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EDITORS: EDWARD J. WEBER
JAMES H. COCK
AMY CHOUINARD

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Cassava Harvesting and Processing

Proceedings of a workshop held at CIAT, Cali, Colombia, 24–28 April 1978

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Economic Implications of New Techniques in Cassava Harvesting and Processing

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Abstract. This paper attempts a broad analysis of the economic benefits of mechanical harvesting technology (MHT) and postharvesting processing (PHP). Although it fails in many instances to provide precise estimates for specific technologies in selected contexts, it does indicate the direct and indirect benefits accruing to the producer, processor, and consumer of all the current postproduction activities. It relates MHT and PHP to the postproduction system, specifies the objectives of new MHT and PHP, and focuses on who receives the benefits of new MHT and PHP. The procedure used here ensures that new technology is appropriate, that desired objectives are met, and that the payoff is worthwhile. It is a method of analysis that should be consistently applied in the design and evaluation of new mechanical harvesting technology and postharvest processing techniques. To be competitive with existing methods, the costs of mechanical harvesting technology must be within the range of U.S. \$2-6/ha; small-scale food-processing techniques, in the range of U.S. \$2–3/t; and chipping and pelleting technology around U.S. \$10/t. The costs of new PHP in other activities are impossible to calculate at present, and the indirect benefits are even more difficult to quantify. The latter include foreign exchange savings and earnings, development of expanded or new products or industries, improved quality of a given product, and less arduous tasks. The analysis suggests that the economic benefits of mechanical harvesting technology are doubtful and that other technologies require close examination in specific contexts.

Economic analysis of mechanical harvesting technology (MHT) and postharvesting processing (PHP) is important for two reasons. First, economics provide a means of assessing the viability of new techniques, and second, economics may focus on stress points in production, processing, marketing, and consumption that can be reduced through appropriate PHP or MHT. Thus, economics may have both a "before" and "after" role in assessing PHP and MHT.

The economic implications of new cassava PHP or MHT must be assessed in light of what the new technologies are supposed to do and how they fit into the system. Fig. 1 (moving outward from the centre) illustrates various stages in processing cassava for its many known uses. It includes final products that need little or no processing — for example, freshly harvested roots that are used directly as animal feed or human food and cassava chips that are exported. The figure also indicates the several routes used to reach a given product. Clearly, the introduction of specific MHT and PHP will be most successful if the interactions of the system are appreciated, and, in fact, if the interactions are ignored, some MHT and PHP may prove unacceptable.

Knowledge of the system must be coupled with an understanding of what the new technologies are to accomplish. Some common objectives may be: to increase revenue/income; to reduce cost; to reduce labour requirements (and/or to make labour tasks simpler); to expand cultivable areas; to improve quality of the harvested product (reduce damage); to improve quality/quantity of processed product; and to make a new product, which implies a new market and perhaps more cassava revenue.

The foregoing list is neither exhaustive nor mutually exclusive. It would change markedly for off-farm processing, the subject of most of the papers in this workshop. Thus, it is necessary to ask *for whom* are the economic implications of new PHP and MHT to be assessed? Some would argue that the assessment should begin with the farmer where production begins, whereas others would argue that it should begin with the customer where demand is rooted. Still others would focus on the processor, the entrepreneur who effectively

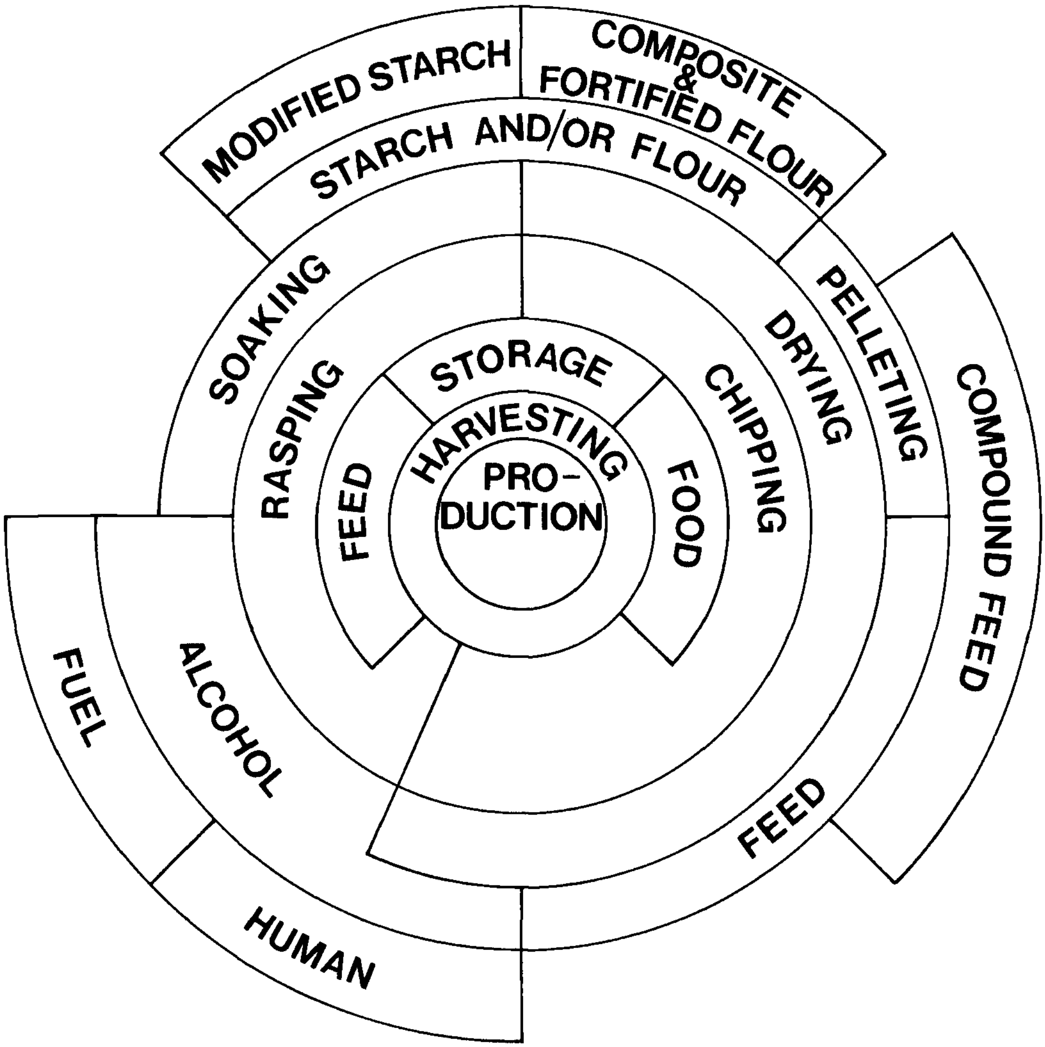

Fig. 1. Cassava postproduction system.

connects supply with demand. This author is not so dogmatic, because the producer-processor-consumer may be one and the same for cassava.

Mechanical Harvesting Technology

Obviously, harvesting is the first step in the postproduction system. Throughout the world, the harvesting of cassava is done almost entirely by manual labour; thus a major objective of MHT must be to reduce the labour requirement of harvesting. In general, the objectives of MHT are: to reduce labour requirements; to improve timeliness of harvesting; and to lessen the damage of roots. If achieved, they will primarily benefit the producer, although consumers and processors may also benefit.

Mechanical harvesting must first of all compare competitively in time and cost with manual harvesting (Table 1). Harvest times, ranging from 13 to 16 man-days/hectare, suggest that there may be great need for a mechanical harvesting system in some countries. But costs are a major constraint. Cassava farmers in most parts of the world do not tend to hire labour to harvest cassava[1], perhaps because they fear pilfering.

[1]In some countries the use of hired labour for other aspects of production is quite common, the extreme case being land preparation in Thailand, which on 90% of the farms is done with hired labour machinery.

Table 1. Manual harvesting requirements in select countries.

Country	Man-days/ha	Cost (U.S.)/ha	% Family labour
Thailand	19.9	$23.00	72
Colombia[a]	30.7	$37.00	–
Colombia[b]	24.6	$16.20	–
Brazil (Bahia)	26.3–30.1	$35.60–$40.90	–[d]
Nigeria	28–60	–	–[d]
Caribbean[c]	17.7–23.7	–	–
Zaire	50.	–	–
Jamaica[c]	12.6–46.9	–	45–85

Sources: Thailand, Phillips 1977; Colombia, Diaz 1974; Brazil, Gramacho 1972; Nigeria, Sonola 1975; Caribbean, Krochnal 1966; Zaire, Johnston 1958; Jamaica, Rankin 1971.

[a]Machinery used for land preparation.

[b]No machinery used for land preparation.

[c]Calculation based on 800-1800 h/man-day.

[d]It appears that the bulk is family labour.

They primarily use family labour and are not accustomed to paying cash for harvesting. The cost of mechanical harvesting, therefore, would have to be very low to compete with manual harvesting. An indication of what farmers would be willing to pay for mechanical harvesting might be derived from their current expenditures on hired labour for harvesting, approximately U.S. $2–6/hectare.

A second constraint to the introduction of mechanical harvesting equipment is that cassava is often planted in consort with perennials or crops with longer growing seasons. In such cases, the cassava must be harvested without disturbing the other crops.

There are also agronomic features of cassava that act as constraints. Unlike other root and tuber crops, the aerial part often exceeds the root and must be cleared before mechanical lifting of the roots. This is especially a problem when the mechanical process must conform to the common practice of reusing the stakes for planting. At present, most topping procedures tend to destroy the stakes. Even if the stakes can be saved, a great deal of soil must be moved to ensure that all roots are lifted.[2] Experiments carried out in Nigeria indicated that a mould board ridger, a mould board plough, and a mould board plough with the board removed exposed the roots to some extent and reduced the tedium of hand harvesting but damaged the roots and buried many of them in overturned soil (Makanjoula 1973). The conclusions drawn from these experiments were that "harvesting equipment of an entirely new design is probably needed" and that a cassava variety "with more compact roots" is also required (Makanjoula 1973). The harvesting equipment demonstrated at this workshop appears promising (p. 53, 58).

A final constraint to the introduction of MHT is that harvesting rates are often determined by processing capacity. For example, a typical producer may only need a 50-kg bag of *farinha* and may only lift 100–200 cassava plants at one time;[3] such small-scale harvesting may not be compatible with mechanical methods. In other words, MHT will only be appropriate if the scale of production is large or if storage methods are used.

Thus, although the rationale for mechanical harvesting of cassava may seem sound, the challenges are such that one cannot be too optimistic about the successful spread of such technology to the typical cassava farmer. Furthermore, the economic advantages of MHT for the typical producer are not clearly apparent.

Processing Human Food

The processing of cassava to produce human food is the most common of the postharvest processing activities. In fact, as much as 80% of world production of cassava is processed for human consumption. Major objectives of PHP for human food are: to improve efficiency and yield; to lessen labour requirements; to improve product; and to produce new products.

If the PHP is successful, the economic benefits will most probably accrue to the processor and consumer, who may in fact also be the producer. Because of the multiplicity of processing methods

[2]In a stand of cassava, 60–70% of the roots have been found to grow along the ridge when the soil is relatively loose, and sideways toward the furrows when the soil is compact (Makanjoula 1973).

[3]This may be a 10-m² area.

and country differences, it is impossible in this brief paper to determine the economic implications of all PHP. Instead, three general, food-processing activities will be examined: gari or *farinha de mandioca* production; flour production; and fortification.

In terms of number of consumers, the most common product is *farinha de mandioca* in Brazil or gari in West Africa. Both products entail the soaking of cut-up cassava, drying, and roasting (Fig. 1). During soaking, the cassava ferments, taking on a new flavour and slightly improved nutritional properties.

Currently, the scale of processing of gari or *farinha de mandioca* ranges from the individual family unit producing probably less than 0.5 t/year to the large commercial operations producing 3000 t/year[4] and the end product is consumed in varying amounts by probably more than 200 million people.

The PHP appropriate for small-scale production will not normally be appropriate for large-scale production. The major need is rasping and roasting equipment to make the processing task less arduous and to improve the product. In fact, mechanizing rasping and roasting is sufficient to allow entrepreneurs to commercialize their operation — witness the *casas de farinha* in Brazil and the rental or co-op ownership of rasping equipment in some Nigerian villages. It must be assumed that any new food-processing technology will have to compete favourably with existing technologies. For example, in northeast Brazil the producers may be willing to pay in kind up to 10% of the *farinha* produced, or about U.S. $2–$3/t of roots.

The PHP equipment owner usually reaps the benefits. If the owner is an intermediary, there is no reason to assume that either the producer or the consumer will benefit directly, although the farmer may indirectly benefit from reduced labour input, as is the case of the Brazilian *casa de farinha*, and the consumer may benefit from a better quality product.

If new food-processing technologies are designed to be used by farmers, they must be inexpensive to operate. Cash availability is a major constraint for many small farmers. To benefit the farmers, food-processing equipment should be designed to meet some of the aforementioned objectives and should be affordable. Given the large number of cassava farmers (probably 3–4 million) in Brazil and West Africa, the impact could be very great.

[4]Both figures relate to gari production (Ezeilo et al. 1975), but the range is also appropriate for *farinha de mandioca* production.

The food-processing technologies required for large-scale producers are quite different and are already in use. They are designed for two types of large-scale producers: those who purchase gari or *farinha de mandioca* and grade, repackage, and market it; and those who purchase fresh roots and do all the processing and marketing themselves. It is probably fair to assume that large firms will develop, or have access to, improved PHP through normal commercial evolution and that they will certainly accrue the benefits in terms of additional profits. Consumers (normally urban) could be expected to receive an improved product. The farmers may or may not receive benefits, but given the atomistic nature of cassava production, it is likely that some farmers will not receive any economic benefits whatsoever.

In summary, new PHP that increases production of gari and *farinha de mandioca* and(or) decreases labour input will result in economic benefits to the user of the technology. If it is assumed that the quality of the food improves with the introduction of new technology, then the consumer will benefit as well, although not in an easily quantifiable way.

Cassava flour is already being used in bakery products, such as *pan de bono* in Colombia or bread in Brazil, which consists of 2–20% cassava flour. Existing and new PHP for the production of flour and(or) bakery products is aimed at improving efficiency of production and(or) producing new bakery products. The economic benefits of this type of technology will accrue mainly to the processors, indirectly going to the consumer in the form of improved and(or) new products. The technologies are large scale, and there is no reason to assume that any economic benefits will be passed on to the farmer — with the possible exception of market expansion. Perhaps the major benefit of flour production technology is that the product can be substituted for imported cereals, which constituted more than 13 million t in 1974 (Halder 1976). If cassava flour is used sparingly in baking (less than 20% of total flour), then conventional bakery procedures can be used. But if cassava flour is to be used at higher levels of concentration, new or modified bakery technologies must be employed. (For a discussion and evaluation of flour production technologies, the reader is referred to the work of Kim and Ruiter 1969. And papers presented at the 1972 Bogota conference "Production and Marketing of Composite Flour Bakery Products and Pasta Goods" explore the possibilities of using cassava flour in bakery products.)

Fortification of processed cassava, perhaps only possible in conjunction with large processing, appears to be one means of improving nutrition without introducing a completely new diet. The objectives of fortification are to improve the nutritional level of diets and to produce new products. The major economic benefits of fortification are reduced medical costs, owing to improved diets, and increased labour productivity, both of which accrue to the entire society but may not be sufficient to attract entrepreneurs. It may be necessary for government to provide incentives for cassava producers and processors to participate in a fortification program (Costa 1972). It is not possible in this brief paper to quantify the economics of such a program.

Processing Alcohol

The possibility of ethyl alcohol from cassava is a relatively new component of the postproduction cassava system. At present, the major objective is to replace a nonrenewable energy resource with a renewable one.

The benefits, which accrue to anyone using conventional internal combustion engines, include the possibility of import substitution and even exports. Ethyl alcohol (ethanol) provides more power and less pollution per unit consumed than does gasoline and can be produced from most starch-rich commodities.

Brazil appears to be the leader in the production and use of ethyl alcohol. In fact, sugarcane-based alcohol was used experimentally in Brazil as a fuel for automobiles as early as the 1920s, and by the 1930s was legally blended with gasoline. Because ethanol has historically been derived from sugarcane, its production has been primarily restricted to cane-producing areas in Brazil. Recently, interest in using cassava for ethanol production has increased, and distilleries are being launched throughout the country (see Menezes p. 41 and Milfont p. 46). Researchers have identified two enzymes that are suitable for cassava liquefaction and saccharification — alpha-amylase and glucoamylase, respectively (Yang et al. 1977). The process of converting cassava to alcohol entails.

- *Preparation:* cassava roots are washed, peeled, and disintegrated to form a mash with 16% water;
- *Conversion:* cooking, liquefaction, and saccharification;
- *Fermentation:* glucoamylase and yeast are added to produce a mixture with an 8% alcohol concentration; and
- *Distillation:* prior to distillation, solid residues are removed from the fermented wort. Distillation produces alcohol, hydrated alcohol, and fusel oil.

Brazilians now replace 2–8% of gasoline with alcohol (Hammond 1977) with the main consumption occurring in Sao Paulo. If the government target of replacing 20% by the early 1980s (estimated to be 3000 million litres of alcohol) is to be realized, there must be a substantial increase in production (Table 2).

The points at issue then become: Is cassava an efficient and viable source for alcohol and will Brazil increase cassava production? Addressing the former question, Yang et al. (1977) found cassava alcohol to be less energy efficient than sugarcane alcohol (Table 3), which owing to the availability of bagasse (fibrous residue of cane), can be produced from energy outputs of the sugarcane alone. Cassava alcohol producers depend on an outside source of fuel, namely firewood. However, from a macro point of view, the energy efficiency of cassava alcohol is high

Table 2. Production of alcohol 1964–73 (millions of litres).

Year	Brazil	% used in gasoline	Central south	North northeast
1964	386.9	17.9	264.3	122.6
1965	602.7	30.6	488.5	114.2
1966	727.5	50.2	600.3	127.2
1967	676.3	64.6	579.9	96.4
1968	473.6	40.4	354.8	118.8
1969	461.6	6.9	336.2	125.4
1970	637.2	28.8	519.6	117.6
1971	613.0	41.4	537.6	75.4
1972	680.0	57.5	599.5	81.4
1973	651.7	53.7	561.0	90.7
1974	740.0	–	600.0	140.0

Source: Lins 1976.

because firewood is a renewable resource that itself has minimal energy input requirements for production. In fact, the net energy ratio for cassava alcohol is 9 (CTP 1978) when forestry is included as part of the system. Thus, the energy efficiency of cassava versus sugarcane alcohol depends very much on where the boundaries of the system are drawn. Besides, any activity that has a net energy ratio of more than 1 is desirable.

Economic analysis shows that production of sugarcane alcohol ($0.397/litre) is more efficient than cassava alcohol ($0.424–$0.472/litre) but not to the same degree as indicated by the energy analysis (Table 4). Lins (1976), on the other hand, suggests that cassava alcohol is cheaper ($0.121/litre) than sugarcane alcohol ($0.124/litre) or sweet potato alcohol ($0.129/litre). Unfortunately, the two sets of calculations are not explained sufficiently to account for the differences.

Cassava alcohol does have the advantage of not being tied to seasonal production, but the fixed Brazilian price of $339/m^3 of alcohol means that neither sugarcane nor cassava alcohol is profitable (Yang et al. 1977). If the government targets for alcohol production are to be realized, there will have to be some changes in the economics of alcohol production.

Whether or not Brazilian farmers will expand production to serve the growing alcohol market is not to be answered in this paper. Current estimates are that farmers can receive U.S. $30/t for raw material to be used in alcohol production. Comparing this figure to their production costs of U.S. $11/t or roots suggests some financial incentive. However, farmers can also receive U.S. $24–37/t of roots to be used in *farinha de mandioca* and will likely choose the more profitable market.

In summary, potential for processing cassava to produce alcohol is promising and should be considered outside Brazil. However, the economics of alcohol processing and the economics of cassava production must be studied together to ensure the viability of all phases of the system.

Processing Industrial Starch

Apart from food processing, the production of starch is perhaps the oldest of postproduction activities. The objectives of new starch PHP are to reduce labour inputs, to improve the product, and to develop new products. Improved starch production methods, either for small- or large-

Table 3. Net energy ratio (NER) comparison between cassava alcohol and sugarcane alcohol (1 m^3 absolute alcohol).

		Energy (kcal)					
			Consumed				
Raw material	Case	Produced	Agri-culture	Dis-tillery	Trans-portation[a]	Total	NER= (produced/ consumed)
Sugarcane	Base distillery	5590820	418150	17330	225000	660480	8.06
Cassava	Base distillery (firewood as fuel)[b]	5567840	301920	4714270	177400	5193590	1.97
Cassava	Oil as fuel[b]	5567840	301920	4130260	177400	4609590	1.21
Cassava	Methane from stillage as supplementary fuel[b]	5567840	301920	4112000	177400	4591320	1.21
Cassava	Cassava stalks as fuel (mechanical drying)[b]	5567840	433570	676590	325060	1435220	3.28
Cassava	Cassava stalks as fuel (sun drying)[b]	5567840	488290	422060	210700	1121050	4.97
Cassava	Continuous conversion (firewood as fuel)[c]	5567840	301930	4069540	177400	4548870	1.22

Source: Yang 1977.
[a]Energy consumption for transportation refers only to materials moved between farms and distillery.
[b]Refers to boiler-fuel systems.
[c]Refers to a distillery process improvement.

scale processing, should result in economic benefits for the processor, as should the development of new products such as modified starches. The latter may also result in national gains by saving or earning foreign exchange.

At present, the market for industrial starch constitutes a small proportion of total production, probably less than 1% (Phillips 1974a, b) and is primarily for export (United States, Japan, and Canada). Projections of the future size of the export starch market suggest a degree of uncertainty, dependent on a multitude of factors (Phillips 1974a, b). Thus, the general economic implications of the export market for industrial starch are not very promising, although some countries or firms will likely profit.

What is possible, and should no doubt be promoted, is the development of domestic markets for cassava starch. For example, in 1974, Brazil imported 1495 t, valued at $1 175 667, of starch products from the United States.[5] Given the appropriate incentives and technology, it would seem that Brazil could produce cassava starches to replace imports. An interesting feature of starch production is that it can be done on a relatively small scale and, hence, may have great local impact. In this context, the experience of Thailand is revealing. The average starch plant yields 19 t of starch per day and operates 150 days per year, utilizing the cassava from approximately 1000 hectares. The older Thai plants produce as little as 2–3 t/day and only serve approximately 100 hectares.

The problem facing many processors, particularly those exporting, is that cassava starch must compete with other starches, particularly maize starch. Maize starch is a complementary product of maize oil production and, therefore, the price of maize starch may not reflect the full cost of production.

Nevertheless, the rate of industrial development in cassava-producing countries suggests that there will be a growing domestic demand for starch.

[5]SITC 599.5 excluding vegetable protein products.

Table 4. Economics of alcohol production (150 m³/day plant; exchange rate Cr. $13./U.S. $1).

Cost item	Sugarcane (operation 180 days/year)	Cassava (operation 330 days/year)				
				Cassava stalks as fuel		
		Base distillery	Continuous conversion[a]	Mechanical drying	Sun drying	Methane from stillage as fuel
Raw materials ($/m³)[b]	173.10	200.00	200.00	200.00	200.00	200.00
Chemicals ($/m³)	4.90	29.30	29.30	29.30	29.30	29.30
Water ($/m³)	0.50	0.40	0.30	0.40	0.40	0.40
Power at $28/50MWh ($/m³)		12.80	10.80	12.90	12.80	13.10
Firewood at $17.00/t ($/m³)		11.70	10.00	17.80[c]	7.90[d]	10.00
By-products credit ($/m³)	(22.40)	(18.40)	(17.80)	(19.90)	(18.20)	(18.90)
Labour ($/m³)	10.70	9.60	9.60	9.60	9.60	9.60
Maintenance of fixed capital ($/m³)[e]	11.10	10.80	9.80	14.50	10.80	12.30
Depreciation ($/m³)	32.80	31.70	27.60	41.00	31.70	34.80
Income tax ($/m³)	25.00	12.50	11.80	16.70	12.50	14.30
Other taxes, insurance, and administrative expenses ($/m³)	99.10	99.50	96.30	110.90	97.50	102.90
Return on investment ($/m³, ROR: 12%/year DCP)	62.20	29.10	27.30	38.80	29.70	33.20
Total product cost ($/m³ alcohol, FOB distillery)	397.00	429.00	415.00	472.00	424.00	441.00

Source: Yang 1977.

[a]The confidence level of cost figures for the alternative is less than for the base distillery, due to insufficient basic design data.

[b]Sugarcane at $11.54/t, and cassava roots at $29.20/t.

[c]Cassava stalks at transportation cost: $3.10/t.

[d]Cassava stalks cost is the sum of costs of transportation and labour for sun drying, $3.50/t.

[e]For sugarcane, 2.3% of fixed capital and for cassava, 3.4% of fixed capital.

Unfortunately, many industries require starch with specific properties not normally found in "natural" starches, and to capitalize on the market, starch producers must devote sufficient research and development to the production of modified cassava starch or the identification of cassava varieties that produce starch with the desired properties. The question is whether there are sufficient benefits to justify the costs of producing specific types of cassava starch and whether the benefits outweigh the high costs of establishing "modern" starch factories (Table 5).

In summary, new starch-processing technology may only be beneficial in cases in which cassava is cheap and readily available, the markets are favourable, and investment capital is available.[6]

Processing Animal Feed

The most dynamic of the cassava-processing activities is the production of an animal feed for commercial markets. The objectives of new animal feed-processing techniques are to improve efficiency, to ensure durability of the product, to improve the product, and to develop new products. The benefits of new animal feed PHP will primarily accrue to the processors of cassava chips and pellets, but manufacturers and(or) exporters also benefit from improved quality, and cassava producers may benefit from an expanded market. If cassava is exported as an animal feed ingredient or used as a substitute for imported feed grains, the nation also benefits. Furthermore, if the processing of cassava for animal feed serves as a focal point for developing or expanding a nation's capacity for producing animal feed, employment opportunities and expanded livestock sectors are possible benefits.

[6]These conditions must exist in varying degrees for any cassava PHP, but the starch industry requirements appear to be among the most demanding of the sectors.

The export market and economic viability of cassava as an animal feed ingredient are clearly demonstrated by Thailand's more than 15 years of exports. In 1977 alone, Thailand exported an estimated 3.3 million t of pellets valued at $367 million. Indications are that the demand for cassava pellets in the European Economic Community (EEC) will expand and, according to the author's projections will reach approximately 5.1 million t by 1980, 6 million t by 1985, and 6.8 million t by 1990.[7]

The market is there, but it can only be reached successfully if cassava producers can meet standards in the quality, volume, and price of pellets. Of these three, the first is probably the easiest to meet. The current minimum standards are: starch content, maximum 62%; raw fibre content, maximum 5%; sand content, maximum 3%; and moisture content, maximum 14% and 14.3% from 1 June to 30 September.

The volume constraint is important for two reasons. Firstly, the EEC compounders are primarily interested in a relatively steady supply of ingredients and hence do not tend to become consumers of insignificant quantities or ingredients that are only delivered three or four times a year. Secondly, conference shipping rates are such as to price cassava pellets out of the market. To be competitive, the potential exporter must have sufficient volume to justify chartering a ship. This minimum volume has been calculated to be 90 700 t/year and as much as 235 820 t/year, the minimum being determined by the size of available ships and cost of chartering.

The EEC price condition is determined by the price of competitive and complementary feed ingredients in the EEC; however, a useful rule-of-thumb would be that the c.i.f. price (Rotterdam) of cassava pellets should be in the

[7]The variance around these projections is approximately 22%.

Table 5. Some estimates of establishing cassava starch plants.

Country	Capacity (t starch/year)	Cost ($'000)
Brazil	10500	450[a]
Brazil	4000 (100 t roots/day)	174[a]
Malaysia	6500	1500[b]
Thailand	4500	225
Thailand	9000	325

Source: Brazil, Rosenthal 1974; Malaysia, Division of Agriculture 1972; and Thailand, Boonjit 1974.
[a]Exchange rate of Cr. $6./U.S. $1.
[b]Estimated starch plant share of starch pellets centre, total cost $2.17 million.

range of 80–85% of the threshold price of maize.[8] At a c.i.f. price of $114/t the Thai price comprises $19.38 freight cost, $13.68 exporter's cost, $6.84 transport cost, $6.84 pelleting cost, $3.42 chipping and drying, $63.84 price to farmer at $27/t fresh roots.

These figures suggest targets for potential cassava pellet exporters. An advantage of the pelleting process is that it costs much less to establish than does starch production. In Thailand, it is estimated that a 3.2-hectare chipping plant with 1.1 hectares of concrete for drying requires only a $10 000 investment, and a Thai pellet plant with a capacity of about 5000 tons of pellets per year requires $20 000 investment (Boonjit 1974).[9] Estimates of the investment requirements of the large-scale imported plants (capacity approximately 100 000 t of pellets/year) are not readily available, but indications are that they exceed $1 million. If this figure is correct, it would appear that the large plants are less efficient than the smaller plants at $11 invested/t of pellets versus $4.50. However, the large-scale pelleters are normally considered to produce a superior quality pellet.

It has been shown (Roa 1973; Mathot 1974; and Thanh 1976) that the drying-pelleting process can technically be improved; it has, however, not been clearly proven that technical improvements are an economic improvement, the result of the already relatively low cost of pelleting and drying (approximately 9% of c.i.f. Rotterdam price). It is, of course, correctly argued that pelleting and cubing methods (Mathot 1974) will increase the density of the final product and hence reduce transportation costs. That Thai pellet producers have not adopted these new ideas may reflect too-high equipment costs, inflexibility in the new technology, or some combination of the two. Although advances in chipping equipment would appear to be economically advantageous, the savings are in the form of reduced drying time and improved quality of the chip. Unfortunately, these do not mean economic gains for the average Thai chipper. At present, the chippers have little incentive to produce a higher quality chip, because the price system does not reward quality.[10] Also, most already have a higher capacity than they are using; therefore, they are not attracted by the promise of greater throughput resulting from shorter drying time. In the wet season, however, when the drying rate is slow and chip deterioration and losses high, they may appreciate a faster drying chip.

The improvements in drying methods may not be to the advantage of the chipper because of potential increased equipment and labour costs.

In summary, it should be noted that the greatest benefit of processing cassava for animal feed may be the development of the infrastructure necessary to accommodate changes of the postproduction system. There are, of course, economic benefits to be realized from the introduction of new PHP, such as potentially lower investment costs, reduced input requirements, and perhaps a more secure market with higher prices. These benefits related to processing will never be greater than the benefits resulting from low processing costs.

Economic benefits arising from the development of viable means to produce single-cell protein are not currently known because the scale of processing has not yet been determined nor has the environment for processing been identified. The most apparent economic benefits are for the processors and consumers of the resulting product and for the nations introducing the industry.

[8]This rule-of-thumb is only applicable if current price relativities are maintained. If the price of barley were to drop substantially below the price of maize or the price of protein-rich ingredients were to experience a relatively large increase, the relative cassava price would have to change.

[9]These are substantially lower than investment costs for a starch plant (Table 5).

[10]The pelleter and exporters have the same legitimate complaint. Furthermore, the history of the industry has been one of increasing prices, demand, and constant complaints about quality.