iodine, zinc, vitamin D and fat were taken as being stable in this study. The nutrients taken as being destroyed during processing were niacin, vitamin A, tocopherol, riboflavin and sulphur amino acids. The predicted losses of niacin and sulphur amino acids were the same for different times and temperatures of drying except at 160°C for 30 seconds. The predicted losses of other restricted nutrients for different drying are reviewed in Table 6.8. Vitamin A and tocopherol were destroyed more at low temperature and long time drying rather than high temperature and short time, the same was found for riboflavin but to a greater extent.

Table 6.7 The restricted constraints of the solutions for different drying methods, with and without calcium carbonate

Without calcium carbonate		With calcium carbonate	
For vacuum drying, foam mat drying and drum drying at 104°C/60 sec			
<u>Lower limit</u>	<u>Upper limit</u>	<u>Lower limit</u>	<u>Upper limit</u>
NIA	CA	CAL	CA
VITD	CU	CL	CU
CALFATL	CALKH	VITD	CALKH
CALVITAL	DHIST	CALFATL	DHIST
VIELINOL		CALVITAL	
CALRIBOL		VIELINOL	
CALIL		CALVITCL	
CALZNL		CALRIBOL	
CAPL		CALPATOL	
CSULAA		CALPIOTL	
		CALFEL	
		CALIL	
		CAPL	
		CSULAA	
For drum drying at 160°C/30 sec			
<u>Lower limit</u>	<u>Upper limit</u>	<u>Lower limit</u>	<u>Upper limit</u>
CAL	CU	The same as	CA
NIA	CALKH	for other	CALKH
VITD		methods of	DHIST
CALFATL		drying	
CALVITAL		listed above	
VIELINOL			
CALRIBOL			
CALPATOL			
CALIL			
CALZNL			
CAPL			
CSULAA			

Table 6.8 Summary on the Cost, Modification of the 236.
Constraints and the Percentage Losses of Restricted Nutrients
for Different Drying Methods

Temperature and time of Drying	Without Addition of Calcium Carbonate				With Addition of Calcium Carbonate			
	Cost	Modification	Percentage losses of Restricted Nutrients ^a		Cost	Modification	Percentage losses of Restricted Nutrients ^a	
52°C for 2 hours	4.214	Calcium upper limit at 760 mg	Vitamin A	4.5	2.874	Modification was not required, calcium upper limit at 630 mg	Vitamin A	4.5
			Tocopherol	4.5			Ascorbic acid	13.0
			Riboflavin	19.5			Riboflavin	19.5
			Sulphur amino acids	2.0			Pantothenic acid	5.5
							Biotin	8.0
							Sulphur amino acids	2.0
71°C for 1 hour	4.218	Calcium upper limit at 760 mg	Vitamin A	5.0	2.880	Modification was not required, calcium upper limit at 630 mg	Vitamin A	5.0
			Tocopherol	4.5			Ascorbic acid	14.0
			Riboflavin	20.5			Riboflavin	20.5
			Sulphur amino acids	2.0			Pantothenic acid	6.0
							Biotin	8.5
							Sulphur amino acids	2.0
77°C for 1 hour	4.221	Calcium upper limit at 760 mg	Vitamin A	5.0	2.882	Modification was not required, calcium upper limit at 630 mg	Vitamin A	5.0
			Tocopherol	4.5			Ascorbic acid	14.5
			Riboflavin	21.5			Riboflavin	21.5
			Sulphur amino acids	2.0			Pantothenic acid	6.0
							Biotin	9.0
							Sulphur amino acids	2.0
89°C for 8 minutes	4.131	Calcium upper limit at 760 mg	Vitamin A	4.5	2.876	Modification was not required, calcium upper limit at 630 mg	Vitamin A	4.5
			Tocopherol	4.0			Ascorbic acid	13.5
			Riboflavin	18.0			Riboflavin	18.0
			Sulphur amino acids	2.0			Pantothenic acid	5.5
							Biotin	8.5
							Sulphur amino acids	2.0
104°C for 60 seconds	4.099	Calcium upper limit at 760 mg	Vitamin A	4.5	2.871	Modification was not required, calcium upper limit at 630 mg	Vitamin A	4.5
			Tocopherol	4.0			Ascorbic acid	13.0
			Riboflavin	17.0			Riboflavin	17.0
			Sulphur amino acids	2.0			Pantothenic acid	5.5
							Biotin	8.0
							Sulphur amino acids	2.0
160°C for 30 seconds	3.662	Histidine and lysine exceeding upper limits	Vitamin A	5.0	2.930	Modification was not required, calcium upper limit at 630 mg	Vitamin A	5.0
			Tocopherol	4.0			Ascorbic acid	15.0
			Riboflavin	17.5			Riboflavin	17.5
			Pantothenic acid	6.0			Pantothenic acid	6.0
			Sulphur amino acid	6.5			Biotin	10.0
							Sulphur amino acids	6.5

^a Figure given to the nearest 0.5 percent.

As a consequence of the highest losses of vitamin A, tocopherol and riboflavin at 77°C and 71°C for 1 hour than other times and temperatures, except at 160°C, the cost of these two solutions were higher than others. However, with the modification of lysine and histidine upper limits, the cost of drum drying at 160°C was the cheapest. As reviewed in Table 6.8, the cost of the solutions tended to decrease when the high temperatures and short times were used.

6.3.2 Obtaining the solutions for different drying methods with the addition of calcium carbonate

The feasible solutions for different times and temperatures of drying were obtained without any modification of the constraints. The nutritional and raw material compositions are shown in Table 6.9.

The raw material compositions. The effect of adding calcium carbonate was found in the differences in the raw material compositions. The solutions with indigenous raw materials contained a high level of collard, sucrose and a moderate level of mungbean starch, duck egg and anchovy. With the addition of calcium carbonate, the solutions contained high levels of sweet potato and moderate levels of sugar, yellow sweet potato, cassava starch and anchovy.

Raw Material Content (g)	Vacuum Drying		Foam mat Drying		Drum Drying		Nutrient Content						
	52°C/2 hr	77°C/1 hr	71°C/1 hr	89°C/8 min	104°C/60 sec	160°C/60 sec	52°C/2 hr	77°C/1 hr	71°C/1 hr	89°C/8 min	104°C/60 sec	160°C/60 sec	
Anchovy	25.8	23.7	24.2	25.2	25.6	32.2	Ascorbic acid mg	101.1	102.9	102.3	101.7	101.1	103.5
Buffalo meat	0.3	0.3	0.3	0.2	0.2	0.2	Thiamine mg	0.71	0.72	0.72	0.71	0.71	0.70
Cassava starch	55.8	55.9	56.1	55.7	55.9	57.5	Riboflavin mg	0.77	0.78	0.77	0.75	0.66	0.75
Coconut	10.1	9.5	9.6	9.9	10.0	8.7	Niacin mg	5.77	5.89	5.87	5.81	5.78	5.30
Collard	25.0	22.7	22.2	25.8	25.3	19.1	Vitamin B ₆ mg	1.5	1.5	1.5	1.5	1.5	1.5
Duck egg	23.9	25.1	24.9	24.1	23.9	26.9	Vitamin B ₁₂ mg	0.003	0.003	0.003	0.003	0.003	0.004
Guava	27.5	30.0	29.8	27.6	27.3	33.9	Pantothenic acid	2.79	2.82	2.82	2.79	2.79	2.82
Stripe mackerel	7.7	9.4	9.1	8.2	7.9	3.1	Folic acid mg	0.24	0.23	0.23	0.24	0.24	0.21
Milk fish	19.9	20.2	20.1	20.1	19.9	17.8	Choline mg	236.0	239.9	238.8	237.1	235.9	242.1
Rice, brown	5.5	6.9	7.0	5.7	5.8	-	Biotin mcg	14.3	14.5	14.4	14.4	14.3	14.7
Rice, parboiled	14.6	12.3	11.8	14.9	14.5	16.0	Sodium mg	193.9	195.6	195.4	194.3	194.0	199.1
Sesame	15.2	15.2	15.2	15.3	15.2	15.5	Chloride mg	213.0	213.0	213.0	213.0	213.0	213.0
Soybean	1.5	1.5	1.5	1.4	1.4	1.5	Potassium mg	1760.0	1760.0	1760.0	1760.0	1760.0	1760.0
Sponge gourd	14.2	13.4	13.6	13.8	14.1	17.7	Calcium mg	630.0	630.0	630.0	630.0	630.0	630.0
Sweet potato, white	104.6	108.5	108.8	104.5	104.8	101.3	Phosphorus mg	450.0	450.0	450.0	450.0	450.0	450.0
Sweet potato, yellow	56.0	55.9	56.2	55.8	56.0	55.3	Magnesium mg	390.9	397.5	398.4	390.1	391.1	377.2
Sucrose	43.7	43.1	43.3	43.4	43.5	45.8	Iron mg	8.8	8.8	8.8	8.8	8.8	8.8
Calcium carbonate	0.75	0.77	0.77	0.75	0.75	0.75	Iodine mg	44.0	44.0	44.0	44.0	44.0	44.0
<u>Nutrient Content</u>							Manganese mg	768.9	784.5	786.8	767.6	770.0	759.0
Weight g	452.1	454.6	454.5	452.4	452.2	453.4	Copper mcg	740.0	740.0	740.0	740.0	740.0	739.7
Dried weight g	203.6	203.7	203.7	203.6	203.6	203.6	Zinc mg	6.0	6.0	6.0	6.0	6.0	6.0
Calorie kcal	880.0	880.0	880.0	880.0	880.0	880.0	Isoleucine mg	989.0	986.0	984.0	989.0	988.0	1007.0
Protein g	22.0	22.1	22.0	22.1	22.0	21.9	Leucine mg	1568.0	1560.0	1559.0	1567.0	1565.0	1600.0
Fat g	17.6	17.6	17.6	17.6	17.6	17.6	Lysine mg	1321.0	1322.0	1321.0	1320.0	1319.0	1358.0
Carbohydrate g	158.2	158.2	158.2	158.2	158.2	158.2	Methionine mg	674.0	675.0	674.0	675.0	673.0	713.0
Fiber g	4.6	4.7	4.7	4.6	4.6	4.8	Cystine mg	224.0	224.0	224.0	224.0	224.0	222.0
Linoleic acid	3106.0	3103.7	3107.3	3114.4	3118.8	3136.2	Phenylalanine	930.0	926.0	924.0	931.0	929.0	942.0
Retinol mcg	110.5	115.4	114.5	111.5	110.5	120.1	Threonine mg	893.0	888.0	888.0	893.0	892.0	911.0
B-carotene mcg	1161.0	1158.6	1160.5	1159.1	1161.0	1149.3	Tryptophan mg	338.0	340.0	339.0	339.0	337.0	331.0
Vitamin A I.U.	2303.7	2315.8	2315.8	2303.7	2303.7	2315.8	Tyrosine mg	738.0	738.0	737.0	739.0	737.0	748.0
Vitamin D I.U.	400.0	400.0	400.0	400.0	400.0	400.0	Valine mg	1179.0	1183.0	1179.0	1182.0	1178.0	1180.0
Vitamin E I.U.	3.30	3.30	3.30	3.20	3.20	3.30	Histidine mg	485.0	486.0	485.0	486.0	484.0	482.0
Vitamin K I.U.	1593.9	1498.8	1475.3	1626.7	1606.9	1310.5	Coat baht	2.875	2.883	2.880	2.876	2.872	2.930

Table 6.9 Nutritional and Raw Material Compositions of the Solutions for Different Methods of Processing with Added Calcium Carbonate

The nutritional compositions. With the addition of calcium carbonate, the content of vitamin K was found to be considerably less. The same was found for ascorbic acid, linoleic acid, vitamin B12, folic acid, choline and iron but to a lesser extent. The differences in the raw material compositions meant that to obtain the nutrients from indigenous raw materials within the specified limits, raw materials with high content of these nutrients must be selected in order to obtain adequately the amount of other nutrients and yet maintain the minimum ratio of calcium to phosphorus.

Regarding protein quality, sulphur amino acids were also at the 70 percent level of egg amino acids. The level of protein per 100 kcal from the solutions for different processing methods were found as follows:

Vacuum drying	at 52 ^o C for 2 hours	was at 2.50 g
Vacuum drying	at 77 ^o C for 1 hour	was at 2.51 g
Foam mat drying	at 71 ^o C for 1 hour	was at 2.50 g
Foam mat drying	at 89 ^o C for 8 minutes	was at 2.51 g
Drum drying	at 104 ^o C for 60 seconds	was at 2.50 g
Drum drying	at 160 ^o C for 30 seconds	was at 2.49 g

It was obvious that if protein was to be corrected as discussed earlier, the levels of protein in these solutions needed to be adjusted to 2.57 g per 100 kcal. Therefore, the solutions with the addition of calcium carbonate required the protein lower level to be modified to 2.57 g per 100 kcal.

Fat contents for all the solutions were also found at their lower limits and associated with the restricted constraint. Therefore, the fat lower limit was not modified

as discussed earlier.

Fibre contents observed for all the solutions were from 0.52 - 0.55 g per 100 kcal. As discussed earlier, it was not necessary to specify the maximum limit for fibre. The costs. With the addition of calcium carbonate, there was a considerable reduction in the costs of the solutions. It was cheaper to select the raw materials without being restricted by the minimum ratio of calcium to phosphorus. In addition, the calcium from synthetic source was cheaper than from indigenous raw materials. In considering the differences in the cost of the solutions for different drying methods, Table 6.7 shows the restricted constraints. In addition to vitamin A, riboflavin and sulphur amino acids, found as restricted constraints in the solutions without calcium carbonate, the other nutrients associated with restricted constraints were pantothenic acid, biotin, iodine and iron. As reviewed in Table 6.8, the highest cost was found in the solution for drum drying at 160°C because of the highest losses of pantothenic acid, biotin and sulphur amino acid. Next was 77°C/1 hour because of riboflavin and biotin, followed by 71°C/1 hour because of riboflavin, ascorbic acid and pantothenic acid, 39°C/8 minutes because of ascorbic acid and biotin, 52°C for 2 hours and the cheapest was at 104°C for 60 seconds. It could be concluded that with less restriction on the calcium and phosphorus ratio, the cost of the solution would be high at very high temperatures such as at 160°C. For the other times and temperatures, there was not much difference in the cost of the lower temperature/long time or high temperature/short time (i.e. 52°C/2 hours, 39°C/8 minutes and 104°C/60 seconds)

but at medium temperatures and times such as 77°C/1 hour and 71°C/1 hour the costs were slightly higher.

6.4 Selection of drying process

As discussed earlier, these 3 drying processes, vacuum drying, foam mat drying and drum drying, were applicable to Thailand as far as cost and availability were concerned. Though the other quality of product such as colour and flavour could be affected by these processes, the differences in these qualities would be only small. Therefore, it was decided in this study to select the process according to the cost and nutritional value of the solutions.

As reviewed in Table 6.8, the cost of the solutions with and without calcium carbonate were cheapest for drum drying i.e. for high temperature and short time process. Nevertheless, a very high temperature process resulted in difficulties in maintaining the nutritional balance. Between the 2 temperatures and times described for drum drying, the lower temperature was cheaper and it was easier to maintain nutritional balance.

Therefore, the drum drying process was selected as the most suitable process. However, further investigation would be needed within this range of temperature, 104-160°C to find the optimum process.

6.5 Conclusion

With the predrying process at the higher temperature it was more expensive and more difficult to comply with the specified nutritional requirement and therefore a low temperature process was more desirable. In this study, a batch process at 98°C was chosen taking into account the suitability of the process for application in Thailand.

Taking into account the losses of nutrients according to the specified conditions of drying, formulations could be obtained to satisfy the specified nutritional requirement in most cases with only modification on the calcium upper limit. When high temperatures were used, modifications were required for the upper limits of amino acids, histidine and lysine. The nutrients influencing the cost of the formulations were vitamin A, tocopherol, riboflavin and sulphur amino acids. Therefore, the costs depended on the extent to which these nutrients were destroyed. In categorizing the temperatures and times of processing at 52°C/2 hours as low temperature and long time, at 71°C and 77°C for 1 hour as medium temperature and time, and at 89°C/8 minutes, 104°C/60 seconds and 160°C/30 seconds as high temperature and short time, it could be concluded that the cost of the formulation at high temperature and short time was the cheapest and at medium temperature and time was the highest. This was directly related to the sensitivities to heat of those nutrients mentioned above. With the particular nutritional requirements of this infant food, nutrients that were quite sensitive to heat such as folic acid, thiamine and ascorbic acid were easier to obtain from the indigenous raw materials and therefore were cheaply maintained at the required nutritional balance.

Having considered the cost and nutritional value of the solutions for different processes, drum drying was chosen as the most suitable process.

As discussed earlier, one of the limiting factors was the calcium to phosphorus ratio and the addition of

calcium carbonate reduced the cost of the formulation markedly. It was also true when processing losses were included in the model. With addition of calcium carbonate, different nutrients were found to affect cost. These nutrients were vitamin A, ascorbic acid, riboflavin, pantothenic acid, biotin and sulphur amino acids.

Overall, it could be concluded that the extent to which the cost of formulation differed with processing methods was small in this study. Nevertheless, it gave the profile of the limiting nutrients, the nutritional value, the raw material composition and the process with the cheapest formulation. In predicting the losses of nutrients during processing, one can select the processing method to give the cheapest formulation according to any nutritional requirement. By this method, process and raw materials can be selected together to give the most suitable nutritional product.

CHAPTER 7

MODIFICATION OF THE LINEAR PROGRAMMING

MODEL FOR PRODUCT ACCEPTABILITY

Having selected the most suitable processing method and the raw materials according to the nutritional requirements, the next consideration was to modify the model for the specified qualitative characteristics i.e. for the product acceptability. The product, using the final formula from the processing model, was processed and evaluated and it was found that additional constraints were required regarding colour and sweetness of the formulation. This chapter discusses the incorporation of the constraints for colour and sweetness into the model.

7.1 Processing of the final formulation

The formula obtained for drum drying at 104°C/60 seconds was processed. Unfortunately, most of the raw materials in this formula were not available in New Zealand. New Zealand raw materials resembling them in nutrient composition, colour and flavour were used as follows:

snapper	was used for	anchovy, milk fish
		stripe mackerel
groper	" "	serpenthead fish
hen egg	" "	duck egg
chicken gizzard	" "	duck gizzard
brussel sprout	" "	collard
spinach	" "	ivy gourd
soybean curd was prepared from soybeans (60).		

The other raw materials in the formula were radish, mungbean starch, sesame and sugar (Table 6.6).

The raw materials were cleaned, prepared as the "edible portion", cut into small pieces and weighed. The mixed raw materials were cooked in a steam jacketed pan as described previously for the predrying process. The temperature was raised to 98°C and held for 31 minutes. The cooked mixture was comminuted with a Jeffco wet disintegrator. The distribution of temperatures during heating up and cooling down was as follows:

Heating			Cooling		
5	minutes	52°C	5	minutes	39°C
10	"	67°C	10	"	32°C
15	"	82°C	15	"	72°C
20	"	96°C	20	"	65°C
23	"	98°C	25	"	54°C
			30	"	43°C
			35	"	38°C
			40	"	34°C
			45	"	30°C

The paste, having total solids of 30 percent, was dried on a single drum dryer to a moisture content of 2.8 percent. With the experimental drum dryer, it was found difficult to have a good control on the drum temperature below 125°C and it was not possible to operate the drum at a speed lower than 2 rpm. Therefore, the drum temperature of 125°C was used and drying time was 15 seconds. Though the distribution of temperature during heating up, cooling down and the drying time and temperature were slightly different to the estimated times and temperatures, the nutrient losses

were calculated to be at the same level as for drum drying at $104^{\circ}\text{C}/60$ seconds. This was because the loss during holding time overshadowed the losses during heating up and cooling down and although a higher temperature was used for drying, the drying time was considerably shorter. Therefore, the optimum formula for drying at $104^{\circ}\text{C}/60$ seconds was valid for the experimental product. It must be noted that the losses of nutrients can be adjusted according to the actual processing conditions, the model then simply modified and the pertinent optimum solution obtained.

7.2 Evaluation of the product

The evaluation of the quantitative and qualitative characteristics should be carried out in Thailand where the Thai raw materials can be used and Thai mothers can judge the product. When 9 out of 13 raw materials could not be obtained in New Zealand, it was felt that evaluation for the quantitative characteristics i.e. the nutritional composition of the product would not be meaningful. For the qualitative characteristics, the product should be evaluated by a number of Thai mothers and fed to Thai infants but it was not possible to fully investigate this in New Zealand.

In order to illustrate how to modify the model for the qualitative characteristics, 5 Thai mothers in Palmerston North were asked for their opinions on the colour, sweetness, consistency and overall acceptability of the product. The consumer panel form is shown in Appendix 15. In preparation of the product for the mothers, the dry powder was mixed with hot water at the ratio of 1 to 5 by weight. Based on the dried weight of the formula at 211 g, the approximate volume to supply a daily energy requirement at

880 kcal would be 1270 ml, which was found to be the volume normally taken by the infant 6-12 month old (81).

For each qualitative characteristic, the descriptions on the questionnaire were assigned a score of 1 to 5 (Appendix 16). The average scores from the five women were as follows:

	Colour	Sweetness	Consistency	Overall acceptability
Average score	3.6	3.8	2.8	3.6
Average opinion	Slightly dark	Slightly sweet	Just right	Acceptable

From the consumer panel, the overall acceptability could be improved by modifying for a lighter colour and a less sweet product. Though a slightly sweet product was preferred by the mothers, the product was slightly sweeter than desired. The consistency of the mixed product was about right. The dilution needed for infant food is usually 5 to 6 parts of water to one part of dry product (5). As a matter of fact, the mother can adjust the amount of water to give the preferred consistency. Though the dilution would have an effect on the flavour and colour to a certain extent, it was not expected to be much within the range of dilution normally used. As the ratio of 5 to 1 used with consumer panel was found to be about right, this dilution was used in this study.

The qualitative characteristics were also evaluated objectively, the DU-COLOR colorimeter was used for colour and the Brookfield viscometer was used for consistency. For the taste as sweetness, the percentage of added sugar in the dry weight was used. The Thai Notification specified sugar related to carbohydrate to be not less than 20 percent,

which was equivalent to 9.2 - 14.3 percent of energy from sugar as discussed in 2.1.16, or approximately 10 - 15 percent sugar on the dry basis. Therefore, the sweetness in the formulation would be overshadowed by the added sugar, as the sugar content derived from other food raw materials would be considerably smaller.

The measurement of colour, consistency and the percentage of added sugar were as follows:

	Colour	Sweetness	Consistency
	CIE Tristimuli	Percentage added sugar on dry weight	cps.
X	37.0		
Y	37.9	49.6	510
Z	21.9		

7.3 Modification of the model according to the required qualitative characteristics

Constraints for colour and sweetness were considered for incorporation into the model.

7.3.1 Constraints for the colour

In the processed infant food, green vegetables, as collard and ivy gourd, were the major raw materials consisting of 42 percent of the total weight.

To select the raw materials taking into account the preferred creamy colour, an expression for the colour constraint had to be put into the linear programming model. It has been shown in the literature that colour and flavour can be incorporated into the model once the expressions for these variables are established (112, 250). Walsh et al. 1971 and Harper and Wanninger 1970 expressed the constraint

for colour related to the processing conditions. In the present study, it was considered more important to express colour as related to the raw materials. Therefore, it was necessary to define the colour of the raw materials and constraints for the colour. The colours of raw materials could be judged either by objective or subjective methods. Though the objective method would be more accurate, the subjective method was simpler and less time consuming. At this stage of research when the purpose was to investigate the possibility of including an acceptable quality into the model, it was felt reasonable to define the colour of raw materials subjectively.

To define the colour of the raw materials, the colour of the cooked raw materials were considered. These raw materials were divided into 4 categories, i.e. raw materials with white or creamy colour such as mungbean starch and fish, yellow colour such as duck egg, brown colour such as duck gizzard and stripe mackerel and green colour such as collard and ivy gourd. Within each category of colour, the colour of raw materials were not equally green, or yellow or brown or creamy white. Taking the differences in these colours, the raw materials in each category were divided into 3 divisions. The raw materials were judged subjectively. The raw materials with the most green, or yellow or brown were assigned a score of 3; the raw materials with the least green or yellow or brown with the score of 1 and the raw materials with the colour of green or yellow or brown in between the first 2 groups were assigned a score of 2. The raw materials with white or creamy colour were not subdivided because of very little

differences in the colour and a score of 3 was assigned to all the raw materials. The raw materials in different categories of colour and colour scores are shown in Table 7.1.

Table 7.1 The Classification of Raw Materials According to Different Colours and Different Scores

Raw materials	Score of colour	Raw materials	Score of colour	Raw materials	Score of colour	Raw materials	Score of colour
<u>White</u>		<u>Yellow, reddish yellow</u>		<u>Brown</u>		<u>Green</u>	
Anchovy	3	Bamboo	1	Beef	3	Peas, snap	3
Bottle gourd	3	Banana	1	Buffalo	3	Cabbage	1
Carp	3	Banana, common	1	Catfish, fresh water	2	Cabbage, chinese	1
Cashew nut	3	variety		Catfish, sea water	2	Collard	3
Cassava starch	3	Carrot	3	Chicken, matured	3	Cowpea, yardlong	3
Coconut	3	Cauliflower	1	Chicken, young	2	Garbean	3
Cucumber	3	Corn	1	Duck	3	Grape	2
Dorab	3	Cowpea, dry	2	Eel	2	Ivy gourd	3
Gouramy	3	Egg, duck	3	Egg plant	2	Mustard, green	2
Milk, dry	3	Egg, hen	3	Gizzard, chicken	3	Peas	2
Milk, whole	3	Guava	1	Gizzard, duck	3	Snake gourd	2
Milk fish	3	Lemon	1	Hardtail fish	2	Swamp cabbage	3
Mullet	3	Mungbean, whole	1	Heart, beef	3		
Mungbean, starch	3	Orange	3	Heart, hog	3		
Peanut, dry	3	Orange, mandarin	3	Liver, beef	3		
Peanut, raw	3	Papaya	3	Liver, chicken	3		
Perch	3	Pigeon pea	1	Liver, duck	3		
Radish	3	Pineapple	2	Liver, hog	3		
Rice flour	3	Prawns, river	1	Mushroom	3		
Rice, glutinous	3	Prawns, sea	1	Pork, lean	2		
flour		Pumpkin	3	Rice, black	1		
Rice, glutinous	3	Soybean	1	glutinous			
milled		Soybean, curd	1	Rice, brown	1		
Rice, milled and	3	Sprouted mungbean	1	Spanish mackerel	2		
polished 5%		Squid	1	Stripe mackerel	3		
Rice, parboiled	3	Sweet potato white	1	Sugar	1		
Serpenthead fish	3	Sweet potato yellow	2				
Sesame	3	Tomato	3				
Skim milk, dry	3	Watermelon	3				
Skim milk, fluid	3						
Snapper	3						
Soybean flour	3						
Sponge gourd	3						
Tax gourd	3						

To define the colour of the product formulation, the term "colour intensity" and "total colour intensity" were used in this study. The colour intensity for each colour was defined as a summation of the weight of each raw material in the formulation multiplied by its colour score. The total

colour intensity was defined as the sum of all colour intensities.

By this definition, the total colour intensity of the processed infant food discussed in 7.1 was divided 13, 49, 11 and 28 percent respectively for brown, green, yellow and white as shown in Table 7.2.

Table 7.2 Determination of the Different Colour Intensities in the Initial Formula

Raw materials	Weight g	Colour rating	Colour intensity
<u>Brown</u>			
Striped mackerel	12.0	3	= 36.0
Gizzard duck	6.7	3	= 20.1
Sugar	105.0	1	= 105.0
		Total brown intensity	= 161.1
<u>Green</u>			
Collard	207.7	3	= 623.1
Ivy gourd	4.0	3	= 12.0
		Total green intensity	= 635.1
<u>Yellow</u>			
Soybean curd	7.8	1	= 7.8
Egg	42.5	3	= 127.5
		Total yellow intensity	= 135.3
<u>White</u>			
Anchovy	26.2	3	= 78.6
Milk fish	13.3	3	= 39.9
Serpent head fish	4.8	3	= 14.4
Radish	5.8	3	= 17.4
Mungbean starch	51.0	3	= 153.0
Sesame	16.8	3	= 50.4
		Total white intensity	= 353.7
Total intensity = 161.1 + 635.1 + 135.3 + 353.7			
= 1285.2			
Brown colour as percentage of total intensity = $\frac{161.1 \times 100}{1285.2} = 13\%$			
Green " " " = $\frac{635.1 \times 100}{1285.2} = 49\%$			
Yellow " " " = $\frac{135.3 \times 100}{1285.2} = 11\%$			
White " " " = $\frac{353.7 \times 100}{1285.2} = 28\%$			

To define the constraint for the colour of the formulation, the colour intensities of the acceptable product were required. Information obtained from the evaluation of the processed product showed that the colour was slightly dark, which meant that the raw materials with green, yellow and brown colours should be reduced. To restrict the selection of coloured raw materials, it was decided to put upper limits on the colour intensity for each of the colour categories. As the colour of green, yellow and brown, each has a different effect in adding colour to the formulation, the limit for each colour intensity was set differently. Consideration was also given to the fact that the total intensity of green, yellow and brown colours must be less than that of the present product (7.1). To start the modification of the model, the upper limits for brown, green and yellow colour intensities were set at 12, 30, 40 percent of the total colour intensity. The intensities of the coloured raw materials added together had to be less than 60 percent of the total intensity of the formulation.

7.3.2 Constraints for the taste

The amount of added sugar in the processed infant food was quite high at 49.6 percent on the dry basis. To select the raw materials taking into account the preferred slightly sweet taste, an expression for the taste constraint was required in the model. As discussed earlier, the sweetness of the formula was due to added sugar more than to indigenous raw materials so the upper limit for sweetness was specified as added sugar. It was also decided to specify sugar based on the dry basis as it would clearly indicate

the amount of added sugar in the dry product. To start the modification of the model, the upper limit of the sugar was specified at 35 percent of the dry solids, a level lower than the previously processed infant food.

7.3.3 Setting up the data for colour and taste constraints

The linear relationships of raw materials with colour was expressed in the same way as for cost and composition in 3.3:

For green raw materials

$$G = \sum_{i=1}^n a_{gi} X_{gi}$$

For brown raw materials

$$B = \sum_{i=1}^n a_{bi} X_{bi}$$

For yellow raw materials

$$Y = \sum_{i=1}^n a_{yi} X_{yi}$$

For white raw materials

$$W = \sum_{i=1}^n a_{wi} X_{wi}$$

where G, B, Y and W represented the green, brown, yellow and white colour intensities of the formulation; a_{gi} , a_{bi} , a_{yi} and a_{wi} represented the colour score and X_{gi} , X_{bi} , X_{yi} , X_{wi} represented the weight of the green, yellow, brown and white raw materials respectively.

The colour constraints were also incorporated into the model as discussed in 3.3, e.g. the upper limit of green colour intensity at less than 30 percent of the total intensity was expressed as

$$G \text{ COLOUR} = \frac{G}{\text{TOTAL I}} \leq 0.3$$

$$G \text{ COLOUR} = G - 0.3 \text{ TOTAL I} \leq 0$$

where G COLOUR represented the upper limit of green colour intensity as proportion of total intensity, TOTAL I represented the total intensity which is $G + B + Y + W$. The constraint on sweetness at less than 35 percent of dry weight was expressed as

$$\text{SWEET} = \frac{\text{SUCROSE}}{\text{DWT}} \leq 0.35$$

$$= \text{SUCROSE} - 0.35 \text{ DWT} \leq 0$$

where SWEET represented the upper limit of added sugar, SUCROSE represented the added sugar.

7.3.4 Obtaining the solution for the modified model

It was found not possible to obtain a solution at the modified level of constraints. The problem had 3 infeasibilities, calorie was lower than the minimum requirement, calcium and green colour intensity upper limits were exceeded. The constraints at bounds were found with the following upper and lower limits.

Upper limits	Lower limits
CU	MA
CALPROH	VITD
CALKH	CALVITAL
DHIST	VIELINOL
SWEET	CALRIBOL
	CALIL
	CALZNL
	CAPL
	CSULAA

In order to obtain a feasible solution, the slackening of the upper limits was considered. It was not possible to obtain a solution by releasing amino acid upper limit as found with drying at 160°C (6.3.1). Among the constraints at bounds, CU, CALPROTEI, CALKE and SWEET, it was decided to modify CU before any modifications either of protein upper limit because this was specified by the Thai Notification, or potassium upper limit because this affected the renal solute load or the level of sugar because this affected taste acceptability. Though there is a possible harmful effect of copper (53), the exact level is not known. The copper in the normal diet for adults is 2 mg per day (56). Therefore, the upper limit was increased from 740 to 900 mcg per day. This level was equivalent to the copper content in the volume of human milk supplying twice as much of the energy requirement and so was considered safe to use for this infant food.

Therefore, the upper limit for histidine was freed and the copper upper limit was set at 900 mcg per day. However, it was not possible to obtain the solution, one infeasibility was found associated with the upper limit of green colour intensity. The possible green colour intensity was found to be approximately 35 percent with copper upper limit at 900 mcg per day and histidine upper limit freed. It was therefore decided to evaluate the acceptability of product from the formulation with 35 percent green colour intensity before any further modification. The nutritional and raw material compositions and cost of the formulation is shown in Table 7.3.

Table 7.3 Nutritional and Raw Material Compositions and Costs of the Solutions with Colour and Taste Constraints Compared to the Original Solution

Raw Material Content (g)	With Colour and Taste Constraints		Original Solution	Nutrient Content	With Colour and Taste Constraints		Original Solution
	Indigenous Raw Materials	Added Calcium Carbonate			Indigenous Raw Materials	Added Calcium Carbonate	
Anchovy	54.9	19.8	26.2	Vitamin D I.U.	400.0	400.0	400.0
Buffalo	0.2	0.2	-	Vitamin E I.U.	4.80	3.30	3.90
Cassava starch	38.7	58.0	-	Vitamin K mcg	6505.9	856.3	994.7
Coconut	3.4	7.7	-	Ascorbic acid mg	139.1	101.1	198.7
Collard	140.0	8.0	207.7	Thiamine mg	0.62	0.72	0.97
Duck egg	6.3	26.7	42.5	Riboflavin mg	0.66	0.66	0.69
Guava	-	37.5	-	Niacin mg	5.13	6.11	5.13
Gizzard duck	-	-	9.0	Vitamin B6 mg	1.12	1.5	1.6
Ivy gourd	7.8	-	4.0	Vitamin B12 mg	0.004	0.003	0.078
Milk fish	-	19.4	13.3	Pantothenic acid	2.98	2.79	2.94
Mungbean starch	50.3	-	31.0	Folic acid mg ^{MS}	0.75	0.16	1.04
Radish	0.4	-	5.8	Cholina mg	326.3	243.2	426.9
Rice, brown	-	5.7	-	Biotin mcg	14.87	14.3	18.4
Rice, parboiled	34.2	5.6	-	Sodium mg	184.8	208.7	264.9
Serpent head fish	-	-	4.8	Chloride mg	213.0	213.0	249.9
Seesaw	23.2	15.8	16.8	Potassium mg	1760.0	1760.0	1830.6
Soybean	-	1.7	-	Calcium mg	719.7	630.0	760.0
Soybean curd	22.9	-	7.8	Phosphorus mg	514.1	450.0	542.9
Sponge gourd	20.3	11.4	-	Magnesium mg	224.9	410.6	209.2
Squid	-	7.7	-	Iron mg	11.0	8.8	15.8
Stripe mackerel	-	14.1	12.0	Iodine mg	44.0	44.0	45.8
Sweet potato, white	-	118.4	-	Manganese mg	104.2	830.5	1.7
Sweet potato, yellow	-	56.5	-	Copper mcg	900.0	740.0	740.0
Sucrose	38.9	45.7	103.0	Zinc mg	4.4	6.2	4.6
Watermelon	20.3	-	-	Isoleucine mg	1349.0	1004.0	1491.0
Calcium carbonate	-	0.85	-	Leucine mg	2113.0	1573.0	2171.0
Nutrient Content				Lysine mg	1784.0	1391.0	2001.0
Weight g	462.0	459.0	503.8	Methionine mg	764.0	690.0	915.0
Dried weight g	204.8	203.7	211.6	Cystine mg	279.0	231.0	289.0
Calorie kcal	880.0	880.0	915.3	Phenylalanine mg	1320.0	922.0	1386.0
Protein g	25.6	22.6	29.6	Threonine mg	1204.0	891.0	1238.0
Fat g	17.6	17.6	18.3	Tryptophan mg	353.0	347.0	427.0
Carbohydrate	156.6	157.5	177.2	Tyrosine mg	881.0	758.0	873.0
Fibre g	3.6	4.9	3.5	Valine mg	1462.0	1226.0	1615.0
Linoleic acid mg	4598.3	3188.4	3741.3	Histidine mg	670.0	498.0	651.0
Retinol mcg	36.9	122.6	176.8	Cost, baht	3.644	2.877	4.009
B-carotene mcg	1306.5	1137.3	1093.0				
Vitamin A	2303.7	2303.7	2408.6				

7.4 Evaluation of the modified product

The product according to the modified formulation was processed as discussed in 7.1 and evaluated for the qualitative characteristics as discussed in 7.2.

7.4.1 Measurements on the qualitative characteristics of the modified product

From another consumer panel test, the average scores

were found as follows

	Colour	Taste	Consistency	Overall acceptability
Average score	3.0	3.5	3.0	4.0
Average opinion	Just right	Just right - slightly sweet	Just right	Acceptable

The product was also measured objectively as in 7.2, the measurement on colour, consistency and the percentage of added sugar were as follows

	Colour	Sweetness	Consistency
	CIE Tristimuli	Percentage added sugar on dry weight	cps.
X	57.3		
Y	54.3	19.00	4000
Z	40.3		

From the formulation, the colour intensities of brown, green, yellow and white were 3, 35, 8 and 54 percent respectively.

7.4.2 Comparison of the initial and modified products

Consideration was given to product acceptability, nutritional composition and cost.

Product acceptability Taking colour, taste, consistency and overall acceptability into consideration, the modified product was accepted slightly better than the initial product as shown in Table 7.4.

Table 7.4 The Consumer Panel Scores for the Original and Modified Products

	Colour	Sweetness	Consistency	Overall Acceptability
	Average score			
Original product	3.6	3.8	3.2	3.6
Modified product	3.0	3.5	3.0	4.0

The colour and consistency were just right but surprisingly the product was still considered slightly sweet although the percent sugar had been reduced from 49 to 19. By restricting the selection of raw materials for their colours and taste and yet requiring the same nutritional value, the raw material compositions for the 2 products were quite different. Green vegetables, in particular collard, decreased. There was also a decrease in the amount of duck egg and sugar in the modified product. Extra raw materials in the modified product were buffalo, cassava starch, coconut, parboiled rice, sponge gourd and watermelon. These differences in the raw materials made the overall acceptability, the colour and taste of the modified product better than the initial product. Though the differences in the amount of sugar and viscosity readings were quite considerable, there was little difference in the acceptability of sweetness and consistency. The modified product was only thought to be slightly less sweet than the initial product and the thicker consistency was accepted.

Nutritional compositions and costs The differences in composition were only slight except for the higher contents of copper, histidine and manganese in the modified product.

Other differences were the contents of vitamin K, ascorbic acid, vitamin B12, choline, biotin, sodium, chloride, potassium, calcium, phosphorus and iron which were slightly less in the modified product. Nevertheless, the nutrient contents of the modified product were within the specified limits, except for copper and histidine. The cost was slightly cheaper in the modified solution, this was due to the slackening of the constraints for copper and histidine.

It could be concluded that having included the constraints for colour and taste, the product was better accepted. The green raw materials and sugar were reduced. Though it was necessary to increase the upper limit of copper and histidine in the formulation, it was in the range considered not to have any harmful effect. Among the constraints for colour and taste, only the green colour intensity was found as a restricted constraint.

The modifications of the constraints for product acceptability in this study were for the colour and sweetness. Whether there was a change in the flavour of the formulation due to difference in the raw material composition was not studied as both initial and modified products were accepted. It was possible that certain raw materials might be preferred more than others. The raw materials' compatibility can be included in a linear programming model (4). However, the raw materials considered in this study were generally used for infant food and the acceptable qualities considered important were colour and sweetness. Therefore, only constraints for colour and sweetness were considered.

In this study, only a certain level of colour and

taste constraints were studied. It would be possible to obtain an acceptable product by varying these colour and taste constraints at other levels. However, it was felt that any more investigation on the modifications would be of limited value until true Thai raw materials could be used and a larger scale of consumer survey was possible.

7.5 Processing of the designed infant food using synthetic raw materials

Nutrients could be added as synthetic raw materials, e.g. vitamins, amino acids and minerals and this would make it easier to obtain a solution (63). An investigation was required for the cost and availability of these synthetic raw materials.

The constraints at lower limits found in the solution for the modified product were NIA, VITD, CALFATL, CALVITL, VIELINOL, CALRIROL, CALIL, CALZNL, CAPL and CSULAA. If the costs of these vitamins and minerals were not too expensive and they were available in Thailand, the addition of these vitamins and minerals would also reduce the cost of the solution.

In this present study, difficulties in obtaining the minimum requirement were only found related to calcium and phosphorus ratio and the addition of calcium independent of phosphorus made the obtaining of the solution easier. In addition, the solution was found cheaper with the addition of calcium as discussed in 3.5 and 6.3.2.

As calcium was found to be the most difficult nutrient to obtain and the addition of calcium carbonate gave a cheaper solution, a better balance in the nutritional composition and because calcium carbonate was available in

Thailand, it was decided to study the acceptability of the product with added calcium carbonate. Therefore, the constraints for colour and taste were included into the model with added calcium carbonate, and with drum drying conditions at 104°C/60 seconds.

As discussed in 6.3.2, the formula with added calcium carbonate required the modifications of protein lower level from 1.80 g to 2.57 g per 100 kcal to compensate for the amino acids at 70 percent of egg amino acids. Therefore, protein lower level was also adjusted to 2.57 g per 100 kcal. The solution was obtained without any modification on copper, histidine or calcium upper limit. The product was processed and evaluated as discussed earlier in 7.1 and 7.2.

7.5.1 Measurements on the qualitative characteristics

From a consumer panel, the average scores were found as follows

	Colour	Sweetness	Consistency	Overall acceptability
Average score	3.0	3.0	3.0	4.5
Average opinion	Just right	Just right	Just right	Acceptable to highly acceptable

The product was also measured objectively as discussed in 7.2, the measurements on colour, consistency and the percentage of added sugar were as follows

	Colour CIE Tristimuli	Sweetness percentage added sugar on dry weight	Consistency cps.
X	64.9		
Y	67.3	21.4	1500
Z	51.5		

From the obtained formulation, the colour intensities of green, yellow, brown and white were found at 3, 41, 9 and 47 percent respectively.

7.5.2 Comparison of the modified product with and without added calcium carbonate

Consideration was given to product acceptability, nutritional compositions and costs.

Product acceptability The product with calcium carbonate was better accepted than the product with only indigenous raw materials as shown in Table 7.5. The raw material compositions of indigenous and calcium carbonate added formulae were quite different. The green vegetables were considerably less than in the formula with indigenous raw materials and less fish and more egg were used. Extra raw materials in the product with added calcium carbonate were guava, milk fish, brown rice, soybean, squid, stripe mackerel and in particular sweet potato which was 36 percent of the total raw materials. These differences in the raw materials made the colour, taste and overall acceptability of the calcium carbonate added formula better than the indigenous formula. From the discussion with the consumer panel, the custard or egg and starch odour was preferred over the green vegetable odour of the indigenous product.

Table 7.5 The Consumer Panel Scores for the Modified Indigenous Product and Calcium Carbonate Added Product

	Colour	Sweetness	Consistency	Overall acceptability
Indigenous product	3.0	3.5	3.0	4.0
Calcium carbonate added product	3.0	3.0	3.0	4.5

The colour intensities of the two products were as follows

	Brown	Green	Yellow	White
	Percentage of total intensity			
Indigenous product	3.0	35.0	8.0	54.0
Calcium carbonate added product	9.0	3.0	41.0	47.0

The sweetness and consistency of the product with added calcium carbonate were found to be just right despite slightly higher content of added sugar and smaller value in the viscosity reading. The differences in the viscosities of the indigenous and calcium carbonate added products were due to the different viscous properties of the extra starchy materials such as cassava starch, mungbean starch, rice and sweet potato.

The colour of the added calcium carbonate product was lighter as shown by the Tristimulus reading but the two colours were equally acceptable to these consumers.

Nutritional compositions and costs The differences in the nutritional composition were in the lower contents of vitamin K, ascorbic acid and the higher content of manganese, copper and calcium were at the original constraints. The cost of the formula with calcium carbonate was approximately 10 percent cheaper.

7.6 Conclusion

To investigate the acceptability of the initially designed product, a consumer panel of 5 Thai married women studying or staying in Palmerston North, who used to look after their children in Thailand, was used to investigate both the mother's opinion and the product acceptability to the infant. The initial product was accepted though it was

thought that slight improvements could be made in colour and taste. A more acceptable product was obtained by including constraints for product acceptability regarding taste and colour which restricted both addition of sugar and the selection of a large amount of coloured raw materials in the formulation.

It was found difficult to reduce the use of green vegetables, and nutritional constraints needed to be adjusted in the copper and histidine upper limits. However, when calcium carbonate was used with the indigenous raw materials, this difficulty was overcome. Not only was adjustment to the initial nutritional constraints not necessary but the product was cheaper and also was more acceptable in flavour, colour and texture to the consumers. The product with added calcium carbonate has a higher potential for acceptability in Thailand.

It was realized that the study was based on the opinion of only a few Thai mothers and besides, most of the raw materials were substituted raw materials available in New Zealand. Nevertheless, the inclusion of the constraints considered important for product acceptability was illustrated and this modification could be done easily once the product was made and tested in Thailand. It might be necessary to include odour and flavour scores of the raw materials into the model.

CHAPTER 8

A POSSIBLE SCHEME FOR DESIGNING AN INFANT FOOD FOR THAILAND

From this study, it is possible to present a scheme to design an infant food product. The scheme was shown by the experimental work to be a practical method, but further work has to be done in Thailand on the final processing method and the testing of the product.

8.1 The scheme

In the design of an infant food, the product specification is first decided. Having the product specification, the next decision is the raw materials and the process to use. When the nutritional quality and cost of the product is of importance as in this present study, the raw materials and process are selected with regard to both the effects of processing on the nutrients and the costs of the raw materials.

The scheme for the design of a nutritional infant food is shown in Figure 8.1. First, the product must be specified according to quantitative and qualitative characteristics. The quantitative characteristics are then modified according to different selected times and temperatures of processing. Possible raw materials are selected to suit the product acceptability characteristics. The linear programming model is then set up according to the modified quantitative characteristics and the qualitative

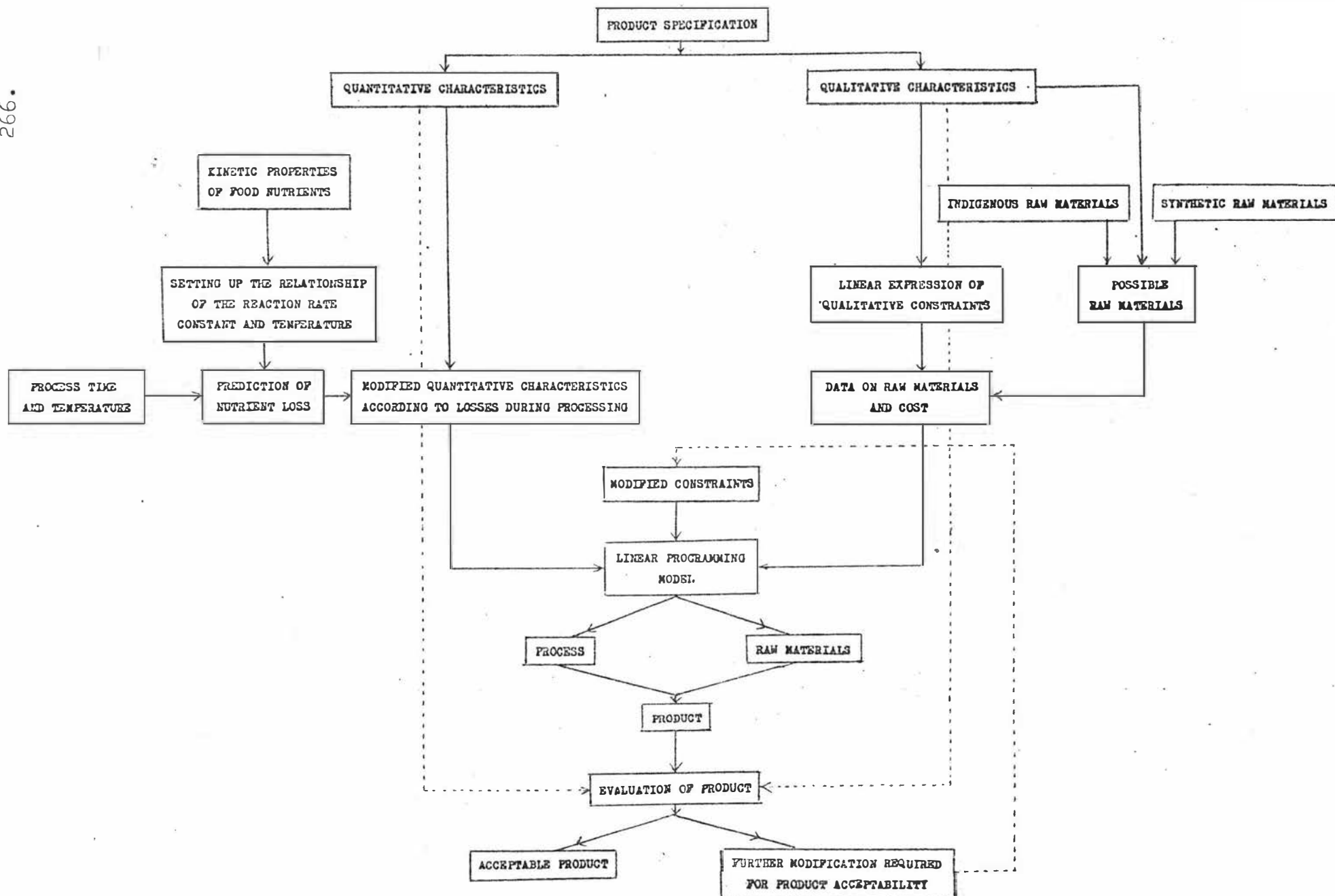


Figure 8.1 The Scheme for the Design of Infant Food

characteristics. With the use of the linear programming technique, the lowest cost formulation, which also provides the required nutrients taking into account the effect of processing, can be obtained. The product is then evaluated for its acceptability. If acceptable the product is ready for manufacturing. When improvement in the product is necessary, appropriate modifications can be incorporated into the model until an acceptable product is obtained.

3.2 The present achievement

The scheme was developed, making it possible in product design to consider nutritional requirements, processing effects and consumer acceptability together in a quantitative system. The usefulness of linear programming in the design of nutritional foods was established by Edwardson (68), nevertheless the losses of nutrients during processing were not included. In this present study, the effect of processing on the destruction of nutrients was precalculated and the losses of nutrients due to processing were included in the linear programming model. The profile of limiting nutrients was obtained; the process and raw materials were selected.

It was also shown that the acceptable features in an infant food, determined by a consumer survey amongst Thai mothers, could be incorporated in the model. The product from the processing model was tested by Thai mothers and then adjustments made to the model until a completely satisfactory infant food was obtained. The final food provided the nutrition needed by the infant and was acceptable in eating quality to the mother.

It was proved that the scheme was a practicable and

logical method for designing infant foods.

8.3 Future work regarding the product

8.3.1 Modifications for composition, cost of raw materials and processing in Thailand

In this present study, the product was designed taking into consideration suitable raw materials available in Thailand and also the processes that would be applicable in Thailand. It is realized that these factors are subject to changes with changes in circumstances. However, any changes in these variables can be studied at any time. The changes in the raw material composition and cost can be easily accommodated by either changing the compositional and cost data of raw materials in the model or incorporating more data for new raw materials. When changing the process, the new losses of nutrients can be predicted, according to the time and temperature of the process, from the relationship of reaction rate constant and temperature detailed in this thesis. The nutritional constraints in the linear programming model can then be modified accordingly and the solution obtained.

8.3.2 Modification for product changes

The change in product specifications can be incorporated into the model by changing constraints and/or inputting more constraints expressing the new quantitative or qualitative characteristics of the product.

Variation in the flavour of the product may be required. This can be achieved by fixing the quantities used of certain raw materials.

The product for infants from birth to 3 months and

3 - 5 months can also be developed using this established model with new constraints related to the nutritional needs of these age groups.

Modification may also have to be made to the model so that the price of the final product is acceptable. The cost of the raw materials to provide the daily requirement of the infant was 3.70 baht using only indigenous food materials and 2.90 baht with addition of calcium carbonate to the indigenous raw materials. The acceptable price obtained from the consumer survey was from 4 - 6 baht. The cost of manufacturing in Thailand will have to be investigated and an attempt made to see that the price of the processed product is acceptable. By the quantitative approach as illustrated in Figure 8.1, modifications to the product, raw materials and process can be made until a product with an acceptable price is obtained. The cost of the product is expected to decrease with the use of synthetic vitamins and minerals, but the possibility of their use in Thailand will have to be investigated and their incorporation into the model studied.

8.3.3 The tests required for the product

Though the designed product was accepted by a small group of Thai mothers, the product must be tested for acceptability when exact Thai materials and a larger number of Thai mothers and infants are available.

Analysis of the nutrient composition of the product is also required after the correct raw materials are available, and processed into the product. As a large number of nutrients were considered in this study, the analysis of all these nutrients would require a lot of time. However, only certain nutrients were difficult to obtain

from the food raw materials and were near their minimum level in the formula. These nutrients should be determined first. For drum drying at $104^{\circ}\text{C}/60$ seconds, as selected for this study, or $125^{\circ}\text{C}/15$ seconds as employed with the experimental product, the predicted limiting nutrients were vitamin A, vitamin E, riboflavin and the sulphur amino acids with the indigenous raw material formulae and the additional limiting nutrients with the added calcium carbonate formulae were ascorbic acid, pantothenic acid and biotin. These nutrients should be considered for assaying before the other nutrients.

It must also be noted that it is important to subject the final product to clinical tests to ensure that there is no hazardous effect to an infant arising from unforeseen properties of the raw materials and the processing technique.

8.4 Future work regarding the model

Though the effects of processing on the nutrient losses were considered in the established model, it was not possible to include this effect directly into the linear programming because of the exponential relationship of the reaction rate constant and temperature. However, it is possible that a subprogramme to calculate the losses of nutrients, such as described by Teixeira et al. 1969, could be attached to the linear programming model and time and temperature for processing could be selected by the model as well as the raw materials.

Further consideration could be given to the compatibility of the raw materials with infant foods as seen by Thai mothers. Though it proved not necessary to

include it in this study, it can be included into the linear programming model by the use of the multidimensional scaling technique when it is needed (4).

In the present study, the kinetic data for the destruction of 11 amino acids and 10 vitamins were collected. Not only is more data required regarding destruction by heat, but the effect of other factors such as moisture content, pH, oxygen and light also need to be included. However, the activation energies predicted from the collected data and the nutrients predicted to have the highest rate of reaction constants were comparable with those reported previously in the literature and this kinetic data can be used until more specific data becomes available.

Though the losses during processing were included in this study, the losses during storage were not included. As already discussed, the rates of reaction changed markedly at low moisture contents. The data on the rate of reaction related to moisture content were limited and it was not possible to predict the nutrient losses during storage. Nevertheless, the collection of data for this study should present the background information for further study in this area. When kinetic data is available, the model can be changed to include the effects of storage on nutrients.

8.5 Conclusion

It was shown that there is a need for a nutritional infant food for Thailand. A quantitative model was established to select the raw materials for this infant food, regarding nutritional requirement, appearance and eating characteristics and processing losses. It was found possible to process from Thai indigenous raw materials an

acceptable product providing a balanced nutritional diet for infants. Not only a processed product can be developed based on this quantitative model, suggestions could also be made for the best use of the raw materials available in the different parts of the country, especially by the low income mothers who can not afford the processed product. This research presented a systematic approach to infant feeding so that improvements in the nutritional status of Thai children can be planned.

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Not seen The original was not seen and the contents of the article were extracted from an abstract.

PERCENTAGE DISTRIBUTION OF MONTHLY HOUSEHOLD EXPENDITURE FOR FOODS, GOODS AND SERVICES
BY REGION IN RURAL AND URBAN AREA. (183)

Region	Recreation		Medical & personal care		Tobacco alcohol expense		Miscellaneous		Food purchase & prepare at home		Food away from home		Housing		Clothes		Transport	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Northeast	5.04	2.84	4.85	8.20	6.89	5.42	6.71	7.70	43.16	41.39	9.91	4.89	10.22	11.63	8.09	13.41	5.13	4.52
North	6.31	3.30	6.54	6.79	4.81	6.18	7.25	7.86	40.78	42.46	7.67	5.54	11.74	7.88	9.46	14.23	5.74	5.76
South	6.40	2.92	5.96	8.02	4.85	5.14	9.13	9.19	37.20	41.39	9.26	8.07	13.65	7.57	8.31	11.91	5.24	5.79
Central	5.29	3.78	5.43	7.33	5.77	5.19	6.94	9.65	41.42	42.76	12.42	6.80	9.70	8.58	8.93	9.97	6.66	5.94
Bangkok	7.46	5.52	5.31	5.30	4.89	5.38	7.49	5.75	33.83	42.79	12.48	10.26	13.21	10.48	7.74	7.65	7.65	6.87
Whole kingdom	6.76	3.36	5.44	7.45	5.18	5.48	7.48	8.51	36.55	42.14	11.18	6.29	12.40	9.16	8.12	12.07	6.89	5.54

APPENDIX 2

BREAST FEEDING FOR INFANT (0-1 YEAR) (179)

	Breast feeding for infant (0-1 year) (in percentage)				
	All areas	Bangkok		Other	
		Middle income	Low income	Urban	Rural
Breast feeding:	100.0	100.0	100.0	100.0	100.0
-yes	88.4	61.5	90.0	78.9	92.3
-no	10.9	38.5	10.0	19.7	7.1
-no answer	0.7	-	-	1.4	0.6
Duration:	100.0	100.0	100.0	100.0	100.0
-less than 6 months	9.4	53.1	16.7	12.7	6.1
-between 6-12 months	13.4	15.6	15.8	14.0	12.9
-between 1-2 years	49.2	31.3	48.1	62.9	46.8
-more than 2 years	22.1	-	16.6	8.6	26.7
-no answer	5.9	-	2.8	1.8	7.5
Reason for weaning:	100.0	100.0	100.0	100.0	100.0
-not enough milk	7.7	28.1	22.1	6.3	5.8
-onset of new pregnancy	16.5	12.5	8.4	10.4	19.6
-children grown up	37.1	15.6	33.4	44.4	36.6
-outside work	15.7	40.7	11.1	19.7	13.9
-bad health	3.6	3.1	5.4	5.0	2.9
-children stop	3.0	-	3.8	3.1	2.8
-others	5.2	-	1.8	8.4	5.0
-no answer	11.2	-	13.0	2.7	13.4

APPENDIX 3

CONSUMER SURVEY FORM

English translation of Thai survey form.

1. Your last child age is

- to 3 months
- 3 - 6 months
- 6 - 12 months

2. For milk feeding, what ages of your children do you feed following milk

	Age from	to	Do not use
Breast milk	<input type="checkbox"/>
Milk powder	<input type="checkbox"/>
Evaporated unsweetened condensed milk	<input type="checkbox"/>
Evaporated sweetened condensed milk	<input type="checkbox"/>
Fresh pasteurized milk	<input type="checkbox"/>
Other kind of milk	<input type="checkbox"/>

3. If you do not use breast feeding, where do you buy milk product to use

- Market
- Grocery
- Supermarket

4. What did you feed your youngest child yesterday

Youngest child age	Breakfast	Middle morning	Lunch	Middle afternoon	Dinner
to 3 months
3-6 months
6-12 months
1-2 years

5. How do you prepare solid food

Birth-3 months 3-5 months 6-12 months 1-2 years

Prepare specially	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Taking from family meals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sometimes prepare specially, sometimes taking from family meals	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Prepare one feeding each time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Prepare few feeding each time and keep to heat up for next feeding	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

6. Do you have any difficulty in preparing solid food

yes no not sure do not know

7. In case there is a convenient infant food, you would like it to be

Dried product

Ready to use canned product

Ready to use bottled product

8. For the product that you are interested in question 7, how much would you prepared to buy for a day feeding

..... baht.

9. You would like the flavour to be

bland

a little sweet

rather sweet

meaty flavour

others as

and the colour to be

- cream or white
 light brown
 light pink
 light greenish
 others as

and the texture when ready to feed

- thick
 medium
 thin
 others as

10. In your household, do you have the following
 appliance

- refrigerator
 thermos
 do not have both

11. Your occupation is

Housewife

Farmer

Business

Government

Working in

Working in

officer

office

factory

12. Your age is

- <20 20-29 30-39
 40-49 >49

13. Your family monthly income is

- less than 500 baht
 500 - 1000 baht
 1000 - 2000 baht
 2000 - 3000 baht
 4000 - 5000 baht
 >5000 baht

APPENDIX 4

MARKET SURVEY FORM

Information were taken regarding following questions.

1. Type of food selling business i.e. groceries or supermarket.
2. Type of baby food i.e. can, bottle, dry powder or other.
3. Description of the baby food products in stock i.e. brand name, description of product, type of package, size of container and price of the product.

APPENDIX 5THE THAI NOTIFICATION ON THE
QUALITY OF INFANT FOOD

By virtue of the provisions of Section 5 (1) (2) (4) (8) and (9) of the Food Quality Control Act B.E. 2507 as amended by Announcement of the Revolutionary Party No. 49 dated 18th January B.E. 2515, the Minister of Public Health hereby issues a notification as follows:

1. Baby food shall be controlled food.
2. Baby food means food which is used in place of the mother's milk for the baby from the date of birth to the age of twelve months.
3. The general quality or standard of baby food shall:
 - (1) not contain matter under the category of hormone or anti-biotic
 - (2) not be found to contain bacteri of the type ecoli in 0.1 gram of baby food
 - (3) contain not over 10,000 bacteri in 1 gram of pasturised baby food, or not over 1,000 bacteri in 1 gram of sterilized baby food
 - (4) have moisture content of not more than 8% of the weight for powder food
 - (5) be dissolved evenly for food which is for drinking
 - (6) give energy of not less than 350 kilocalories per 100 grams of food, excluding the weight of water
 - (7) give energy of not less than 65 kilocalories and not more than 70 kilocalories per 100 grams of food which is liquid for drinking.

4. The quality or standard of baby food in the volume of food to give energy of 100 kilocalories for baby food to feed baby from the time of birth shall contain:

(1) Reference protein of not less than 1.8 grams and not more than 3.5 grams; as for other proteins either whole or part those proteins shall have consumable value of not less than 70% of the proteins of egg, but all proteins of such baby food when calculated in comparison with reference protein shall not be less than 1.8 grams and not more than 3.5 grams.

(2) Fat of not less than 2 grams and not more than 4 grams, and fatty acid, linoleic type, of not less than 200 milligrams.

(3) Sugar of not less than 40% of all carbohydrate.

(4) Vitamins in the quantity as follows:

(a) Vitamin A not less than 250 international units or 75 micrograms, calculated in retinol, or not less than 450 micrograms, calculated in betacarotein.

(b) Vitamin D not less than 60 international units

(c) Vitamin E not less than 1 international unit to 1 gram of linoleic acid

(d) Vitamin K not less than 8 micrograms

(e) Vitamin C not less than 10 milligrams

(f) Vitamin B1 not less than 50 micrograms

(g) Vitamin B2 not less than 70 micrograms

(h) Nicotinamide not less than 500 micrograms

(i) Vitamin B6 not less than 50 micrograms

(j) Pantothenic acid not less than 300 micrograms

- | | | | |
|-----|-------------|---------------|----------------|
| (k) | Folic acid | not less than | 4 micrograms |
| (l) | Biotine | not less than | 5 micrograms |
| (m) | Vitamin B12 | not less than | 0.05 microgram |
| (n) | Kolin | not less than | 12 milligrams |

(5) Minerals in the quantity as follows:

- | | | | |
|-----|------------|---------------|--|
| (a) | Sodium | not less than | 20 milligrams,
and not over
80 milligrams |
| (b) | Potassium | not less than | 80 milligrams,
and not over
200 milligrams |
| (c) | Chloride | not less than | 60 milligrams,
and not over
150 milligrams |
| (d) | Calcium | not less than | 50 milligrams |
| (e) | Phosphorus | not less than | 25 milligrams |
| (f) | Magnesium | not less than | 6 milligrams |
| (g) | Iron | not less than | 1 milligram |
| (h) | Iodine | not less than | 5 micrograms |
| (i) | Copper | not less than | 60 micrograms |
| (j) | Zinc | not less than | 0.5 milligram |
| (k) | Manganese | not less than | 0.2 milligram |

However, the ratio of calcium to phosphorus shall not be less than 1.2 and not over 2.0.

5. The quality or standard of baby food in the volume of food to give energy of 100 kilocalories for baby food to feed baby from three months old and upwards shall contain:

- (1) Reference protein of not less than 1.8 grams and not more than 3.5 grams; as for other proteins either whole or part those proteins shall have consumable value of not less than 70% of the proteins of egg, but all proteins of such baby food when calculated in comparison with

reference protein shall not be less than 1.8 grams and not more than 3.5 grams.

(2) Fatty acid, linoleic type, of not less than 200 milligrams.

(3) Sugar of not less than 20% of all carbohydrate.

(4) Vitamins in the quantity as follows:

(a) Vitamin A not less than 250 international units or 75 micrograms, calculated in retinol, or not less than 450 micrograms, calculated in betacarotein.

(b) Vitamin E not less than 1 international unit per 1 gram of linoleic acid

(c) Vitamin C not less than 10 milligrams

(d) Vitamin B1 not less than 50 micrograms

(e) Vitamin B2 not less than 70 micrograms

(5) Minerals in the quantity as follows:

(a) Sodium not over 80 milligrams

(b) Chloride not over 150 milligrams

(c) Calcium not less than 50 milligrams

(d) Iron not less than 1 milligram

(e) Iodine not less than 5 micrograms

The ratio of calcium to phosphorus shall not be less than 1.2 and not over 2.0.

6. Baby food which is liquid shall have to go through the process of pasturised or sterilized, as the case may be.

7. Pasturised baby food shall be kept in the temperature of not over 10⁰ centigrade and the period of time for sale shall not be over two days from the date of packing in the container for sale.

8. The container for baby shall:

(1) be properly sealed, clean and hygenic

(2) be sufficiently protected from moisture, if used to contain powder food.

9. Baby food which has been brought or imported into the Kingdom for sale, or manufactured for sale or sold shall be labelled, and such label shall contain at least the following in clearly readable Thai language:

(1) "Baby food" in letters of not less than 5 millimeters in size, and stating the content that it is used for feeding baby from the date of birth or for feeding baby from the age of three months upwards, as the case may be.

(2) "Pasturised" or "Sterilized" for baby food which has been through the process of pasturised or sterilized, as the case may be.

(3) Name and registration number of food.

(4) Name and address of place of manufacture.

(5) Net weight or volume of food.

(6) Date of manufacture or code which has been registered with the Ministry of Public Health.

(7) Date of expiration for the age of use for pasturised baby food.

(8) Volume of important ingredient in percentage of weight or in units.

(9) Method of application.

APPENDIX 6CODEX ALIMENTARIUS DRAFT STANDARD
FOR INFANT FORMULA1. SCOPE

This standard applies to food in liquid or powdered form intended for use as a substitute for human milk in meeting the normal nutritional requirements of infants. It also applies to those foods intended for infants with special nutritional requirements, except with regard to other provisions concerning these special requirements.

2. DESCRIPTION

2.1 Infant formula, when in liquid form, may be used either directly or diluted with water before feeding as appropriate. In powdered form it requires water for preparation.

2.2 The product shall be nutritionally adequate to promote normal growth and development when used in accordance with its directions for use.

2.3 The product is so processed by physical means only and so packaged as to prevent spoilage and contamination under all normal conditions of handling, storage and distribution in the country where the product is sold.

3. DEFINITIONS

3.1 The term "infant" means a person not more than 12 months of age.

3.2 The term "calorie" means a kilocalorie or "large calorie" (1 kilojoule is equivalent to 0.239 kilocalories).

4. ESSENTIAL COMPOSITION AND QUALITY FACTORS4.1 Essential Composition

4.1.1 Infant formula is a product based on milk of cows or

other animals and/or on other edible constituents of animal, including fish, or plant origin, which have been proved to be suitable for infant feeding.

4.1.2 Infant formula shall contain, per 100 available calories (or 100 kilojoules) of intake, the following minimum and maximum levels of vitamins, minerals in an available form, choline, protein, fat and linoleate:

(a) <u>Vitamins</u> <u>other than</u> <u>vitamin E</u>	Amounts per 100 available calories		Amounts per 100 available kilojoules	
	<u>Minimum</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Maximum</u>
Vitamin A	250 I.U. or 75 mcg expressed as retinol	750 I.U. or 225 mcg expressed as retinol	60 I.U. or 18 mcg expressed as retinol	180 I.U. or 55 mcg expressed as retinol
Vitamin D	40 I.U.	100 I.U.	10 I.U.	24 I.U.
Ascorbic acid (Vitamin C)	8 mg	none specified	1.9	none specified
Thiamine (Vitamin B1)	40 mcg	"	10 mcg	"
Riboflavin (Vitamin B2)	60 mcg	"	14 mcg	"
Nicotinamide	250 mcg	"	60 mcg	"
Vitamin B6 ¹	35 mcg	"	9 mcg	"
Folic acid	4 mcg	"	1 mcg	"
Pantothenic acid	300 mcg	"	70 mcg	"
Vitamin B12	0.15 mcg	"	0.04 mcg	"
Vitamin K1	4 mcg	"	1 mcg	"

¹ Formulae with a higher protein content than 1.8 g.protein/100 calories should contain a minimum of 15 mcg vitamin B6 per gram of protein.

Biotin (Vitamin H)	1.5 mcg	none specified	0.4 mcg	none specified
(b) <u>Vitamin E</u> (α - tocopherol compounds) minimum of 1 I.U. per g linoleic acid	-	"	-	"
(c) <u>Minerals</u>				
Sodium (Na)	20 mg	60 mg	5 mg	15 mg
Potassium (K)	80 mg	200 mg	20 mg	50 mg
Chloride (Cl)	55 mg	150 mg	14 mg	35 mg
Calcium (Ca) *	50 mg	none specified	12 mg	none specified
Phosphorus (P) *	25 mg	"	6 mg	"
Magnesium (Mg)	6 mg	"	1.4 mg	"
Iron (Fe)	1 mg**	"	0.25 mg**	"
Iron (Fe)	0.15 mg	"	0.04 mg	"
Iodine (I)	5 mcg	"	1.2 mcg	"
Copper (Cu)	60 mcg	"	14 mcg	"
Zinc (Zn)	0.5 mg	"	0.12 mg	"
Manganese	5 mcg	"	1.2 mcg	"
(d) <u>Choline</u>	7 mg		1.7 mg	
(e) <u>Protein</u> (per 100 available calories) <u>1</u>				

* The Ca:P ratio shall be not less than 1.2 and not more than 2.0.

** This product is to be labelled Infant Formula with Iron.

1 Amounts per 100 available kilojoules: multiply all figures given per 100 available calories by 0.239.

- (i) Shall not be less than 1.8 g protein of nutritional quality equivalent to that of casein or a greater quantity of other protein in proportion to its biological value. The quality of the protein shall not be less than 85% of that of casein. The total quantity of protein shall not be more than 4 g. The minimum value set for quality and the maximum for quantity of the protein may be modified by national authorities according to their own regulations and/or local conditions.
- (ii) Isolated amino acids may be added to infant formula only to improve its nutritional value for infants. Essential amino acids may be added to improve protein quality, only in amounts necessary for that purpose. Only natural L forms of amino acids may be used.
- (f) Fat and Linoleate
- The product shall contain linoleic acid (in the form of glycerides) at a level not less than 300 mg per 100 available calories (or 70 mg per 100 available kilojoules) and fat at a level not less than 3.3 g and not more than 6 g per 100 available calories (or not less than 0.8 g and not more than 1.5 g per 100 available kilojoules).

4.2 Optional Ingredients

4.2.1 In addition to the vitamins and minerals listed under 4.1.2 (a), (b) and (c), other nutrients may be added when required in order to provide nutrients ordinarily found in human milk and to ensure that the formulation is suitable as the sole source of nutrients of the infant.

4.2.2 The usefulness of these nutrients shall be scientifically shown.

4.2.3 When any of these nutrients is added, the formula shall contain significant amounts of these nutrients, based on levels in human milk.

4.3 Consistency and Particle Size

When prepared according to the label directions for use, the product shall be free of lumps and of large coarse particles and suitable for being fed through a soft rubber or plastic nipple.

4.4 Purity Requirements

All ingredients shall be clean, of good quality, safe and suitable for ingestion by infants. They shall conform with their normal quality requirements, such as colour, flavour and odour.

4.5 Specific Prohibition

The product and its components shall not have been treated by ionizing radiation.

5. FOOD ADDITIVES

(List of food additives to be established).

6. CONTAMINANTS

6.1 Pesticide Residues

The product shall be prepared with special care under good manufacturing practices, so that residues of those pesticides which may be required in the production, storage or processing of the raw materials or the finished food do not remain, or, if technically unavoidable, are reduced to the maximum extent possible.

6.2 Other Contaminants

The product shall be free from residues of hormones and antibiotics and practically free from other contaminants.

7. HYGIENE

7.1 To the extent possible in good manufacturing practice the product shall be free from objectionable matter.

7.2 When tested by appropriate methods of sampling and examination the product:

- (a) shall be free from pathogenic micro-organisms;
- (b) shall not contain any substances originating from micro-organisms in amounts which may represent a hazard to health; and
- (c) shall not contain any other poisonous or deleterious substances in amounts which may represent a hazard to health.

7.3 The product shall be prepared, packed, and held under sanitary conditions and should comply with the Code of Hygienic Practice for Foods for Infants and Children (to be prepared by the Committee on Food Hygiene).

8. PACKAGING

8.1 The product shall be packed in containers which will safeguard the hygienic and other qualities of the food.

When in liquid form the product shall be packed in hermetically sealed containers; nitrogen and carbon dioxide may be used as packing media.

8.2 The containers, including packaging materials, shall be made only of substances which are safe and suitable for their intended uses. Where the Codex Alimentarius Commission has established a standard for any such substance used as packaging materials, that standard shall apply.

9. FILL OF CONTAINER

In the case of products in ready-for-use form, the fill of container shall be:

- (i) not less than 80% v/v for products weighing less than 150g (5oz).

- (ii) not less than 85% v/v for products in the weight range 150-250 g (8 oz.); and
- (iii) not less than 90% v/v for products weighing more than 250 g (8 oz.) of the water capacity of the container. The water capacity of the container is the volume of distilled water at 20°C which the sealed container will hold when completely filled.

10. LABELLING

In addition to Sections 1, 2, 4 and 6 of the Recommended International General Standard for the Labelling of prepackaged Foods (CAC/RS 1-1969), the following specific provisions apply (subject to endorsement by the Codex Committee on Food Labelling):

10.1 The Name of the Food

10.1.1 The name of the product shall be either "Infant Formula" or any appropriate designation indicating the true nature of the food, in accordance with national usage.

10.1.2 The sources of protein in the product shall be clearly shown on the Label.

10.1.3 If 90% or more of the protein is derived from whole or skim milk, as such or with minor modification, the product may be labelled "Infant Formula based on Milk".

10.1.4 A product which contains neither milk nor any milk derivative may be labelled "free from milk and milk products".

10.2 List of Ingredients

10.2.1 A complete list of ingredients shall be declared on the label in descending order of proportion except that in the case of added vitamins and added minerals, these ingredients shall be arranged as separate groups for vitamins and minerals, respectively, and within these groups the vitamins and minerals need not to be listed in descending order of proportion.

10.2.2 The specific and not the class name shall be declared for ingredients of animal or plant origin and for food additives.

10.3 Declaration of Nutritive Value

The declaration of nutrition information shall contain the following information in the following order:

10.3.1 The amount of energy, expressed in calories (kcal) or kilogoules (kj), and the number of grams of protein, carbohydrate and fat per 100 grams of the food as sold as well as per specified quantity of the food as suggested for consumption.

10.3.2 The total quantity of each vitamin, mineral, choline and any optional ingredient as listed in paragraphs 4.1.2 and 4.2 of this standard per 100 grams of the food as sold as well as per specified quantity of the food as suggested for consumption. In addition, the declaration per 100 calories (or per 100 kilojoules) is permitted.

10.4 If special dietary claims are made that the food contains proteins, vitamins or minerals, the label shall also contain the following information: The amount per 100 grams of the food as sold as well as per specified quantity of the food as suggested for consumption of protein and each of the stated vitamins and minerals expressed in percentage of the recommended daily intake of the respective nutrient.

10.5 Net Contents

The net contents of Infant Formula shall be declared by volume if it is in liquid form, or by weight if it is in powdered form. The declaration of weight or volume shall be made in either the metric ("Systeme international" units)

or in a system of measurement as required by the country in which the food is sold, or in both systems.

10.6 Name and Address

The name and address of the manufacturer, packer, distributor, importer, exporter or vendor of the food shall be declared.

10.7 Country of Origin

10.7.1 The country of origin of the food shall be declared if its omission would mislead or deceive the consumer.

10.7.2 When the food undergoes processing in a second country which changes its nature, the country in which the processing is performed shall be considered to be the country of origin for the purposes of labelling.

10.8 Lot Identification

Each container shall be embossed or otherwise permanently marked, in code or in clear, to identify the producing factory and the lot.

10.9 Date Making and Storage Instructions

10.9.1 The date of manufacture or the date of expiry shall be declared in clear and which ever is used shall be indicated.

10.9.2 Storage instructions shall appear on the label or on the accompanying leaflet.

10.10 Information for Utilization

10.10.1 Directions as to the preparation and use of the food, and its storage and keeping after the container has been opened shall appear on the label or on the accompanying leaflet.

10.10.2 Information that infants over six months of age should receive supplemental foods in addition to formula shall appear on the label.

APPENDIX 7

THE AVERAGE WEIGHT OF MALE AND FEMALE

INFANTS BY AGE GROUP (139)

Age months	Weight Kg (Male)	Weight Kg (Female)	Average weight
At birth	3.12	3.01	3.07
1	4.65	4.46	4.56
2	5.59	5.29	5.44
3	6.34	5.61	5.98
4	6.5	6.56	6.53
5	7.56	6.80	7.18
6	7.74	7.33	7.54
7	8.19	7.48	7.84
8	8.5	7.76	8.13
9	8.62	7.96	8.29
10	8.48	8.22	8.35
11-12	9.06	7.93	8.50

APPENDIX 8

SUMMARY OF LINEAR PROGRAMMING MODELS
IN NUTRITION PROBLEMS

Year	Author	Area	Number of foods	Number of nutrients	Nutrients
1945	Stigler ^a	U.S.A.	77	9	calories, protein, Ca, Fe, vit A, thiamine, riboflavin, niacin, vit C
1959	Smith, V.E. ^b	U.S.A.	73	12	as Stigler plus carbohydrate,
			83	12	fat, P
			572	12	included restrictions on foods
1961	Smith, P.E. ^c	U.S.A.	400	8	as Stigler less
			30	8	calories; plus vit. E.
			40	8	
1961	Sukhatme ^d	World	10 food groups	3	calories, animal protein, vegetable protein
1964	Wirths et al. ^e	Germany	38+3 vitamin tablets	12	as Stigler plus total fat, vegetable fat and animal protein
1965	Wirths et al. ^f	Develop- ing nations	10 food groups	8	calories, protein, animal protein, isoleucine, lysine, methionine, threonine and tryptophan
1966	de Moor et al. ^g	Belgium	n.a.	10	as Stigler plus fat
1969	Hruby ^h	Czechoslovakia	16 food groups	11	as Stigler plus animal protein and fat

1969	Inglett et al. ⁱ	general	6	7	protein, lysine, S-amino acids, isoleucine, threonine, tryptophan, valine
1971	Patrick et al. ^j	Brazil	n.a.	n.a.	n.a.
1971	Pinto ^k	Brazil	n.a.	n.a.	included essential amino acids
1972	Cavins et al. ^l	general	6	11	protein and 10 essential amino acids

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APPENDIX 9
RECORDED AND ESTIMATED YEARLY PRODUCTION
OF RAW MATERIALS. (163)

Food raw materials	Production (tons)	Estimated production (tons)	Food raw materials	Production (tons)	Estimated production (tons)
<u>Fruits</u>			<u>Cereals; starchy roots, tubers and fruits, legumes, nut and seeds</u>		
Banana 1 common variety	1,410,310	-	Cashew nut	-	11.96
Banana 2 dwarf	330,699	-	Cassava starch	(211,2 million babb)	-
Grape	89,457	-	Cowpea dry	-	119.6
Guava	76,392	-	Coconut	-	-
Lemon	-	104.0	Mungbean, whole	169,826	-
Orange	-	26.0	Mungbean, starch	-	29.9
Orange, mandarine	760,814	-	Peanut, raw with shell	182,826	-
Papaya	-	104.0	Peanut, dry and shelled	-	-
Pineapple	474,209	-	Pigeon pea	-	119.6
Watermelon	620,764	0	Rice black, glutinous	↑	-
<u>Meats and poultry</u>			Rice brown	↓	-
Beef	4,667,000	-	Rice flour	↓	-
Buffalo	87,165	-	Rice glutinous, flour	13,270,000	-
Chicken, matured	691,634	21,333.0	Rice glutinous, milled	↓	-
Chicken, young	for export as		Rice, milled and polished	↓	-
Duck	breeding only	2,666.0	Rice, parboiled	↓	-
Liver, beef	↑		Sesame	24,030	-
Liver, chicken	Included in beef	-	Soybean	69,334	-
Liver, duck	duck, chicken and		Soybean card	-	19.5
Liver, hog	swine production	↓	Soybean flour	-	29.9
<u>Eggs and milk</u>			Sugar	17,900	-
Egg, hen	↓	4.8 million egg/day	Sweet potato	285,791	-
Egg, duck	-	2.5 million egg/day	Sweet potato yellow	-	-
Milk, cow whole	-	↑	<u>Vegetables</u>		
Skim, fluid	-	240	Bamboo	-	69.8
Milk, dry	-	↑	Beans, snap	-	3.0
Skim, dry	-	15	Cabbage	98,448	-
<u>Fish and selffish</u>			Cabbage, chinese	-	40.0
Anchovy*	-	-	Cauliflour	-	72.1
Catfish, fresh water*	-	-	Collard	-	100.1
Catfish, sea water*	-	-	Cowpea, yardlong	-	80.1
Carp	12,223	-	Goatbean	-	2.0
Dorab*	-	-	Ivygourd	-	2.0
Eel	1,634	-	Peas	7,746	-
Gouramy	11,152	-	Mustard, green	-	32.0
Hardtail	42,615	-	Spouted mungbean	-	72.1
Mackerel, spanish*	-	-	Swampcabbage	-	20.0
Mackerel, stripe	166,308	-	Bottle gourd	-	1.0
Milkfish*	-	-	Carrot	-	2.0
Mullet*	-	-	Corn	1,938.2	-
Prawns, river, medium	4,058	-	Cucumber	-	320.3
Prawns, sea	129,623	-	Eggplant	-	80.1
Perch	8,458	-	Mushroom	-	40.0
Snapper*	-	-	Pumpkin	-	200.0
Serpenthead	20,232	-	Radish	99,797	-
Squid*	-	-	Saake gourd	-	2.0
* Miscellaneous fish	322,055	-	Sponge gourd	-	80.0
			Wax gourd	-	200.0
			Tomato	-	27,527.0

APPENDIX 10LIST OF REFERENCES FOR THE
FOOD COMPOSITIONS

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APPENDIX 11

RAW MATERIAL COMPOSITION TABLES

A complete list of the nutrient composition data used for the application of the linear programming model for the design of infant food is given. Compositional data on each of the nutrients is included for 96 raw materials.

Compositional data is divided into 3 parts as follows:

1. Cost, proximate analysis, vitamins and minerals.
2. Vitamins and minerals (continued).
3. Essential amino acids.

PART 1

FOOD	COST	WEIGHT	DRIED WEIGHT	CALORIES	PROTEIN	FAT	CARBO- HYDRATE	FIBRE	CALCIUM	PHOS- PHORUS	IRON	SODIUM	POTASSIUM	RETINOL	B-CAROTENE	THIAMINE	RIBOFLAVIN	NIACIN	ASCORBIC ACID
	BAHT/100G	100G	G/100G	KCAL/100G	G/100G	G/100G	G/100G	G/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MCG/100G	MCG/100G	MG/100G	MG/100G	MG/100G	MG/100G
ANCHOVY	2.4658	1.00	23.10	99.00	18.50	2.20	0.00	0.00	279.00	264.00	1.20	147.00	447.00	25.00	0.00	0.01	0.08	3.50	3.00
BANHO	0.7143	1.00	9.00	28.00	2.50	0.30	5.30	1.20	17.00	47.00	0.90	6.00	402.00	0.00	15.00	0.11	0.09	0.60	9.00
BANANA1	0.4762	1.00	28.40	100.00	1.20	0.30	26.10	0.60	12.00	32.00	0.80	4.00	401.00	0.00	225.00	0.03	0.04	0.60	14.00
BANANA2	0.9061	1.00	20.80	72.00	1.80	0.20	18.00	0.20	10.00	24.00	1.30	18.00	435.00	0.00	80.00	0.03	0.04	0.60	8.00
BEEF	3.5294	1.00	28.20	150.00	20.00	7.20	0.00	0.00	9.00	171.00	3.00	93.00	489.00	15.00	5.00	0.07	0.34	6.70	0.00
BENSNAP	0.3158	1.00	8.50	28.00	1.90	0.40	5.60	1.00	75.00	49.00	1.20	2.00	196.00	0.00	323.00	0.05	0.10	0.60	18.00
BOTTLEGD	0.2353	1.00	4.70	16.00	0.60	0.20	3.50	0.70	14.00	16.00	0.40	3.00	151.00	0.00	10.00	0.03	0.03	0.04	10.00
BUFFALO	3.5294	1.00	23.50	120.00	17.70	4.90	0.00	0.00	14.00	221.00	3.30	91.00	273.00	5.00	1.00	0.06	155.00	3.50	0.00
CABBAGE	0.4070	1.00	7.00	22.00	1.60	0.30	4.40	0.80	55.00	31.00	0.80	10.00	238.00	0.00	280.00	0.60	0.06	0.30	46.00
CABBAGEC	0.4069	1.00	5.80	17.00	1.70	0.20	3.10	0.70	102.00	46.00	2.60	22.00	279.00	0.00	2305.00	0.07	0.13	0.90	53.00
CARB	1.9300	1.00	54.30	69.00	11.30	2.30	0.00	0.00	20.00	135.00	0.70	73.00	261.00	0.00	0.00	0.04	0.11	1.60	0.00
CARROT	2.6506	1.00	10.40	37.00	1.10	0.30	8.30	0.90	36.00	38.00	1.20	70.00	245.00	0.00	7000.00	0.06	0.05	0.70	8.00
CASHEW	0.7000	1.00	96.00	568.00	18.00	46.30	28.70	0.60	28.00	462.00	3.60	26.00	420.00	0.00	5.00	0.25	0.34	2.40	1.00
CASSAVAS	0.4000	1.00	88.00	354.00	0.50	0.20	86.90	0.00	0.00	0.00	0.00	11.00	926.00	0.00	0.00	0.00	0.00	0.00	0.00
CATFISHP	1.6320	1.00	21.90	98.00	18.20	2.20	0.00	0.00	34.00	116.00	0.20	63.00	440.00	85.00	0.00	0.10	0.04	2.20	3.00
CATFISHS	2.449	1.00	21.50	91.00	19.30	1.00	0.00	0.00	37.00	181.00	1.50	103.00	468.00	25.00	0.00	0.08	0.09	1.50	3.00
CAULIF	0.9167	1.00	9.50	29.00	2.80	0.20	5.70	0.90	30.00	58.00	1.00	20.00	349.00	0.00	55.00	0.07	0.08	0.70	72.00
CHICKENM	2.6250	1.00	44.00	302.00	18.00	25.00	0.00	0.00	14.00	200.00	1.50	46.00	407.00	170.00	145.00	0.08	0.16	8.00	0.00
CHICKENY	2.8000	1.00	28.50	151.00	20.20	7.20	0.00	0.00	14.00	200.00	1.50	46.00	407.00	50.00	40.00	0.08	0.16	6.10	0.00
COCONUT	0.6000	1.00	48.30	312.00	3.20	28.20	16.00	3.00	23.00	112.00	2.50	7.00	555.00	0.00	0.00	0.05	0.03	0.60	3.00
COLLARD	0.3378	1.00	11.00	35.00	3.00	0.40	6.80	1.20	230.00	56.00	2.00	42.00	490.00	0.00	270.00	0.10	0.13	0.40	93.00
CORN	0.5405	1.00	37.50	134.00	4.20	1.70	30.70	1.10	5.00	126.00	0.90	3.00	259.00	0.00	160.00	0.20	0.11	1.50	8.00
COTLEAD	0.5000	1.00	88.50	340.00	22.70	1.60	61.00	4.20	110.00	382.00	6.50	6.00	688.00	0.00	10.00	0.59	0.22	2.30	1.00
COWPEAYD	0.2273	1.00	11.70	37.00	3.00	0.20	7.90	1.60	44.00	45.00	0.70	6.00	233.00	0.00	225.00	0.12	0.11	1.00	22.00
CUCUMBER	0.3346	1.00	3.80	12.00	0.60	0.10	2.70	0.50	21.00	24.00	0.40	13.00	154.00	0.00	85.00	0.03	0.04	0.20	11.00
MORAB	1.5405	1.00	23.50	95.00	21.00	0.60	0.00	0.00	97.00	278.00	1.10	128.00	235.00	25.00	0.00	0.04	0.06	6.60	3.00
DUCK	2.5000	1.00	45.60	326.00	16.00	28.00	0.00	0.00	15.00	188.00	1.80	100.00	319.00	0.00	0.08	0.10	0.24	5.60	0.00
EEL	2.8571	1.00	18.00	77.00	16.50	0.70	0.00	0.00	30.00	93.00	3.30	116.00	172.00	25.00	0.00	0.04	0.22	1.80	0.00
EGGOK	1.4848	1.00	29.40	188.00	13.20	14.20	0.70	0.00	64.00	220.00	3.60	191.00	258.00	370.00	185.00	0.16	0.40	0.20	0.00
EGGFEN	1.9318	1.00	26.30	163.00	12.90	11.50	0.80	0.00	61.00	222.00	3.20	158.00	176.00	500.00	170.00	0.10	0.40	0.10	0.00
EGGPLANT	0.3240	1.00	8.00	26.00	1.60	0.30	5.60	1.00	22.00	37.00	0.90	7.00	221.00	0.00	50.00	0.08	0.07	0.70	6.00
GIZOCHIC	3.6082	1.00	23.90	107.00	20.30	2.00	0.60	0.00	28.00	150.00	0.50	0.00	200.00	0.00	0.00	0.05	0.22	5.10	0.00
GIZEDUCK	3.6082	1.00	22.30	110.00	20.20	2.30	0.80	0.00	28.00	154.00	5.10	0.00	0.00	0.00	0.00	0.70	0.20	5.60	0.00
GOARN	0.3158	1.00	10.50	34.00	1.90	0.10	7.90	1.60	53.00	48.00	0.20	3.00	205.00	0.00	340.00	0.19	0.08	1.00	21.00
GOURAMY	2.1054	1.00	19.10	81.00	17.00	0.80	0.00	0.00	70.00	177.00	2.30	72.00	278.00	295.00	65.00	0.05	0.19	2.00	0.00
GRAPE	1.9231	1.00	14.00	50.00	0.50	0.30	12.80	0.90	9.00	20.00	0.60	6.00	111.00	0.00	50.00	0.10	0.06	0.20	4.00
GUAVA	0.4082	1.00	19.40	69.00	1.00	0.40	17.30	5.60	15.00	24.00	0.70	4.00	291.00	0.00	75.00	0.05	0.04	1.10	132.00
HARDTAIL	1.7379	1.00	22.60	99.00	19.80	1.60	0.00	0.00	45.00	140.00	0.60	102.00	390.00	25.00	0.00	0.07	0.13	6.00	3.00
HEARTPF	2.6804	1.00	21.90	122.00	14.40	5.80	1.00	0.00	7.00	147.00	4.80	80.00	300.00	40.00	10.00	0.35	0.36	7.00	1.00
HEARTPHG	1.9231	1.00	23.10	123.00	15.20	5.90	1.20	0.00	26.00	169.00	3.00	0.00	134.00	25.00	5.00	0.36	0.71	5.40	1.00
IVYGOURD	0.6000	1.00	9.40	28.00	4.10	0.40	4.20	1.00	126.00	30.00	4.60	38.00	461.00	0.00	10845.00	0.17	0.13	3.80	48.00
LEMON	0.7463	1.00	9.60	28.00	0.70	0.80	7.60	0.70	32.00	19.00	0.30	4.00	137.00	0.00	15.00	0.04	0.02	0.10	50.00
LIVERBF	3.0928	1.00	28.40	128.00	19.00	3.10	5.00	0.00	7.00	310.00	8.70	110.00	213.00	11850.00	2635.00	0.32	1.68	12.80	24.00
LIVERCH	3.6082	1.00	28.00	144.00	17.80	6.60	2.30	0.00	10.00	297.00	9.70	86.00	335.00	8695.00	1930.00	0.36	1.92	10.00	7.00
LIVERDK	3.6082	1.00	30.30	168.00	16.90	9.70	2.20	0.00	14.00	244.00	3.90	86.00	325.00	5000.00	0.00	0.36	1.32	10.00	8.00
LIVERHOG	3.9175	1.00	28.10	131.00	19.90	4.10	0.40	0.00	8.00	361.00	14.40	110.00	447.00	3835.00	850.00	0.40	2.34	16.60	13.00
MACK	2.9231	1.00	22.60	103.00	18.50	2.70	0.00	0.00	20.00	224.00	1.30	70.00	471.00	10.00	0.00	0.07	0.17	6.60	0.00
MACKST	2.1930	1.00	22.00	98.00	18.50	2.10	0.00	0.00	94.00	153.00	1.20	110.00	486.00	35.00	10.00	0.05	0.09	7.90	3.00

PART 1

FOOD	COST	WEIGHT	DRIED WEIGHT	CALORIES	PROTEIN	FAT	CARBO- HYDRATE	FIBRE	CALCIUM	PHOS- PHORUS	IRON	SODIUM	POTASSIUM	RETINOL	B-CAROTENE	THIAMINE	RIBOFLAVIN	NIACIN	ASCORBIC ACID
	BAHT/100G	100G	G/100G	KCAL/100G	G/100G	G/100G	G/100G	G/100G	MG/100G	MG/100G	MG/100G	MG/100G	MG/100G	MCG/100G	MCG/100G	MG/100G	MG/100G	MG/100G	MG/100G
MILKCOWH	1.1110	1.00	12.30	63.00	3.10	3.50	5.00	0.00	114.00	102.00	0.10	36.00	149.00	35.00	20.00	0.04	0.14	0.20	1.00
MILKDR	5.0000	1.00	96.20	490.00	26.00	26.60	37.60	0.00	895.00	740.00	0.90	380.00	1330.00	210.00	180.00	0.20	1.00	0.80	2.00
MILKFISH	2.1739	1.00	27.40	138.00	20.60	5.50	0.00	0.00	42.00	153.00	1.10	80.00	381.00	65.00	120.00	0.10	0.10	5.80	0.00
MULLET	3.3077	1.00	25.90	124.00	20.70	3.90	0.00	0.00	56.00	203.00	1.40	69.00	485.00	45.00	0.00	0.07	0.15	4.60	0.00
MURGENST	0.7000	1.00	88.00	356.00	1.70	0.30	85.40	0.00	35.00	43.00	1.30	7.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
MURGENFW	0.4700	1.00	89.40	341.00	22.90	1.20	61.80	4.40	105.00	330.00	7.10	6.00	1132.00	0.00	55.00	0.53	0.26	2.50	4.00
MUSHROOM	1.6484	1.00	11.30	37.00	2.70	0.90	5.70	0.90	8.00	103.00	1.00	12.00	322.00	0.00	0.00	0.10	0.42	4.80	3.00
MUSTARDG	0.6667	1.00	8.20	24.00	2.40	0.40	4.30	1.00	160.00	48.00	2.70	24.00	297.00	0.00	1825.00	0.06	0.14	0.80	73.00
ORANGE	0.9375	1.00	11.40	40.00	0.80	0.20	9.90	0.40	21.00	20.00	0.30	2.00	162.00	0.00	150.00	0.07	0.04	0.40	43.00
ORANGEM	0.8571	1.00	11.40	41.00	0.70	0.20	10.20	0.30	26.00	14.00	0.20	1.00	149.00	0.00	465.00	0.90	0.04	0.40	42.00
PAPAYA	0.2778	1.00	12.90	45.00	0.50	0.10	11.80	0.50	24.00	22.00	0.70	4.00	221.00	0.00	710.00	0.03	0.05	0.40	73.00
PEANUT	0.3846	1.00	57.80	303.00	15.00	19.40	21.80	1.10	56.00	245.00	2.10	4.00	421.00	0.00	20.00	0.97	0.18	9.70	11.00
PEANUTDR	0.7000	1.00	92.70	548.00	23.40	45.30	21.60	2.10	58.00	357.00	2.20	5.00	662.00	0.00	0.00	1.00	0.13	16.80	0.00
PEAS	2.1050	1.00	24.40	94.00	6.20	0.40	16.90	2.40	32.00	102.00	1.20	6.00	350.00	0.00	405.00	0.28	0.11	2.80	27.00
PERCH	2.0860	1.00	18.00	81.00	17.20	0.80	0.00	0.00	70.00	177.00	2.30	73.00	108.00	295.00	65.00	0.15	0.19	2.00	0.00
PIAPPLE	0.3636	1.00	13.00	47.00	0.70	0.30	11.60	0.50	17.00	12.00	0.50	2.00	125.00	0.00	35.00	0.06	0.03	0.30	22.00
PIEPEA	0.6294	1.00	88.50	339.00	20.40	1.20	63.40	4.40	103.00	224.00	4.90	26.00	654.00	0.00	160.00	0.49	0.21	2.20	0.00
POKIL	3.9024	1.00	49.90	376.00	14.10	35.00	0.00	0.00	8.00	151.00	2.10	45.00	400.00	0.00	0.00	0.69	0.16	3.70	0.00
PRAWNDR	9.3910	1.00	21.00	82.00	16.20	1.30	0.40	0.00	161.00	292.00	2.20	418.00	316.00	25.00	0.00	0.04	0.13	2.00	1.00
PRAWNS	12.0000	1.00	20.80	87.00	17.60	0.90	0.90	0.00	79.00	184.00	1.60	185.00	333.00	20.00	5.00	0.04	0.08	2.30	1.00
PUMPKIN	0.2990	1.00	8.10	27.00	0.70	0.20	6.60	0.80	24.00	33.00	0.70	8.00	350.00	0.00	785.00	0.03	0.04	0.50	14.00
RADISH	0.2409	1.00	7.00	24.00	1.00	0.10	5.30	1.00	27.00	30.00	0.40	27.00	228.00	0.00	0.00	0.02	0.03	0.06	42.00
RICEBL	0.3500	1.00	87.90	360.00	7.40	2.10	77.10	0.80	21.00	243.00	3.40	11.00	288.00	0.00	0.00	0.30	0.12	5.00	0.00
RICEBRD	0.4000	1.00	86.50	354.00	7.60	1.80	76.00	0.70	16.00	246.00	2.80	5.00	202.00	0.00	0.00	0.34	0.07	5.00	0.00
RICEPIO	0.6000	1.00	88.20	366.00	6.40	0.80	80.60	0.30	24.00	135.00	1.90	5.00	241.00	0.00	0.00	0.10	0.05	2.10	0.00
RICEGLUF	0.7000	1.00	91.20	372.00	6.60	0.40	82.70	0.30	12.00	148.00	0.80	4.00	84.00	0.00	0.00	0.10	0.02	1.70	0.00
RICEGLUM	0.3500	1.00	86.10	359.00	8.40	1.60	75.40	0.50	16.00	130.00	1.20	3.00	282.00	0.00	0.00	0.16	0.06	2.40	0.00
RICEIPO	0.3470	1.00	88.20	366.00	6.40	0.80	80.40	0.30	24.00	135.00	1.90	5.00	241.00	0.00	0.00	0.10	0.05	2.10	0.00
RICEPAID	0.4240	1.00	87.60	364.00	6.70	1.00	79.30	0.60	7.00	135.00	1.20	2.00	200.00	0.00	0.00	0.20	0.08	2.60	0.00
SERHEAD	2.7272	1.00	18.00	75.00	16.60	0.50	0.00	0.00	20.00	58.00	0.70	73.00	108.00	0.00	0.00	0.15	0.10	3.20	0.00
SESAME	1.0660	1.00	94.20	582.00	17.20	52.80	19.80	5.40	750.00	614.00	12.00	49.00	508.00	0.00	15.00	0.72	0.17	5.10	0.00
SKIMDR	5.0000	1.00	95.80	359.00	34.80	1.00	52.00	0.00	1200.00	980.00	1.00	470.00	1745.00	5.00	0.00	0.30	1.60	1.10	5.00
SKIMFLU	1.0000	1.00	9.00	34.00	3.40	0.10	4.80	0.00	110.00	92.00	0.10	38.00	149.00	0.00	0.00	0.04	0.16	0.10	2.00
SNAGOURD	0.2222	1.00	5.70	18.00	0.90	0.00	4.50	0.50	19.00	34.00	1.00	3.00	123.00	0.00	810.00	0.04	0.05	0.70	6.00
SNAPPER	2.546	1.00	22.10	99.00	18.70	2.10	0.00	0.00	34.00	144.00	1.00	1200.00	373.00	25.00	0.00	0.06	0.11	4.70	3.00
SOYEN	0.4500	1.00	89.80	400.00	35.10	17.70	32.00	4.20	226.00	546.00	8.50	6.00	1504.00	0.00	10.00	0.66	0.22	2.20	0.00
SOYENCD	1.2000	1.00	13.30	63.00	7.90	4.10	0.40	0.10	150.00	104.00	2.20	12.00	151.00	0.00	0.00	0.04	0.02	0.40	0.00
SOYB.F	0.7500	1.00	94.00	429.00	29.80	19.50	39.90	3.80	189.00	540.00	7.50	340.00	1660.00	0.00	90.00	0.40	0.16	2.00	0.00
SPRINGEN	0.2151	1.00	9.90	30.00	4.20	0.20	5.00	0.90	15.00	71.00	1.20	7.00	222.00	0.00	20.00	0.11	0.10	0.80	18.00
SPOCOURD	0.2532	1.00	5.70	19.00	1.10	0.20	4.00	1.00	2.00	30.00	0.70	3.00	154.00	0.00	170.00	0.03	0.04	0.30	10.00
SQUID	0.1613	1.00	18.00	75.00	15.30	0.80	0.70	0.00	15.00	194.00	1.00	176.00	266.00	15.00	0.00	0.03	0.08	3.20	0.00
SUCROSE*	0.5000	1.00	94.20	389.00	1.10	0.30	90.80	0.00	0.00	72.00	5.80	14.00	324.00	0.00	0.00	0.500	0.10	0.00	0.00
SWABBAG	0.4167	1.00	10.00	30.00	2.70	0.40	5.60	1.10	60.00	42.00	2.50	44.00	469.00	0.00	2865.00	0.09	0.16	0.10	47.00
SWEETPOP	0.1724	1.00	27.70	108.00	1.00	0.30	25.60	0.80	21.00	50.00	0.90	31.00	210.00	0.00	35.00	0.14	0.05	0.70	21.00
SWEETPOY	0.1724	1.00	29.30	115.00	1.20	0.30	27.10	0.80	36.00	56.00	0.90	36.00	304.00	0.00	1680.00	0.12	0.05	0.60	30.00
TOMATO	0.3723	1.00	6.20	20.00	1.20	0.30	4.20	0.70	7.00	30.00	0.60	4.00	235.00	0.00	505.00	0.06	0.04	0.60	23.00
TAMELON	0.2542	1.00	8.60	30.00	0.80	0.10	7.40	0.10	4.00	10.00	0.70	6.00	86.00	0.00	140.00	0.03	0.02	0.40	6.00
WAXCOURD	0.2111	1.00	3.80	12.00	0.50	0.10	2.90	0.60	17.00	19.00	0.40	5.00	111.00	0.00	5.00	0.03	0.03	0.20	20.00

* sugar content 90.8 g/100g

PART 2

FOOD	VITAMIN B6 MG/100G	PANTOTHENIC ACID MG/100G	VITAMIN B12 MCG/100G	FOLIC ACID MG/100G	MAGNESIUM MG/100G	MANGANESE MG/100G	ZINC MG/100G	COPPER MG/100G	IODINE MG/100G	LINOLEIC ACID MG/100G	VITAMIN E IU/100G	VITAMIN K MCG/100G	BIOTIN MCG/100G	COLINE MG/100G	CHLORIDE MG/100G	VITAMIN D IU/100G
ANCHOVY	0.26	1.00	6.30	0.012	38.00	0.02	0.50	199.00	0.40	44.46	0.42	0.00	4.00	85.00	197.00	720.00
BANANO	0.24	0.62	0.00	0.007	88.00	0.30	1.10	190.00	2.80	0.00	0.55	0.00	0.50	13.50	31.00	0.00
BANANA1	0.51	0.31	0.00	0.009	41.00	0.10	0.20	200.00	8.90	0.00	0.33	0.00	0.00	0.00	79.50	0.00
BANANA2	0.51	0.31	0.00	0.009	41.00	0.10	0.20	200.00	8.90	0.00	0.33	0.00	0.00	0.00	78.50	0.00
BEEF	0.42	0.47	1.40	0.006	28.00	0.02	2.20	160.00	2.30	290.00	0.66	0.00	3.00	90.00	70.00	0.00
BENSNAP	0.15	0.20	0.00	0.027	23.00	0.03	0.12	130.00	1.00	0.00	0.00	116.20	0.70	32.30	22.70	0.00
BOTTLEGD	0.04	0.16	0.00	0.005	14.00	0.15	0.70	0.12	0.53	0.00	0.00	0.00	0.40	0.00	36.50	0.00
BUFFALO	0.18	0.47	1.40	0.010	28.00	0.02	2.20	160.00	2.30	290.00	0.69	0.00	3.00	90.00	70.00	0.00
CABBAGE	0.15	0.21	0.00	0.046	17.00	0.11	0.50	160.00	2.00	0.00	0.22	2320.00	0.10	17.09	39.60	0.00
CABBAGEC	0.16	0.20	0.00	0.019	17.08	0.11	0.18	230.00	21.00	0.00	0.11	4880.00	0.50	17.09	39.60	0.00
CARB	0.19	0.15	1500.00	0.001	30.00	0.02	0.50	100.00	73.40	16.10	0.42	0.00	4.00	85.00	197.00	40.00
CARROT	0.25	0.18	0.00	0.008	15.00	0.20	0.15	80.00	7.00	0.00	0.55	104.00	0.60	7.00	68.50	0.00
CASHEW	1.00	1.30	0.00	0.077	131.00	2.00	3.50	310.00	2.10	0.00	11.40	0.00	2.00	170.00	15.00	0.00
CASSAVAS	0.11	0.52	0.00	0.024	4.00	263.00	0.20	100.00	3.00	50.70	0.00	0.00	0.47	34.34	13.10	0.47
CATFISHF	0.17	0.46	3.40	0.015	38.00	0.02	0.50	199.00	2.00	44.46	0.42	0.00	4.00	85.00	47.30	40.00
CATFISHS	0.37	0.46	2.50	0.015	27.00	0.02	0.50	199.00	42.00	20.30	0.42	0.00	4.00	85.00	141.00	40.00
CAULIF	0.27	1.00	0.00	0.060	22.00	0.20	0.20	140.00	12.00	0.00	0.16	3800.00	1.50	15.00	33.60	0.00
CHICKENM	0.50	0.85	0.40	0.003	29.00	0.02	1.50	180.00	1.40	2980.00	0.28	0.00	10.00	92.00	61.00	0.00
CHICKENY	0.22	1.00	0.40	0.007	29.00	0.02	1.50	180.00	1.40	860.00	0.27	0.00	10.00	92.00	61.00	0.00
COCONUT	0.07	0.33	0.00	0.027	160.00	1.30	5.00	50.00	2.10	1110.00	2.57	0.00	2.00	66.48	114.00	0.00
COLLARD	0.15	0.21	0.00	0.461	19.00	0.19	0.18	70.00	9.40	0.00	0.22	4565.00	0.50	17.09	39.60	0.00
CORN	0.22	0.58	0.00	0.043	15.00	0.20	0.20	90.00	0.50	901.00	1.61	33.20	0.00	13.13	0.00	0.00
CORPEAD	0.42	1.20	0.00	0.439	53.00	1.77	3.42	306.00	2.30	0.00	8.62	0.00	17.00	290.00	60.00	0.00
CORPEAYD	0.14	0.20	0.00	0.027	23.00	0.03	0.12	90.00	1.50	0.00	2.10	292.50	0.70	34.00	22.70	0.00
CUCUMBER	0.04	0.24	0.00	0.006	15.00	0.20	0.20	90.00	0.50	0.00	0.11	0.00	0.40	0.00	24.50	0.00
DCRAB	0.50	0.53	1.00	0.079	38.00	0.02	0.50	199.00	73.40	12.10	0.42	0.00	4.00	85.00	197.00	40.00
DUCK	0.50	0.90	0.40	0.003	20.95	0.02	1.50	392.00	1.40	6864.00	0.28	0.00	10.00	92.00	61.00	0.00
EEL	0.23	0.14	1.00	0.013	38.00	0.03	0.50	100.00	80.00	14.20	0.42	0.00	4.00	85.00	46.00	35.00
EGGDK	1.70	1.70	4.50	0.016	11.00	0.02	0.80	55.00	9.59	987.80	2.20	11.00	25.00	408.00	159.00	70.00
EGGHEM	0.10	1.70	2.00	0.004	11.00	0.02	0.90	55.00	10.83	800.00	2.20	80.00	25.00	480.00	159.00	70.00
EGGPLANT	0.09	0.23	0.00	0.015	18.00	0.20	0.30	90.00	0.50	0.00	0.00	0.00	0.40	0.00	61.00	0.00
GIZZCHIC	0.15	0.75	19.00	0.000	13.00	0.05	0.50	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GIZZDUCK	0.15	0.75	19.00	0.000	13.00	0.05	0.50	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GOASN	0.15	0.20	0.00	0.027	23.00	0.03	0.12	90.00	1.50	0.00	2.10	0.00	0.70	39.90	22.70	0.00
CORRAMEY	0.50	0.53	1.00	0.001	38.00	0.02	0.50	100.00	73.40	16.10	0.42	0.00	4.00	85.00	197.00	40.00
GRAPE	0.09	0.04	0.00	0.005	6.60	0.20	0.10	70.00	0.50	0.00	0.00	0.00	0.00	0.00	0.90	0.00
GUAVA	0.14	0.17	0.00	0.006	8.00	0.20	2.40	20.00	1.00	0.00	0.00	0.00	0.00	0.00	5.90	0.00
HARDTAIL	0.60	0.50	1.00	0.079	38.00	0.02	0.50	100.00	8.00	32.40	0.42	0.00	4.00	85.00	197.00	40.00
HEARTBF	0.36	2.50	133.00	0.000	19.00	0.05	1.53	280.00	7.30	707.00	1.18	0.00	8.00	170.00	113.00	0.00
HEARTHOG	0.36	2.50	33.00	0.011	13.00	0.10	1.60	285.00	15.00	719.00	1.18	0.00	8.00	230.00	113.00	0.00
IVYCOURD	0.19	0.17	0.00	0.083	19.10	0.11	0.22	230.00	8.40	0.00	0.11	0.00	0.50	17.09	39.60	0.00
LEMON	0.04	0.10	0.00	0.005	11.60	0.20	0.41	260.00	2.60	240.00	0.00	0.00	0.16	5.00	2.60	0.00
LIVERBF	0.82	7.70	52.70	0.250	20.80	0.30	3.06	1500.00	6.30	1249.00	1.54	36.00	100.00	490.00	100.00	45.00
LIVERCH	0.72	6.00	27.90	1.128	23.30	0.20	3.06	300.00	1.80	1429.00	1.10	96.00	80.00	340.00	100.00	45.00
LIVERDK	0.72	4.10	32.00	0.380	23.30	0.20	3.06	300.00	1.80	1429.00	1.10	96.00	80.00	340.00	100.00	45.00
LIVERHOG	0.62	6.40	65.20	0.259	23.30	0.30	3.06	510.00	12.00	1429.00	1.10	96.00	80.00	540.00	102.00	45.00
MACK	0.28	0.24	2.40	0.036	35.00	0.02	0.50	200.00	40.00	140.00	0.42	0.00	4.00	85.00	62.70	700.00
MACKST	0.27	0.16	0.90	0.005	38.00	0.02	0.50	199.00	53.00	42.60	0.42	0.00	4.00	85.00	73.10	700.00

PART 2

FOOD	VITAMIN B6 MG/100G	PANTOTHENIC ACID MG/100G	VITAMIN B12 MCG/100G	FOLIC ACID MG/100G	MAGNESIUM MG/100G	MANGANESE MG/100G	ZINC MG/100G	COPPER MG/100G	IODINE MG/100G	LINOLEIC ACID MG/100G	VITAMIN E IU/100G	VITAMIN K MCG/100G	BIOTIN MCG/100G	CHOLINE MG/100G	CHLORIDE MG/100G	VITAMIN D IU/100G
MILKCOWH	0.04	0.30	0.40	0.000	16.00	0.00	0.40	20.00	9.90	105.00	0.06	8.30	2.00	15.00	98.00	1.00
MILKDR	0.27	2.40	2.30	1.795	124.87	0.02	3.12	156.00	70.40	798.00	0.33	0.00	13.00	117.00	784.00	12.00
MILKFISH	0.42	0.53	3.40	0.015	38.00	0.02	0.50	160.00	71.24	111.60	0.42	0.00	4.00	85.00	197.00	720.00
MULLET	0.38	0.72	8.60	0.013	33.00	0.02	0.50	160.00	67.00	79.10	0.42	0.00	4.00	85.00	39.58	720.00
MUNGENST	0.25	2.50	0.00	0.121	270.00	1.77	3.42	760.00	2.50	900.00	0.00	207.00	2.60	280.00	1.80	0.00
MUNGENW	0.47	2.50	0.00	0.121	270.00	1.77	3.42	760.00	2.50	900.00	1.85	20.750	207.50	280.00	1.80	0.00
MUSHROOM	0.53	0.21	0.00	0.03	14.00	0.10	0.30	65.00	18.00	0.00	0.08	0.00	17.00	0.00	84.50	0.00
MUSTARDG	0.16	0.21	0.00	0.167	27.00	0.11	0.18	230.00	8.40	0.00	0.11	3320.00	0.50	17.09	89.00	0.00
ORANGE	0.04	0.25	0.00	0.005	10.00	0.20	0.41	0.12	1.50	60.00	0.22	0.00	1.00	5.00	3.20	0.00
ORANGEM	0.03	0.22	0.00	0.005	10.00	0.03	0.60	56.00	1.50	60.00	0.22	0.00	1.00	5.00	2.40	0.00
PAPAYA	0.03	0.22	0.00	0.005	8.00	0.01	0.40	14.00	1.00	0.00	0.00	0.00	0.00	0.00	5.90	0.00
PEANUT	0.30	2.80	0.00	0.124	185.00	1.60	1.90	420.00	6.80	6300.00	4.65	18.00	17.00	170.00	6.80	0.00
PEANUTDR	0.50	4.49	0.00	0.141	198.80	2.50	2.00	446.70	7.20	14711.00	11.40	18.00	18.00	180.00	7.20	0.00
PEAS	0.15	0.82	0.00	0.025	33.00	0.04	0.77	240.00	4.20	0.00	0.11	610.00	0.50	70.76	38.00	0.00
PERCH	0.20	0.15	1.50	0.001	30.00	0.02	0.50	100.00	73.40	16.10	0.42	0.00	4.00	85.00	197.00	40.00
PIAPPLE	0.09	0.15	0.00	0.006	22.00	0.11	0.26	380.00	4.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PIGPEA	0.25	1.50	0.00	0.193	108.00	2.00	4.20	710.00	2.30	0.00	2.31	116.20	17.00	64.00	60.00	0.00
POKIL	0.18	0.86	1.40	0.010	26.10	0.03	2.50	49.20	4.50	3750.00	0.69	0.00	4.00	105.00	49.00	0.00
PRAWNRIV	0.17	0.21	1.00	0.001	42.00	0.02	0.50	99.00	2.00	0.00	0.42	0.00	4.00	85.00	500.00	0.00
PRAWNS	0.17	0.21	1.00	0.001	42.00	0.02	0.50	199.00	112.00	0.00	0.42	0.00	4.00	85.00	500.00	0.00
PUMPKIN	0.11	0.40	0.00	0.009	10.00	16.00	0.10	210.00	1.10	0.00	0.00	0.00	0.40	0.00	36.50	0.00
RADISH	0.06	0.18	0.00	0.007	15.00	0.05	20.00	150.00	8.00	50.70	0.05	0.00	0.47	0.00	20.00	0.00
RICEBL	0.17	0.55	0.00	0.010	17.00	1.10	2.20	280.00	2.00	466.00	0.38	0.00	3.00	90.00	27.00	0.00
RICEBRO	0.55	1.10	0.00	0.019	90.00	1.33	0.18	0.34	1.80	355.00	0.95	0.00	9.00	100.00	130.00	0.00
RICEFLO	0.16	0.22	0.00	0.003	14.00	0.90	1.50	230.00	2.00	1770.00	0.00	0.00	3.00	90.00	27.00	0.00
RICESGLUF	0.17	0.55	0.00	0.010	17.00	1.10	2.20	280.00	2.20	88.00	0.38	0.00	3.00	90.00	27.00	0.00
RICESLUM	0.17	0.55	0.00	0.010	17.00	1.10	2.20	280.00	2.00	350.00	0.38	0.00	3.00	90.00	27.00	0.00
RICEMFO	0.11	0.22	0.00	0.003	14.00	0.90	1.50	230.00	2.00	180.00	0.38	0.00	3.00	90.00	27.00	0.00
RICEPAD	0.42	0.90	0.00	0.019	52.00	1.33	1.90	340.00	2.00	220.00	0.38	0.00	10.00	90.00	27.00	0.00
SEYDEAD	0.19	0.15	1.50	0.001	30.00	0.02	0.50	100.00	73.40	16.10	0.42	0.00	4.00	85.00	197.00	40.00
SESAME	1.25	0.38	0.00	0.00	10.65	1.77	3.42	360.00	2.10	16700.00	10.45	0.00	17.00	138.40	1.80	0.00
SKIMDR	0.38	3.60	3.20	0.002	364.90	0.02	3.12	156.24	12.00	30.00	0.03	0.00	16.00	10.00	1130.00	0.00
SKIMFLU	0.04	0.37	0.40	0.000	16.00	0.00	0.40	20.00	4.50	3.00	0.00	0.00	2.00	1.00	102.00	0.00
SNAGOURD	0.04	0.16	0.00	0.006	14.00	0.15	0.70	122.00	0.45	0.00	0.00	0.00	0.40	0.00	36.50	0.00
SNAPPER	0.20	0.20	0.10	0.050	38.00	0.02	0.50	100.00	30.30	42.60	0.42	0.00	4.00	197.00	197.00	40.00
SOYBN	0.82	1.60	0.00	0.210	236.00	1.20	3.80	300.00	2.50	900.00	27.25	207.50	17.96	280.00	1.80	0.00
SOYBND	0.10	0.21	0.00	0.027	27.00	0.15	0.60	39.00	3.30	214.00	6.31	48.05	2.70	41.47	0.50	0.00
SOYBNF	0.57	1.60	0.00	0.210	236.00	1.20	3.80	300.00	2.50	900.00	27.00	207.50	17.90	233.30	0.45	0.00
SPMUNGEN	0.24	0.62	0.00	0.007	29.00	0.19	0.37	83.60	0.27	0.00	0.55	0.00	0.50	17.09	31.00	0.00
SPOCCURD	0.04	0.16	0.00	0.006	14.00	0.15	0.70	122.00	0.00	122.00	0.00	0.00	0.40	0.00	36.50	0.00
SQUID	0.07	0.06	1.30	0.012	38.00	0.02	0.50	20.90	22.50	16.20	0.42	0.00	4.00	85.00	197.00	0.00
SWEABBAG	0.19	0.17	0.00	0.122	17.00	0.11	0.18	70.00	2.10	0.00	0.11	4000.00	0.50	17.09	39.60	0.00
SWEETOP	0.27	0.80	0.00	0.052	201.00	387.00	2.00	260.00	0.45	50.70	0.05	277.00	0.47	11.66	20.00	0.00
SWEETPOY	0.27	0.80	0.00	0.052	201.00	387.00	2.00	260.00	0.45	50.70	0.05	277.00	0.47	11.66	20.00	0.00
TOMATO	0.08	0.31	0.00	0.006	15.00	0.20	0.20	190.00	1.70	0.00	0.24	310.00	1.20	0.00	51.00	0.00
WAMELON	0.05	0.30	0.00	0.000	15.00	0.03	0.18	70.00	1.00	0.00	0.00	0.00	3.60	0.00	45.00	0.00
WAXCOURD	0.04	0.16	0.00	0.005	14.00	0.15	0.70	122.00	0.70	0.00	0.00	0.00	0.40	0.00	36.50	0.00

FOOD	ISOLEUCINE MG/G PROT.	LEUCINE MG/G PROT.	LYSINE MG/G PROT.	METHIONINE MG/G PROT.	CYSTINE MG/G PROT.	PHENYLALANINE MG/G PROT.	TYROSINE MG/G PROT.	THREONINE MG/G PROT.	TRYPTOPHAN MG/G PROT.	VALINE MG/G PROT.	HISTIDINE MG/G PROT.
ANCHOVY	338	563	598	229	62	281	251	321	83	366	168
BAMBOO	210	340	320	71	52	220	131	210	64	260	100
BANANA	110	290	230	36	42	140	72	160	72	170	420
BANANA	110	290	230	36	42	140	72	160	72	170	420
BEEF	300	550	570	140	75	280	220	280	69	340	220
BENGAL	234	432	344	81	53	266	209	241	63	306	147
BONFLEGG	256	406	300	94	69	312	231	219	67	400	138
BUFFALO	252	452	442	142	67	230	187	241	59	262	220
CABBAGE	190	250	260	89	130	210	38	230	38	230	110
CABBAGE	242	296	148	36	0	58	0	54	27	76	110
CARE	579	958	1121	362	108	506	434	542	125	633	362
CARROT	120	200	190	38	30	130	82	150	46	190	81
CASHEW	250	400	306	56	69	256	125	250	100	369	131
CASSAVAS	247	338	544	83	90	202	60	225	72	262	136
CATFISH	289	499	552	231	77	224	207	274	168	404	163
CATFISH	289	499	552	231	77	224	207	274	61	404	163
CAULIF	302	436	356	99	500	225	88	264	86	347	120
CHICKEN	334	460	497	157	82	250	209	248	64	318	164
CHICKEN	498	456	492	155	81	248	207	246	63	314	164
COCONUT	280	450	220	110	110	260	167	190	130	350	128
COLLARD	375	413	387	56	65	356	81	287	75	325	110
CORN	240	780	170	110	150	310	140	240	46	340	150
COMPEAD	277	468	428	65	74	358	183	235	76	294	165
COMPEAYD	416	561	374	187	25	442	192	294	63	302	147
CUCUMBER	240	390	310	67	26	250	210	240	58	340	120
DORAB	331	505	575	181	87	281	225	275	61	337	168
DUCK	418	575	589	196	102	312	261	310	80	398	164
EEL	280	510	380	170	59	230	260	300	58	360	130
EGGDK	403	568	506	450	79	343	269	271	106	464	134
EGGHEN	378	547	417	192	150	348	240	302	106	437	160
EGGPLANT	270	380	330	71	33	260	240	230	51	320	130
GIZZCHIC	344	577	510	141	67	349	201	322	67	306	106
GIZZDUCK	344	577	510	141	67	349	201	322	67	306	106
GOVERN	234	432	344	81	53	266	209	241	63	306	147
GORAMY	331	505	575	181	87	281	225	275	61	337	168
GRAPE	50	130	140	210	100	130	110	170	25	170	230
GUAVA	63	146	292	10	42	104	42	125	83	156	64
HARDTAIL	249	379	501	151	62	199	194	224	57	344	168
HEARTBF	464	581	622	220	79	273	217	272	63	326	179
HEARTHOG	488	498	615	244	90	291	228	293	63	350	182
IVYCOURD	180	380	320	34	27	240	200	220	72	240	120
LEMON	188	328	219	94	156	188	266	188	63	172	64
LIVERBF	368	598	501	211	80	369	227	248	92	440	185
LIVERHOG	448	583	492	199	99	288	212	250	77	356	166
LIVERDK	456	575	438	163	75	269	188	238	63	313	119
LIVERCH	456	575	438	163	75	269	188	238	63	313	119
MACK	313	444	719	194	68	188	224	356	53	338	220
MACKST	277	425	539	152	68	212	224	247	99	413	220

FOOD	ISOLEUCINE MG/G PROT.	LEUCINE MG/G PROT.	LYSINE MG/G PROT.	METHIONINE MG/G PROT.	CYSTINE MG/G PROT.	PHENYLALANINE MG/G PROT.	TYROSINE MG/G PROT.	THREONINE MG/G PROT.	TRYPTOPHAN MG/G PROT.	VALINE MG/G PROT.	HISTIDINE MG/G PROT.
MILK COWH	320	590	480	150	50	280	350	270	92	410	160
MILKDR	398	581	550	275	20	313	299	263	104	445	191
MILKFISH	375	626	639	220	86	328	274	364	75	436	168
MULLET	310	550	670	200	85	260	240	280	81	320	200
MUNGENST	257	439	586	125	31	344	152	202	118	269	181
MUNGENW	257	439	586	125	31	344	152	202	118	269	181
MUSHROOM	140	230	280	29	33	130	120	170	64	160	84
MUSTARDG	242	296	148	36	70	58	115	54	27	76	110
ORANGE	180	170	330	94	75	230	130	94	44	240	94
ORANGEM	180	170	330	94	75	230	130	94	44	240	94
PAPAYA	63	146	292	10	42	104	42	125	83	156	64
PEANUT	201	350	210	58	58	261	156	188	69	314	137
PEANUTDR	201	350	210	58	58	261	156	188	69	314	137
PEAS	360	510	450	25	71	200	220	220	61	610	39
PERCH	881	1459	1706	550	165	771	660	826	190	963	550
PIAPPLE	94	219	225	47	63	156	63	188	78	209	64
PIGPEA	419	588	650	169	44	419	225	263	35	400	363
FORKL	507	484	584	220	74	248	234	339	61	400	305
PRAWNRIV	245	485	500	159	71	253	198	238	63	387	110
PRAWNS	245	485	500	159	71	253	198	238	63	387	110
PUMPKIN	150	213	436	145	330	184	81	242	67	125	97
RADISH	40	64	42	11	12	42	48	50	13	61	19
RICEBL	188	450	175	56	81	194	94	150	90	269	113
RICEBRO	285	536	248	141	104	344	295	243	78	403	150
RICEFLO	277	521	263	146	76	338	172	236	76	350	155
RICEGLUF	188	450	175	56	81	194	94	150	90	269	113
RICEGLUM	188	450	175	56	81	194	94	150	90	269	113
RICEMIPO	277	521	263	146	67	338	172	236	72	350	155
RICEPABO	306	563	219	225	100	350	300	288	73	463	188
SERHEAD	850	1408	1647	531	159	744	637	797	183	930	531
SESAME	293	487	196	204	62	338	219	295	87	354	168
SKIMDR	418	583	559	228	24	312	286	283	81	424	161
SKIMFLU	320	590	480	150	50	280	350	270	92	410	160
SNAGOURD	256	406	300	94	69	312	231	219	67	400	138
SNAPPER	319	489	603	193	80	256	249	287	74	441	221
SOYBN	290	494	391	84	81	341	165	247	76	291	168
SOYBNF	290	494	391	84	81	341	165	247	76	291	168
SOYBNCD	261	448	333	78	78	321	169	170	96	264	191
SFMUNGEN	256	369	500	106	25	288	281	300	144	375	144
SFOGOURD	256	406	300	94	69	312	231	219	67	400	138
SQUID	314	425	491	152	87	229	222	205	52	399	103
SWCABBAG	190	250	260	89	65	170	130	210	38	230	110
SWEETPOP	250	400	260	67	76	260	300	310	79	380	120
SWEETFOY	250	400	260	67	76	260	300	310	79	380	120
TOMATO	81	160	190	31	8	150	190	120	31	87	86
WAMELON	200	180	640	64	20	160	120	280	67	160	64
WAXGOURD	256	406	300	94	69	312	231	219	67	400	138

APPENDIX 12

ABBREVIATED NAMES USED FOR
ROWS AND COLUMNS

PROBLEM: 'LE INFANT' SUMMARY

COLUMN SUMMARY

45	ANCHOVY	42	BAMBOO	40	BANANA1	40	HANANA
42	BEEF	43	BNSNAP	40	BOTTLEGD	42	BUFFALO
43	CABEAGE	43	CABBAGEC	46	CARB	44	CARROT
45	CASHEW	32	CASSAVAS	46	CATFISHS	43	CAULIF
42	CHICKENY	42	CHICKENM	45	CUCONUT	44	COLLARD
43	COOK	45	COWPEAD	44	COWPEAYD	40	CUCUMBER
45	DORAB	41	DUCK	46	EEL	45	EGGDK
45	EGGHEH	41	EGGPLANT	34	GIZZCHIC	33	GIZZDUCK
42	GUABN	45	GOURAMY	40	GRAPE	39	GUAVA
46	HARDTAIL	44	HEARTBF	43	HEARTHOG	43	IVYGOURD
41	LEMON	46	LIVERBF	46	LIVERCH	45	LIVERDK
46	LIVERHOG	45	MACK	46	MACKST	45	MILKCOWH
44	MILKDR	45	MILKFISH	45	MULLET	45	MUNGBNST
46	MUNGBNW	41	MUSHROOM	44	MUSTARDG	43	ORANGE
43	ORANGEM	39	PAPAYA	46	PEANUT	43	PEANUTDR
46	PERCH	40	PIAPPLE	46	PIGPEA	40	PORKL
41	PUMPKIN	46	RADISH	41	RICEBL	41	RICEBRO
39	RICEFLO	40	RICEGLUF	40	RICEGLUM	40	RICEMIPO
40	RICEPABO	46	SERHEAD	45	SESAME	41	SKIMFLU
42	SKIMDR	38	SNAGGURD	47	SOYBN	46	SOYBNF
47	SOYBNCD	42	SPMUNGBN	40	SPOGGOURD	45	SGUID
44	SWCABBAG	43	SWEETPOP	43	TOMATC	41	WAMELON
39	WAXGOURD	15	SUCROSE	3	WEIGHT	1	DWT
36	CAL	20	PROT	2	FAT	1	CHO
3	CA	3	P	1	FE	2	NA
2	K	1	RETINOL	1	B-CARO	1	THIA
1	RIBU	1	NIA	1	VITC	1	VITB6
1	PANTCA	1	VITB12	1	FOLIC	1	MG
1	MN	1	ZN	1	CU	1	I
1	VITE	1	BIOTIN	1	CHOLINE	2	CL
2	VITD	2	ISO	2	LEU	2	LYS
2	METH	2	CYS	2	PHE	2	THREO
2	TRYP	2	TYR	2	VAL	2	HIST
2	LINGA	1	VITK	35	CATFISHF	44	PEAS
30	PRAWNRIV	34	PRAWNS	34	SNAPPER	44	SWEETPOY
2	VITA						

ROW SUMMARY

96	COST	96	WEIGHT	96	DWT	96	CAL
96	PROT	95	FAT	90	CHO	72	FIB
95	CA	95	P	95	FE	93	NA
95	K	45	RETINOL	78	B-CARO	95	THIA
95	RIBU	94	NIA	77	VITC	95	VITB6
95	PANTQA	51	VITB12	93	FOLIC	95	MG
95	MN	95	ZN	95	CU	93	I
78	VITE	87	BIOTIN	77	CHOLINE	92	CL
37	VITD	91	ISO	91	LEU	91	LYS
91	METH	91	CYS	91	PHE	91	THREO
91	TRYP	91	TYR	91	VAL	91	HIST
82	LINGA	33	VITK	1	SUGAR	2	CALPROTL
2	CALPROTH	2	CALFATL	2	CALFATH	2	CALLINOL
2	CHOSUL	2	CALDWT	2	VITA	2	CALVITAL
2	CALVITDL	2	VIELINOL	2	CALVITKL	2	CALVITCL
2	CALTHIAL	2	CALRIBCL	2	CALNIAL	2	CALB6L
2	CALB12L	2	CALPATOL	2	CALFULL	2	CALBIOTL
2	CALCHOL	2	CALNAL	2	CALNAH	2	CALKL
2	CALKH	2	CALCLL	2	CALCLH	2	CALCAL
2	CALPL	2	CALMGL	2	CALFEL	2	CALIL
2	CALCUL	2	CALZNL	2	CALMNL	2	CAPL
2	CAPH	2	DISC	2	DLEU	2	DLYS
3	DSULAA	3	DAROMAA	2	DTHREO	2	DTRYP
2	DVAL	2	DHIST	2	CISO	2	CLEU
2	CLYS	3	CSULAA	3	CAROMAA	2	CTHREO
2	CTRYP	2	CVAL	2	CHIST	2	CALVITAH
2	CALVITDH						

APPENDIX 13

THE TEMPERATURES AND TIMES COLLECTED
FOR DIFFERENT METHODS OF DRYING

Product type and detail	Time and temperature	Reference
<u>I. Vacuum drying</u>		
Tomato juice	71°C for 1 hour	Copley et al. 1956 (52)
Tomato juice	Shelf temperature at 105°C, product at 57- 77°C for 1 hour	Kaufman et al. 1955 (132)
Tomato juice at 46.1° Brix, 1/8" depth on tray - pulp removed	Shelf temperature at 93°C, product 49-68°C for 2 hours, pressure at 2 mm Hg.	Noyes 1969 (187)
Tomato pulp	Shelf temperature 93°C for 1 hour	Noyes 1969 (187)
Orange juice, with pulp concentrated to 60° Brix	Shelf temperature at 93°C, product temperature at 52°C for 45 minutes	Torrey 1974 (238)
<u>II. Foam mat drying^a</u>		
General product, thickness 0.1 - 0.5mm	66°C for few minutes	Van Arsdel 1973 (243)
General product	49-104°C at the beginning and 49-71°C towards the end	Noyes 1969 (187)
Tomato juice at 30% solid, 0.7% mono- glyceride as stabilizer, density 0.5 g/ml	77°C for 8 minutes and 49°C for 4 minutes	Van Arsdel 1973 (243)
Tomato juice at 30% solid, 0.7% mono- glyceride as stabilizer density 0.5 g/ml, thickness 1/32"	77°C for 1-2 minutes	Van Arsdel 1973 (243)

Tomato juice at 30% solid, sucrose dipalmitate as stabilizer, density 0.4 g/ml, thickness 1/4"	71°C for 90 minutes	Noyes 1969 (187)
thickness 1/8"	82°C for 45 minutes	
thickness 3/16"	77°C for 60 minutes	
thickness 1/4"	82°C for 60 minutes	
Tomato paste, 30% solid, glyceryl monostearate as stabilizer, density 0.4 g/ml, final moisture content 2%	At 71°C for 8 minutes and relative humidity at 5%	Torrey 1974 (238)
Citrus juice	In 3 stages of drying temperatures at 89, 77 and 54°C for total time of 12 minutes	Graham et al. 1965 (100)
Orange juice, 55% solid, soya bean protein as stabilizer density 0.35 g/ml, final moisture content 3%	Temperature range of 82-54°C for 12 minutes	Torrey 1974 (238)
Banana paste, methocel as stabilizer, density 0.27 g/ml, thickness 1/4"	At 77°C for 2½ hours	Torrey 1974 (238)
Potato paste, glyceryl monostearate as stabilizer density 0.45 g/ml, thickness 1/8"	At 71°C for 60 minutes	Torrey 1974 (238)
Potato paste, glyceryl monostearate as stabilizer, density 0.45 g/ml, thickness 1/8"	At 71°C for 60 minutes	Noyes 1969 (187)

^aAll temperatures are air temperatures

III. Drum drying^a

Orange juice, 60° Brix, sodium carboxymethyl cellulose as stabilizer, thickness 1/10"	At 112°C for 10.2 seconds	Torrey 1974 (238)
Banana paste	At 138-177°C, preferable temperature at 149°C, for 4 seconds, steam at 90 psi	Torrey 1974 (238)
Potato paste, 20% solids final moisture content 4.5-5.0%	At 159-162°C, for 20 seconds, steam at 75-80 psi	Van Arsdel 1973 (243)
Sweet potato, 18-25% solids, final moisture content 2-4%	At 149°C for 17 seconds steam at 75 psi	Noyes 1969 (187)
Potato with fish, final moisture content 3%	At 134°C for 8, 12, 16, 20 seconds depending on drum clearance	Noyes 1969 (187)
Pumpkin flake, 16-18% solids, moisture content 2-4%	At 157°C, steam at 70 psi	Noyes 1969 (187)
Sweet potato or pumpkin 20% solids, final moisture content 4.5-5.0%	At 159°C-162°C for 20 seconds, steam at 75-80 psi	Van Arsdel 1973 (243)
Cooked egg, with 20% water	At 142°C, steam at 40 psi	Noyes 1969 (187)
Fruit cereal baby food, mixture of cereal grain flour, fruit, sugar, milk, vegetable oil; preferable solids at 25%, final moisture content 2%	Range of steam at 30-90 psi, preferable at 80 psi	Torrey 1974 (238)

High protein baby food	At 165 ^o C for 30 seconds	Chesswas (42)
High starch baby food	At 153 ^o C for 20 seconds	Chesswas (42)

^aAll temperatures are drum temperatures

APPENDIX 14

PRODUCT TEMPERATURES DURING VACUUM

DRYING OF TOMATO JUICE

 Given by Kaufman et al. 1955

Time, minutes	Temperature, °C
5	-15
10	-22
20	-22
30	-8.3
40	4.4
50	37.0
55	57.0
60	80.0
65	77.0
70	52.0
75	27.0

Given by Hoyer 1969

Time, minutes	Temperature, °C
10	16
45	49
65	68
90	62
120	68

CONSUMER PANEL FORM

This is an infant food product designed to supply the daily requirement for Thai infant, age from 6 months to one year. The product as a dry powder is prepared by dissolving in hot water.

Please look and taste the prepared product carefully and give your opinion on the acceptability of the colour, taste and consistency by placing a tick (✓) in the space beside the opinion which is closest to your own.

1. Opinion of colour

Comments on colour

- much too dark
 slightly dark
 just right
 slightly pale
 too pale

2. Opinion of consistency

Comments on consistency

- much too thick
 slightly thick
 just right
 slightly thin
 too thin

3. Opinion of taste

Comments on taste

- | | |
|---|---|
| <input type="checkbox"/> too sweet | <input type="checkbox"/> too salty |
| <input type="checkbox"/> slightly sweet | <input type="checkbox"/> slightly salty |
| <input type="checkbox"/> just right | |
| <input type="checkbox"/> slightly bland | |
| <input type="checkbox"/> too bland | |

4. Take everything into consideration, what is your opinion on

- highly acceptable
 acceptable
 just acceptable
 not quite acceptable
 unacceptable

the overall acceptability of the product.

5. Any other comments

APPENDIX 16

SCORING FOR THE MOTHERS' OPINIONS

The mothers tasted the product individually and recorded their opinions and comments on the forms. They also discussed the product with the panel organizer. To obtain an "average" opinion on the product, the opinions on the consumer panel form were given scores as shown below and the mean of the score was determined. This was only meant as an indication and in no way was statistical accuracy assumed.

The description on the form in Appendix 15 were scored from 5 to 1, 5 being the top description and the bottom description at 1. For example, the scoring of colour opinion was

Colour opinion	Score
much too dark	5
slightly too dark	4
just right	3
slightly pale	2
too pale	1

For overall acceptability, "highly acceptable" was scored at 5 and "unacceptable" at 1.

The average scores were calculated and the "average opinion" were taken from these scores.