Cassava in Asia: Trends in Cassava Production, Processing and Marketing[1]

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ABSTRACT

This paper describes the current (2006) situation of cassava production, utilization and marketing in Asia with emphasis on its role as a raw material for various agro-industries. The paper describes in some detail the great diversity of products that can be made from cassava. It then analyses the future potential of the crop and how it might maintain its competitive edge in the world market.

Over the past decade the cassava planted area in Asia has slightly decreased but yields have markedly increased, resulting in a steady increase in production, from 49.6 million tonnes in 1994 to 60.2 million tonnes in 2004. In most countries, cassava is utilized domestically, but in Thailand it is destined mainly for the export market, while China is presently a major net importer. In almost all countries in Asia cassava is principally used in food, while in Thailand and China it is used mainly for feed and industrial purposes.

Potential markets for cassava are mainly in the area of starch and starch-based products, for domestic animal feed production, and for processed food; recently, a new market for production of ethanol is rapidly developing in Thailand, China and the Philippines. Cassava starch can generally compete with other sources of starch on the basis of price in the mass market, and on the basis of its functional starch properties in certain specialized markets. However, cassava lacks the wide range of intrinsic starch characteristics found in the gene pool of some competing crops like maize and potato. There is a great potential in developing "high-value" cassava varieties with specific starch characteristics suitable for particular industries.

To maintain cassava's competitiveness in world markets, further research is required to increase yields, reduce production costs, broaden the range of starch functional properties and increase the starch content or nutritional value of roots. In addition, processing efficiency needs to be improved, new processes and products developed, and new markets for cassava-based products identified. This can only be achieved by the integration of production, processing and marketing, by the active collaboration of the various institutions involved, and through an effective partnership between the public and private sector.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) has its origin in Latin America where it has been grown by the indigenous Indian population for at least 4000 years. After the discovery of the Americas, European traders took the crop to Africa as a potentially useful food crop; later it was also taken to Asia to be grown as a food security crop and for the extraction of starch. Thus, in the 19th century cassava became an important food crop in southern India, as well as on Java island of Indonesia and in the southern Philippines, while in Malaysia and parts of Indonesia it was also used for extraction of starch. After the Second World War it became an important industrial crop in Thailand, mainly to produce starch for local consumption, and dried chips and later pellets for the rapidly growing European animal feed market. In southern China it was initially used as a food crop but has become more recently an important crop for on-farm feeding of animals, mainly pigs, and for processing into various industrial products such as native starch, modified starch, MSG, sweeteners and alcohol. In Indonesia the crop remains first and foremost a food crop, used in a great variety of dishes, but on the outer islands, especially in southern Sumatra, it is now mainly grown for starch extraction. In Malaysia the once important cassava starch industry has nearly disappeared as the crop could not compete with more lucrative plantation crops like rubber and oil palm.

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PRESENT SITUATION

1. Cassava Production Trends

Figure 1 shows the cassava growing areas in the world, while **Figure 2** shows in more detail the current distribution of cassava in Asia. **Figure 1** and **Table 1** indicate that in 2004 about 53.% of cassava in the world was produced in Africa, 30% in Asia, and only 17% in Latin America and the Caribbean. **Table 2** indicates that cassava production in Asia increased at a high rate of 3% annually during the lately 70s and early 80s, slowed down during the 90s, and has been growing quite rapidly again at 2.5% per year during the past nine years. This, in spite of a modest reduction in area, as it was driven solely by a remarkable increase in yields, averaging 3.1% per year; the latter compares with annual yield increases of only 0.7% in Africa and 1.8% in Latin America. **Figure 3** shows the aggregate changes in area, production and yield of cassava in Asia over the past four decades, while **Figure 4** shows the production and yield in the main cassava producing countries in Asia. In some countries, cassava production kept pace with increases in population, while in others it decreased as a result of rapid urbanization and a more secure supply of the preferred food, rice. A marked exception is Thailand, where cassava production increased rapidly in the 1970s and 80s in response to a rapidly growing demand for animal feeds in Europe, as well as a favorable tariff structure. But when the Common Agricultural Policy (CAP) in the EU changed in the late 80s, cassava became less competitive with locally produced barley, and exports of cassava pellets declined rapidly, from a peak of 9.1 million tonnes in 1989 to 4.0 million tonnes in 2003 and less than 0.3 million tonnes in 2005 (**Figure 5**). This near-collapse of the export market in Europe was partially offset by accelerated growth in the production of starch and starch derivatives, as well as by increasing demand for cassava chips in China. Meanwhile in Vietnam, cassava production was in decline during the 1980s and 1990s as the economy improved and production of rice increased. But during the past four years, cassava production suddenly increased from about 2 million tonnes in 2000 to over 5.6 million tonnes in 2004, in order to meet buoyant internal demand for starch, and for export of chips and starch. This ability to increase production was a result of a substantial increase in planted area, from 235,500 ha in 1998 to 383,600 ha in 2004, as well as a remarkable increase in yield, from 7.53 t/ha in 1998 to 14.53 t/ha in 2004. In both Thailand and Vietnam, the yield increases achieved during the past 10 and 5 years, respectively, are mainly due to a concerted effort to distribute widely the new high-yielding and high-starch varieties, as well as to the adoption of improved cultural practices, such as more balanced fertilizer use and soil conservation measures (Howeler *et al*., 2004). In Thailand, new varieties are now planted in nearly 100% of the area, while 70-80% of farmers apply chemical fertilizers; in Vietnam the new varieties are now planted in about 60% of the cassava area while about 80% of farmers apply chemical and/or organic manures. These two factors combined nearly doubled yields in Vietnam over the past six years.

2. Production Systems

Most crops are produced in those areas where the soil and climatic conditions are most suitable for their growth. But cassava thrives basically in those areas where it has a competitive advantage over other crops, i.e. where production of other crops is constrained by unfavorable soil or climatic conditions more so than cassava. Cassava is known to be a very drought-tolerant and water-efficient

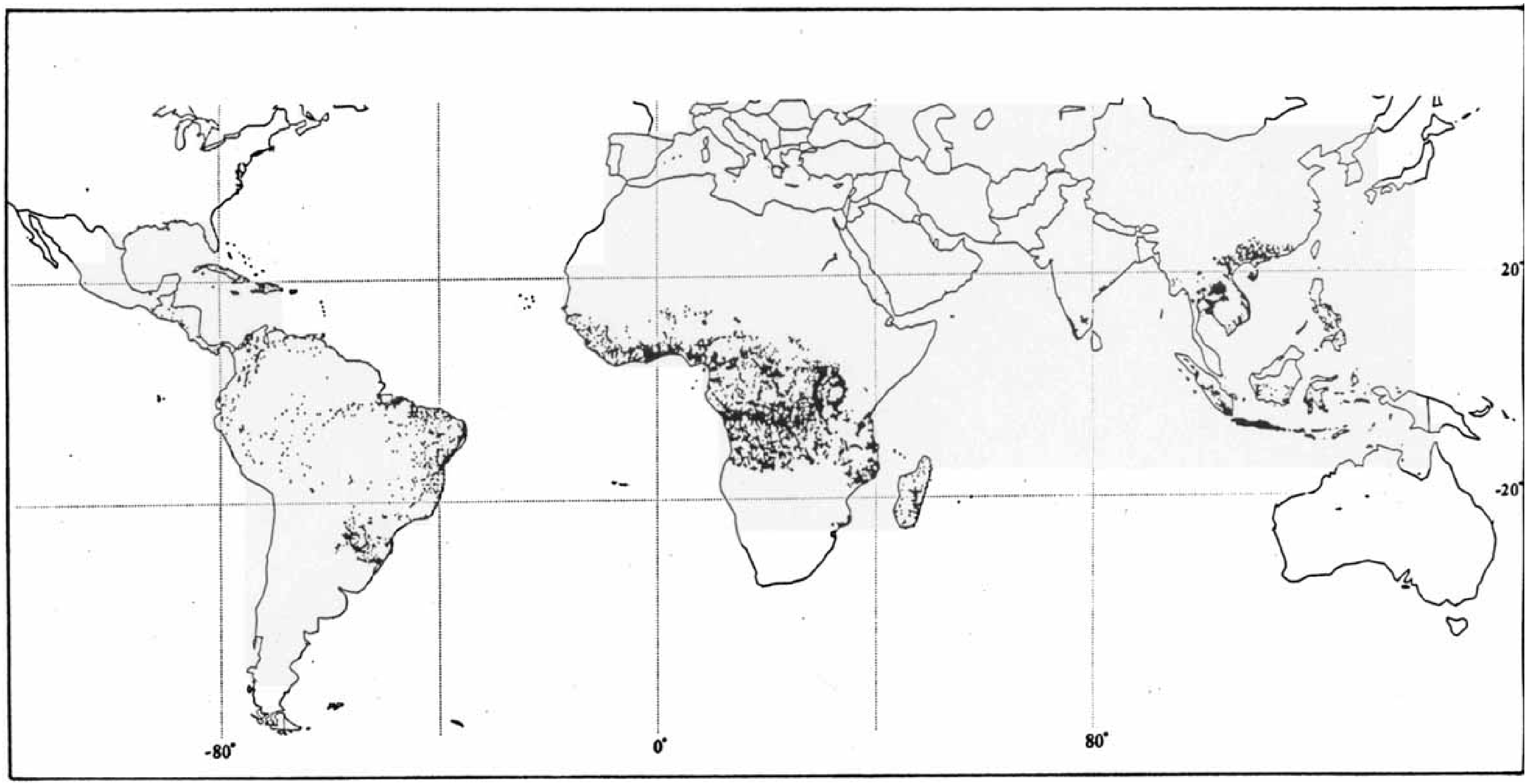


Figure 1. Distribution of cassava in the world. Each dot represents 1,000 ha.
Source: *Henry and Gottret, 1996.*

crop, while the crop is also exceptionally tolerant of high soil acidity and low levels of available phosporus (P).

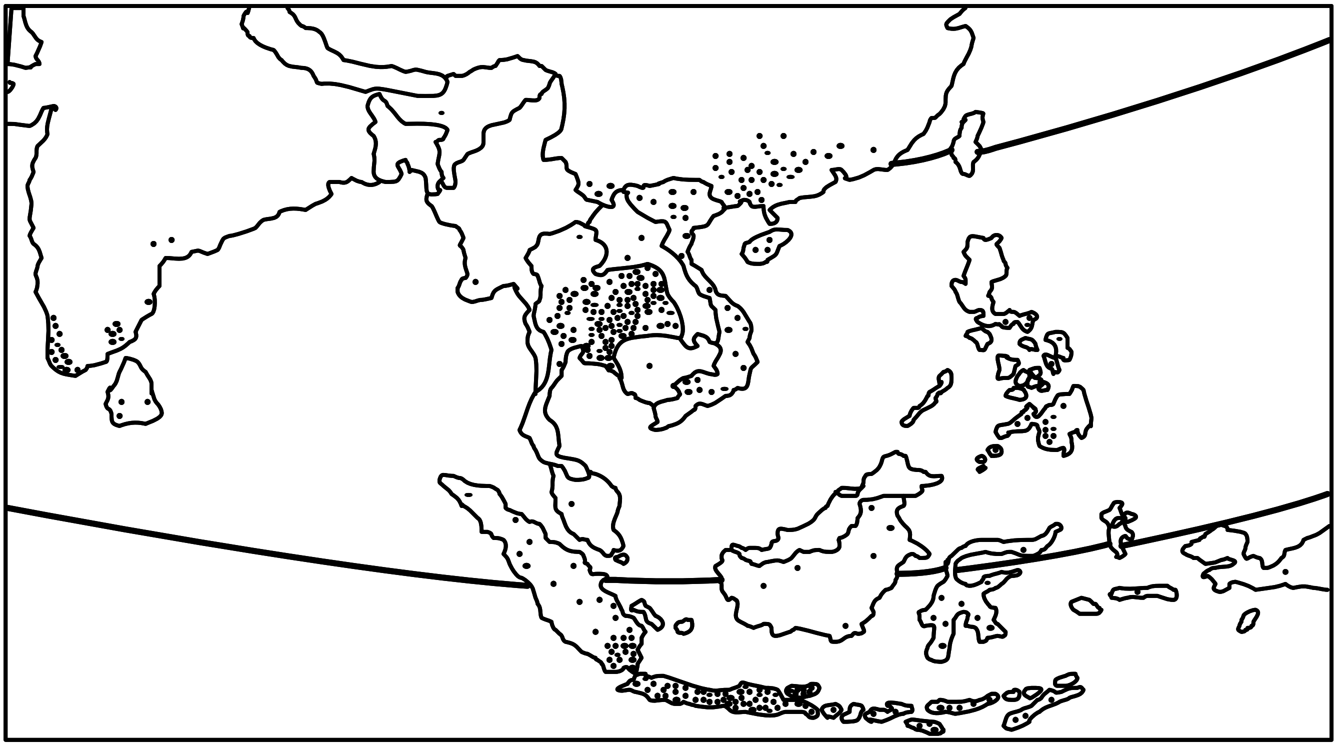


Figure 2. Cassava production zones in Asia in 1999. Each dot represents 10,000 ha of cassava.

Table 1. Cassava production, area, and yield in the world, the continents and in various countries in Asia in 2004.

	Production ('000 tonnes)	Area ('000 ha)	Yield (t/ha)
World	**203,618**	**18,475**	**11.02**
-Africa	108,470 (53%)	12,252	8.85
-LAC	34,727 (17%)	2,696	12.88
-Asia	60,245 (30%)	3,511	17.16
-Cambodia	362	23	16.09
-China	4,216	251	16.81
-India	6,700	240	27.92
-Indonesia	19,425	1,255	15.47
-Laos	56	8	6.81
-Malaysia	430	41	10.49
-Myanmar	139	12	11.30
-Philippines	1,640	206	7.97
-Sri Lanka	221	23	9.54
-Thailand	21,440	1,057	20.28
-Timor-Leste	42	10	4.15
-Vietnam	5,573	384	14.53

Source: *FAOSTAT, April 2006.*

Table 2. Annual growth rates (%) in cassava production, area and yield, by continent, 1976-2004.

	Production			Area			Yield		
	'76-85	'86-95	'96-04	'76-85	'86-95	'96-04	'76-85	'86-95	'96-04
Africa	2.6	4.1	2.7	1.3	2.2	2.0	1.3	1.9	0.7
Asia	**3.0**	**0.3**	**2.5**	**1.4**	**-0.9**	**-0.6**	**1.7**	**1.2**	**3.1**
Latin America	-1.2	0.0	3.7	-1.1	-0.3	1.9	-0.1	0.2	1.8

Source: *calculated from FAOSTAT, April, 2006.*

Thus, cassava can compete with other, more valuable, crops such as maize, soybean and vegetables mainly in areas of acid and low-fertility soils, and those with low or unpredictable rainfall, such as the northeast of Thailand, the central coast of Vietnam and in east Java.

Cassava production practices vary widely across the region (**Table 3**). The vast majority of farms in Asia are small, usually in the range of 0.5-5 ha. In areas where farms are relatively large, cassava competes mainly with tree crops such as rubber in Thailand, coconuts in the Philippines, oil palm and rubber in Malaysia and in the outer islands of Indonesia, and with cashew nut and rubber in south Vietnam. In Thailand cassava competes mainly with sugarcane in the northeast and with rubber and pineapple in the eastern part of the country.

Cassava in Asia is mainly planted in monoculture, but intercropping is common in many parts of Java where land holdings are extremely small and cropping is very intensive. Here, cassava is often planted at wide row spacing with 3-4 rows of upland rice between cassava rows, and with maize between cassava plants in the row. After the rice and maize harvest, short-season grain legumes such as soybean, mungbean or cowpea are planted between rows in the space previously occupied by rice. Thus, farmers may get four crops per year. In Tamil Nadu state of India, intercropping with vegetables is common, especially where both cassava and the intercrop can be irrigated. In China and Vietnam, maize, peanut, black beans, and various vegetables such as watermelon and pumpkin may be intercropped.

Cassava itself is also used as an intercrop during the establishment of young tree crops like rubber and cashew, especially in China and south Vietnam. Recently, both monocropped and intercropped cassava in China is often planted on plastic mulch, mainly to control weeds and warm the soil during the cool spring; this greatly enhances early growth and canopy closure and usually increases yields.

Production practices may be completely manual, partially mechanized, or animal-powered, especially for land preparation. Increasing daily wages and shortage of labor in Thailand and Malaysia have motivated farmers to mechanize their operations. Thus, in Thailand land preparation is usually done by hired tractor, weeding may be done by hand tractor, and in some areas harvesting is facilitated by the use of a tractor-mounted harvesting tool. In Malaysia both planting and harvesting may be mechanized. In most countries, weeding is still done by hand, but the use of herbicides is becoming more popular in Thailand, Malaysia, and south Vietnam. Fortunately, there are no economically important pests or diseases in Asia – with the exception of India – so there is no need for the use of pesticides. Fertilizers or organic manures are commonly used on cassava, but not necessarily in adequate amounts or in the right proportions of N, P and K. Usually, responses to organic manures can be greatly enhanced by additional application of chemical fertilizers high in N and K.

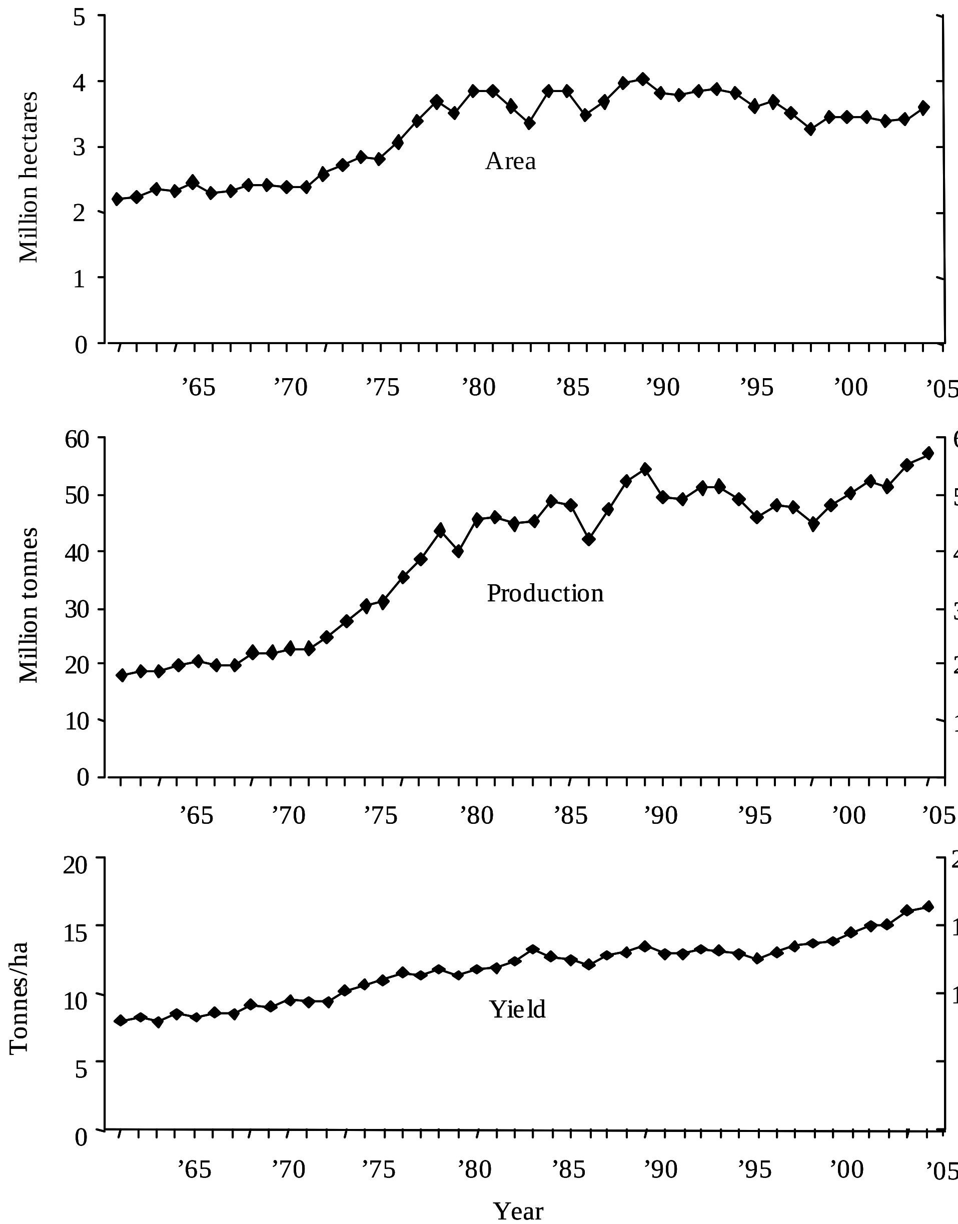


Figure 3. Total harvested area, production and yield of cassava in 12 cassava growing countries in Asia, 1961-2004.

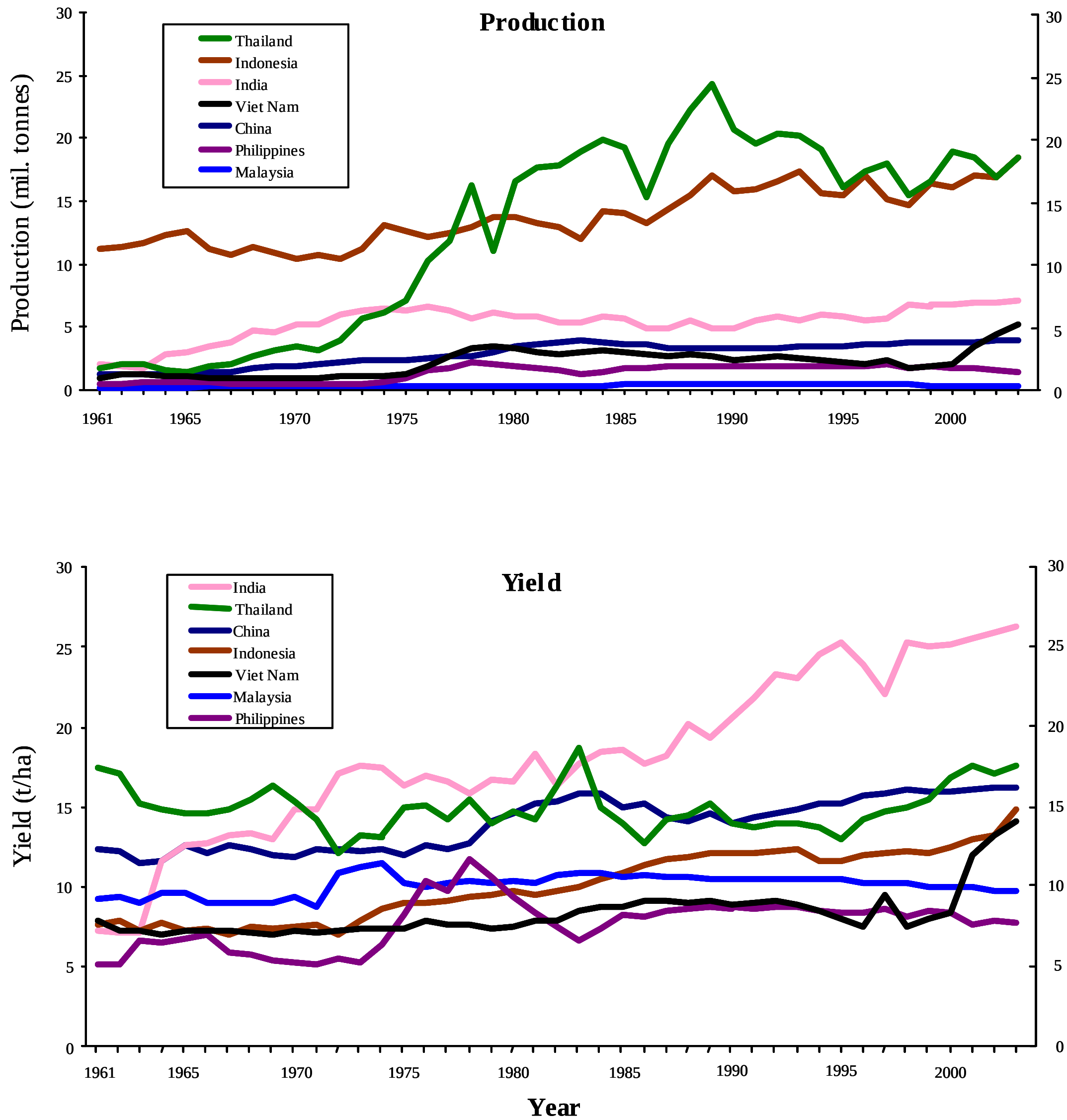


Figure 4. Cassava production and yield trends in Asia's principal cassava producing countries, 1961-2003
Source: *FAOSTAT, July 2004.*

Production costs vary significantly across the region (**Table 4**). Production costs for advanced farmers in Thailand are higher than in Indonesia and the Philippines, but lower than in Vietnam, China and India. When calculated per tonne of fresh roots, production costs in Thailand are slightly higher than in Indonesia or the Philippines, but much lower than in India and China. While yields of irrigated cassava in Tamil Nadu state of India are extremely high, the cost of production, especially for weeding, is equally high, resulting in relatively high production costs, even when calculated per tonne of roots produced. Nonetheless, on average, net income per hectare is quite high in India. **Table 5** shows that for the "average" Thai cassava farmer the cost of production per hectare is lower, but the cost of production per tonne is considerably higher due to the lower yields obtained as compared to "advanced farmers". It is clear that cassava products from Thailand can remain competitive only if farmers increase their yields through the use of improved varieties and better production practices. This became especially apparent in the early 1990s, when demand for cassava chips

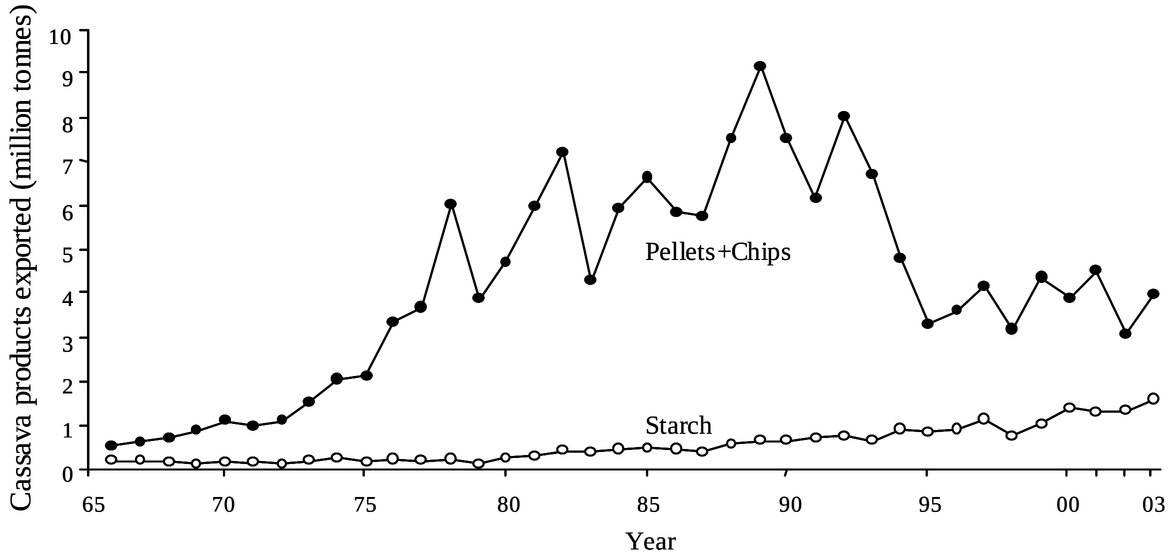


Figure 5. Quantities of cassava products exported from Thailand from 1996 to 2003.

***Source:** Adapted from TTTA, 2004,*

and pellets fell sharply (**Figure 5**).

3. Products and Markets

Both cassava roots and leaves (or young plant tops) have multiple end-uses, including direct human consumption of fresh roots and leaves (after boiling), on-farm animal feeding, commercial production of animal feed, production of starch or starch derivatives, and more recently, for ethanol to be used in liquor or as an automotive fuel. **Figure 6** shows the many different processes to turn fresh roots or green tops into a multitude of value-added products. **Figure 7** shows in more detail the various products made from cassava starch and dried chips, as well as from the peels and pulp, which are by-products from the starch industry.

Table 6 shows the quantity of cassava produced in each of 13 cassava producing countries in Asia in 2003, the amounts imported and exported and the amount of cassava available for domestic use; the table also shows the amounts (in fresh root equivalents) used for food, feed and other, mainly industrial, purposes. It is clear that Thailand is the only major exporting country, while China is a major importer, importing about 75% of its domestic requirement. In Indonesia cassava is mainly used for human food, either after drying or after processing into starch or other food products. But in India, Philippines, Cambodia and East Timor, the proportion of root production destined for human food is actually higher than in Indonesia (**Table 7**). In Vietnam and China, large amounts of cassava are used for animal feeding, either on-farm or as an ingredient in commercial animal feed. In Thailand, a major proportion is used for human food, mainly in the form of starch or MSG, while nearly 67% is destined for other uses or is waste. Probably the residue from the starch industry is a major component of these unclassified uses. Part of this residue is dried and incorporated into pellets for export, and part is used domestically as an animal feed, for the production of compost or for growing mushrooms.

a. Fresh roots for human consumption

In Kerala state of India, as well as in the Philippines, Cambodia, Laos and East Timor, fresh cassava roots are consumed directly after boiling or roasting. In most other parts of Asia cassava is not consumed as fresh roots, but only after some form of processing.

b. Flour for human consumption

The simplest and most common form of processing, used widely in Indonesia, is to peel the roots, wash and slice and then sun-dry for 2-3 days to produce dry cassava chips or chunks, in Indonesia known as *gaplek. Gaplek* can be stored and is traded in village markets. When needed, the dry root pieces are pounded into a flour, which is shaken on a bamboo screen with some water to produce granules, called *tiwul.* The size and shape of these granules is similar to rice grains and the *tiwul* is often cooked together with rice to extend the family's limited supply of rice. Presently, small processing plants in Indonesia buy fresh roots to be processed directly into various flour mixes (supplemented with vitamins and flavors) as well as semi-cooked *instant tiwul*. These are mainly destined for urban consumers.

c. Chips and pellets for animal feed.

Up until very recently, cassava chips and pellets were the mainstay of the Thai "tapioca" trade, mainly for export to Europe (**Figure 5**). Fresh cassava roots are taken in small trucks from the field to the "chipping yard". These chipping and drying yards consists of a concrete floor, varying in size from about 0.5 ha to as large as 30 ha; they are scattered all through the cassava growing regions. Using a tractor-mounted front loader, cassava roots are piled up and loaded into large electric or diesel-powered chipping machines. The chipped roots are then spread evenly over the concrete floor and left there for 2-3 days of sun drying. The chips are turned regularly using a rake mounted under a tractor or motor vehicle. When dry (about 14-15% moisture content) the chips are gathered by a tractor with blade and pushed into piles. These dried chips are then taken by truck to the pelleting factories, where the chips are ground up into meal, mixed with a little palm oil and steam and then extruded through a die in the pelleting machine. After cooling, the resulting product consists of small hard sticks, about 2 cm long and 0.5 cm in diameter. These compressed pellets are ideal for long-distance transport, even as far away as Europe. Pelleting reduces the volume (saving transport costs) and the dust, as compared to dried chips. Normally, one tonne of fresh roots produces 450 kg of chips or 440 kg of hard pellets (**Table 8**).

In 2005, Thailand exported less than 0.3 million tonnes of cassava pellets to Europe, down from 6.0 million tonnes in 1989, but unlike in 1989 it exported considerable quantities of dry chips, about 2.8 million tonnes, to China, where it is used for production of commercial animal feed, and alcohol.

Table 3. Characteristics of cassava production and utilization in Asian countries.

	China	India	Indonesia	Malaysia	Philippines	Thailand	Vietnam
Cassava production('000 t) 2004	4,216	6,700	19,425	430	1,640	21,440	5,573
Cassava harvested area ('000 ha)	250	240	1,255	41	206	1,057	384
Cassava yield (t/ha)	16.8	27.9	15.5	10.5	8.0	20.3	14.5
Utilization -main	Starch -domestic	Human consumption	Human consumption	Starch -domestic	Human consumption	Animal feed (50%) -exp. (90)/dom. (10)	On-farm pig feed
-secondary	On-farm pig feed	Starch -domestic	Starch -dom./export		Starch -domestic	Starch (50%) -exp. (60)/dom. (40)	Starch -export/dom.
Farm size (ha/farm)	0.5-1.0	0.4-0.6	0.4-1.0	2-3	3-4	4-5	0.6-0.8
Cassava area (ha/farm)	0.2-0.4	0.3-0.4	0.3-0.5	-4	-	2-3	0.25-0.30
Crop. system (%) -monocrop	40	70	40	99	60	95	65
-intercrop	60	30	60	1	40	5	35
Time of planting	March	Apr/Sept	Oct/Nov	year round	May-Aug	Apr-May Oct-Nov	Feb-May
Land preparation	manual/oxen	manual/oxen	oxen/manual	tractor	oxen	tractor	oxen/manual
Planting position	horizontal	vertical	vertical	horizontal	horizontal	vertical	horizontal
Weed control	manual/ herbicides	manual/gorru	manual/ herbicides	herbicides/ manual	manual/ oxen	manual/mech./ herbicides	manual
Fertilization -organic	some	some	some	none	some	some	some
-chemical	low	rel. high[1)]	rel. low (N only)	high	low	low-medium	low
Labor cost (US$/day)	1-2	2-3	1-2	4-5	2-3	3-4	1-2
Production costs (US$/ha)	500-550	900	300-350	390-520	350-400	400-450	350-456

[1)] in irrigated areas

Source: ***Adapted from Howeler, 2000.***

Table 4. Cassava production costs (US $ /ha) and profitability in various countries in Asia in 1998-2000.

	China[1)]	India[2)]	Indonesia[3)]	Philippines[4)]	Thailand[5)]	Vietnam[6)]
Labor Costs ($/ha)	***167.40***	***421.70***	***185.37***	***218.80***	***167.18***	***213.60***
Labor costs ($/manday)	1.86	1.29	1.11	2.00	3.24	1.78
-land preparation (mandays/ha)	*7.5*	*1.5*	*45*	*8.1*	*2.4*	*5*
-preparation planting material	-	*1.9*	*5*	-	-	*5*
-planting	*15.0*	*14.8*	*15*	*9.4*	*9.1*	*10*
-application fert. and manures	*5.0*	*10.7*	*12*	*2.5*	*6.4*	*5*
-application other chemicals	-	*0.3*	-	-	-	-
-irrigation	-	*51.9*	-	-	-	-
-weeding and hilling up	*40.0*	*208.6*	*40*	*26.9*	*8.0*	*40*
-harvesting (includes loading)	*22.5*	*37.2*	*50*	*37.5*	*25.7*	*55*
-transport and handling	-	-	-	*25.0*	-	-
Total (mandays/ha)	*90.0*	*326.9*	*167*	*109.4*	*51.6*	*120*
Other Costs ($/ha)	***260.22***	***242.15***	***80.55***	***163.25***	***198.73***	***171.07***
-Fertilizers and manures	130.11	159.39	79.44	53.75	61.97	80.36
-Planting material	-	26.83	1.11	25.00	-	-
-Other materials (herbicides, sacks)	37.17	2.23	-	20.00	25.84	-
-Transport of roots	-	-	-	-	70.38	-
-Land preparation by tractor	92.94	53.70	-	64.50	40.54	90.71
Total Variable Costs ($/ha)	**427.62**	**663.85**	**265.92**	**382.05**	**365.91**	**384.67**
-Land rent and/or taxes	94.94	236.50	46.67	-	48.89	60.00
Total Production Costs ($/ha)	**520.56**	**900.35**	**312.59**	**382.05**	**414.80**	**444.67**
Yield (t/ha)	20	40	20	25	23.40	25
Root price ($/t fresh roots)	29.74	38.00	17.78	25.00	21.62	21.42
Gross income ($/ha)	294.80	1,520.00	355.60	625.00	505.91	535.50
Net income ($/ha)	74.24	619.65	43.01	242.95	91.11	90.83
Production costs ($/t fresh roots)	26.03	22.51	15.63	15.28	17.73	17.79

Sources: [1)]Tian Yinong for Guangxi, China
[2)]Srinivas, 2001; for irrigated cassava in Tamil Nadu, India
[3)]J. Wargiono for monoculture cassava in Lampung, Indonesia
[4)]Bacusmo, 2001; for monoculture cassava in the Philippines
[5)]Adapted from TTDI, 2000; average of 527 advanced farmers in Thailand
[6)]Farmers estimate for monoculture cassava in Dongnai province of Vietnam

Table 9 shows that the export of dry cassava products is still dominated by Thailand, but that Vietnam is also exporting increasing quantities of dry chips and starch, mainly to China. China presently imports about 60% of chips from Thailand and 11% from Vietnam, while it imports 40-50% of starch from Thailand and 20-30% from Vietnam (TTTA, 2004).

Table 5. Cassava production costs (US $/ha) in Thailand in 1999/2000.

	Average all farmers[1)]	Average advanced farmers[2)]
1. Labor costs ($/ha)	***168.48***	***167.18***
-Labor costs ($ /manday)	3.24	3.24
-land preparation (mandays/ha)	*1.6*	*2.4*
-planting	*9.1*	*9.1*
-fertilizer application	*6.1*	*6.4*
-weeding	*14.0*	*8.0*
-harvesting	*19.4*	*25.7*
-loading	*1.8*	-
Total (mandays/ha)	*52.0*	*51.6*
Other costs ($/ha)	***125.68***	***198.73***
-Fertilizers and manures	20.23	61.97
-Planting materials	26.66	-
-Herbicides and pesticide	8.57	25.84
-Fuel and lubricants	2.15	-
-Inplements and others	3.64	-
-Land preparation by tractor	40.50	40.54
-Transport of harvest	-	70.38
-Interest and opportunity costs	23.93	-
Total Variable Costs ($/ha)	**294.16**	**365.91**
Land rent and taxes	44.15	48.89
Depreciation of machinery	3.39	-
Total Production Costs ($/ha)	**341.70**	**414.80**
Yield (t/ha)	16.52	23.40
Root price ($/t fresh roots)	21.62	21.62
Gross income ($/ha)	357.16	505.91
Net income ($/ha)	15.46	91.11
Production costs ($/t fresh roots)	20.68	17.73

1US $ = 37 baht in 1999/2000.; cost of labor 120 baht/day
Sources: [1)] *Office of Agric. Economics (OAE), 2001.*
[2)]*Adapted from TTDI, 2000.*

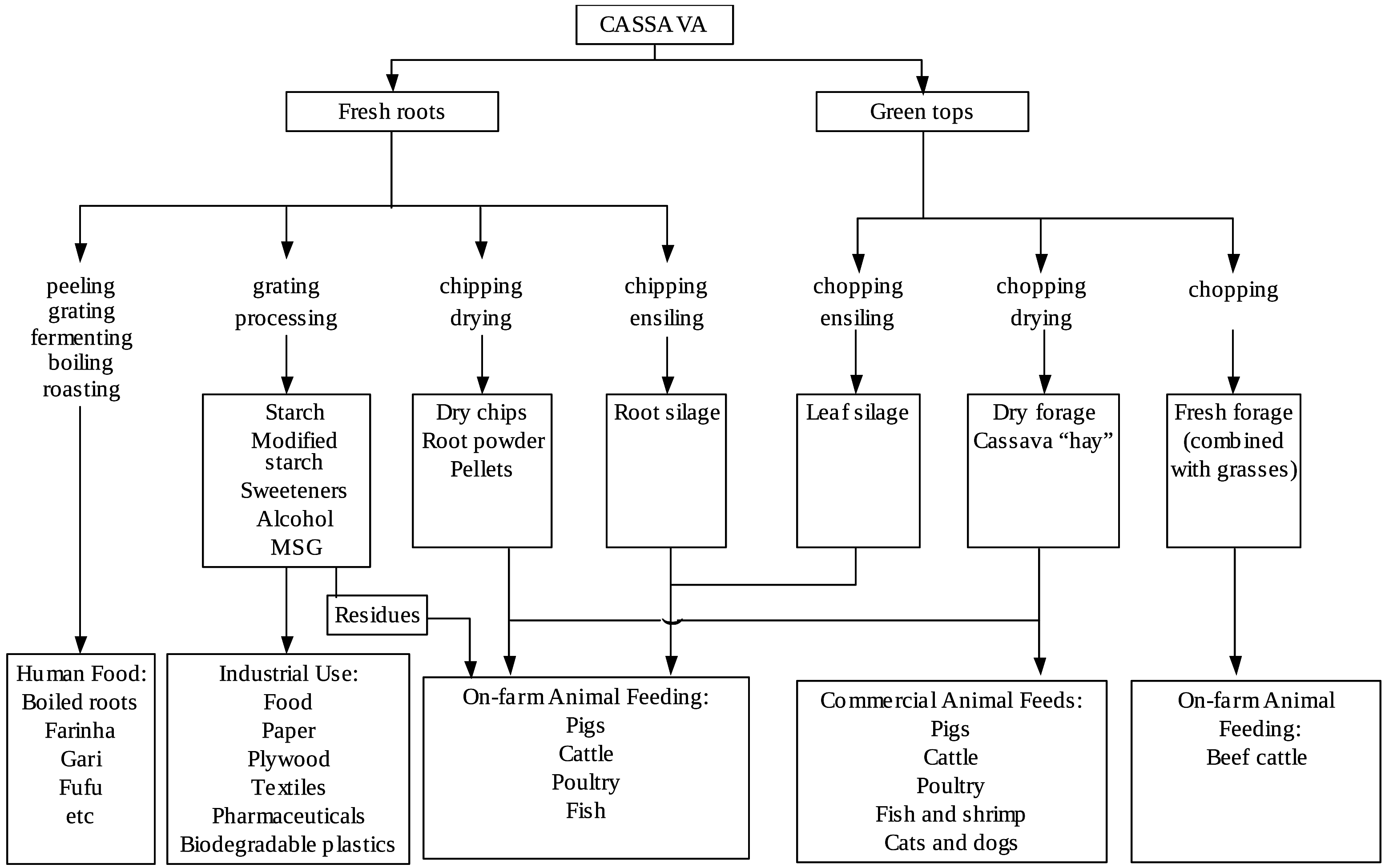


Figure 6. Pathways of processing cassava fresh roots or green tops into a multitude of products used for human or animal consumption or for industrial purposes.

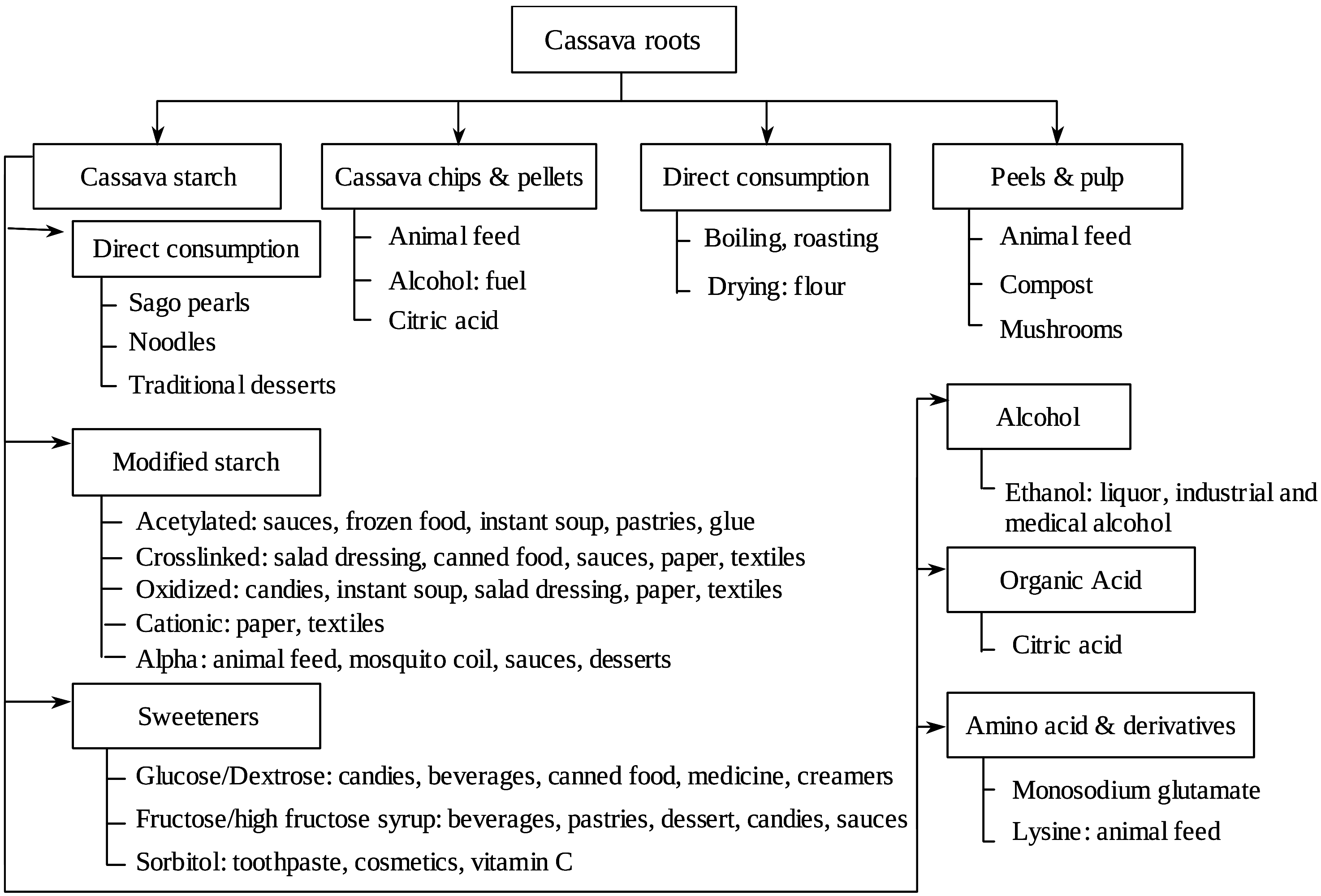


Figure 7. Cassava root processing into value-added products
Source: *Adapted from TTFITA, 2000.*

Table 6. Production, supply and domestic utilization of cassava in 13 cassava producing countries in Asia in 2003. Data are in fresh root equivalent.

Region/country	Domestic supply ('000 t)				Domestic utilization ('000 t)			
	Production	Import	Export	Domestic uses	Food	Feed	Other uses	Waste
Asia	**55,844**	**14,469**	**16,911**	**51,179**	**25,291**	**12,085**	**9,786**	**4,018**
-Indonesia	18,524	950	131	19,343	13,189	370	3,484	2,300
-Thailand	18,430	0	14,466	1,578	652	3	2	922
-India	7,000	19	5	7,015	6,665	-	-	350
-Vietnam	5,228	-	1,806	3,422	397	2,764	-	261
-China	4,015	11,498	485	15,191	1,889	8,798	4,381	124
-Philippines	1,622	125	5	1,743	1,557	65	120	-
-Malaysia	400	379	5	775	363	20	371	20
-Sri Lanka	229	25	6	248	161	57	18	12
-Cambodia	138	1	-	139	132	-	-	7
-Myanmar	130	1	-	131	118	-	-	13
-Laos	83	11	-	94	78	8	-	8
-East Timor	42	-	-	42	40	-	-	1
-Bangladesh	-	105	-	105	26	-	78	-

[1)]much of the "waste"(peels, solid residue from starch extraction etc.) is used for industrial purposes or animal feed

Source: *FAOSTAT, Food Balance Sheet, April 2006.*

Table 7. Total domestic supply (in fresh root equivalent, '000 t) and utilization (%) of cassava, as well as the per capita supply as food and its contribution to the daily diet in 13 cassava producing countries in Asia in 2003.

Region/country	Population (mil. people)	Total supply ('000 t)	Domestic utilization (%)				Per capita supply			
			Food	Feed	Other uses	Waste	Fresh eq. (kg/yr)	Calories (no/day)	Protein (g/day)	Fat (g/day)
Asia	**3,823**	**51,179**	**49.4**	**23.6**	**19.1**	**7.9**	**6.6**	**17.8**	**0.1**	**0.0**
-Indonesia	220	19,343	68.2	1.9	18.0	11.9	60.0	168.0	0.7	0.3
-Thailand	63	1,578	41.3	1.9	0.1	-	10.4	31.0	0.3	0.1
-India	1,065	7,015	95.0	-	-	5.0	6.3	14.2	0.1	0.0
-Vietnam	81	3,422	11.6	80.7	-	7.6	4.9	13.5	0.1	0.0
-China	1,311	15,191	12.5	57.9	28.8	0.8	1.4	4.3	0.0	0.0
-Philippines	80	1,743	89.3	3.7	6.9	-	19.5	53.8	0.4	0.2
-Malaysia	24	775	46.8	2.6	47.9	2.6	14.9	40.5	0.3	0.1
-Sri Lanka	12	248	64.9	23.0	7.3	4.8	8.5	36	0.2	0.0
-Cambodia	14	139	95.0	-	-	5.0	9.3	25.8	0.2	0.1
-Myanmar	27	131	90.0	-	-	10.0	2.4	7.0	0.0	0.0
-Laos	6	94	83.0	8.5	-	8.5	13.7	37.6	0.2	0.1
-East Timor	<1	42	95.2	-	-	2.3	51.8	126.9	0.5	0.2
-Bangladesh	66	105	24.8	-	74.3	-	0.2	0.0	0.0	0.0

Source: *FAOSTAT, Food Balance Sheet, April 2006.*

Table 8. Conversion factors for cassava-based products.

1 tonne of fresh cassava roots (38% DM) produces:
- 450 kg of dry chips (85% DM)
- 440 kg of hard pellets
- 250-300 kg of native starch
- 160-200 l of ethanol[1)]

1 tonne of dry cassava chips (85% DM) produces:
- 665 kg of native starch
- 665 kg of modified starch
- 665 kg of liquid glucose
- 770 kg of sorbitol 70%
- 770 kg of maltol 70%
- 500 kg of crystal sorbitol
- 500 kg of mannitol
- 350-420 l of ethanol[1)]

1 tonne of native cassava starch produces:
- 1,111 kg of sago
- 1,087 kg of glucose syrup
- 770 kg of glucose
- 665-1000 kg of maltose
- 833 kg of sorbitol
- 417 kg of MSG

[1)] 1 tonne of maize produces 350-400 l of ethanol
1 tonne of sugarcane produces 70 l of ethanol
1 tonne of molasses produces 250-300 l of ethanol

Table 9a. Total world trade in cassava products in 2004.

	Exports ('000 t)					
	Fresh root equivalent	Dry products ('000 t)				
		Starch	Tapioca pearl	Chips+ pellets	Flour	**Total**
World	23,895`	1,376	88	6,467	81	**8,012**
-USA	6	1	-	0	-	**1**
-EU(15)	959	6	0	365	3	**374**
-Asia	**22,551**	**1,346**	**86**	**6,006**	**76**	**7,514**
-China	75	3	12	0	-	**15**
-India	6	0	1	0	0	**1**
-Indonesia	1,659	185	29	234	0	**448**
-Japan	1	0	0	0	-	**0**
-Korea (ROK)	1	0	0	0	-	**0**
-Philippines	2	0	0	1	0	**1**

-Thailand	18,259	1,040	27	5,019	76	**6,162**
-Vietnam	1,874	-	-	750	0	**750**

Table 9b. Total world trade in cassava products in 2004.

	Imports ('000 t)					
	Fresh root equivalent	Dry products ('000 t)				
		Starch	Tapioca pearl	Chips+ pellets	Flour	**Total**
World	26,168	1,825	57	6,672	15	**8,569**
-USA	293	21	9	58	0	**88**
-EU(15)	6,701	33	5	2,602	1	**2,641**
-Asia	**18,330**	**1,621**	**40**	**3,995**	**7**	**5,663**
-China	14,142	1,088	4	3,473	0	**4,565**
-India	19	0	4	0	0	**4**
-Indonesia	286	56	1	2	0	**59**
-Japan	741	130	2	30	1	**163**
-Korea (ROK)	1,204	10	0	460	0	**470**
-Philippines	268	46	1	12	0	**59**
-Thailand	4	0	0	0	1	**1**
-Vietnam	-	-	-	-	-	**-**

Source: *FAOSTAT, April 2006.*

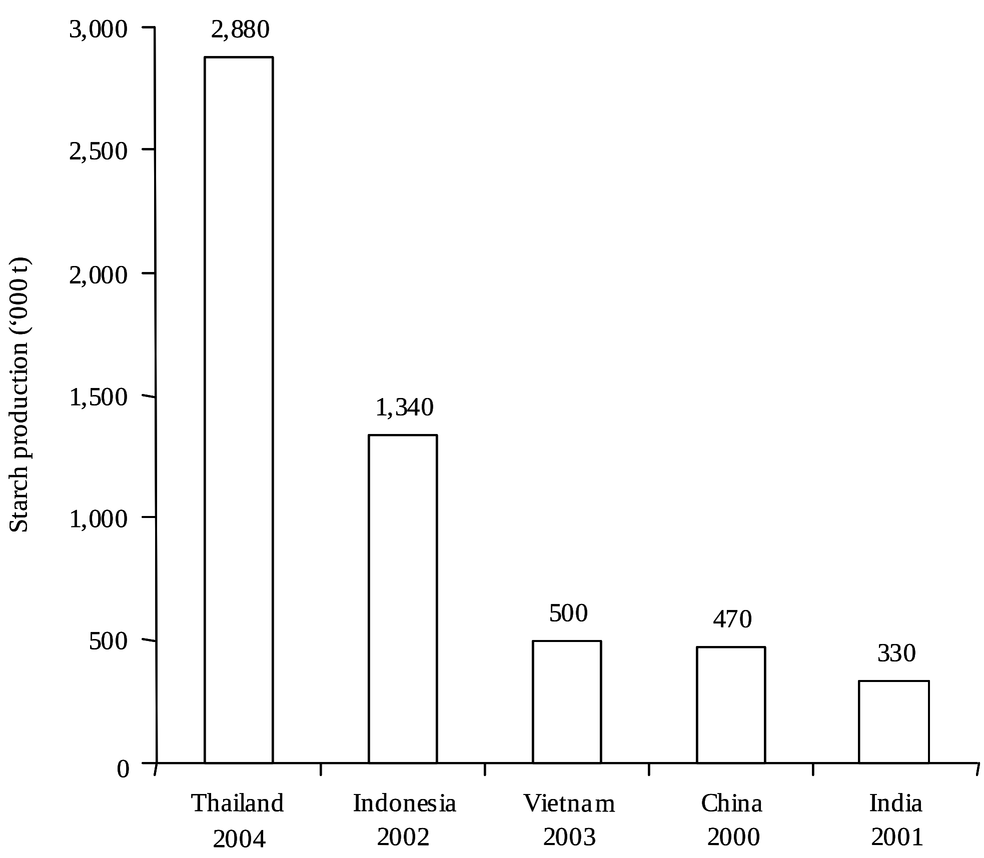
d. Starch for food and industry

Cassava starch can be divided into *native starch* and *modified starch*. The production of native starch is a relatively simple process, that can be done at many scales, either at the household level, such as in some villages in north Vietnam, Cambodia and on Java island of Indonesia, up to very large and fully-mechanized starch factories, such as those in Thailand, south Vietnam and in Lampung province of Indonesia. Sometimes the small-scale processors produce only wet starch, while the larger factories may buy the wet starch for further processing into high quality dry starch. Starch factories usually prefer to process fresh roots, but whenever the harvesting season is concentrated into only a few months of the year, the starch factory can also process dry chips or wet starch. In general, the process is less efficient and the quality of the resulting starch is lower than when fresh roots are processed into starch. One tonne of fresh roots usually results in 250-300 kg of starch (**Table 8)**.

The technology for modifying starches involves physical, chemical or micro-biological processes; these technologies are highly advanced and evolving rapidly. Thus, the intrinsic characteristic of the native starch, which depends on the source of the starch (mainly maize, potato, wheat or cassava), can be changed to correspond with specific needs for a particular usage (**Figure 7**). Still, to reduce costs or to reduce concern for chemical contamination in foods, some companies would prefer to use native starch from a particular source if the characteristics of that starch correspond to its particular requirements. Thus, there is room for native cassava starch to enter specific niche markets based on its intrinsic starch characteristics. A good example is the production of *krupuk* in Indonesia which requires characteristics specific to cassava starch, while maize starch would be unsuitable. Also, for sensitive foods like baby food, consumers may prefer "natural" starches over chemically modified starches. In the future, many of these specific characteristics required for particular uses may be incorporated into the plant itself through breeding or bio-engineering, thus eliminating the need for post-harvest modification. But, at the present there is an increasing demand for modified starch used in various industrial processes and foods (**Figure 7**).

Besides its use for production of modified starch, native starch can also be used for production of sweeteners, such as glucose, dextrose, high fructose syrups and sorbitol, which all have a wide range of applications (Jin Shuren, 1992, 2000, 2001; Dang Thanh Ha *et al*., 1996), as well as for production of alcohol, organic acids, amino-acids and MSG (**Figure 7**).

Figure 8 shows the comparative size of the cassava starch industry in each country. Thailand and Indonesia are the principal producers of cassava starch. Recently, the cassava starch industry in Thailand has expanded very rapidly (**Figure 5**), and total production in 2004 was approximately 2.9 million tonnes consuming about 47% of the total (estimated) production of 22.7 million tonnes of cassava roots (TTTA, 2005 and **Figure 9**). In Indonesia the cassava starch industry suffered significant losses due to the 1997 economic crisis, but has now completely rebounded; starch production increased at an annual rate of 5.5% since 1998, with a total production of 1.34 million tonnes in 2002 (PT Corinthian, 2004. Practically all cassava starch produced in Indonesia is for the domestic market, of which two-thirds is used for production of "*krupuk*". In India, most cassava starch is produced in Tamil Nadu (about 90%) and Andhra Pradesh (10%) with a total annual production of cassava starch and tapioca pearls (or sago) of 330,000 tonnes (Edison, 2001). In China, cassava starch production is about 470,000 t/year (Tian Yinong, 2001), while in Vietnam it is increasing rapidly and for 2003 it was estimated at about 500,000 tonnes, of which 70% was exported (mainly to China, Taiwan and Korea) and 30% used domestically (Hoang Kim, personal communication).



In China the total annual consumption of starch and derived products in 1998 was about 4.03 million tonnes, of which 3.32 million tonnes (82.3%) was maize starch, 470,000 tonnes (11.7%) cassava starch, 96,000 tonnes (2.4%) each of sweet potato and wheat starch and 48,000 tonnes (1.2%) potato starch (Tian Yinong, 2001). In 2005, China imported about 2.7 million tonnes of cassava chips and pellets and 262,000 tonnes of starch from Thailand. Most of the chips and pellets are used for production of alcohol and animal feed, respectively, while the starch is used mainly for production of sweeteners and MSG. It is estimated that China imported at least 360,000 tonnes of cassava chips and 80,000 tonnes of starch from Vietnam.

e. Modified starch

As indicated in **Figure 10**, native starch can be modified by either physical, chemical or enzymatic processes, producing different forms of “modified” starch with distinctly different properties and different uses. Modified starches are used in many different types of foods as well as in industry, mainly for production of high quality paper, for textile sizing and some animal feeds (**Figure 7**). One of the main users of modified starch is the paper industry. Tupper (2000) predicted in 1996 that of the 80 new paper machines to be installed in the world, 65 would be in Asia, as the paper industry in SE Asia was growing at a rate of 14%, versus 2% in the US and 6% in Japan and Korea. Since each tonne of paper requires 55 kg of starch, he predicted an additional annual starch requirement of 480,000 tonnes for the new paper machines in Asia. Cationic starches made from cassava starch are particularly suitable for the sizing and coating of paper in high-speed paper making machines (Jin Shuren, 2001). Other main users of modified starch are in the food industry, textiles, in agriculture and in animal feed, while smaller amounts are used in construction materials, in casting, oil drilling and medicines. **Table 10** and **Figures 7** and **10** describe the various types of modified starch, the production processes and their application.

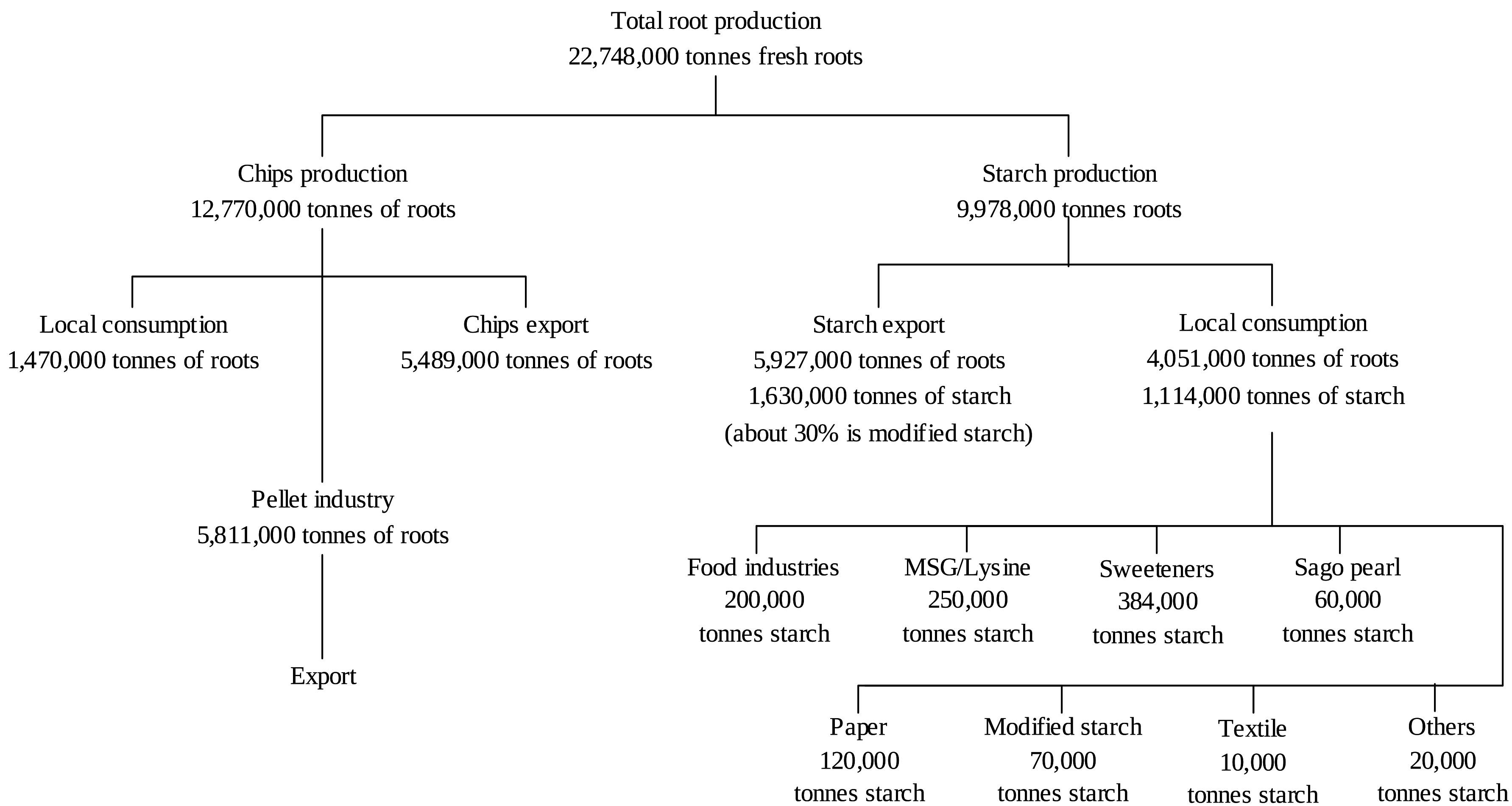


Figure 9. Approximate distribution of cassava roots for industrial procesing in Thailand in 2003/04 (Oct to Sept).
***Source:** based on data from TTTA, 2004.*

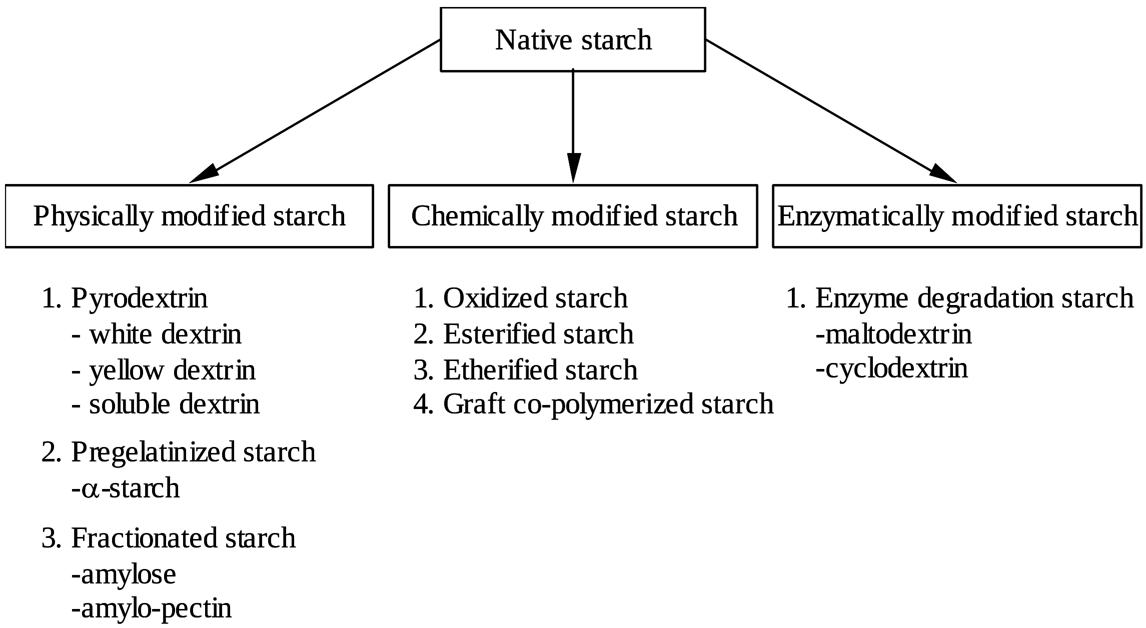


Figure 10. Modified starch processing technologies and products.
Source: *Jin Shuren, 2001.*

Table 10. Principal modified starch products in China, their production process and application.

Product	Production process	Application
Yellow dextrin	Heat for roasting	Casting, construction materials
White dextrin	Heat for roasting	Binding agent in medicines
Pregelatinized starch	Dried and milled by drum	Feed, casting, construction materials
Oxidized starch	Oxidized by oxidizing agent	Binding agent for cardboard, textile, food
Acid-hydrolyzed starch	Hydrolyzed by acid	Food, sizing for textile, paper making
Starch acetate	Esterification by acetic acid	Paper making, textile casting, food, snack food
Cationic starch	Etherification by trimethyl amine	Paper pulp additive coating
Complex modified starch		Paper pulp additive coating
Carboxymethyl starch	Etherification by chloroacetic acid	Lubricant for oil drilling medicine, construction materials
Hydroxy-propyl starch		Food,candy
Cross-linked starch		Food, medicine, textile, chemical industry
Graft co-polymerized starch	Graft co-polymerized by acrylo-nitrile	High water-absorbent materials, such as disposable diapers, female napkins, textile sizing material

Source: *Jin Shuren, 2001.*

f. Starch-based sweeteners

Cassava starch can be used for the production of many types of sweeteners after hydrolyzation by either acids or enzymes, or both. These sweeteners include maltose, glucose syrup, glucose and fructose, which can be further processed into various oligo-saccharides (Jin Shuren, 2001).

g. Hydrogenated sweeteners

These include sorbitol, mannitol and maltol. They are produced by treating starch with hydrogen gas in high-pressure tanks, using a special catalyst and ion-exchange resins. Sorbitol is used mainly for the production of vitamin C and as a moisture conditioner in toothpastes (Jin Shuren, 2000).

h. Ethanol

In some countries cassava is used for the production of ethanol. In the late 1970s several alcohol distilling factories were set up in Brazil using fresh cassava roots as raw material. The alcohol was used as automotive fuel, either mixed with gasoline (up to 20% ethanol) for which no motor modification is required, or as pure anhydrous ethanol, in which case the carburator and some other parts need to be modified (de Souza Lima, 1980). Both result in less atmospheric pollution than the use of 100% gasoline. By the late 1980s, however, nearly all cassava-based distilleries in Brazil were converted over to using sugarcane as the raw material, since sugarcane bagasse could be used as fuel, thus saving on energy costs in the distillation process. Moreover, in Brazil cassava suffers from serious disease and pest problems, resulting in low yields and high production costs.

In China, several factories in Guangxi are now using the solid waste (pulp) of the cassava starch industry for the production of ethanol (Gu Bi and Ye Gozhen, 2000). Other alcohol factories in China are switching from the use of molasses to that of cassava chips for alcohol production, because of ever stricter pollution control requirements that makes the use of molasses uneconomical. In addition, it is expected that the Chinese government will support the use of "gasohol" (about 10-20% ethanol mixed with gasoline) as automotive fuel by 2008; this is expected to markedly increase demand for cassava chips, as this is the cheapest raw material. Similarly, in the Philippines cassava chips are now considered an economic alternative to the traditional use of locally produced molasses for production of alcohol. Current plans are to use annually about 180,000 tonnes of dry cassava chips.

In Thailand "gasohol", containing 10% ethanol, is presently available in nearly all gas stations and this has become the most popular fuel because of its lower price. The ethanol is still made mostly made from sugarcane, but one factory in Khon Kaen is now producing ethanol from cassava. According to an intensive study by Kasetsart University (Kuakoon Piyachomkwan *et al*., 2002) dry cassava chips would be the cheapest and most convenient raw material for large-scale production of ethanol for automotive fuel in Thailand.

i. Degradable plastics

Various types of starches are being used for the production of bio- or photo-degradable plastics, either by mixing starch or modified starch with polyvinyl hydrocarbons, or by polymerization of starch, which is then blended with various other polymers (Klanarong Sriroth *et al*., 2001). Intensive research on the use of cassava starch for these processes is being conducted by Kasetsart University in Thailand.

j. Organic acids

Organic acids made from cassava starch include citric acid, acetic acid, lactic acid and itaconic acid, which are used in the food industry as well as for the production of plastics, synthetic resins, rubber products etc. Lactic acid is produced by the fermentation of starch with *Lactobacillus amylovorus* (Wang Xiaodong *et al*., 2000).

k. Monosodium glutamate (MSG) and Lysine

MSG is a well-known flavor-enhancing agent used in many Asian kitchens. It is made through the microbial fermentation of starch or sugar (molasses) in the presence of ammonium salts. Cassava starch is first hydrolyzed using α-amilase enzyme to form glucose, which is then fermented for several days in the presence of *Micrococcus glutamicus* or *Brevibacterium* spp. in the presence of urea. Finally the glutamic acid is transformed into crystalline mono-sodium glutamate by addition of a sodium salt (Maneepun, 1996). In Thailand, MSG production is the main consumer of native cassava starch (**Figure 9**). Lysine is an important amino-acid used as a supplement in animal feed, especially for pigs.

FUTURE POTENTIAL

Cassava-based products can only be competitive in the world market if the cost of processing and the cost of the raw materials is lower than those of competing crops. The competitiveness also depends on government policies, on import duties, tariffs and other trade barriers. Thus, during the 1970s and 80s the Thai tapioca export industry benefited from relatively low import duties into the European markets as well as artificially high prices of domestic coarse grains; but those policies changed in the late 80s. With ever increasing trade liberalization, products will more and more have to compete on the basis of price and quality characteristics.

After the near-collapse of the cassava export market to Europe, the Thai cassava sector quickly changed directions, moving more and more from animal feed to cassava starch production, identifying new markets for chips and pellets, mainly in Asia, and by increasing the efficiency of cassava production and processing, in order to maintain a competitive edge over other energy sources. Other countries in Asia are moving in a similar direction, but producing a wide range of diverse products depending on local conditions and constraints (**Table 11**).

1. Food

Table 12 shows the relative potential for growth of various cassava-based products in the seven major cassava producing countries in Asia. Fresh cassava for human consumption does not have major growth potential as rice remains the preferred food in the region. Total food demand may increase due to increases in population, but as Asian societies become more affluent, they are likely to reduce their consumption of high-energy staples like rice and cassava in preference for meat products or convenience foods. Moreover, in Asia, as in other parts of the developing world, there is an unrelenting trend for rural populations to move to the cities in search of jobs, greater opportunities, and better health and educational services. In some Asian countries, like the Philippines and Malaysia, already more than 50% of the population is urban, while in most others the rural population ranges from 60-80%. It is expected that after 2020 more than 50% of the population in Asia will be urban rather than rural. This will have profound effects on food consumption patterns as urban populations have to buy all their food, and they prefer clean, attractively packaged and convenient foods. For that reason, there is likely to be a greater future potential for processed foods and snack foods, where cassava-based products may find a niche market.

Table 11. Present constraints in cassava production, processing and marketing, and potential future cassava products.

Country	Constraints	Future potential
China	Crop competition Small farms Soil erosion Low soil fertility	Animal feed Starch Ethanol Modified starch MSG
India	Crop competition Mosaic disease Small farms Markets	Starch Modified starch Converted starch Sweeteners Snack foods
Indonesia	Small farms Price fluctuations Soil erosion Low soil fertility	Starch Modified starch Animal feed Flour MSG
Malaysia	Crop competition High labor cost	Starch Modified starch Animal feed Snack foods
Philippines	Financial resources Markets Low soil fertility	Starch Animal feed Alcohol
Thailand	Price fluctuations Labor shortages Low soil fertility Soil erosion	Modified starch Ethanol Domestic animal feed MSG Lysine
Vietnam	Small farms Financial resources Low soil fertility Crop competition	Starch MSG Animal feed

Source: *Compiled by R. Howeler from interviews, personal observations and national program data.*

Table 12. Summary of market potential[1)] for cassava by country in 2000.

	Food		Animal feed		Starch and starch-based products	Ethanol
	Fresh	Processed	Domestic	Export		
China	*		**		***	***
India -Kerala	*	**				
- Tamil Nadu					***	
Indonesia	*	**	**	*	**	
Malaysia		***	**		**	
Philippines	*	**	**		***	
Thailand			***	*	***	***
Vietnam-North	*	**	**	*	***	
-South		**	**	*	***	

1) * = maintenance of existing consumption levels
** = growth in existing markets
*** = unexploited growth potential

2. Feed

Table 12 shows that in all countries in Asia except India there is likely to be a substantial growth in the domestic animal feed market. This market is still largely untapped in Thailand, which has traditionally concentrated on the export of cassava-based animal feed. However, since the export of cassava pellets to Europe becomes increasingly more difficult, there is a large potential to develop the use of both cassava roots and leaves for the domestic animal feed market. Previously, this was unattractive due to large domestic supplies of other sources of feed ingredients, such as maize, broken rice, rice bran and soybean. But, starting in the 1990s Thailand became an importer of maize and especially soybeans, the latter used for extraction of oil and as a protein supplement in the domestic animal feed market. While world soybean prices have been in decline since 1997, they are markedly increasing in 2004 due to high demand in China. Cassava leaves may be a good alternative source of protein which could be incorporated, together with root meal, into animal feed rations. When the crop is well-managed, cassava tops can be cut five times in a one-year crop cycle producing 13-15 t/ha of dry leaves and 2.5-2.8 t/ha of crude protein; this is 3-4 times higher than a good crop of soybean!

Figure 11 shows the trend in production of cattle, chickens and pigs in the seven major cassava growing countries in Asia since 1963. Both chicken and pig production increased markedly as increasing affluence in many countries increased demand for meat products, and thus for animal feed. Some of this meat was produced by on-farm animal feeding, especially pigs and chickens in China and Vietnam, while much of it was produced in large-scale industrial farms using commercial feed.

Even though production of the major food and feed crops, i.e. rice, maize and cassava, increased dramatically in Asia over the past four decades (**Figure 12**), this still could not satisfy the high demand for feed ingredients, resulting in major increases in grain imports, especially of maize and soybeans (**Figure 13**). Whether or not locally produced cassava chips and pellets can compete with maize as a major feed ingredient depends largely on the prices of maize, cassava chips and soybean, as the latter will need to be mixed with cassava at a ratio of about 85:15 to obtain the same protein content of a maize-based feed (**Table 13**). Since the mid 1990s the prices of nearly all feed ingredients (not adjusted for inflation) have shown a downward trend (**Figure 14**), but during the past two years these prices have increased substantially, especially the price of soybean. While the cassava–soybean mix tended to be cheaper than locally produced barley in Europe during the 1990s, this is presently not the case. A study conducted at Kasetsart University in 1997, indicated that in Thailand the cassava-soybean mix was cheaper than maize in only 35 out of 144 months (Rojanaridpiched and Sriroth, 1998). However, using a linear-programming model and average commodity prices during 1991-2001, Fuglie (2004) found that, unlike most other countries in Asia, in Thailand the cassava-soybean mix provided the lowest-cost animal feed, considerably lower than the traditional maize-soybean mix, both for manufactured and farm-grown feed. In spite of recent price increases of all three crops, the cassava-soybean or cassava chips-leaf meal-soybean mixes are now considerably cheaper than maize-soybean mixes with the same crude protein contents (**Table 13**). Further research is urgently needed concerning the large-scale production and utilization of cassava leaves as a protein source in commercial feeds.

Table 13. Approximate prices of various feed ingredients and the final cost and protein content of feed mixes in Thailand in 2003.

	Protein (%)	Price (baht/tonne)	Price (US$/tonne)
Ingredients			
-Maize	8.5	4,920	123
-Cassava chips or pellets	2.5	2,563	64
-Soybean meal	44.0	9,310	233
-Cassava chips (85.5%) + soybean meal (14.5%)	8.5	3,643	91
-Cassava leaf meal-1	20.0	5,000	125
-Cassava leaf meal-2	25.0	6,000	150
Feed mixes			
-Milk cows:			
Maize (82%) + soya (18%)	14.9	5,710	143
Cassava chips (70%) + soya (30%)	15.0	4,587	115
Cassava chips (56%) + leaf meal-1 (24%) + soya (20%)	15.0	4,497	112
Cassava chips (59%) + leaf meal-2 (24%) + soya (17%)	15.0	4,535	113
-Pigs:			
Maize (76%) + soya (24%)	17.0	5,974	149
Cassava chips (65%) + soya (35%)	17.0	4,924	123
Cassava chips (61%) + leaf meal-1 (7%) + soya (32%)	17.0	4,892	122

Cassava chips (62%) + leaf meal-2 (7%) + soya (31%)	16.9	4,895	122
-Chickens:			
Maize (73%) + soya (27%)	18.1	6,105	153
Cassava chips (63%) + soya (37%)	17.9	5,059	126
Cassava chips (60%) + leaf meal-1 (5%) + soya (35%)	17.9	5,046	126
Cassava chips (60%) + leaf meal-2 (6%) + soya (34%)	18.0	5,063	127

1 US$ is 40-42 baht in 2003

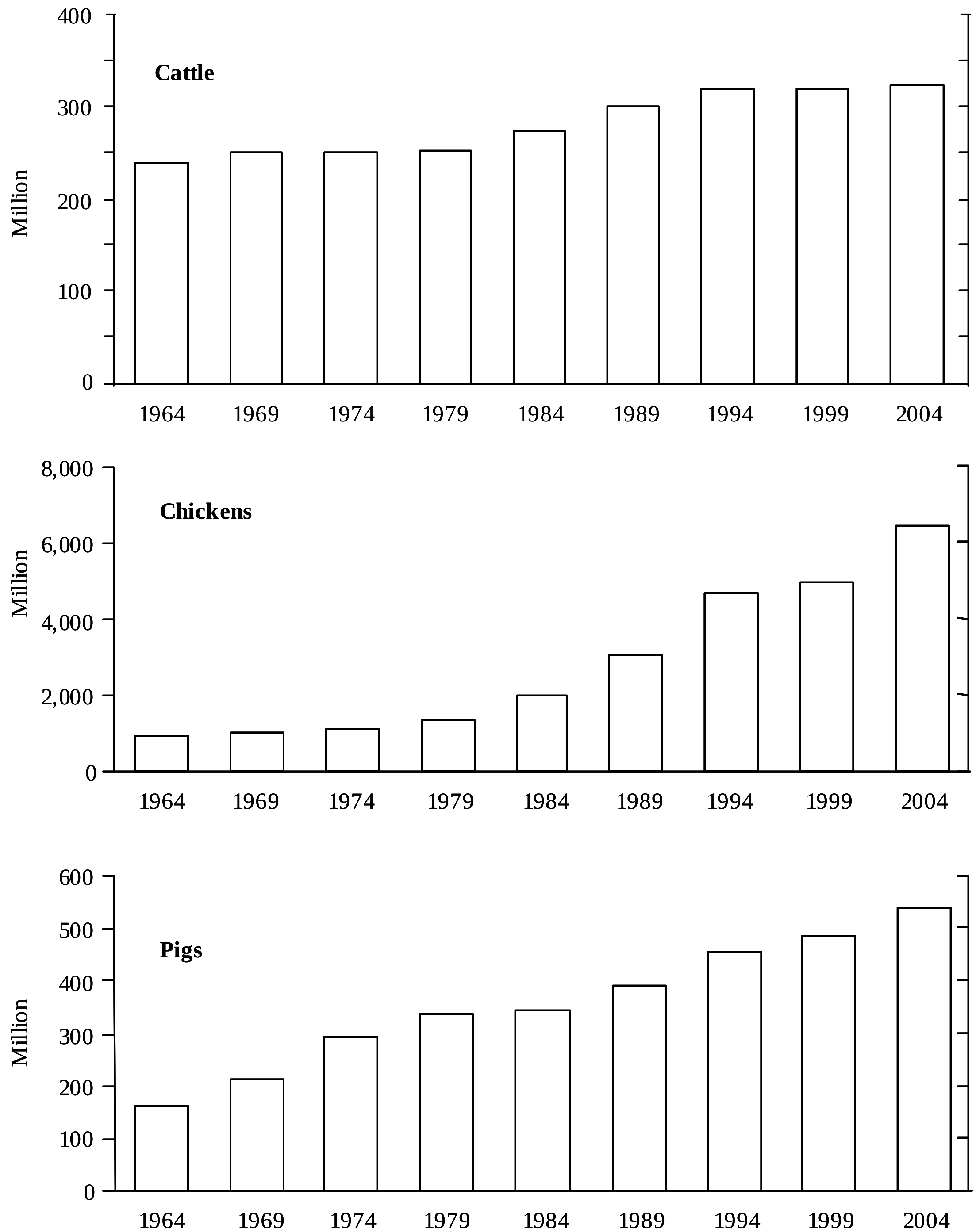


Figure 11. Trend in the number of cattle, chickens and pigs in the seven major cassava growing countries in Asia from 1964 to 2004.
Source: *FAOSTAT, April 2006.*

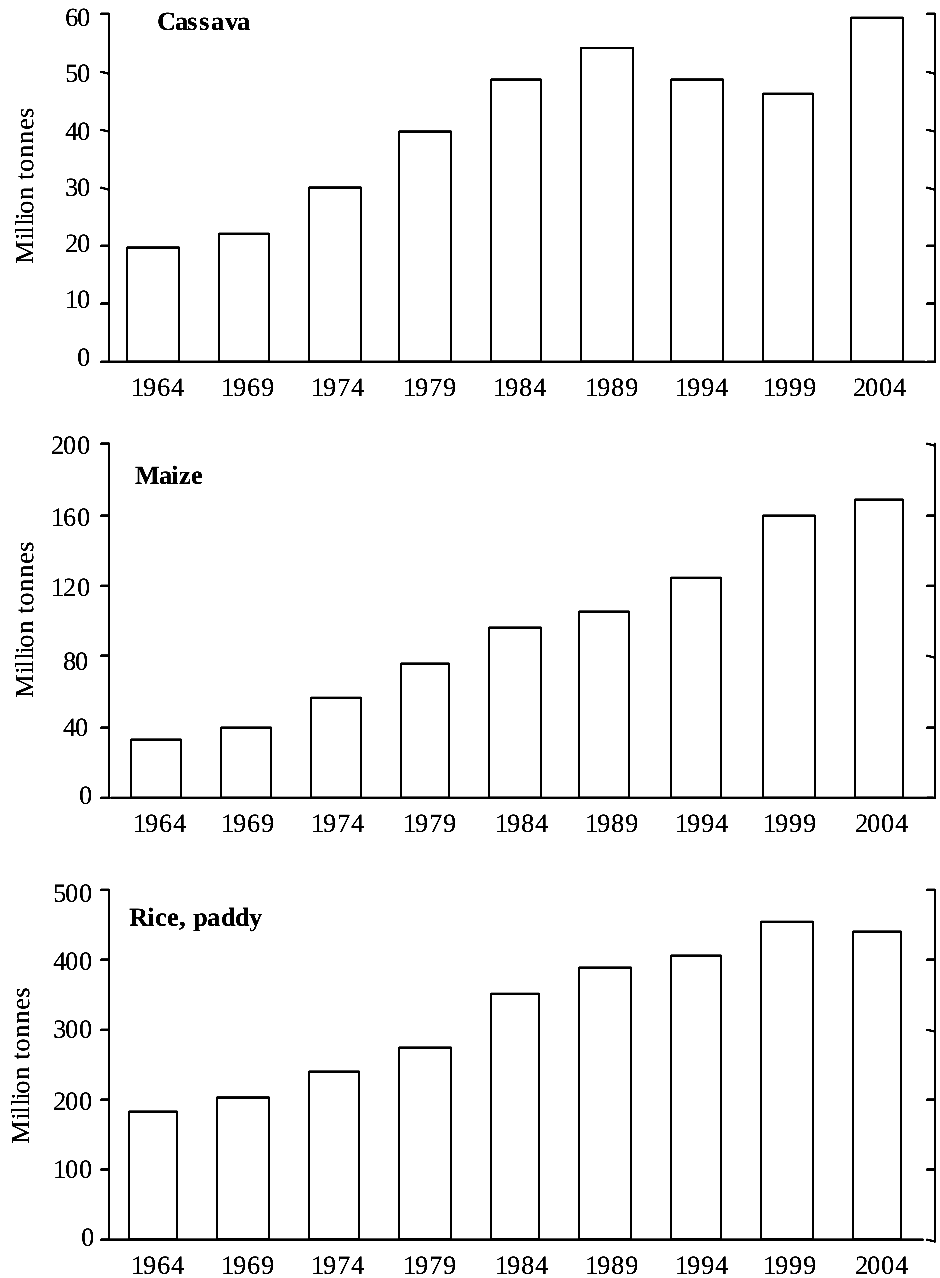


Figure 12. Trend in the production of cassava (fresh roots), maize and rice in the seven major cassava growing countries in Asia from 1964 to 2004.
Source: *FAOSTAT, April 2006.*

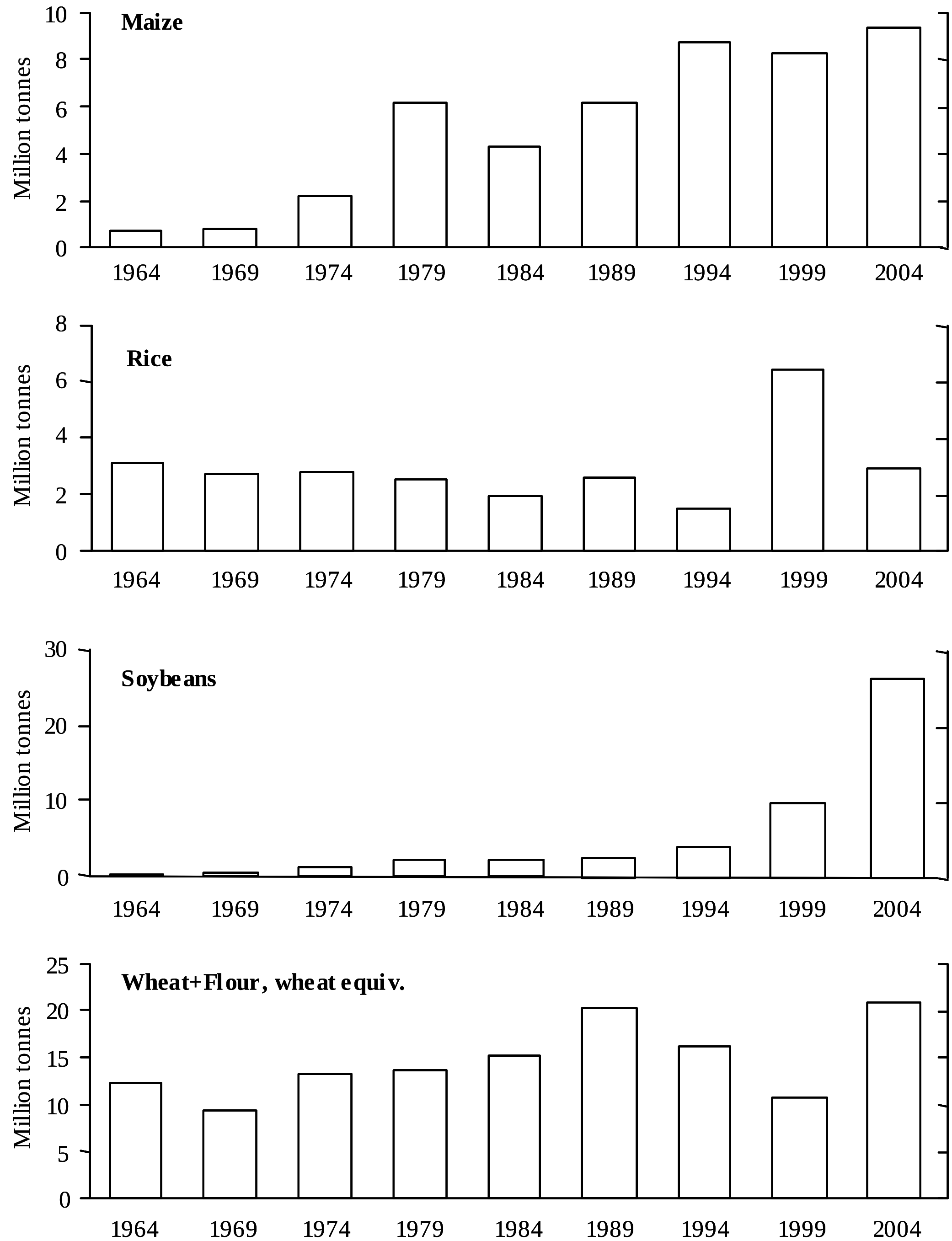


Figure 13. Trend in the quantity of imported maize, rice, wheat and soybean in the seven major cassava growing countries in Asia from 1964 to 2004.
***Source:** FAOSTAT, April 2006.*

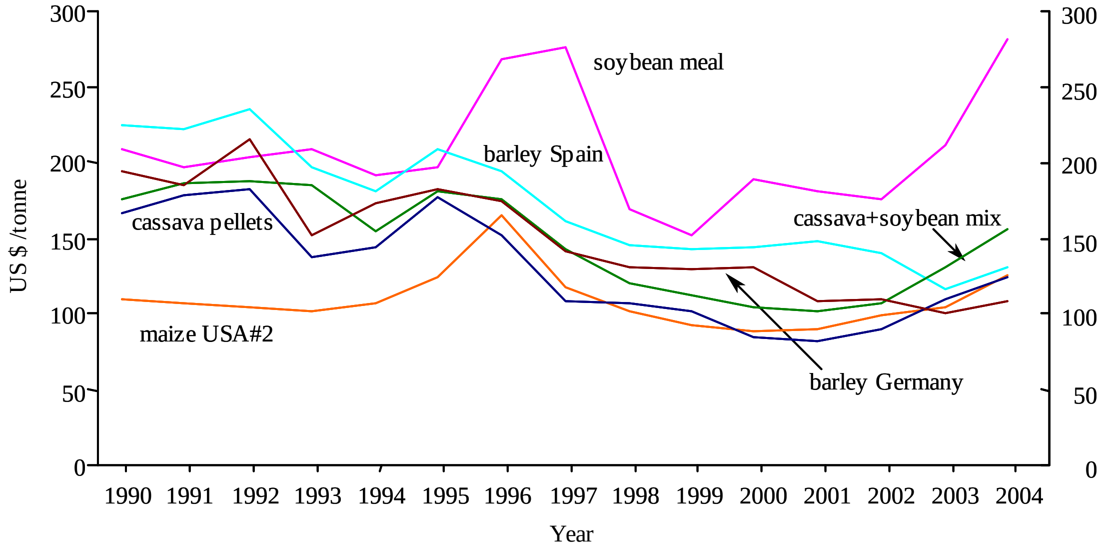


Figure 14. Price trends of Thai cassava pellets, soybean meal, cassava/soybean mix, maize and barley on the world market; 1990-2004.
Note: *data for 2004 are for Jan-June*
cassava and soybean, FOB and CIF, Rotterdam, respectively
cassava+soybean mix in ratio of 80:20
Source*: for cassava and soybean: Oil World*
for barley: Eurostat "Agricultural Prices"

3. Starch and Derivatives

Table 12 indicates that most countries foresee the greatest future potential for cassava in the area of starch and starch-based products. This is due to the increasing demand for starch in processed food, in the paper and textile industry, as well as a very large potential demand for biodegradable plastics and ethanol. In most of these markets cassava has to compete with maize, wheat, and potato, but in the ethanol market it has to compete with sugarcane or molasses. **Table 14** indicates that Thai cassava starch is very competitively priced in comparison with maize, wheat or potato starch in the US market. Similarly, using producer price series for 1966-2001 (FAOSTAT, 2003), Fuglie (2004) calculated that the price of cassava starch in Thailand was only 69% of that of maize starch, while the prices of rice, sweet potato and potato starches were 103, 516 and 663% of that of maize starch, respectively. Thus, for products where cassava starch can substitute for these other starches in terms of starch characteristics, there is little doubt that cassava starch is the cheapest source. However, in cases where specific starch characteristics, such as low-amylose content, are required, as in the production of biodegradable plastics, cassava starch may lose its competitive edge to waxy (low amylose) maize or potato starches. Intensive research will be required to breed for low-amylose cassava or to produce these varieties through genetic transformation. On the other hand, cassava starch is characterized by a neutral taste and odor, and the transparency, smoothness and viscosity of the gel, making it particularly suitable for many processed food items. Native cassava starch is also very resistant to acid conditions, it is intermediately resistant to freezing but very unstable during heating (sterilization), making it suitable for some and unsuitable for other applications (Dufour *et al*., 2000).

Table 14. Price (US $ per tonne) trends of cassava, potato, maize and wheat starch in the US market; 1996-2003.

	Cassava starch[1)]	Potato starch [1)]	Maize starch [2)]	Wheat starch [1)]
1996	449	595	468	416
1997	403	500	449	441
1998	412	440	499	457
1999	357	424	437	305
2000	347	406	460	363
2001	370	402	427	349
2002	325	398	392	483
2003	291	396	410	596

[1)] CIF port of arrival in US
[2)] FAS (free alongside ship); this does not include ship loading charges
Source: *International Trade Commission, US Department of Commerce*

4. Ethanol

With the increasing price of oil on the world market and the threat of global warming as a result of increasing production of greenhouse gasses, including automotive exhaust fumes, governments everywhere are looking for alternative sources of energy, especially renewable energy such as ethanol. Thus, in several countries, such as Brazil, USA and Thailand, most cars are now using “gasohol”, which is a mixture of 10-20% ethanol and 90-80% gasoline.

In Thailand, cassava - both fresh roots and dry chips - is considered the most promising raw material for production of ethanol. It is estimated that ethanol consumption as automotive fuel will increase from 0.3 million l/day at the end of 2005 to 1.0 mil. l/day in 2007, and to 3.0 mil. l/day in 2011 (Chareinsak Rojanaridpiched and Vicharn Vichukit, 2006). In late 2005 three factories were producing a total of 0.275 mil. l/day, all from molasses, while one factory produced 0.13 mil. l/day from cassava. It is expected that by the end of 2006 another factory will produce an additional 0.17 mil. l/day from cassava, while a second factory will produce 0.1 mil. l/day from cassava and sugarcane, for a total capacity of 0.675 mil. l/day. For 2008, there will be eight factories producing 1.95 mil. l/day. This will require about 4.2 million tonnes of fresh cassava roots/year. The Thai Department of Agriculture has designed a “road map” to indicate how cassava production in the country will need to increase to meet the increasing domestic and export demand for cassava chips, starch, and ethanol (**Table 15**). Since the cassava planting area can not increase substantially, this will require an intensive effort by both the public and private sector to increase cassava yields from the 2005 level of 17.1 t/ha to 26.2 t/ha by 2008. Similarly, in China cassava has been identified as a primary raw material for production of fuel alcohol, opening up a huge new market for both fresh cassava roots and dry chips.

AREAS OF PROJECTED GROWTH

A recent study by IFPRI and CIP used the International Model for Policy Analysis of Commodities and Trade (IMPACT) to determine the growth potential of various root and tuber crops by considering the historical production and consumption of these and other food crops in the world, and projecting these into the future up to the year 2020. **Table 16** shows their projected cassava production and utilization estimates for different countries or regions in the world for the year 2020, as well as projected annual growth rates for cassava utilization for food, feed and total utilization. Their model predicts the highest rate of growth in total cassava utilization in Sub-Saharan Africa, followed by South Asia (other than India), Latin America and Southeast Asia. They also foresee very high growth in cassava used for the animal feed sector in China, high growth in the food sector in South Asia and moderate growth in Southeast Asia; the latter includes consumption of fresh roots, as well as semi- and fully-processed food. The model predicts that cassava production in Southeast Asia will far outstrip utilization allowing for substantial export of cassava products to other countries and regions. The model may not take adequately into account the industrial usage of cassava, as it predicts that production in China will be greater than utilization in 2020, while presently China has to import already large amounts of cassava to satisfy demand mainly for industrial purposes such as for alcohol, paper and textiles.

Table 15. Road map for production of cassava to satisfy both domestic and export requirements for cassava chips, pellets, starch and ethanol in Thailand from 2004/05 to 2007/08.

Year	Area (mil. ha)	Yield (t/ha)	Production (mil. tonnes)	Utilization (mil. tonnes fresh root equivalent) Chips	Pellets	Starch	Ethanol
2004/05	0.99	17.1	16.9	6.59 -1.18 dom. -5.41 exp.	1.01 -0 dom. -1.01 exp.	9.30 -2.88 dom. -6.42 exp.	0
2005/06	1.04	18.2	18.9	6.34 -0.69 dom. -5.65 exp.	1.06 -0 dom. -1.06 exp.	10.86 -4.08 dom. -6.78 exp.	0.64
2006/07	1.05	22.3	23.4	7.55 -1.19 dom. -6.36 exp.	1.05 -0 dom. -1.05 exp.	12.60 -5.06 dom. -7.54 exp.	2.20
2007/08	1.05	26.2	27.5	8.26 -1.25 dom. -7.01 exp.	1.04 -0 dom. -1.04 exp.	13.50 -5.41 dom. -8.09 exp.	4.70

Table 16. Projected production and utilization of cassava in 2020, and the annual growth rates for 1993-2020.

	Production in 2020 (million tonnes)	Utilization in 2020 (million tonnes)			Growth rate for utilization 1993-2020 (percent per year)		
		Food	Feed	Total	Food	Feed	Total
Southeast Asia	**48.2**	**19.5**	**0.9**	**24.4**	**0.97**	**0.89**	**0.96**
China	**6.5**	**2.8**	**3.0**	**6.4**	**0.17**	**1.61**	**0.84**
Other East Asia	**NA**	**0.1**	**-**	**1.9**	**0.83**	**0.21**	**0.05**

India	**7.0**	**6.9**	**NA**	**7.3**	**0.93**	**NA**	**0.93**
Other South Asia	**1.3**	**1.3**	**-**	**1.4**	**2.03**	**NA**	**1.62**
Latin America	41.7	13.9	21.9	42.9	0.70	1.75	1.30
Sub-Saharan Africa	168.6	130.2	7.5	168.1	2.49	1.53	2.44
Developing	274.7	175.9	33.9	254.6	1.99	1.62	1.93
Developed	0.4	0.4	19.4	20.5	-0.50	0.01	-0.04
World	275.1	176.3	53.4	275.1	1.98	0.95	1.74

Note: “Total” use includes food, feed and other (mostly industrial) uses

Source: *Scott et al., 2000.*

MAINTAINING A COMPETITIVE EDGE

To keep cassava-based products competitive in domestic as well as world markets is a real challenge. While cassava has many favorable attributes in the area of production, it also has some negative attributes, especially in terms of post-harvest handling due to its high water content and rapid deterioration. The content of cyanogenic glucosides in the roots is an important consideration in the use of cassava for direct human consumption, but is of less importance for production of processed food, animal feed or starch. The low content of protein in cassava roots increases the efficiency of starch extraction, but also means the absence of a valuable high-protein by-product, as is the case for maize starch. Finally, since cassava can not be grown in temperate climates, it has never received the same research attention in developed countries as for instance maize, rice, wheat, soybean and potato. Research on cassava had been minimal until the early 1970s when the international research centers – CIAT in Colombia and IITA in Nigeria – received the mandate for cassava research and development, which in turn triggered the formation of many national cassava research programs. Nevertheless, the number of researchers working on cassava, and the research budgets dedicated to this crop, are minimal in comparison with those for most of the competing crops.

Still, cassava thrives in Asia because of the ability of farmers, processors, traders, researchers and policy makers to adapt to rapidly changing physical, biological, economic and social conditions. To maintain this competitive edge will require special attention in three areas: 1) improving the production system in order to reduce the cost of raw material while maintaining reasonable profit margins for farmers; 2) adding post-harvest value by the development of new products and more efficient processes; and 3) stimulating higher demand for cassava-based products by market development. To be really successful, these three research streams should not work independently, but should closely coordinate their activities, seek collaboration between institutions and forge a strong partnership between the public and the private sector.

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