DEVELOPMENT, ACCEPTABILITY, AND NUTRITIONAL EVALUATION OF NEW HIGH-PROTEIN RICE-BASED FOODS FOR THAI CHILDREN

by

ALVIN SIEGEL

B. S., University of Rhode Island, 1968
M. S., Michigan State University, 1970

A DISSERTATION

submitted in partial fulfillment of the

requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1974

Approved by:

Major Professor

TABLE OF CONTENTS

LIST OF TABLES vi

LIST OF FIGURES viii

INTRODUCTION 1

LITERATURE REVIEW 4

A. THE FOOD AND NUTRITION PROBLEM IN THAILAND 4

1. Population 5
2. Food Production 5
3. Urbanization 5
4. Poverty 6
5. Education 6
6. Dietary Pattern 6

B. PROTEIN MALNUTRITION IN EARLY CHILDHOOD 7

C. PROTEIN MALNUTRITION IN THAI CHILDREN 10

D. IMPROVING THE NUTRITIONAL STATUS OF THAI CHILDREN 15

1. Protein Food Development Project 15
2. Child Nutrition Centers 16

E. DEVELOPMENT OF NEW HIGH-PROTEIN FOODS FOR THAI CHILDREN 16

1. Rice 28
2. Soybeans and Soybean Products 29
3. Sesame Seeds 29
4. Fish Protein Concentrate 29

F. ACCEPTANCE OF NEW FOODS BY CHILDREN 30

G. NUTRITIONAL EVALUATION OF HIGH-PROTEIN FOODS 30

MATERIALS AND METHODS 34

I. HIGH-PROTEIN DEHYDRATED SOY-RICE NOODLES 34

A. DEVELOPMENT 34

1. Initial Studies 34
a. Noodle discs 34
b. Formulations 35
c. Preliminary rice noodle preparation 36

2. Factory Preparation of Rice Noodles 36
a. Traditional method--regular rice noodles 36
b. Dehydrated soy-rice noodles 37

3. Cooking Studies on Dehydrated Soy-Rice Noodles 44
a. Cooking time 44
b. Rehydration tests 46

4. Storage Studies on Dehydrated Soy-Rice Noodles 47
a. Storage temperature and relative humidity 47
b. Moisture content of dehydrated noodles 47
c. Rancidity development--refractive index 47
d. Water absorption and disintegration 48
e. Taste panel noodle evaluation 48

5. Product Costs 49

B. ACCEPTABILITY STUDIES 49

1. Child Nutrition Centers 49
2. Kasetsart University Nursery School 51

C. NUTRITIONAL EVALUATION 53

1. Chemical Analyses 53
a. Proximate analyses 53
b. Vitamin and mineral analyses 53
c. Amino acid analyses 53
d. Nutrient cooking losses 55
e. Chemical score 56

2. Biological Studies 56
a. Protein efficiency ratio (PER) and net protein utilization (NPU) 56
b. Protein costs based on PER 57

II. HIGH-PROTEIN RICE-BASED SNACKS 57

A. DEVELOPMENT 57

1. Initial Studies 57
a. Formulations 57
b. Preliminary snack preparations 58

2. New High-Protein Rice-based Snacks 58
a. Laboratory prototypes 58
b. Factory preparation--soy chips 59
c. Extruded snack--soy curls 62
d. Moisture and fat contents 62

3. Regular Snacks 63
a. Fried chips and soy cookies 63
b. Moisture and fat contents in chips 64

4. Product Costs 64

B. ACCEPTABILITY STUDIES 64

1. Elementary School Children 64

C. NUTRITIONAL EVALUATION 66

1. Proximate Analyses 66
2. Vitamin and Mineral Analyses 67

RESULTS AND DISCUSSION 69

I. HIGH-PROTEIN DEHYDRATED SOY-RICE NOODLES 69

A. DEVELOPMENT 69

1. Product Design 69
2. Cooking Studies 73
a. Cooking time 73
b. Rehydration tests 74

3. Storage Studies 74
a. Storage temperature and relative humidity 74
b. Moisture content of dehydrated noodles 75
c. Rancidity development--refractive index 80
d. Water absorption and disintegration 80
e. Taste panel noodle evaluation 87

4. Product Costs 98

B. ACCEPTABILITY 101

1. Child Nutrition Centers and Kasetsart University Nursery School 101

C. NUTRITIONAL EVALUATION 115

1. Chemical Analyses 115
a. Proximate analyses 115
b. Vitamin and mineral analyses 118
c. Amino acid analyses 118
d. Nutrient cooking losses 121
e. Chemical score 121

2. Biological Studies 124
a. Protein efficiency ratio (PER) and net protein utilization (NPU) 124
b. Protein costs based on PER 130

II. HIGH-PROTEIN RICE-BASED SNACKS 133

A. DEVELOPMENT 133

1. Product Design 133
2. Moisture and Nutrient Changes 135
a. Storage 135
b. Frying 135

3. Product Costs 140

B. ACCEPTABILITY 143

1. Elementary School Children 143

C. NUTRITIONAL EVALUATION 157

1. Proximate Analyses 157
2. Vitamin and Mineral Analyses 157

SUMMARY AND CONCLUSIONS 161

LITERATURE CITED 169

ACKNOWLEDGMENTS 175

VITA 177

LIST OF TABLES

TABLE

I. SURVEY SUMMARY OF THAI DAILY DIETARY INTAKE 8

II. RECOMMENDED DAILY ALLOWANCES (RDA) AND INTAKE FOR THAI CHILDREN COMPARED TO THE RDA FOR AMERICAN CHILDREN 14

III. PROXIMATE ANALYSES FOR SOYBEAN AND MUNGBEAN PROTEIN ISOLATES, SOY FLOUR, KASET PROTEIN, AND SOY COOKIES 27

IV. FORMULATIONS OF SOY-RICE SOLUTIONS AND COMPOSITION OF SOY-RICE NOODLES 45

V. ANALYTICAL METHODS FOR VITAMIN AND MINERAL ASSAYS OF NOODLE SAMPLES 54

VI. FORMULATIONS OF LABORATORY SNACK PROTOTYPES 59

VII. FORMULATION OF SOY CHIPS 61

VIII. EXTRUDED SNACK (SOY CURLS) FORMULATION 61

IX. PREFERENCE SCORING OF SNACKS BY CHILDREN 65

X. SCORING SCHEDULE FOR SNACKS 65

XI. VITAMIN ASSAYS AND METHODS OF ANALYSIS FOR SOY CHIPS AND SOY CURLS 68

XII. REHYDRATION RATIO AND WATER CONTENT OF REHYDRATED RICE NOODLES (CONTROL) AND SOY-RICE NOODLES 75

XIII. ATMOSPHERIC CONDITIONS DURING STORAGE OF DEHYDRATED NOODLES FOR FIVE MONTHS 77

XIV. REFRACTIVE INDEX OF DEHYDRATED RICE NOODLES STORED FOR FIVE MONTHS 81

XV. TASTE PANEL EVALUATION OF DEHYDRATED RICE NOODLES STORED FOR FIVE MONTHS 91

XVI. ANALYSIS OF VARIANCE (AOV) OF TASTE PANEL SCORES FOR STORED DEHYDRATED RICE NOODLES--DIFFERENCES AMONG SAMPLES 92

XVII. ANALYSIS OF VARIANCE (AOV) OF TASTE PANEL SCORES FOR STORED DEHYDRATED RICE NOODLES--EFFECT OF STORAGE TIME 95

XVIII. COST OF PROTEIN IN DEHYDRATED RICE NOODLES 99

XIX. STATISTICAL EVALUATION OF CONSUMPTION OF NON-NOODLE AND NOODLE DISHES BY CHILDREN 113

XX. STATISTICAL COMPARISON OF CONSUMPTION OF NON-NOODLE AND NOODLE DISHES BY CHILDREN AT THREE DAY-CARE CENTERS 116

XXI. PROXIMATE ANALYSES AND CALORIC VALUES OF RICE NOODLES 117

XXII. VITAMIN AND MINERAL ANALYSES OF RICE NOODLES 119

XXIII. AMINO ACID COMPOSITION OF RICE NOODLES 120

XXIV. NUTRIENT LOSSES DURING COOKING OF DEHYDRATED RICE NOODLES . . . 122

XXV. ESSENTIAL AMINO ACID PATTERN AND CHEMICAL SCORES OF RICE NOODLES 123

XXVI. PROTEIN EFFICIENCY RATIOS (PER) OF RICE NOODLES 125

XXVII. NET PROTEIN UTILIZATION (NPU) OF RICE NOODLES 126

XXVIII. DIET FORMULATION FOR PROTEIN EFFICIENCY RATIO (PER) ASSAYS OF RICE NOODLES 127

XXIX. STATISTICAL ANALYSES OF NET PROTEIN UTILIZATION (NPU) DATA FOR RICE NOODLES 129

XXX. PROTEIN COST RATIO (PCR) OF RICE NOODLES 131

XXXI. SUMMARY OF NUTRITIONAL DATA FOR RICE NOODLES 132

XXXII. NUTRIENT CHANGES IN SNACK CHIPS AFTER DEEP-FAT FRYING 141

XXXIII. COST OF PROTEIN IN SNACKS 142

XXXIV. SNACK SCORES BY ELEMENTARY SCHOOL CHILDREN 153

XXXV. SNACK SCORES OF STORED SNACKS BY ELEMENTARY SCHOOL CHILDREN . . 154

XXXVI. STATISTICAL EVALUATION OF SNACK SCORES BY ELEMENTARY SCHOOL CHILDREN 156

XXXVII. PROXIMATE ANALYSES AND CALORIC VALUES OF SNACKS 158

XXXVIII. VITAMIN AND MINERAL ANALYSES OF SOY CHIPS AND SOY CURLS 159

LIST OF FIGURES

Figure

1. Comparison of weight of Thai and American children 12

2. Flow chart for the production of mungbean protein isolate 18

3. Flow chart for the production of soy protein isolate 20

4. Flow chart for the production of full-fat soy flour 22

5. Flow chart for the production of 'Kaset' protein 24

6. Flow chart for the production of soy cookies 26

7. Preparation of rice flour slurry for the production of rice noodles 39

8. Transfer of rice flour slurry into the feeding trough of a rice noodle-making machine 39

9. View of noodle-making machine 41

10. Production of rice noodle sheets 41

11. Air-drying rice noodle sheets 43

12. Rice noodle sheets being cut into noodle strips 43

13. Dehydrated and cooked regular rice, 20% soy-rice, 30% soy-rice, and wheat noodles 72

14. Thai noodle dishes containing 30% soy-rice noodles 72

15. Moisture contents of dehydrated regular rice, 20% soy-rice, and 30% soy-rice noodles stored for five months 79

16. Rates of water absorption for dehydrated rice noodles at the time of preparation and stored for one, two, three, four, and five months 83

17. Rates of disintegration for dehydrated rice noodles at time of preparation and stored for one, two, three, four, and five months 85

18. Score sheet used for taste panel evaluation of dehydrated rice noodles by adults 89

19. Consumption of non-noodle dishes and wheat, rice, and soy-rice noodle dishes for pre-school children at the Child Nutrition Center in Ban Yang Village 103

20. Consumption of non-noodle dishes and wheat, rice, and soy-rice noodle dishes for pre-school children at the Child Nutrition Center in Ban Mai Village 105

21. Consumption of non-noodle dishes and wheat, rice, and soy-rice noodle dishes for pre-school children attending the Kasetsart University Nursery School 107

22. Consumption of non-noodle dishes and wheat, rice, and soy-rice noodle dishes for pre-school children attending three day-care centers 112

23. New high-protein rice snacks 137

24. Regular snacks 137

25. Moisture contents of new rice snacks and regular snacks stored for three and six months 139

26. Score sheet used for evaluating snack food preferences with elementary school children 145

27. Preference scores for new rice snacks and regular snacks for elementary school children at Bang Bua School 147

28. Preference scores for new rice snacks and regular snacks for elementary school children at Kasetsart Demonstrated School . . . 149

29. Preference scores for new rice snacks and regular snacks for elementary school children at Bang Bua and Kasetsart Demonstrated Schools 151

INTRODUCTION

Childhood protein malnutrition is a major global problem whose existence has been the topic of great concern and recognition. The impact of this world nutritional problem is far-reaching and significant. It directly affects the well-being of the future generation of many nations, thereby affecting the development of those nations.

Deficiency of protein in the diet of children is an increasing problem in both urban and rural areas of Thailand. The group most vulnerable to protein deficiencies is pre-school children, i.e., children one to five years of age. Childhood protein malnutrition is critical because this period is very important for growth and development, both physical and mental. Increase in child mortality and impairment in normal growth processes are major results of protein inadequacies at this early age. In Thailand, dietary protein deficiency is being combatted through the establishment of child nutrition centers where newly developed high-protein foods are included in children's diets.

The introduction of new foods in Thailand to increase protein intake in children can be accomplished in two basic ways: a) protein-supplementation of familiar foods, and b) development of new high-protein foods. These new food items should be readily adaptable to the Thai dietary pattern, easy to prepare, suitable for child feeding, highly acceptable, high in nutritive value, made of locally available raw materials, and low in cost. Good storage stability and ease of handling for transporting are additional important features for the products.

This investigation was initiated to develop new high-protein foods to be used for supplementary feeding programs in child nutrition (day care) centers. Studies concerning the acceptability of these foods by children and overall nutritional evaluations using chemical and biological methods were included. The main objective of this research was to develop foods which could be significant in promoting good nutrition in Thai children whose diet would otherwise be lacking in adequate protein essential for good health. A main consideration was the development of foods which would have the potential of being used in other developing countries with protein deficient diets.

This study was conducted under a 211 (d) Grant AID/csd 1931 "Grain Utilization in India" awarded to Kansas State University by the United States Agency for International Development. The main objective of this particular program was to train graduate students in food grain utilization in India and other developing countries and to further increase the competency of Kansas State University in those areas. Political factors deemed it necessary that an alternative country to India, in this case Thailand, be chosen for conducting this research. As outlined in the Grant, the application of the studies to other developing countries is an important part of this grain utilization program.

The Institute of Food Research and Product Development (IFRPD), Kasetsart University, Bangkok, Thailand, has taken positive steps in establishing a program aimed at improving the nutritional state of children through the development of new high-protein foods. Child nutrition centers (CNC) have been established by the Thai government for implementing feeding programs designed to increase the protein level of children's diets. The work reported in this dissertation was conducted at IFRPD over a period of 15 months from August, 1972, to October, 1973, under a program jointly planned by Prof.

Amara Bhumiratana, Director of IFRPD, and by the Department of Grain Science and Industry at Kansas State University. Studies were also conducted at CNC's in the northern province of Chiang Mai in co-operation with the Thai Ministry of Health. The results and opinions expressed in this paper do not necessarily reflect the views of the United States Agency for International Development or the institutions at which the work was performed.

LITERATURE REVIEW

A. THE FOOD AND NUTRITION PROBLEM IN THAILAND

Thailand, a tropical, agricultural nation in Southeast Asia, occupies a total area of approximately 200,000 square miles (1) with a population in mid-1971 of over 37 million (2). Like most developing nations in the tropical region of the world, Thailand has an increasing food and nutrition problem which affects the well-being of the inhabitants.

The overall concept of good nutrition is concerned with the availability of proper food needed to meet the necessary dietary intake of essential nutrients. Protein is a nutrient of extreme importance because it is required by the body for growth, repair, and the regulation of vital body functions (3) Protein deficiency diseases lead to serious impairment of health, especially in young children who are in a state of rapid growth. Increase in illnesses of children and an overall poor state of health, often leading to death, has been noted in developing countries where protein malnutrition of children exists (4).

Protein malnutrition in children is dependent upon three major factors (5): dietary inadequacies, infection, and socio-cultural factors. Unavailability of protein food as dictated by poverty, over-population, and lack of nutrition education causes dietary inadequacies. Intestinal worms and diseases, including cholera and tuberculosis, are serious infections which can magnify protein deficiencies in children. Socio-cultural factors can dictate the protein status of children since these factors concern early feeding practices, food preparation, food customs, and overall dietary pat-

terns. Protein malnutrition exists among a significant number of Thai pre-school children.

Population, food production, urbanization, poverty, education, and the Thai dietary pattern are major points to consider in evaluating the food and nutrition problem in Thailand.

1. Population

The annual rate of population growth in Thailand is approximately 3.0%, one of the highest in the world. Children under age 15 comprise 44% of Thailand's population and 13% of the population are pre-school children aged one to five (6). A high birth rate coupled with a rapidly decreasing death rate indicates that the number of children will continue to increase rapidly, unless there is a marked decline in the birth rate (2).

2. Food Production

Agriculture employs 78% of Thailand's people. Although the rate of food production is increasing at an annual rate of 6.8%, any increase in protein food supplies will be hindered by the increasing population. As a rice economy, Thailand had a total rice production of 12.4 million tons in 1968, representing about 90% of total cereal grain production. Other sources of additional vegetable protein were mungbeans, peanuts, soybeans, and sesame seeds (1, 7). It is unlikely that the Thai diet will change from being rice-based. The ability to increase protein intake will be linked to the advent of supplementing the rice diet with protein-rich foods, mainly legumes and other vegetable protein foods.

3. Urbanization

Large numbers of rural people are abandoning their villages and subsis-

tence farms and are moving into squatter settlement in slums bordering large cities (8). Slum dwelling, accompanied by crowded living conditions, inadequate sewage facilities, and poor personal health, creates widespread infections. Metabolic processes are altered by diseases and infection, and the body of the affected individual is incapable of retaining protein even with a high-protein diet (9). Furthermore, upon urbanization families are faced with unemployment, wage dependency, and an unfamiliar money economy (10).

4. Poverty

Thailand's gross national income of $120 per capita (11) indicates low food-purchasing power for providing an adequate diet. Household expenditure surveys (12) show that almost 50% of a family's income is spent on food items, 40% of which is for rice and cereals. Overall, the purchases of protein foods are limited by their high cost with people concentrating their food buying on low-cost, low-protein cereal grains.

5. Education

People lack adequate knowledge to purchase as highly nutritious combinations of foods as possible with a limited low income. According to Ritchie (13), mothers need basic education concerning proper methods of storing and cooking foods, the benefits of breast-feeding, and the special nutritional needs of pre-school children. Meal preparation and planning, using a variety of foods, is also needed by homemakers.

6. Dietary Pattern

The Thai dietary pattern is typical of other developing tropical countries exhibiting a general similarity found among low-income families. Jelliffe (5) states that tropical diets tend to be based on a limited number

of foodstuffs which are prepared for use in a limited number of dishes. The main bulk of the diet and, therefore, the main source of protein and calories comes from one or more carbohydrate staples which are eaten with small amounts of vegetables. Products of animal origin, including beef, pork, chicken, fish, milk, and eggs, are usually eaten in rather limited amounts mainly due to cost and availability. This description of a typical tropical diet is reflected in the rice-based Thai diet illustrated in Table I, using data obtained from food surveys.

In general, the basic food and nutrition problem in Thailand stems from various factors which limit the consumption of protein by particularly vulnerable groups, namely pre-school children, although total food supplies may seem adequate for the population as a whole.

B. PROTEIN MALNUTRITION IN EARLY CHILDHOOD

The effects of protein malnutrition in young children are serious. Children aged one to five are most vulnerable since they are continously involved in growth and development, thereby having greater protein needs than other segments of the population. It is well known that retardation of growth is one of the first consequences of malnutrition, preceding the appearance of clinical signs and significant changes in biochemical parameters (16). Initial indicators for assessment of protein-calorie malnutrition in young children have included anthropometric measurements, height and weight data, and comparison to standard height-weight curves for normal healthy children (17).

Brain growth in early life relates to an increase in both cell number and size. It has been found that malnourished children having small head circumferences and underweight bodies had significantly lower IQ scores than

TABLE I. SURVEY SUMMARY OF THAI DAILY DIETARY INTAKE

	Survey Areas		
	Bangkok[a] (urban, 1955)	Chiang Mai[a] (rural, 1955)	Entire Kingdom[b] (1960)
A. Average intake of foods (g./capita)			
Rice, raw	228	497	440
Other cereals and starchy foods	18	3	19
Animal origin	143	54	132
Total food consumption	537	678	616
B. Average intake of nutrients			
Calories	1409	1851	1770
Protein (g.)	47	46	47
Carbohydrate (g.)	208	365	357
C. Diet composition (%)			
Share of protein from animal sources	51	17	32
Carbohydrate content	59	79	58
Calories from rice	60	87	87

[a]Reference 14

[b]Reference 15

their healthy counterparts (18). Studies on the effect of protein malnutrition in young children indicate that there is a relationship between this deficiency and impaired mental development (19, 20). A study of the relationship between malnutrition and intelligence in Thai children clearly indicated that underweight children were inferior to normal children in IQ scores (21). Recent investigation into the role of malnutrition in retarding intellectual development presented an additional hypothesis that malnourished children have restricted activities and learning opportunities (22). It was concluded that nutritional factors do contribute to depressed intellectual levels and learning failures in children in two major ways: either directly by irrepairable alterations of the nervous system, or indirectly by interference in the learning process of the developing organism at critical points in the developmental course (23).

Specific results and dangers of protein deficiency diseases have been investigated. Present terminology emphasizes a tendency to consider protein malnutrition in connection with calorie deficiency. Protein-calorie malnutrition (PCM) is a collective term which refers to a variety of definite clinical forms of malnutrition. PCM is the term used for a group of conditions which are due to a diet low in protein but having different caloric intakes from carbohydrates (5). If protein deficiency occurs in children who are receiving an adequate quantity of calories, the syndrome that develops is referred to as classic Kwashiorkor (24). This condition is characterized by edema, skin lesions, apathy, and subnormal height and weight. The effects of protein malnutrition are compounded when the diet is also deficient in calories. Nutritional marasmus develops which has the cardinal features of severe tissue-wasting, an absence of subcutaneous fat, and a marked reduction in statural growth.

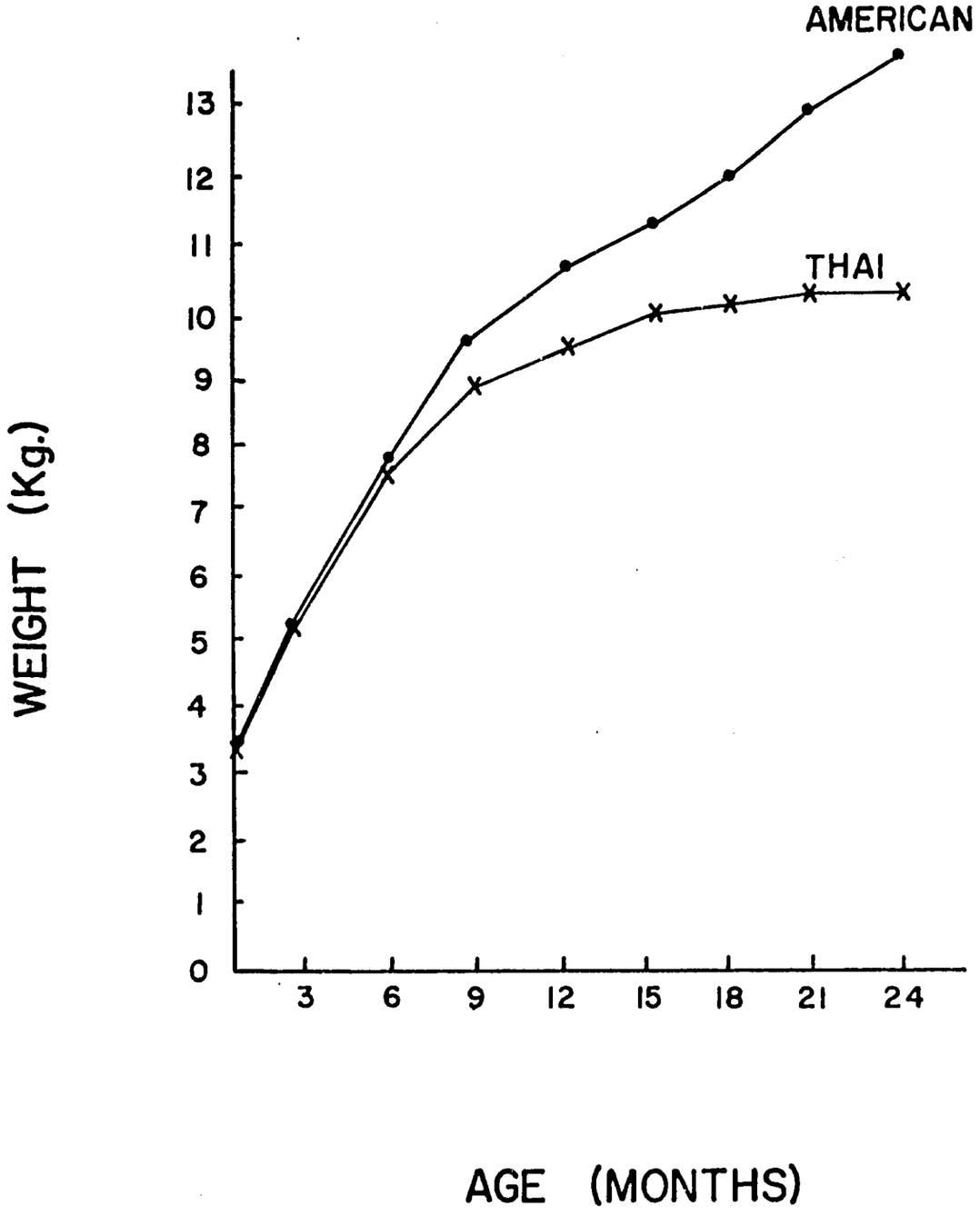
Diseases, including measles and tuberculosis, have been found to a greater extent in protein-deficient children than in adequately fed ones (4). Unsanitary housing conditions and food preparation habits can lead to parasitic infections, such as intestinal worms and diarrhea, thereby robbing the already malnourished child of vital nutrients (9). In recent years it has been recognized that infection and malnutrition produce a true synergism so that their combined result is more detrimental than the summation of the two independent factors (25). A child's resistance to disease is consequently lowered when he is suffering from protein malnutrition.

C. PROTEIN MALNUTRITION IN THAI CHILDREN

Early feeding practices, coupled with traditional food habits, clearly indicate that protein malnutrition both exists and has the potential to increase among young Thai children. It is well-established that breast-feeding, with minimal supplementation, is sufficient for normal growth in children during the first six months of life, and failure to breast feed in these early months is dangerous (26). The weight of Thai children compare favorably with those of American children up to the age of six months, at which time a marked deviation from a standard U. S. curve (Fig. 1) is observed (27). Furthermore, it has been reported (28) that Thai children from northern villages followed the 50th percentile of the Boston Standard Curve for their first few months of life, dropping to the 10th percentile shortly thereafter.

Recent investigations showed that 25% of urban pre-school children from slum areas were never breast-fed during their early months of life, and 25% of those who were breast-fed were done so for only six months (8). One-third of the children surveyed consumed inadequate amounts of commercially-available milk. In addition, early introduction of solid foods, in the form of pureed

Fig. 1. Comparison of weight of Thai [well-baby clinic in Bangkok (3,490 subjects, 1960-61)] and American (Children's Medical Center, Boston, Mass., U.S.A.) children (27).



rice and bananas, was predominant with introduction of protein foods, in relatively low amounts, occurring relatively late at over one year of age.

As previously noted, early diet surveys indicated that the nutritional status of urban people living in Bangkok was better than that of rural people living in the North (14). A general nutrition survey conducted in 1960 by the Interdepartmental Committee on Nutrition for National Defense (ICNND) confirmed earlier findings that most of the protein intake in rural diets was of vegetable origin, mainly rice, with small amounts of pork, beef, and fish being consumed (15). Overall, the supply of foodstuffs was considered sufficient in terms of caloric intake, but low in quality based on protein intake. An average protein intake of 47 g., mostly from vegetable origin and rice, indicated that the demanding protein requirements of young children were not being met. Table II illustrates recommended daily allowances of protein and calories for pre-school children as compared to actual intake.

Specific cases of protein malnutrition have been reported in Thai children. A study of kwashiorkor in Bangkok slum areas revealed that it existed in more than 50 pre-school children during a four year period (32). Marked malnutrition, bordering on kwashiorkor, was diagnosed in a 1957-1958 survey of pre-school children from low-income, rural families, indicating that 10% of rural Thai children suffered from severe protein malnutrition (33). Kwashiorkor and other forms of protein malnutrition were also reported in Bangkok and in rural areas (27). Early childhood protein malnutrition in northern Thailand, as evidenced by the admittance of 111 children to Chiang Mai hospital in one year, has been reported by Thanangkul and Whitaker (34). Diagnoses indicated that 46% had marasmus, 44% had kwashiorkor, and 8% had protein-calorie malnutrition. Almost 90% of these children were aged six months to four years. The characteristic clinical signs associated with PCM

TABLE II. RECOMMENDED DAILY ALLOWANCES (RDA) AND INTAKE FOR THAI CHILDREN COMPARED TO THE RDA FOR AMERICAN CHILDREN

RDA[a]			Thai intake[b]
T	A	F	
A. Protein (g.)			
17.0	25.0	16.0	< 10.5-16.3
21.0	30.0	20.4	16.0
B. Calories			
1200	1100-1250	1360	< 544-865
1550	1400-1600	1830	1186

[a]T = Thai (29), A = American (3), F = FAO (30)

[b]Reference 31

syndromes were in evidence as follows: edema, muscle wasting, growth retardation, irritability, and anorexia.

In a comprehensive study on health problems of children from birth to age six (8), it was found that some form of protein-calorie malnutrition occurred in over 80% of the children in three of the four Bangkok slum areas surveyed. The proportion of children with second and third degree malnutrition (equivalent to marasmus) was strikingly high by its occurrence in 20% of the children living in two surveyed districts.

D. IMPROVING THE NUTRITIONAL STATUS OF THAI CHILDREN

The Thai government, recognizing an urgent need to improve the protein consumption of children, established a Food and Nutrition Policy which included the establishment of a Protein Food Development Project (35).

1. Protein Food Development Project

The main objective of this project, which was initiated at the Institute of Food Research and Product Development (IFRPD), Kasetsart University, Bangkok, was to develop new, high-protein, low-cost food supplements for preschool children. Originally, 57 Child Nutrition Centers (CNC) were established in collaboration with the Nutrition Division, Department of Health, for conducting nutritional and acceptability studies with 2,500 children. Mungbeans and soybeans were local protein-rich raw ingredients used for product development. Specific foods developed included textured vegetable proteins from mungbeans and soybeans, and cookies made from full-fat soy flour. A combination of mungbean and soybean proteins was used to develop 'Kaset' protein, a meat-like protein supplement (11). The processes used for producing the textured proteins and soy flour are illustrated in Figs. 2-4 (11). Flow charts for the formulation of 'Kaset' protein and soy cookies are

illustrated in Figs. 5 and 6, respectively. Proximate analyses of the protein ingredients in the foods are indicated in Table III.

2. Child Nutrition Centers

As outlined by Nondasuta (36), the primary aim of a child day care center is to provide a means for continuously and effectively improving the nutritional status of children through the introduction of supplementary feeding programs. Child Nutrition Centers (CNC), each accommodating 50-80 children, emphasize the prevention and/or correction of nutritional problems. Early recognition of protein-calorie malnutrition through periodic clinical observation and height-weight measurements is possible. The diet of preschool children is supplemented with sufficient amounts of protein-rich foods, e.g. 'Kaset' protein and soy cookies, and adequate amounts of calories. Also, childhood disease control and prevention is monitored through regular checkups and subsequent proper treatment and immunization.

Currently, there are over 500 CNC reaching approximately 25,000 preschool children. Feeding programs to provide needed protein and calories include a mid-day meal and snacks. This additional protein, when combined with protein obtained from a normal home diet, provides children with their daily recommended protein requirements (11).

E. DEVELOPMENT OF NEW HIGH-PROTEIN FOODS FOR THAI CHILDREN

Rice noodles and snack foods are familiar items in Thailand. Both products are eaten by people of all ages and varying economic status. A report (37) of rural village life indicated that small children often ate between-meal snacks including leftover foods or items purchased from vendors. In a sampling of 76 children, an average of three snacks were eaten by each child regardless of whether or not lunch had been eaten. Thai children from upper

Fig. 2. Flow chart for the production of mungbean protein isolate (11).

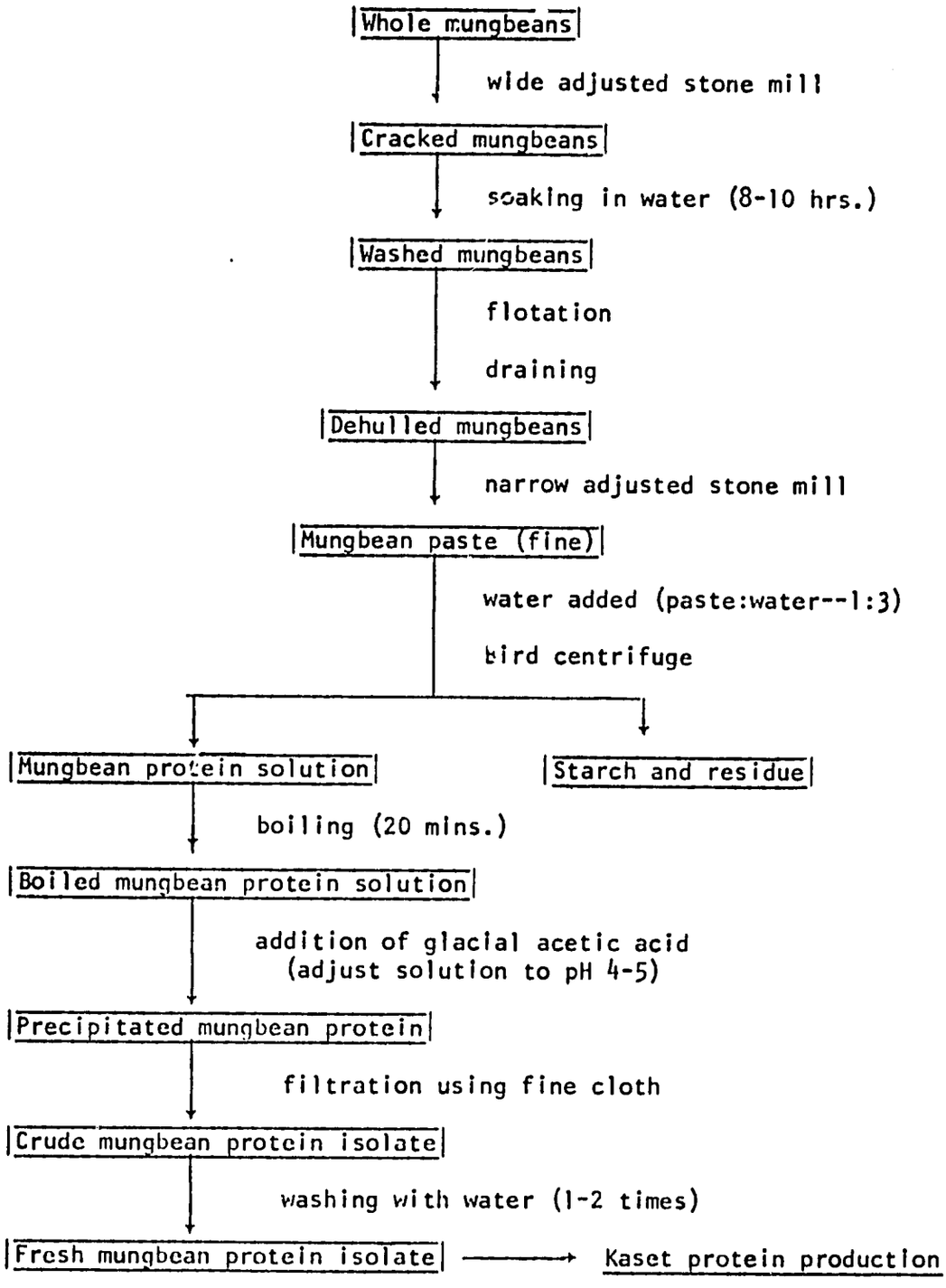
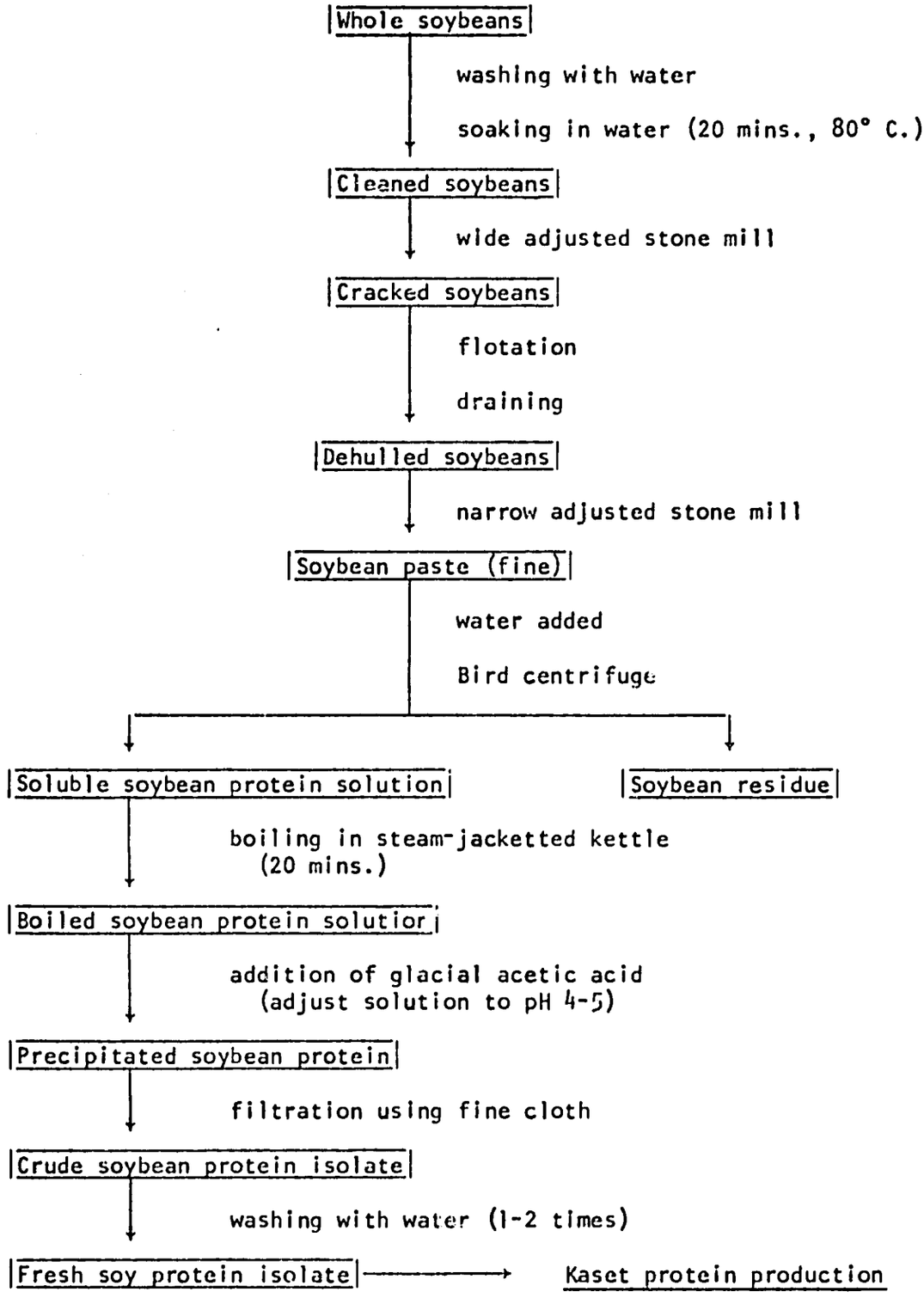


Fig. 3. Flow chart for the production of soy protein isolate (11).



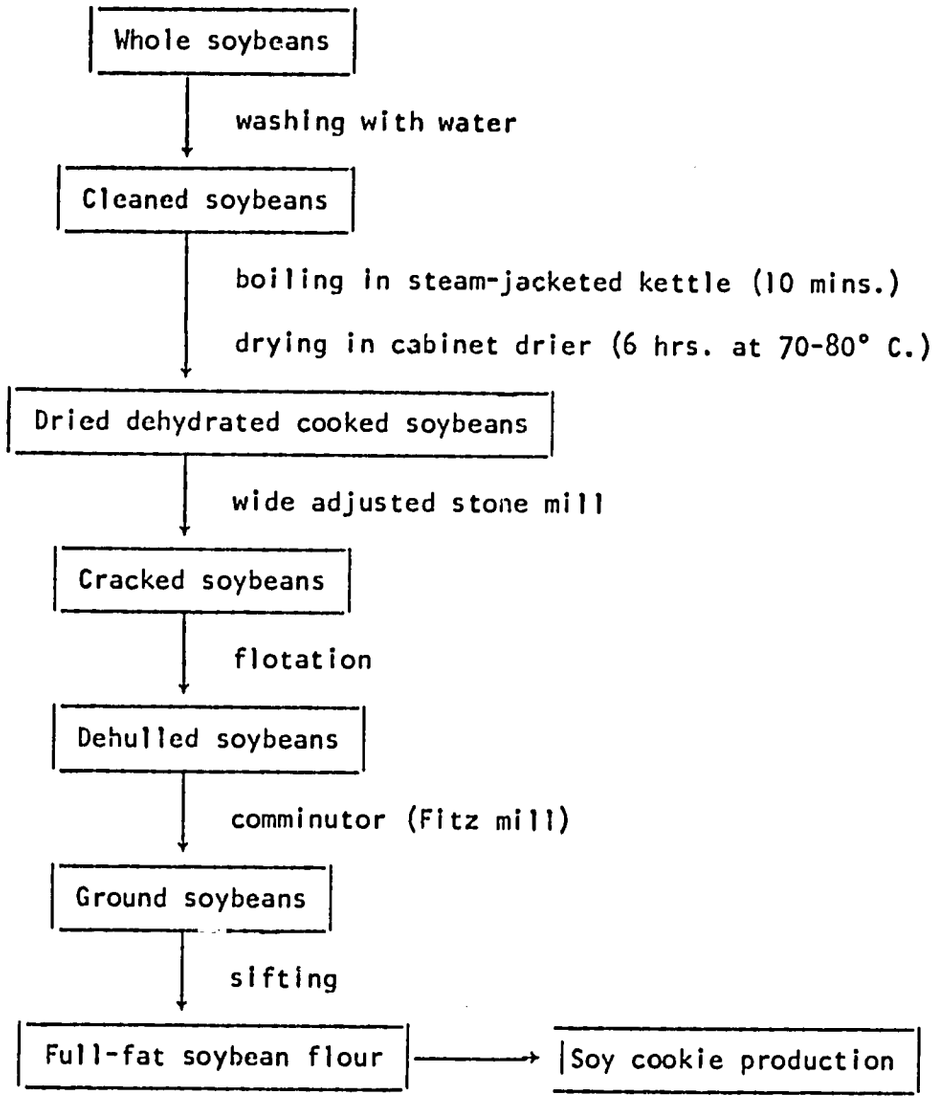


Fig. 4. Flow chart for the production of full-fat soy flour (11).

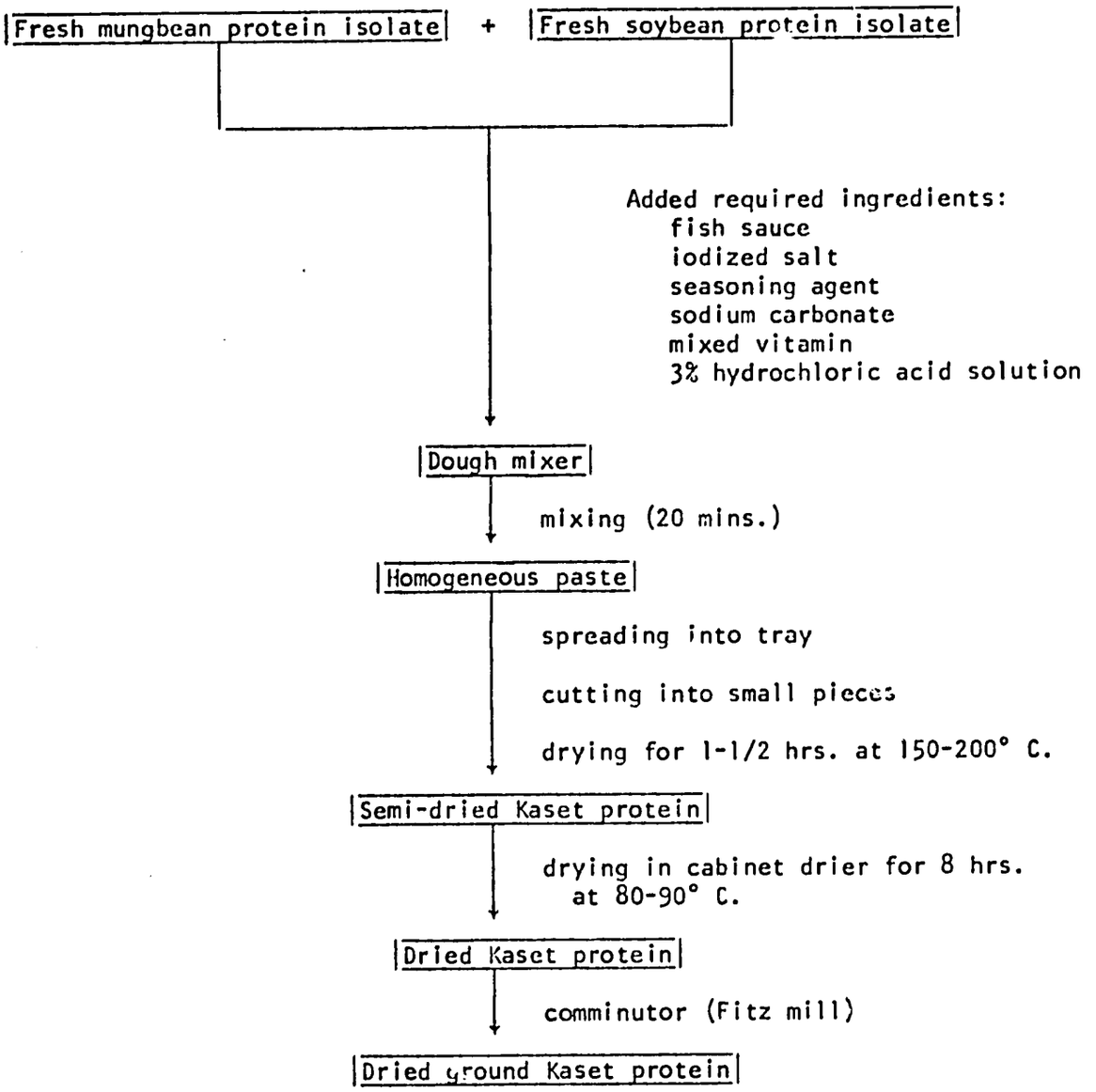


Fig. 5. Flow chart for the production of 'Kaset' protein (11).

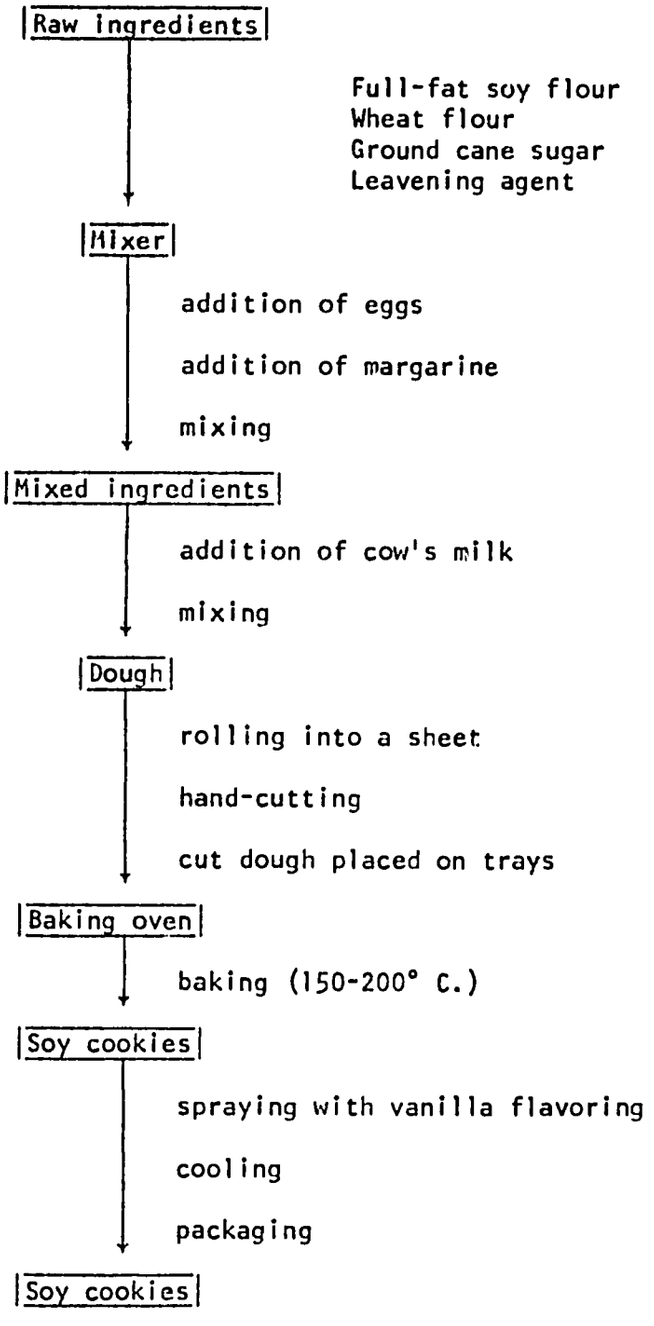


Fig. 6. Flow chart for the production of soy cookies (11).

TABLE III. PROXIMATE ANALYSES FOR SOYBEAN AND MUNGBEAN PROTEIN ISOLATES, SOY FLOUR, 'KASET' PROTEIN, AND SOY COOKIES[a]

Product	Protein %	Moisture %	Ash %	Fiber %	Fat %	Carbohydrate %
Mungbean protein isolate	78.9	3.0	NR[b]	NR	NR	NR
Soybean protein isolate	57.6	6.2	NR	NR	NR	NR
Full-fat soy flour	48.8	3.3	4.3	2.2	20.9	20.6
'Kaset' protein (Formula 17)	56.3	3.2	7.1	1.3	17.6	14.5
Soy cookies	18.2	1.1	2.8	0.5	22.5	54.9

[a]Reference 11

[b]NR = Not reported

middle-class families eat an average of two snacks per day (38). Methods used to improve the nutritional status of Thai children include increasing the protein content in foods ordinarily eaten, e.g. rice noodles, or by creating new high-protein foods which are acceptable for child feeding, e.g. snacks. Development of high-protein foods should utilize available protein sources. The nutritive value of vegetable proteins are affected by availability and amino acid content. For optimum utilization of proteins, there must be a liberation of essential amino acids during digestion at rates permitting mutual supplementation (39). Proteins from different sources mutually supplement each other, and blends of two or more may possess a higher biological value than the individual proteins. Numerous products have already been developed for child feeding using mixtures of various protein sources. Proteins from vegetable and animal sources, including soybeans, sesame seeds, and fish protein concentrate, normally have been added to a cereal staple (40).

1. Rice

Rice, like most cereal grains, has protein of lower biological value than protein of animal origin. Rice protein, however, is considered one of the best vegetable proteins due to its relatively well-balanced amino acid content (41). The generally low protein content of rice demonstrates a quantitative deficiency in this food grain. The protein content for nine varieties of Thai rice was found to be 6.48-10.98% (N X 5.95) with an average of 7.88% (42). This low protein content produces a low protein-calorie ratio. Hence, the young of a Thai population will suffer, as greater amounts of a higher quality protein are essential for optimum growth. The quality of a rice-based diet may be satisfactory for adults, but not for children.

2. Soybeans and Soybean Products

Soy flour is the product obtained after whole soybeans have been cleaned, boiled in water, cracked, dehulled, and ground (43). Altschul (44) reported that there are two main types of soy flour, classified according to fat content: full-fat soy flour (40% protein), and defatted soy flour (50% protein). Full-fat soy flour has the advantage of supplying both protein and calories. Furthermore, it was noted (45) that soybean oil is rich in essential fatty acids and is a good source of tocopherols which are responsible for the good keeping quality of full-fat soy flour.

Soy protein concentrates containing 60-70% protein are made by removing soluble carbohydrates, oil, and seed coats. The protein concentrate is usually obtained by aqueous extraction of the protein at its isoelectric point, thereby precipitating the protein (44).

Various foods designed specifically for children have been developed using soy flour and soy concentrates. These foods include bread, biscuits, breakfast cereals, soups, and beverages (40, 45, 46).

The development of wheat noodles containing soy flour has been investigated (47). Acceptable wheat noodles containing soy flour have been developed and studied for use in Thai diets (11, 48).

3. Sesame Seeds

Sesame seed, an oilseed containing about 35% protein, can be ground into a meal for incorporation into foods. It has been used in a new protein beverage powder developed for children as a means for increasing dietary protein intake (46).

4. Fish Protein Concentrate

The use of fish protein concentrate (FPC) as a protein-supplement in

foods utilizes an otherwise neglected source of high quality, animal protein. It is a pale, grey powder made from eviscerated, whole ground fish (49). Solvent extraction for fat removal and dehydration produces a stable concentrate containing approximately 70% protein. Rice pasta containing 10% FPC produced an acceptable product possessing both an increased protein content and increased nutritive value as compared to an unsupplemented product (50).

F. ACCEPTANCE OF NEW FOODS BY CHILDREN

Early reports (51) note that food acceptance is based mainly on flavor and, therefore, new product acceptance must be evaluated organoleptically, i.e., by taste. In a review of food preferences of pre-school children (52), it was noted that, in addition to product taste and texture, food acceptance is dependent upon dietary habits and eating patterns which have been conditioned by the availability of foods. Children learn about foods in their day-to-day experiences.

Methods designed to evaluate food acceptance by young children emphasize recording the actual food consumption in a typical meal situation. Food consumption data can be taken for each child by weighing the amount of food served and subsequently making appropriate corrections for leftovers or extra servings (53). An effective, reliable method has been reported (54) for measuring food acceptance and preference with elementary school children in which a 5-point hedonic scale, corresponding to a series of five faces, was used for grading various food items. The facial expressions, ranging from very happy to very sad, relate to a child's feeling towards the food item being judged.

G. NUTRITIONAL EVALUATION OF HIGH-PROTEIN FOODS

A combination of chemical and biological methods can give an indication

of the nutritional value of high-protein foods by determining both the quantity and quality of the protein.

The quantity of protein in food is determined chemically by direct analysis of nitrogen. Nitrogen is multiplied by a factor (normally 6.25) to obtain crude protein content (55). Other factors are used for specific foods including cereals and their products.

The quantity of protein in food is important. A joint report by the United Nations Food and Agriculture Organization (FAO) and the World Health Organization (WHO) (30) points out that, although foods with low protein content can provide useful amounts of protein if consumed in sufficient quantity, the amount of food eaten is largely determined by the requirement for energy rather than for protein. Consequently, consumption of such foods is curtailed before enough is eaten to meet protein requirements. This is the case when one considers food consumption by children and the fact that a child can not physically consume sufficient low-protein food, such as rice, to meet his protein needs.

The efficiency with which dietary protein is used for growth and maintenance is a measure of its quality. This is determined by its overall amino acid composition and its essential amino acid pattern (56). Since essential amino acids cannot be synthesized in the body, their presence in adequate amounts governs protein quality. Chemical score which reflects essential amino acid balance is one indicator of protein quality. This score illustrates the limiting amino acid in a food by comparing its amino acid pattern to that of a reference (30).

Indices of protein quality, as derived from biological tests, include protein efficiency ratio (PER) and net protein utilization (NPU). PER is a measure of the rate of growth of weanling rats on a standardized protein diet

(usually 10%) during a 3-4 week assay period. Ad libitum feeding is used and all essential nutrients for growth and maintenance are provided (57). The formula for determining PER is as follows:

$$PER = \frac{\text{Wt. gain (g.)}}{\text{Protein intake (g.)}}$$

Various studies have supported PER as an index of protein quality, including an early report by Worcester and Hegsted (58) in which a very high correlation between gain in weight and protein efficiency (gain per gram of protein eaten) was found.

NPU is defined as the difference in final carcass nitrogen content between a test group fed any given diet and another group fed a protein-free diet, expressed as a percentage of the nitrogen intake of the test group (57). Basically, test rats are on a diet in which protein is the single limiting nutritional factor, and the NPU is determined by measuring the percentage of ingested nitrogen that was retained for growth, repletion, or maintenance. A new method for determining NPU was introduced by Miller and Bender (59) in which body nitrogen is not measured but is calculated from the water content of the animal since the ratio of nitrogen to water (N: H_2O) is constant at any age. The basic formula for determining NPU is as follows:

$$NPU = \frac{B - (B_k - I_k)}{I}$$

where B and B_k are the total body nitrogen of the animals on the test and non-protein diets, respectively, and I and I_k are the intake of nitrogen for the two groups.

PER and NPU values obtained from animal feeding studies are compared to those values obtained for a test group in which casein is the protein

source. PER for other foods is adjusted for casein (PER = 2.50). Chemical score, PER, and NPU are useful in determining protein quality in new foods since these values can be compared to those for foods previously established to have high protein quality.

MATERIALS AND METHODS

I. HIGH-PROTEIN DEHYDRATED SOY-RICE NOODLES

A. DEVELOPMENT

1. Initial Studies

a. Noodle discs

Dehydrated rice noodles supplemented with full-fat soy flour were prepared. Factory-obtained rice flour solution was used for initial development studies in which full-fat soy flour was incorporated in various amounts.

Rice flour solution was made from broken rice which had been soaked overnight and passed through a stone grinder to produce a ground rice slurry containing approximately 42% solids. All full-fat soy flour used in this project was prepared at the Institute of Food Research and Product Development (IFRPD), Kasetsart University, Bangkok, Thailand, by the method described by Bhumiratana and Nondasuta (11).

Initially, rice flour solutions containing various amounts of soy flour were made into dehydrated rice noodles in the form of discs. The soy-rice solutions were maintained at 42% solids by addition of water. Plain rice flour solutions were used to prepare control samples. Aliquots (10 mls.) of the rice flour solutions were added to petri dishes and the dishes were heated in a steam blancher for three minutes under moderate steam pressure. Upon removal from the blancher, the petri dishes containing the noodle discs were allowed to cool for several minutes. The discs were then peeled from the

dishes, placed on perforated metal trays, and dried in an air oven for 4-5 hours at 45-50° C.

b. Formulations

Soy flour was added to rice flour solutions in amounts equal to 5, 10, 15, 20, 25, 30, 35, and 40% calculated on a dry basis. Solids contents of the resulting mixtures were adjusted to approximately 42%, which was equivalent to that of the original rice flour solution. Initial experiments included subjective sensory evaluation of the noodle disc samples by ten Thai adults. Factors considered were appearance, texture, uniformity, and taste. Cooking quality of the discs was evaluated by water absorption, cooking time, and resistance to breakage during cooking.

These initial studies indicated that, with more than 30% soy flour, the noodle discs were judged unacceptable with respect to the subjective quality factors. Observations of cooking quality, compared to control samples, indicated that soy flour at the higher levels had a detrimental effect on some aspects of cooking quality. A high degree of breakage occurred in disc samples containing more than 20% soy flour.

Subsequent testing to improve noodle quality indicated that small additions of cassava flour (0.5% for every 10% addition of soy flour) to soy-rice solutions decreased the tendency of the noodle discs to break apart upon rehydration in boiling water, and significantly improved cooking quality and other factors associated with acceptable noodle products. A moisture content of flour solutions was determined by a modified A.O.A.C. method (55) in which 10-g. samples in aluminum weighing dishes were initially evaporated to visual dryness on a water bath and then placed in an air oven for 1 hour at a temperature of 130° C.

c. Preliminary rice noodle preparation

Further preliminary studies centered upon small-scale preparation of traditional dehydrated rice and dehydrated soy-rice noodles. Full-fat soy flour was added to factory-obtained rice flour solution in amounts equal to 15, 20, 25, and 30% (on a dry basis). These mixtures were made into traditional dehydrated noodles. The soy-rice solutions and a normal rice solution (control) were poured onto rectangular metal trays and allowed to spread evenly into a thin layer covering the entire tray surface. A subsequent 2-minute steam treatment in a blancher, followed by adequate cooling, produced a rectangular noodle sheet which was semi-dried for 2 hours in a cabinet drier at 45° C. The noodle sheet was cut into noodle strips (10 in. x 1/8 in.) on a conventional roller cutter. The strips were oven-dried to produce experimental dehydrated soy-rice noodles. These samples were used as initial prototypes, being subjected to sensory evaluation by the 10-member adult panel. Quality factors and cooking tests previously listed were employed. An overall evaluation of these studies indicated that the previously determined amounts of cassava flour added to soy-rice flour mixtures improved the overall quality of the rehydrated products. It was decided that large-scale noodle production would involve preparation of rice noodles supplemented with 20 and 30% soy flour (on a dry basis) with 1.0 and 1.5% added cassava flour (on a dry basis), respectively. Samples were also prepared containing 0.2 and 0.3% (dry basis) dl-methionine in the 20% and 30% soy-rice noodles, respectively.

2. Factory Preparation of Rice Noodles

a. Traditional method--regular rice noodles

Rice noodles (senlek) eaten in Thailand are prepared in a standard, traditional manner in numerous noodle factories throughout the nation.

Initially, after broken rice is washed and soaked overnight, it is passed through a stone grinder while water is added to produce a rice flour slurry from which the noodles are prepared (Fig. 7). The rice flour slurry is fed into a trough on a standard noodle-making machine (Fig. 8). A rotating roller adjacent to the trough allows even distribution of the solution onto a metal sheet which slowly moves through a steam tunnel (Fig. 9). A continuous sheet of noodle comes out of the machine to be cut into large squares by a rotating knife (Fig. 10). The squares are then draped over bamboo sticks which are suspended from the ceiling to be air-dried for approximately 5 hours (Fig. 11). These semi-dried squares are cut into noodle strips using a standard rice noodle cutter consisting of a slowly moving board on which a stack of noodle squares are placed (Fig. 12). A sharp knife cuts through the noodle squares in a continuously thrusting vertical motion as the board slowly moves forward. Relatively uniform, semi-dried noodles are produced for sale to food shops and restaurants. Also, rice noodles are further air-dried to lower moisture content for subsequent packaging and distribution as a dehydrated noodle to local or out-of-town shops, market places, and restaurants.

b. Dehydrated soy-rice noodles

Five dehydrated soy-rice noodle samples were prepared at the Lim-ching-heng Noodle Factory in Bangkok. These were formulated as follows:

(1) Control Noodles: regular rice noodles

(2) Soy-rice Noodles:

--20% full-fat soy flour

--30% full-fat soy flour

--20% full-fat soy flour plus 0.2% dl-methionine

--30% full-fat soy flour plus 0.3% dl-methionine

Fig. 7. Preparation of rice flour slurry for the production of rice noodles.

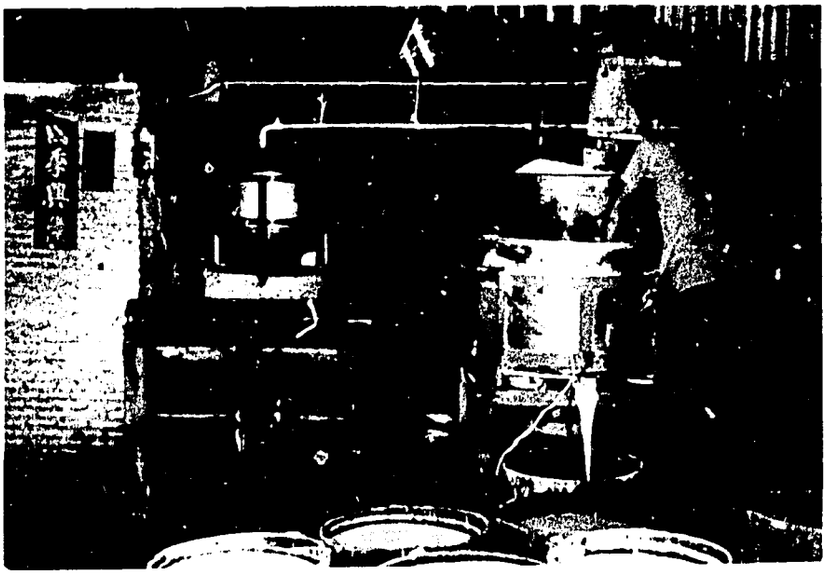


Fig. 8. Transfer of rice flour slurry into the feeding trough of a rice noodle-making machine.

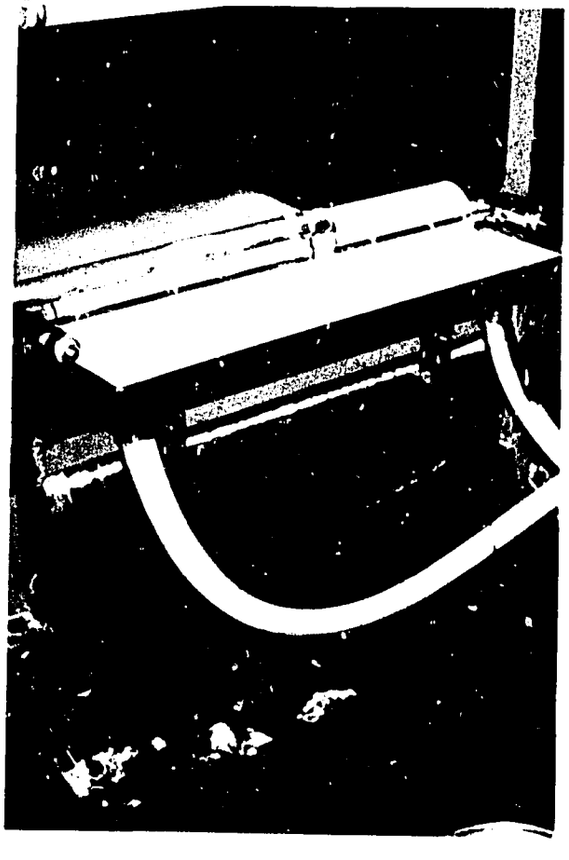


Fig. 9. View of noodle-making machine (steam tunnel).

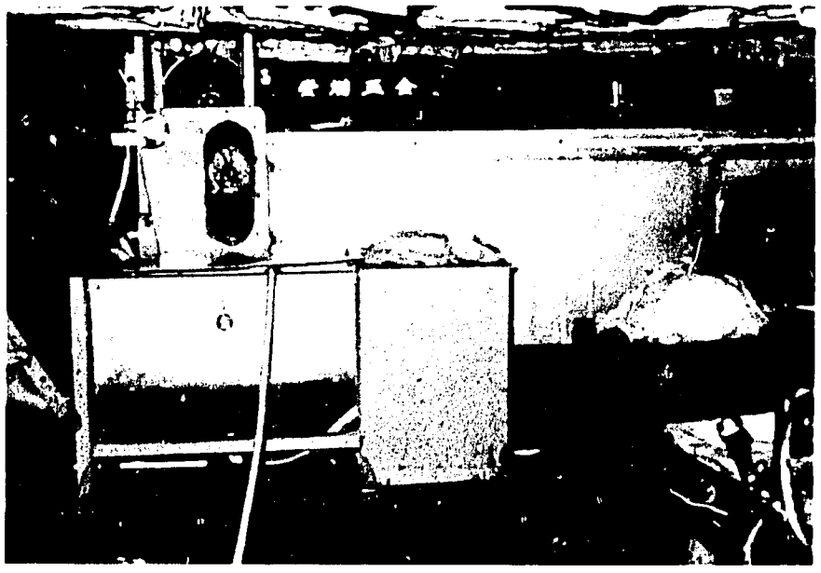


Fig. 10. Production of rice noodle sheets.

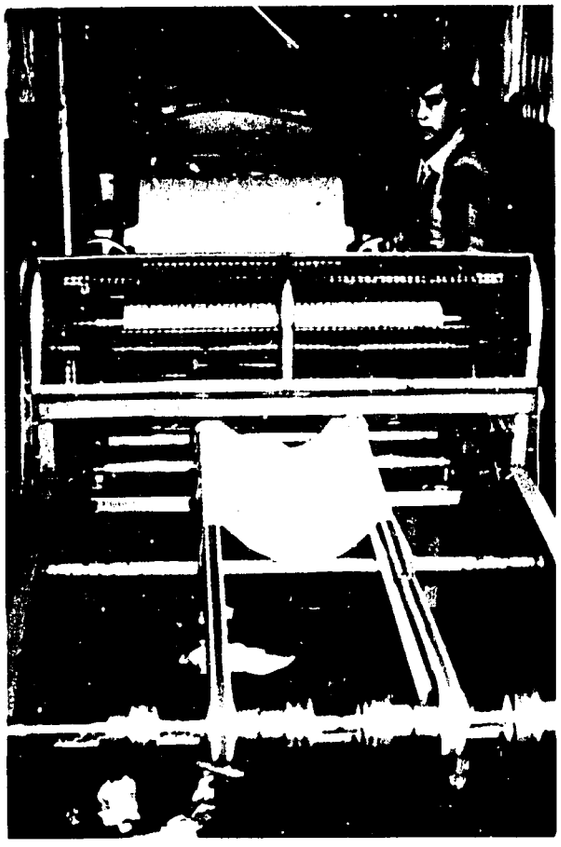


Fig. 11. Air-drying rice noodle sheets.

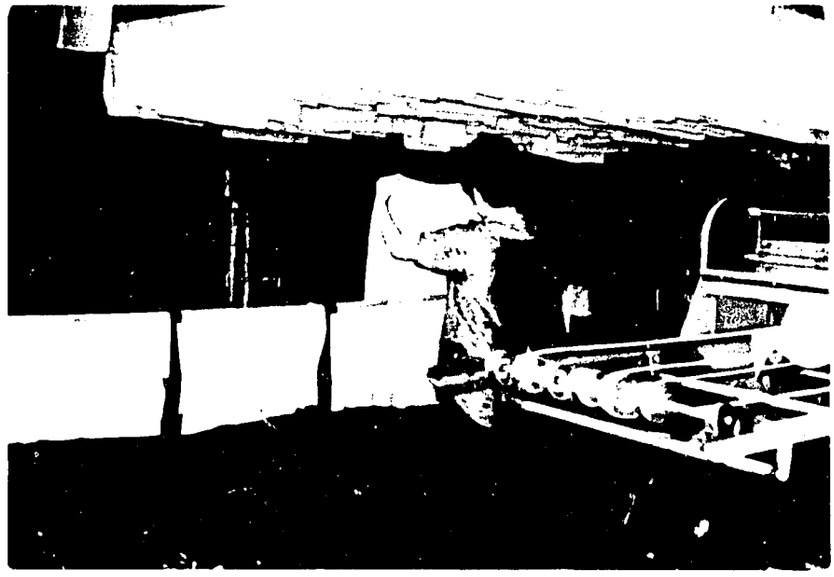
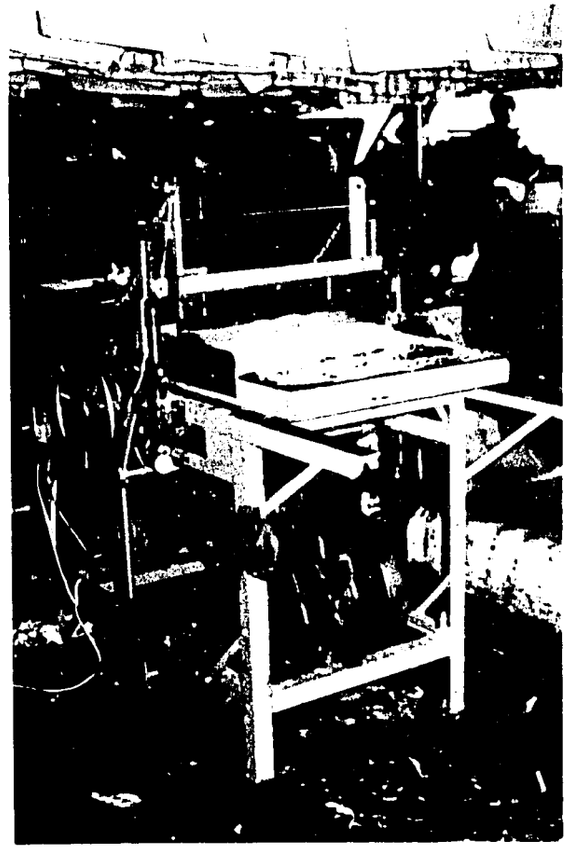


Fig. 12. Rice noodle sheets being cut into noodle strips.



All ingredients added to the rice flour solution were calculated on a dry basis. Basic formulations of the soy-rice solutions (based on 42% solids) are shown in Table IV.

Preparation of the soy-rice noodles was similar to the established traditional manner used for making regular rice noodles. Broken rice was washed in a Nippon stainless-steel rice washer, soaked overnight, and ground into a rice flour slurry in a Sengmui stone grinder. A measured amount of rice flour solution was transferred to a wooden bucket to which pre-weighed full-fat soy flour and pre-measured water was added. The soy flour was hand-stirred with a wooden paddle into the rice solution to obtain a homogeneous mixture. Cassava flour (and methionine) was then added and blended into the mixture. A Sengmui noodle-making machine was used for noodle preparation. The uniform layer of solution on a metal sheet passed through the steam tunnel in 75 seconds. Batch formulations were calculated to yield approximately 40 kilograms of fresh noodles prepared during 10 minutes of machine operation. Soy-rice noodle squares were dried on bamboo sticks for approximately 5 hours. The semi-dehydrated squares were stacked and placed on a Kang Song Lee cutter for cutting into noodle strips (10 in. x 1/8 in. x 1/32 in.).

Soy-rice noodles (600-g. portions) and a control sample were placed in a single layer on perforated metal trays and air-dried outdoors for 4-5 hours. The dehydrated noodles (1-kilogram portions) were double bagged in polyethylene bags. The bags were packed, two to a cardboard carton, and sealed for shipping to Child Nutrition Centers and for future laboratory studies.

3. Cooking Studies on Dehydrated Soy-rice Noodles

a. Cooking time

The method used for cooking noodles consisted of placing 5-g. samples

TABLE IV. FORMULATIONS OF SOY-RICE SOLUTIONS AND COMPOSITION OF SOY-RICE NOODLES

Ingredient	20% Soy	30% Soy	20% Soy plus dl-methionine	30% Soy plus dl-methionine
A. Soy-rice solution				
Rice-flour (42% solids) solution (ml.)	35,040	30,660	35,040	30,660
Full-fat soy flour (g.)	4,000	6,000	4,000	6,000
Cassava flour (g.)	184	276	184	276
dl-methionine (g.)	0	0	37	55
Water (ml.)	8,440	12,660	8,440	12,660
B. Soy-rice noodle[a]				
Rice Flour	79.2	69.0	79.0	68.7
Full-fat soy flour	19.8	29.5	19.8	29.5
Cassava flour	1.0	1.5	1.0	1.5
dl-methionine	0	0	0.2	0.3

[a]Percent, dry basis

(control, 20% soy and 30% soy) into a noodle cooker which consisted of a small round wire basket with a handle. Proper cooking time was determined by placing the cooker and samples into a beaker of boiling water for one, two, three, four, five, six, and seven minutes in individual tests. The wire basket with samples was then immersed in a beaker of cold water for several seconds and removed. Excess water adhering to noodles was removed by placing them on Whatman No. 1 filter paper and applying suction through a Buchner funnel for one minute. A 10-member panel rated each sample cooked at each time period for overall acceptance using a 1-5 hedonic scale (1 corresponded to very bad and 5 corresponded to very good). Appearance, texture, and uniformity were main scoring factors. The cooking times which produced the most acceptable products were used in all future studies and noodle preparation procedures.

b. Rehydration tests

Rehydration ratio and percent of water in rehydrated noodles cooked for two, four, five, six, eight, and ten minutes were determined using modified methods described by von Loesceche (60). The formula for determining rehydration ratio (R) is as follows:

$$R = \frac{W_r}{W_d}$$

where W_r is the drained weight of the rehydrated sample and W_d is the initial weight of the dehydrated sample. The percent of water (W) in rehydrated samples was determined by the following formula:

$$W = \frac{W_r - [W_d - (W_d \times W_m)]}{W_r} \times 100$$

in which W_r is the drained weight of the rehydrated sample, W_d is the weight of the original dehydrated sample, and W_m is the percent moisture in the dehydrated sample. Duplicate 3-g. samples of dehydrated noodles were used in these tests.

4. Storage Studies on Dehydrated Soy-Rice Noodles

a. Storage temperature and relative humidity

Storage studies were conducted during a five-month period on dehydrated soy and regular noodles. Noodles (1-kilogram) were packed in polyethylene bags in cardboard containers for the studies. The samples were stored at temperatures and relative humidities nearly equal to those of outdoor conditions. Daily temperature (° C) and relative humidity (%) were recorded on weekly climatic graphs using a recording instrument (Thies Co., Göttingen, Germany). Monthly average temperatures and relative humidities were tabulated from the graphs.

b. Moisture content of dehydrated noodles

Moisture in the stored samples was determined initially and at 15 (± 2)-day intervals. Representative 25-g. samples were ground in a blendor at medium speed for one minute and duplicate 2-g. aliquots were transferred to tared weighing dishes, covered, dried in an air oven for one hour at 130 ± 3° C., cooled in a dessicator, and weighed. Percent moisture in the samples was calculated from weight loss (55).

c. Rancidity development--refractive index

Rancidity development in stored products was determined using refractive index measurements of the oil contained in the noodles. Refractive index is a useful indicator of oxidative rancidity of oil because the refractive index

increases with oxidation of fat (61). Noodle samples (25-g.) were ground in a blendor at medium speed for one minute. Oil samples were obtained from 10-g. aliquots of these ground samples by Soxhlet extraction (55) for 16 hrs. with petroleum ether. Refractive indices were determined monthly on an Abbe 3L Bausch and Lomb refractometer. All values were reported and calculated at 25° C.

d. Water absorption and disintegration

The rates of water absorption and disintegration of noodle samples were determined monthly according to a modified method described by Radley as stated in Matz (62). Individual 3-g. samples were placed in tared cookers, placed in a beaker of cold water, and weighed. Subsequently, the cooker was immersed in boiling water for five minutes then weighed again in cold water. It was removed, slung in air to remove water adhering to the outside, and wiped dry before being weighed in air. The cooker was returned to the boiling water for an additional five minutes and the weighing processes, in cold water and in air, were repeated for 60 minutes or until the noodles were completely disintegrated. The empty cooker was reweighed in water and air.

A curve for the rate of water absorption was drawn by plotting the weights determined in air against cooking time. The curve obtained from plotting weights determined in water versus cooking time indicated the rate of noodle disintegration since water in the product does not contribute to the observed weight when the product is submerged.

e. Taste panel noodle evaluation

A taste panel comprised of 11 Thai females employed at the Institute was used to evaluate stored noodles. This sensory panel subjectively evaluated the soy-rice noodles and control initially and at monthly intervals during

the five-month storage period. The methionine-fortified samples were also included in sensory evaluation to observe whether or not any differences could be observed among samples as a result of the amino acid fortification. A 9-point hedonic scale method for measuring product preferences was used as described by Peryam and Pilgrim (63). Quality factors scored included appearance, color, flavor, and texture. A score for overall acceptability was determined from the average of the quality factor scores. A sample taste panel score sheet is shown in Fig. 18. Individual portions of all five samples were served to each member in small bowls marked with a two-number code. The noodles were rehydrated in boiling water for the proper cooking time as determined in previous studies. A small amount of hot water was added to each bowl to keep the noodles warm and to maintain freshness. Tests were held during mid-afternoon in the Institute's cafeteria.

5. Product Costs

The consumer costs of all five dehydrated samples were calculated using the following costs (cents per pound) based on September 1, 1973, Bangkok retail prices: broken rice, 4.3; full-fat soy flour, 13.9; cassava flour, 7.7; and dl-methionine, 197.7. Product costs were also calculated as cost per pound of protein with allowances being made for carbohydrate and fat content (64).

B. ACCEPTABILITY STUDIES

1. Child Nutrition Centers

Pre-school age children (average age: 4.5 years) from lower income families attending two child nutrition centers in rural northern Thailand participated in acceptability feeding studies. Seventy children in Ban Yang

Village, Fang District, Chiang Mai Province, and 55 children in Ban Mai Village, San Patong District, Chiang Mai Province, were fed soy-rice noodles, with and without methionine fortification, and regular rice noodles on an alternating schedule once a week for 24 weeks. Regular dehydrated wheat noodles prepared at the Institute were also included in the feeding test schedule for comparison purposes.

Noodles were incorporated into two traditional Thai dishes served on alternate weeks as the mid-day meal. Preliminary investigation into the eating habits of the children and cooking facilities at the Centers indicated that noodle soup and noodles with topping would best fit into the meal schedules at the Centers. Both noodle dishes contained 'Kaset' protein [a textured mungbean and soybean protein (1:1) meat analog]; various vegetables, including pumpkin and cabbage; and small amounts of egg or pork prepared as a vegetable soup or a vegetable topping which was added to boiled noodles.

Approximately 60-g. portions of cooked noodles plus an equal amount of vegetable mixtures were initially given to each child. These amounts were determined from previously-obtained data on daily food consumption and recipe development. Noodle consumption, as an indicator of acceptability, was observed and recorded. Data were reported in four categories as follows:

Category	Extent of Noodle Consumption
1	None
2	Some
3	All
4	Extra portions requested

Initially, visual observations were made of the amount of noodles remaining on each child's plate, and it was recorded by the teachers as 0, 1/4, 1/2, 3/4, and 4/4 (all) of the initial serving. All fractional amounts of uneaten

initial noodle portions were grouped together into category 2 (some) for final tabulation and data reporting. In addition, the total amount of noodles consumed by all children for a particular meal was recorded by measuring the initial amount prepared and subtracting any remaining at the end of the meal. Only noodle consumption was recorded.

During the 24-week test period, each of the four soy-rice noodle samples, the control rice noodle, and the wheat noodle sample were fed twice in two different dishes. Also, data were recorded in the same manner for overall consumption of non-noodle dishes to observe general food acceptability among the children. These dishes included soups and fried or boiled vegetable toppings eaten with rice. Consumption of these dishes was recorded in the same manner used for noodle consumption.

2. Kasetsart University Nursery School

Seventy-two pre-school children (average age: 3.5 years) from upper income families, attending the Kasetsart University Nursery School in Bangkhen, Bangkok, participated in feeding studies during a 14-week period. A similar procedure to that used in the village Child Nutrition Centers was used with a few exceptions. Exact weighing of all initial and additional portions was employed. Each child had a numbered tray in order to keep an exact record of his or her noodle consumption. Noodles remaining after the meal were weighed and subtracted from the amounts originally given. Noodle consumption was reported in four categories from weighed data as follows:

Category	Noodle Consumption	Percent of Initial Serving Eaten
1	None	Less than 10%
2	Some	10-90%
3	All	More than 90%
4	Extra portions requested	More than 100%

Noodle dishes contained various meat ingredients, including fish and ground pork, and vegetables, including kale, bean sprouts, and mushrooms, to make the noodle soup or noodle with topping dishes.

Each soy-rice sample, regular sample, and wheat sample was given once in each of two dishes for the first 12 weeks of the testing period. Also, once-a-week, overall consumption of the regular mid day meal was recorded for comparison purposes. During the last two weeks of the study, children were given a choice of noodles as follows:

Choice

a. 30% soy-rice noodles or regular rice noodles

b. 30% soy-rice noodles or regular wheat noodles

Portions (60-g.) of each noodle product were placed on the same plate, separate from the vegetable-meat mixture. Each child was asked to taste both kinds of noodles and to decide which one he wanted to eat for the meal, being reminded that only one kind of noodle could be chosen. Since the soy-rice, wheat, and regular rice noodles had definite color differences, brown, yellow, and white, respectively, it was possible to visually distinguish and separate the noodle pairs during the day's test. The percentage of children choosing each noodle product was recorded.

In acceptability studies conducted at both rural and urban locations, it was possible to evaluate acceptability of stored noodle samples since all samples were made at the same time. They were served to children after storage for up to six months. All samples were stored in plastic bags under natural environmental conditions.

C. NUTRITIONAL EVALUATION

Dehydrated soy-rice noodles, in some cases with methionine-fortification, and regular dehydrated rice noodles (control) were subjected to various assays and studies as outlined below. Except as noted, these tests were conducted by WARF Institute, Madison, Wisconsin. All samples were ground in a Fitz mill through a coarse sieve, packed in 1-kg. amounts in polyethylene bags, sealed, and put in cardboard boxes.

1. Chemical Analyses

a. Proximate analyses

Protein, moisture, ash, fiber and fat were determined for the samples according to official A.O.A.C. methods (55). Protein content in soy-rice samples was reported as %N X 6.25 according to the prescribed procedure, whereas, protein content in plain rice noodles was expressed as %N X 5.95 since this factor is used for rice (41). Carbohydrate was determined by difference and caloric value was calculated according to the Atwater factors of 4.0 kcal. per g. for protein, 9.0 kcal. per g. for fat, and 4.2 kcal. per g. for carbohydrate (30).

b. Vitamin and mineral analyses

Noodle samples were subjected to vitamin and mineral assays using the procedures outlined in Table V.

c. Amino acid analyses

The amino acid pattern in samples was determined by amino acid analysis using an automatic amino acid analyzer (65). In addition, methionine, cystine, and tryptophan contents were determined microbiologically (66). Percent available lysine was measured according to a published method (67).

TABLE V. ANALYTICAL METHODS FOR VITAMIN AND MINERAL ASSAYS OF NOODLE SAMPLES

	Nutrient	Analytical Method
Vitamin	A	A.O.A.C. (55)
	D	U.S.P. (68)
	alpha-Tocopherol (E)[a]	Association of Vitamin Chemists (69)
	Thiamin (B-1)	A.O.A.C. (55)
	Riboflavin (B-2)	A.O.A.C. (55)
	Pyridoxine (B-6)	Atkins *et al.* (70)
	B-12	U.S.P. (71)
	Niacin	A.O.A.C. (55)
	Folic Acid	A.O.A.C. (72)
Mineral		
	Calcium	Atomic Absorption Spectrometry (73)
	Iron	Atomic Absorption Spectrometry (73)
	Magnesium[a]	Ethylenediamine-tetra-acetic acid (74)
	Phosphorous	A.O.A.C. (55)

[a]Analysis by Department of Science, Ministry of Industry, Bangkok

d. Nutrient cooking losses

The amount of extracted solids, nitrogen, and methionine lost during the rehydration process was determined. Extracted solids were found by cooking 5-g. soy-rice samples and the control in 200 ml. of water using tared beakers. Noodles were cooked for the appropriate time (5 minutes for soy-rice noodles and 6 minutes for regular noodles) as determined in previous tests. After removing the noodles, the cooking water was evaporated to near dryness using electric coil heaters. The beakers were then placed in an air oven for one hour at 130° C., cooled in a desiccator, and weighed. The percent solids extracted was calculated as follows:

$$\% \text{ Solids extracted} = \frac{B_2 - B_1}{5.00} \times 100$$

where B_1 was the initial weight of the beaker and B_2 was the weight of the beaker after cooking.

Nitrogen and protein losses during cooking were determined in appropriate samples which had been rehydrated, cooled in cold water, and air-dried for 5-6 hours. Nitrogen content was determined by the Kjeldahl method (55) on a representative sample of the cooked and uncooked noodles. The difference in calculated protein contents was reported as protein losses during cooking.

In a similar manner, cooked and uncooked methionine-fortified noodles were used for amino acid analyses using an amino acid analyzer in the Department of Chemistry, Kasetsart University, Bangkok. The amount of methionine, expressed as mg./g. of dry product, was found and the differences between cooked and uncooked samples were used to indicate methionine loss during cooking.

e. Chemical score

Chemical score was calculated from essential amino acid patterns according to the procedure described by FAO (30). A new amino acid scoring pattern was used in this procedure. The chemical score, expressed as a percentage, is related to the value of the most limiting amino acid found in the test samples. It is calculated from the following equation:

$$\text{Chemical score} = \frac{\text{mg. of amino acid in one g. test protein}}{\text{mg. of amino acid in reference protein}} \times 100$$

The amino acid having the lowest percentage (chemical score) is the limiting amino acid and represents the chemical score for that protein.

2. Biological Studies

a. Protein efficiency ratio (PER) and net protein utilization (NPU)

The nutritive value of the noodles was evaluated using experimental animals. Two parameters were used to evaluate protein quality: protein efficiency ratio (PER) and net protein utilization (NPU) (57). According to the official method for determining PER (55), 10 male albino rats were fed *ad libitum* during a 4-week period on a 7.1% protein diet based upon the noodle samples. The ration contained added sucrose, oil, fiber, and adequate amounts of vitamins and minerals for optimum rat growth. A reference group using casein as the protein source was also included in the study. Food consumption and weight gain were recorded and averaged weekly. The PER was determined as follows:

$$\text{PER} = \frac{\text{Weight gain}}{\text{Protein intake}}$$

The PER values were compared to casein and corrected values were reported based upon a PER of 2.50 for casein.

NPU was determined during a 10-day feeding study using 5 animals per group per sample on a 7.1% protein diet. The values obtained were compared to casein at the same protein level in the diet. The NPU was calculated as follows (59):

$$NPU_{7.1} = \frac{\text{Carcass } N_2 \text{ Test Group} - \text{Carcass } N_2 \text{ Non-protein Group}}{N_2 \text{ Intake of Test Group}} \times 100$$

b. Protein costs based on PER

PER was used to illustrate the nutritive value of the soy-rice noodles on a protein cost basis as compared to regular (control) rice noodles. A protein cost analysis for these products was made in which a factor, termed protein cost ratio (PCR), was determined (75). PCR gives the weight gain per unit cost of protein consumed. The following costs (cents per pound) were used to calculate PCR: regular dehydrated rice noodle, 6.4; 20% soy noodle, 8.3; 30% soy noodle, 9.3; 20% soy noodle plus methionine, 8.7; 30% soy noodle plus methionine, 9.9; and casein, 65.

II. HIGH-PROTEIN RICE-BASED SNACKS

A. DEVELOPMENT

1. Initial Studies

a. Formulations

Initial snack formulations were based upon the addition of high-protein ingredients to rice flour. Full-fat soy flour (25 or 30% based on rice flour), with and without additions of ground sesame and fish protein concentrate, was added to a 1:1 mixture of rice flour and water. Preliminary studies had shown that 2% salt (rice flour basis) gave an acceptable product

as judged both by adults and elementary school children. Subsequently, small additions of curry powder and chili pepper powder with salt were added to the rice flour and protein supplements for preparation into snack prototypes.

b. Preliminary snack preparations

Snack prototypes were initially developed using the various amounts of full-fat soy flour, ground sesame, and fish protein concentrate added to a rice flour base. Rice flour was made at the Institute in the traditional manner using a stone grinder. A 1:1 mixture of rice flour (54% solids) and water were blended with the ingredients to form a solution containing approximately 36% solids. The snacks were made in a manner similar to that used for making rice noodles. Mixtures were poured onto rectangular metal trays and allowed to spread evenly over the entire surface. After steam blanching for two minutes, the trays were allowed to cool for several minutes. The rectangular noodle sheet was peeled from the tray and semi-dried in a cabinet drier at 45° C. The sheet was then hand-cut into various-sized, small squares and rectangular pieces and oven-dried for 1 hour at 70° C. The dried snack pieces were subsequently placed in hot oil (approximately 175° C) for several seconds to produce an edible, textured, crispy snack food item. Further formulation studies were continued to develop the most acceptable products using appearance, texture, and flavor as prime criteria for product acceptance.

2. New High-protein Rice Snacks

a. Laboratory prototypes

Initially, six formulations were used to prepare prototypes formulated as shown in Table VI. These formulations, prepared into laboratory prototypes, were used for initial subjective preference evaluation by elementary

TABLE VI. FORMULATIONS OF LABORATORY SNACK PROTOTYPES

Ingredient %[a]	Formula Number					
	1	2	3	4	5	6
Rice flour	100	100	100	100	100	100
Water	100	100	100	100	100	100
Full-fat soy flour	30	30	30	25	25	25
Ground sesame	0	0	0	5	5	0
Fish protein concentrate	0	0	0	0	0	5
Salt (iodized)	2	2	2	2	2	2
Curry powder	2	1	0.5	1	0.5	0.5
Chili pepper powder	0	0	0.5	0	0.5	0.5
Scores[b]	3.70	3.86	4.42*	4.09*	4.32*	3.82

[a]Rice flour basis. Each ingredient is shown as a percent of the amount of rice.

[b]Average score obtained using a five-point hedonic scale: 1 = very bad, 5 = very good. * Significantly equal ($P < 0.01$).

school children using a 5-point hedonic scoring system. The three snacks obtaining the highest score (Formulae 3, 4, and 6) were used for further development and acceptability studies. These included soy flour as the main protein-supplement and combinations of soy flour with ground sesame or fish protein concentrate. Sesame seed is a locally-available, high-protein oilseed which contains a high amount of methionine, an essential sulfur-amino acid most deficient in soy flour. Fish protein concentrate contains a high level of animal-quality protein in addition to a large amount of calcium and phosphorous.

The soy-sesame and soy-fish snacks were prepared in the laboratory in the manner previously described which was similar to that used for making rice noodles. The various sized, dried snack pieces (500 g.) were packed in polyethylene bags, placed in a plastic bucket with cover, and stored at ambient temperature for future evaluation and acceptability studies. The formulation containing soy flour as the only protein-supplement (Formula 3) was used for large-scale preparation of snack "soy chips" at the noodle factory.

b. Factory preparation--soy chips

Rice flour solution, full-fat soy flour, and seasonings were mixed with additional water to obtain a mixture containing 40% solids. This enabled ingredients to be added at the same dry-basis percentage used in the original prototype. In addition, this snack contained approximately the same amount of soy flour and rice found in the 30% soy-rice noodle. The factory-prepared soy chip snack was in essence a modified form of a soy-rice noodle. Soy chips were formulated as shown in Table VII.

Since the snack was prepared in a manner similar to that used for making rice noodles, a Sengmui noodle-making machine was used to prepare large snack

TABLE VII. FORMULATION OF SOY CHIPS

Ingredient	Batch formulation	Dry basis %
Rice flour solution	30,660 ml.	65.7
Full-fat soy flour	6,000 kg.	29.6
Cassava flour	276 g.	1.5
Salt (iodized)	440 g.	2.3
Curry powder	110 g.	0.6
Chili pepper powder	55 g.	0.3

TABLE VIII. EXTRUDED SNACK (SOY CURLS) FORMULATION

Ingredient	Dry basis %
Broken rice	67.7
Soy protein concentrate	29.1
Salt (iodized)	2.3
Curry powder	0.6
Chili pepper powder	0.3

sheets. After semi-drying in air for five hours in the usual fashion, the snack squares were transported to the Institute where they were cut into small circles or discs using cookie cutters. These soy snack pieces were placed in a single layer on perforated metal trays and dried in an air oven for 1.5 hours at 70° C. Polyethylene bags containing 100-g. portions of the snack chips were put in a plastic bucket, covered, and stored for future use in evaluation and acceptability studies.

c. Extruded snack--soy curls

Extrusion cooking is a useful method for developing and producing crispy, textured, ready-to-eat, cereal-based snack items possessing good shelf life. A wide range of product forms, shapes, and densities can be produced on a cooker extruder using various raw ingredients including cereal grains, oilseeds, and legumes (76).

A high-protein snack in the form of a puffed curl was made on a Wenger X-25 cooker extruder under a pressure of 200 psi at a temperature of 125° C. The snack formulation included soy protein concentrate, broken rice, salt, curry powder and chili pepper powder. The soy protein concentrate was prepared by acid precipitation of a soy protein solution (44). Broken rice was ground into a coarse flour on a Fitz mill. The extruded product was machine cut into 2 inch long pieces (curls) and dried in a continuous tunnel drier for 17 minutes at 130° C. An initial 50 kg. batch was used in the test. The extruded snack formulation is shown in Table VIII. The dried snacks were packed in polyethylene bags and stored in plastic buckets for future acceptability testing.

d. Moisture and fat contents

The moisture contents in the high-protein snacks were determined

initially and at 3- and 6-month intervals. The moisture content in the extruded snack was determined initially and after 3 months of storage. Samples (25 g.) of each snack were ground in a blendor for one minute at medium speed and duplicate 2-g. portions were placed in aluminum weighing dishes, covered, and oven-dried for one hour at 130° C. The dishes were later cooled in a desiccator and weighed. Moisture content was calculated as the weight loss in the samples.

Changes in moisture and fat content in the snacks after deep-fat frying were determined using standard analytical methods. Moisture content was measured in the same manner used for snacks before frying. Fat content was determined using Soxhlet extraction with petroleum ether (55).

3. Regular Snacks

a. Fried chips and soy cookies

Three commercially available snack food items were used in sensory evaluation studies as control samples: 1. shrimp-flavored chips; 2. red-colored chips; 3. soy cookies. The chip snacks were dehydrated pieces which were deep-fat fried for several seconds into enlarged, crispy, snack chips. The shrimp chip was a relatively expensive and familiar snack food containing ground, dehydrated shrimp added to a cassava flour base. In contrast, the red chip was an inexpensive snack containing food coloring added to a mixture of cassava and rice flours. Both products were available in rural and urban market places. Soy cookies (Fig. 6), recently introduced snack products which were developed at the Institute as a protein supplement for Child Nutrition Centers (11), were also included as a control.

b. Moisture and fat contents in chips

Moisture content was determined in the dried, shrimp-flavored and red-colored chips initially and after 3-months storage. The moisture and fat contents in these snacks after frying were also measured according to previously described methods.

4. Product Costs

Consumer costs of the high-protein rice snacks and regular snacks were calculated using the following costs (cents per pound) based on September 1, 1973, Bangkok prices: broken rice, 4.3; full-fat soy flour, 13.9; ground sesame, 18.2; fish protein concentrate, 35.0; soy protein concentrate, 61.2; iodized salt, 8.0; curry powder, 56.8; chili pepper powder, 56.8; shrimp-flavored chips, 24.3; red-colored chips, 8.3; and soy cookies, 31.8. Product costs were also calculated per pound of protein with allowances being made for carbohydrate and fat contents (64).

B. ACCEPTABILITY STUDIES

1. Elementary School Children

Elementary school children in Bangkok participated in acceptability tests of snacks. One hundred and sixteen first-graders from upper income families attending the Kasetsart Demonstrated School and 82 first-graders from lower income families at the Bang Bua Elementary School participated in preference scoring of these snacks. A five-point hedonic scale containing five facial expressions was used. The pictures were designed to correspond to a child's feeling concerning the snack item (54). The snacks were scored on a 1.0-5.0 scale, having five preference categories corresponding to facial expressions, as shown in Table IX. A sample snack evaluation score sheet is

TABLE IX. PREFERENCE SCORING OF SNACKS BY CHILDREN

Score	Facial expression	Word association
1.0	Very sad	Really bad
2.0	Sad	Pretty bad
3.0	Neither happy nor sad	So-so
4.0	Happy	Pretty good
5.0	Very happy	Great

TABLE X. SCORING SCHEDULE FOR SNACKS

Snack	Storage periods (months)		
	0	3	6
Soy chips (factory-prepared)	K[a]	K,B[b]	K,B
Soy-sesame chips (original prototype)	K	---	K
Soy-fish chips (original prototype)	K	---	K
Soy curls (extruded)	K,B	K,B	---
Shrimp-flavored chips	K,B	K,B	---
Red-colored chips	K,B	K,B	---
Soy cookies	K,B	K,B	---

[a]K-Kasetsart Demonstrated School

[b]B-Bang Bua Elementary School

shown in Fig. 26.

The percentage of children scoring the snacks in each category was tabulated and the combined percentage of those scoring the snacks 4.0 and 5.0 (corresponding to the appropriate facial expression) was established as the Snack Acceptability Index (SAI).

The six preliminary prototypes were initially scored by the children at the Kasetsart Demonstrated School. Subsequent scoring of the two highest scoring items (Formulae 4 and 6), those containing combinations of soy and sesame or fish, was conducted after 6-months storage. The snack containing only soy (Formula 3), which was factory-prepared into chips, was scored initially and after 3- and 6-months storage. The extruded puffed curls, regular shrimp-flavored chips, red-colored chips, and soy cookies were scored by these children initially and after 3-months storage.

The school children at Bang Bua School participated in similar snack acceptability scoring tests. The factory-prepared soy chips were scored after 3- and 6-months storage. Extruded snacks, shrimp-flavored chips, red-colored chips, and soy cookies were rated initially and after 3-months storage. A summary of the scoring schedule for each snack by inidividual schools is outlined in Table X.

C. NUTRITIONAL EVALUATION

1. Proximate Analyses

Protein, moisture, ash, fiber, and fat were determined according to official A.O.A.C. methods (55). Carbohydrate was calculated by difference and caloric value by Atwater factors for calories per gram of nutrient (30).

2. Vitamin and Mineral Analyses

The soy chips and soy curls were analyzed for vitamin and mineral content at the Department of Science, Ministry of Industry, Bangkok. Vitamins were assayed according to procedures of the Association of Vitamin Chemists (69) as shown in Table XI.

Calcium, iodine, and iron content were determined according to official A.O.A.C. methods (55). Phosphorous content was determined colorimetrically (77), and magnesium content was measured by the ethylenediamine-tetra-acetic acid method (74).

TABLE XI. VITAMIN ASSAYS AND METHODS OF ANALYSIS FOR SOY CHIPS AND SOY CURLS

Vitamin	Method of Analysis[a]
A	Ultraviolet (UV)
alpha-Tocopherol (E)	Colorimetric
Thiamin (B-1)	Fluorometric
Riboflavin (B-2)	Fluorometric
Pyridoxine	Microbiological assay
Niacin	Microbiological assay

[a]Reference 69

RESULTS AND DISCUSSION

I. HIGH-PROTEIN DEHYDRATED SOY-RICE NOODLES

A. DEVELOPMENT

1. Product Design

Dehydrated soy-rice noodles could meet the basic need for increasing the protein intake of Thai children. Protein supplementation of traditional rice noodles by addition of full-fat soy flour has the advantage of presenting a new high-protein food in a familiar form. Consequently, soy-rice noodles could easily be adapted to the Thai dietary pattern without changing existing food habits. Introduction of soy-supplemented rice noodles as a dietary protein source in child feeding programs utilizes the country's cereal staple in combination with a familiar and available vegetable protein source.

Rice noodles are a popular food consumed in every part of the country by people of all ages and of all economic status. They are readily available in numerous food shops both in urban and rural localities. Noodle dishes are especially popular at lunch, when they are eaten as a complete mid-day meal. Quickly-prepared traditional rice noodle dishes include soup and noodles-with-topping which contain vegetables, small amounts of beef, pork, or fish, and various spices added to the noodles. Since noodles are consumed in large quantities as a main dish, high-protein noodles represent a suitable means for increasing protein intake. These noodles have potential for production at the village level since the processing method is simple and similar to

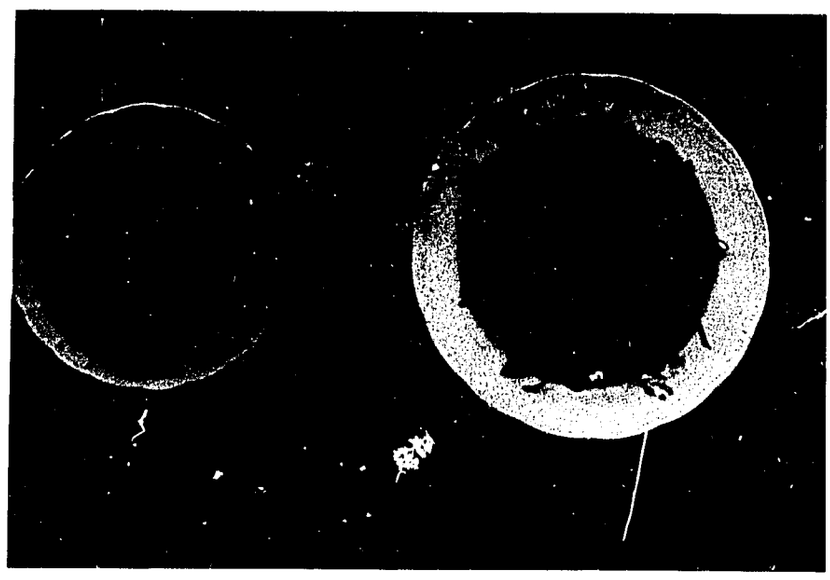
that used for making ordinary rice noodles.

Dehydrated soy-rice noodles have additional favorable features which support their use in child feeding programs at rural localities. As a low moisture product, soy-rice noodles have long shelf life and ease of handling during transport. Meal preparation is relatively simple since no additional cooking utensils or equipment are needed other than those normally available and used at Child Nutrition Centers. Since the noodles are prepared separately from the soup or topping mixture by boiling in water, standardized recipes can be used. Specific amounts of noodles can be served to each child and the protein intake from noodles can be calculated. Figs. 13 and 14 show the soy-rice noodles and control samples (regular rice and wheat noodles) used in product evaluation studies and soy-rice noodle dishes used for child acceptability studies, respectively.

Studies on the development of soy-wheat noodles specifically for Thailand have demonstrated the feasibility of incorporating this food into the Thai diet as an acceptable protein source (48). Furthermore, previous investigations (47, 50) concerning the development of wheat noodles containing soy flour have shown definite improvement in both protein quality and quantity as compared to regular products. A combination of two protein sources has the advantage of providing mutual supplementation of the proteins. Similarly, the high amount of lysine found in soy flour can compensate for the corresponding low amount present in rice. Consequently, this blend exhibits a higher biological value than would otherwise occur for the individual proteins (37). A protein efficiency ratio (PER) of 2.77 (casein = 2.50) was reported for a mixture of rice and soy flours in which rice provided two-thirds of the protein and soy flour provided one-third of the protein (78).

Fig. 13. Dehydrated and cooked noodles: regular rice (1), 20% soy-rice (2), 30% soy-rice (3), and wheat (4).

Fig. 14. Thai noodle dishes containing 30% soy-rice noodles: noodle soup (1), and noodles with topping (2).



The dehydrated soy-rice noodles developed for this study contained 20 and 30% full-fat soy flour (dry basis). In these noodles rice provided approximately 40 and 30% of the protein and soy flour provided 60 and 70% of the protein, respectively. In addition, since soy flour has been reported (78) to be deficient in methionine, 20 and 30% soy-rice noodles fortified with 0.2 and 0.3% dl-methionine (dry basis), respectively, were made. Additions of soy flour to rice flour were intended to increase both the quantity and quality of protein in the soy-rice noodles. These noodles were formulated to contain more than twice the protein found in ordinary rice noodles. Protein quality, as determined by chemical and biological evaluation (chemical score, PER, NPU), was intended to compare favorably with that of animal protein sources. The ability of soy-rice noodles to provide higher amounts of good quality protein than regular rice noodles would be advantageous since less protein would have to be provided by more expensive animal protein sources.

2. Cooking Studies

a. Cooking time

The optimum cooking time for dehydrated regular and soy-rice noodles, as judged by a ten-member panel, was determined. Individual samples (5 g.) of each product were scored on a 5-point hedonic scale (1 = very bad, 5 = very good) after rehydration in boiling water at one-minute intervals for one to seven minutes. Regular and soy-rice samples cooked for one, two, and three minutes received the lowest average score of 1.0. Regular rice noodles cooked for four, five, six, and seven minutes received average scores of 1.1, 2.0, 4.4, and 2.2, respectively. Similarly, soy-rice noodles cooked for four, five, six, and seven minutes received scores of 2.8, 4.4, 2.2, and 1.1,

respectively. These scores indicated that regular noodles were best-liked after rehydration for six minutes (score 4.4), whereas soy-rice noodles were best-liked after cooking for five minutes (score 4.4). Soy-rice noodles, therefore, reached optimum rehydration after a shorter cooking time than noodles not containing added soy flour. Regular noodles could be cooked longer because the rice gel structure could absorb more water than the soy-rice gel. The soy-rice noodles contained less starch since soy flour is deficient in starch.

b. Rehydration tests

The rehydration ratio and water content of rehydrated noodles were determined in samples cooked for two, four, five, six, eight, and ten minutes (Table XII). The rehydration ratios for regular noodles ranged from 2.4 to 4.4, whereas soy-rice noodles had similar ratios ranging from 2.3 to 4.4. An increase in rehydration ratios with increased cooking times was observed for both products. The percent water in rehydrated samples (regular and soy-rice) increased with increasing cooking time. Overall, regular noodles absorbed more water than those containing soy flour at corresponding cooking times. Addition of soy flour to wheat noodles has been reported to decrease water absorption during cooking (79). A decrease in water absorption and a firmer product is a result of the higher fat content in soy noodles. The water content for noodles cooked five and six minutes averaged 74.8% for regular noodles and 73.4% for soy-rice products.

3. Storage Studies

a. Storage temperature and relative humidity

Atmospheric conditions were recorded daily during the five-month period

TABLE XII. REHYDRATION RATIO[a] AND WATER CONTENT OF REHYDRATED RICE NOODLES (CONTROL) AND SOY-RICE NOODLES

Samples	Cooking time (min.)						
	0	2	4	5	6	8	10
Drained weight (g.) of rehydrated noodles[b]							
Regular rice noodle	3.0[c]	7.2	9.7	10.0	11.3	13.2	13.3
20% Soy-rice noodle	3.0	7.0	8.5	10.0	10.4	11.5	13.2
30% Soy-rice noodle	3.0	7.0	9.0	9.7	11.0	11.3	12.6
Rehydration ratio							
Regular rice noodle	0	2.4	3.2	3.3	3.8	4.4	4.4
20% Soy-rice noodle	0	2.3	2.8	3.3	3.5	3.8	4.4
30% Soy-rice noodle	0	2.3	3.0	3.2	3.7	3.8	4.2
Water content (%) of rehydrated noodles							
Regular rice noodle	10.8	62.8	72.4	73.2	76.3	79.7	79.9
20% Soy-rice noodle	9.5	61.2	68.1	72.8	73.9	76.4	79.4
30% Soy-rice noodle	8.5	60.8	69.5	71.7	75.0	75.7	78.2

[a]Rehydration ratio = $\frac{\text{weight of rehydrated sample}}{\text{weight of dehydrated sample}}$

[b]Initial weight (dehydrated) was 3.0 g.

[c]Average of three measurements for all data

dehydrated noodles were stored. Temperatures (° C.) and relative humidities (%) were recorded on climatic graphs and their monthly average was calculated (Table XIII). A small decrease in the average monthly temperature with a corresponding increase in average monthly relative humidity was observed. Average temperature during the five-month storage period was 29.6° C. (85.3° F.), and the average relative humidity was 79.8%. Since the storage studies were conducted from May through September, which corresponded to the rainy season in Thailand, the observed climatic data was that anticipated. Atmospheric conditions experienced during this period represent unfavorable storage conditions for dehydrated foods due to large amounts of precipitation and high relative humidities. However, studies on the "keeping quality" of food products, e.g., dehydrated noodles, during severe weather conditions can give a true indication of the storage stability of these products.

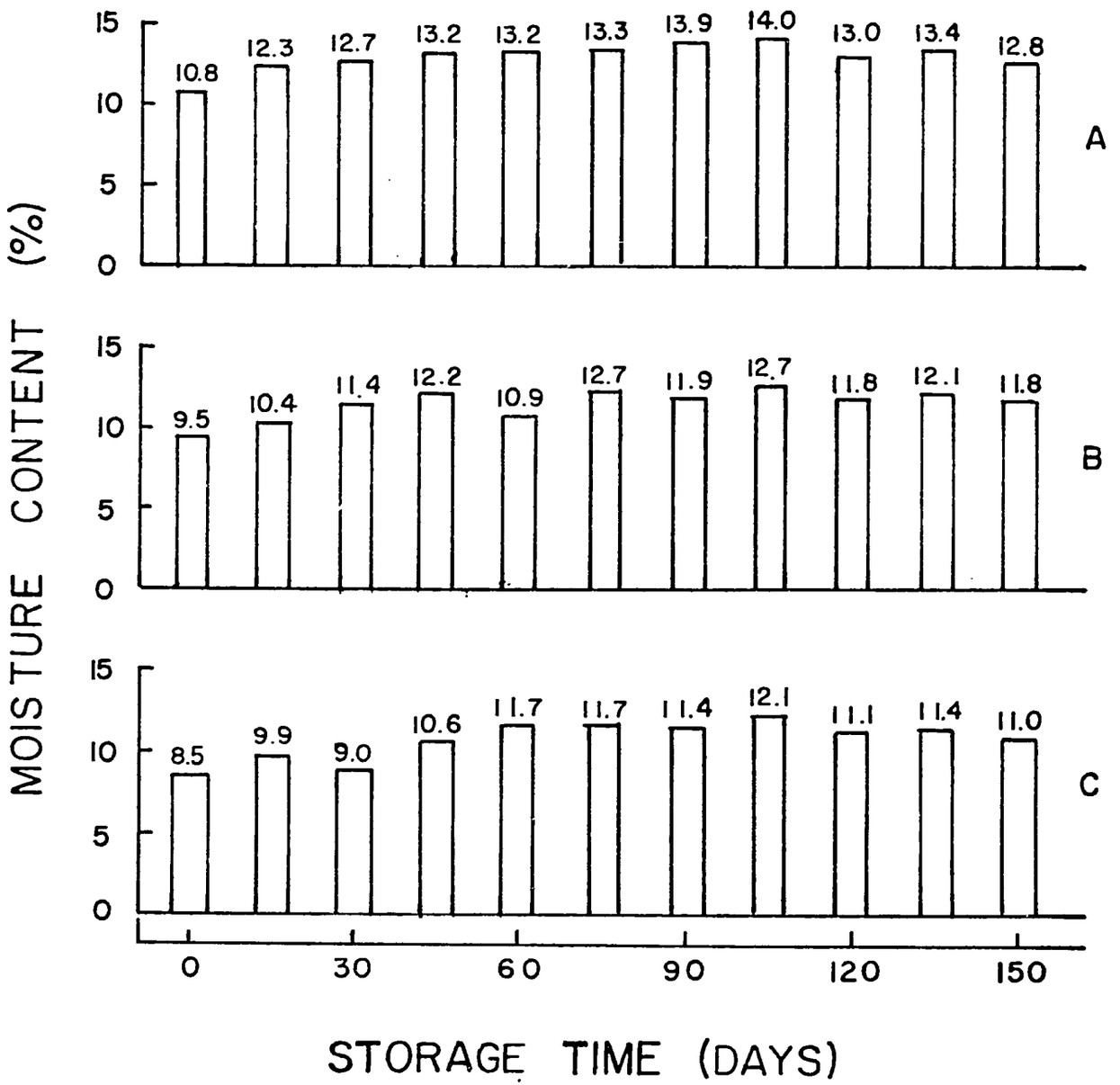
b. Moisture content of dehydrated noodles

Moisture contents of dehydrated noodles determined initially and at 15 (±2) day intervals are illustrated in Fig. 15. An increase in moisture content was observed in both regular and soy-rice noodle samples. A similar increase of moisture content in soy-wheat noodles stored for a period of several months has been reported (48). Moisture uptake in stored cereal products depends upon the amount of water vapor corresponding to relative humidity present in the atmosphere (80). Conditions of high humidity will result in increased moisture content in stored products. All samples reached maximum moisture content after storage for 105 days. After this a slight decrease and subsequent stabilizing of moisture content was observed. Regular, 20% soy-rice, and 30% soy-rice noodles had maximum moisture contents of 14.0, 12.7, and 12.1%, respectively. Moisture uptake by soy-rice noodles was less

TABLE XIII. ATMOSPHERIC CONDITIONS DURING STORAGE OF DEHYDRATED NOODLES FOR FIVE MONTHS

Month	Average temperature °C.	Average temperature °F.	Average relative humidity %
1	30.4	86.6	76.1
2	29.9	85.8	80.1
3	29.7	85.4	79.4
4	29.2	84.6	80.4
5	28.9	84.0	83.1
Average	29.6	85.3	79.8

Fig. 15. Moisture contents of dehydrated regular (control) rice noodles (A), dehydrated 20% soy-rice noodles (B), and dehydrated 30% soy-rice noodles (C) stored for five months.



than that for regular samples. These findings support previous observations of decreased moisture absorption in soy-supplemented macaroni products (47).

c. Rancidity development--refractive index

Refractive index measurements (Abbe refractometer) of the oil content in stored rice noodles were used as indicators of rancidity development. A major factor related to the "keeping quality" of foods involves development of rancidity by oxidation of fat. A correlation between increase in refractive index and increase in fat oxidation has been reported (61). As illustrated in Table XIV, the refractive indices for stored rice noodle samples (control and soy-rice) did not change as indicated by monthly determinations. The average refractive indices at 25° C. for regular, 20% soy-rice, and 30% soy-rice samples were 1.462, 1.470, and 1.472, respectively. The values for soy-rice noodles correspond to values reported (1.474-1.476) for soybean oil (61). The refractive index for rice oil was found to be 1.464. Apparent stability of the oil content in stored noodles, as indicated by a lack of changes in refractive index, was observed.

d. Water absorption and disintegration

The rates of water absorption and disintegration were determined for stored noodles at monthly intervals as indicators of noodle strength and quality. Figs. 16 and 17 illustrate water absorption and noodle disintegration rates, respectively, at the time of noodle preparation (0 time) and after storage for one, two, three, four, and five months. Regular rice noodles had higher rates of water absorption with corresponding lower rates of disintegration than did soy-rice noodles initially and during the first two months of storage. A definite increase in the strength of the regular rice noodles was observed during this two-month storage period.

TABLE XIV. REFRACTIVE INDEX OF DEHYDRATED RICE NOODLES STORED FOR FIVE MONTHS

Sample	Refractive Index[a] Storage time (months)						Average
	0	1	2	3	4	5	
Regular (Control)	1.462	1.463	1.463	1.462	1.462	1.463	1.462 ± 0.0005
20% Soy	1.468	1.469	1.468	1.472	1.470	1.470	1.470 ± 0.001
30% Soy	1.473	1.472	1.472	1.472	1.472	1.472	1.472 ± 0.0002

[a]Average of three measurements for duplicate samples. Refractive index reported at 25° C.

[b]Standard deviation.

Fig. 16. Rates of water absorption for dehydrated rice noodles at time of preparation (0 time) (A) and stored for one (B), two (C), three (D), four (E), and five months (F): —— control, ---- 20% soy, . . . 30% soy.

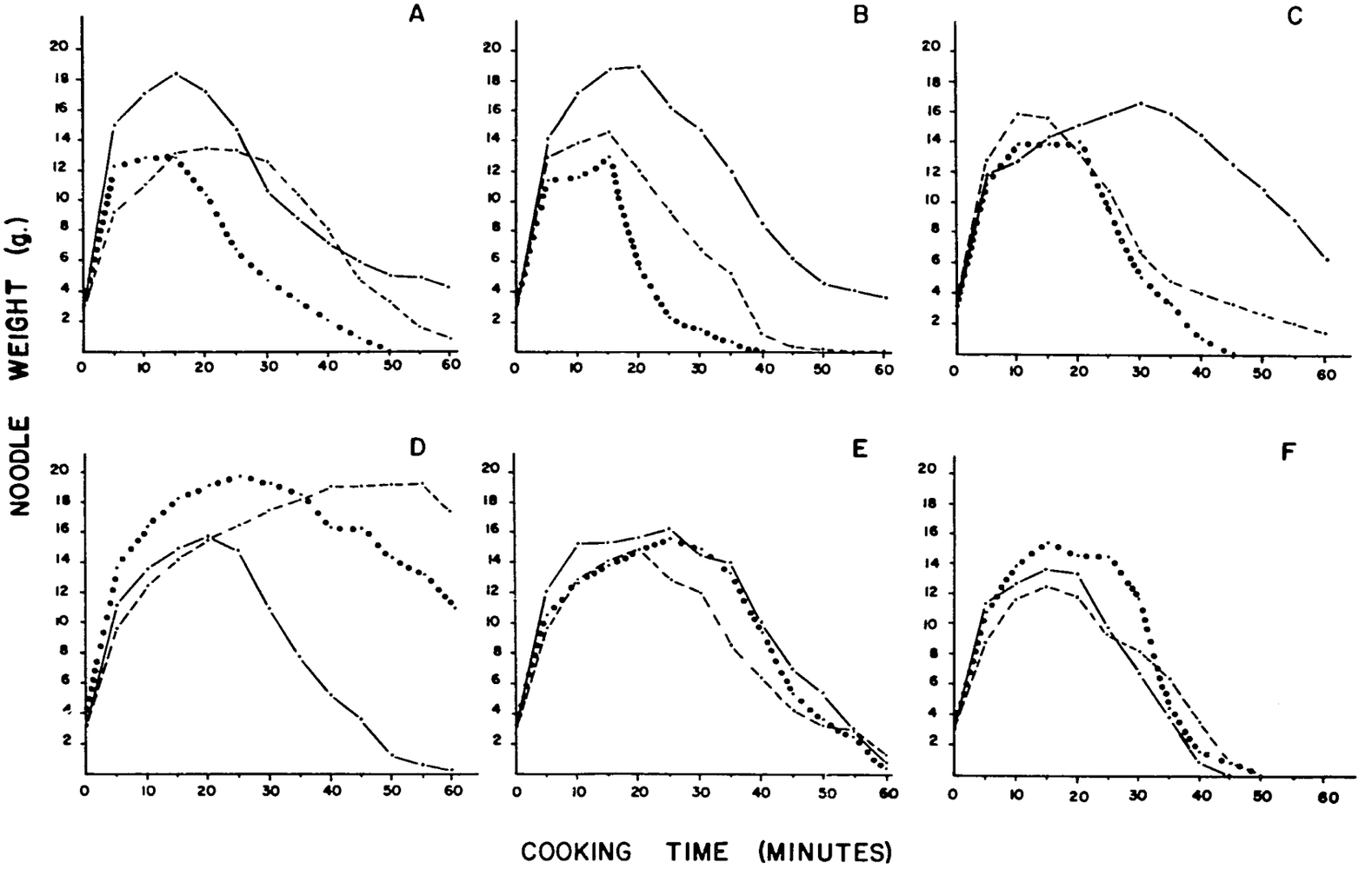
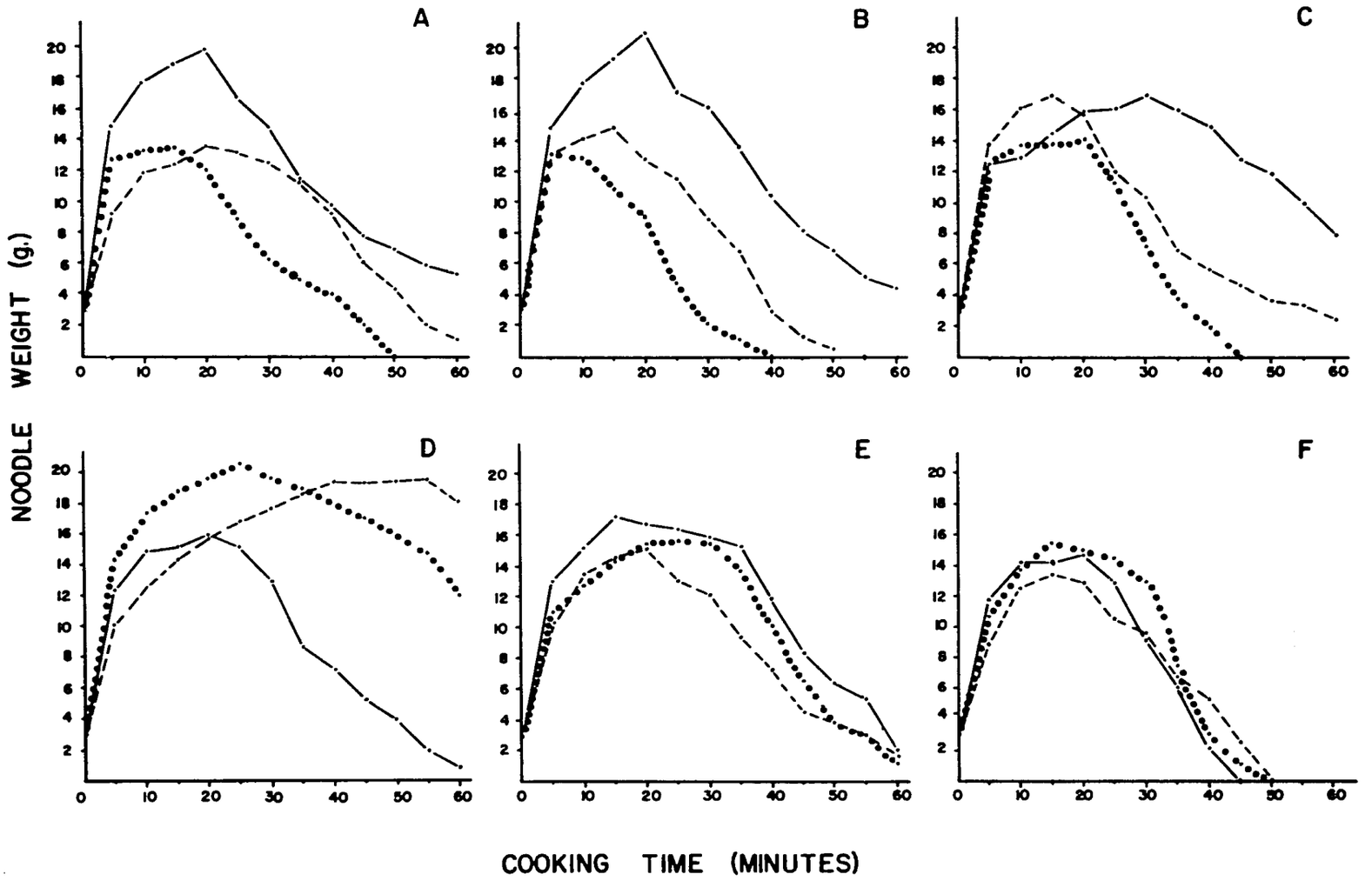


Fig. 17. Rates of disintegration for dehydrated rice noodles at time of preparation (0 time) (A) and stored for one (B), two (C), three (D), four (E) and five months (F): —— control, ---- 20% soy, . . . 30% soy.



Continued absorption and disintegration studies illustrated significant changes in the cooking properties of regular and soy-rice noodles. After three months storage [Figs. 16(D) and 17(D)], soy-rice noodles exhibited a marked increase in their rates of water absorption and decrease in noodle disintegration. A continuous decrease in absorption rates and increase in disintegration rates for the regular product was observed. As studies continued up to five months, similar decreases in absorption rates and increases in disintegration rates were observed for the soy-rice noodles.

Upon reviewing these studies, it is interesting to observe that regular noodles had increasing absorption and decreasing disintegration rates up to two months of storage. After this time, these rates sharply reversed. Soy-rice noodles, however, continuously increased in noodle strength (low disintegration rates) from the initial storage to three months, after which there was an increase in disintegration rates. Apparently, noodle strength and water absorption capacity of soy-rice noodles improved more markedly during storage than that of regular noodles. Maximum water absorption occurred after three months storage for regular rice noodles at a cooking time of 20 minutes, whereas that of the soy-rice noodles occurred after three months storage at a cooking time of 55 and 25 minutes for the 20% and 30% soy-rice noodles, respectively, after three months storage.

Increased firmness and cohesion has been reported in macaroni products containing soy flour (47). The improved cohesion and strength of soy-rice noodles as compared to regular rice noodles can be attributed to the presence of lecithin in full-fat soy flour. Soy-rice noodles are gels made from solids (soy, rice) dispersed in a liquid (water). Since lecithin is a surfactant, it can form a stable, solid-liquid dispersion by lowering the interfacial tension of the solid particles in the initial soy-rice solutions, thus

forming a cohesive soy-rice noodle gel.

Increases in water absorption and strength characteristics to maxima during storage might furthermore be associated with development of free fatty acids in the rice noodles. Although no increase in rancidity due to fat oxidation was evident in stored rice noodles as indicated by constant refractive indices, it is possible that some non-enzymatic hydrolysis of fat did occur with production of free fatty acids. The higher fat content in soy-rice noodles than in regular noodles would provide opportunity for more fatty acids to be produced. Increases in free fatty acid contents with increases in peak viscosities have been observed in stored milled rice (81).

Knowledge concerning the water absorption and disintegration rates of stored dehydrated rice noodles is important since subsequent preparation of the noodles for consumption involves rehydration in boiling water. Changes in the nature of the noodles which would adversely affect texture and disintegration of the product are detrimental. Higher losses of solids could affect both the nutritional quality and acceptability of the product. Although significant changes, primarily in noodle texture, did not occur during normal rehydration (five to six minutes), observations of changes resulting from longer rehydration periods may lead to the improvement in the quality of soy-rice noodles.

e. Taste panel noodle evaluation

An 11-member adult taste panel scored dehydrated regular rice and soy-rice noodles to evaluate quality changes during a five-month storage. The score sheet, based on a nine-point hedonic scale, is shown in Fig. 18. Mean scores of the quality factors (appearance, color, flavor, texture) and the averages of mean scores appear in Table XV. These scores were tested

Name_____

(English Translation)

Taste Panel Score Sheet--Rice Noodle Evaluation

Please score the rice noodle dishes for appearance, color, flavor, and texture using a nine (9) point scale which is described below. The highest score is nine (9) and the lowest score is one (1).

1.--extremely bad

2.--very bad

3.--moderately bad

4.--slightly bad

5.--neither good nor bad
(neither like nor dislike)

6.--slightly good

7.--moderately good

8.--very good

9.--extremely good

Sample Code	Appearance	Color	Flavor	Texture

Fig. 18. Score sheet used for taste panel evaluation of dehydrated rice noodles by adults.

statistically (analysis of variance) and both the differences among samples for quality factors at each time interval (Table XVI), and the differences among storage times for each product and quality factor (Table XVII) were determined for $P < 0.05$.

As shown in Table XV, the mean scores for regular rice noodles were higher than those for soy-rice noodles for every quality factor after different storage times. The averages of the mean scores illustrated overall preference and evaluation of the products. These scores ranged from 7.3 to 7.6 for the regular noodles. Average scores for 20% soy-rice noodles ranged from 5.0 to 6.0, whereas those for 30% soy-rice noodles were in the range of 4.2 to 5.9.

Table XVI illustrates that, in most cases, significant differences were recorded among the five samples for each quality factor at each time period. Overall, the quality of regular rice noodles, with the exception of texture, was superior to that of soy-rice noodles. Texture scores were significantly equal after one, two, three, and four months of storage, indicating that no difference in this factor was detected among the samples. It is interesting to note that these significantly equal texture scores for all products after one, two, three, and four months of storage corresponded to the reported improvement in noodle texture as indicated by water absorption and disintegration studies.

Soy-rice noodles were not significantly different from each other in fifty percent of the score groups (Table XV). The highest number of differences among soy-rice samples was found for color scores after one, two, three, and four months of storage. This fact indicated that color differences among soy-rice samples were detectable at these storage times. Noodle appearance and flavor scores were similar, with respect to soy-rice samples, having

TABLE XV. TASTE PANEL EVALUATION[a] OF DEHYDRATED RICE NOODLES STORED FOR FIVE MONTHS

Noodle Sample	Quality Factors				Average
	Appearance	Color	Flavor	Texture	
Month 0					
Regular	7.6	7.9	7.2	6.5^{x}	7.3
20% Soy	5.3^{x}	5.2^{x}	4.4^{x}	5.1^{xy}	5.0^{xy}
20% Soy + met[b]	5.4^{x}	5.5^{x}	5.6	4.9^{y}	5.4^{x}
30% Soy	4.4^{x}	4.7^{x}	3.8^{x}	3.9^{y}	4.2^{y}
30% Soy + met[b]	5.2^{x}	5.0^{x}	4.2^{x}	5.1^{xy}	4.9^{xy}
Month 1					
Regular	7.9	8.2	6.7^{x}	6.4^{x}	7.3
20% Soy	6.2^{x}	5.9^{x}	5.7^{xy}	6.1^{x}	6.0^{xy}
20% Soy + met[b]	5.7^{xy}	5.8^{x}	5.0^{y}	5.7^{x}	5.6^{xy}
30% Soy	4.5^{y}	4.5^{y}	4.3^{y}	5.4^{x}	4.7^{y}
30% Soy + met[b]	5.5^{xy}	5.5^{xy}	5.2^{y}	6.0^{x}	5.6^{x}
Month 2					
Regular	8.2	8.1	7.6	6.0^{x}	7.5
20% Soy	5.4^{x}	6.0^{x}	5.7^{x}	5.6^{x}	5.7^{x}
20% Soy + met[b]	6.0^{x}	5.7^{xy}	5.2^{x}	6.1^{x}	5.7^{x}
30% Soy	5.0^{x}	4.7^{y}	4.9^{x}	5.1^{x}	4.9^{x}
30% Soy + met[b]	5.9^{x}	6.0^{x}	5.0^{x}	5.4^{x}	5.6^{x}
Month 3					
Regular	7.8	8.1	7.8	6.5^{x}	7.6
20% Soy	6.2^{x}	5.9^{x}	5.5^{x}	5.9^{x}	5.9^{x}
20% Soy + met[b]	5.4^{x}	5.4^{xy}	5.3^{x}	5.7^{x}	5.5^{x}
30% Soy	5.8^{x}	5.0^{y}	4.8^{x}	5.3^{x}	5.4^{x}
30% Soy + met[b]	6.1^{x}	5.8^{xy}	5.4^{x}	6.3^{x}	5.9^{x}
Month 4					
Regular	8.1	7.7	7.7	6.9^{x}	7.6
20% Soy	5.7^{x}	6.0^{xy}	5.8^{x}	6.2^{x}	6.0^{x}
20% Soy + met[b]	5.7^{x}	5.4^{xy}	5.3^{x}	6.2^{x}	5.7^{x}
30% Soy	5.2^{x}	5.1^{y}	5.1^{x}	5.4^{x}	5.2^{x}
30% Soy + met[b]	6.2^{x}	6.1^{x}	5.4^{x}	5.7^{x}	5.8^{x}
Month 5					
Regular	8.0	8.0	7.3	7.1^{x}	7.6
20% Soy	5.7^{x}	5.8^{x}	5.8^{x}	6.3^{xy}	5.9^{x}
20% Soy + met[b]	6.0^{x}	6.0^{x}	5.4^{x}	6.4^{x}	6.0^{x}
30% Soy	5.5^{x}	5.4^{x}	5.4^{x}	5.3^{y}	5.4^{x}
30% Soy + met[b]	6.1^{x}	6.0^{x}	5.0^{x}	5.4^{y}	5.6^{x}

[a]Eleven-member adult panel. Average scores (means) reported using a nine-point hedonic scale: 1 = extremely bad, 9 = extremely good. Means having the same superscript (x, y) are not significantly different ($P < 0.05$) within groups.

[b]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

TABLE XVI. ANALYSIS OF VARIANCE (AOV) OF TASTE PANEL SCORES[a] FOR STORED DEHYDRATED RICE NOODLES--DIFFERENCES AMONG SAMPLES

Source of Variation	Degrees of Freedom	Mean Square	F value[b]	LSD[c]
Month 0				
Appearance	4	16.5182	11.8914	1.0051
Error	50	1.3891		
Total	54			
Color	4	18.1636	10.8824	1.1018
Error	50	1.6691		
Total	54			
Flavor	4	20.9818	10.9281	1.1817
Error	50	1.9200		
Total	54			
Texture	4	9.7454	3.1567	1.4984
Error	50	3.0873		
Total	54			
Average	4	15.2461	16.8010	0.8124
Error	50	0.9074		
Total	54			
Month 1				
Appearance	4	16.7000	6.3171	1.3866
Error	50	2.6436		
Total	54			
Color	4	19.5909	13.3024	1.0349
Error	50	1.4727		
Total	54			
Flavor	4	9.2000	2.8717	1.5264
Error	50	3.2036		
Total	54			
Texture	4	1.5909	0.6731*	------
Error	50	2.3636		
Total	54			
Average	4	9.8262	7.3983	0.9828
Error	50	1.3282		
Total	54			

TABLE XVI.--Continued

Source of Variation	Degrees of Freedom	Mean Square	F value[b]	LSD[c]
Month 2				
Appearance	4	16.8636	8.0234	1.2364
Error	50	2.1018		
Total	54			
Color	4	16.5181	8.4907	1.1895
Error	50	1.9454		
Total	54			
Flavor	4	14.1182	6.2320	1.2836
Error	50	2.2654		
Total	54			
Texture	4	1.9545	0.8973*	------
Error	50	2.1782		
Total	54			
Average	4	10.2397	10.0480	0.8609
Error	50	1.0191		
Total	54			
Month 3				
Appearance	4	9.0909	6.2657	1.0272
Error	50	1.4509		
Total	54			
Color	4	15.6636	16.2549	0.8371
Error	50	0.9636		
Total	54			
Flavor	4	15.3000	9.9704	1.0564
Error	50	1.5345		
Total	54			
Texture	4	2.6636	1.3847*	
Error	50	1.9236		
Total	54			
Average	4	8.7188	11.7586	0.7343
Error	50	0.7415		
Total	54			

TABLE XVI.--Continued

Source of Variation	Degrees of Freedom	Mean Square	F value[b]	LSD[c]
Month 4				
Appearance	4	13.5273	6.6787	1.2137
Error	50	2.0254		
Total	54			
Color	4	11.2454	9.2590	0.9398
Error	50	1.2145		
Total	54			
Flavor	4	12.8454	6.2083	1.2267
Error	50	2.0691		
Total	54			
Texture	4	3.7000	1.9492*	------
Error	50	1.8982		
Total	54			
Average	4	9.2695	8.8656	0.8720
Error	50	1.0456		
Total	54			
Month 5				
Appearance	4	10.7727	6.7483	1.0775
Error	50	1.5964		
Total	54			
Color	4	11.0182	8.0585	0.9972
Error	50	1.3673		
Total	54			
Flavor	4	8.7545	4.1725	1.2353
Error	50	2.0982		
Total	54			
Texture	4	6.5000	4.3598	1.0413
Error	50	1.4909		
Total	54			
Average	4	8.2847	8.8761	0.8239
Error	50	0.9333		
Total	54			

[a]Eleven-member adult panel. AOV for five samples of noodles (regular rice, 20% soy, 20% soy + methionine, 30% soy, 30% soy + methionine) and five treatments (appearance, color, flavor, texture, average) at each storage period.

[b]F_{95} (4, 54) = 2.54. *Not significantly different at 0.05.

[c]Least significant difference at 0.05 probability.

TABLE XVII. ANALYSIS OF VARIANCE (AOV) OF TASTE PANEL SCORES[a] FOR STORED DEHYDRATED RICE NOODLES--EFFECT OF STORAGE TIME

Source of Variation	Degrees of Freedom	Mean Square	F value[b]
Appearance			
Regular	5	0.4242	0.64*
Error	60	0.6606	
Total	65		
20% Soy	5	1.7000	1.07*
Error	60	1.5848	
Total	65		
20% Soy + met[c]	5	0.7789	0.37*
Error	60	2.0939	
Total	65		
30% Soy	5	3.4697	1.40*
Error	60	2.4879	
Total	65		
30% Soy + met[c]	5	1.6879	0.67*
Error	60	2.5121	
Total	65		
Color			
Regular	5	0.2909	0.45*
Error	60	0.6424	
Total	65		
20% Soy	5	1.0697	0.62*
Error	60	1.7182	
Total	65		
20% Soy + met[c]	5	0.5333	0.40*
Error	60	1.3333	
Total	65		
30% Soy	5	1.1788	0.70*
Error	60	1.6788	
Total	65		
30% Soy + met[c]	5	2.1364	1.18*
Error	60	1.8151	
Total	65		

TABLE XVII.--Continued

Source of Variation	Degrees of Freedom	Mean Square	F value[b]
Flavor			
Regular	5	1.8788	1.40*
Error	60	1.3394	
Total	65		
20% Soy	5	3.5182	1.72*
Error	60	2.0485	
Total	65		
20% Soy + met[c]	5	0.5454	0.22*
Error	60	2.4394	
Total	65		
30% Soy	5	3.5424	1.64*
Error	60	2.1636	
Total	65		
30% Soy + met[c]	5	2.1242	0.72*
Error	60	2.9394	
Total	65		
Texture			
Regular	5	1.6606	0.88*
Error	60	1.8970	
Total	65		
20% Soy	5	1.1424	0.44*
Error	60	2.6151	
Total	65		
20% Soy + met[c]	5	3.1879	1.56*
Error	60	2.0424	
Total	65		
30% Soy	5	3.5182	1.54*
Error	60	2.2879	
Total	65		
30% Soy + met[c]	5	2.1818	1.07*
Error	60	2.0394	
Total	65		

TABLE XVII.--Continued

Source of Variation	Degrees of Freedom	Mean Square	F value[b]
Average			
Regular	5	0.2207	0.39*
Error	60	0.5716	
Total	65		
20% Soy	5	1.6969	1.61*
Error	60	1.0535	
Total	65		
20% Soy + met[c]	5	0.4700	0.50*
Error	60	0.9314	
Total	65		
30% Soy	5	2.2562	1.95*
Error	60	1.1590	
Total	65		
30% Soy + met[c]	5	1.4383	1.14*
Error	60	1.2644	
Total	65		

[a]Eleven-member adult taste panel. Analysis of variance (AOV) of five samples (regular, 20% soy, 20% soy + methionine, 30% soy, 30% soy + methionine) at six time intervals (0 month, 1 month, 2 months, 3 months, 4 months, and 5 months) for each quality factor.

[b]F_{95} (5, 65) = 2.36. *Not significantly different at 0.05.

[c]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

significantly equal scores except at one-month storage time. The averages of mean scores were significantly equal from the second through the fifth months of storage time.

Significant differences among all samples for each quality factor at individual storage times, with the exception of texture, indicated that the taste panel definitely preferred regular rice noodles to soy-rice noodles. Differences among soy-rice samples, however, were generally not detectable. An overall view of statistical patterns (Table XV) illustrates a conditioning effect, i.e., panel members became more accustomed to the appearance, flavor, and texture of soy-rice noodles with time, and, consequently, preferences among these samples were similar.

Changes in quality factors for each product with storage time were similarly tested statistically (analysis of variance) (Table XVII). No significant differences in mean scores of individual products for each quality factor throughout the storage period were found for $P < 0.05$. Similarly, the averages of mean scores were not different for each product during the storage study. These results indicated that the quality of regular rice and soy-rice noodles, as related to preference scores, did not differ. The taste panel, therefore, did not detect changes in appearance, color, flavor, texture, and overall acceptability scores for these products during the storage period.

4. Product Costs

The retail price and relative costs of protein in dehydrated regular and soy-rice noodles (with and without methionine fortification) are listed in Table XVIII. Comparisons of these costs with those for casein, beef, and pork are included. The net cost per pound of protein is calculated from the retail product cost after allowances have been made for carbohydrate and fat

TABLE XVIII. COST OF PROTEIN IN DEHYDRATED RICE NOODLES

Product	Retail product cost[a] ¢ per lb.	Protein cost per lb. of product[b] ¢	Net cost per lb. of protein ¢	Protein cost adjusted for NPU[c] ¢ per lb.
Dehydrated rice noodles				
Regular	6.4	1.8	23.1	53.7
20% Soy	8.3	2.9	19.3	47.1
30% Soy	9.3	3.6	20.0	36.4
20% Soy + met[d]	8.7	3.3	22.0	46.8
30% Soy + met[d]	9.9	4.2	23.3	43.2
Casein	65.0	65.0	74.7	103.8
Beef	45.4	25.6	58.4	87.2
Pork	50.0	22.1	107.8	189.1

[a]Based on local ingredient and production costs (with the exception of imported casein) in Bangkok (September 1, 1973).

[b]After allowing for carbohydrate (based on broken rice, 4.3 cents per lb.) and fat content (based on vegetable cooking oil, 36.0 cents per lb.).

[c]NPU values for dehydrated rice noodles and casein from Table XXVII; NPU values for beef and pork, reference 78.

[d]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

content, using the least expensive Thai sources of these nutrients. Protein costs adjusted for net protein utilization (NPU) values indicate the actual costs for protein which is utilized during normal metabolic processes.

The retail product cost for regular rice noodles (6.4 ¢/lb.) is lower than those for soy-rice noodles (8.3 to 9.9 ¢/lb.) It is evident that additions of soy flour and methionine to rice flour result in a correspondingly higher price for the products. The net cost per pound of protein gives a better indication of product costs since protein content of the noodle product is of major concern. Since soy-rice noodles contain more protein than regular rice noodles, this fact is dominant when protein costs are calculated. The 20% soy-rice noodles have the lowest net cost per pound of protein (19.3¢) corresponding to a cost which is 16% less than that for regular rice noodles. Only the 30% soy plus methionine-rice noodle samples are higher in cost per pound of protein than regular noodles. Product and protein costs for animal protein sources, namely casein, beef, and pork are substantially higher than those for all noodle samples. In reference to the protein cost adjusted for NPU, it is observed that all soy-rice noodle samples are lower than regular noodles. The 30% soy-rice noodles are superior in this respect, having a cost of 36.4¢ per pound, which is 32% lower than that for regular noodles.

A summary of protein costs for dehydrated regular and soy-rice noodles illustrates a definite price advantage for the soy-rice noodles. Although the retail product costs are higher for soy-rice noodles, their ability to supply greater amounts of protein results in lower protein costs. The higher ingredient costs for soy-supplemented and methionine-fortified noodles are compensated for by the increased availability of protein per pound of product per unit cost. Although casein, beef, and pork are good sources of high quality animal protein, the significantly higher costs for these products

make their purchase by low income families prohibitive.

B. ACCEPTABILITY

1. Child Nutrition Centers and Kasetsart University Nursery School

Acceptability studies were conducted at two rural Child Nutrition Centers (CNC) and at the Kasetsart University Nursery School in Bangkok. The amount of noodles consumed by each individual was used as the index of acceptability. Figs. 19-21 illustrate consumption patterns (none, some, all, extra portions) for soy-rice noodle dishes compared to regular rice noodle, wheat noodle, and non-noodle dishes at Ban Yang and Ban Mai Villages, and the nursery school, respectively. The percent of children consuming various amounts of the different dishes illustrates the general eating pattern and acceptability for these dishes.

Noodle consumption data for the children at the CNC's were calculated as follows: normal (non-noodle) dish, average of 16 meals; noodle dishes (wheat, rice, soy-rice), average of four noodle soup and four noodles with topping meals. Similarly, data for nursery school children were calculated from an average of 12 normal (non-noodle) meals, and an average of two noodle soup and two noodles-with-topping meals for all noodle products. Consumption of methionine-fortified 20% soy-rice noodles was combined with that of the unfortified 20% soy-rice noodles. This procedure was also followed for 30% soy-rice noodles. Statistical analysis (Chi square) showed that the consumption patterns for soy-rice noodles and their methionine-fortified counterparts were equal ($P < 0.01$).

The overall consumption patterns for children in Ban Yang Village (Fig. 19) illustrated that non-noodle dishes were preferred slightly more than

Fig. 19. Consumption of normal (NOR) (non-noodle) dishes and wheat (W), control rice (R), 20% soy-rice (RS_{20}), and 30% soy-rice (RS_{30}) noodle dishes for pre-school children at the Child Nutrition Center in Ban Yang Village: N = none, ; S = some, ; A = all, ; x = extra portions, .

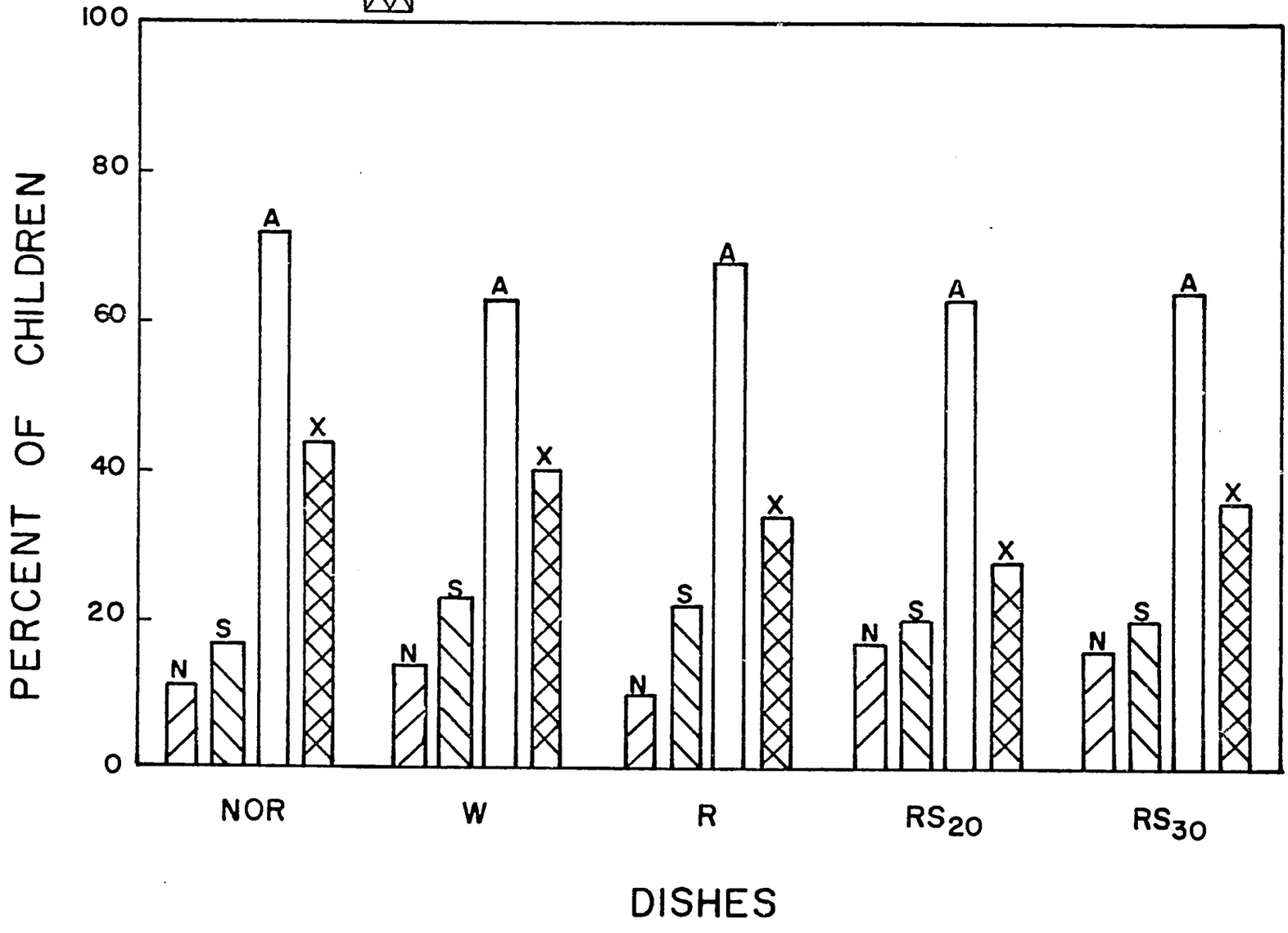


Fig. 20. Consumption of normal (NOR) (non-noodle) dishes and wheat (W), control rice (R), 20% soy-rice (RS_{20}), and 30% soy-rice (RS_{30}) noodle dishes for pre-school children at the Child Nutrition Center in Ban Mai Village: N = none, ; S = some, ; A = all, ; X = extra portions, .

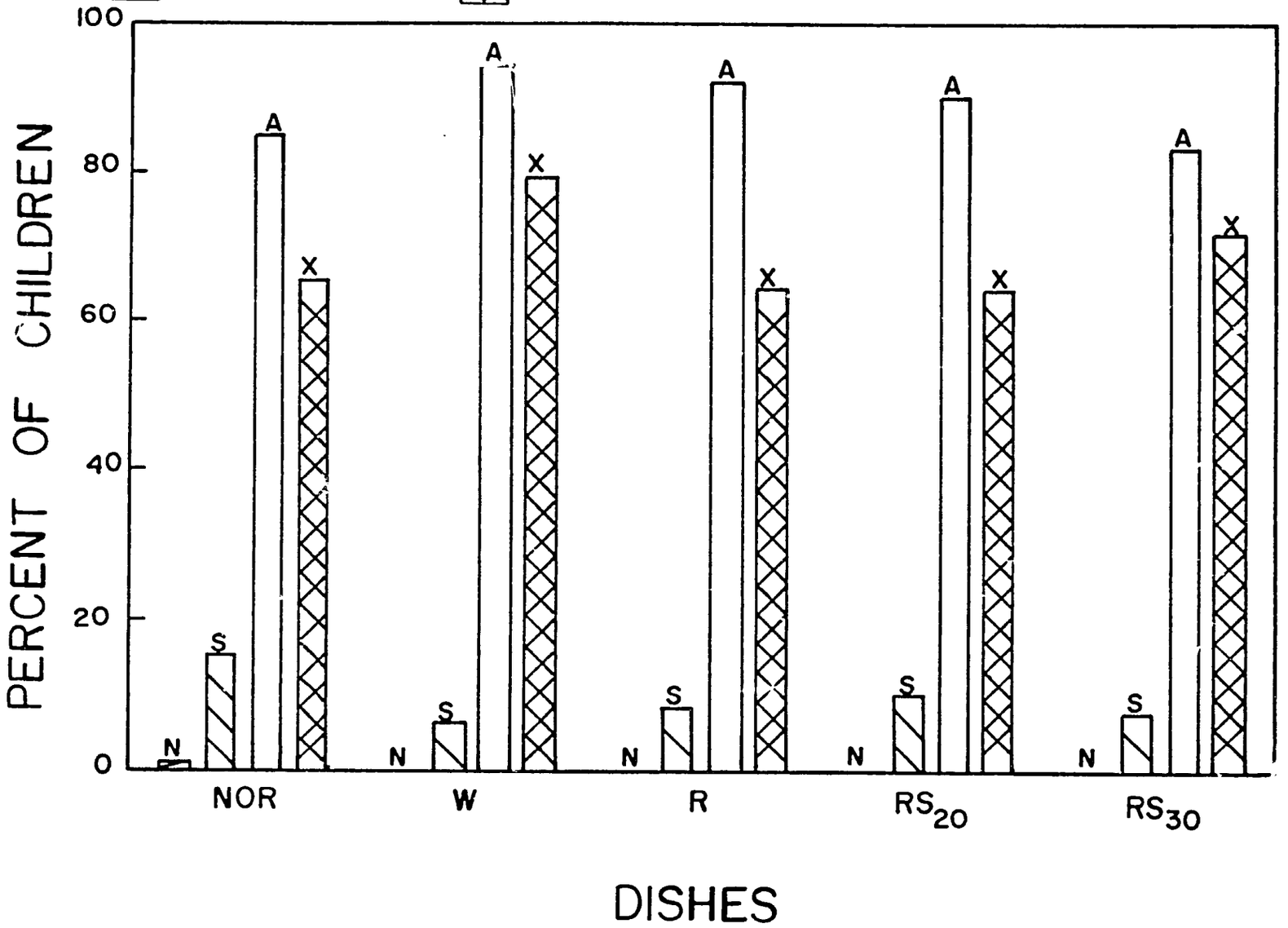
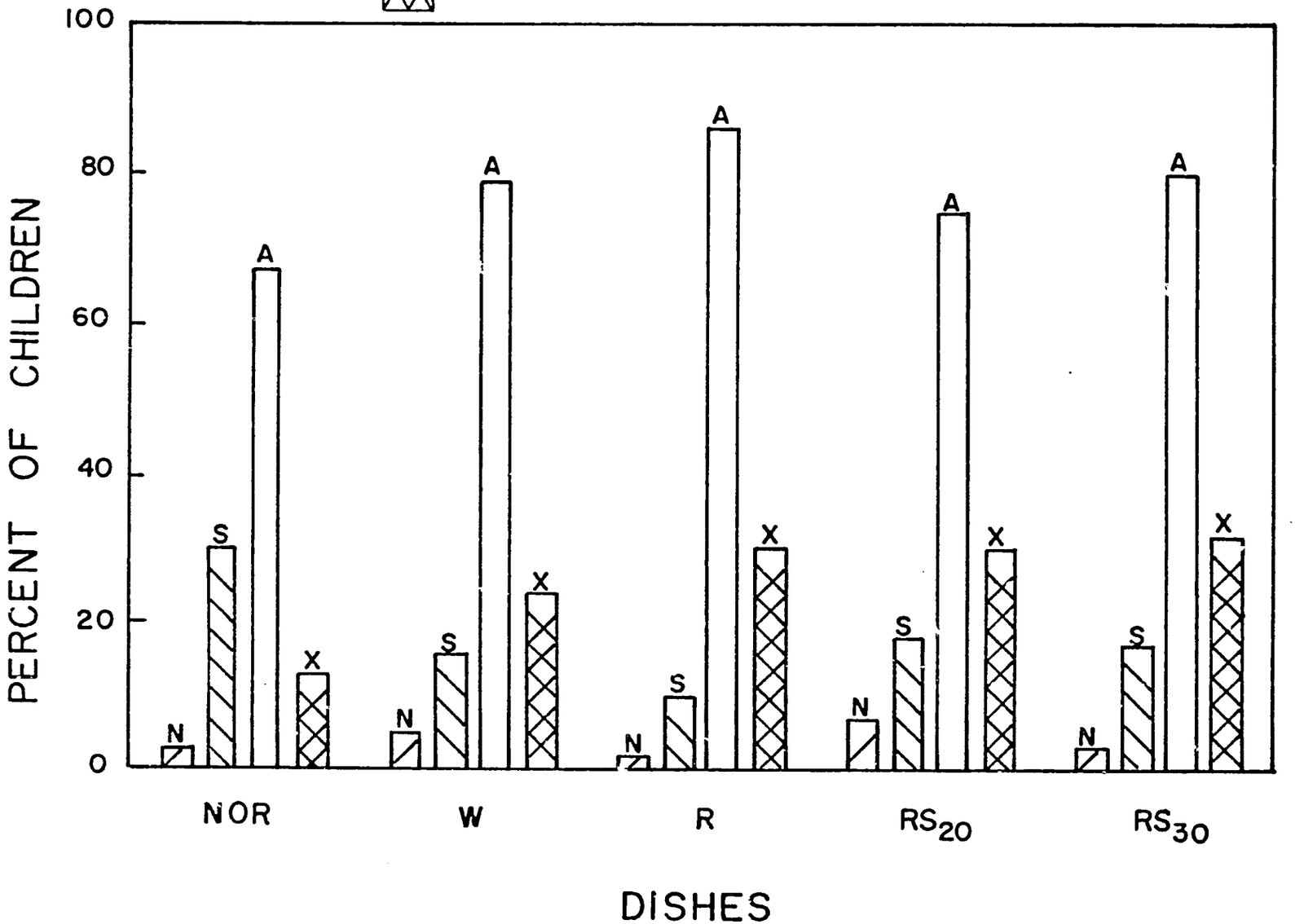


Fig. 21. Consumption of normal (NOR) (non-noodle) dishes and wheat (W), control rice (R), 20% soy-rice (RS_{20}), and 30% soy-rice (RS_{30}) noodle dishes for pre-school children attending the Kasetsart University Nursery School: N = none, ; S = some, ; A = all, X = extra portions, .



noodle dishes. Non-noodle dishes were similar to those dishes eaten as the mainstay of the diet, i.e., boiled or fried vegetables containing small additions of beef, chicken, and egg. 'Kaset' protein (a textured mungbean and soybean protein meat analog) was used in place of regular meat ingredients. These dishes are eaten with boiled, white rice. Noodles, rice and wheat, are available in the market place, but to a limited extent. In addition, noodles are higher in cost than whole rice as the main carbohydrate source. More initial servings of regular rice noodles were eaten than other noodle dishes, and more extra servings of wheat noodles were requested than other noodle dishes. The average noodle consumption per child for regular rice and wheat noodles was 75 g. and 94 g., respectively. The consumption of soy-rice noodles was slightly less than other dishes, with more of the 30% soy-rice noodles being consumed than the 20% soy-rice product. The average noodle consumption per child for both soy-rice noodles was 87 g. Children eating all of the initial food portions ranged from a high of 72% for the non-noodle dish to a low of 63% for the 20% soy-rice noodles. Children requesting extra servings ranged from 44% for the non-noodle dish to 28% for the 20% soy-rice noodles.

Fig. 20 illustrates a markedly different meal consumption pattern for children attending the CNC in Ban Mai Village. They generally consumed a larger amount of all dishes. Children eating all of the initial wheat noodle servings (94%) and those requesting additional portions (79%) of wheat noodles were the highest for all dishes. Average wheat noodle consumption per child was 107 g. Consumption of 20% soy-rice noodles was similar to that for regular rice noodles. Although the number of children (83%) eating all of the 30% soy-rice servings was the lowest of all dishes, a relatively high number of children (72%) requested additional servings of this product. Average

noodle consumption per child for regular rice and soy-rice noodles was 92 g. for each product. Initial and additional portions of non-noodle dishes were consumed to about the same extent or less than noodle dishes.

The food habits for children in this village are similar to those in the other village. Their rice-based diet consists of various vegetables eaten with small amounts of beef, chicken, and egg. The consumption of traditional rice or wheat noodles is similarly limited by availability and cost. The high consumption of all foods could be related to the lack of a sufficient early morning meal.

Children attending the Kasetsart University Nursery School preferred regular rice noodles to other dishes (Fig. 21). This dish was followed in preference by the 30% soy-rice noodles. Average noodle consumption per child was 68 g., 64 g., and 63 g. for the regular rice, soy-rice (20 and 30%), and wheat noodles, respectively. The proportion of children (approximately 30%) requesting additional servings of regular and soy-rice noodles were nearly identical. The non-noodle dish was least preferred on the basis of consumption. Children consuming initial portions ranged from 86% for regular rice noodles to 68% for the non-noodle dishes. Additional servings of 30% soy-rice noodles were requested by 32% of the children in contrast to 13% requesting extra servings of non-noodle dishes.

Children attending the Kasetsart University Nursery School were from significantly higher-income families than those children living in the villages. Non-noodle dishes, vegetables and meat, were similar to the traditional dishes eaten at home. Noodles are more available in an urban than a rural area, however, their overall consumption is still less than that for non-noodle dishes.

Children attending the nursery school were also given a choice of eating

either regular or soy-rice noodles in two separate tests. Soy-rice noodles (30% soy) were selected by 78.5% of the children as compared with 21.5% choosing regular rice noodles. In the second test, 30% soy-rice noodles and wheat noodles were used; 56.3% of the children selected the soy-rice noodles for their meal as compared with 43.7% choosing wheat noodles.

A comparison of the consumption patterns for children at the three testing localities is shown in Fig. 22. The proportion of children eating all of the initial servings and requesting extra servings for all dishes is illustrated. It is evident that consumption of all foods is higher in Ban Mai Village than at the other two testing locations. In most cases, consumption of soy-rice noodles was similar to that of other noodles. Although soy-rice noodles were eaten less than other noodle products in some specific situations, their overall consumption was relatively high and they fit the general eating pattern of children at the individual centers or nursery school.

Statistical analysis of noodle consumption data was conducted to determine whether specific eating patterns for certain dishes were significantly equal. A scoring system was devised in which a consumption point average (CPA) was tabulated from data on the number of children eating none, some, all, or extra portions of the various dishes. Score points were designated as follows: 0 points--none, 1 point--some, 2 points--all, and 3 points--extra portions. The approximation to the normal distribution (Z value) was calculated from CPA's and significant differences among consumption patterns were determined.

Statistical evaluation of noodle consumption patterns at each testing locality for all dishes is illustrated in Table XIX. The consumption point average (CPA) for non-noodle (NOR) dishes at the Ban Yang Center is 2.05, the

Fig. 22. Consumption of normal (NOR) (non-noodle) dishes and wheat (W), control rice (R), 20% soy-rice (RS_{20}), and 30% soy-rice (RS_{30}) noodle dishes for pre-school children attending the Kasetsart University Nursery School (A) and Child Nutrition Centers in Ban Yang (B) and Ban Mai (C) Villages: A = All, ; X = extra portions, .

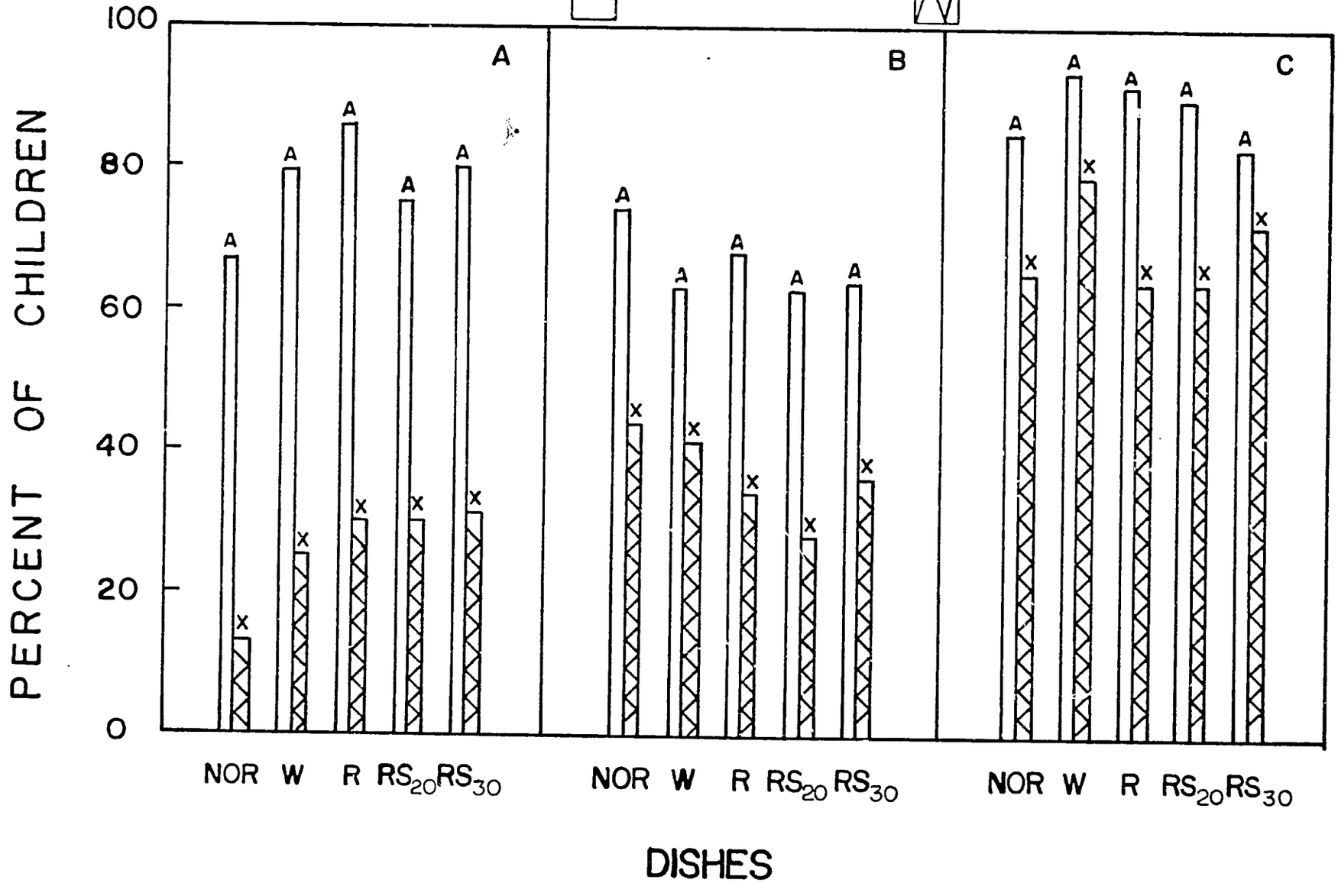


TABLE XIX. STATISTICAL EVALUATION OF CONSUMPTION OF NON-NOODLE AND NOODLE DISHES BY CHILDREN

Consumption[a] Point Average (CPA)	Dishes[b]	Z values[c]				
		NOR	W	R	RS_{20}	RS_{30}
A. Ban Yang Center						
2.05	NOR	----	1.86	1.77	5.19	3.20
1.90	W	1.86	----	0.23	1.79	0.52
1.92	R	1.77	0.23	----	2.25	0.85
1.74	RS_{20}	5.19	1.79	2.25	----	1.55
1.85	RS_{30}	3.20	0.52	0.85	1.55	----
B. Ban Mai Center						
2.50	NOR	----	4.61	1.26	1.14	3.75
2.73	W	4.61	----	2.62	3.37	1.46
2.56	R	1.26	2.62	----	0.31	1.58
2.55	RS_{20}	1.14	3.37	0.31	----	2.30
2.65	RS_{30}	3.75	1.46	1.58	2.30	----
C. Kasetsart Nursery School						
1.77	NOR	----	2.94	5.50	3.62	5.48
1.98	W	2.94	----	1.69	0.00	0.97
2.14	R	5.50	1.69	----	1.90	0.96
1.99	RS_{20}	3.62	0.00	1.90	----	1.12
2.06	RS_{30}	5.48	0.97	0.96	1.12	----

[a]CPA is the average score obtained from consumption data: none = 0, some = 1, all = 2, extra portions = 3 points.

[b]NOR-normal (non-noodle) dish, W-wheat noodles, R-regular rice noodles, RS_{20}-20% soy-rice noodles, RS_{30}-30% soy-rice noodles.

[c]Z_{99} = 2.58; values greater than 2.58 are significantly different. Underlined values are significantly different ($P < 0.01$).

highest of all dishes at that location. The non-noodle dish was consumed more than soy-rice noodle dishes and the same as regular rice and wheat noodle dishes ($P < 0.01$). Soy-rice, regular rice, and wheat noodle dishes, however, were significantly equal ($P < 0.01$) in their consumption patterns. The 20% soy-rice, 30% soy-rice, regular rice, and wheat noodle dishes have CPA's of 1.74, 1.85, 1.92, and 1.90, respectively. Although soy-rice noodles were consumed significantly less than non-noodle dishes, they were equally acceptable as indicated by consumption compared to traditional rice (regular) and wheat noodle dishes.

The reported high consumption of all dishes at the Ban Nai CNC was evident in the CPA's calculated for the various dishes. The CPA values range from 2.73 for wheat noodles to 2.50 for non-noodle dishes. The non-noodle dish was consumed significantly less than wheat and 30% soy-rice noodles, whereas its consumption was the same as regular rice and 20% soy-rice noodle dishes ($P < 0.01$). The high consumption of wheat noodles was equal only to that of the 30% soy-rice noodles and was higher than other dishes. The soy-rice and regular rice noodles were equal in acceptability as indicated by consumption ($P < 0.01$).

The acceptability of soy-rice noodles at Kasetsart Nursery School is definitely indicated by statistical evaluation of meal consumption data. Non-noodle dishes were consumed significantly less ($P < 0.01$) than all noodle dishes as indicated by a consumption point average (CPA) of 1.77. The average CPA for noodle dishes was 2.04. Consequently, the consumption pattern of all noodle products, both traditional and soy-supplemented ones, were significantly equal ($P < 0.01$).

Consumption data for the choice tests at the Kasetsart Nursery School were similarly tested statistically. As stated previously, soy-rice noodles

(30%) were preferred to either regular rice or wheat noodles in both choice situations. No significant differences ($P < 0.01$) in the overall consumption of all samples were found. The Z values ($Z_{99} = 2.58$) for comparing consumption point averages (CPA) among the soy-rice, regular rice, and wheat noodles were less than 0.89, indicating significantly equal eating patterns.

Comparative statistical analyses for the consumption of normal (NOR) (non-noodle), wheat, regular rice, and soy-rice noodle dishes are shown in Table XX. Significant differences ($P < 0.01$) were found in the eating patterns for these dishes among the three day care centers. Children at Ban Mai Village consumed the highest amount of all dishes. Children at the Kasetsart Nursery School consumed the lowest amount of the non-noodle dish, whereas children at Ban Yang Village consumed the lowest amount of soy-rice noodles. Consumption of wheat and regular rice noodle dishes were equal at the Kasetsart Nursery School and Ban Yang center.

C. NUTRITIONAL EVALUATION

1. Chemical Analyses

a. Proximate analyses

Proximate analyses for the regular rice noodle and soy-rice noodles are given in Table XXI. The protein content (dry basis) of 20% soy-rice noodles (15.0%) and 30% soy-rice noodles (18.0%) is two to two and one-third times that of regular rice noodles (7.8%). The effects of adding full-fat soy flour to rice flour include increased fat, ash, and fiber content in addition to increased protein content. The caloric value of soy-rice noodles is slightly higher due to the higher fat content.

TABLE XX. STATISTICAL COMPARISON OF CONSUMPTION OF NON-NOODLE AND NOODLE DISHES BY CHILDREN AT THREE DAY-CARE CENTERS

Consumption Point Average[a] (CPA)	Centers[b]	Z values[c]		
		BY	BM	KN
A. Normal (non-noodle) Dish				
2.05	BY	-----	10.23	6.63
2.50	BM	10.23	-----	19.58
1.77	KN	6.63	19.58	-----
Pattern: BM > BY > KN				
B. Wheat Noodle Dish				
1.90	BY	----	9.64	0.85
2.73	BM	9.64	----	9.36
1.99	KN	0.85	9.36	----
Pattern: BM > KN = BY				
C. Regular Rice Noodle Dish				
1.92	BY	----	8.07	2.41
2.56	BM	8.07	----	5.54
2.14	KN	2.41	5.54	----
Pattern: BM > KN = BY				
D. Soy-Rice (20 and 30%) Dish				
1.79	BY	----	18.70	4.50
2.60	BM	18.70	-----	13.63
2.02	KN	4.50	13.63	----
Pattern: BM > KN > BY				

[a]CPA is the average score obtained from consumption data: none = 0, some = 1, all = 2, extra portions = 3 points.

[b]Centers: BY--Ban Yang CNC, BM--Ban Mai CNC, KN--Kasetsart Nursery School.

[c]Z_{99} = 2.58; values greater than 2.58 are significantly different. Underlined values are significantly different ($P < 0.01$).

TABLE XXI. PROXIMATE ANALYSES[a] AND CALORIC VALUES OF RICE NOODLES

Rice Noodles	Nutrient					Calories[c]
	Protein[b] %	Ash %	Fiber %	Fat %	Carbohydrate %	
Regular (control)	7.8	0.3	0.2	2.3	89.4	427
20% Soy	15.0	1.2	0.6	5.6	77.6	436
30% Soy	18.0	1.6	0.9	7.2	72.3	440

[a]Moisture-free basis, analyses by WARF Institute.

[b]N X 5.95 for regular noodles; N X 6.25 for soy-rice noodles.

[c]Dry basis, per 100 g. sample (30).

b. Vitamin and mineral analyses

Vitamin and mineral contents of regular and soy-rice noodles are shown in Table XXII. Although the emphasis in development of soy-rice noodles was upon protein content, the amounts of vitamins and minerals in the products were determined since specific ones are essential for good health in children. The data illustrate that addition of soy flour to rice flour increased the content of important vitamins and minerals. Although relatively low amounts of these vitamins were found in soy-rice noodles, a small increase in vitamin content is important. Alpha-tocopherol content (vitamin E) increased most with soy flour-supplementation, resulting in soy-rice noodles containing approximately six to eight times more of this vitamin than regular rice noodles.

Soy flour-supplementation resulted in definite increases in mineral content. Soy-rice noodles contained as much as four times the calcium, twice the iron, twelve times the magnesium, and three times the phosphorous content of ordinary rice noodles. Consequently, soy-rice noodles could provide important amounts of these minerals in the diet of Thai children.

c. Amino acid analyses

The amino acid compositions of rice noodles, regular and soy, are shown in Table XXIII. It is noteworthy that there is an increase in lysine content with increasing soy content in the noodles. Conversely, the content of both methionine and cystine decrease with increasing soy content. This can be attributed to the high lysine content and low sulfur-amino acid content in soy flour (45). Available lysine for the regular, 20% soy-rice, and 30% soy-rice noodles is 4.87, 5.53, and 5.55 percent of the protein (dry basis), respectively.

TABLE XXII. VITAMIN AND MINERAL ANALYSES[a] OF RICE NOODLES

Nutrients	Rice Noodles		
	Regular	20% Soy	30% Soy
Vitamins			
A[b]	less than 100	less than 100	less than 100
D[b]	0	0	trace
alpha-Tocopherol[c] (E)	0.37	2.06	3.04
Thiamin (B-1)	0.03	0.05	0.05
Riboflavin (B-2)	0.021	0.050	0.048
Pyridoxine (B-6)	0.021	0.063	0.116
B-12[d]	0.057	0.100	0.101
Niacin	0.243	0.296	0.564
Folic acid	0.022	0.041	0.061
Minerals[a]			
Calcium	19.2	73.6	80.0
Iron	2.33	3.46	4.68
Magnesium[c]	5.2	40.0	64.8
Phosphorous	74.0	156.0	208.0

[a]Mg. per 100 g. sample; assays by WARF Institute.

[b]Units per 100 g. sample.

[c]Assay by Department of Science, Ministry of Industry, Bangkok.

[d]μg per 100 g. sample.

TABLE XXIII. AMINO ACID COMPOSITION[a] OF RICE NOODLES

Amino Acid	Rice Noodles		
	Regular	20% Soy	30% Soy
Alanine	51.5	37.9	47.4
Arginine	65.9	65.3	65.3
Aspartic acid	80.0	102.2	109.8
Cystine[b]	14.5	12.0	9.2
Glutamic acid	145.8	161.0	163.5
Glycine	25.9	30.0	26.7
Histidine	7.4	10.4	12.3
Isoleucine	34.7	38.6	40.7
Leucine	66.7	68.1	70.6
Lysine	21.6	32.9	41.6
Methionine[b]	22.9	19.2	17.5
Phenylalanine	37.0	40.0	39.8
Proline	41.1	44.3	45.6
Serine	38.3	41.4	42.0
Threonine	26.8	30.4	31.3
Tryptophan[b]	10.4	9.9	9.6
Tyrosine	33.5	31.1	31.0
Valine	51.6	46.6	46.9

[a]Mg. per g. protein, amino acid analyses by WARF Institute. All values are dry basis.

[b]Microbiological assay.

d. Nutrient cooking losses

The amounts of solids, protein, and methionine lost during the cooking process for rehydrating dehydrated rice noodles are important from the standpoint of product quality and nutrition. As illustrated in Table XXIV, the amount of total extracted solids was higher for soy-supplemented noodles. This higher solids loss can be attributed to increased loss of soy carbohydrates. From a nutritional point of view, carbohydrates in soy flour are mostly pentoses which are not utilized for energy (caloric) purposes (47). Determination of the amount of nitrogen (N) extracted during cooking is important with respect to protein losses attributable to noodle preparation. Protein loss was relatively low, i.e., not more than one percent for all samples. Those soy-rice samples which were fortified with methionine experienced losses of this amino acid during cooking. Methionine losses for the 20 and 30% soy-rice noodles were 10.4 and 23.4%, respectively.

e. Chemical score

Chemical scores calculated from essential amino acid patterns using the FAO reference pattern (30) are illustrated in Table XXV. A significant increase in the chemical scores for soy-supplemented rice noodles was observed. Mutual supplementation of the rice and soy proteins brings about an increase in chemical score. The chemical score for regular rice noodles is 40, whereas 20 and 30% soy-rice noodles have chemical scores of 60 and 76, respectively. The first limiting amino acid in all samples is lysine. The low methionine content in soy flour is also indicated by a decrease in the individual amino acid score for methionine in unfortified soy noodles; whereas methionine-fortified soy noodles have chemical scores comparable to that of the FAO pattern for methionine.

TABLE XXIV. NUTRIENT LOSSES DURING COOKING[a] OF DEHYDRATED RICE NOODLES

Sample	Total extracted solids %	Extracted N %	Calculated extracted protein[b] %	Methionine loss %
Regular	5.60	0.09	0.54	----
20% Soy	7.00	0.07	0.43	----
30% Soy	8.20	0.16	1.00	----
20% Soy + met[c]	6.80	0.10	0.62	10.4
30% Soy + met[c]	7.80	0.10	0.62	23.4

[a]Cooking times: regular, 5 minutes; soy, 6 minutes.

[b]Regular sample, N X 5.95; soy samples, N X 6.25. Calculated on dry basis.

[c]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

TABLE XXV. ESSENTIAL AMINO ACID PATTERN AND CHEMICAL SCORES OF RICE NOODLES[a]

Essential Amino Acid[b] or Limiting Amino Acid	Rice Noodles								
		Soy							
	Regular	20%	30%	20% + met[c]	30% + met[c]	Casein	Beef	Pork	FAO[d] (1973)
Essential Amino Acid									
Isoleucine	35	39	41	39	41	54	48	57	40
Leucine	67	68	71	68	71	95	81	90	70
Lysine	22	33	42	33	42	81	89	100	55
Methionine + Cystine	37	31	27	31	27	32	40	44	35
Phenylalanine + Tyrosine	70	71	71	71	71	111	80	86	60
Threonine	27	30	31	30	31	47	46	51	40
Tryptophan	10	10	10	10	10	16	11	14	10
Valine	52	47	47	47	47	67	50	62	50
Chemical Score and Limiting Amino Acid[e]									
Lysine	40	60	76	60	76	100+	100+	100+	100
Methionine + Cystine	100+	89	77	100+	94	91	100+	100+	100
Threonine	68	75	78	75	78	100+	100+	100+	100

[a]Noodle samples, analysis by WARF Institute; casein, beef, pork (78).

[b]Mg. per g. protein (dry basis) compared to FAO reference pattern (30).

[c]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

[d]Reference 30.

[e]Chemical scores for the three most limiting amino acids in the test proteins. The lowest score in each group is the chemical score (%) for the most limiting amino acid.

The relationship between the chemical score of a protein and its nutritional value may be affected by amino acid imbalance. Experiments on protein mixtures having a wide range of chemical scores have been conducted (57). Results indicated that rat growth was depressed if the chemical score was below 50.

2. Biological Studies

a. Protein efficiency ratio (PER) and net protein utilization (NPU)

The PER and NPU values for rice noodles, regular and soy, were determined by standard rat growth studies and are given in Tables XXVI and XXVII, respectively. The diet formulation for PER assays is shown in Table XXVIII. Soy-rice noodles, with and without methionine, were significantly superior to regular noodles in respect to these biological values.

PER assays demonstrated an increase in the protein quality of rice noodles as the amount of soy flour supplementation and methionine fortification increased. The PER values for soy-rice noodles were substantially higher than those for regular noodles and the casein reference. The effect of methionine fortification was very evident. The 20 and 30% soy-rice samples without added methionine had PER values of 2.56 and 2.58, respectively. Those samples fortified with methionine had higher PER values of 2.69 and 3.00 for the 20 and 30% soy-rice noodles, respectively. PER values were calculated and reported on the basis of 2.50 for casein. Regular rice noodles had a PER of 2.16.

NPU is another recognized index of protein quality which takes into consideration body maintenance. Results of rat feeding studies for the determination of NPU (Table XXVII) further indicated that the protein quality in

TABLE XXVI. PROTEIN EFFICIENCY RATIOS (PER) OF RICE NOODLES

Diet		Avg. Body Weight[a] g.	Avg. Weight Gain[a] g.	Avg. Protein Intake[a] g.	PER[b]	Adjusted PER[c]
	0 wk.	45	0	0		
	1 wk.	59	14	4.0		
Control	2 wk.	69	10	5.2		
	3 wk.	85	16	6.0		
	4 wk.	99	14	6.5		
	Total		54	21.7	2.49	2.16
	0 wk.	44	0	0		
	1 wk.	61	17	4.4		
20% Soy	2 wk.	75	14	6.0		
	3 wk.	98	23	7.4		
	4 wk.	117	19	7.5		
	Total		73	25.3	2.89	2.56
	0 wk.	44	0	0		
	1 wk.	60	16	3.7		
30% Soy	2 wk.	75	15	5.6		
	3 wk.	93	18	6.3		
	4 wk.	108	15	6.4		
	Total		64	22.0	2.91	2.58
	0 wk.	44	0	0		
	1 wk.	63	19	4.5		
20% Soy +	2 wk.	78	15	6.4		
met[d]	3 wk.	102	24	7.4		
	4 wk.	123	21	7.9		
	Total		79	26.2	3.02	2.69
	0 wk.	44	0	0		
	1 wk.	64	20	4.3		
30% Soy +	2 wk.	80	16	6.2		
met[d]	3 wk.	107	27	7.9		
	4 wk.	133	26	8.3		
	Total		89	26.7	3.33	3.00
	0 wk.	44	0	0		
	1 wk.	57	13	4.0		
Casein	2 wk.	71	14	4.8		
	3 wk.	90	19	6.3		
	4 wk.	106	16	6.8		
	Total		62	21.9	2.83	2.50

[a]Average of ten animals per group.

[b]$PER = \frac{\text{Weight gain}}{\text{Protein intake}}$

[c]PER adjusted on the basis of 2.50 for casein.

[d]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

TABLE XXVII. NET PROTEIN UTILIZATION (NPU) OF RICE NOODLES

Diet	Body N test group g.	Body N non-protein group g.	N Retention g.	N Intake g.	NPU[a] %
	1.73	1.14	0.59	1.32	45
	1.81	1.18	0.63	1.45	43
Regular noodle	1.72	1.05	0.67	1.25	54
	1.54	1.15	0.39	1.23	32
	1.67	1.14	0.53	1.34	40
Average:[b]	1.69	1.13	0.56	1.32	43
	1.66	1.14	0.52	1.30	40
	1.62	1.18	0.44	1.28	34
20% Soy-rice	1.65	1.05	0.60	1.25	48
	1.74	1.15	0.59	1.39	42
	1.64	1.14	0.50	1.28	39
Average:	1.66	1.13	0.53	1.30	41
	1.93	1.14	0.79	1.34	59
	1.86	1.18	0.68	1.32	52
30% Soy-rice	1.66	1.05	0.61	1.40	44
	1.92	1.15	0.77	1.26	61
	1.84	1.14	0.70	1.17	60
Average:	1.84	1.13	0.71	1.30	55
	1.77	1.14	0.63	1.44	44
	1.70	1.18	0.52	1.28	41
20% Soy + met[c]	1.81	1.05	0.76	1.17	65
	1.80	1.15	0.65	1.26	52
	1.54	1.14	0.40	1.23	33
Average:	1.72	1.13	0.59	1.28	47
	1.73	1.14	0.59	1.30	45
	1.96	1.18	0.78	1.37	57
30% Soy + met[c]	1.75	1.05	0.70	1.24	56
	2.04	1.15	0.89	1.36	65
	1.76	1.14	0.62	1.31	47
Average:	1.85	1.13	0.72	1.32	54
	1.69	1.14	0.55	1.07	51
	1.82	1.18	0.64	1.16	55
Casein	1.78	1.05	0.73	1.27	57
	1.75	1.15	0.60	1.20	50
	1.66	1.14	0.52	1.05	50
Average	1.74	1.13	0.61	1.15	53

[a] $NPU = \frac{N\ Retention}{N\ Intake} \times 100$

[b] Average of five animals per group.

[c] The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

TABLE XXVIII. DIET FORMULATION FOR PROTEIN EFFICIENCY RATIO (PER) ASSAYS OF RICE NOODLES

Diet	Constituent[a]						
	Protein source	Salt	Oil[b]	Fiber	Vitamins[c]	Water	Sucrose
Control	93.9	3.7	1.2	0.2	1.0	0	0
20% Soy	52.4	3.4	1.0	0	1.0	3.0	42.2
30% Soy	41.8	3.4	1.7	0.1	1.0	5.4	52.0
20% Soy + met[d]	50.3	3.4	1.3	0	1.0	4.5	44.0
30% Soy + met[d]	43.5	3.3	0.7	0	1.0	5.1	51.5
Casein	8.2	3.8	1.9	0.4	1.0	8.8	84.7

[a]Percent on moisture-free basis.

[b]Cottonseed oil.

[c]A.O.A.C. vitamin mixture (55).

[d]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

most soy-rice noodles was higher than that of regular rice noodles. The NPU for regular rice noodles was 43, whereas the NPU for 20% soy-rice plus methionine, 30% soy-rice, and 30% soy-rice plus methionine was 47, 55, and 54, respectively. The 20% soy-rice noodles had a significantly lower NPU of 41, comparable to that for regular rice noodles. The NPU for the standard casein reference was 53. This study illustrated that supplementation with 20% soy flour did not significantly increase protein quality of the noodles as judged by NPU value. However, methionine fortification at this amount of soy flour was sufficient to increase protein quality to a level comparable to casein. The 30% soy-rice noodles, with and without methionine fortification, were equal in NPU values and were superior to the 20% soy-rice noodles.

Statistical analysis (t test) of NPU values further illustrated the high protein quality in soy-rice noodles compared to casein. As illustrated in Table XXIX, NPU values for soy-rice noodles containing 20% soy plus methionine, 30% soy, and 30% soy plus methionine were significantly equal ($P < 0.05$) to the NPU value for casein. The 30% soy-rice samples, with and without methionine, had NPU values most nearly equal to that for casein.

Evaluation of NPU data indicates that rice noodles containing higher amounts of soy flour (30%) are superior in protein quality to both rice noodles containing lower amounts of soy flour (20%) and regular rice noodles without soy flour supplementation. Although PER values for methionine-fortified samples are higher than non-fortified ones, 30% soy-rice noodles containing no added methionine represent the best high protein-quality product. This product had both a high protein quality and quantity in addition to having the lowest protein cost of all rice noodles.

TABLE XXIX. STATISTICAL ANALYSIS OF NET PROTEIN UTILIZATION (NPU)[a] DATA FOR RICE NOODLES

Sample groups	t test[b]					
	Control	20% Soy	30% Soy	20% Soy + met[c]	30% Soy + met[c]	Casein
Control	-	0.55	2.41	0.79	2.40	3.29
20% Soy	0.55	-	3.09	1.28	3.19	6.15
30% Soy	2.41	3.09	-	1.41	0.16	0.45
20% Soy + met[c]	0.79	1.28	1.41	-	1.32	1.43
30% Soy + met[c]	2.40	3.19	0.16	1.32	-	0.27
Casein	3.29	6.15	0.45	1.43	0.27	-

[a]NPU values for the control, 20% soy, 30% soy, 20% soy + met[c], 30% soy + met[c], and casein were 43, 41, 55, 47, 54, and 53, respectively.

[b]Five NPU values per group were used for determining t test values. t_{95} (8) = 2.306; values greater than 2.306 are significantly different. Underlined groups are significantly different at $P < 0.05$.

[c]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

b. Protein costs based on PER

A protein cost analysis for rice noodles was made in which the protein cost ratio (PCR) was determined. PCR illustrates the weight gain of laboratory animals per unit cost of protein consumed. A comparison of PCR values as a protein cost criterion (Table XXX), gives an indication of the most economical protein food source with reference to its protein quality (weight gain). Soy-rice noodles have substantially higher PCR's (62.8 to 68.7 g. per cent cost) than regular rice noodles (48.8 g. per cent cost).

A summary of nutritional data, presented in Table XXXI, indicates that various nutritional benefits were derived from development of soy-supplemented rice noodles. A main consideration was increasing the availability of protein having high biological quality. Soy-rice noodles contain higher amounts of protein and a higher protein-calorie ratio than regular rice noodles. In addition, protein quality, as measured by chemical score, PER, and NPU, is significantly higher, with one exception, than regular rice noodles. The 20% soy-rice noodles without methionine had an NPU value similar to that for regular rice noodles. This low value could be attributed to the imbalance in the amino acid content of the first, second, and third limiting amino acids in the 20% soy-rice noodles (see Table XXV). Protein cost analyses illustrate that soy-rice noodles can provide higher amounts of protein at lower cost than regular rice noodles.

Additional nutritional benefits of soy-rice noodles include the ability to provide important amounts of calcium, phosphorous, iron, and magnesium needed in the diet of children. Calcium and phosphorous are the major mineral constituents of bones and teeth (3). Since young children are in a rapid state of skeletal growth, high intakes of these minerals are necessary to insure their proper retention and utilization. Iron is a main constituent of

TABLE XXX. PROTEIN COST RATIO (PCR) OF RICE NOODLES

Product	Wt. gain[a] g.	Protein intake[a] g.	Protein cost[b] ¢ per g.	PCR[c] (Wt. gain per 1¢ cost) g.
Dehydrated rice noodles				
Regular	54	21.7	0.051	48.8
20% Soy	73	25.3	0.042	68.7
30% Soy	64	22.0	0.044	66.1
20% Soy + met[d]	79	26.2	0.048	62.8
30% Soy + met[d]	89	26.7	0.051	65.4
Casein	62	21.9	0.165	17.2

[a]Based on unadjusted PER values from Table XXVI.

[b]From Table XVIII.

[c]$PCR = \frac{PER}{\text{Protein cost}}$. Expressed as g. weight gain per unit cost (¢) of protein consumed.

[d]The 20 and 30% soy-rice noodles were fortified with 0.2 and 0.3% dl-methionine, respectively.

TABLE XXXI. SUMMARY OF NUTRITIONAL DATA FOR RICE NOODLES

Item	Rice noodles				
	Control	20% Soy	30% Soy	Methionine-fortified	
				20% Soy	30% Soy
Protein (%[a])	7.8	15.0	18.0		
Calcium[b]	19.2	73.6	80.0		
Iron[b]	2.33	3.46	4.68		
Magnesium[b]	5.2	40.0	64.8		
Phosphorous[b]	74.0	156.0	208.0		
Protein-cal. ratio[c]	7.3	13.8	16.4		
Chemical scores[d]	40	60	76	60	76
PER[e]	2.16	2.56	2.58	2.69	3.00
NPU[e]	50	48	62	54	61
Costs					
Protein[f]	23.1	19.3	20.0	22.0	23.3
PCR[g]	48.8	68.7	66.1	62.8	65.4
Protein[h]	53.7	47.1	36.4	46.8	43.2

[a]Dry basis, N X 5.95 for control; N X 6.25 for soy-rice noodles.

[b]Mg. per 100 g. product.

[c]Calories derived from protein as percent of total calories.

[d]Chemical scores based on the most limiting amino acid (lysine) compared to FAO reference pattern (30).

[e]PER based on casein = 2.50; NPU based on casein = 60 (59).

[f]Protein cost (cents per pound) of product with allowances being made for carbohydrate and fat content using broken rice and vegetable cooking oil as the cheapest sources of these nutrients, respectively.

[g]Protein Cost Ratio (PCR) is the g. weight gain of experimental animals per unit cost (cent) of protein.

[h]Protein cost per pound of product adjusted for NPU values (Table XVIII).

hemoglobin and it is needed, therefore, to maintain adequate hemoglobin levels in the blood. Magnesium is an important constituent of soft tissue and bone, and it is associated with neuromuscular contraction and protein synthesis (3).

II. HIGH-PROTEIN RICE-BASED SNACKS

A. DEVELOPMENT

1. Product Design

The development of high-protein snacks is a means by which important amounts of protein can be added to the diet of Thai children. The consumption of small amounts of these products between meals can supplement otherwise protein-deficient diets.

As previously stated, a study reported that snack consumption among Thai children is popular (38). Traditional Thai snacks include rice- or cassava-based items which are deep-fat fried into edible, crisp chips. Snacks containing only rice and/or cassava are very low in both protein quality and quantity. Snacks containing high levels of protein are also high in cost. The consumption of snack foods can be observed throughout Thailand in both urban and rural areas. Snacks are readily available from numerous shops and vendors.

The rice-based snacks developed for this study contained approximately 30% (dry basis) of added high-protein ingredients, namely, full-fat soy flour, soy protein concentrate, ground sesame, and fish protein concentrate (FPC) (see Table VI). Salt, curry powder, and chili pepper powder were included in the formulation. Sesame and FPC comprised approximately 5% (dry basis) of the product. Combinations of rice with these ingredients can result

in both increased protein quantity and quality in the developed products. The beneficial effect of adding soy protein to rice protein has been previously illustrated and discussed in connection with the nutritional evaluation of soy-rice noodles. Snacks containing soy flour or soy concentrate are relatively similar to the 30% soy-rice noodles in the amount of soy ingredient added to the rice base.

Ground sesame seeds were suitable for incorporation with soy and rice flours to develop high-protein snacks. Sesame contains a relatively high amount of methionine (78) which can supplement the low amount found in soy flour. The additional benefits of nut-like flavor and crunchy texture were present.

The use of small amounts (5%) of FPC in snack formulations was significant since animal protein is utilized without it dominating the flavor of the product. In addition, protein from FPC provided a significant amount of the total calories (20%) owing to the high protein content of FPC. The addition of 5% fish meal to milled rice has been reported to have increased the PER by 50% compared to unsupplemented rice (82). This can be attributable to the high level of lysine in FPC which supplemented the low level of lysine found in rice.

Six formulations initially used (Table VI) to prepare laboratory snack prototypes received average scores from 3.70 to 4.42 on a five-point hedonic scale as judged by elementary school children. The three highest scores were 4.42, 4.32, and 4.09 for soy, soy-sesame, and soy-fish formulations. The soy snack formulation was used to prepare soy chips at the noodle factory. This product is similar in its soy and rice flour mixture to that of the 30% soy-rice noodles. Nutritional data reported for 30% soy-rice noodles can be considered in evaluating the soy chips. The soy-sesame and soy-fish snacks were

included in product evaluation studies.

A snack (soy curls) was prepared on a cooker extruder from a basic mixture of soy protein concentrate and rice. The good keeping character and high protein quality of extruded products containing mixtures of rice and soy flours has been reported (82). One such mixture produced a protein-rich snack food having an NPU of 65. Soy curls developed in this study were a ready-to-eat product, as opposed to other snacks which required brief deep-fat frying to produce an edible snack food.

New high-protein rice snacks were designed to be similar to popular Thai snacks. Typical snack items used as controls were shrimp-flavored chips (rice and cassava flours), red-colored chips (rice and cassava flours), and soy cookies (soy and wheat flours). Soy cookies were developed at the Institute (11). High-protein rice snacks and regular snacks (controls) used for evaluation studies are shown in Figs. 23 and 24, respectively.

2. Moisture and Nutrient Changes

a. Storage

Moisture contents of soy, soy-sesame, and soy-fish chips determined initially and after three and six months storage are illustrated in Fig. 25. In addition, the moisture content for soy curls, shrimp-flavored chips, and red-colored chips initially and after three months storage are also shown in this Table. Increases in moisture content with increasing length of storage was observed for all products. The final moisture content in soy, soy-sesame, and soy-fish chips was 10.3, 10.1, and 11.1%, respectively.

b. Frying

Nutrient changes in soy, shrimp-flavored, and red-colored chips after

Fig. 23. High-protein dehydrated and fried rice snack chips and extruded rice snack: soy chips (A), soy-sesame chips (B), soy-fish chips (C), and soy curls (D).

Fig. 24. Regular (commercially available) dehydrated and fried snack chips and cookies: red-colored chips (E), shrimp-flavored chips (F), and soy cookies (G).

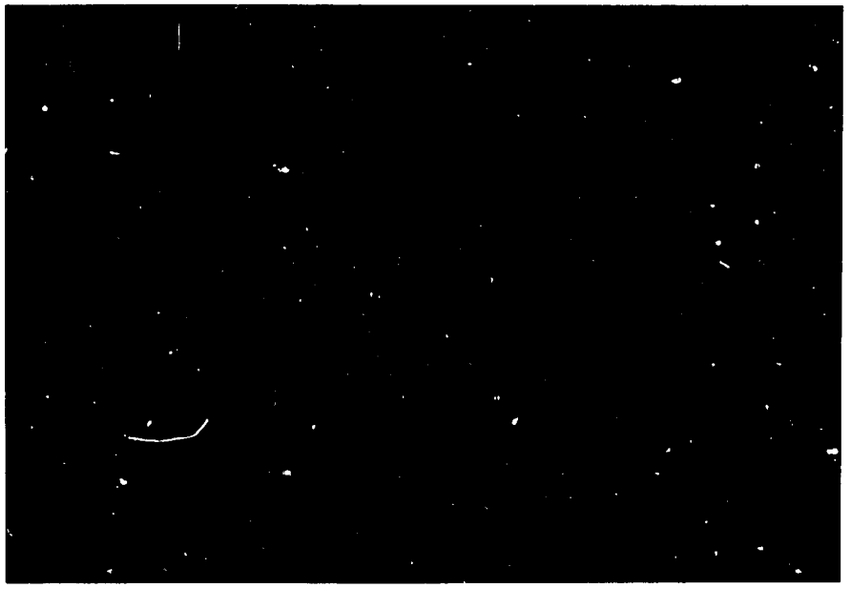
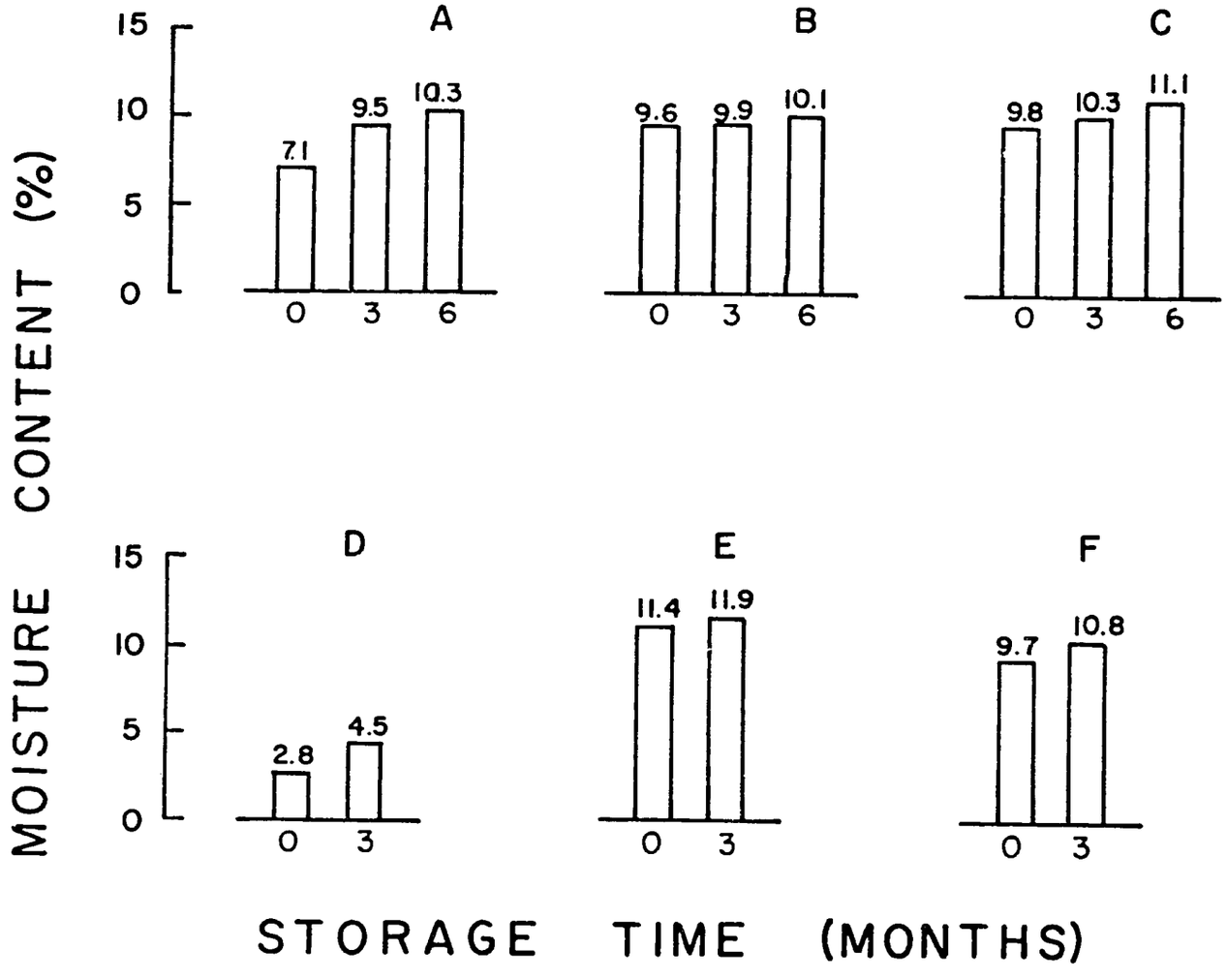


Fig. 25. Moisture contents of rice snacks [soy chips (A), soy-sesame chips (B), soy-fish chips (C), soy curls (D)] and regular snacks [red-colored chips (E) and shrimp-flavored chips (F)] stored for three (D, E, F) and six months (A, B, C).



deep-fat frying are shown in Table XXXII. All products decreased in moisture content with a concurrent increase in fat content. The moisture contents for all snacks after frying were relatively equal, averaging 3.9%. Protein contents reported after frying indicate the actual content in the edible snack.

The amount of fat absorption is important because it affects the protein-calorie ratio in addition to the texture and flavor of the snacks. Soy chips absorbed the lowest amount of fat by weight (six times) as compared to the regular shrimp-flavored (16 times) and red-colored (76 times) chips. High fat absorption in the regular snacks could be attributed to the coarse texture of the rice and cassava flours used in making the snacks. Soy chips contained finer ground rice and soy flours. Soy flour supplementation in doughnuts has also been found to prevent excessive fat absorption during frying (79). Soy chips maintained a high protein-calorie ratio (15%), whereas this value decreased in regular snacks. The fat used in frying the snacks increased the calorie content without contributing to their protein content.

3. Product Costs

Retail product costs and protein costs for the new rice snacks and regular snacks are given in Table XXXIII. Retail product costs for rice snacks and regular snacks are based on local ingredient, production, and labor costs in Bangkok; profit and transportation costs are not included. Soy-sesame and soy-fish chips are lower in retail costs than shrimp-flavored chips or soy cookies. Red-colored chips have the lowest retail cost of all snacks. Soy curls have the highest retail cost of new rice snacks. High cost is partially attributable to the high ingredient cost of soy protein concentrate that is produced in small quantities at the Institute.

The net cost per pound of protein for new rice snacks ranges from 31.4¢

TABLE XXXII. NUTRIENT CHANGES IN SNACK CHIPS AFTER DEEP-FAT FRYING

Snack chips	Moisture %		Protein %		Fat %		Calories		Protein-Calorie Ratio[c]	
	I[a]	A[b]	I[a]	A[b]	I[a]	A[b]	I[a]	A[b]		
Soy	9.8	3.6	18.0	17.4	3.1	18.6	403	464	17.9	15.0
Shrimp-flavored	11.7	3.6	15.8	15.2	2.0	32.3	403	535	15.7	11.4
Red-colored	11.6	4.4	3.7	3.5	0.3	22.9	404	494	3.7	2.8

[a]Initial values reported and calculated on a dry basis.

[b]Values after deep-fat frying calculated on a fried product basis.

[c]Calories derived from protein as percent of total calories (1 g. of protein is equal to 4 calories).

TABLE XXXIII. COST OF PROTEIN IN SNACKS

Item	Retail product cost[a] per lb. ¢	Protein cost per lb. of product[b] ¢	Net cost per lb. of protein ¢
New snacks			
Soy-sesame[c]	10.5	6.2	36.1
Soy-fish[c]	11.5	7.5	35.0
Soy chips[d]	9.8	5.6	31.4
Soy curls[e]	22.8	19.6	79.8
Regular snacks			
Shrimp-flavored chips	24.3	19.3	122.2
Red-colored chips	8.3	5.2	140.5
Soy cookies	31.8	21.2	115.2

[a]Based on local ingredient and production costs (with the exception of fish, which was imported FPC) in Bangkok (September 1, 1973).

[b]After allowing for carbohydrate (based on broken rice, 4.3 cents per lb.) and fat content (based on vegetable cooking oil, 36.0 cents per lb.). These are cheap Thai sources of these nutrients.

[c]Laboratory prototypes.

[d]Factory-prepared.

[e]Extrusion-cooked product.

for soy chips to 79.8¢ for soy curls. In contrast, net protein costs for regular snacks are three and one-half to four times higher than the average net protein cost for the three rice snack chips (soy-sesame, soy-fish, and soy); net protein costs for regular snacks are one and one-half times higher than the protein cost for soy curls.

The costs indicate that the newly-developed rice snacks provide higher amounts of protein at substantially lower prices than commercially available snacks. The ability of snacks to provide protein in deficient diets is definitely associated with the availability of the product and is also determined primarily by its cost.

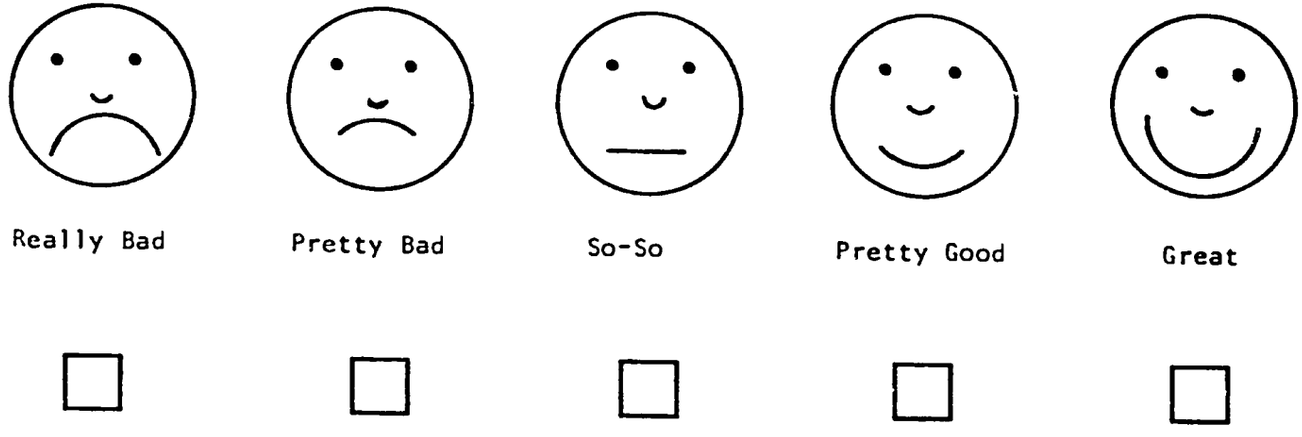
B. ACCEPTABILITY

1. Elementary School Children

Acceptability studies were conducted with first grade elementary school children (seven to eight years of age) using a five-point hedonic scale (54). A score sheet appears in Fig. 26. Initial snack preferences by children at Bang Bua School for soy-rice snacks and regular snacks are graphically shown in Fig. 27. Snack preferences by children at Kasetsart Demonstrated School are shown in Fig. 28, including preferences for soy-sesame and soy-fish chips. Fig. 29 compares snack preference scoring by children at both schools for soy chips, soy curls, red-colored chips, shrimp-flavored chips, and soy cookies.

Fig. 27 illustrates that all the snack products were well-accepted by children at Bang Bua School. More than 75% of the children gave scores of 5.0 (very happy face--great) to the snack products. Children at the Kasetsart Demonstrated School (Fig. 28), however, were more discriminating in their preference for specific snacks. Soy-sesame chips were most preferred of the new rice snacks followed by soy chips and soy-fish chips; soy curls were least

(English Translation)



Check (✓) the box that shows how this food makes you feel.

Fig. 26. Score sheet used for evaluating snack food preferences with elementary school children.

Fig. 27. Preference scores for soy chips (A), soy curls (B), red-colored chips (C), shrimp-flavored chips (D), and soy cookies (E) for elementary school children at Bang Bua School. A five-point hedonic scale was used to measure preference: 1 = really bad, 5 = great.

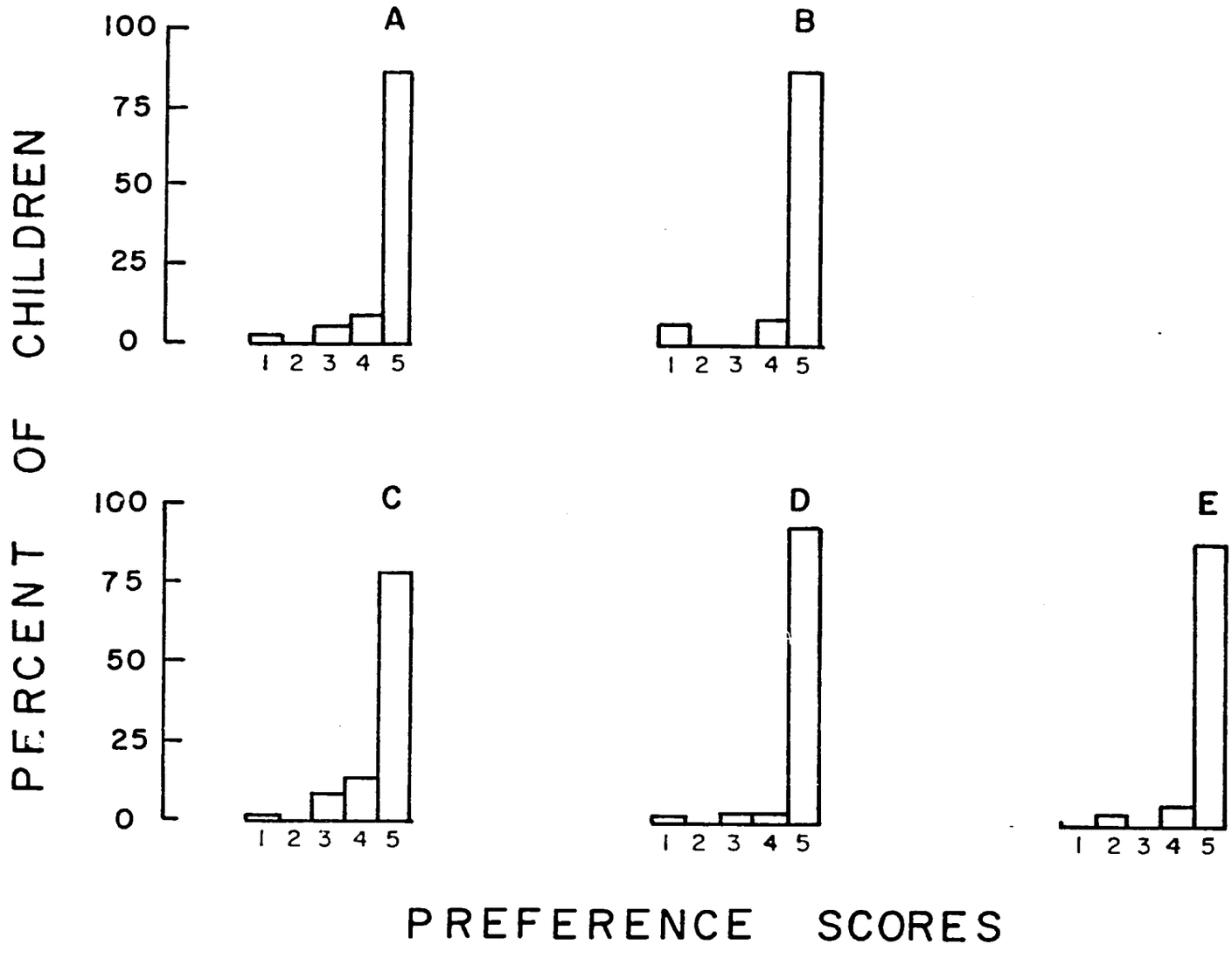


Fig. 28. Preference scores for soy chips (A), soy-sesame chips (B), soy-fish chips (C), soy curls (D), red-colored chips (E), shrimp-flavored chips (F), and soy cookies (G) for elementary school children at Kasetsart Demonstrated School. A five-point hedonic scale was used to measure preference: 1 = really bad, 5 = great.

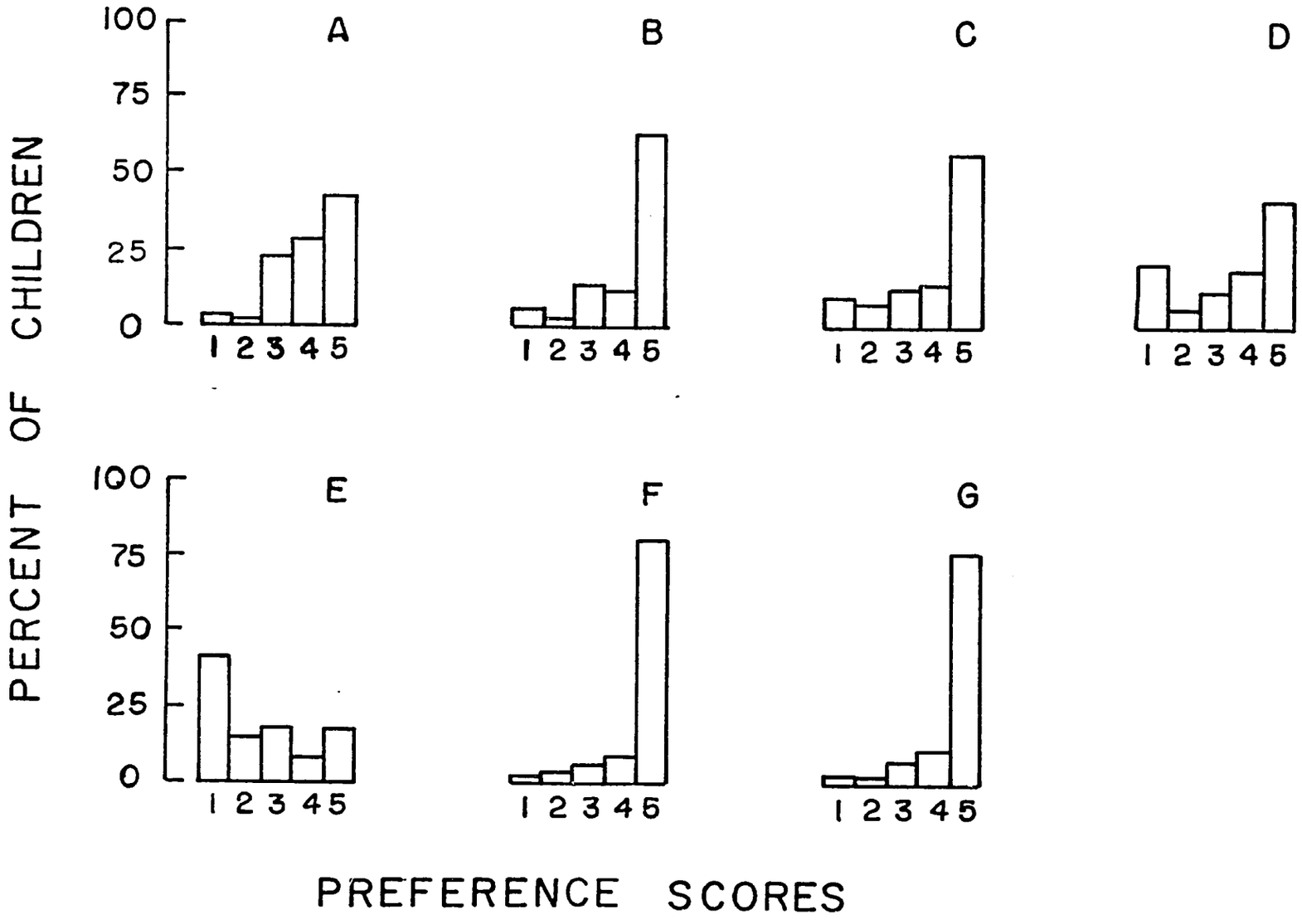
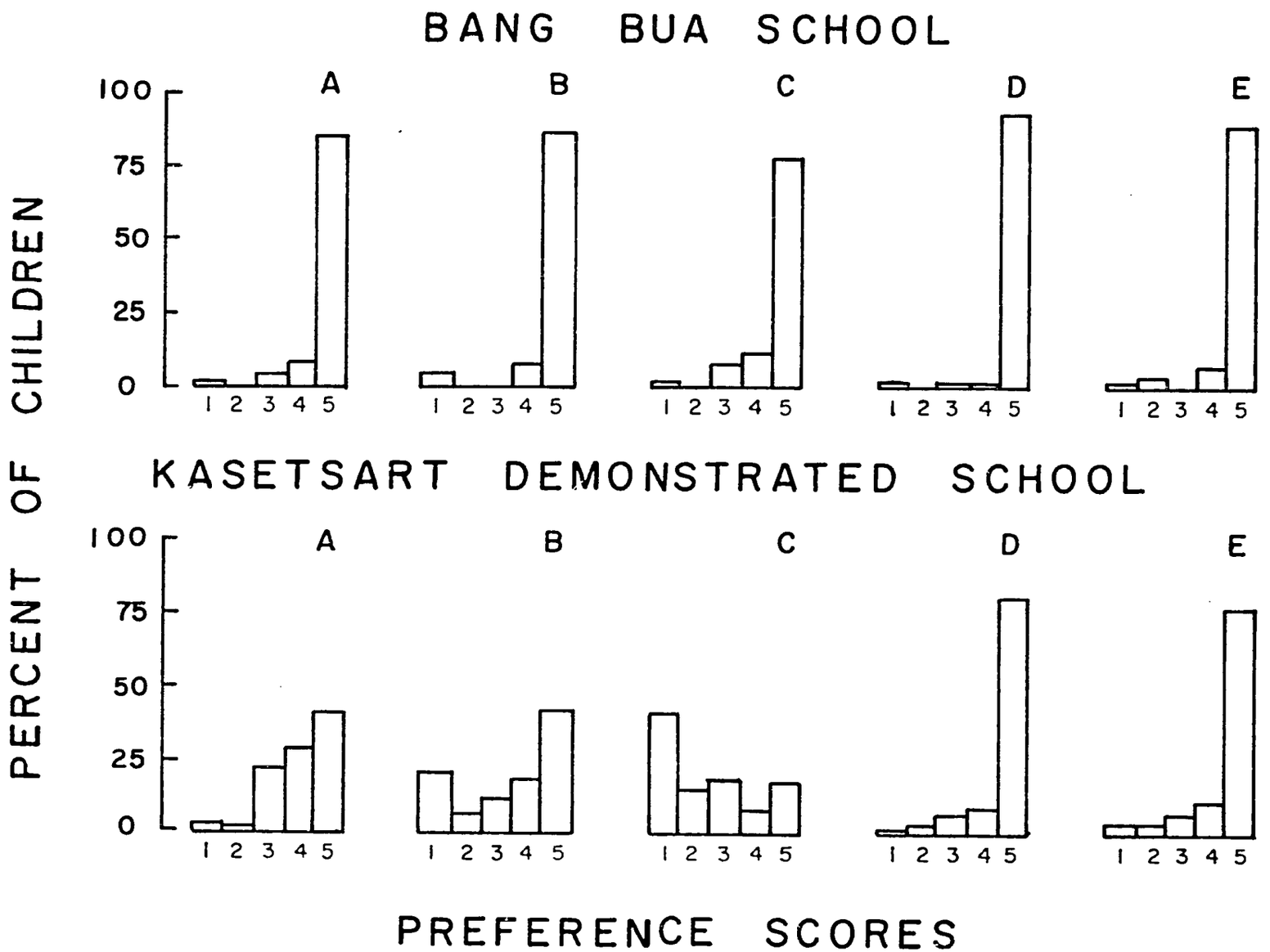


Fig. 29. Preference scores for soy chips (A), soy curls (B), red-colored chips (C), shrimp-flavored chips (D), and soy cookies (E) for elementary school children at Bang Bua and Kasetsart Demonstrated Schools. A five-point hedonic scale was used to measure preference: 1 = really bad, 5 = great.



liked. Regular shrimp-flavored chips and soy cookies were equally well-accepted, whereas red-colored chips were rated as being very objectionable.

A comparison (Fig. 29) between the two schools of snack acceptability shows that higher preference scores were given by children at Bang Bua School (lower-income families) than by those at Kasetsart Demonstrated School (higher-income families). At the former school, soy, soy-sesame, and soy-fish chips compared favorably to the high acceptability of regular shrimp-flavored chips and soy cookies.

Scoring systems for evaluating preference scores are given in Table XXXIV. The score point average and snack acceptability index (SAI) for the initial scores given the various snacks are shown. Bang Bua School children gave score point averages ranging from 4.67 to 4.83 and SAI values ranging from 91.5 to 95.1%. These high scores support the fact that all snacks were very acceptable to those children. Scores given by children at Kasetsart Demonstrated School indicate that snacks were not equally acceptable. Shrimp-flavored chips had both the highest score point average (4.63) and corresponding SAI (89.6%) of all snacks at Kasetsart Demonstrated School. In contrast, red-colored chips had the lowest scores, namely, a score point average of 2.42 and a SAI value of 24.6%. Rice chips had score point averages ranging from 4.01 to 4.27 and SAI values ranging from 70.7 to 77.2%. Soy curls were least liked of rice snacks, having scores of 3.55 and 60.4% for the score point average and SAI, respectively. Scoring systems demonstrate acceptabilities for snacks compared to other snacks and between schools.

Changes in the acceptability of stored snacks were investigated. Table XXXV gives the score point averages for snacks stored three and six months. Scores by Bang Bua School children were slightly higher after storage. The Kasetsart Demonstrated School children gave scores which were lower after

TABLE XXXIV. SNACK SCORES BY ELEMENTARY SCHOOL CHILDREN

Snacks	Scoring system	
	Score pt. avg.[a]	SAI[b]
Bang Bua School		
New Rice Snacks		
Soy chips	4.77	93.9
Soy curls	4.67	93.7
Regular Snacks		
Shrimp-flavored chips	4.83[c]	95.1
Red-colored chips	4.67	91.5
Soy cookies	4.78[c]	95.1
Kasetsart Demonstrated School		
New Rice Snacks		
Soy-sesame chips	4.27	77.2
Soy-fish chips	4.01	71.4
Soy chips	4.03	70.7
Soy curls	3.55	60.4
Regular Snacks		
Shrimp-flavored chips	4.63[c]	89.6
Red-colored chips	2.42	24.6
Soy cookies	4.56[c]	87.7

[a]Average score obtained from preference categories using a five-point hedonic scale: 1 = really bad, 5 = great. Preference categories correspond to facial expressions shown in Fig. 26.

[b]Snack acceptability index: combined percentages of children scoring snacks 4 and 5.

[c]Not significantly different ($P < 0.01$) between schools.

TABLE XXXV. SNACK SCORES OF STORED SNACKS BY ELEMENTARY SCHOOL CHILDREN

Snacks	Score point average[a] Storage period (months) 0	3	6	Z values[b]
Bang Bua School				
New Rice Snacks				
Soy chips	----	4.77	4.90	1.55
Soy curls	4.67	4.81	----	1.05
Regular Snacks				
Shrimp-flavored chips	4.83	4.89	----	0.63
Red-colored chips	4.67	4.77	----	0.97
Soy cookies	4.78	4.85	----	0.60
Kasetsart Demonstrated School				
New Rice Snacks				
Soy-sesame	4.27	----	4.14	0.67
Soy-fish	4.01	----	3.89	0.53
Soy chips[c]	4.03	3.93	4.17	0.63, 1.03, 1.57
Soy curls	3.55	3.44	----	0.53
Regular Snacks				
Shrimp-flavored chips	4.63	4.34	----	2.33
Red-colored chips	2.42	2.31	----	0.55
Soy cookies	4.56	4.43	----	0.94

[a]Score point average is the average score obtained from the preference score categories using a five-point hedonic scale: 1 = really bad, 5 = great. The preference score categories correspond to facial expressions shown in Fig. 26.

[b]$Z_{99} = 2.58$; values greater than 2.58 are significantly differently ($P < 0.01$).

[c]Z values for the comparison of soy chips: 0 month storage with 3-month storage, 0 month storage with 6-months storage, and 3-months storage with 6-months storage, respectively.

storage of all products with the exception of soy chips which had an increase in score after six months storage. All changes in scores for both schools, however, were relatively slight.

The difference in score point averages among the snacks and between the two schools were tested statistically. Scores obtained for both fresh and stored products were evaluated to determine whether or not preferences were significantly different.

Table XXXVI illustrates the statistical evaluation of snack scores at each school. Differences among the scores at Bang Bua School were not significant, whereas differences among scores at Kasetsart Demonstrated School were significant for $P < 0.01$. Snack scores for soy-sesame chips, shrimp-flavored chips, and soy cookies were significantly equal at Kasetsart Demonstrated School. The red-colored chips were significantly inferior to all snack products. Differences among the rice snacks were found. Soy-sesame and soy chips were superior to soy curls, whereas soy-fish chips and soy curls were equal in preference scores. Although only the soy-sesame rice snack was significantly equal in preference scores to the familiar shrimp-flavored and cookie snacks, all rice snacks scored significantly higher than regular red-colored chips. In general, the higher-priced shrimp-flavored chips would be a more familiar snack food item than the lower-priced red-colored chips. Both snacks are available in urban and rural market places, but the shrimp snacks would be purchased more by children of higher economic status than by children of lower economic status.

Snack scores between each school (Table XXXIV) were significantly different for soy chips, soy curls, and red-colored chips. Shrimp-flavored chips and soy cookies were scored equally ($P < 0.01$). Differences in snack scores for all stored samples were not significant for $P < 0.01$ (Table XXXV).

TABLE XXXVI. STATISTICAL EVALUATION OF SNACK SCORES BY ELEMENTARY SCHOOL CHILDREN

Scores[a]	Snacks[b]	Z values[c]						
Bang Bua School								
4.77	SC		----					
4.67	CR		0.74	----				
4.83	SH		0.58	1.17	----			
4.67	RD		0.91	0.00	1.44	----		
4.78	CK		0.11	0.80	0.44	0.97	----	
			SC	CR	SH	RD	CK	
Kasetsart Demonstrated School								
4.27	SM	----						
4.01	FH	1.20	----					
4.03	SC	1.42	0.07	----				
3.55	CR	3.55	2.10	2.67	----			
4.63	SH	2.23	3.36	4.62	6.34	----		
2.42	RD	9.39	7.40	9.32	5.51	13.54	----	
4.56	CK	1.72	2.89	3.89	5.76	0.61	12.75	----
		SM	FH	SC	CR	SH	RD	CK

[a]Average score obtained from preference categories using a five-point hedonic scale: 1 = really bad, 5 = great. Preference categories correspond to facial expressions shown in Fig. 26.

[b]SC--soy chips, CR--soy curls, SM--soy-sesame chips, FH--soy-fish chips, SH--shrimp-flavored chips, RD--red-colored chips, CK--soy cookies.

[c]Z_{99} = 2.58; values greater than 2.58 are significantly different. Underlined values are significantly different ($P < 0.01$).

C. NUTRITIONAL EVALUATION

1. Proximate Analyses

Proximate analyses and caloric values for high-protein rice snacks and regular snacks appear in Table XXXVII. The protein content (dry basis) in extruded soy curls (24.6%) is the highest. Protein contents for other new rice snacks range from 17.2 to 21.4%. Regular snacks contain as high as 18.4% protein in the soy cookies and as low as 3.7% in the red-colored chips. A 10-g. portion of soy-sesame chips, soy chips, soy-fish chips, and soy curls can provide 8, 9, 10, and 12%, respectively, of the Thai recommended daily allowances (RDA) of protein (29) for pre-school children aged four to six years. Higher percentages of the Thai RDA for protein (10-14%) can be provided by these new rice snacks for younger children (one to three years of age). Protein-calorie ratios, i.e., the percentage of calories derived from protein, for soy chips, soy curls, shrimp-flavored chips, red-colored chips, and soy cookies are 15.0, 24.4, 11.4, 2.8, and 14.4%, respectively.

Soy curls and red-colored chips have very low fat contents before frying (0.2 and 0.3%, respectively). Soy cookies have a relatively high fat content (22.8%), mostly attributable to the milk, margarine, and eggs included in their formulation. The caloric content of each snack sample is associated with fat contents. Soy cookies contain 512 calories per 100 g. sample, whereas the other snacks contain an average of 406 calories per 100 g. sample.

2. Vitamin and Mineral Analyses

Vitamin and mineral assays for soy chips and soy curls are reported in Table XXXVIII. These snacks contain higher amounts of alpha-tocopherol (vitamin E) than the other vitamins assayed. Significant amounts of calcium, magnesium, and phosphorous are present in the samples. Soy curls contain

TABLE XXXVII. PROXIMATE ANALYSES[a] AND CALORIC VALUES OF SNACKS

Snack Item	Nutrient					
	Protein[b] %	Ash %	Fiber %	Fat %	Carbohydrate %	Calories[c] %
New high-protein rice snacks						
Soy-sesame[d]	17.2	2.4	2.9	3.1	74.4	409
Soy-fish[d]	21.4	2.4	2.8	2.4	71.0	405
Soy chips[e]	18.0	2.4	4.3	3.1	72.2	403
Soy curls[f]	24.6	2.3	0.5	0.2	72.4	404
Regular snacks						
Shrimp-flavored chips	15.8	0.6	4.9	2.0	76.7	403
Red-colored chips	3.7	0.5	3.6	0.3	91.9	404
Soy cookies	18.4	2.8	0.5	22.8	55.5	512

[a]Percent composition on a dry basis.

[b]N X 6.25.

[c]Dry basis, per 100 g. sample (30).

[d]Laboratory prototypes

[e]Factory-prepared

[f]Extrusion cooked

TABLE XXXVIII. VITAMIN AND MINERAL ANALYSES[a] OF SOY CHIPS AND SOY CURLS

Nutrients	Soy Chips	Soy Curls
Vitamins		
A	0	0
alpha-Tocopherol (E)	4.30	5.20
Thiamin (B-1)	0.03	0.02
Riboflavin (B-2)	0.08	0.07
Pyridoxine (B-6)	0.17	0.12
Niacin	0.79	1.21
Minerals		
Calcium	94.5	75.1
Iodine (mg./kg.)	6.8	2.1
Iron	2.0	36.3
Magnesium	70.8	36.8
Phosphorous	204.8	226.9

[a]Mg. per 100 g. sample. Analyses by Department of Science, Ministry of Industry, Bangkok.

substantially more iron than soy chips. The effect of using iodized salt in the snack formulations is evident although the iodine content is still quite low. The use of salt containing higher amounts of iodine would be more favorable. Rice and soybeans are lacking in this important mineral. The occurrence of goiter in individuals on iodine-deficient diets, attributable to low intake of sea foods and high intake of goitrigenic foods (e.g., cabbage), is well-established. A similar dietary pattern is observed in rural villages of northern Thailand.

The overall nutritional importance of soy-rice snacks is their ability to provide important amounts of high-quality protein and various minerals when eaten in relatively small amounts as between-meal foods. High-protein snacks which are low in cost are suitable food supplements in child feeding programs for improving the nutritional status of Thai children.

SUMMARY AND CONCLUSIONS

High-protein dehydrated rice noodles and rice-based snacks were developed for this study at the Institute of Food Research and Product Development, Kasetsart University, Bangkok, Thailand, for incorporation into child feeding programs. The acceptability of the products was determined with children and their nutritional quality was evaluated using chemical and biological methods.

The increasing occurrences of protein-malnutrition among Thai children of pre-school age has resulted in the establishment of government programs aimed at improving the protein status of children. The establishment of Child Nutrition Centers and the development of new high-protein, low-cost foods and supplements has been an important step in providing foods to meet the dietary protein needs of young children.

Rice noodles were supplemented with 20 and 30% (dry basis) full-fat soy flour to produce high-protein traditional food. In addition, 20 and 30% soy-rice noodles fortified with 0.2 and 0.3% (dry basis) dl-methionine, respectively, were prepared. The mixture of rice and soy flours utilized Thailand's food staple in combination with an available protein-rich food source to produce a food product familiar to the Thai dietary pattern.

Dehydrated noodle samples increased in moisture content during six months of storage. Soy-rice noodles exhibited an improvement in texture and cooking strength during five-month storage studies. Regular noodles initially absorbed more water and disintegrated to a lesser degree during prolonged cooking than did soy-rice noodles. Stored regular noodles, however, decreased

in water absorption capacity and disintegrated to a greater degree as storage time increased, whereas soy-rice noodles had marked improvement for these factors. All noodle samples exhibited poorer texture and cooking quality towards the end of the storage study.

Quality evaluation of stored dehydrated noodle samples was conducted monthly with an adult taste panel during five months of storage. Preference scores were given by members using a nine-point hedonic scale. Statistical analysis (AOV) of mean scores for appearance, color, and flavor showed that regular rice noodles were significantly preferred ($P < 0.05$) to all soy-rice noodle samples. Texture scores were significantly equal, however, for all products during most of the storage study. The 20 and 30% soy-rice samples, with and without methionine fortification, were significantly equal to each other for all quality factors in 60% of the scoring tests. The most objectionable factor was color, whereas flavor and texture were the least objectionable. The taste panel, however, did not distinguish between the two amounts of soy supplementation or additions of methionine in the rice noodles. Scores for each product and quality factor did not significantly change ($P < 0.05$) during the five-month storage study.

Cost analyses of soy-rice noodles compared to regular rice noodles and animal-protein foods illustrated that the soy-rice noodles had a definite advantage. The net cost of protein per pound for all soy-rice noodles, with the exception of the 30% soy-plus-methionine sample, was lower than that for regular rice noodles. Protein costs for casein, beef, and pork were approximately three to four times more than those for soy-rice noodles. Methionine-fortified noodles had generally higher protein costs, attributable to the high cost of methionine.

Acceptability studies were conducted with pre-school children at two

Child Nutrition Centers (CNC) located in northern Thailand and at a nursery school in Bangkok. Children attending the nutrition centers were from lower income families, whereas those attending the Kasetsart University Nursery School were from higher income families. The number of children consuming none, some, and all of the initial soy-rice noodle servings and those requesting extra portions illustrated the consumption pattern for soy-rice products. Two separate acceptability studies were conducted for 24 weeks and 14 weeks at the nutrition centers and the nursery school, respectively, in which soy-rice noodles were incorporated into traditional Thai dishes. Noodle consumption was used as an index of acceptability. Consumption patterns for regular rice (control) noodles, wheat noodles, and normal (non-noodle) dishes were similarly determined for comparison with those of soy-rice noodles.

Differences for the consumptions of various dishes were tested statistically for $P < 0.01$. The consumption of soy-rice noodles was significantly equal to that of regular (control) rice noodles at each testing locality. The consumption of the other control dishes, wheat noodles and non-noodle dishes, varied among schools, being acceptable in most cases. The acceptability of soy-rice noodles, at both amounts of soy-supplementation and methionine fortification, however, was favorable at all places. Furthermore, no significant differences in preference were found between either the 20 and 30% soy-rice noodles or the methionine-fortified samples. All soy-rice noodles, therefore, were equal in acceptability to traditional regular rice noodles. Although there was a significantly higher consumption of all dishes at one CNC, the income level of the children's families did not seem to influence the acceptability of the soy-rice noodles. In addition, children attending the nursery school (Kasetsart) preferred soy-rice noodles (30%) to either regular rice or wheat noodles when given a choice in two separate testing

situations.

The nutritional quality of soy-rice noodles was determined by means of chemical analysis and biological testing procedures. The protein content in soy-supplemented rice noodles was two to two and one-third times that of regular rice noodles. Vitamin and mineral assays showed that addition of full-fat soy flour to rice flour greatly increased the content of essential dietary minerals in soy-rice noodles compared to regular ones. The contents of calcium, iron, magnesium, and phosphorous were four, two, twelve, and three times that of ordinary rice noodles, respectively. Soy-rice noodles had increased amounts of vitamin E and B-complex vitamins, although at a lesser improvement than reported for mineral contents.

Chemical score, protein efficiency ratio (PER), and net protein utilization (NPU) were determined for rice noodle samples as indicators of protein quality. Amino-acid analyses indicated a marked improvement in the amino acid pattern and subsequent chemical score as a result of supplementation of rice flour with soy flour. A chemical score of 40 for regular rice noodles increased to 60 for 20% soy-rice noodles and to 76 for 30% soy-rice noodles. These scores were calculated using the FAO (1973) reference pattern. Lysine was the first limiting amino acid in all samples. The amounts of methionine used for fortifying the 20 and 30% soy-rice noodles (0.2 and 0.3%, respectively) compared favorably with the FAO amino acid reference pattern.

PER and NPU values were determined using standard rat growth studies. The PER for regular rice noodles was 2.16, in contrast to PER values of 2.56, 2.58, 2.69, and 3.00 for the 20%, 30%, 20% plus methionine, and 30% plus methionine soy-rice samples, respectively, based on a PER for casein of 2.50. Soy-supplemented noodles had PER values similar to casein. Furthermore, methionine-fortified soy-rice noodles had higher PER values than non-fortified

soy samples. Similarly, soy-rice noodles had higher NPU values than regular rice noodles. Casein had an NPU value of 53, which was significantly equal ($P < 0.05$) to the respective NPU values of 47, 55, and 54 for the 20% soy plus methionine, 30% soy, and 30% soy plus methionine samples. Regular rice noodles and 20% soy-rice noodles had significantly lower respective NPU values of 43 and 41 compared to casein and other soy samples. NPU values illustrated a beneficial effect of methionine fortification at 20% soy supplementation, whereas the 30% soy samples, with and without added methionine, had significantly equal NPU values.

In general, soy-supplemented rice noodles demonstrated improvement in availability of high-quality protein compared to unsupplemented ones. Soy-rice noodles contained higher amounts of protein, vitamins, and minerals in addition to providing animal-quality protein. Since soy-rice noodles were equally acceptable to regular rice noodles, they were suitable for use in child feeding programs.

The high-protein rice-based snacks developed as a supplement in child feeding programs contained 30% (dry basis) of added high-protein ingredients, namely, full-fat soy flour, soy protein concentrate, ground sesame, and fish protein concentrate (FPC). Rice snacks, with the exception of one product, were modified rice noodle formulations, with spices and seasoning, prepared into dehydrated chips of various sizes and shapes. A blend of rice flour and soy protein concentrate (30% on a dry basis) was used to prepare one extrusion-cooked snack item in the shape of curls.

New rice snacks had substantially lower protein and product costs than three regular (control) snacks commercially available in Thailand, namely shrimp-flavored chips, red-colored chips, and soy cookies. The new high-protein rice snacks were approximately equal in protein cost with the exception

of the extruded soy curls which were twice the cost. The protein cost of regular snacks, however, ranged from one and one-half to four times that of new rice snacks.

Preference scoring tests were used to determine acceptability of the new high-protein snack products. First-grade elementary school children from lower- and upper-income families participated in these studies. Score point averages were determined for the snack foods using a five-point hedonic scale which corresponded to facial expressions. Children were asked to relate their feelings for each snack to the appropriate facial expression which, in turn, was equal to a preference score of one to five. Three regular commercially-available snacks (shrimp-flavored chips, red-colored chips, and soy cookies) were included in the acceptability studies as controls.

Differences in score point averages among the various snacks, both within each school and between schools, were tested statistically for $P < 0.01$. All snack products, new and control, received significantly equal high scores at the school attended by children from lower income families. In contrast, children from upper income families, who attended the other school, scored the snack products over a wider range. The rice snack containing a blend of soy flour and ground sesame had a high score point average significantly equal to those for two control samples. Scores for three rice snacks, excluding the extruded snack curls, were significantly equal and higher than those for the third control sample (red-colored chips). The extruded snack received the lowest score of all rice snacks; however, it scored significantly higher than the third control sample. A comparison between scores definitely showed that the new rice snacks were more preferred at the first school than at the second ($P < 0.01$). Overall scores did indicate, however, that most of the new high-protein snacks were well-liked although they were not equal between the schools.

Several new and regular snacks were scored after three and six months storage time. No significant differences ($P < 0.01$) in these scores attributable to storage time were found.

Nutritional evaluation of rice snacks was concerned primarily with protein content of the samples. Soy snacks contained from 17.2 to 24.6% protein, whereas the protein content in regular snacks ranged from 3.7 to 18.4%, all samples calculated on a dry basis. High amounts of calcium, phosphorous, and magnesium were observed in the high-protein snacks. Previous investigations into the nutritional quality of soy-rice blends in the form of noodles showed substantial protein quality improvement. New rice snacks which were primarily blends of soy and rice flours should exhibit similar nutritional improvements as indicated in the soy-rice noodles.

High-protein, soy-supplemented rice noodles and rice-based snacks proved to be both acceptable and nutritional food products suitable for use in child feeding programs. The development of both products related to blending low-cost, high-protein, locally-available food sources, mainly soy flour, to rice flour base. The preparation of either dehydrated noodles or snacks used similar basic procedures with a few modifications. Extrusion cooking also produced a high-protein rice snack. The nutritional quality of the new foods was equal to that of animal-protein foods as evaluated by chemical and biological studies. Furthermore, protein costs were significantly lower for the newly developed foods than for regular products. Overall, 30% soy-rice noodles without methionine fortification proved to be the best noodle product from a combined nutritional and cost point of view, although all soy-rice products were equally acceptable. Soy, soy-sesame, and soy-fish chips were relatively equal in possessing high acceptability.

Freedom from nutritional diseases, particularly protein malnutrition, is a basic human right for all children. The development of new low-cost, acceptable, high-protein foods can help meet the challenge of eliminating childhood protein deficiency. Soy-supplemented rice noodles and rice-based soy snacks should afford an excellent means for providing increased amounts of protein in the diet of Thai children at day-care centers.

LITERATURE CITED

1. United Nations Food and Agriculture Organization. Production yearbook. FAO: Rome (1970).

2. Institute of Population Studies. Population growth in Thailand. Chulalongkorn University: Bangkok (1972).

3. National Academy of Sciences. Recommended dietary allowances. 7th edition. Washington, D. C. (1968).

4. Swaminathan, M. The nutrition and feeding of infants and pre-school children in the developing countries. World Rev. Nutr. Diet. 9: 85 (1968).

5. Jelliffee, D. B. Child nutrition in developing countries. United States Agency for International Development: Washington, D. C. (1969).

6. United Nations. United Nations demographic yearbook. New York (1970).

7. National Statistics Office. Statistics handbook of Thailand. Bangkok (1968).

8. Khanjanasthiti, P., and Wray, J. D. Early protein-calorie malnutrition (PCM) in slum areas. An unpublished report. Ramathibodi Hospital, Mahidol University: Bangkok (1971).

9. Pollack, H. Diseases as a factor in word food problems. Amer. J. Clin. Nutr. 21: 868 (1968).

10. Burk, M. C., and Ezekiel, M. Food and nutrition in developing economies. In: Agricultural development and economic growth, ed. by H. M. Southworn and B. F. Johnston; Cornell University Press: Ithaca, New York (1968).

11. Bhumiratana, A., and Nondasuta, A. Report on protein food development project. Nutrition Division, Health Department, Ministry of Public Health; Bangkok (1972).

12. National Statistics Office. Household expenditure survey. Bangkok (1963).

13. Ritchie, J. A. S. Learning better nutrition. FAO: Rome (1968).

14. Chandrapanond, A. Diet surveys in Thailand. J. Med. Assoc. Thailand. (Abstract) 38: 157 (1955).

15. Interdepartmental Committee on Nutrition for National Defense (ICNND). Nutrition survey. The Kingdom of Thailand. October-December, 1960. National Institute of Health: Bethesda, Maryland (1962).

16. Jelliffee, D. B. The assessment of the nutritional status of the community. United Nations World Health Organization. WHO Monograph, Series No. 53. WHO: Geneva (1966).

17. Bengoa, J. M., Jelliffee, D. B., and Perez, C. Some indicators for a broad assessment of the magnitude of protein-calorie malnutrition in young children in population groups. Am. J. Clin. Nutr. 7: 714 (1959).

18. Stoch, M. B., and Smythe, P. M. Does undernutrition during infancy inhibit growth and subsequent intellectual development? Arch. Dis. Child. 38: 546 (1963).

19. Jackson, R. L. Effect of malnutrition on growth of the pre-school child. In: Pre-school children malnutrition. Primary deterrent to human progress. National Academy of Science--National Research Council. The Academy: Washington, D. C. (1966).

20. Scrimshaw, N. S. Infant malnutrition and adult learning. Saturday Review. March 16: 29 (1968).

21. Rajatasilpin, A., Suepsaman, B., and Yamarat, V. Intellectual development and its relationship to the nutritional status among school children. J. Med. Assoc. Thailand 53: 788 (1970).

22. Latham, M. C., and Cobas, F. The effects of malnutrition on intellectual development and learning. Am. J. Pub. Health 61: 1307 (1971).

23. Birch, H. G. Malnutrition, learning, and intelligence. Am. J. Pub. Health 62: 733 (1972).

24. Jelliffee, D. B. The incidence of protein-calorie malnutrition of early childhood. Am. J. Pub. Health 53: 905 (1963).

25. Cutting, W., and Cutting, M. The interaction of nutrition and infection in childhood. League of International Food Education (L.I.F.E.) Newsletter. The League: Washington, D. C. May (1971).

26. Aitken, F. C., and Hytlen, F. E. Infant feeding: comparison of breast feeding. Nutr. Abstr. Rev. 30: 341 (1960).

27. Valyasevi, A. Protein-calorie malnutrition in Thailand. In: Far East Symposium on Nutrition, Taipei, Taiwan (1964).

28. Suskind, L. A Report from the Applied Nutrition and Field Research Division, Anemia and Malnutrition Research Center, Chiang Mai, Thailand (1972).

29. Thailand Recommended Daily Allowances. Department of Health, Nutrition Division, Bangkok (1968).

30. United Nations Food and Agriculture Organization. Energy and protein requirements. Joint FAO/WHO ad hoc Committee (March-April, 1971). FAO: Rome (1973).

31. Chandrapanond, A., Ratchatasilpin, A., and Tausuphasiri, S. Daily nutrient Thai intake. Unpublished data. (1968).

32. Netrasiri, A., and Netrasiri, C. Kwashiorkor in Bangkok: An analytical study of 54 cases. J. Trop. Pediat. 1: 148 (1955).

33. Stahlie, T. D. Some aspects of child health in Thailand. J. Trop. Med. Hyg. 64: 79 (1961).

34. Thanangkul, O., Whitaker, J. A., and Fert, E. G. Malnutrition in Northern Thailand. Am. J. Clin. Nutr. 18: 379 (1966).

35. Pisolyabutra, U. Thailand Country Report. FAO/USSR Seminar on Nutrition in Food Policy and Planning. Moscow (1971).

36. Nondasuta, A. Child nutrition centers. A means to reach the pre-school child. J. Med. Assoc. Thailand 53: 508 (1970).

37. Wood, L. E. Thailand, its environment and its people. In: Protein food development project report, ed. by A. Bhumiratana and A. Nondasuta; Nutrition Division, Health Department, Ministry of Public Health, Bangkok (1968).

38. McKinnon, N. E., Chom, C., and Limpsurapong, N. Report of nutrition study on pre-school children. Preliminary Report. Unpublished. Department of Home Economics, Kasetsart University, Bangkok (1972).

39. Rao, M. N., and Swaminathan, M. Plant proteins in the amelioration of protein deficiency status. World. Rev. Nutr. Diet. 2: 106 (1969).

40. Orr, E. The use of protein-rich foods for the relief of malnutrition. Tropical Products Institute: London (1972).

41. Houston, D. F., and Kohler, G. O. Nutritional properties of rice. National Academy of Sciences: Washington, D. C. (1970).

42. Juliano, B. O., Cagampang, G. B., Cruz, L. J., and Santiago, R. G. Some physiochemical properties of rice in Southeast Asia. Cereal Chem. 41: 275 (1964).

43. Albrecht, W. J., Mustakas, G. C., McGhee, J. E., and Griffin, Jr., E. L. A simple method for making full-fat soy flour. Cereal Sci. Today 12: 81 (1967).

44. Altschul, A. M. Food: proteins for humans. Chem. Eng. News. November 24: 68 (1969).

45. Swaminathan, M. The use of soybeans and its products in feeding infants and in the prevention of protein malnutrition in weaned infants and pre-school children in developing countries. J. Nutr. Diet. (India) 3: 138 (1966).

46. Altschul, A. M. Low-cost foods: fortified cereals and beverages. In: Protein-enriched cereal foods for world needs, ed. by M. Milner, p. 82. American Association of Cereal Chemists. The Association: St. Paul, Minnesota (1969).

47. Paulsen, T. M. A study of macaroni products containing soy flour. Food Technol. 15: 118 (1961).

48. Thantaspongsi, T. The development of high protein noodles from soy bean for Thailand. A Thesis. Massey University, New Zealand (1970.

49. Borgstrom, G., ed. Fish as food. Vol. I. Academic Press: New York (1961).

50. Kwee, W. H., Sidwell, V. D., Wiley, R. C., and Hammerle, O. A. Quality and nutritive value of pasta made from rice, corn, soya, and tapioca enriched with fish protein concentrate. Cereal Chem. 47: 78 (1969).

51. Crocker, E. C., Sjostrom, L. B., and Tallman, G. G. Measurement of food acceptance. Ind. Eng. Chem. 40: 2254 (1948).

52. Bryan, M. S., and Lowenberg, M. E. The father's influence on young children's food preferences. J. Am. Diet. Assoc. 34: 30 (1958).

53. Skeel, A. B. Factors in food acceptance. School Lunch J. 14: 32 (1960).

54. La Chance, P. A., Moskowitz, R. B., and Winawer, H. W. Balanced nutrition through food processor practice of nutrification. Model experience in school food services. Food Technol. 26: 30 (1972).

55. Association of Official Analytical Chemists. Official methods of analysis (11th ed.). The Association: Washington, D. C. (1970).

56. Allison, J. B., Wannemacher, R. W., Middleton, E., and Spoerlein, T. Dietary protein requirements and problems of supplementation. Food Technol. 13: 598 (1959).

57. National Academy of Sciences. National Research Council. Evaluation of protein quality. Pub. 1100. The Academy: Washington, D. C. (1963).

58. Worcester, J., and Hegsted, D. M. A study of the relationship between protein efficiency and gain in weight on diets of constant protein content. J. Nutr. 33: 685 (1947).

59. Miller, D. S., and Bender, A. E. The determination of the net utilization of proteins by a shortened method. Brit. J. Nutr. 9: 392 (1955).

60. von Loesecke, H. W. Drying and dehydration of foods. Reinhold Pub. Co.: New York (1955).

61. Triebold, H. O., and Aurand, L. W. Food composition and analysis. D. Van Nostrand Co.: Princeton, New Jersey (1963).

62. Matz, S., ed. The chemistry and technology of cereals as food and feed. AVI Pub. Co.: Westport, Connecticut (1959).

63. Peryam, D. R., and Pilgrim, F. J. Hedonic scale method of measuring food preferences. Food Technol. (Symposium) 2: 9 (1957).

64. Scoville, O. J. Protein enrichment of cereal foods in Pakistan--An economic evaluation. Food and Feed Grain Institute. Kansas State University. Manhattan, Kansas (1973).

65. Spackman, D. H., Stein, W. H., and Moore, S. Automatic recording apparatus for use in the chromatography of amino acids. Anal. Chem. 30: 1190 (1958).

66. Henderson, L. M., and Snell, E. E. A uniform medium for determination of amino acids with microorganisms. J. Biol. Chem. 172: 15 (1948).

67. Carpenter, K. J. The estimation of available lysine in animal protein foods. Biochem. J. 77: 604 (1960).

68. The United States Pharmacopoeial Convention, Inc. The United States Pharmacopoeia (U.S.P.). The Convention: Mack Pub. Co.: Easton, Pennsylvania 15: 889 (1955).

69. The Association of Vitamin Chemists. Methods of vitamin assay. The Association: Interscience Pub., Inc.: New York (1966).

70. Atkins, L., Schultz, A. S., Williams, W. L., and Frey, C. N. Yeast microbiological methods for determination of vitamins. Pyridoxine. Ind. Eng. Chem. 15: 141 (1943).

71. The United States Pharmacopoeial Convention, Inc. The United States Pharmacopoeia (U.S.P.). The Convention: Mack Pub. Co.: Easton, Pennsylvania 17: 865 (1965).

72. Association of Official Agricultural Chemists. Offical methods of analysis. (8th ed.). The Association: Washington, D. C. 8: 830 (1955).

73. Perkin-Elmer Corp. Analytical methods for atomic absorption spectrometry. The Corporation: Norwalk, Connecticut.

74. Forster, W. A. The determination of magnesium in plant materials by means of ethylenediamine-tetra-acetic acid. Analyst 78: 179 (1953).

75. Shemer, M., Wei, L. S., and Perkins, E. G. Nutritional and chemical studies of three processed soybean foods. J. Food. Sci. 38: 112 (1973).

76. Smith, O. B. Why use extrusion? American Association of Cereal Chemists. Symposium. Unpublished report. St. Louis (1971).

77. Allport, N. L. Colorimetric analysis. Chapman and Hall, Ltd.: London (1947).

78. United Nations Food and Agricultural Organization. Amino-acid content of foods and biological data on proteins. FAO: Rome (1970).

79. Wolf, W. J. Soybean proteins: their functional, chemical, and physical properties. J. Agr. Food. Chem. 18: 969 (1970).

80. Felt, C. E., Buechele, A. C., Borchardt, L. F., Koehn, R. C., Collatz, F. A., and Heldebrand, F. C. Determination of shelf life of packaged cereals. Cereal Chem. 22: 261 (1945).

81. Barber, S. Milled rice changes during aging. In: Rice: Chemistry and technology, ed. by D. F. Houston, p. 245; American Association of Cereal Chemists. The Association: St. Paul, Minnesota (1972).

82. Kik, M. C. Nutritional improvement of rice. J. Am. Diet. Assoc. 32: 647 (1956).

83. Smith, O. B. History and status of specific protein-rich foods: extrusion-processed cereal foods. In: Protein-Enriched Cereal Foods for World Needs, ed. by M. Milner, p. 140; American Association of Cereal Chemists. The Association: St. Paul, Minnesota (1969).

ACKNOWLEDGMENTS

The author expresses his sincere appreciation to his major professor, Dr. David R. Lineback, for his guidance, encouragement, and friendship throughout his graduate program and for his valuable help and criticism during the preparation of this manuscript.

The author also extends his acknowledgment and thanks to the members of his committee, Prof. Beatrice Finkelstein, Dr. William J. Hoover, Head of the Department of Grain Science and Industry, Dr. Orlin J. Scoville, and Dr. Cho C. Tsen for their advice in initiating this research and for their helpful suggestions in preparing this manuscript. The author also wishes to thank Dr. George A. Milliken and Mr. Fraizorz Khorasani, Department of Statistics, Kansas State University, for their assistance in the statistical evaluation of the data.

The author expresses his appreciation to the Department of Grain Science and Industry, Kansas State University, and the United States Agency for International Development for the financial support of this project.

Numerous individuals in Thailand have taken an active role in giving valuable assistance to the author in conducting this project. It is most fitting to mention that this work would not have been possible without their help. Special thanks, therefore, are extended to Prof. Amara Bhumiratana, Director of the Institute of Food Research and Product Development, Kasetsart University, Bangkok, Thailand, for his support of this project; to Miss Saipin Maneepun for her language, laboratory, and field work assistance; to Mrs. Korbkaew Suwannasorn, Chiang Mai Health Office, for her administrative help

during studies at Child Nutrition Centers; to the teachers and children at the Child Nutrition Centers and elementary schools who aided and participated in acceptability studies; to Dr. Merrill M. Shutt, United States Operations Mission to Thailand (USOM), for his friendship and help during the author's stay in Thailand; and to the Department of Home Economics, Kasetsart University, for the use of the nursery school facilities.

The author is appreciative of the friendship of the staff and workers at the Institute of Food Research and Product Development who assisted him in various ways. The author also thanks the members of the taste panel for their time and cooperation during the project.

Lastly, the author wishes to dedicate this dissertation to his parents, Mr. and Mrs. Irving Siegel, whose understanding of the value of an education has truly been appreciated.

VITA

Alvin Siegel was born in Providence, Rhode Island, on March 17, 1945, the second child of Mr. and Mrs. Irving Siegel. After graduating from Classical High School he attended the University of Rhode Island where he earned a Bachelor of Science degree in January, 1968, with a major in agricultural chemistry. His Master of Science in food science was awarded by Michigan State University in March, 1970.

The author's interests in food science and nutrition as applied to world food problems and international development prompted his decision to pursue a Doctoral degree at Kansas State University, where he received an international fellowship in cereal science. This fellowship, awarded to the Department of Grain Science and Industry by the United States Agency for International Development, enabled him to conduct research for the dissertation in Thailand.

Alvin Siegel is a member of the following honorary and professional societies: Sigma Xi, Institute of Food Technologists, and American Association of Cereal Chemists. His 15-month stay in Thailand enabled him to travel throughout that country. In addition, he has visited several Asian nations observing food research and agricultural development programs.

DEVELOPMENT, ACCEPTABILITY, AND NUTRITIONAL EVALUATION OF NEW HIGH-PROTEIN RICE-BASED FOODS FOR THAI CHILDREN

by

ALVIN SIEGEL

B. S., University of Rhode Island, 1968
M. S., Michigan State University, 1970

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the

requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1974

Soy-supplemented rice noodles and rice-based snacks were developed for use in supplementary feeding programs at Child Nutrition Centers in Thailand. Acceptability studies were conducted with pre-school and elementary school children in rural and urban localities. Nutritional evaluations of the products were determined using chemical and biological testing procedures.

Dehydrated rice noodles, protein-supplemented with 20 and 30% full-fat soy flour, with and without methionine fortification at respective levels of 0.2 and 0.3%, were prepared in the same manner as traditional rice noodles. Acceptability studies were held with 197 pre-school children for five and three months at two rural Child Nutrition Centers and at a Bangkok nursery school, respectively. Each sample was given as the mid-day meal once a week on a rotating schedule. Regular rice and wheat noodles served as controls. Initial amounts of each dish served and additional portions requested were recorded. Proximate, vitamin, mineral, and amino acid analyses, in addition to rat growth studies, determined nutrient content and protein quality.

Soy-rice noodle consumption was not significantly different ($P < 0.01$) from that for regular rice noodles at all testing localities. No significant differences in preference for noodles at the two amounts of either soy supplementation or methionine fortification were found. Other control dishes were eaten equally in most feeding situations. The 20 and 30% soy noodles contained 15.0 and 18.0% protein (dry basis), respectively; the control contained 7.8% protein. Additions of full-fat soy flour to rice increased the amount of vitamin E and B-complex vitamins found in soy-rice noodles compared to regular ones. Marked increases in mineral content were found in soy-supplemented noodles as compared to regular noodles as follows: calcium, four times; iron, two times; magnesium, twelve times; and phosphorous, three times. Chemical scores for regular, 20% and 30% soy-rice noodles were 40, 60, and 76, respec-

tively. Protein efficiency ratios (PER) using laboratory animals were 2.16, 2.56, 2.58, 2.69, and 3.00 for regular, 20% soy, 30% soy, 20% soy plus methionine, and 30% soy plus methionine noodles, respectively, corrected to 2.50 for standard casein. Net protein utilization (NPU) values for the 20% soy plus methionine and 30% soy noodles, with and without methionine, were significantly higher ($P < 0.05$) than the control sample, and not different from the NPU for casein.

Snacks were prepared containing additions of protein-supplements to a 70% rice base (dry basis) as follows: 30% soy, 25% soy plus 5% ground sesame, 25% soy plus 5% fish protein concentrate (FPC), and 30% soy protein concentrate. The latter product was an extrusion-cooked puffed curl. The remaining products were dehydrated pieces deep-fat fried into edible chips. Acceptability studies with 198 children at two schools employed a five-point hedonic scale corresponding to facial expressions (very happy to very sad). Scores for extruded curls were 3.44-4.81 on a 5.0 scale, while rice chips had scores ranging from 3.82-4.92. New rice snacks contained 17.2 to 24.6% protein (dry basis). New rice snacks had scores significantly higher ($P < 0.01$) than one regular commercial (control) snack food and comparable with two others.

Chemical and subjective studies on changes in products (noodles and snacks) during storage (five and six months) showed no detrimental changes in quality factors. Protein costs of the new foods were substantially lower than those for regular products. A mixture, primarily of soy and rice flours, enabled the introduction of acceptable animal-quality protein foods suitable for improving the protein status of Thai children.