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Box 1

Urban cassava markets

The impact of fresh root storage

W. Janssen and C. Wheatley 1985

The authors explain how although fresh cassava is important in rural nutrition, its importance in urban areas is limited and declining. In Colombia, the third most important cassava-producing country in Latin America, both the structure of the marketing channel and consumer preferences are considered in explaining this difference. The principal factor limiting urban market volume and demand is identified as the rapid root post-harvest deterioration which necessitates high margins to cover marketing risks. Appropriate storage techniques which overcome this problem are evaluated and their possible positive impact, through reduction of marketing margins, on retail and farmgate prices and on urban consumption is estimated. A strategy for storage technology adoption is discussed.

Keywords: Cassava; Colombia; urban food markets

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[1]FAO, *FAO Production Yearbook*, FAO, Rome, 1982.
[2]J.H. Cock, 'Cassava: a basic energy source in the tropics', *Science*, Vol 218, pp 755–762.
[3]*Ibid*.
[4]R.O. Diaz, and P. Pinstrup-Andersen, *Descripcion Agro-economica del Proceso de Produccion de Yuca en Colombia*, CIAT, Cali, Colombia, 1977.
[5]R.R. Tejada and W. Moscoso, 'Resumen estudio perdidas post-cosecha en yuca en la Republica Dominicana', *Seminario Sobre la Reduccion de Perdidas Post-*
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Cassava is the major root crop of the Latin American lowland tropics with a total producton of 31.6 million tonnes in 1981.[1] It has several qualities which enable it to yield well in the marginal environments characteristic of many tropical regions especially in areas of poor soils and/or low rainfall.[2] The roots have no period of absolute maturity, and can be harvested over a timespan of several months if necessary.[3] The vigorous nature of cassava growth makes it especially suitable for integration into the associated cropping systems important in small-scale tropical agriculture. Despite a relatively high labour requirement per hectare, this is evenly spread throughout the growth period.[4] Cassava has a low cost of production per calorie at farm level (Table 1).

The crop does, however, have some disadvantages: a protein content of only 1% of fresh weight, a moisture content of between 60 and 70% which increases transport costs, and a very short post-harvest storage life. This is due to a rapid physiological deterioration of the root and can lead to very high losses within two or three days of harvest. The losses have been estimated at 14 to 75%.[5]

Cassava still constitutes an important part of the human diet in Latin America, supplying 7% of total calorie requirements in 1971.[6] Data do, however, suggest that this proportion is decreasing (Table 2). Between 1971 and 1981 world cassava production increased by 24% but fell by 12% in Latin America (Table 2). During the same period, yearly population increases averaged 2.96% in Latin America, ie per capita cassava production decreased by 24%, compared with a 4% decrease for potatoes and a 4% increase for rice (Table 1). The role of cassava as a calorie source has thus been declining during the last 10 years with other crops, especially rice, expanding to take its place.

Fresh root consumption of cassava comprises about 17% of total Latin American production, including Brazil, and about 50% excluding Brazil. The remainder is used for starch, flour, animal feed or alcohol production.[7] Current evidence suggests that fresh cassava consumption is declining rapidly, due to two main factors: a decrease in consumption per capita in urban areas (Table 3) and the rapid migration from rural regions to urban centres (Table 4 and 5). Cassava consumption is falling in urban areas because of its increasing price relative to that of other products (Table 6).

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Table 1. Direct production costs of rice, potatoes and cassava in Colombia in 1981 (US dollars per hectare).

	Irrigated rice	Potato	Cassava
Machinery	185	83	81
Labour	108	473	289
Water	74	-	-
Seed	93	335	93
Other inputs	201	502	88
Total costs	661	1 394	551
Yield (kg)	2 560	20 000	22 000
Yield (kcal)	913 206	1 400 000	2 398 000
Total costs per kg	0.26	0.07	0.03
Total costs 100 000 kcal	72.4	99.6	23.0
Total cost-labour 100 000 kcal	60.6	65.78	10.93
Total costs 100g protein	0.34	0.42	0.27

Sources: For rice, CIAT, *Annual Report*, CIAT, Cali, Colombia, 1981; for potato, Flores, *et al*, *Costos de Produccion de Algunos Cultivos*, Documento de Trabajo, ICA-Bogota, Colombia, 1979; for cassava, CIAT, Cassava Program Internal Document, mimeograph, CIAT, Cali, Colombia, 1983.

Note: The table considers only direct costs, not land. Data are slightly biased in favour of cassava because of its longer growing cycle, entailing higher land management and capital costs. These costs can be estimated at approximately US$100 per crop for rice, US$160 for potato and US$173 for cassava.

Table 2. Area, yield and production of cassava, rice and potatoes on a global and Latin America basis, 1971 and 1981.

	World			Latin America		
	Area (thousands of hectares)	Yield (kg ha⁻¹)	Production (thousands of tonnes)	Area (thousands of hectares)	Yield (kg ha⁻¹)	Production (thousands of tonnes)
1971						
Cassava	10 836	9 436	102 248	2 597	13 788	35 808
Rice	134 148	2 304	309 096	6 581	1 706	11 224
Potato	22 294	13 140	292 945	1 127	8 189	9 229
1981						
Cassava	14 054	9 055	127 161 (24%)[a]	2 734	11 569	31 631 (−12%)
Rice	144 915	2 855	413 785 (34%)	8 220	1 896	15 586 (39%)
Potato	17 861	14 387	256 978 (−12%)	1 046	11 261	11 779 (28%)

Note: [a] Growth over 10-year period given in parentheses.

Source: FAO, *Production Yearbooks*, FAO, Rome, 1972 and 1982.

Table 3. Consumption of fresh cassava in Latin American countries; total urban and rural consumption per head (kg/year).

	Rural	Urban	Total
Bolivia (1972)[a]	17.0	5.4	15.3
Brazil (1975)	11.2	2.7	6.3
Colombia (1970)	35.0	16.5	20.4
Cuba (1976)	30.0	12.4	18.8
Dominican Republic (1975)	42.3	20.0	33.1
Ecuador (1974)	31.0	6.0	19.0
Paraguay (1976)	180.0	35.0	110.1
Peru (1976)	18.3	5.6	11.0
Venezuela (1975)	27.4	5.0	9.8
Total	19.1	5.9	11.4

Note: [a] Year of estimate in parentheses.

Source: Lynam and Pachico, *op cit*, Ref 7.

Table 4. Latin America: rural, urban and total population, 1960 and 1981.

	Rural population	Urban population	Total population
1960 absolute	101 611 000	100 142 000	201 753 000
Percentage	50.4	49.6	100.0
1981 absolute	114 067 000	235 139 000	349 206 000
Percentage	32.7	67.3	100.0
Yearly growth	0.55%	4.15%	2.65%

Source: Interamerican Bank, *Annual Report*, IDB, Washington, DC, 1981.

Table 5. Colombia: rural, urban and total population, 1960 and 1981

	Rural population	Urban population	Total population
1960 absolute	8 957 000	8 256 000	17 213 000
Percentage	52.0	48.0	100.0
1981 absolute	5 833 000	20 832 000	26 665 000
Percentage	21.9	78.1	100.0
Yearly growth	−1.5%	4.5%	2.1%

Source: Interamerican Development Bank, *Annual Report*, IDB, Washington, DC, 1981.

Table 6. Change in consumption and price of cassava, rice and potatoes in Cali, 1970–82.

	Per capita consumption (kg/year) 1970	Per capita consumption (kg/year) 1982	Percentage change in consumption	Percentage change in price
Cassava	27.4	12.8	−53.3	210
Rice	33.2	37.8	13.8	16.0
Potato	27.9	56.6	102.9	−4.3

Source: P. Pinstrup-Andersen and N. de Londoño, *Estudio de Consumidores de la Ciudad de Cali*, CIAT, Cali, Colombia, 1971; Nora de Londoño, personal communication, 1983.

Cassava post-harvest deterioration

Among the tropical root and tuber crops, cassava is unique in having such a restricted post-harvest life.[8] The deterioration in quality can be remarkably fast: sometimes roots become unacceptable for human consumption within 24 hours of harvest, although a 24 to 72 hour period is more usual.[9]

Cassava has a short post-harvest life because of the development of a blue-black pigmentation in the vascular tissues of the storage root accompanied by desiccation of the parenchymal (starch containing) cells. These combine to give the roots an unwholesome black or brown appearance, very unsatisfactory cooking qualities and a bitter taste. These pigmentation reactions are the result of complex physiological changes in the root tissues, which are initiated within a few hours of harvest,[10] and which require oxygen.[11] Hence moisture loss from root tissues acts to accelerate the deterioration reactions.[12] Areas of damage, where moisture loss is most rapid, are therefore the regions where deterioration first appears. The avoidance of root damage by careful harvesting and handling can, by itself, reduce the incidence of deterioration significantly.

In order to increase the storage life of cassava roots this physiological deterioration must be prevented. However, there is a subsequent, microbial deterioration, consisting of general rotting and tissue fermentation which develops in roots stored for longer than four to seven days. In some ways symptoms can be similar to those of physiological deterioration since the vascular pigmentation can also occur, but with a different distribution in the root tissues. Establishment of the root pathogens involved in rotting is aided by the presence of damage, giving the microorganisms easy access to the starch and sugar substrates of the root interior.

At present this microbial deterioration is rarely a problem since root acceptability is invariably affected previously by physiological deterioration. If this latter were prevented, however, a method for controlling this microbial problem would be necessary. Control of one without the other would hardly improve root storage life over the present one to three days.

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cosecha de Productos Agricolas en el Area del Caribe y America Central, Santo Domingo, Republica Dominicana, 1979, pp 1–7; D.G. Coursey and R.H. Booth, 'The post-harvest phytopathology of perishable tropical produce', *Review of Plant Pathology*, Vol 51, 1972, pp 751–765; Janssen, unpublished data, CIAT, Cali, Colombia.

[6]J. Lynam, 'Options for Latin American countries in the development of integrated cassava production programs', in Development Studies Centre Monograph No 11, Australian National University, 1978.

[7]J.K. Lynam and D. Pachico, 'Cassava in Latin America, current status and future prospects', mimeograph, CIAT, Cali, Colombia, 1983.

[8]R.H. Booth, 'Storage of fresh cassava (*Manihot esculenta*) I. Post-harvest deterioration and its control', *Experimental Agriculture*, Vol 12, 1976, pp 103–111.

[9]*Ibid*; C.C. Wheatley, 'Studies on cassava (*Manihot esculenta* Crantz) root post-harvest physiological deterioration', PhD thesis, London University, 1982.

[10]Booth, *op cit*, Ref 8; J.E. Rickard, 'Biochemical changes involved in the post-harvest deterioration of cassava roots', *Tropical Science*, Vol 23, 1981, pp 235–237; Wheatley, *ibid*.

[11]Booth; *ibid*; R.A. Noon and R.H. Booth, 'Nature of post-harvest deterioration of cassava roots', *Transactions of the British Mycological Society*, Vol 69, 1977, pp 287–290.

[12]J. Marriott, B.O. Been and S. Perkins, 'The aetiology of vascular discolouration in cassava roots after harvesting: association with water loss from wounds', *Physiologia Plantarum*, Vol 44, 1978, pp 38–42.

Effect of deterioration on cassava root marketing

Currently, no storage methods are used in the marketing of fresh cassava roots in Colombia. The rapid deterioration which occurs in the prevailing post-harvest ambient conditions effectively makes cassava storage impossible. Roots must be consumed within two days of harvest. In the case of urban markets, often distant from the producing regions, roots have to be handled within a very short time to reach the consumer before deterioration becomes visible. There is a substantial risk to the wholesalers and retailers that roots will deteriorate before they can be sold.

This necessitates a close integration of producer, intermediary, wholesaler, retailer and consumer, so that the daily demand can be transferred backwards down the marketing channel to the producer. Because of this reverse demand integration of the marketing channel, the following description will work from retailer to producer.

In Colombia, retailers often have established contacts with wholesalers. For example, the retailers in the Atlantic coast region trade in rather small quantities of roots – around 50 kg of roots per day – and travel daily to the wholesale market to purchase this quantity.[13] This is because (a) they do not want to risk being left with unsold, perishable roots, (b) they must make many small transactions each day and (c) they are dispersed throughout the town in order to facilitate shopping by housewives. A higher percentage of cassava than of other crops is sold in local neighbourhood markets despite the higher price found for cassava compared with large, central markets (Table 7).

Although retailers attempt to minimize the risk of having unsold cassava left at the end of the day, deterioration is a serious problem for them. They were, in fact, left with unsalable, deteriorated roots 14% of the time.[14] For them, cassava is a risky product with a high cost structure.

Urban wholesalers usually buy their cassava from rural intermediaries, without having to leave the town. These wholesalers also handle small volumes of roots per day (around 2000 kg in the Atlantic Coast region of Colombia). A wholesaler who buys 2000 kg a day and sells to retailers in 50 kg lots must make 40 transactions a day. These transactions are made in the early morning, allowing the retailer to sell the cassava during the remainder of the day. This, together with the risk of having unsold roots, effectively prevents him from increasing the quantity of roots handled.

Often, wholesalers will arrange future purchases and fix prices with rural intermediaries, who then organize producers' harvests to obtain the required quantity.. They offer prices to farmers based on the knowledge that the price with the wholesalers is already agreed. When agreement is reached between intermediary and farmer, the harvest is

[13]Cassava Economics, CIAT, unpublished survey material, CIAT, Cali, Colombia, 1983.
[14]*Ibid.*

Table 7. Percentage of total volume of cassava, potatoes and rice sold in neighbourhood shops and in the central market place in Cartagena, Colombia, 1973, compared with their price in each location.

	Neighbourhood shop		Central market place.	
Commodity	Percentage sold	Price/kg[a]	Percentage sold	Price/kg
Cassava	46	0.15	50	0.13
Rice	32	0.25	57	0.25
Potato	39	0.23	55	0.23

Note: [a] Prices in US$.

Source: CEIMA, *Estudio del Mercadeo de Alimentos*, CEIMA, Bogota, Colombia, 1973.

Table 8. Characteristics of the wholesale sector of Cucuta, 1973.

Wholesalers	Number of employees	Buying frequency (days)	Average purchase (tons)	Trade per wholesaler per month (tons)	Always buy at same supplier (percentage)
Grains, processed products	2.7	13.7	34.1	76	37.5
Potato	1.0	1.6	6.6	140	0.
Plantain/cassava	1.3	1.1	2.5	75	100.

Source: CEIMA *Estudio del Mercadeo de Alimentos*, CEIMA, Bogota, Colombia, 1973.

usually arranged for the following day, although sometimes longer-term agreements are made when demand is guaranteed. Thus it is clear that many people are involved in making small transactions: a feature which inevitably increases prices (Table 8).

Another factor contributing to high prices is related to the risk wholesalers and retailers face of having roots left unsold at the end of the day: deterioration could make them unmarketable the next day.

In order to avoid this traders will tend to order less than they expect to sell on an average day. Suppliers will be faced with an intermediate demand actually lower than the final consumer demand and will deliver a restricted amount of cassava onto the market. Oversupply in the market will thus be much less likely than undersupply and consequently daily prices above equilibrium level will be more likely than prices below equilibrium level (Figure 1). This mechanism also holds at the level of the rural intermediary: he will harvest a sufficient amount to cover his guaranteed sales and no more. It is possible that he will not be able to harvest a sufficient quantity of roots to meet this target (eg when

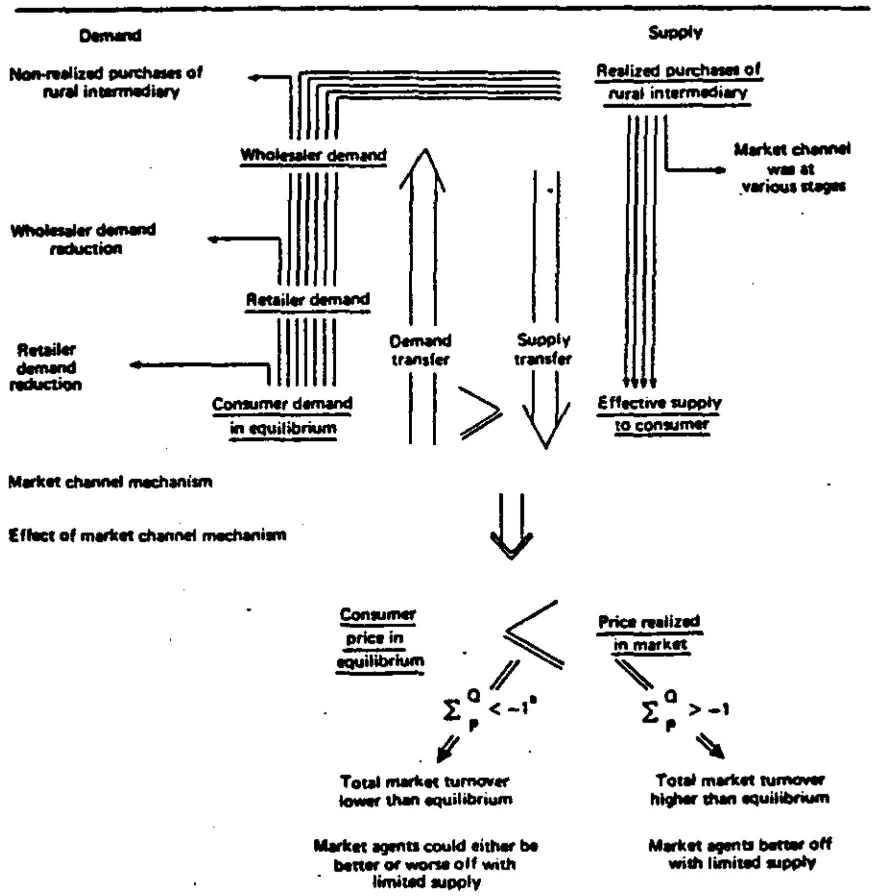

Figure 1. The demand mechanism of fresh cassava in Colombia and its effects on prices.

The upward arrows represent demand that is transferred, downward arrows are the actual amount of supplied cassava. Starting from consumers' demand in equilibrium, demand transfer decreases gradually and eventually less cassava than actually demanded reaches the consumer. This causes a price above the equilibrium level.

* $\varepsilon\,^{Q}_{P}$ = price elasticity of demand

$= \frac{\text{percentage change in demand}}{\text{percentage change in price}}$

harvests get delayed) but he will never harvest more than the needs. When the price elasticity of demand for cassava falls within a range of −1 to 0, a restriction of marketed volumes leads to higher money turnovers, favouring the marketing agents: they get more money for less work. Cassava price elasticity has been estimated at −0.8 and −0.96,[15] indicating that market restriction favouring traders could indeed be occurring in Colombia.

Deterioration thus puts pressure on the supply to be below the equilibrium level. Prices increase as a result, leaving traders with extra profits. This mechanism also explains why, while market prices are high, many farmers do not start growing more cassava: if they are not integrated into the market channels via the rural intermediaries they will be unable to sell their produce.

The negative effects of deterioration on the fresh market are twofold: the marketing channel has to be fast moving and labour intensive and the high risk involved with this crop diminishes the quantities marketed and causes price rises. As a result the marketing margin for cassava is very high, approximately US$0.30 a kilogram, ie 60% or more of the final retail price. The retail margin comprises US$0.12 to 0.20, the wholesale margin US$0.03 to 0.06 and the assembly-agents' margin US$0.05 to 0.12. Transport costs account for less than 20% of the total margin. For potatoes, a similarly bulky product produced at farms of similar size, a marketing margin of only 36% was calculated at US$0.13 a kilogram in Colombia during 1982.[16]

Advantages and disadvantages for consumers

In the rural areas cassava can often be 'stored' simply by harvesting plants only when required. In the town, however, where consumers must buy and eat cassava on the same day, the high cassava shopping frequency that this necessitates leads to increased consumer purchasing costs because of the often large distances between home and market-place.

These storage and market characteristics strongly influence the suitability of cassava for consumption by rural and urban societies This is shown in Table 9, where the relative advantages and disadvantages of cassava for rural and urban consumers have been compared with those of rice and potatoes by assigning values to 10 consumer demand factors.

Cassava is a very attractive crop for rural subsistence communities; it has a low price and production costs (see Table 1), ease of association with other crops and year-round availability. The deterioration problem is not severe in rural areas since roots can usually be left unharvested until required for immediate local consumption. The low nutritional value due to the poor protein content is only a problem when additional protein sources are absent. The available data on nutrition in Latin America suggest that this is not the case.[17]

In the urban market, however, the rapid perishability of the roots becomes a major disadvantage: because of the risk of large losses in storage, wholesalers and retailers need high marketing margins, which result in the roots being expensive for urban consumers. Low cassava production costs are completely outweighed by the higher marketing costs. The supply of roots may also vary throughout the year as storage to even out fluctuations in supply and demand is impossible. Finally, the

[15] L.R. Sanint, L. Rivas, M.C. Duque and C. Sere, 'Food consumption patterns in Colombia – a cross-sectional analysis of the DANE–DRI–1981 Household Survey', *Trends in CIAT Commodities*, 1984, pp 31–63, CIAT, Cali, Colombia; D. Pachico, W.G. Janssen and J. Lynam, 'Ex ante analysis of new technology: A comparison of cassava for the feed and fresh markets in Colombia', *Agricultural Systems*, Vol 11, 1983, pp 131–142.

[16] D.E. Van der Zaag and D. Horton, *Potato Production and Utilization in World Perspective with Special Reference to the Tropics and Sub-Tropics*, mimeograph, CIP, Lima, Peru, 1983, 41 pp.

[17] FAO, *Food Balance Sheets*, FAO, Rome, 1980.

Table 9. Comparison of the different characteristics of cassava, rice and potato in both rural self-producing and urban-purchasing communities.

Characteristics	Rural Cassava	Rural Rice	Rural Potato	Urban Cassava	Urban Rice	Urban Potato
Price[a]	5	3	4	3	5	3
Composition (nutritional quality)	2	4	4	2	4	4
Production[b] flexibility	4	2	3	na	na	na
Combination in the diet[c]	3	4	2	3	4	3
Availability through year	2	3	2	3	5	4
Perishability	4	4	3	1	4	3
Acquisition cost/ effort	na	na	na	1	5	3
Waste in preparation	3	3	3	3	5	4
Facility of preparation	4	4	4	4	4	4
Utilization possibilities[d]	5	3	4	na	na	na
Minimum size of consumption/purchase[e]	3	5	3	2	5	3

Note: [a] In rural societies this means production costs, especially cash expenses. In urban areas it refers to the retail price; [b] As regards inter- and mixed cropping, planting and harvest times and spread of labour needs through crop cycle; [c] Different ways in which it can be incorporated into a meal; [d] Different ways the crop can be processed; [e] Size of minimum purchase unit.

The scale used was: 5, good; 1, bad; na means not applicable.

Source: Cassava Economics CIAT, *Consumption Survey in the Atlantic Coast Region of Colombia*, unpublished data, 1983.

rapid perishability means that consumers must make frequent small purchases and still risk a considerable likelihood of deterioration before consumption. As a consequence of rapid deterioration cassava is more expensive than either rice or potatoes in urban areas (Table 10). The urban consumer regards purchase of cassava as involving considerable effort and risk. Thus while it is well adapted to rural consumption, cassava is out performed by almost all other major foodstuffs in urban areas.

All the above factors contribute to explaining the difference in cassava consumption per head found between rural and urban areas. For rural consumers who do not produce cassava themselves the situation is intermediate: they still face the high margin and the risk of deterioration, but to a more limited extent since marketing channels are shorter and quicker.

The emphasis placed on cassava in helping to feed expanding Third-World populations is based heavily on its production properties, but these are outweighed in urban communities by the marketing problems of fresh roots caused by post-harvest deterioration. In the last two decades urbanization has continued at a rapid rate in Latin America (Table 2), limiting the incentive to improve cassava cultivation for rural communities and reducing the advantageous impact of improvements

Table 10. Relative price and consumption of potatoes and rice in comparison with cassava in several Latin American countries.

	Potato Relative price[a]	Potato Relative consumption[b]	Rice Relative price	Rice Relative consumption
Brazil[3]				
Recife	3.19	1.06	0.66	13.0
Sao Paulo	2.15	8.18	0.35	115.0
Colombia				
Barranquilla	1.51	0.63	0.65	5.7
Bogota	0.85	3.06	0.43	7.18
Peru				
Lima	1.41	7.54	0.66	27.0
Venezuela				
Caracas	1.16	1.06	0.20	2.93

Note: [a] Price calorie of rice or potato divided by price/calorie of cassava; [b] Calories of rice or potato/calories of cassava.

Sources: Lynam and Pachico, *op cit*, Ref 7 for price data. For consumption figures, for Brazil: *Estudio Nacional da Despesa Familiar*, Secretaria de Planeamiento da Presidencia da Republica, Rio de Janeiro, 1977; for Colombia, ECIEL-studies, Brookings Institute, Washington, DC, 1978; for Peru, P. Lizardo de las Casas Moyas, *A Theoretical and Applied Approach Towards the Formulation of Alternative Agricultural Sector Policies in Support of the Peruvian Agricultural Planning Process*, PhD thesis, Iowa State University, IA, USA, 1977; for Venezuela, *Longterm Forecasts of the Supply and Demand of Agricultural and Livestock Products in Venezuela*, Consejo de Bienestar Rural, Caracas, Venezuela, 1965.

since the rural subsistence populations are relatively declining. An improvement in the production potential of cassava can only have a limited impact on its urban consumption as a fresh root since only 35% of the final urban price reaches the producer. To increase the role of cassava in the nutrition of the urban population of Latin America, a more direct and effective strategy would be to develop a solution to the problem of cassava root deterioration. In this manner, the marketing margin could be diminished and the attractiveness of fresh cassava roots to the urban consumer increased.

Prevention of post-harvest root deterioration

There are three aspects to the solution of the deterioration problem. One concerns the storage conditions which prevent the appearance of physiological deterioration, the second involves the inhibition of microbial growth and subsequent root rots which can develop during storage and the third relates to the correct handling and selection of roots before storage with the aim of avoiding damaged roots which will not store. It is essential, even for relatively short-term storage of only one week, that all three of these factors are taken into account. Together, they should not add greatly to the costs of marketing and should be simple to carry out with minimal capital costs because the producers of cassava tend to be small farmers with limited access to funds.

Some high-cost, high-technology storage processes have been developed for cassava which could be useful in the limited sphere of export markets, where the high product price would permit higher storage costs. Examples of this are paraffin wax coating of roots developed by IIT in Bogota, Colombia[18] and freezing of peeled, parboiled root pieces for supermarket sale. However, if there is a desire to introduce root storage into the normal fresh root marketing chain as presently operating in Colombia, a simple, low-technology method is required.

Before consideration of simple storage methods, the question of damage caused during harvest and handling must be considered: however effective the storage method may be, if broken or damaged roots are used the result will invariably be poor.

Both physiological and microbially-induced deteriorations tend to be initiated at points or regions of injury and subsequently spread to the rest of the root. When roots are separated from the plant, two points of injury are necessarily made, one at the distal and one at the proximal end. In addition, the bark is often damaged.

After harvest, careful handling of roots is crucial. Frequently, roots are piled up into heaps in the field – sometimes even thrown, not placed. The bark easily becomes damaged as roots rub against each other. An improved harvesting and handling process, in which roots were not subjected to the more damaging practices, would be a simple way of reducing the incidence of both types of deterioration without the use of costly inputs, as well as reducing losses due to broken, damaged roots which are currently unmarketable. The percentage of roots suitable for storage would also be increased.

Traditional cassava cultivators, who are principally subsistence farmers producing cassava for their own consumption, avoid the deterioration problem by harvesting a few plants at a time as needed. Where root storage is required after harvest, the usual practice is to

[18]L.E. Zapata and H. Riveras, 'Preservacion de la yuca fresca', *IIT Tecnologia*, Vol 115, 1978, pp 9–20, Bogota, Colombia.

rebury the roots in a trench, covering them with soil. This is rather unreliable because of the dependence on local environmental conditions and does not seem to be in widespread use.[19]

In a TDRI/CIAT project this reburial method was improved through the use of a straw lining, ventilation pipes and a drainage ditch. This worked well in less extreme tropical climates, but when temperatures inside the 'field clamp' structure exceeded 40°C, losses from microbial rotting were considerable.[20] The method has not been adopted on a commercial basis, because in addition to its relative unreliability, it does not solve the problem of marketing fresh cassava, since roots cannot be transported during storage.

The reburial, or field clamp, method relies for its success on the natural wound repair processes which the root itself initiates given the right conditions, namely high temperature (higher than 30°C) and high relative humidity (higher than 85%).[21] The root lays down a protective barrier over any injured tissues, effectively preventing moisture loss and air entry into the root. This takes approximately five days and completely inhibits the initiation of the reactions producing physiological deterioration, as well as providing a barrier against pathogen access to the starch substrate of the root interior. This curing process cannot, however, be completely effective if the amount of damage is too great: hence the importance of root selection prior to storage.

Unfortunately, the conditions needed to obtain fast curing are also favourable for the growth of microorganisms. Despite the physical barrier laid down over damaged areas, post-harvest root rots can rapidly develop. A method of controlling this must therefore be integrated into any method in which root curing is used.

The prevention of physiological deterioration by root curing has been used in the development of two simple storage systems with low-technology inputs which do seem to be suitable for fresh cassava marketing since, unlike the previous systems mentioned, storage is possible during transport and marketing operations.

In the first system,[22] roots were stored in wooden boxes packed with moist sawdust or other locally available materials. Roots could be stored successfully for from six to eight weeks and were of an acceptable quality for both human and animal consumption.[23] They did, however, have a slightly sweeter taste caused by a breakdown of the root starch to sugars. However transport costs are relatively high since box and packing material must also be transported. This method appears suitable for high-value export markets only.

More recently, trials of roots stored in plastic bags have proved successful.[24] The microclimate inside the bag is ideal for root curing: the roots themselves rapidly generate sufficient heat and humidity. However, a fungicide application prior to storage is necessary to inhibit the growth of microorganisms. If no applications are made, roots begin to rot only five to seven days after harvest. Of course, it is necessary to ensure that any fungicide used does not leave toxic residues in the interior of the root, although this is unlikely given the thickness of the peel layer.

Given good control of the microbial rotting problem, storage times of two to three weeks with losses of less than 5%, or only 1% after one week, are readily obtainable.[25] Roots maintain a fresh appearance both internally and externally and taste and texture after boiling are not altered, although there is a tendency for roots to taste sweeter after

[19] J.S. Ingram and J.R.O. Humphries, 'Cassava storage: a review', *Tropical Science*, Vol 14, 1972, pp 131–148; J.E. Rickard and D.G. Coursey, 'Cassava storage, Part I, storage of fresh cassava roots', *Tropical Science*, Vol 23, 1981, pp 1–32.
[20] R.H. Booth 'Storage of fresh cassava (*Manihot esculenta*), II: Simple storage techniques', *Experimental Agriculture*, Vol 13, 1977, pp 119–128.
[21] *Ibid.*
[22] *Ibid.*
[23] R.H. Booth, T.S. de Buckle, O.S. Cardenas, G. Gomez and E. Hervas, 'Changes in quality of cassava roots during storage', *Journal of Food Technology*, Vol 11, 1976, pp 245–264.
[24] D.D. Oudit, 'Polythene bags keep cassava tubers fresh for several weeks at ambient temperature', *Journal of the Agricultural Society, Trinidad and Tobago*, Vol 76, 1976, pp 63–66; J.C. Lozano, J.H. Cock and J. Castaño, 'New advances in cassava storage', in T. Breckelbaum, A. Bellotti and J.C. Lozano, eds, *Proceedings of the Cassava Protection Workshop*, CIAT, Cali, Colombia, 1978, pp 135–142; CIAT, *Annual Report*, CIAT, Cali, Colombia, 1982.
[25] C.C. Wheatley, unpublished material.

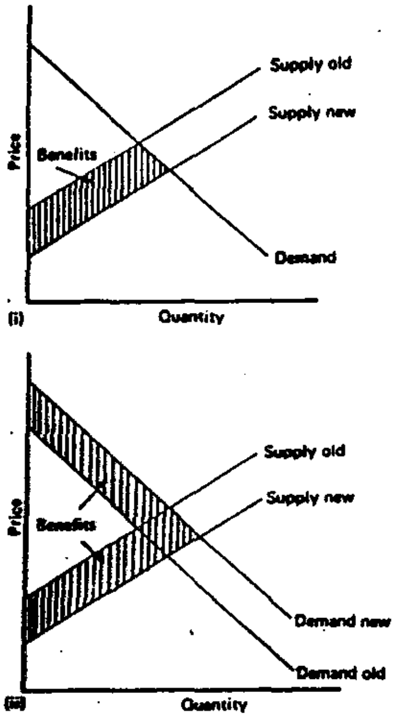

Figure 2. Effects of successful deterioration research on socioeconomic benefits.

(i) Decrease in the marketing margin **and subsequent** shift of supply function: **traditional case** of socioeconomic **benefits.**

(ii) Increase in the willingness to pay **because of** improved quality and decrease in the marketing margin and subsequent shift of supply function: non-traditional case of socioeconomic benefits.

more than two weeks of storage as the root sugar content increases slightly. Neither the amount of roots packed per bag, nor the bag thickness or colour has any effect. It is, however, important that roots should be packed within three hours of harvest. A longer delay allows physiological deterioration to start and curing is thus not completely effective. Root treatment and packing must be carried out in the field for this deadline to be met.

Plastic-bag storage has advantages over the other methods mentioned previously. It is the best adapted for integration into the current marketing system. With the additional costs of plastic bags (US$0.01 a kilogram) and chemical treatment (US$0.01 a kilogram) the traditional flexibility of the marketing chain is greatly improved. The two week storage time made feasible by this method is more than adequate to eliminate the problems of marketing fresh cassava.

Expected benefits from cassava storage technology

Eliminating deterioration of cassava in the fresh market through use of the storage technology discussed above will basically have two effects. First, the pressure on the market channel for quick handling and limitation of traded volumes will be relieved. As a consequence of storage technology the cost of commercialization will decrease. Thus traders can transfer back the final demand at a lower cost and, assuming open access to cassava trading, the marketing margin would fall. This should lead to increased consumption (see Figure 2(i)). In Colombia in 1982 the marketing margin for cassava was US$0.30 a kilogram. A maximum reduction of this marketing margin would be to about US$0.13, close to the marketing margin of potatoes (a similarly bulky but non-perishable crop). Taking into account the cost of the developed storage techniques (estimated at US$0.02 a kilogram) plus some extra labour costs it would be more reasonable to expect margins between US$0.18 and 0.23.

Second, the quality of cassava as a consumer commodity will be improved. If deterioration can be prevented a constant availability in the market place is more easily guaranteed. The risk of perishability at home will be small and no special items like refrigerators will be needed to store cassava. Waste due to deterioration developing between purchase and food preparation will be reduced. Purchasing costs will fall since the necessity to buy fresh roots every day will disappear. In this way, cassava would become a more attractive foodstuff for urban consumers who would be willing to pay more for it (Figure 2(ii)). Although almost all research tends to influence not only the availability of a product but also the quality, estimates of this effect are rare.

Consumer willingness to pay more for storable cassava is difficult to measure *ex ante* because of the highly abstract nature of the question and the difficulty for the consumer of making a reliable estimate of the fall in costs on cassava consumption. Instead three different values have been estimated for the increase in the willingness to pay (WNP): a zero increase, implying no growth in the WNP (ie the benefits calculation in its traditional form), a US$0.05 a kilogram increase, equal to a 10% increase in WNP; and a US$0.10 increase, equal to a 20% increase in WNP. The modest US$0.05 increase is probably the best of these estimates.

The benefits of successful storage technology were estimated with economic surplus theory.[26] In 1982 in Colombia almost 15 million people were living in towns of over 100 000 people,[27] where reduction of deterioration could have considerable effect on the marketing margin. The consumption of cassava in these towns was estimated at 10 kg per capita (40% down from the 1970 estimate). The price elasticity of demand was estimated at −0.88, the average of the two values mentioned before. Values of 0.5 and 1.0 for the price elasticity of supply were assumed.[28] Other assumptions were: linear demand and supply functions, a perfectly elastic supply of marketing services and a parallel shift in final demand and supply function through the application of storage technology. With these assumptions and using the method of Freebairn, Davis and Edwards,[29] the benefits of successful storage technology for the fresh market of Colombia would be between US$ 19 and 28 million per year (Table 11).

Consumption per head in the urban areas would increase from 10 kg to between 11.3 and 12.3 kg (Table 11, Projected consumption per capita). Prices at the consumer level would fall from US$0.47 to between US$0.45 and US$0.39 a kilogram (Table 11, Projected prices at retail level). Farm-level prices would increase from an average US$0.17 to between US$0.29 and US$0.24 a kilogram (Table 11, Projected prices at farm level).

In Latin America as a whole, fresh consumption of cassava is seven times greater than that in Colombia alone. The importance of rural versus urban consumption is similar to that of Colombia (Table 4). A rough estimate of total benefits for Latin America of cassava deterioration research then should be seven times the figure for Colombia, ie between US$133 and 189 million per year if the assumptions made for Colombia hold for Latin America in general.

[26]M. Curry, A. Murphy and A. Schmidt, 'The concept of economic surplus and its use in economic analysis', *The Economic Journal*, Vol 81, 1971, pp 741–799; R.D. Willig, 'Consumer's surplus without apology', *The American Economic Review*, Vol 66, 1976, pp 589–597.

[27]F.N.M. Hulsbosch, *Colombia*, Koninklijk Instituut Voor de Tropen Amsterdam, 1981, 77 pp.

[28]A. Pastore, 'A oferta de productos agricolas no Brazil', *Pesquisa e Planejamento*, Vol 1, 1971, pp 171–234.

[29]W. Freebairn, S. Davis and G.W. Edwards, 'Distribution of research gains in multistage production systems', *American Journal of Agricultural Economics*, Vol 64, 1982, pp 39–46.

Table 11. Effect of successful cassava-deterioration research in Colombia.

		Price elasticity of supply 0.5		Price elasticity of supply 1.0	
		Margin decreases to		Margin decreases to	
		0.18	0.23	0.18	0.23
Expected benefits (million US$/year)					
Willingness to pay (WNP):	0	18.89	10.74	19.17	10.84
	+10%	27.42	18.89	27.99	19.17
	+20%	36.35	27.42	37.31	27.99
		consumer benefits = 59.7%		consumer benefits = 74.8%	
		producer benefits = 40.3%		producer benefits = 25.2%	
Projected consumption per capita (present consumption = 10 kg)					
(WNP)	+ 0	11.29	10.76	11.60	10.94
	+10%	11.82	11.29	12.26	11.60
	+20%	12.35	11.82	12.93	12.26
Projected prices at retail level, (present retail price = US$0.47)					
(WNP)	+ 0	0.40	0.43	0.38	0.42
	+10%	0.42	0.45	0.39	0.43
	+20%	0.44	0.47	0.41	0.44
Projected prices at farm level (present farm price = US$0.17)					
(WNP)	+ 0	0.22	0.20	0.20	0.19
	+10%	0.24	0.22	0.21	0.20
	+20%	0.26	0.24	0.23	0.21

Note: Most reasonably to be expected values are underlined.

Strategy for increasing urban availability of cassava

Previous sections of this paper show that storage technology could have considerable impact on the urban fresh cassava market. Another, production-orientated (yield increasing) strategy would also be expected to have impact on cassava consumption in urban areas. Yield increases of 67% were estimated to benefit Colombia by approximately US$5 million per year.[30] An additional benefit of around US$2 million would be produced in the animal feed market. Thus, the expected value of storage technology could be four to five times that of production-orientated technology in Colombia.

In order to compare the relative advantages of these two different technological strategies, the cost of their successful introduction needs to be assessed. Basically, two major cost components can be distinguished: the research cost of designing appropriate technology and the cost involved in the actual introduction of this technology in the specific region under consideration.

Development of appropriate technology for yield-increasing research requires the identification of high-yielding, good quality cassava varieties integrated in a package of agricultural practices (such as land preparation, fertilization and weed control). Identification of high-yielding cassava varieties is highly complex, given the regional specificity of the different varieties. The development of an appropriate technological package is therefore a long-term activity, especially because of the generally poor development of national cassava research programmes. A simple, practical storage method has already been developed and tested, with only minor factors (such as bag size and optimum harvest procedures) still to be determined. Storage technology has given stable results over different environments, except for the socioeconomic factors involved. Thus, from a research point of view, regionally-adapted storage technology will be far easier to develop than productivity improvements.

Once appropriate forms of technology have been developed and tested, introduction into the target region can commence. Since almost every Latin American developing country operates a relatively successful agricultural extension service, the adoption of adequate improved production technology can occur through already established channels. Considerable experience with the introduction of agricultural improvements is available, suggesting that such new production technology will be disseminated rather easily, though perhaps slowly, to the user. To introduce storage technology however, new adoption strategies must be used. The technology has to be accepted by small farmers and traders. Whereas the first group can be reached through the extension service, traders might be difficult to approach. They are very rarely actively involved in development programmes and are often suspicious of any institutional action. However, their adoption of storage technology will critically depend on the acceptance of stored cassava by the final consumer.

For the final consumer, storage technology in plastic bags will change the appearance of the product. At present consumers are used to purchasing unpacked cassava often cut open as an indication of an undeteriorated state. Adoption of storage technology will necessitate purchase of roots in a plastic bag, preferably intact. Consumers also have to become aware that storage of cassava at home is possible if roots

[30] Pachico *et al*, *op cit*, Ref 15.

are kept inside the bag (bags must be resealed after removal of part of the contents).

The coordinated and simultaneous demonstration and introduction of storage technology to farmers, traders, retailers and consumers will be necessary. The use of consumer panels will enable the acceptability of stored roots to be judged and will provide a means of making consumers aware of this new 'product'. In-store experiments will serve the same purpose for traders and retailers. On-farm demonstrations of the storage technology will enable farmer interest to be gauged. Communication between the different test groups will be important in ensuring that the technology is adopted (traders will be aware of consumer willingness to buy and of farmer willingness to supply stored roots).

Information must also reach the general urban consumer, probably through the use of leaflets and the mass media: this will have marked similarities with a commercial product-release campaign rather than the usual low profile of most development projects, normally directed to market structure improvement. Personnel resources will have to be directed into non-traditional areas where government institutions lack experience.

Thus, although technology development and testing costs will be lower for storage research than for production research, the extension and market acceptability costs will be higher. The introduction lead time might well be shorter than for production technology, perhaps being comparable with normal industrial product-adoption lead time of two years.[31]

Improvements in storage technology will have a greater impact on the urban availability of fresh cassava than will production-orientated technology. The marketing approach required to achieve the adoption of this storage technology demands the use of unconventional development models. Subsequently, yield related technology, which has a longer lead time, will further improve fresh cassava supplies at reduced costs in urban areas. A combination of these two complementary research and development strategies should maximize the contribution of fresh cassava to improved urban nutrition.

[31]P. Kotler, *Marketing Management: Analysis, Planning and Control*, Prentice Hall, Englewood Cliffs, NJ, USA, 1976.