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Trends and Prospects for Cassava in Thailand

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TRENDS AND PROSPECTS FOR CASSAVA IN THAILAND

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CONTENTS

TABLES

ILLUSTRATION

FOREWORD

Cassava is a staple food crop cultivated in several developing countries, largely by small farmers. It is a source of subsistence and of cash income for poor farmers as well as a source of rural employment, particularly of women. During the past 20 years, production of cassava has expanded rapidly in Asia, particularly in Thailand in response to expanded demand for its import in the European Community, where it is used as livestock feed. There are concerns, however, about the likely decline in demand for cassava as food as incomes rise in developing countries and also about the stability of the European demand. To assess the prospects for cassava in the future, IFPRI has examined the trends and prospects for production, utilization, and trade of cassava in Third World countries under a special project partially funded by the International Development Research Centre (IDRC) of Canada.

In addition to the analysis of international data at the global and regional levels, case studies were taken up in six countries: India, Indonesia, the Philippines, and Thailand in Asia and Nigeria and Zaire in Sub-Saharan Africa. The results of these studies were discussed at a workshop in Washington, D.C. in August 1987, where project researchers, selected cassava scientists, and representatives of international organizations participated. The report on the proceedings of the workshop will be published separately. The results of the individual case studies are being published as a series of working papers. Trends and Prospects for Cassava in Thailand, by Chaiwat Konjing, is the sixth in the series.

J. S. Sarma

1. INTRODUCTION AND CURRENT SITUATION

Since cassava has become an important export crop, the rapid expansion of cassava production and exports has exposed the Thai cassava industry to problems of uncertainty in production and vulnerability to external factors. In order to minimize these problems, ways have been sought to expand the domestic market and the potential utilization of cassava products. This research project thus has the following specific objectives. First, to determine the prices of cassava and protein supplements that will make it possible to substitute them for corn and sorghum in livestock feed. Second, to determine what yields would make cassava profitable to the producers at those prices, and last, to examine the effects on the unit costs of production if these yields are achieved.

The data used in this study included primary data collected from a field survey made in mid-1986 and secondary data covering the period 1960-85. Data on the field survey are given in Table 1.

Table 1--Surveyed samples in the Kasetsart University field survey, 1986

Location	Farm Households	Commercial Livestock Farms	Feed Manufacturing Firms
Rayong	40	...	...
Nakorn Ratchasima	63	...	...
Udorn Thani	30	...	...
Bangkok	...	...	15
Chachoengsao	...	5	...
Nakorn Pathom	...	10	...

Source: Kasetsart University, "Field Survey of Cassava-based Feed Pilot Project Area," Bangkok, 1986.

Notes: Rayong is in Central region, Nakorn Ratchasima and Udorn Thani are in Northeast region. Personal interviews were also conducted with technicians in the following organizations: the Department of Livestock Development (the General Director of the Feed Quality Control Division in Bangkok); the Thai Feed Mills Association; the Field Crop Research Division of the Department of Agriculture; and the Rayong Province Field Crops Research Center.

The methodologies employed in data analysis include trend estimation and projection, the calculation of annual growth rates, and simulation analysis. Projection of the data were made to 1990 and 2000. Financial assistance for this research project was obtained from the International Development Research Centre of Canada (IDRC) through the research network of the International Food Policy Research Institute, Washington, D.C.

Among roots and tuber crops cultivated in Thailand, cassava is the most important economic crop, occupying 1.3 million hectares or 97 percent of the total area of roots and tuber crops during 1981-84. Its harvested area accounted for 3.8 percent of total agricultural land or 8.3 percent of total area under food and feed crops (Table 2). Annual production of cassava over the same period amounted to 19 million metric tons, forming as high as 98 percent of total root and tuber crop production or 6.1 percent of total agricultural production.[1]

Table 2--Share of cassava in harvested area, production, and export trade, 1982-84 average

Item/Crops	1982-84 Average
	(percent)
Harvested area	
Cassava in total roots and tuber crops	97.0
Cassava in total food and feed crops	8.3
Cassava in total cultivated area	3.8
Production	
Cassava in total roots and tuber crops	98.0
Cassava in total food and feed crops	11.8
Cassava in total agricultural production	6.1
Export trade	
Cassava in total agricultural exports	16.3
Cassava in total exports	10.7

Source: Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, 1984/85 (Bangkok: Ministry of Agriculture and Cooperatives, 1985).

[1]In this report, all tons are metric tons.

At its start in Thailand, cassava was grown mainly for domestic consumption. With a more favorable foreign demand from the countries of the European Community (EC), during the past decades cassava has become an important export crop. It earned foreign exchange equal to 16.3 percent of total agricultural export value or 10.7 percent of overall export earnings during 1982-84 (Table 2).

Utilization of cassava can be put into three categories. Human consumption is mainly in the form of cassava flour and tapioca granules (sago). Animal feed uses cassava chips and pellets. It is mainly for export. Industrial uses include the manufacture of paper, textiles, plywood, and monosodium glutamate.

Cassava is not a staple food in Thailand. Most of the crop produced each year is exported, mainly for animal feed. During 1981-83, the domestic utilization of cassava flour for human consumption averaged 114,000 tons. This was only 1.7 percent of total processed cassava output of 6.9 million tons (Table 3). The industrial uses of cassava accounted for 1.8 percent. The rest was exported in forms of animal feed (88.7 percent) and cassava flour (7.7 percent). In fact, during 1981-83, only 3.5 percent of total cassava output was consumed domestically. The rest, 96.5 percent, was exported, mainly to the EC.

Table 3--Uses of cassava by product type in Thailand, 1981-83 average

Product	Production Volume		
	Input	Output	Share
	(1,000 metric tons of fresh roots)	(1,000 metric tons)	(percent)
Cassava flour	1,958.2	767.6	11.20
Dried cassava (chips and pellets)	16,177.4	6,083.5	88.70
Tapioca (sago, granulate)	14.0	2.8	0.04
Tapioca (sago, starch)	24.1	6.0	0.09
Cassava meal[a]	...	0.45	...
Total	18,173.4	6,859.9[b]	100

Source: Based on Food and Agriculture Organization of the United Nations, "Supply Utilization Accounts Tape," Rome, 1980.

[a]This is a by-product of cassava flour processing and manufacturing.

[b]This figure excludes cassava meal.

Cassava has gained in popularity among small farmers in Thailand because of its yield stability and its high tolerance to drought. Other advantages of cassava include a greater flexibility in planting and harvesting times, fewer pest and disease problems, and its ability to grow well in a variety of soil conditions.[2] Cassava growing in Thailand is labor intensive. Only land preparation is mechanized. Most of the crop is grown on marginal land or in sandy soils with a minimum of fertilization or none at all. In general, cassava is an inexpensive crop; it requires few purchased inputs while maintaining high and stable yields. During 1979-83, cassava yields fluctuated slightly around 14-15 tons per hectare. The average yield of 1981-83 was 15.7 tons per hectare, compared with the world average, 8.5 tons per hectare. In fact, cassava yields in Thailand are about 83.5, 38.1, and 32.8 percent higher than the average of the world, the South America region, and Asia region respectively (Table 4). Factors contributing to the high yields of Thai cassava are improved varieties, especially Rayong 1, and favorable agroclimatic conditions.

Table 4--Cassava yields in Thailand and the rest of the world, 1981-83 average

Country/Region	Yield	Percent of World Average
	(metric tons/ hectare)	
Thailand	15.7	183.5
Asia	11.8	138.2
South America	11.4	132.9
Africa	6.1	71.4
Oceania	10.6	124.4
World average	8.5	100.0

Sources: The figure for Thailand is from Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, 1984/85 (Bangkok: Ministry of Agriculture and Cooperatives, 1985). The figures for the rest of the world are from Food and Agriculture Organization of the United Nations, Production Yearbook, 1983 (Rome: FAO, 1984).

[2] Arwooth Na Lampang et al., "Thailand Country Report," Economic and Social Council of Asia and the Pacific (ESCAP) Expert Group Meeting on Coarse Grains, Pulses, Roots, and Tuber Crops, Bangkok, 6-9 October 1981 (mimeographed).

The Northeast is the most significant cassava-growing region in Thailand. It had 59.0 percent of the country's cassava planted area and produced 56.8 percent of total cassava output during 1981-84. The Central region ranks second with 37.1 percent of planted acreage and 39.0 percent of total cassava output during the same period. Only about 4.2 percent of the country's total cassava production came from the Northern region (Figure 1 and Table 5).

Figure 1--Principal cassava-growing regions in Thailand, 1983

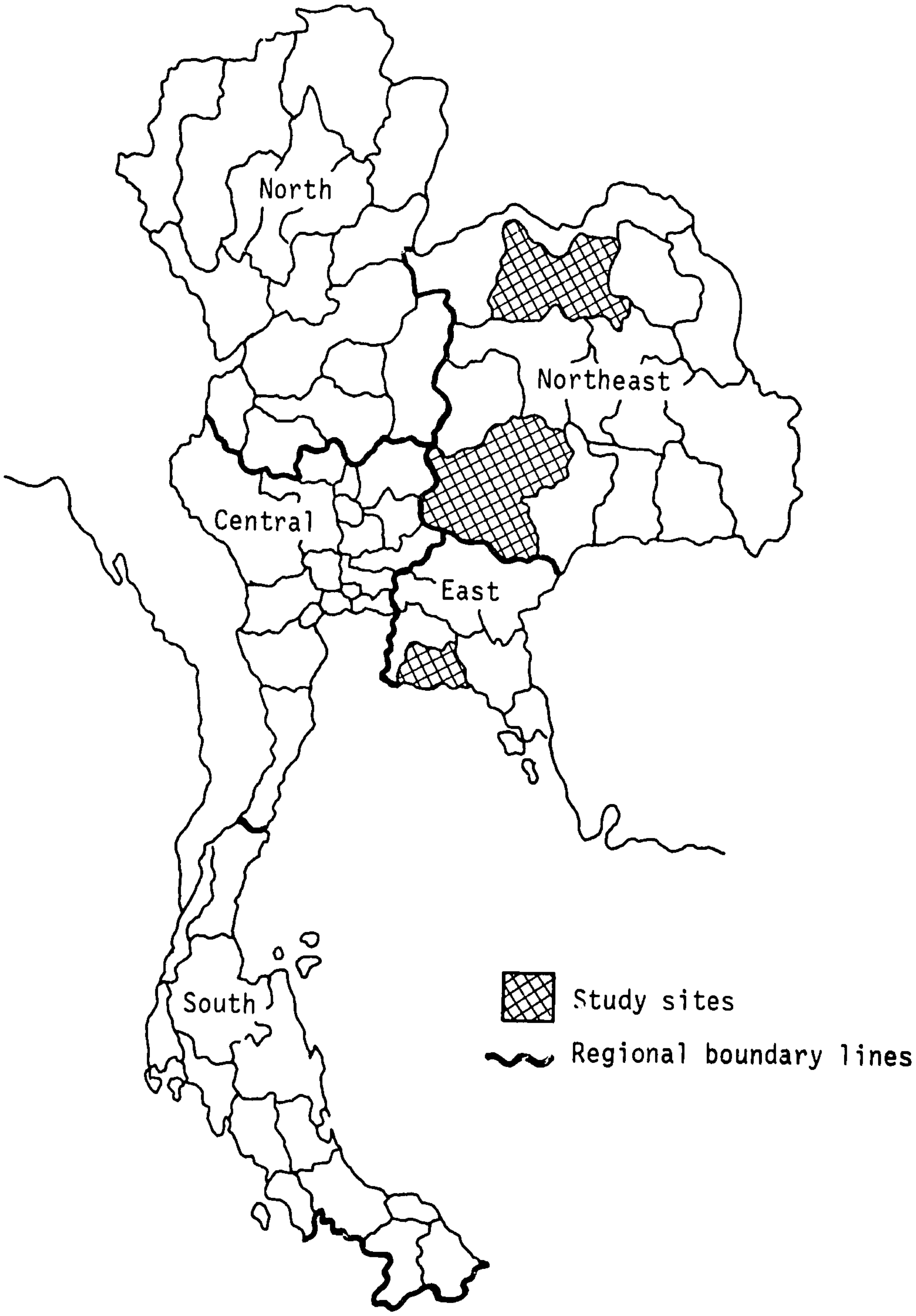

Table 5--Regional distribution of cassava production, 1974-78 and 1981-84 averages

Region	1974-78				1981-84				Change	
	Area	Share of Total Area	Output	Share of Total Output	Area	Share of Total Area	Output	Share of Total Output	Area	Output
	(1,000 hectares)	(percent)	(1,000 metric tons)	(percent)	(1,000 hectares)	(percent)	(1,000 metric tons)	(percent)	(percent)	
North	8.0	1.1	308	3.2	51.0	3.9	787	4.2	537.5	155.7
Northeast	383.5	52.4	4,314	45.2	778.4	59.0	10,578	56.8	103.0	145.2
Central	330.4	45.1	4,779	50.0	490.2	37.1	7,262	39.0	48.4	52.0
South	10.1	1.4	152	1.6	...	...	...	...	...	...
Total	732.0	100.0	9,553	100.0	1,319.6	100.0	18,627	100.0	80.3	95.0

Sources: Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, 1975/76 (Bangkok: Ministry of Agriculture and Cooperatives, 1976); Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, 1985/86 (Bangkok: Ministry of Agriculture and Cooperatives, 1986).

Despite high yields, the most serious cultivating problem for cassava is the deterioration of the fertility of soils under cassava. Repeated crop cultivation in the same units of land year after year without fertilization has caused average yields to decline and so has posed a constraint on increasing output. In general, cassava output in Thailand has increased because of increases in area. Limited and declining export volume to the EC market following an agreement between Thailand and the EC has been another constraint to expanding cassava production. A third constraint has been the implementation of a government policy to limit cassava-sown area in response to decreased exports to the EC, though it has been a less-effective constraint than the other two.

In general, cassava is cultivated by small and poor farmers who cannot afford highly capital-intensive farming. With its flexible planting and harvesting times, cassava has been the most promising cash crop serving both the cash and food-security needs of small farmers residing in remote and less productive farm areas. In particular, in rice-deficit areas or in areas that are vulnerable to drought and crop failure, cassava provides cash income enabling farmers to procure enough food for family consumption. In rice-surplus areas, on the other hand, cassava provides additional cash income for rice while playing a minimum direct role in the family's food consumption.

Cassava cultivation in Thailand usually begins in April. The harvest season commences in March in the following year. Another crop, normally small, is planted in December after the end of the rainy season and is harvested in November in the following year. About 48 percent of the harvested output is marketed in March, 12 percent in April, and 17 percent in November. The rest is almost equally distributed between February, May, October, and December.[3]

Statistical data on cassava in Thailand are less complicated than data on rice and sugar. This is because cassava is an export crop. Data on exports and production can be counterchecked by the Office of Agricultural Economics of the Ministry of Agriculture and Cooperatives and the Custom Department of the Ministry of Finance. Statistical data collected by the Thai Cassava Trade Association also provide a base for cross-checking production and export data. Data on the domestic consumption and industrial uses of cassava are based on an estimation using input-output coefficients and crop balance sheets. There has not yet been either a direct survey or a network to collect data on the domestic utilization of cassava, particularly on the direct consumption of cassava roots and cassava products. This is a major statistical gap in Thailand.

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[3]Kasetsart University, Center for Applied Economics Research, Agricultural Marketing Improvement in Thailand's Northeastern Region. Center for Applied Economics Research, Bangkok, 1984, p. 101.

2. TRENDS IN CASSAVA PRODUCTION, UTILIZATION, TRADE, AND PRICES

AREA AND YIELDS

The expansion of cassava output in Thailand during the past two decades was based mainly on the expansion of planted areas. Yields were stable. The area planted with cassava during 1961-63 increased rapidly through 1971-73 and reached almost 1.3 million hectares during 1983-85 (Table 6). The average annual growth rate of cassava area from the early 1960s to the early 1970s reached as high as 10.51 percent. It increased from 1971-73 to 1983-85, but the rate for the period as a whole (1961-63 to 1983-85) was 11.38 percent. The annual growth rate of cassava areas among regions in the latter decade was highest in the Northeast, followed respectively by the North and Central regions.

Similarly, annual production of cassava also showed a rapid increase between 1961-63 and 1971-73, with an average annual growth rate of 4.07 percent (Table 6). Annual cassava output also increased substantially, to 18.2 million tons during 1983-85, following the rapid increase in planted area, with an average annual growth rate of almost 12 percent. However, the rate of growth of cassava output over the two decades was slower than the rate for planted area due to a low growth rate in yields. That is, cassava yields in Thailand fluctuated slightly around 15 tons per hectare or even showed a declining trend over the period 1961-73. A slight improvement in yields of Thai cassava was observed during 1971-85, putting long-term growth at zero.

The contribution of the Northeast region to the overall growth of cassava production in Thailand has been significant. On the other hand, the Central region gained a somewhat higher share of production because of improved productivity even though its share of total planted area fell. In fact, from a long-term perspective, growth in cassava output through expansion of area is not promising in all regions; improvement in yields are feasible.

CHANGES IN DOMESTIC UTILIZATION

Total domestic utilization of cassava products in Thailand during 1961-63 averaged 94,100 tons per year (Table 7). Of this, 35.9 percent were used as human food and 64.1 percent as industrial

Table 6--Trends in area, production, and yield of cassava, 1960-85

Period	Area	Production	Yield
	(1,000 hectares)	(1,000 metric tons)	(metric tons/ hectare)
1960	71.5	1,222	17.09
1965	101.9	1,475	14.46
1970	224.5	3,431	15.28
1975	594.4	8,100	13.62
1980	1,160.0	17,110	14.75
1985	1,476.8	20,660	13.99
1961-63 average	120.7	1,987	16.46
1971-73 average	328.0	4,592	14.00
1983-85 average	1,291.6	21,221	16.43
Annual growth rate		(percent)	
1961-63 to 1971-73	10.51	8.74	-1.60
1971-73 to 1983-85	12.10	13.60	1.34
1961-63 to 1983-85	11.38	11.34	0.00
1973-85			
North	12.60	12.89	0.71
Northeast	15.52	16.06	1.59
Central	6.32	6.91	2.04
South	...	...	...

Source: Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, various issues 1960-1984/85 (Bangkok: Ministry of Agriculture and Cooperatives, various years).

Notes: Ellipses indicate a negligible amount.

The national data are revised each year to take into account estimates by the private Cassava Trade Association. Therefore data for recent years are close to data from the Food and Agriculture Organization of the United Nations.

Table 7--Trends in the domestic utilization of cassava products, 1961-83

Period	Cassava Flour: Food	Cassava Flour: Industrial Use	Sago	Cassava Chips and Pellets
		(metric tons)		
1961	32,472	59,528	8	1
1965	37,708	62,292	18	62
1970	62,743	59,257	18	58
1975	91,061	78,939	17	78
1980	109,627	120,373	29	14
1983	116,820	128,180	1,052	2
1961-63 average	33,784	60,216	10	90
1971-73 average	76,577	62,756	30	143
1981-83 average	113,673	126,328	354	81
Annual growth rate		(percent)		
1961-63 to 1971-73	8.53	0.41	11.61	4.74
1971-73 to 1981-83	4.02	7.25	28.00	-5.85
1961-63 to 1981-83	6.25	3.77	19.52	-0.005

Source: Computed using a crop balance sheet approach, based on data in Agricultural Statistics of Thailand, various issues 1961-85/86 (Bangkok: Ministry of Agriculture and Cooperatives, various years).

Notes: The conversion factors used were 4.5:1.0 for root to flour; 2.5:1.0 for root to chips; 2.55:1.0 for root to pellets; and 1.00:0.98 for chips to pellets.

a dessert made from cassava flour and modified tapioca starch (sago). During 1981-83, domestic human consumption of cassava products increased, and made up 47 percent of total domestic utilization over the same period. The utilization of cassava chips or pellets as animal feed forms an insignificant share of total domestic utilization, less than 1 percent. The average annual growth rate of cassava flour used for human food decreased between the 1961-63 and 1971-73 period and the 1971-73 to 1981-83 period. The industrial use of cassava products, on the other hand, grew at a far higher rate in the later period than in the earlier one. The industrial use of cassava during this later period more than doubled from the 1961-63 period. The average annual growth rate of domestic utilization over the past two decades was significantly higher for human consumption of cassava flour th for industrial uses. The human consumption of sago showed a high vth rate, although consumption was still very low. Recent food innovations, such as cassava snacks (fried cassava chips) have been observed, but changes in the utilization have not yet been recorded.

CHANGES IN CASSAVA EXPORTS

Thailand is not the world's largest producer of cassava. However, because of the low domestic utilization of the crop, Thailand has become the world's largest exporter of cassava products. Thailand's exports of cassava during 1961-63 consisted mostly of cassava flour, with smaller amounts of tapioca granules and starch (sago), dried cassava chips, and cassava meal (Table 8). No cassava pellets were produced or exported during the early 1960s. However, since the early 1970s cassava pellets have been gaining importance in total cassava exports. Exports of cassava pellets increased more than fourfold within the 10-year period between 1971-73 and 1981-83. Exports of cassava flour and cassava chips, on the other hand, decreased substantially during 1971-73 but recovered rapidly after 1971.

However, the average annual growth rate of cassava flour exports over the 1961-85 period was still low due to the rapid decline of exports during the 1961-73 period. Exports of dried cassava chips faced a similar problem over the same period. The export of cassava pellets, on the other hand, increased dramatically, with an average annual growth rate of 104 percent during 1961-73. It then declined to 16 percent during 1971-83. Exports of cassava meal showed a rapidly decreasing trend during the 1960s and 1970s. In sum, the growth of exports of cassava flour over the past two decades was stable, while that of sago increased considerably. Exports of cassava pellets increased tremendously from the 1960s to the 1980s; meanwhile, exports of dried cassava chips formed only a small share and exports of cassava meals became negligible. This was due to favorable foreign demand for cassava pellets and cassava flour, including sago, and

Table 8--Trends in exports of cassava by type of product and use, 1960-85

Period	Human Food and Industrial Uses		Animal Feed		
	Cassava Flour	Tapioca (Sago and Starch)	Cassava Chips	Cassava Pellets	Cassava Meal
			(1,000 metric tons)		
1960	241.42	0.36	2.96	...	24.99
1965	220.92	0.18	400.53	...	97.81
1970	148.68	0.18	8.11	1,163.98	5.91
1975	144.70	0.19	70.59	2,168.74	1.22
1980	246.28	1.00	159.19	4,811.22	...
1984	449.18	5.83	137.81	5,975.14	1.77
1961-63 average	304.90	0.33	38.17	...	16.85
1971-73 average	152.70	0.75	7.70	1,259.46	2.36
1981-83 average	355.00	2.45	379.12	5,689.10[a]	0.45
Annual growth rate			(percent)		
1961-63 to 1971-73	-6.68	8.56	-14.79	104.18	-17.85
1971-73 to 1981-83	8.80	12.56	47.65	16.27	-15.27
1961-63 to 1981-83	0.76	10.54	12.16	54.08	-16.57

Source: Bank of Thailand, Monthly Bulletin, various issues.

Notes: The conversion factors used were 4.5:1.0 for root to flour; 2.5:1.0 for root to chips; 2.55:1.0 for root to pellets; and 1.00:0.98 for chips to pellets.

[a]Because of export limits set by the EC, exports of cassava pellets are expected to be limited to 7.0-7.5 million metric tons by the end of the next decade.

reflects an increasing potential of cassava for use as animal feed, food, and industrial raw materials in most cassava-importing countries.

TRENDS IN CASSAVA PRODUCT PRICES

Before 1967 there was no record of farmgate prices of agricultural commodities in Thailand because there was no agency responsible for data collection. Similarly, price data for cassava pellets has become available only since 1970 and the introduction of pelletized cassava.

Between 1971 and 1983 the prices of cassava products showed a considerably increasing trend. In particular, the prices of cassava flour and cassava pellets exhibited a parallel increase in both wholesale and export markets. That is, the average wholesale price of cassava flour in Bangkok almost doubled between 1971-73 and 1981-83, with an average growth rate of almost 8 percent per year (Table 9).

Table 9--Trends in cassava product prices at the farmgate and wholesale and export market prices in Bangkok, 1960-84

Period	Farmgate Price	Wholesale Price		Export Price	
		Cassava Flour	Cassava Pellets	Cassava Flour	Cassava Pellets
		(฿/metric ton)			
1965	n.a.	1,839	n.a.	1,568	n.a.
1970	470	2,235	n.a.	1,818	859
1975	400	3,507	1,570	3,080	1,857
1980	750	5,770	2,470	5,344	2,731
1984	580	4,253	1,750	4,351	2,380
1971-73 average	443	2,363	980	1,920	1,137
1981-83 average	603	5,087	2,193	5,167	2,561
Annual rate of change			(percent)		
1971-73 to 1981-83	3.13	7.97	8.39	10.40	8.46

Sources: The farmgate prices are from Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, various issues 1967-1984/85 (Bangkok: Ministry of Agriculture and Cooperatives, various years). The wholesale and export prices are from Bank of Thailand, Monthly Bulletin, various issues 1967-84.

Note: Where n.a. appears, the figure was not available.

Similarly, the export price of cassava flour almost tripled over the same period, an increase of more than 10 percent per year. The price of cassava pellets in both the wholesale and export markets also increased at fairly high rates. The farmgate price of cassava roots, on the other hand, increased at a slower rate.[4] In addition, there was a large difference between the farm and wholesale prices of cassava products, although they were moving in the same direction.

TRENDS IN OUTPUT OF PROCESSED CASSAVA

Most cassava roots are processed into dried chips and are then pelletized. A part of the total supply of cassava roots is also processed into flour. Tapioca starch and granules are made from modified cassava flour, but output is still low or insignificant. Between 1961-63 and 1981-83, the production of cassava pellets increased substantially, with an average annual growth rate of 54.08 percent (Table 10). The output of cassava flour, on the other hand, increased at a rate of 0.24 percent per year from the early 1960s to the early 1980s. The output of cassava chips and sago increased considerably, but the production volume was not significant. In general, the production of processed cassava products, particularly the cassava pellets and cassava flour that formed the largest part of total cassava supply, showed an increasing trend following an expansion of the production of cassava roots year after year, despite the government effort to curb the growth of cassava area. As previously mentioned, the rapid increase in the production of processed cassava in Thailand was induced mainly by an increase in foreign demand. The increase in the domestic utilization of cassava was still slower, although it showed a potential for expansion.

TRENDS IN THE CONSUMPTION OF CASSAVA AS FOOD

On average, the consumption of cassava as food accounted for 36 percent of the annual utilization in the 1961-63 period, increased to 55 percent in the 1971-73 period, then dropped to 47 percent in the 1981-83 period (Table 11). The average annual growth rate of consumption of cassava as food was highest between 1961-63 and 1971-73. The actual consumption of cassava as food during 1981-83 was 49 percent higher than during 1971-73.

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[4]The average cassava price during 1983, for the equivalent of 1 ton of pellets, was ฿ 1,507.50 per ton (฿ 603 per ton of cassava roots times a conversion factor of 2.50). With an average processing cost for hard pellets of ฿ 200 per ton, the estimated wholesale price of hard pellets during the corresponding period was ฿ 1,707.50 per ton. ฿ 27 equals US$1.00.

Table 10--Trends in the ouput of processed cassava products, 1961-83

Period	Cassava Flour	Tapioca (Sago and Starch)	Cassava Chips	Cassava Pellets
		(1,000 metric tons)		
1961	666.91	0.38	8.41	...
1965	148.18	0.20	400.59	...
1970	87.42	0.20	8.11	1,164.00
1975	378.65	0.21	70.59	2,385.45
1980	579.85	3.72	159.19	5,217.70
1983	2,190.10	12.00	279.91	5,196.75
1961-63 average	731.09	0.34	38.17	...
1971-73 average	306.06	3.45	7.70	1,259.46
1981-83 average	767.61	8.82	379.12	5,689.10
Annual growth rate		(percent)		
1961-63 to 1971-73	-9.10	26.08	-14.79	...
1971-73 to 1981-83	9.63	9.84	47.65	16.27
1961-63 to 1981-83	0.24	17.62	12.16	...

Source: Food and Agriculture Organization of the United Nations, Production Yearbook, various issues 1961-83 (Rome: FAO, various years).

Notes: Ellipses indicate a negligible amount.

The conversion factors used were 4.5:1.0 for root to flour; 2.5:1.0 for root to chips; 2.55:1.0 for root to pellets; and 1.00:0.98 for chips to pellets.

Table 11--Trends in per capita consumption of cassava products as food, 1961-83

Period	Total Domestic Utilization	Consumption as Food	Food as Share of Total Utilization	Per Capita Consumption
	(metric tons)		(percent)	(kilograms)
1960	92,009	32,480	35	1.23
1965	100,080	37,726	38	1.23
1970	122,076	62,751	51	1.72
1975	170,095	91,078	53	2.20
1980	230,043	109,656	48	2.36
1983	246,054	119,556	48	2.42
1961-63 average	94,100	33,794	36	1.23
1971-73 average	139,506	76,607	55	1.98
1981-83 average	240,436	114,207	47	2.36
Annual growth rate		(percent)		
1961-63 to 1971-73	4.02	8.53	...	4.88
1971-73 to 1981-83	5.59	4.07	...	1.77
1961-63 to 1981-83	4.80	6.28	...	3.31

Sources: Pusadee Kanikul, "The Tapioca Starch Markets and Utilization in Thailand" (M.S. thesis, Kasetsart University, 1982); and Food and Agriculture Organization of the United Nations, computer printout sheets on production and utilization statistics, Rome, 1985.

Notes: The conversion to cassava flour from cassava root was done at the rate of 4.5:1.0. Data on the consumption of cassava in the form of fresh root is not available, but it is insignificant in the Thai diet.

Actual per capita consumption of cassava as food increased noticeably between 1961-63 and 1981-83. Yet, the consumption of cassava as food remains low compared with the consumption of rice, which averaged 150 kilograms per capita in 1980. The growth rate of per capita consumption of cassava as food declined between the 1961-63 to 1971-73 period and the 1971-73 to 1981-83 period.

The utilization of cassava as animal feed was unrecorded but rarely found among the farmers. This is because farmers can find animal feed ingredients that are cheaper than cassava. Furthermore, the farmers' need of cash income is so great that they hardly realize the benefit of using cassava as animal feed. This is why the on-farm utilization of cassava as animal feed is found only among farmers who are trained to feed the animals with cassava-mixed feed under the special research and extension projects carried out by Kasetsart University.

3. TRENDS IN LIVESTOCK PRODUCTS

PRODUCTION OF LIVESTOCK PRODUCTS

According to official statistics, the livestock raised in Thailand during 1961-65 included 5.2 million head of buffalo, 3.7 million head of cattle, 3.5 million swine, 44.1 million chickens, and 6.6 million ducks (Table 12). The number of buffalo, cattle, and swine increased very slowly over the following 20 years, while the number of chickens and ducks increased more rapidly. The growth rate of the buffalo population between 1973-77 and 1981-85 was low.

Table 12--Trends in the number of livestock, 1961-84 and projections to 1990 and 2000

Period	Buffalo	Cattle	Swine	Chicken	Duck
			(1,000)		
1961-65 average	5,191	3,715	3,472	44,105	6,569
1973-77 average	5,544	4,266	3,954	50,408	9,839
1981-85 average	6,090	4,597	4,403	70,975	15,026
Annual growth rate 1973-77 to 1981-85 (percent)	1.18	0.94	1.35	4.37	5.44
Projections					
1990	6,121	4,677	4,251	77,802	19,267
2000	6,249	4,790	4,315	94,933	29,978

Source: Computed using data from Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, various issues 1961-1985/86 (Bangkok: Ministry of Agriculture and Cooperatives, various years).

Note: The projections were made with the equation $\ln Y = a + bt$, which was used to fit 1961-85 national data; Y is the number of the type of livestock in question, t is the number of years.

The total amount of meat produced increased between 1961-65 and 1973-77, and reached the record of 735,200 tons per year during 1980-84 (Table 13). While the average annual growth rate of total meat production was 7.7 percent between 1973-77 and 1980-84, the annual growth rate of production of beef was 3.22 percent and that of buffalo meat was estimated to be 1.42 percent over the same period. The annual rate of growth of poultry meat during the same period was estimated to be 11.19 percent, and that of pigmeat was estimated to be 3.34 percent.[5] In general, the rate of expansion of poultry meat production was highest. This was due to the rapid expansion of commercial poultry farms, which adopted new breeds and employed modern feeding technology. The expansion of the production of beef and pigmeat was considered to be moderate during the 1970s and the early 1980s. The production of buffalo meat, on the other hand, expanded at a much slower rate due to a shortage of parent stocks and the high demand for draft animals. In addition, buffalo in Thailand are raised for draft power and then for meat after retirement. Modern commercial buffalo raising is hardly seen. However, the slow expansion of buffalo meat production has been offset by the rapid growth of both poultry and pork production.

The production of milk also showed a rapid growth rate. Between 1961-65 and 1980-84 milk production in Thailand increased from 6,400 to 29,000 tons with an average annual growth rate of 15.9 percent.

The production of eggs, on the other hand, showed a declining trend between 1973-77 and 1980-84. The eggs produced during 1961-65 averaged 96,400 tons, increased to the record of 170,000 during the mid-1970s, then declined to 125,400 tons during the early 1980s. The most important factors that resulted in the decline in egg production included a fall in egg prices that followed a decline in export markets and the relatively higher profitability of broiler farming, which, in general, influenced a shift from layers.

Cattle, buffalo, and pigs are raised mainly by individual farm units that are scattered through all regions. Poultry farms, on the other hand, are large, commercial enterprises. Milk is also produced by individual farm units. These are organized into either cooperatives or contractors of private or semiprivate milk processing enterprises. The statistics on the livestock products broken down by groups of enterprises have not yet been officially compiled and are not available.

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[5]This was computed based on data in Food and Agriculture Organization of the United Nations, <u>Production Yearbook</u>, various issues 1960-84 (Rome: FAO, various years 1961-85).

TRENDS IN CONSUMPTION OF LIVESTOCK PRODUCTS

The aggregate consumption of livestock products during 1973-77 to 1980-84 was most rapid in meat (Table 13). Actual consumption levels during 1980-84 were 703,100 tons of meat, 66,300 tons of milk, and 123,300 tons of eggs. It should be noticed that, for most livestock products, the increase in consumption followed closely the increase in production. In particular, the rapid increase in the domestic production of milk between 1973-77 and 1980-84 resulted in a considerable decrease in milk imports. For eggs, a sharp decline in production was associated with a parallel decrease in consumption.

PROJECTIONS OF PRODUCTION AND CONSUMPTION OF LIVESTOCK PRODUCTS

Based on the growth rates of production and consumption of livestock products during 1973-77 to 1980-84, and the income elasticities of demand for the products, the output of meat is projected to be 1.2 million tons in 1990 and 2.3 million tons in 2000 (Table 13). The projections of meat consumption in the two corresponding periods are 873,580 and 1,053,400 tons, respectively. For milk, the projected output is 38,000 tons for 1990 and 81,000 tons for 2000. The projected milk consumption in the corresponding periods are 90,200 and 132,500 tons, respectively, suggesting a more rapid increase in consumption than in domestic production in the next decade.

The projections of egg production are 138,400 tons in 1990 and 156,500 tons in 2000. The projected consumption levels are 129,500 and 137,800 tons for the corresponding periods. The production of eggs is projected to grow at about the same rate as the consumption of eggs.

SURPLUSES AND DEFICITS IN LIVESTOCK PRODUCTS

With a faster rate of growth in meat production than in consumption, Thailand still produced a meat surplus of 27,100 during the 1980-84 period (Table 13). The projected meat surpluses in 1990 and 2000--342,120 and 1,244,840 tons, respectively--are mostly poultry meat. These surpluses have a potential for export as the markets for frozen meat, especially chicken, are expected to be more favorable in the future.

Thailand has been deficient in milk since the beginning or the 1960s. The deficit, however, tended to decline successively from 1961-65 to 1980-84, following a high growth rate in the domestic production while the imported supply declined gradually. The projected deficits in milk suggest that milk is to be more important in Thai diets. Domestic production alone is unlikely to keep pace

Table 13--Trends in the production and consumption of livestock products, 1961-84 and projections for 1990 and 2000

Product	Production	Consumption	Surplus or Deficit
		(1,000 metric tons)	
Meat			
1961-65 average	329.6	312.4	17.2
1973-77 average	438.5	431.0	7.5
1980-84 average	735.2	703.1	27.1
Annual growth rate (percent)			
1973-77 to 1980-84	(7.7)	(7.2)	(20.14)
Projections			
1990	1,215.70	873.58	342.12
2000	2,298.24	1,053.40	1,244.84
Milk			
1961-65 average	6.4	69.4	-63.0
1973-77 average	10.3	45.2	-34.9
1980-84 average	29.0	66.3	-37.3
Annual growth rate (percent)			
1973-77 to 1980-84	(15.90)	(5.6)	(-1.0)
Projections			
1990	38.0	90.2	-52.2
2000	81.0	132.5	-51.5
Eggs			
1961-65 average	96.4	59.4	37.0
1973-77 average	170.4	167.2	3.2
1980-84 average	125.4	123.3	2.1
Annual growth rate (percent)			
1973-77 to 1980-84	(-4.3)	(-4.3)	(-5.8)
Projections			
1990	138.4	129.5	8.9
2000	156.5	137.8	18.7

Source: Food and Agriculture Organization of the United Nations, Production Yearbook, various issues 1961-84 (Rome: FAO, various years).

Notes: The projections of consumption were based on the equation

$$C_t = C_{1982} (1 + Y_y X_n)^{T - 1982},$$

where

C_t = total consumption in the year t,
C_{1982} = consumption of the commodity in 1982,
Y_y = the trend annual growth rate of real income,
n = the income elasticity of demand for the commodity (0.43-0.36 for meat, 0.80 for milk, and 0.50 for eggs), and
t = 1990 or 2000.

with the projected increase in consumption. Imports of milk, particularly powdered milk, are envisaged for the next decade.

The domestic production of eggs was much higher than consumption during 1961-65, resulting in a surplus of 37,000 tons of eggs per year. The surplus, however, declined substantially during the mid-1970s and early 1980s due to a slower increase in egg production than consumption. Egg supply and demand is considered to have been well balanced in 1980-84. However, with production projected to be higher in the next decade, egg surpluses are projected for 1990 and 2000. The currently narrower export market of eggs would not provide much potential for exporting egg surpluses.

4. TRENDS IN CEREAL AND OTHER FEEDS

FEED REQUIREMENTS OF LIVESTOCK INDUSTRIES

The requirements for animal feed vary with the type of livestock. In practice, buffalo and cattle in Thailand are heavily dependent on noncereal feeds such as hay, rice straw, and natural pasture. The use of compound and mixed feeds is found only in dairy farming. Therefore, most commercial mixed and compound feed is produced just for swine and poultry. Among compound feed ingredients, cereals form the highest percentage, 50-55 percent, most of which is maize and broken rice.

Total commercial requirements of the livestock industries for both compound and mixed feed range between 1.5 and 2.0 million tons a year. In terms of cereals, total requirements during the period 1966-70 was 1.8 million tons. On a cereal equivalent basis, the requirements for pulses (soybean and groundnut meals) was 21,300 tons during the same period (Table 14). Between 1976 and 1980, the annual requirements for cereals rose to 2.3 million tons. The requirement for pulses also rose, to 31,000 tons per year. The annual growth rate of the cereal requirement was estimated to be smaller than for pulses during 1966-80, 2.6 percent against 3.9 percent. At most, negligible amounts of other feed ingredients such as roots and tuber crops, bananas, and plantains were used as animal feeds.

Based on the trend projections of livestock products and feed uses, the projected feed requirements in 1990 include 3.3 million tons of cereals, 100 tons of roots and tuber crops, 33,600 tons of pulses (mainly soybean meal and groundnut meal) and 100 tons of plantains. In 2000, the projected feed requirements are 4.5 million tons of cereals (maize, sorghum, rice and rice by-products), 100 tons of roots and tubers, 46,400 tons (in cereal equivalent) of pulses, especially soybean meal and groundnut meal, and 100 tons of plantains. For cereals, the projected figures by the year 2000 double the figures for 1976-80. In general, the feed requirements in Thailand in the next decade will still be heavily concentrated on cereals and pulses. However, due to a shortage in the supply of pulses, particularly soybean meal, most of the requirement for pulses will be met by imports.

Table 14--Projected feed requirements for the livestock sector, 1990 and 2000

Period	Cereals	Roots and Tubers	Soybeans and Groundnuts	Bananas and Plantains
		(1,000 metric tons)		
1966-70 average	1,774.0	0	21.3	0
1976-80 average	2,293.9	0	31.1	0
Annual growth rate 1966-70 to 1976-80 (percent)	(2.6)	(0)	(3.9)	(0)
Projections[a]				
1990				
Growth rate at 4.35 percent	3,265.1	0.1	33.6	0.1
Growth rate at 3.26 percent	3,111.9	0.1	32.0	0.1
2000				
Growth rate at 4.35 percent	4,516.3	0.1	46.4	0.1
Growth rate at 3.26 percent	4,131.9	0.1	42.5	0.1

Sources: Computed based on data from Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, various issues 1961-1983/84 (Bangkok: Ministry of Agriculture and Cooperatives, various years); Food and Agriculture Organization of the United Nations, Production Yearbook, various issues 1961-84 (Rome: FAO, various years).

Notes: All noncereal feed data are expressed in terms of cereal equivalents.

[a]The projections were made assuming that the annual per capita income growth rate was either 4.35 or 3.26 percent and that the annual population growth rate was a constant 1.78 percent. They were based on the historical trend of feed use from 1966 to 1980, taking into account the per capita consumption rate of each kind of livestock.

TRENDS IN EXPORTS OF FEEDGRAINS

Thailand is still a net exporter of feedgrains, most of which are maize. Sorghum exports constituted only 8.5 percent of total coarse grains exports during the period 1981-83. During the early 1960s, an average of only 594,300 tons of maize and none of sorghum were exported (Table 15). Exports of maize increased gradually following the rapid output expansion of both maize and sorghum in the late 1960s to about 1.7 million tons of maize and 155,700 tons of sorghum in the early 1970s. These exports increased further in the early 1980s to 2.7 million tons of maize and 245,900 tons of sorghum. Exports of maize grew rapidly through 1971-73 (at 11.07 percent per year), and decreased to 4.58 percent per year from then to 1981-83, resulting in an average long-term growth of 7.78 percent per year over the entire 1961-63 to 1981-83 period. Sorghum exports also grew more rapidly--65.66 percent per year during the early 1960s. They dropped to 4.68 percent per year during the early 1970s. Therefore, during the past two decades, the average export growth of sorghum exceeded 30 percent per year.

Table 15--Trends in exports of coarse grains 1960-84 and projections to 1990 and 2000

Period	Maize	Sorghum
	(1,000 metric tons)	
1960	515	...
1965	804	54
1970	1,447	79
1975	2,104	200
1980	2,175	181
1984	3,116	219
1961-63 average	594.3	...
1971-73 average	1,698.7	155.7
1981-83 average	2,659.3	245.9
Annual growth rate (percent)		
1961-63 to 1971-73	11.07	...
1971-73 to 1981-83	4.58	4.68
1961-63 to 1981-83	7.78	...
Projections		
1990	2,858	291
2000	3,380	372

Source: Computed based on data in Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Agricultural Statistics of Thailand, various issues 1960-1984/85 (Bangkok: Ministry of Agriculture and Cooperatives, various years).

Note: The projections were made with the equation $\ln Y = a + bt$; Y is the estimate of the variable in year t, t is the number of years (1960 was the base year).

5. EXISTING AND POTENTIAL YIELDS OF CASSAVA

Findings of field surveys carried out during mid-1986 and experiment data and records collected by the Department of Agriculture make it appear that the current yield per hectare of cassava in farmers' fields with no fertilizer or irrigation ranges from 10.2 tons on inferior soil to 14.8 tons on ordinary soil.[6] Both the national average from the Department of Agriculture records and the sample survey's average are consistent with each other. On inferior soil, the sample average of 1985 crop yields was 10.2 tons per hectare, while that of the national average was 10.6 tons per hectare. On ordinary soil, yield based on the sample survey was 14.8 tons per hectare compared to a national average of 15.6 tons (Table 16). Cassava yields with fertilizer applied to the farmers' field also varied with soil conditions. On inferior soil, the yields ranged from 13.7 to 15.6 tons per hectare, while those on the ordinary soil ranged from 18.3 to 23.1 tons per hectare. In general, the existing cassava yields from farmers' fields in Thailand are already higher than the world average and exhibit a significant variation between those with and without fertilizer and those under inferior and ordinary soil conditions.

In on-farm trials, cassava yields without fertilizer treatment seem not to deviate much from those in farmers' fields with inferior soils, that is, they range between 8.8 and 10.6 tons per hectare. However, on ordinary soil, on-farm trial yields have proved superior to yields in farmers' fields: 17.7 to 20.6 tons per hectare against 14.8 to 15.6 tons per hectare. In addition, on-farm trials with the application of fertilizer showed much higher yields of cassava on ordinary soil than on inferior soil (see Table 16).

Cassava yields from research stations can also be classified into two categories: yields with and without fertilizer applications. According to 1985 data, the average yield with fertilizer was 18.7 tons per hectare on inferior soil and 31.9 tons per hectare on ordinary soil. Yields achieved without fertilizer treatment ranged from 14.4 tons per hectare on inferior soil to 20.6 tons per hectare on ordinary soil. On average, yields with fertilizer have been 44 percent higher than those without fertilizer across various soil conditions. In particular, on inferior soil and without fertilizer use, yields in research stations were considerably higher than those

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[6]No cassava area in Thailand is irrigated.

from trials either on-farm or on farmers' fields. However, yields with fertilizer treatments on inferior soil in research stations were not significantly superior to those from on-farm trials. For ordinary soil, on the other hand, yields at all three alternative field sites suggest that existing varieties of cassava have a high response to fertilizer.

Table 16--Yields of cassava, 1985

Type of Yield	Inferior Soil National Average	Inferior Soil Field Survey[a]	Ordinary Soil National Average	Ordinary Soil Field Survey[b]
	(metric tons/hectare)			
Farmers' fields				
Without fertilizer or irrigation	10.6	10.2	15.6	14.8
With fertilizer and without irrigation	15.6	13.7	23.1	18.3
On-farm tests				
Without fertilizer or irrigation	10.6	8.8	20.6	17.7
With fertilizer and without irrigation	18.1	13.5	28.7	33.6
Research stations				
Without fertilizer or irrigation	14.4	n.a.	20.6	n.a.
With fertilizer and without irrigation	18.7	n.a.	31.9	n.a.

Source: Kasetsart University, "Field Survey of Cassava-Based Feed Pilot Project Area," Bangkok, 1986; unpublished data from the Ministry of Agriculture and Cooperatives, Department of Agriculture.

Note: Where n.a. appears, the data were not available.

[a]These figures are for Chachoengsao, Nakorn Ratchasima, and Udorn Thani provinces.

[b]These figures are for Rayong, Khon Kaen, and Chonburi provinces.

With existing varieties and no fertilizer application, the cassava yields in farmers' fields are not expected to improve much. By 1990, for example, yields without fertilizer application are expected to change little; they will be about 10.6 tons per hectare on inferior soil and 15.6 tons per hectare on optimum soil (Table 17). With new or improved varieties, the yields per hectare are expected to improve slightly, to 11.2 tons on inferior soil and 16.2 tons on optimum soil. Yield improvements at research stations are expected to be greater.

Yield improvements through the use of fertilizer are not expected to be significant in the farmer' fields. With existing varieties, yields by 1990 are expected to remain at the current level. However, with new or improved varieties and fertilizer use, yields are expected to improve and reach 27.5 tons per hectare compared to 23.1 tons per hectare with existing varieties (see the characteristics of improved varieties shown in Table 18). By 2000, cassava yields from farmers' fields, both with and without fertilizer, are expected to improve slightly from 1990. Without fertilizer and with existing varieties, yields are projected to be 11.2 tons per hectare on inferior soil or 16.2 tons per hectare on optimum soil, an improvement of 45 percent. With fertilizer, on the other hand, existing varieties are expected to yield up to 16.2 tons per hectare on inferior soil or 24.3 tons per hectare on optimum soil. On the other hand, with improved varieties and with fertilizer applications, the cassava yields in farmers' fields by 2000 are expected to reach 19.3 tons per hectare on inferior soil or 30.0 tons per hectare on optimum soil. Again, yields in research stations are expected to be better, 24.3 to 41.2 tons per hectare. These yields suggest that existing varieties of cassava in Thailand respond to fertilizer. At the same time, new and improved varieties could perform even better.

Table 17--Potential yields of cassava, 1990 and 2000

Type of Yield	1990 Inferior Soil	1990 Optimum Soil	2000 Inferior Soil	2000 Optimum Soil
	(metric tons/hectare)			
With existing varieties				
Farmers' fields				
Without fertilizer or irrigation	10.6	15.6	11.2	16.2
With fertilizer and without irrigation	15.6	23.1	16.2	24.3
Research stations				
Without fertilizer or irrigation	14.4	20.6	15.0	20.6
With fertilizer and without irrigation	18.7	31.9	20.6	35.0
With new varieties				
Farmers' fields				
Without fertilizer or irrigation	11.2	16.2	11.2	23.7
With fertilizer and without irrigation	17.5	27.5	19.3	30.0
Research stations				
Without fertilizer or irrigation	15.6	23.0	16.2	23.7
With fertilizer and without irrigation	22.5	38.1	24.3	41.2

Source: Thailand, Ministry of Agriculture and Cooperatives, Department of Agriculture, unpublished data.

Table 18--Characteristics of high-yielding cassava varieties, Rayong 1 and Rayong 3

Characteristics	Rayong 1	Rayong 3
Tip color	Purple	Light green
Color of first four mature leaves	Purple-green	Light green
Color of petiole	Purple-green	Red-green
Color of stem	Green	Light brown
Branch layers	3	5
Height of first branch (centimeters)	220	80
Height (centimeters)	282	174
Color of root peel	Cream	Light brown
Color of root pit	White	White
Brown leaves disease resistance	Moderate	Moderate
Hydrocyanic acid content (parts per million)	43	34
Carotene (milligram/100 grams)	79.70	94.68
Vitamin A (unit/100 grams)	133	158
Harvest index	0.45	0.57
Yield (metric tons/hectare)	25.94	24.37
Dry yield (metric tons/hectare)	8.325	9.306
Percentage of starch	18.3	23.4
Starch production (metric tons/hectare)	4.77	5.71

Source: Rayong Province Field Crops Research Center, unpublished data, 1986.

6. SUBSTITUTABILITY OF CASSAVA AND PROTEIN SUPPLEMENTS FOR FEEDGRAINS

PRODUCTION SUBSTITUTABILITY

Under existing crop cultivation practices, cassava growing requires two major inputs, land and labor. Compared to other upland crops, cassava cultivation is land and labor intensive and most land under cassava is less productive or not suitable for other field crops. Among crops competing with cassava, however, are upland rice, maize, and kenaf. During 1975-84, the areas planted with upland rice and maize showed an upward trend. In particular, the area under maize, the most important feedgrain, increased rapidly from 1.30 million hectares in 1975 to 1.78 million hectares in 1984 (Table 19).

Table 19--Areas planted with rice, cassava, maize, and kenaf, 1975-84

Year	Rice	Cassava	Maize	Kenaf
		(million hectares)		
1975	8.9	0.69	1.30	0.32
1976	8.6	0.85	1.28	0.16
1977	9.0	1.17	1.20	0.26
1978	10.0	0.85	1.39	0.32
1979	9.4	1.15	1.52	0.22
1980	9.6	1.26	1.44	0.18
1981	9.6	1.23	1.57	0.19
1982	9.6	1.37	1.68	0.22
1983	10.0	1.41	1.86	0.21
1984	10.0	1.41	1.78	0.16

Source: Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Selected Economic Indicators Relating to Agriculture (Bangkok: Ministry of Agriculture and Cooperatives, 1985).

The area under rice also grew, but with some variations around an upward trend. Cassava area expanded at a rapid rate, from 0.69 million hectares in 1975 to 1.41 million hectares in 1984, an increase of more than twofold over the 10-year period. The areas planted with kenaf, on the other hand, fluctuated widely and exhibited a strong decreasing trend. Therefore, maize and rice do not compete with cassava in terms of land use, while there are signs that cassava may be a substitute for kenaf. Such an argument applies directly to the Northeast region, where almost all kenaf is produced. However, substitution between cassava and kenaf is location-specific. Not all locations can be planted to either cassava or kenaf or both.

Among small farmers, because the price and profitability of kenaf have been low in recent years, kenaf production has ceased in most of the Northeast region. Only cassava and rice are cultivated. Again, at the farm level, rice and cassava do not compete in terms of land use and labor employment. A survey of the crop production pattern in such major cassava-producing provinces as Nakorn Ratchasima and Udorn Thani in the Northeast region and Rayong-Chonburi in the East region indicate that cassava planted area has not replaced rice area. In Rayong province, the average area planted with rice per farm remained the same between 1982 and 1985, 1.1 hectares, while the area planted with cassava declined from 5.6 to 4.8 hectares (Table 20).

Table 20--Average crop area per farm in surveyed areas, 1982-85

Province/Crop	1982	1983	1984	1985 Area	1985 Production
		(hectares)			(metric tons)
Rayong					
Rice	1.1	1.1	1.1	1.1	2.0
Cassava	5.6	5.6	5.5	4.8	62.3
Coconuts	2.7	2.6	2.6	3.0	1,508.0[a]
Nakorn Ratchasima					
Rice	2.0	2.0	2.1	2.0	4.7
Cassava	3.8	3.9	4.0	4.2	44.8
Sorghum	...	...	...	...	...
Udorn Thani					
Rice	3.7	3.7	3.7	3.7	14.2
Cassava	4.0	5.3	4.9	4.9	47.6
Maize and sorghum	...	...	...	...	...

Source: Kasetsart University, "Field Survey of Cassava-based Feed Pilot Project Area," Bangkok, 1986.

Notes: The ellipses indicate a nil or negligible amount.
The survey included 40 households in Rayong, 63 households in Nakorn Ratchasima, and 30 households in Udorn Thani.

[a]This figure is the number of coconuts.

Similarly, in Nakorn Ratchasima and Udorn Thani, rice area per farm remained unchanged while cassava area per farm was larger and kept increasing. An insignificant fraction of land was planted with coarse grains (maize, sorghum). These findings make it clear that cassava did not compete in land use with other crops, as it can grow well on the marginal or less fertile soil while having high tolerance to drought and disease. Moreover, cassava area has been expanded into either unused farm land or public reserved forests.

The field survey of small cassava farmers in the above mentioned provinces also showed that farmers did not have labor constraints in the production of rice and cassava. In other words, rice and cassava did not compete for the labor of farm families. For instance, in Udorn Thani province, the average farm in 1985 had 4.2 laborers, who could work full time up to 995 man-days each year (Table 21). However, total use of both family and hired labor for production of rice and cassava was 675.4 man-days, or 68 percent of total family labor. Of this, family labor worked only 432.7 man-days, 64 percent of the total labor used to produce rice and cassava. Hired labor worked 36 percent of total employed man-days. However, rice production absorbed more family labor than hired labor while cassava production required an almost equal proportion of family and hired labor. Of particular interest is the low employment of the family's farm labor, which accounted for only 43.5 percent of the family's total working man-days.

Labor employment in production of cassava and rice in Nakor Ratchasima also showed family farm labor as underemployed. Total labor used in farming rice and cassava in 1985 was 444.6 man-days, of which 123.2 man-days, or 28 percent, were from family labor. The rest, 72 percent of total man-days used, was from hired labor. The use of family labor, in fact, accounted for only 15 percent of total family labor available for full-time farm work, suggesting that farmers used hired labor in farm work while family labor was mainly on off-farm jobs. A similar conclusion also comes from Rayong province where family labor working on-farm accounted for 17 percent of the total available family labor force. The use of hired labor in farming rice and cassava accounted for 68 percent of total labor use. These case studies reveal that at the farm level, cassava production does not compete for labor with other crops. Farmers still underutilized their own farm labor force or preferred to exploit hired labor than family labor in their own farming. Therefore, expanded cassava production does not face labor constraints. Instead, it could reduce underemployment and contribute to more efficient use of farm family labor.

Table 21--Household labor used in the production of cassava and rice in surveyed areas, 1985

Type of Labor	Udorn Thani		Nakorn Ratchasima		Rayong	
	Rice	Cassava	Rice	Cassava	Rice	Cassava
	(man-days/crop year)					
Family labor						
Land preparation	10.0	...	3.0	...	1.0	...
Cultivation and care	125.2	113.6	53.4	27.8	22.3	43.2
Harvesting	118.2	65.7	19.1	19.9	19.0	33.0
Total	253.4	179.3	75.5	47.7	42.3	76.2
Hired labor						
Land preparation	4.8	...	6.6	...	17.6	...
Cultivation and care	9.7	92.6	21.8	178.3	12.5	112.3
Harvesting	57.9	77.7	47.3	67.4	33.8	71.8
Total	72.4	170.3	75.7	245.7	63.9	184.1
Total labor employed						
Land preparation	14.8	...	9.6	...	18.6	...
Cultivation and care	134.9	206.2	75.2	206.1	34.8	155.5
Harvesting	176.1	143.4	66.4	87.3	52.8	104.8
Total	325.8	349.6	151.2	293.4	106.2	260.3

	Udorn Thani	Nakorn Ratchasima	Rayong
Family size (persons)	6.0	6.0	5.0
Farm laborers (persons)	4.2	3.4	3
Total family labor (man-days)	995.0	806.0	711.0
Total labor employed producing cassava and rice	675.4	444.6	366.5

Source: Kasetsart University, "Field Survey of Cassava-based Feed Pilot Project Area," Bangkok, 1986.

COSTS AND RETURNS OF CROP PRODUCTION

In general, farms grow not only cassava but other cash and food crops. Cassava is one of the most profitable cash crops cultivated by farmers in the Northeast. However, the profitability rate of each cash crop changed from time to time, resulting in changes in its profitability rate as well as level of production output. A comparison of unit cost of each cash crop provided an indication of how cassava gained cost advantage over other cash crops. The time series data on unit cost and price of rice, maize, cassava, and kenaf during 1980-84 are shown in Table 22. In absolute terms the unit cost per hectare of kenaf was higher than for other crops in 1980.

Table 22--Average unit costs and returns of selected major crops, 1980-84

Year	Rice	Cassava	Maize	Kenaf
		(฿)		
Unit cost per hectare				
1980	5,231	5,871	3,658	5,948
1981	5,346	6,041	3,803	5,666
1982	5,404	9,814	3,073	5,343
1983	5,569	9,034	4,011	5,844
1984	5,537	6,512	4,247	5,538
Unit cost per metric ton				
1980	3,100	410	1,750	4,810
1981	3,070	430	1,730	5,460
1982	3,290	450	2,070	5,820
1983	3,050	440	1,900	5,060
1984	2,973	460	1,830	5,610
Farm price per metric ton				
1980	2,994	750	2,400	3,260
1981	3,435	540	2,230	3,570
1982	2,938	540	2,250	4,140
1983	2,966	730	2,370	3,690
1984	2,942	580	2,360	7,400
Net return per metric ton				
1980	-106	310	650	-1,550
1981	365	110	500	-1,890
1982	-352	90	180	-1,680
1983	-84	290	470	-1,370
1984	-31	120	530	1,790

Source: Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, Selected Economic Indicators Relating to Agriculture (Bangkok: Ministry of Agriculture and Cooperatives, 1985).

It decreased gradually to ฿ 5,844 in 1983, and fell further to ฿ 5,538 in 1984. The per hectare cost of cassava ranked the second highest, ฿ 5,871 in 1980 and increased to ฿ 9,034 in 1983. The production costs of maize and paddy rice were, respectively, ฿ 3,658 and ฿ 5,231 per hectare in 1980, and rose to ฿ 4,247 and ฿ 5,537 per hectare in 1984. Of these four crops, the production cost per hectare in 1984 was cheapest for maize, followed by rice and kenaf. The unit cost per hectare of cassava was highest.

Cassava output yielded the lowest unit cost per ton, ฿ 410 in 1980 and ฿ 460 in 1984. For maize, the production cost per ton was highest, ฿ 2,070 in 1982, dropping to ฿ 1,830 in 1984. The unit cost of rice output varied between ฿ 3,650 and ฿ 3,290 per ton. The cost of kenaf output was the highest of all, ฿ 5,610 per ton in 1984.

With average market prices in 1984 of ฿ 2,942 per ton for rice, ฿ 580 per ton for cassava, ฿ 2,360 per ton for maize, and ฿ 7,400 per ton for kenaf, the net return per ton to farmers was highest for kenaf, ฿ 1,790, followed by maize and cassava. For rice, the farmer's return was an average loss of ฿ 31 per ton. It should be noticed that kenaf farmers lost every year from 1980 to 1983 before their gain in 1984. Rice farmers had negative net returns every year, but they continued to grow rice because rice is the most important staple food. Based on the net return per ton of output, it is worthwhile to grow maize and cassava as cash crops while returns on kenaf are still uncertain. However, some farmers cannot get away from cassava because they have constraints on geographical and soil conditions that do not favor the cultivation of maize, the most profitable crop.

Generally speaking, the results of the mid-1986 cross section survey of sample farms confirm the previous findings (Tables 23 and 24). For example, for Rayong farmers, the net returns per kilogram of paddy were negative (a loss of ฿ 1.00), whereas the net returns of cassava were ฿ 0.20, equivalent to ฿ 200 per ton. The cost/return ratio per hectare for rice was 1.48 and the cost/price ratio was 1.45. But for cassava, the cost/return ratio per hectare was 0.69 while the cost/price ratio was 0.70, indicating that cassava had a cost advantage over rice. The ratios of cost to returns and prices of rice and cassava in Nakorn Ratchasima were comparable. The cost/return per hectare was 0.71 for rice and 0.67 for cassava, while the cost-price ratios were 0.72 and 0.67. In Udorn Thani, on the other hand, the cost ratios of rice were considerably higher than those of cassava. Therefore, rice was more profitable there than cassava. Generally speaking, cassava production had a comparative advantage over rice and provided higher returns per hectare than maize.

Table 23--Average net returns on rice and cassava production in surveyed areas, 1985

Item	Rayong		Nakorn Ratchasima		Udorn Thani	
	Rice	Cassava	Rice	Cassava	Irrigated Rice	Cassava
Average farm size (hectare)	1.1	4.8	2.0	4.2	3.7	4.9
Cost per farm (฿)	6,459	28,623	8,462	18,296	16,103	22,128
Output per farm (metric tons)	2.0	62.3	4.7	44.8	14.2	47.6
Output value per farm (฿)	4,400	41,118	11,703	27,328	39,760	37,6045
Net return per farm (฿)	-2,059	12,495	3,241	9,032	23,657	15,476
Average yield (metric ton per hectare)	1.8	13.0	2.4	10.7	3.8	9.7
Cost per hectare (฿)	5,872	5,963	4,231	4,356	4,352	4,516
Output value per hectare (฿)	4,000	8,566	5,852	6,507	10,746	7,674
Net return per hectare (฿)	-1,872	2,603	1,621	2,151	6,394	3,158
Price received (฿)/kilogram	2.20	0.66	2.49	0.61	2.80	0.79
Cost per kilogram (฿)	3.20	0.46	1.80	0.41	1.10	0.46
Net return per kilogram (฿)	-1.0	0.20	0.69	0.20	1.70	0.33
Per hectare cost per return ratio	1.48	0.69	0.71	0.67	0.41	0.59
Cost per price ratio	1.45	0.70	0.72	0.67	0.39	0.58

Source: Kasetsart University, "Field Survey of Cassava-based Feed Pilot Project Area," Bangkok, 1986.

Table 24--Average cost of production of rice and cassava in surveyed areas, 1985 crop year

Item	Rayong		Nakorn Ratchasima		Udorn Thani	
	Rice	Cassava	Rice	Cassava	Rice	Cassava
	(฿/farm)					
Human labor wage	4,302	10,179	4,415	6,149	9,956	10,564
Animal labor wage	146	274	138	4	556	86
Tractor services	444	5,545	1,372	4,504	1,613	5,025
Seed and seedlings	161	1,163	246	1,860	312	2,009
Fertilizers	224	4,510	226	714	197	...
Pesticides	30	1,103	22	49	...	...
Tool maintenance	...	11	8	521	77	50
Fuel	70	26	105	103	135	39
Loan interest	280	1,954	342	713	140	393
Average variable costs	5,657	24,765	6,874	14,617	12,986	18,166
Average fixed costs	802	3,884	1,588	3,679	3,117	3,962
Average total costs	6,459	28,623	8,462	18,296	16,103	22,128

Source: Kasetsart University, "Field Survey of Cassava-based Feed Pilot Project Area," Bangkok, 1986.

COSTS AND RETURNS OF CASSAVA FROM DIFFERENT CULTIVATION PRACTICES

Table 25 presents estimates of costs and returns of cassava under different soil conditions and cultivation practices--with and without using chemical fertilizers. The main concern about cassava production is soil fertility depletion caused by repeated cassava cropping. Improved varieties are of great interest but do not pose as serious a problem. This is because with existing varieties, particularly Rayong 1, there is a great potential for increasing yields through improvements of cultural practice, particularly the application of chemical fertilizer. Irrigation technology for cassava, on the other hand, is not of concern to scientists and farmers because the geography of the areas where cassava is planted does not favor it.

The application of chemical fertilizer to cassava is found to be profitable on both inferior and ordinary soils. In particular, on inferior soil, which badly needs soil quality improvement, the application of fertilizer of the formula N-P-K 15-15-15 at the rate of 312.5 kilograms per hectare has been found to raise cassava yields to the maximum of 31.2 tons per hectare in on-farm tests.

Table 25--Costs and returns of cassava production with and without using fertilizer in farmers' field, 1985

Category	Yield	Output Value	Production Cost Per Hectare	Production Cost Per Ton	Net Profit
	(metric tons/ hectare)	(฿)	(฿/hectare)	(฿/ metric ton)	(฿/ hectare)
Inferior soil					
National average					
Without fertilizer	10.6	6,148	5,625	530.6	523
With fertilizer	15.6	9,048	6,165	395.2	2,883
Field survey					
Without fertilizer	10.2	7,038	4,459	437.2	2,579
With fertilizer	13.7	9,453	4,069	297.0	5,384
On-farm tests (average)					
Without fertilizer	9.7	6,693	6,780	699.0	87
With fertilizer	15.8	10,902	9,578	606.2	1,324
Optimum soil					
National average					
Without fertilizer	15.6	9,048	5,625	360.6	3,423
With fertilizer	23.1	13,398	6,165	266.9	7,233
Field survey					
Without fertilizer	14.8	10,212	6,450	435.8	3,672
With fertilizer	18.3	12,627	6,057	331.0	6,570
On-farm tests (average)					
Without fertilizer	19.2	13,248	6,252	326.5	6,996
With fertilizer	31.2	21,528	9,220	295.5	12,308

Sources: The national averages and the data from the on-farm tests are from Thailand, Ministry of Agriculture and Cooperatives, Department of Agriculture, unpublished data; the field survey data are from Kasetsart University, "Field Survey of Cassava-based Feed Pilot Project Area," Bangkok, 1986.

Similarly, the national figures showed that the use of fertilizer raised yields from 10.6 to 15.6 tons per hectare although the production costs also increased, from ฿ 5,625 per hectare to ฿ 6,165 per hectare. However, on a tonnage basis, the unit cost was reduced to ฿ 395.2 per ton with fertilizer, compared with ฿ 530.6 without it;

this was a cost reduction of 26 percent. This raised the gross profits per hectare to ฿ 2,883 against ฿ 523 with no fertilizer used. The data obtained from the mid-1986 field survey also support such an argument. With fertilizer applied on inferior soil, the yield of cassava was raised from 10.2 to 13.7 tons per hectare and resulted in a reduction in units costs from ฿ 437.2 per ton to ฿ 297.0 per ton, while increasing gross profits from ฿ 2,579 to ฿ 5,384 per hectare, about a twofold increase. This is equivalent to an increase in gross profit from ฿ 252.8 per ton to ฿ 393.0 per ton, an increase of 55 percent. The results of on-farm trials, however, showed less impressive profits because the costs incurred by more comprehensive crop cultivation were higher, as were wages and administrative costs.

The benefits of using fertilizer in cassava cultivation were even more pronounced on optimum or ordinary soils. The available time series and cross-section data from both farmers' fields and on-farm trials showed that a considerable increase in yields was associated with the application of fertilizers. The incremental yield per hectare ranged between 3.5 tons in farmers' fields to 12 tons in on-farm trials. These were followed by increased net profits of between ฿ 2,898 and ฿ 5,312 per hectare, or ฿ 442.67 to ฿ 828.00 per ton.

UNIT COST OF PRODUCTION OF COMPOUND FEED

In general, manufacturing compound feed is based not only on the nutrition contents but also on the prices of the individual feed ingredients. Therefore, the production costs of compound feeds vary with the raw materials used. For example, from a technical point of view there are three formulas for pig-finisher rations, shown in Table 26. The main feed ingredients in ration 1 are broken rice and rice bran while those in ration 2 are maize and soybean meal. In ration 3, cassava, soybean meal, and rice bran are the main ingredients. To choose between these three rations, one has to consider their advantages in terms of the available raw materials and their market prices with a view to minimizing production costs.

Based on July 1986 prices, it appears that ration 1 provided the lowest feed costs, ฿ 2,809.5 per ton compared to ฿ 3,309.50 and ฿ 3,285.50 per ton for ration 2 and ration 3 respectively. With such prices it makes no significant difference to the production costs of the ration whether cassava or maize is used as the main feed ingredient. As a consequence, ration 1 has a cost advantage over the other two. However, using the average 1984/85 market prices of individual feed ingredients, it appears that ration 3, in which cassava has the highest weight, turned out to be the cheapest ration. During a low price period for either broken rice or maize, however, mixing cassava into a compound feed to replace maize or broken rice would result in higher feed costs. On the other hand, during a high price period for maize or broken rice, using cassava in the feed mixture could help minimize feed costs.

Table 26--Examples of pig-finisher rations with and without cassava

Ingredient	Ration 1	Ration 2	Ration 3
		(percent)	
Broken rice	56.00	...	13.90
Maize	...	82.70	...
Cassava	...	...	50.00
Rice bran	30.00	...	15.00
Soybean meal	9.00	12.00	15.00
Fish meal	3.00	3.00	4.00
Dicalcium phosphate	1.50	1.70	1.50
Oyster shell	0.20	...	...
Sugar	...	...	...
Tallow fat	...	...	...
Salt	0.25	0.35	0.35
Premix	0.25	0.25	0.25
Methionine	...	...	...
Total	100.20	100.00	100.00
Total costs (฿)[a]	280.95	330.95	328.55
Total maximum cost (฿)[b]	463.65	442.59	422.40

Source: Unpublished data from Kasetsart University, Department of Animal Husbandry, Bangkok, 1985.

Notes: These rations are standard technical formulas. The figures are put on the basis of a 100 kilogram ration. Ration 1 is broken rice, rice bran, and soybean meal with a fish meal supplement. Ration 2 is maize and soybean meal with a fish meal supplement. Ration 3 is cassava and soybean meal with a fish meal supplement.

[a] These costs were assessed at July 1986 prices.

[b] These costs were assessed at the highest prices of 1984 and 1985.

There are many ways to reduce feed costs using cassava, however. The examples given in Tables 27 and 28 show alternative ways of mixing pig rations with and without using cassava as a substitute for maize or broken rice. To produce 100 kilograms of farm-mixed pig-starter, 40 kilograms of maize, 30 kilograms of rice bran, and 30 kilograms of concentrate feed are required. (See Table 29 for details of concentrate feeds.) On the other hand, if cassava is to be substituted partially for maize, 20 kilograms of cassava chips, 25 kilograms of maize, 30 kilograms of rice bran, 5 kilograms of dried leucaena leaves, and 9 kilograms of concentrate feed are needed.

Table 27--Cost comparison of farm-mixed pig rations, with cassava substituting for maize, 1985

Type of Ration/ Ingredient	Current Market Price	Ration With Cassava		Ration Without Cassava	
		Amount	Cost	Amount	Cost
	(฿/kilogram)	(kilograms)	(฿)	(kilograms)	(฿)
Pig-starter ration					
Cassava chips	1.87	20	37.40	...	...
Maize	2.17	25	54.25	40	86.80
Rice bran	2.77	30	83.10	30	83.10
Dried leucaena leaves	1.50	5	7.50	...	...
Concentrate feed	9.00	20	180.00	30	270.00
Total	...	100	362.25	100	439.90
Pig-finisher ration					
Cassava chips	1.87	50	93.50	...	...
Maize	2.17	...	...	55	119.35
Rice bran	2.77	30	83.10	30	83.10
Dried leucaena leaves	1.50	10	15.00	...	...
Concentrate feed	8.85	10	88.50	15	132.75
Total	...	100	280.10	100	335.2

Source: Computed from technical data provided by the Department of Animal Husbandry at Kasetsart University, Bangkok, 1985.

Notes: These rations are on a 100 kilogram basis.

Table 28--Cost comparison of farm-mixed pig rations with cassava substituting for broken rice, 1985

Type of Ration/ Ingredient	Current Market Price	Ration With Cassava		Ration Without Cassava	
		Amount	Cost	Amount	Cost
	(฿/kilogram)	(kilograms)	(฿)	(kilograms)	(฿)
Pig-starter ration					
Cassava chips	1.87	20	37.40	...	...
Broken rice	3.18	25	79.50	40	127.20
Rice bran	2.77	30	83.10	30	83.10
Dried leucaena leaves	1.50	5	7.50	...	...
Concentrate feed	9.00	20	180.00	30	270.00
Total	...	100	387.50	100	480.30
Pig-finisher ration					
Cassava chips	1.87	50	93.50	...	...
Broken rice	3.18	...	...	55	174.90
Rice bran	2.77	30	83.10	30	83.10
Dried leucaena leaves	1.50	10	15.00	...	...
Concentrate feed	8.85	10	88.50	15	132.75
Total	...	100	280.10	100	390.75

Source: Computed from technical data provided by the Department of Animal Husbandry at Kasetsart University, Bangkok, 1985.
Notes: These rations are on a 100 kilogram basis.

Table 29--Recommended concentrated feed components for pigs and poultry

Component	Pig-Starter	Pig-Finisher	Chickens		Ducks	
			Broilers	Layers	Broilers	Layers
	(kilograms of dry matter)					
Soybean meal	10.0	6.0	8.0	9.0	7.0	6.0
Coconut meal	4.0	12.0	7.0	3.0	7.0	3.0
Fish meal	10.0	8.0	9.0	10.0	10.0	12.0
Rice bran	2.0	2.0	2.0	...	2.0	...
Oyster shell	1.0	...	2.0	5.0	2.0	6.0
Bone meal	2.0	1.0	1.0	2.0	1.0	2.0
Salt	...	...	0.5	0.5	0.5	0.5
Premix	0.7	0.5	0.5	0.5	0.5	0.5
Total	29.7	29.5	30.0	30.0	30.0	30.0
C-protein[a] (percent)	39.7	37.7	37.7	36.2	38.1	35.8

Source: Kasetsart University, "Report on Demonstration Village Project of Tapioca-based Diet," Bangkok, 1985.
Note: Totals may not add to 30.0 due to rounding.
[a]C-protein means crude protein on a dry matter basis.

For a pig-finisher ration, 100 kilograms of feed requires 50 kilograms of cassava chips, 30 kilograms of rice bran, 10 kilograms of dried leucaena leaves, and 10 kilograms of concentrate feed. An alternative ration consists of 55 kilograms of maize, 30 kilograms of rice bran, and 15 kilograms of concentrate feed. The costs of a mixed feed with cassava were estimated to be ฿ 2,801 per ton compared with costs of ฿ 3,352 per ton for a mixed feed with maize but no cassava chips. In other words, the pig-finisher ration of 100 kilograms with cassava was ฿ 55.10--16 percent--cheaper than the ration with maize. For pig-starter, the cassava-mixed feed of 100 kilograms was ฿ 77.65--18 percent--cheaper than maize-mixed feed.

The substitution of cassava for broken rice leads to the same conclusion. Replacing broken rice with cassava in pig rations yielded lower feed costs (Table 28). That is, for a pig-starter ration, the costs per 100 kilograms of feed with cassava were ฿ 387.50 against ฿ 480.30 for the feed with broken rice. Therefore, the cassava-mixed feed was ฿ 92.80 per 100 kilograms cheaper, that is, 19 percent cheaper than the feed with broken rice. For a pig-finisher ration, the cassava-mixed feed cost only ฿ 280.10 per 100 kilograms while feed with broken rice cost ฿ 390.75. The inclusion of cassava in mixed feeds leads to a cost reduction of ฿ 110.65 per 100 kilograms of feed, or 28 percent.

7. CURRENT SITUATION AND PAST TREND OF FORMULA FEEDS

PRODUCTION OF COMPOUND AND MIXED FEEDS

Manufacturing of formula feeds in Thailand has become significant since the late 1960s, particularly during the past 8 years. The number of feed mills increased from 30 in 1977 to 41 in 1985 (Table 30). The total amount of mixed and compound feeds produced increased from 855,700 tons to 1,966,000 tons over the same period. About 20 percent of the annual production of compound feeds is concentrate formula, the rest is regular formula feeds. The growth rate of all feed production between 1977 and 1985 was 7.8 percent per year. The growth rate of production of regular feeds was 7.3 percent per year.

Table 30--Commercial production of compound and mixed feeds, 1977-84

Year	Number of Feed Mills	Concentrate Feeds (Mixed)	Regular Feeds (Compound)	Total
		(1,000 metric tons)		
1977	30	171.1	684.6	855.7
1978	30	230.6	922.4	1,153.0
1979	34	240.0	960.0	1,200.0
1980	35	286.4	1,145.6	1,432.0
1981	32	312.0	1,248.0	1,560.0
1982	32	300.0	1,200.0	1,500.0
1983	34	300.0	1,200.0	1,500.0
1984	34	360.0	1,440.0	1,800.0
1985	41	393.2	1,572.8	1,966.0

Sources: Thailand, Ministry of Agriculture and Cooperatives, Department of Livestock Development, Feed Division, unpublished data; Thai Feed Mill Association, Feed Business, various issues.

The feed industry can be classified into three groups by production capacity. Large-scale industry has an annual production capacity of over 100,000 tons. Medium-scale industry has an annual capacity of between 50,000 and 100,000 tons. Small-scale feed mills have an annual capacity of less than 50,000 tons per year. The share of the large-scale industry in production in 1985 was 51 percent; the share of medium-scale industry was 30 percent; and the share of small-scale industry was 19 percent (Table 31). Total capacity of all 41 feed factories operating, on average, 10 hours per day was 3 million tons in 1985. (On a 24-hour-per-day basis, it was estimated to be 6 million tons.) However, the actual production capacity in the same year reached only about 2 million tons or about 65 percent of total capacity (Table 32).

Table 31--Animal feed mills classified by production capacity, 1985

Capacity Classification	Number of Mills	Capacity Average	Capacity Total	Share of All Mills
(metric tons/ year)		(metric tons/ mill)	(metric tons)	(percent)
Less than 10,000	2	2,993	5,985	0.20
10,000-49,999	14	39,427	551,984	18.43
50,000-100,000	13	70,200	912,600	30.48
Over 100,000	12	126,970	1,523,640	50.89
Total	41	73,029	2,994,209	100.00

Source: Thailand, Board of Investment; Thailand, Ministry of Agriculture and Cooperatives, Department of Livestock Development; and Thai Feed Mill Association, "Survey of Feed Mills," 1986 (mimeographed).

Note: The capacity figures assume an average working day of 12 hours.

Table 32--Production of compound and mixed feeds by selected large mills, 1985

Company	Monthly Production	Annual Production	Production Share
	(metric tons/ month)	(metric tons/ year)	(percent)
Chareon Pokaphan and affiliated firms	60,000	720,000	51.7
P. Chareonphan	18,000	216,000	15.5
Laemtong	9,000	108,000	7.8
Betago	7,000	84,000	6.0
Centago	7,000	84,000	6.0
Lee Watana	7,000	84,000	6.0
Thai Farmer Feed Company	8,000	96,000	6.9
Total	116,000	1,392,000	100
Overall production	166,333	1,996,000	...
Share of overall production (percent)	69.74	69.74	...

Source: Kasetsart University, "Field Survey of Cassva-based Feed Pilot Project Area," Bangkok, 1986; and Thai Feed Mill Association, Feed Business, various issues.

However, of total feeds actually produced in 1985, about 1.4 million tons or 69 percent were produced by the six largest firms, which have production capacities ranging from 7,000 tons to 60,000 tons per month. Of total feeds produced, 65 percent were poultry feeds, 39 percent were swine feeds, and 5 percent were cattle and duck feeds.

COMPOSITION OF FEEDS

Major components of compound feeds in Thailand include cereals, oilmeal and cakes, fish meal, rice bran, and minerals. Cereal feeds mainly include maize and small broken rice. The oilmeal and cake used include soybean and groundnut meal, most of which is imported. During 1974-84, the utilization of maize as animal feed increased more than twofold, while the use of broken rice in animal feeds tended to decline, with the exception of 1984. During the mid-1970s, the use of maize as feeds averaged 508,000 tons. It increased to 996,700 tons during the early 1980s with an average annual growth rate of 8.78 percent (Table 33). The use of broken rice in formula feeds decreased from 668,200 tons to 583,000 tons over the same period, at a declining rate of 1.68 percent per year.

Table 33--Major components of formula feeds, 1974-84

Year	Cereal		Oilmeal and Cake[a]	Fish Meal	Rice Bran
	Maize	Broken Rice			
			(1,000 metric tons)		
1974	450	710.0	55.6	71.0	502.8
1975	538	630.2	73.8	62.7	449.5
1976	536	664.5	94.2	94.3	519.4
1977	686	516.9	142.3	66.1	511.1
1978	717	613.4	142.9	87.3	469.1
1979	826	589.3	139.5	69.9	592.7
1980	921	148.5	154.8	87.3	529.2
1981	968	536.3	143.0	69.8	586.2
1982	997	143.9	208.5	92.8	593.6
1983	1,004	496.9	191.5	97.2	547.0
1984	989	1,109.2	137.4	127.2	651.0
Averages					
1974-76	508.0	668.2	74.5	76.0	490.6
1982-84	996.7	583.3	179.1	105.7	597.2
Annual growth rate (percent)	8.78	-1.68	11.59	4.21	2.49

Source: Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, "Report on the Animal Feed Situation." Bangkok, 1986 (mimeographed).

[a]This includes soybean meal and groundnut meal.

The use of oilmeals, on the other hand, grew at a rapid rate, 11.59 percent per year between the mid-1970s and the early 1980s. That is, during 1974-76, the use of oilmeals averaged only 74,500 tons, increased to 179,100 tons during 1982-84, more than doubling. The use of fish meal and rice bran increased by 4.21 percent per year for fish meals and 2.49 percent per year for rice bran. Total use of fish meal and rice bran during 1982-84 were 105,700 and 597,200 tons per year respectively. Chemical additives and minerals were also important in animal feed mix, but they were required in only small proportions. Dried cassava chips and pellets, although significant feed ingredients, are hardly used in Thai animal feeds (the nutritional content of cassava products is given in Table 34). This is because other feed ingredients, which require fewer protein supplements than cassava does are available at relatively low costs. In addition, the export market for cassava pellets has been favorable since the early 1970s, which has discouraged the use of cassava in domestic feed production. As mentioned above, cassava use is limited, particularly when the prices of cereal feeds are high.

Table 34--Proportions of nutritional contents of cassava products

Type of Product	Water	Protein	Fats	Fiber	Ash	Carbohydrats
			(percent)			
Dried cassava leaves	12.32	27.39	7.17	10.90	7.02	35.20
Dried cassava chips	10.34	2.14	0.62	2.05	2.69	82.16
Cassava pellets	13.58	2.44	0.62	2.83	6.52	74.01
Cassava meal	12.14	7.23	0.29	7.23	6.15	66.96

Source: Thailand, Ministry of Agriculture and Cooperatives, Department of Livestock Development, Feed Division, unpublished data, 1981.

FORMULA FEED SCHEDULES

Measured by standard weights, general formula feeds contain 75-80 percent starch and fats, 15-20 percent protein, 4-5 percent minerals, and 1-2 percent vitamins. In general, the starch and fats are obtained from cereals (maize and broken rice) or cassava starch.

Protein and minerals can be obtained from concentrate feeds from a protein-based ingredient such as oilmeal or fish meal, or from chemical additives (Tables 35 and 36). The protein content is the most important component of the formula feeds, since it has to meet the physical requirements for a proper growth rate of the animals. Protein requirements also vary with growth periods and types of livestock. For example, for broilers and layers the crude protein required ranges from 18 to 22 percent. For pig-starter, pig-grower, and pig-finisher rations, the crude protein requirements are 17, 15, and 11-13 percent respectively (Table 36). Dairy cattle and fattening cattle also require 11-13 percent of crude protein.

Table 35--Nutritional requirements of standard animal feeds

Nutrient	Requirement
	(percent)
Starch and fat	75-80[a]
Vitamins	1-2
Minerals	4-5[b]
Protein	15-20[b]

Source: Prateep Rachpaetayakom, "Use of Mixed Feed in Animal Raising," Department of Animal Husbandry, Kasetsart University, Bangkok, 1983 (mimeographed).

[a]The starch and fat requirement can be obtained from cereals or up to half can be obtained from tapioca starch.

[b]Minerals and proteins can be obtained from concentrate feed. The amounts can be decreased, but this will slow the growth rate of the animal's weight.

Table 36--Protein requirements for mixed feed, by type of feed

Type of Feed	Amount of Crude Protein
	(percent)
Broiler or layer ration	18-22
Pig-starter ration	17
Pig-grower ration	15
Pig-finisher ration	11-13

Sources: Thailand, Board of Investment; Thailand, Ministry of Agriculture and Cooperatives, Department of Livestock Development; and Thai Feed Mill Association, "Survey of Feed Mills," 1986 (mimeographed).

To put the feed in a nutritional balance, other feed ingredients are required in proper proportions. Examples of farm-mixed feeds that are recommended to small livestock farmers are shown in Table 37.

Table 37--Farm-mixed feed rations recommended and adopted in demonstration village projects in the East and Northeast of Thailand, 1982-1984

	Pig Rations			
	Pig-starter		Pig-finisher	
Feed Ingredient	a	b	c	d
	(kilograms)			
Cassava chips (ground)	20	...	50	...
Broken rice	25	40	...	55
Rice bran	30	30	30	30
Dried leucaena leaves	5	...	10	...
Concentrate	20	30	10	15
Total	100	100	100	100

	Poultry Rations			
	Broiler		Layer	
	Chickens	Ducks	Chickens	Ducks
Feed Ingredient	e	f	g	h
	(kilograms)			
Cassava chips (ground)	30	30	35	30
Broken rice/maize	20	10	...	...
Rice bran (fine)	20	20	40	40
Rice bran (coarse)	...	10	...	...
Dried leucaena leaves	15	15	10	15
Concentrate	15	15	15	15
Total	100	100	100	100

Source: Kasetsart University, "Report on Demonstration Village Project of Tapioca-based Diet," Bangkok, 1985.

Notes: Ration a contains cassava mixed with broken rice. Rations b and d contain no cassava but have different proportions of broken rice. Rations c, g, and h contain no broken rice but have different proportions of cassava chips. Rations e and f contain cassava mixed with broken rice in different proportions.

The recommended formulas were put together assuming that farmers buy concentrate feeds from the market and mix them with cassava chips or broken rice together with rice bran and dried leucaena leaves, which are available locally. The two pig-starter rations, a and b, are optional, depending on the availability of the feed ingredients. If cassava chips are not used, ration b, the mix of broken rice, rice bran, and concentrate feed in the proportions 40-30-30 per 100 kilograms, can provide nutrition equivalent to ration a. Similarly, two alternative pig-finisher rations are recommended to farmers. In ration c, up to 50 kilograms of cassava chips are used together with 30 kilograms of rice bran, 10 kilograms of leucaena leaves, and 10 kilograms of concentrate. On the other hand, if cassava chips are not added, the use of 55 kilograms of broken rice mixed with 30 kilograms of rice bran and 15 kilograms of concentrate feeds could provide equivalent nutrition. The layer rations show the substitution of rice bran for broken rice, while the cassava chips are kept at about the same level as in broiler rations. The recommended feed rations indicate that cassava could be mixed in the formula feeds. In some cases, cassava could substitute totally for cereal feeds, although it requires more protein supplement. In practice, however, it is difficult to determine an optimum use of cassava for each type of animal.[7] It is also difficult to establish a definite rule for substituting between cassava and maize or broken rice. The optimum use of these feed ingredients depends largely on their availability and their relative prices. From a technical point of view, many types of formula feeds, particularly the pig-fattening rations, can contain up to 60 percent cassava if the remaining 40 percent of the ingredients are available to balance the nutritional requirements.

Because cassava roots are low in protein content, the protein supplement in a high-cassava ration should usually be high in protein, fiber, and ash. Cassava-based diets may also be deficient in essential fatty acids. Fat supplementation is therefore important to correct this deficiency. Furthermore, the relative prices of these diets are essential for the selection of an optimum feed mix that yields the lowest possible cost of the ration.

With this complicated feeding schedule, the mixing process for compound feeds is usually carried out by computerized machines adopted by most large-scale feed factories. Table 38 shows examples of simulated feed rations that use cassava as a substitute for maize and broken rice. All the rations shown are least-cost rations, specifying the appropriate amounts of cassava and protein supplements to be mixed in the rations under 1981-83 market prices. It is obvious that cassava formed the highest proportion in total weight in the broiler ration, 316.75 kilograms, followed by soybean and kapok

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[7]Technically, the mixture of cassava and soybean meal in the proportion of 85:15 has a nutritional content equal to maize.

Table 38--Simulated feeding schedules for least-cost rations, given the technical limits on the proportion of cereals and cassava in animal feeds, 1981-83

Ingredient	Pig-Starter	Pig-Finisher	Broiler (1-28 days)	Layer (4-8 weeks)	Layer (8-22 weeks)
			(kilograms)		
Cassava	325.24	351.21	316.75	384.77	432.99
Rice bran	250.00	416.56	126.14	300.00	300.00
Soybean meal	200.19	35.75	275.36	115.40	31.98
Fish meal	59.69	50.00	75.00	50.00	50.00
Kapok meal	100.00	100.00	100.00	100.00	100.00
Tallow fat	20.08	30.00	58.71	...	...
Cassava leaves	29.36	...	30.52	33.66	68.91
Methionine	0.44	0.94	2.52	1.18	1.12
Premix	15.00	15.00	15.00	15.00	15.00
Lysine	...	0.55	...	...	...
Total	1,000.00	1,000.00	1,000.00	1,000.00	1,000.00
Total cost (฿)	4,604.83	3,832.15	5,489.57	4,001.26	3,642.60
Total cost of maize-based ration (฿)	4,607.44	3,915.13	5,555.09	4,029.62	3,707.69

Source: Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, "Economic Analysis of the Use of Cassava Product in Livestock Rations and Its Market Prospects, Cassava/Nutrition Project Report," Bangkok, 1984.

Notes: The average price of cassava was ฿ 2.05 per kilogram; of maize, ฿ 3.18 per kilogram; of soybean meal, ฿ 7.49 per kilogram; of fish meal, ฿ 10.90 per kilogram; and of broken rice, ฿ 3.72 per kilogram.

meals, with 275.36 and 100 kilograms, respectively. Fast-growing broilers require more energy, therefore the percentages of crude protein and fats are high. In the layer ration, the requirements of crude protein and fats decrease as the animals become older. In addition, all the cassava-based rations had lower costs than the maize-based rations. For instance, the pig-finisher ration using cassava cost only ฿ 3,832.15 per ton against ฿ 3,915.13 per ton for the ration using maize. The cassava-based feeds, therefore, reduced the cost of the pig-finisher ration by ฿ 82.98 per ton, or 2.1 percent. Similarly, for the broiler ration, the use of cassava as a substitute reduced the cost about ฿ 65.52 per ton over the ration using maize, a cost reduction of 1.2 percent. The same argument can be applied to the other feed rations shown in Table 38.

Cassava prices ranged from ฿ 1.05-฿ 2.45 per kilogram and the average maize price was ฿ 3.18 per kilogram during 1981-83. Cassava began to substitute for maize in broiler rations when cassava prices were between ฿ 2.15 and ฿ 2.25 per kilogram or lower. This implies that the price differential was ฿ 0.93-฿ 1.03 per kilogram or 29-32 percent between maize and cassava. This means that in order to substitute for maize in broiler rations, cassava must be at least 29 percent cheaper than maize. In such a situation, the optimum use of cassava is up to 46 percent by weight of the ration.

The substitution of cassava for maize took up from 10.7 to 32.5 percent of pig rations. This was followed by a cost reduction of 10-19 percent over the cost of diets without cassava use. At the same time, changes in cassava prices from the maximum ฿ 2.45 per kilogram to the minimum ฿ 1.45 per kilogram would result in an increase of 0.13-1.54 million tons in the use of cassava as a substitute for maize in animal feeds.

The examples of formula feeds adopted by the commercial feed mills during 1984-85 and 1986 (June-July) also provided supportive evidence on the possibility of cassava substituting for maize or broken rice in animal feeds. The least-cost rations shown in Table 39 are for pig rations established by computerized feed mills. During a period of high prices for maize (1984-85), the use of cassava-based diets was obviously profitable. That is, the mixture of 430 kilograms of cassava in pig-starter rations together with 305 kilograms of soybean meal, 214 kilograms of rice bran, and supplementary vitamins and minerals yielded the lowest cost ration, ฿ 4,465 per ton. In this situation, maize and broken rice were too expensive (฿ 3.75 and ฿ 4.20 per kilogram) to be used. The cassava-maize price ratio was 0.77, suggesting that cassava could substitute for maize in pig rations as long as the price of cassava did not exceed 77 percent of the price of maize.[8] In other words, if the cassava-maize price

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[8]Cassava entered the least-cost ration at or below a cassava-maize price ratio of 0.55. In the EC, cassava entered the ration at price ratios less than 0.77.

Table 39--Least-cost pig feed rations adopted by commercial feed mills during high- or low-feed price situations, 1984-85 and 1986

Price Situation/ Ingredient	Market Price	Pig-Starter		Pig-Finisher	
		Amount	Cost	Amount	Cost
	(฿/kilogram)	(kilograms)	(฿)	(kilograms)	(฿)
High-price situation (1984-85)					
Cassava	2.90	430.00	1,247.00	464.00	1,345.60
Soybean meal, solv-52	6.50	305.00	1,982.50	213.00	1,384.50
Rice bran, polished	3.90	214.00	834.60	293.00	1,142.70
Tallow fat	6.25	20.00	125.00	...	...
Dicalcium phosphate	8.00	13.00	104.00	8.00	64.00
Calcium carbonate	0.35	9.00	3.15	12.00	4.20
Salt	1.20	5.00	6.00	5.00	6.00
Vitamins	12.35	2.50	30.88	2.50	30.88
Methionine	75.00	1.64	123.00	1.53	114.75
Trace minerals	9.38	1.00	9.38	1.00	9.38
Fish meal 65	10.15	...	...	...	...
Broken rice	4.20	...	...	...	...
Maize (broken)	3.75	...	...	...	...
Lysine	93.00	...	...	...	...
Total	...	1,001.14	4,465.51	1,000.03	4,102.01
Low-price situation (1986)					
Broken price	2.25	515.00	1,158.75	524.00	1,179.00
Rice bran, polished	1.45	268.00	388.60	333.00	482.85
Soybean meal, solv-52	6.50	122.00	793.00	69.00	448.50
Fish meal-65	10.15	79.00	801.85	53.00	537.95
Calcium carbonate	0.35	9.00	3.15	14.00	4.90
Salt	1.20	5.00	6.00	5.00	6.00
Vitamins	12.35	2.50	30.88	2.50	30.88
Trace minerals	9.38	1.00	9.38	1.00	9.38
Lysine	93.00	0.60	55.80	0.40	37.20
Methionine	75.00	0.05	3.75	0.24	18.00
Cassava	2.30	...	...	...	...
Maize (broken)	2.40	...	...	...	...
Dicalcium phosphate	8.00	...	...	...	...
Total	...	1,002.15	3,251.16	1,002.14	2,754.66

Source: Thai Feed Mill Association, Bangkok, unpublished data, 1986.

ratio exceeds 0.77, it would be cheaper to use maize in the pig-starter rations. Similarly, for pig-finisher rations, a low-priced cassava relative to maize could yield even cheaper rations--that is, costing ฿ 4,102 per ton against ฿ 4,465.5 per ton of pig-starter rations.

Nevertheless, when the prices of maize and broken rice were low (mid-1986), cassava was too expensive to be used in the pig rations, although it had a lower price than in 1981-83. The cassava/maize price ratio during this period rose to 0.96, suggesting that cassava lost its price advantage over maize. Cassava was even more expensive than broken rice, which had a price of ฿ 2.25 per kilogram. At the same time, maize was still more expensive than broken rice. Therefore, using broken rice in pig rations when cereal prices are relatively low results in even cheaper feed costs--฿ 3,251.6 and ฿ 2,754.7 per ton for pig starter and pig-finisher rations respectively.

The poultry rations shown in Table 40 also suggest the advantage of cassava over maize or broken rice when prices of the latter are high (as in 1984-85). Under such circumstances, the cassava-based diets yielded the least-cost rations at ฿ 4,928 per ton for broiler grower rations and ฿ 4,225.75 per ton for the layer ration.

During the period of low cereal prices, on the other hand, maize and broken rice proved superior to cassava in the poultry ration. That is, in the broiler grower ration, the mixture of maize, rice bran, soybean meal, fish meal, and tallow fat provided the optimum feed mix. In the layer ration, the mixture of broken rice, rice bran, fish meal, and soybean meal yielded cheaper feed costs than using cassava or maize.

In sum, in commercial feed compounding, cassava can be a good substitute for maize or broken rice provided that cassava price is at least 23 percent cheaper than maize or 31 percent cheaper than broken rice.

FEEDING PERFORMANCE OF CASSAVA-BASED DIETS

The experience of the EC compound-feed industry shows that cassava-based diets, when properly prepared and fed, can totally substitute for cereals in pig rations without detrimental effects on either growth performance or carcass quality.[9] There is evidence from

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[9]W. Engelhardt, "Tapioca As a Feed Ingredient in West Germany," The Thai Tapioca Trade Association Yearbook 1984 (Bangkok: Thai Tapioca Association, 1984), pp. 68-77.

Table 40--Least-cost poultry feed rations adopted by commercial feed mills during high- and low-feed price situations, 1984-85 and 1986

Price Situations/ Ingredient	Market Price	Broiler Grower		Layer	
		Amount	Cost	Amount	Cost
	(฿/kilo-gram)	(kilo-grams)	(฿)	(kilo-grams)	(฿)
High-price situation (1984-85)					
Cassava	2.90	527.00	1,528.30	470.00	1,363.00
Soybean meal, solv-52	6.50	232.00	1,508.00	252.00	1,638.00
Fish meal-65	10.15	113.00	1,146.95	38.00	385.70
Rice bran, polish	3.90	86.00	335.40	136.00	530.40
Tallow fat	6.25	36.00	225.00	...	...
Vitamins	25.80	2.50	64.50	2.50	64.50
Methionine	75.00	1.47	110.25	1.37	102.75
Salt	1.20	...	...	5.00	6.00
Trace minerals	9.65	1.00	9.65	1.00	9.65
Broken rice	4.20	...	...	...	...
Maize (broken)	3.75	...	...	...	...
Dicalcium phosphate	8.00	...	...	12.00	96.00
Calcium carbonate	0.35	...	...	85.00	29.75
Lysine	93.00	...	...	...	...
Total	...	998.97	4,928.05	1,002.87	4,225.75
Low-price situation (1986)					
Maize (broken)	2.40	485.00	1,164.00	...	...
Rice bran, polished	1.45	213.00	308.85	243.00	352.35
Soybean meal, solv-52	6.50	172.00	1,118.00	77.00	500.50
Fish meal-65	10.15	85.00	862.75	105.00	1,065.75
Tallow fat	6.25	34.00	212.50	...	...
Calcium carbonate	0.35	3.00	1.05	83.00	29.05
Vitamin	25.80	2.50	64.50	2.50	64.50
Salt	1.20	...	...	...	...
Methionine	75.00	1.07	80.25	0.32	24.00
Trace minerals	9.65	1.00	9.65	1.00	9.65
Lysine	93.00	0.47	43.71	...	...
Cassava	2.30	...	...	...	...
Broken rice	2.25	...	...	486.00	1,093.50
Dicalcium phosphate	8.00	...	...	...	...
Total	...	997.04	3,865.26	997.82	3,139.30

Source: Thai Feed Mill Association, Bangkok, unpublished data, 1986.

the EC that growing and finishing pigs on cassava-based diets perform as well as those on cereal diets, although the crude protein content should be at an optimum level. When properly compounded, cassava-based diets for swine are more digestible than cereal diets. Experiments show that cassava roots can be incorporated into growing-finishing diets at levels as high as 50 percent for pigs weighing 15-35 kilograms and 68-70 percent for those of heavier weight, provided that the diets are carefully balanced to include vitamins, minerals, and amino acids (see Table 41). In general, up to 40-50 percent of diets for growing-finishing swine consist of cassava roots.

Table 41--Recommended rates of substitution of cassava for cereals in animal feeds

Animal/Age or Weight	Recommendations
Broiler	
Age 0-8 weeks	Cassava can make up 57.5 percent of pelletized feed or less. For powdered feed, cassava can make up 20 percent of the ration or less.
Layers	
Age 0-7 weeks	The ration can consist of up to 40 percent cassava.
Age 7-20 weeks	The ration can consist of up to 60 percent cassava.
Age 22-62 weeks (laying period)	The ration can consist of up to 50 percent cassava.
Pigs	
Weight 15-35 kilograms	The ration can consist of up to 50 percent cassava.
Weight 35-60 kilograms	The ration can consist of up to 60 percent cassava.
Weight 60-100 kilograms	The ration can consist of up to 70 percent cassava.
Dairy cattle	
Milking period	Cassava can make up 65 percent or less of low-protein diets, or 69 percent or less of high-protein diets.

Source: Thai Feed Mill Association, Bangkok, Monthly Bulletin, January-March 1985.

For layers, cassava meal can be used as a substitute for maize meal. Laying birds can tolerate up to 40 percent cassava meal in a dry mash without losing the palatability of the diet. However, 25 percent of cassava roots in a diet generally yields successful results. According to Jalaludin and Leong, the 50-60 percent of cassava meal in a diet tended to decrease the production and feed efficiency of the laying birds.[10]

Tests of the quality of eggs with cassava-based diets were also carried out by Hamid and Jalaludin.[11] It was found that egg yolks became progressively whiter as cassava meal increased from 20 to 60 percent of the ration. Two factors were assumed to cause this. First, the absence of pigmenting xanthophyll. Second, the low fat content of cassava flour meal, which indicates a low level of carotene. To overcome this problem, it is recommended that compounders use synthetic xanthophyll in cassava-based rations.

For broilers, the incorporation of 10 percent of cassava root flour into broiler rations resulted in a normal growth performance. However, with 20-30 percent, weight gain and feed efficiency deteriorated. Vogt also confirmed that only after broilers become four weeks old can they consume a cassava-based diet at levels higher than 10 percent.[12] Cassava in ruminant feeds also gave successful results. Several reports claimed that beef cattle fed with cassava-based diets increased their live weight gains. For dairy cattle, cassava-based diets yielded firmer butter and did not taint the milk.

The technical experiments in Thailand gave results similar to experiences in the EC. That is, for three kinds of pig rations--pig-starter, pig-grower, and pig-finisher--the inclusion of cassava to substitute for rice by-products in the rations up to 65.6, 68.5 and 75.0 percent, respectively, together with high quality protein yielded satisfactory results. Similarly, the experiments with

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[10]Jalaludin and Leong, 1973, quoted in J. Khajarern et al., "Biological Titration of Thai Cassava Root Chips in Rations." KKU-IDRC Cassava/Nutrition Project Annual Report, Khon Kaen University, Northeast of Thailand, 1982.

[11]Hamid and Jalaludin, 1966, quoted in J. Khajarern et al., "Biological Titration of Thai Cassava Root Chips in Rations." KKU-IDRC Cassava/Nutrition Project Annual Report, Khon Kaen University, Northeast of Thailand, 1982.

[12]Vogt, 1966, quoted in J. Khajarern et al., "Biological Titration of Thai Cassava Root Chips in Rations." KKU-IDRC Cassava/Nutrition Project Annual Report, Khon Kaen University, Northeast of Thailand, 1982.

substituting cassava for maize in pig rations also suggested that all three rations can include up to 60 percent cassava.[13]

Recommended poultry diets containing cassava chips of more than 50 percent should be supplemented with 2.5 to 5.0 percent of fats.[14] For example, the substitution of cassava for up to 50 percent of the cereal in layer rations showed no effect on hen-day production, feed conversion, egg weight, and egg quality throughout the 280-day production period.[15] In addition, the inclusion of an iodine supplement in the diets made up of 50 percent cassava at the rates of 3.0, 6.0 and 9.0 milligrams of iodine per kilogram showed no significant negative effects on either laying ability or egg quality.

The performance of the cassava-based diets at the farm level has not yet been evaluated and tested comprehensively. Only limited information is available for citation. The performance records for small farmers reveal that pigs fed with a farm-mixed cassava-based diet were found to take 10 more days on average to gain weight up to a standard level of 100 kilograms.[16] Other performances could not be identified by the farmers.

In addition, interviews with most large-scale feed manufacturing firms also suggested that there are some quality problems with products from livestock fed a high cassava-based diet, though these have not yet been confirmed by scientific experiments. That is, pigs fed with cassava-based diets reportedly produce harder bellies or bacon that does not fit the Thai consumer's taste. Moreover, the cassava-based diet tainted the lard.

DEVELOPMENT OF MANUFACTURING TECHNOLOGY OF CASSAVA-BASED DIETS

In order to make the substitution of cassava together with protein supplements for maize and other cereal feeds more effective,

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[13]Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, "Economic Analysis of the Use of Cassava Product in Livestock Rations and Its Market Prospects, Cassava/Nutrition Project Report," Bangkok, 1984, p. 8.

[14]S. Khajarern et al. "A Preliminary Evaluation of Cassava-based Diets for Small Pig Raisers." KKU-IDRC Cassava/Nutrition Project Annual Report, Khon Kaen University, Northeast of Thailand, 1979.

[15]S. Khajarern et al. "Biological Titration of Thai Cassava Root Chips in Rations." KKU-IDRC Cassava/Nutrition Project Annual Report, Khon Kaen University, Northeast of Thailand, 1982.

[16]Kasetsart University, "Field Survey of Cassava-based Feed Pilot Project Area," Bangkok, 1986.

improvement of the manufacturing technology for both cassava pelletization and feed compounding is necessary. With improved breeding technology in pigs and poultry, fast-growing swine and broilers need more energy than older types of animals. Thus there exists a great demand for higher-density nutrients. The installation of additional compounding equipment such as sprayers to allow greater use of fat to increase the energy content of pig and poultry rations has been widely accepted by feed compounders. The installation of this equipment also allows greater use of cassava in animal feed. So does the pelleting process of dried cassava chips. Improvement in modern pelleting plants has contributed significantly to higher density, durability, and quality of pellets while reducing transportation and handling costs. The addition of moisture or heat has increased the effectiveness of the pelleting machines and the nutritional value of cassava products by making it possible to add more fats and protein into cassava pellets. This kind of technological improvement has created more demand for cost-saving cassava-based diets in the EC, the largest market for Thailand's feed cassava.

8. PROSPECTS FOR CASSAVA PRODUCTION AND UTILIZATION

PROJECTED AREA UNDER CASSAVA

The area under cassava in Thailand is expected to increase further as long as the price of cassava continues to increase or stay about the same as in 1986. The estimated annual growth rate of cassava areas along the trend line of 1971-84 is 6.40 percent. The annual variations in cassava area were small. The projected areas for 1990 is 1.66 million hectares for all four presumed alternatives (Table 42). This is about 28 percent higher than the 1980-84 average. Alternative A projects the lower extreme for estimated output, while alternative D assumes extremely high cassava output, following the nationwide adoption of new varieties together with fertilizer use.

By 2000, the area under cassava is projected to increase to 1.72 million hectares, or 3.7 percent higher than the 1990 projection and 33.4 percent higher than average area in 1980-84. These projected figures, however, are made with the assumption that the current government policy to reduce or limit cassava area does not effectively influence a nationwide reduction in cassava area. The projection also takes into account the limitation of export markets of cassava pellets in the EC, which are subject to import quotas of 5.5 million tons per year up to 1992. However, with the present market and structure of demand for cassava products, it is projected that the price of cassava roots will remain at the current level, about ฿ 600 per ton, which is still high enough to induce further expansion of cassava production.

PROJECTED YIELD AND OUTPUT OF CASSAVA

By 1990 cassava yields in farmers' fields are expected to decline from the 1980-84 yields if farmers still use existing varieties and use no fertilizer. This is because of the soil-depleting nature of cassava itself. The projected yield for 1990 is 13.10 tons per hectare, compared with 16.43 tons per hectare for 1980-84. However, new varieties are projected to increase the yield slightly to 13.70 tons per hectare, which is still lower than the current yield.

If fertilizer is used, on the other hand, yield of cassava for 1990 is projected to be 19.35 tons per hectare with existing varieties or 22.50 tons per hectare with new varieties. These yields would result in total cassava output for 1990 ranging between an extreme low of 21.76 million tons and an extreme high of 37.38 million tons.

Table 42--Prospects for cassava production in Thailand in 1990 and 2000

Period/Alternative	Area	Yield	Output
	(1,000 hectares)	(metric tons/ hectare)	(million metric tons)
1961-63 average	120.7	16.46	3.239
1971-73 average	328.0	14.00	4.827
1983-85 average	1,291.6	16.43	18.174
1990 projections[a]			
Alternative A	1,661.2	13.10	21.76
Alternative B	1,661.2	13.70	22.76
Alternative C	1,661.2	19.35	32.14
Alternative D	1,661.2	22.50	37.38
2000 projections[b]			
Alternative A	1,723.6	13.70	23.61
Alternative B	1,723.6	17.45	30.59
Alternative C	1,723.6	20.25	34.90
Alternative D	1,723.6	24.65	42.49
Projected annual growth rate (percent)[c]	6.40	1.80	8.50
Past trend equations (1976-84)			
Area (1,000 hectares)	$Y_a = 4,635.97(1.064)^T$; $R^2 = 0.54$, $S_b = 0.372$.		
Yield (metric tons/hectare)	$Y_y = 2.089 + 0.04\ T$; $R^2 = 0.51$, $S_b = 0.015$.		
Output (1,000 metric tons)	$Y_o = 8,536.47 + 1,217.35T$; $R^2 = 0.68$, $S_b = 312.5$.		

Source: Computed from data in Table 6.

Notes: Alternative A assumes continuing cultivation of existing varieties without fertilizer or irrigation. Alternative B assumes cultivation of new varieties with fertilizer. Alternative C assumes cultivation of existing varieties with fertilizer. Alternative A assumes cultivation of new varieties with fertilizer and without irrigation. All projections use an average of poor and optimum soils.

[a]The projection of area is made using the upper bound of trend values, taking into account the higher price cycle of cassava products.

[b]The projection of area is made using the lower bound of trend values, with a lower price cycle of cassava products assumed.

[c]The projected growth rates are based on the past trend equations.

By 2000, and under the same alternative assumptions, the yield of cassava is projected to be 13.7 tons per hectare with existing varieties and without fertilizer. On the other hand, with fertilizer and with existing varieties, cassava yield is projected to reach 20.25 tons per hectare. Moreover, if new varieties are adopted widely, the yield would be even higher. Therefore, the projected yield ranges from 17.45 tons per hectare with no fertilizer use to 24.65 tons per hectare with fertilizer. This is followed by projected total output of 35-43 million tons under alternatives C and D, compared with the extremely low estimate of 24-31 million tons under alternative assumptions A and B.

PROSPECTS FOR CASSAVA UTILIZATION FOR FOOD

Cassava utilization for food in Thailand during 1981-83 was 114,200 tons per year, accounting for 47 percent of total domestic utilization. Per capita consumption of cassava flour and tapioca starch products during the same period was 2.36 kilograms per year. In fact, cassava is not a staple food in Thai diets. The demand for cassava products as food, particularly for cassava flour, is income inelastic and negative (-0.20), indicating that as income changes, the quantity demanded for cassava as human food changes in the opposite direction by less than a proportionate change of income.

Ignoring the price effect, changes in the demand for cassava flour as food will depend largely on changes in population size, while a negative income effect will tend to offset the population effect. With population growth rates projected to be 1.78 and 1.60 percent in 1990 and 2000, the projected population in the respective years would be 56.49 and 66 millions (Table 43). The rural population is projected to be 45.19 million in 1990 and 49.50 million in 2000. The urban population is projected to be 11.30 million in 1990 and 16.50 million in 2000.

With an assumed negative income elasticity of demand of -0.22 for 1990 and -0.24 for 2000, total cassava consumption as food is projected to reach 127,800 and 133,600 tons of cassava flour equivalent in the two years. These projected amounts are greater than the 1981-83 average by 12.40 and 17.50 percent, respectively. Per capita consumption, on the other hand, is expected to decline from 2.36 kilograms per year during 1981-83 to 2.26 kilograms per year in 1990 and 2.02 kilograms per year in 2000. The prospects for cassava as food are not impressive because of the inferior nutritional characteristics of cassava in the Thai diets.

Table 43--Projected demand for cassava for food in 1990 and 2000

Item	1990	2000
Projected population (millions)	56.49	66.00
Urban areas	11.30	16.50
Rural areas	45.19	49.50
Projected average growth rate of population (percent/year)	1.78	1.60
Projected average growth rate of real per capita income (percent/year)	4.346	4.346
Estimated income elasticity of demand for cassava	-0.22	-0.24
Projected total demand for cassava for food (metric tons)	127,816	133,645[a]
Projected per capita consumption (kilograms)	2.26	2.02
Projected exports (metric tons)	709.6	1,654.6

Source: Computed from data in Table 11, and Thailand, Ministry of Agriculture and Cooperatives, Agricultural Statistics of Thailand, various issues, 1960-1984/85 (Bangkok: Ministry of Agriculture and Cooperatives, various years).

Notes: The projections of demand for cassava as food were based on the equation

$$C_t = C_{1983} (1 + r_y n)^{t - 1983},$$

where

C_t = total consumption in the year t,

C_{1983} = consumption of the commodity in 1983,

r_y = the trend annual growth rate of real income,

n = the income elasticity of demand for the commodity (0.43-0.36 for meat, 0.80 for milk, and 0.50 for eggs).

t = 1990 or 2000.

The export projections were made with the equation $\ln Y_t = a + bt$, which was used to fit 1960-84 data.

[a]This is equivalent to approximately 603,000 metric tons of fresh cassava roots.

PROSPECTS FOR CASSAVA UTILIZATION FOR FEED

The projected feed requirements in Thailand by 1990 and 2000 were shown in Table 14. The requirement for feed cassava was projected to be low--100 tons per year. This is because cassava is an export crop. It is technically feasible for cassava to be substituted for maize and broken rice in animal feed, but cheap cassava faces strong competition from cereals. As a consequence, a large part of the feed cassava produced in Thailand (cassava pellets) is channeled each year to export markets, particularly the EC, where cassava is widely used as animal feed.

However, there is potential demand for cassava in domestic feed manufacturing. It is expected that during the next decade cassava output will increase more rapidly, following the adoption of improved cassava varieties that is now underway and improvements in soil fertility through the use of fertilizers. It is, therefore, anticipated that the price of cassava will tend to decline. At the same time, the export markets for maize and sorghum are expected to be more favorable, so higher prices of feed cereals are envisaged.

With this scenario, the possibility of substitution between cassava and cereals in animal feed compounding is great. In the extreme case, if the price of cassava pellets declines from the current ฿ 2.56 per kilogram to a possible minimum of ฿ 1.45 per kilogram, while the price of maize remains as high as ฿ 2.80-฿ 3.50, the utilization of cassava in livestock feeds is expected to increase between 0.13 million and 1.50 million tons.[17]

In particular, at the average price of cassava chips of ฿ 2.05 per kilogram, the demand for cassava chips as animal feed was estimated to be at 1.01 million tons for the whole animal feed sector in Thailand. Of this, 477,600 tons were absorbed by the commercial feed industry.[18]

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[17]This is based on an assumed price elasticity of demand for cassava pellets of -5.18 for prices of ฿ 1.45 per kilogram and higher. The estimates were based on simulated optimum proportions of cassava chips in animal feed mixed under 1980-82 prices. The assumed minimum price of cassava pellets, ฿ 1.45 per kilogram, is economical for each of the four alternatives in Table 42. Taking into account the processing costs of pellets, this price is equivalent to ฿ 0.49 per kilogram of fresh roots. Cassava farmers can be expected to survive if the minimum price of cassava roots is ฿ 0.40 per kilogram.

[18]Thailand, Ministry of Agriculture and Cooperatives, Office of Agricultural Economics, "Economic Analysis of the Use of Cassava Product in Livestock Rations," p. 23.

Despite such an optimistic view, however, the export potential of compound feeds is low because imported protein supplements, such as soybean meal, are expensive. Similarly, fish meal produced in Thailand is still relatively expensive. For example, the price ratio between soybean meal and cassava was 2.24 in 1981-83 and it increased to 2.89 during 1985-86, suggesting that soybean meal became even more expensive relative to cassava. The same conclusion can be applied to fish meal.

In addition, due to the low price of feedgrains in major importing countries, the price ratio between cassava and maize is not attractive enough to facilitate substitution of a cassava-based diet for cereal-based diets. For instance, in 1981 the imported prices of cassava and maize in Japan were ฿ 4.03 and ฿ 4.15 per kilogram respectively, yielding a price ratio of 0.97, which indicates the cost disadvantage of using cassava against maize in livestock feed (also see Table 44). If this price differential is less than 23 percent, the possibility of producing and exporting high cassava-based rations is unlikely to exist, at least within the next decade. Instead, it will be feasible and profitable to produce and export cassava pellets for feed compounding in foreign countries that have a great import demand for feedgrains.

Table 44--Estimated costs of 16 percent protein diets with and without cassava, Thailand and the European Community

Ingredient	1981 Price	Maize Diet		Cassava Diet	
		Formula	Cost	Formula	Cost
	(฿/kilogram)	(kilogram)	(฿/metric ton)	(kilogram)	(฿/metric ton)
Thailand					
Maize	3.20	800	2,560.00	...	...
Cassava	2.01	...	...	636	1,280.80
Soybean meal	7.80	200	1,560.00	364	2,839.20
Total	...	1,000	4,120.00	1,000	4,120.00
European Community					
Maize	22.82	800	18,256.00	...	...
Cassava	15.90	...	...	636	10,112.00
Soybean meal	22.95	200	4,590.00	364	8,354.00
Total	...	1,000	22,846.00	1,000	18,466.00

Source: United Nations and the Economic and Social Council of Asia and the Pacific (ESCAP), "Research Implications of Expanded Production of Selected Upland Crops in Tropical Asia," Workshop Proceedings, Bangkok, 27-30 November 1984.

PROSPECTS FOR OTHER USES OF CASSAVA

The prospects for other uses of cassava in Thailand are good. The products that are most promising are modified starch and alcohol for use in manufacturing. Modified starch is a product that can be made from cassava or other cereal flour through an enzymatic process for specific industrial uses such as manufacturing paper, textiles, adhesives, cosmetics, drugs, and food. The demand for modified starch has been increasing in recent years in both domestic and export markets. Major export markets include Japan, Republic of Korea, Taiwan, the United States, and the Soviet Union.

The projected demand for modified starch in 1987 is 204,600 tons for the domestic market and 485,000 tons for export (Table 45).

Table 45--Production of modified starch from cassava, 1985 and prospects for demand in 1987

Firm	Annual Production Capacity	Production
	(metric tons)	
Thai Modified Starch Co.	20,000	4,000
Thai Wiscon Chemistry	10,000	10,000
Pirap Starch Co.	3,600	3,600
Thai Tapioca Starch Trade Co.	15,000	15,000
Siam Modified Starch Co.	56,000	56,000
Thai Tapioca Products Co.	2,400	500
Total	107,000	89,100
Projected total demand in 1987	...	689,600
Projected export demand	...	485,000
Projected domestic utilization	...	204,600[a]

Source: Agribusiness Group Holland, Market Study on the Utilization of Cassava-based Starch, Modified Starch and Ethanol for Thailand (Bagnkok: Agribusiness Group Holland, 1985).

[a]This was calculated using the trend equation fitted to data for 1965-80:

$$Y_2 = 35,645.92 + 6,792.20t;$$

$r^2 = 0.99.$

There are at present 6 manufacturing firms with a production capacity ranging from 2,400 tons to 56,000 tons per year. In total, these firms can produce up to 107,000 tons per year. However, actual production reached only 89,100 tons, meeting only 13 percent of the potential demand both domestically and abroad. In the future, the demand for modified starch is expected to increase substantially. A simple trend projection indicates that the industrial use of cassava starch is projected at 210,000 tons in 1990 and 280,000 tons in 2000 (for the methodology, see Table 45). On the other hand, the use of cassava as a raw material in producing alcohol for fuel and industrial uses is at the experiment stage in Thailand.

PROJECTED SUPPLY-DEMAND BALANCES FOR CASSAVA

The projected supply-demand balances for cassava were based on the realistic assumption that the possibility of widespread adoption of new varieties of cassava is still low due to the limited supply of planting materials (Table 46). The possibility that farmers will apply more fertilizer to existing crop varieties, on the other hand, is a real one, as cassava now gives higher profits to farmers than other cash crops. Therefore, by 1990, it is projected that cassava production in Thailand could reach 32 million tons of fresh roots, of which 576,000 tons will be used as food, 255 tons will be used as feed, and 1 million tons will be used in industry. This makes total domestic utilization 1.6 million tons, leaving a surplus of 31 million tons available for export.

Table 46--Projected supply-demand balances of cassava, 1990 and 2000

Item	1990	2000
	(1,000 metric tons)	
Production	32,140	34,900
Domestic utilization	1,584	2,003
Food use	576	603
Feed use	...[a]	...[a]
Industrial use	1,008	1,400
Surplus	30,556	32,897

Source: Computed based on data in Tables 7 and 42.
Note: This projection is made with existing varieties and with fertilizer use, but without irrigation.
[a]Less than 500 tons.

The projected figures for 2000 increase to 35 million tons for 2000. Domestic utilization in 2000 is projected to be 2 million tons. Of this, 603,000 tons is for food use, 255 tons is for feed, and 1.4 million tons is for industrial use. The surplus is projected to be 33 million tons. This cassava surplus is about 85 percent higher than 1981-83 average exports.

With higher yields per hectare assumed, the unit costs of cassava roots are expected to fall. Based on the results of past experiments in farmers' fields, detailed in Table 23, the average per unit cost of cassava roots is expected to fall between 10 and 32 percent following increases in yield per hectare. The cassava price, on the other hand, is expected to fall by the same proportion. With an assumed price elasticity of -2.36 of export demand for cassava pellets, for example, and with free trade in cassava exports assumed, a 20 percent decline in the cassava pellet price would be associated with an increase of pellet exports of 47 percent.[19] Were there import restrictions in the markets where cassava pellets are sold, the story would be somewhat different.

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[19]The price elasticity was adopted from Chaiwat Konjing and Asipith Issariyanukula, "Output Demand and Marketing of Rice and Upland Crops in Thailand," in Food Policy Analysis in Thailand, ed. Theodore Panayotou (Bangkok: Agricultural Development Council, 1985). The 20 percent fall in the pellet price is based on the calculated decline in the per unit cost data of producing cassava roots shown in Table 25.

9. MAIN CONCLUSIONS AND POLICY IMPLICATIONS

A rapid increase in cassava production in Thailand since the late 1960s is attributable to a rapid expansion in planted area, while yield per hectare remained stable and higher than the world average. Cassava growing is concentrated in the Northeast region where most of the area planted with cassava is not suitable for other crops and is vulnerable to drought. Thus cassava is not only a promising cash crop but also a food security crop grown by small farmers, which form the majority in the Northeast region. In addition, in terms of land and labor use, cassava does not compete with maize or rice at the farm level.

Most cassava products produced each year are exported in the form of dried chips or pellets for use as animal feed abroad. Domestic utilization, mainly industrial use, accounts for only a small percentage of total processed cassava output, 3.5 percent. Cassava is not directly a staple food, but it provides cash income for small and poor farmers.

Although the domestic utilization of cassava in human food within the next decade is projected to increase by 12-17 percent, per capita consumption is expected to decline due to a negative income effect of cassava consumption demand. On the other hand, the utilization of cassava as an industrial raw material is expected to increase more than ninefold during the next decade.

The prospects for the domestic utilization of cassava as animal feed, however, are not bright, because the price differential between cassava and feedgrains is low. Cassava was found to substitute for maize in animal rations only when cereal prices were high, so that the price ratio between cassava and maize or broken rice was at or below 0.77. In the computerized least-cost rations, cassava entered the rations when the cassava-maize price ratio was less than 0.55, suggesting that to minimize costs cassava must be at least 45 percent cheaper than maize. In general, cassava can be substituted for maize or broken rice at a relative price ratio of 0.23. Technically, cassava can be incorporated in animal feeds up to 70 percent by weight, depending on the type of animal. However, because of the relatively low prices of feedgrains, the use of cassava as animal feed is not yet attractive to feed compounders. In addition, high cassava-based diets are believed to produce some undesirable characteristics in livestock products, such as pork belly that is hard and lard that is tainted. For broilers, high cassava-based feeds with an insufficient mix of synthetic xanthophyll will cause the chicken's skin to be whiter.

As the largest exporter of cassava products in the world, Thailand still relies on export market outlets, particularly markets for cassava pellets, cassava flour, and modified cassava starch. Exports of these products during the last decade increased rapidly. The prospects for exports of cassava flour and modified starch look bright and are expected to double by 2000. The prospects for exports of cassava pellets, however, will be limited by restrictions on imports into the EC and are expected to reach a ceiling of 7.0-7.5 million tons by the end of the next decade. The prospects for exports of cassava-based rations are also low, because imported protein supplements are expensive and price competition from competing feedgrains is strong.

Therefore, the prospects for cassava utilization as food and animal feed seem to be low while those for industrial uses of both flour and modified starch look promising.

The policy options for Thailand, thus, are those involving cost reductions through appropriate use of cost-reducing technologies that would make cassava more competitive in both the domestic and the world markets. Otherwise, a reduction of cassava production is needed. The following measures are relevant. First, a strengthening of production and extension programs for hybrid or improved varieties and improved cultivating practices. Second, commercial and investment policy designed to encourage expansion of manufacturing of cassava products by granting investment privileges, business tax cuts, and preferential loan programs.

Research on cassava production currently under way includes breeding and varietal trials attempting to raise yields per hectare and to increase the starch content of cassava. These could lower production costs. An introduction of new products--cassava fries and gari--following successful improvements in breeding also reflect a new move in cassava research in Thailand.[20] However, research on post harvest processing including tests of flour quality and flour enrichment technologies is still limited in scale. Moreover, research on cassava consumption and nutrition seems to have been neglected due to the insignificant role of cassava in Thai diets.

Again, since the scope for increased utilization of cassava as feed is limited by a narrow margin between cassava and cereal prices,

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[20]The research on gari is designed to diversify exports of cassava products to African countries. However, because the costs of production are high, the gari produced seems to be too expensive for African consumers.

efforts using the cost-reducing technologies in feed manufacturing are important in increasing the economic viability of cassava-based feeds. Based on the previous discussion, the price differential of at least 23 percent between cassava and cereal feeds would make substitution between cassava and maize in feed compounding possible. Furthermore, a decline of the price of cassava pellets from ฿ 2.25 per kilogram to ฿ 1.45 per kilogram could raise domestic consumption of cassava as feed to as much as 1.5 million tons.

To be effective, market policies to widen the price gap between cassava and maize and sorghum are required. Among them, the cost-reducing technologies both on the farm and in manufacturing are important and should be made available. In addition, the public media and extension programs need to be strengthened to support the adoption of new technologies.

As far as the Thai cassava industry is concerned, there is a need to set priorities in cassava research. To this end, it is important that the top priority in research be given to developing cost-reducing technologies in cassava production. Research on the nutritional content of cassava flour and product innovation is also a critical need. The need for research on the consumption and nutrition effects of cassava in both human diets and livestock feed is of equal importance.

75

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