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CHAPTER XII CASSAVA: Post-harvest Operations

3. Overall losses and labour requirements

It has been established that the post-harvest system of cassava requires more labour than most other staple crops (IITA, 1996). One hectare of cassava containing 10 tons of roots (the average root yield in Africa) needs approximately 721 man-hours to harvest and process: of this labour, 212 man-hours are needed for harvesting, 156 for handling, and 353 for processing.

The Collaborative Study of Cassava in Africa (COSCA) has shown that in 67 percent of cases, cassava processing activities were carried out by women only compared to 6 percent of cases for men only. Women along with children participated in another 19 percent of cases, and in 6 percent of cases women worked alongside men. This represents 92 percent participation by women in cassava processing (Nweke, 1994). However, the number of men involved in cassava processing increases as the opportunities for commercialisation increase (Ugwu and Ay, 1992). Although men are seldom involved in cassava processing operations, they tend to perform more of the heavy-duty farm operations. It was observed that as mechanised processing equipment (such as graters and mills) is acquired, men's participation in cassava processing tends to increase, since they often control and operate these machines. It appears therefore that gender role in cassava processing tends to change as processing becomes more mechanised.

With such a large number of processing steps, the opportunities for food loss in the whole system also become numerous. Major losses occur during processing (23.2 percent), harvesting (13.6 percent) and handling (8.5 percent). Harvesting losses are higher during the dry season because it is more difficult to dig; roots break and remain in the soil. The size, shape, hardness, moisture content and the type of equipment used affect the processing efficiency. Recently, IITA has assembled a technology package for cassava processing in rural areas (IITA, 1996). The package, which is in the form of a village processing centre, contains a chipping and grating machines, a pressing device, a mill, a gari fryer and sifters. Such package has been tested and found to reduce food losses during cassava processing from 22.3 percent to 10.1 percent and the labour input from 295.2 man-hours to 87.6 man-hours per 10 tons of cassava roots (See Figure 6).

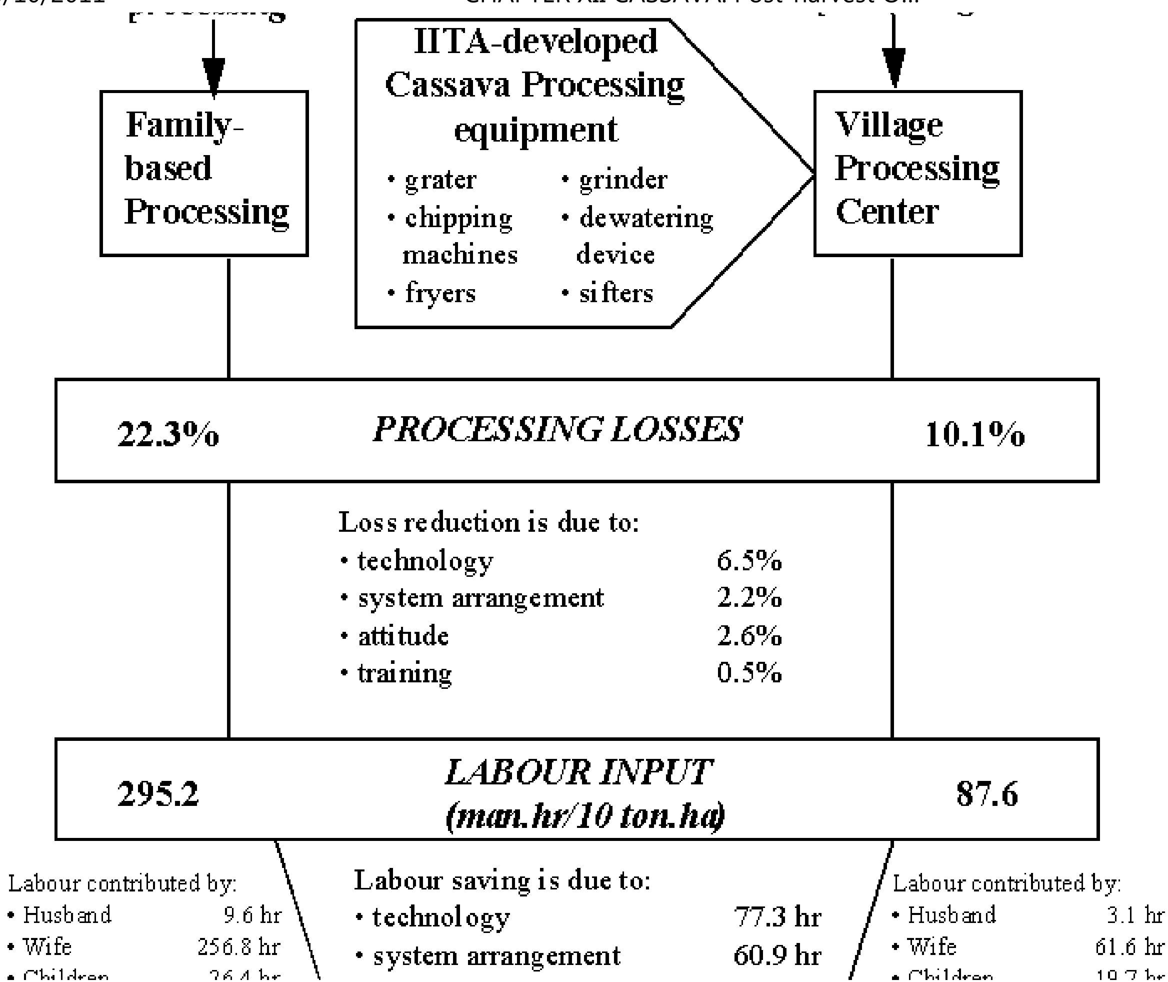
IITA-developed Cassava Processing equipment
• grater
• grinder
• chipping machines
• dewatering device
• fryers
• sifters
Family-based Processing
Village Processing Center
22.3%
PROCESSING LOSSES
10.1%
Loss reduction is due to:
• technology 6.5%
• system arrangement 2.2%
• attitude 2.6%
• training 0.5%
295.2
LABOUR INPUT (man.hr/10 ton.ha)
87.6
Labour contributed by:
• Husband 9.6 hr
• Wife 256.8 hr
Labour saving is due to:
• technology 77.3 hr
• system arrangement 60.9 hr
Labour contributed by:
• Husband 3.1 hr
• Wife 61.6 hr

Figure 6. Effect of improved cassava processing on labour requirements and post-harvest food loss in the cassava post-harvest system. (Source: IITA, 1996).

A food exchange scheme based on the improved cassava processing technology package was tested in rural Nigeria (IITA, 1996). Using traditional methods, a family normally obtains 12 kg of gari or 18 kg of *lafun* per 100kg of fresh roots; using the new technology, the yield is 14 kg of gari or 20 kg of *lafun.* In the food exchange scheme, women bring their cassava roots to the processing centre and receive 12 percent of the roots weight as gari or 18 percent as lafun. They get what they would have obtained should they have processed the cassava by themselves. Moreover, the product they receive is also of better quality. The processing centre keeps the 2 percent of extra product and uses it to cover its processing and maintenance costs. Benefits to women are labour savings and improvement in food quality. They have more time to devote to other chores, to leisure or to self-advancement. The processing centre is also an employment opportunity and source of income for women who are employed there. The food exchange scheme has shown that it can significantly improve the quality of life in a rural community.

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5. Economic and social considerations

In the last 25 years, the world cassava production has been growing at over 2 percent per year. The crop has demonstrated its ability to provide food security to populations in the tropical world, particularly in Africa, that were faced with severe drought, civil unrest or economic breakdown. It has shown in Thailand that it can be a major foreign exchange earner and a building block for industrial development. In Latin America, particularly in Brazil, cassava has proven to be a reliable raw material for the food manufacturing industry and for animal feed production.

Recently, cassava production in Africa has been increasing at rates (4.2 percent) exceeding the population growth rate (see Table 6). In addition to playing its traditional role of providing food security and low cost food, cassava can be promoted as a modern food ingredient and as a modern input in the growing agro-industrial sector, thus raising farmers' income. The demand for animal feed (particularly poultry feed) is expected to increase in the next five years (FAO, 1997); production of starch and alcohol from cassava in Nigeria is only meeting 10 percent of the demand or less. Other African cassava producing countries are almost completely dependent on importation to meet their starch and alcohol needs.

To facilitate the adoption of cassava as viable raw material, the highly perishable cassava roots need to be transformed, as closer to the farm as possible, into stable products with a longer shelf life and lighter to transport than the fresh roots. Such product can be cassava chips or cassava flour. Its production technology is simple and inexpensive and can be adopted by farmers. In Nigeria, small-scale farmers have formed associations for processing cassava into flour that is sold to biscuit factories. Others are producing chips for the ethanol factory. In Ghana, there is a burgeoning cassava chips export market.

Due to policy changes in the European Community, cassava exports from Thailand to Europe have been declining, forcing Thailand to develop and expand its domestic utilisation of cassava. Food and non-food industries are steadily increasing their uptake of cassava (Titawatanakun, 1996). However, because of the large volume of cassava that is exported, domestic cassava prices in Thailand are determined by export prices. There is great pressure on Thai entrepreneurs to develop the most efficient cassava-based processes in order to remain in business.

In Africa, Asia and Latin America, the cassava post-harvest sector need to be relied upon to ensure that cassava continues to provide food, feed and industrial raw materials. Cassava research and development efforts should be expanded if cassava is to meet such expectation in the next millennium.

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CHAPTER XII CASSAVA: Post-harvest Operations

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7 Annex

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CHAPTER XIII PLANTAIN CASE STUDY: POST-HARVEST OPERATIONS

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1. Introduction

Post-harvest systems differ fundamentally depending on whether commodity is meant either for consumption in its production area, or for export at international or intercontinental levels. Procedures are linked to various factors:

- Fragility of the product;

- Importance of the relative values granted to quality criteria;

- Existence of recommended and established norms;

- Eating habits;

- Utilisation of sub-products of the commodity;

- Consumer revenues;

- Cultural data.

The evaluation of the system after harvest should consider the type of market.

In the export channels meant to supply remote markets (such as plantain export circuits from Central America to the United States or from Africa to Europe), the product is subjected to the specifications and taste preferences of importers:

- Calibre of fruits;

- Cleanliness;

- Identification of the origin of the commodity;

- Packaging in cartons.

The selling price of the packed and dispatched plantain is meant to encourage producers and exporters to maintain or even improve the quality of their products.

Goods appreciate in price according to its presentation in packaging (packaging is the first criteria that can be observed) and agronomic characteristics. When the product does not adhere to export norms, it is put aside and often enters the local commercial channel.

The different actors of the traditional channel grant a relative and secondary importance to the packaging of the commodity. The most important point here is availability of the product for consumption. The post-harvest system does not place much importance on the state of the product.

Cooked banana plantains are food crops, in Africa mainly consumed in their production areas.

The typical observer often thinks that the rough handling of the crop creates the important losses of the harvest. Logically this would indicate scant availability of this food for consumers with a corresponding drop in revenues of the sellers.

The traditional channel is old using local practices. Actions intended to improve this situation have been confronted with problems. Custom and habit block application of methods used in the international export of dessert bananas.

The evaluation of losses after harvest in traditional channel based on the criteria of international export of banana often leads to exaggeration of the issue.

Despite the importance of plantain and the socio-economic role it plays, post-harvest practices are somewhat identical from country to the country, from continent to continent.

The most recent survey shows that after harvest, physical losses are limited (Kuperminc, 1985; Lendres, 1990 ; N'da Adopo, 1992 and 1993) to scarcely over 5 percent.

Several factors explain this situation:

- Production areas are either locales with great demand, or are not far from them. The product arrives at the market before being unfit for consumption;

- Plantain is consumed at all stages of ripeness. Even those eliminated as a result of rough handling are collected and used. The declassified fruit that is no longer purchased by a category of consumers is sold to poorer people. Beside the standard distribution professionals, there are auxiliary sellers who introduce damaged fruits in a sub-market: Hence everything is eventually recovered;

- There is no excess of plantains when compared with actual eating needs. Plantain is part of food crop production (See Tables 1);

- The producer manages the clusters for his own consumption and does not harvest important quantities of plantains if he thinks that he will not be able to sell them;

- The means used by the intermediary for the acquisition of clusters from the producer and their transport to the consumption market prevents him from accepting the loss of this commodity.

Post-harvest loss of the plantain is generally restricted to the decrease of the commercial value as compared to expected gains.

Table 1. Per capita consumption of the main food crops in Côte d'Ivoire from 1985 to 1990 (kg)

Year	Rice	Maize	Other cereals	Gnam	Cassava	Plantain	Cocoyam	Groundnut	Wheat
1985	57,8	28,7	2,4	118,2	97,2	67,7	8,2	7,0	3,7
1986	58,4	28,6	2,4	115,6	96,8	68,3	8,0	7,0	3,8
1987	59,0	28,5	2,4	113,0	96,4	68,8	7,9	7,1	3,8
1988	59,6	28,4	2,3	110,4	96,0	69,4	7,7	7,1	3,9
1989	60,2	28,2	2,3	108,0	95,6	69,9	7,6	7,2	3,9
1990	60,8	28,1	2,2	105,6	95,2	70,4	7,4	7,2	4,0

(Source: Food crops consumption estimates, July 1987, Statistical office, Ministry of Rural Development

The most obvious losses occur in field. The reasons for this are:

- There is no one available to buy non-harvested clusters;

- Loss of potential production due to decrease in yields, destruction of banana trees by hurricanes, parasites, pests and poor soil. (See Figures 1 and 2). These losses increase with the age of the plantain and can be significant (See Tables 2, 3 and 5).

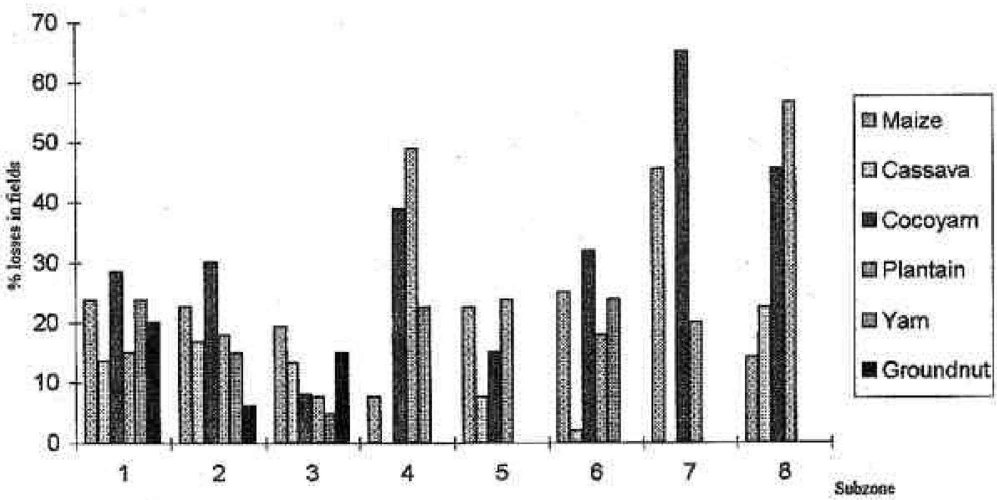


Figure 1: Percentage of some food crops losses in fields in 8 subdivisions of Fako zone, South - west District of Cameroon (TLU, IRA-Ekona, 1987)

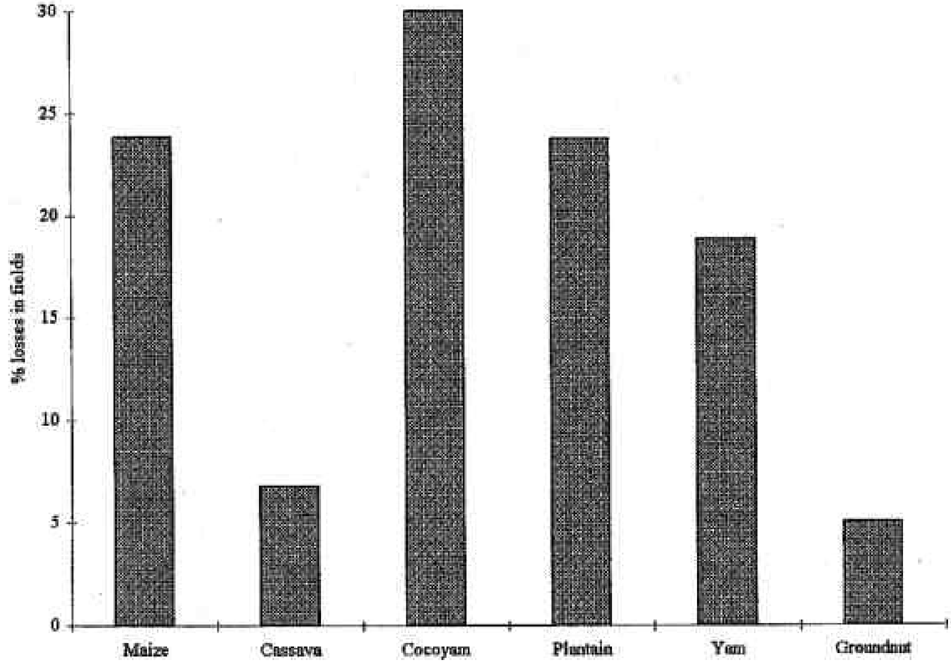


Figure 2: Average percentages of field losses of some food crops in Fako zone (Cameroon)(TLU, IRA-Ekona, 1987)

Table 2: Estimated losses of plantain plants based on age of the plantation (agricultural sector of Kunda Southwest Cameroon)

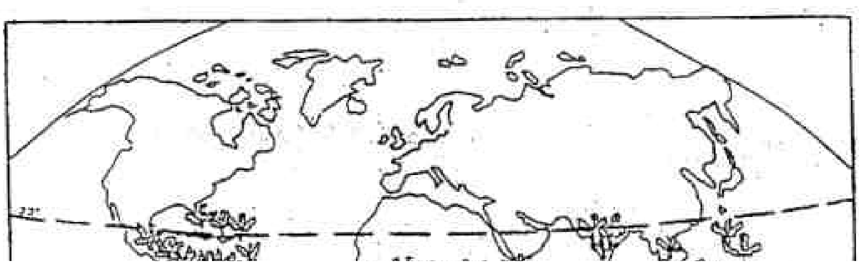
Cropping cycle	Parasites and wind	Mechanical destruction
1	2 - 5	Accident
2	10 - 25	_ 2%
3	20 - 50	

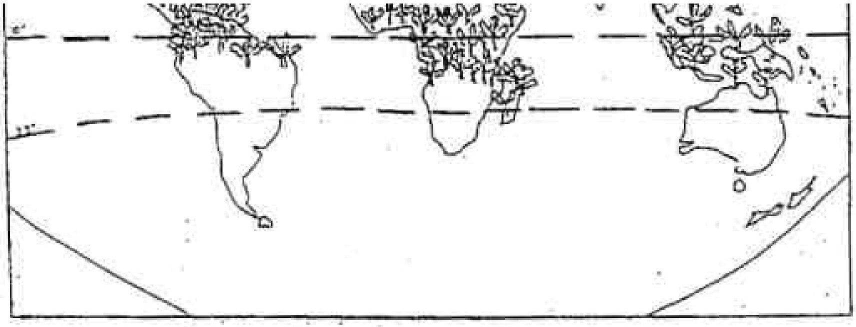
Table 3: Estimated percentages of seasonal distribution of plant decreases caused by hurricanes, compared to all damaged plants (Kumba Zone, Southwest Cameroon)

DRY SEASON	WET SEASON
November - March	April - May June - October
5 % maximum	20 % 95 % 80 %

The channel should be viewed as a global design where methods are balanced with eating habits, the means and tradition. (See Figures 3 and 4).

a) In the world





b) Main regions in Africa

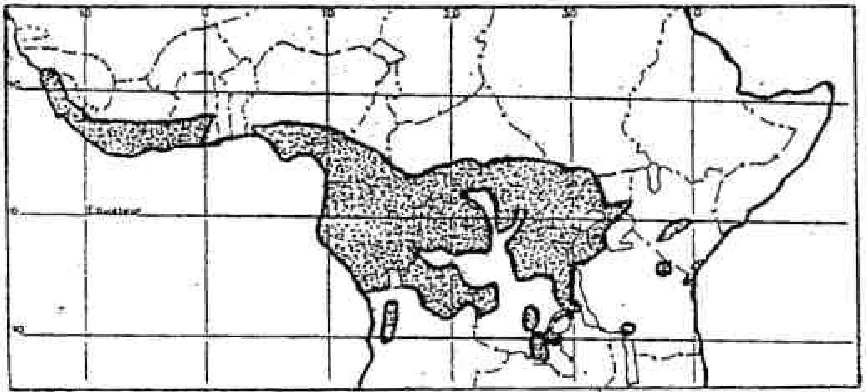


Figure 3: Regions producing bananas plantain in the world and in Africa

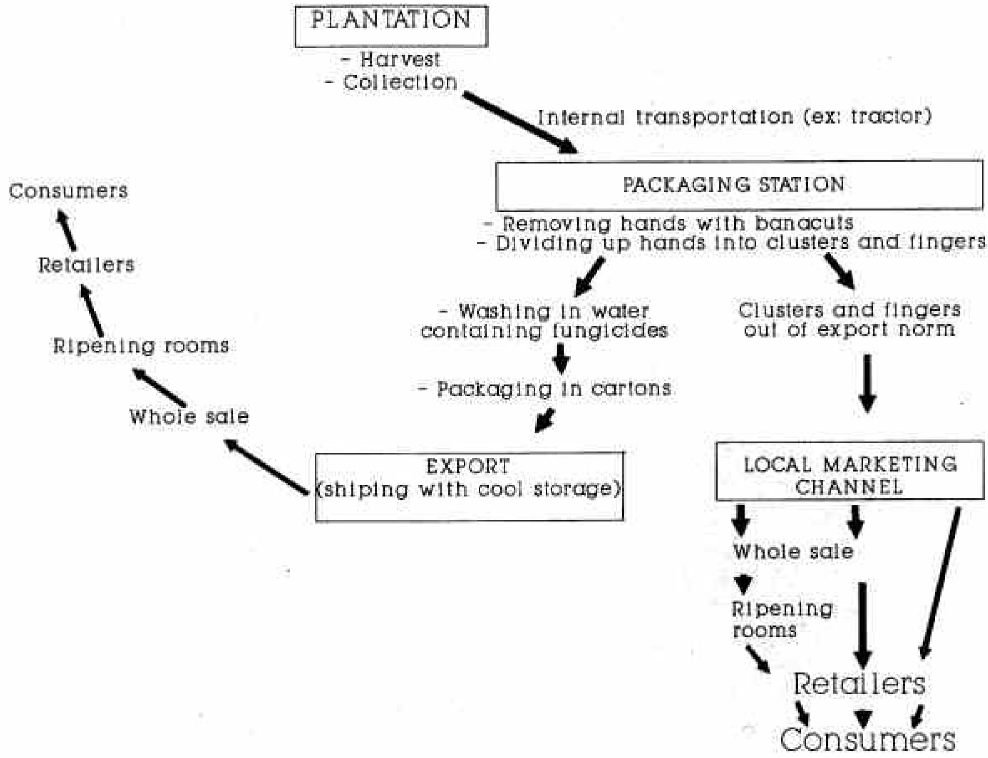


Figure 4: Summary of operations in banana export trade

At the farm level, men (often husbands) manage the commercialisation of the plantain in the field while the product is abundant.

Women are more numerous than men in the distribution circuit. If wholesalers are the sector where men are most represented (more than 50 percent), retail sale of the clusters and fingers is largely dominated by women (more than 95 percent of retailers in Africa).

Mainly adults participate in the distribution of the crop. One often encounters in markets, sedentary retailers more than fifty or 16 years old maximum (See Figures 5a-c). Activities require many trips to visit farms for many days to collect the product, negotiate with carriers, which are accomplished by the most young and vigorous age group. Typical handlers are young men (See Figure 6).

Figure 5a+b+c: 
Commercialization takes place in the lorry during unloading

Figure 6: 
Harvesting bananas for modern trades (export). One handler to cut with a machete and the other to receive the bunch carefully (Simmonds, 1959)

1.1 Economic and social impact of the crop

The classification of banana trees is based on the hypothesis that all edible bananas come from two parents, two species of the *Musa* type: *Musa acuminata* (AA) and *Musa balbisiana* (BB). These two fertile species crossed in the wild state. Letters A and B designate the ploid and composition of gene in these parents (Simmonds, 1959; De Langhe, 1976; Rowe, 1976). The absence of meiose at the level of female gametes caused the formation of AAA, AAB, ABB triploids and even tetraploids (See Figure 7) (Champion, 1976).

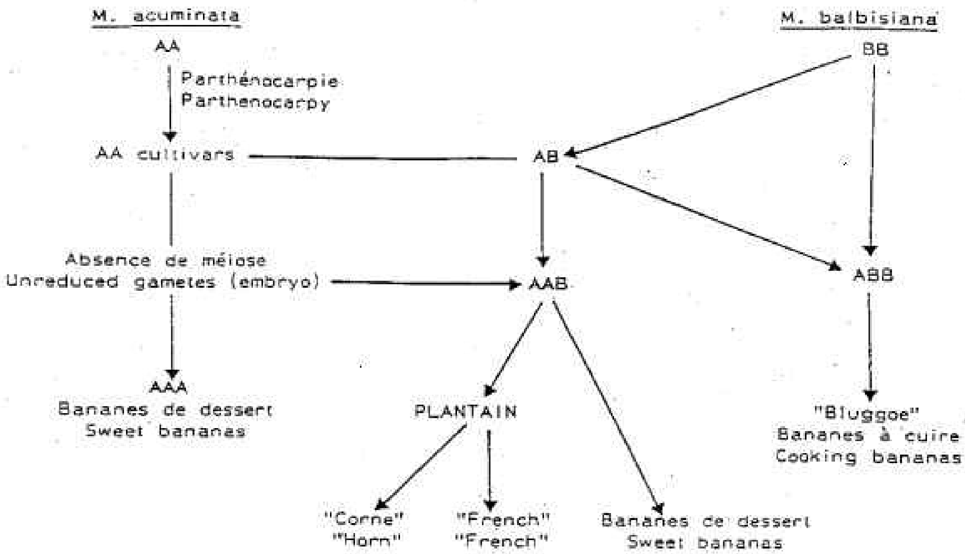


Figure 7: Schematic way indicating origin of bananas and plantains, by Champion (Fruits, Vol. 31, no 9, 1976)

True plantains are triploids AAB, and divide themselves into *French plantain* and *Horn plantain*. Within these two types, there are a great many varieties (cultivars) grown. The *French* plantain cluster possesses a persistent male axis, whereas that of type *Horn* is absent or degenerates quickly after flowering. Several clones of these plantains differentiate themselves mainly by the number of hands, the size of the fruit and the cluster. It is possible to find small, medium, giant French, false and true Horns (See Figure 8). In broad terms, plantain refers to all cooking bananas (ABB).

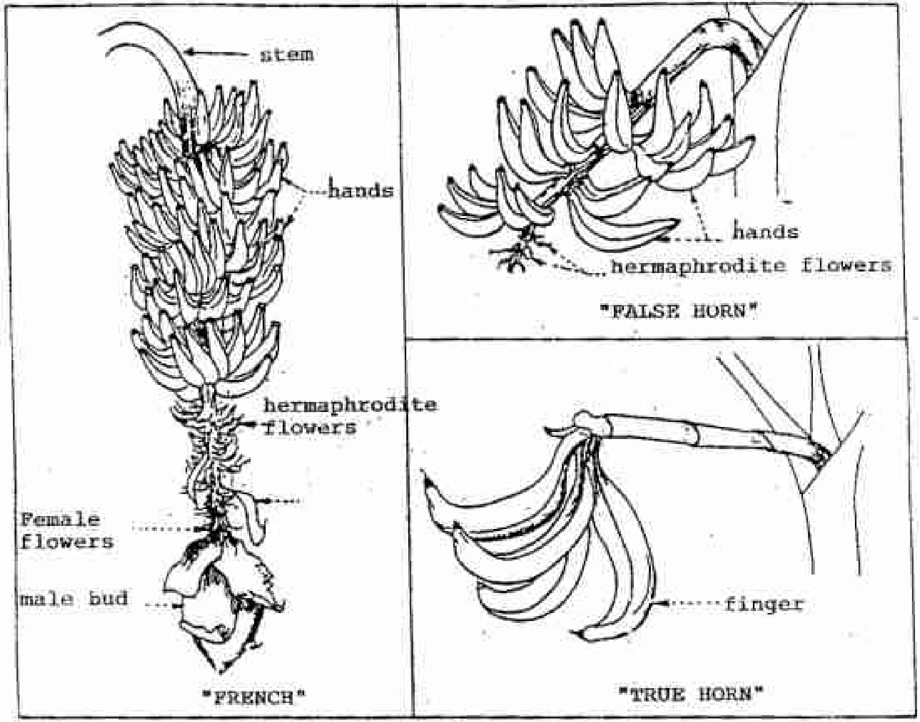


Figure 8: The 3 major types of plantain bunches
(source: Fruits, Vol. 38, no 6, 1983)

False Horn and true Horn are found extensively in Côte d'Ivoire (at least 90 to 95 percent of the production). The French species comprise 50 percent of plantains in Cameroon. Rwanda and Burundi are important producers of cooking bananas and of cultivars used for preparing local traditional «beers» called beer bananas.

Table 4: Characteristics of some plantain and cooking bananas

Groups	Name allocated	Length of cycle (forest zone)	Size	Sensitivity to wind	Sensitivity to the black stripes diseases	Drops out	Number of hands per clusters	Productivity	Utilisation
Great French	Essong, Ovang, Zue, Ekon	15 to 18 months	big	very sensitive	sensitive	weak	8 to more than 10	very good	fried, boiled
Medium French	French sombre, French Claire, Elat	12 to 15 months	medium	sensitive	sensitive	good	6 to 8	good	fried, boiled
Dwarf French	Njockkon	18 months	small	a little sensitive	sensitive	very weak	8 to more than 10	good	fried, boiled
False Horn	Big Ebanga, Bâtard, Ebang, Mbouroukou	less or equal to 12 months	medium	sensitive	sensitive	good	4 to 7	medium	roasted, pounded
	One (two or								

True Horn	One (two or three) hand plantain	12 months	medium to large	sensitive	sensitive	medium	1 to 3	weak	fried, boiled
Other cooking bananas	Pelipita, Assubu, Baro Baro, Bluggoe Fongamou, Cacambou Popoulou	12 to 5 months	medium	a little sensitive	good resistance to sensitive	good	6 to more than 10	good	fried, boiled (as plantain)
Hybrids to cook	FHIA 1 FHIA 3	14 months 12 months	medium medium	great resistance great resistance	good resistance a little sensitive	medium good	9 8 to 9	good very good	fried, fried

(Source: Le Courrier of C.R.B.P., n_ 38 September 1994, Cameroon)

1.2 World trade

World production of plantain was estimated in 1985 at 25 million tons. Of this 16.6 tons was projected for Africa; Latin America was the second place producer at 4.1 millions of tons (FAO, 1987).

Plantain cultivation is not limited to big plantations but is often grown in small orchards which sometimes go unnoticed (WILSON, 1983). The usual production takes many forms (Chataigner, 1988):

- Next to or behind the home in a garden (generally a maximum of 50 plants),

- On cleared forest, or on swaths in association with other food production (coffee, cocoa).

These fields represent at least 95 percent of cultivation.

They are of modest size as growing areas vary from 0.5 to 4 ha (Tlu, Ira-Ekona, 1987; N'guessan et al., 1993).

Plantain is usually cultivated first for self-consumption, in random form, in rotation followed by fallow. The surplus of available production is sold.

In this crop system of extensive cultivation, densities measure a maximum of 1000 plants to the 1666-advocated yield. Yields are from 3 to 54 tons/hectare. Peasants who use low technology input on poor soil grow the lowest limit. Invariably, technology with high inputs, intensive production to obtain high yields is rarely transferable to peasants due to required initial funding required (WILSON, 1983).

High technology in the pure culture of plantains is rather uncommon in Africa. It is extended to the Caribbean and Latin America who are oriented to export trade.

In despite of its increases, production for export represents a very small proportion of the harvest.

The types of distribution are:

- Traditional. Plantains are sent from efficient producing countries to others that produce little or no banana crops. These are mostly border countries: Cameroon to Gabon, Côte d'Ivoire to Burkina Faso;

- Modern (Packaged in cartons). Plantains are sent to North America and Europe. Latin America has a long history of this export and big plantations are dedicated to trade. Andean zone is the biggest producer in the American continent, but export is only 4 percent of production (Lescot, 1993).

The marketing of the production in the Southwest district of Cameroon, stems from five principal productive strategies (TEMPLE and al., 1983):

- Subsistence strategies where small family production is used for the household food-supply;

- Pioneer strategies of migrant farmers who are in zones, which grow plantains;

- Firm strategies where farmers have consolidated their cultivation extension process;

- Diversification strategies of farmers often with a main non-agricultural activity who try to invest in plantain;

- Food-producing strategies in garden or small food-growing plots to supplement family food supplies.

These strategies depend on four variables:

- Objective of the farmer;

- Structure of production;

- Cultivation system;

- Marketing process.

Table 5. : Economic viability of production systems (cost per hectare)

	Extensive forest system (1st cycle)	**Extensive forest system (3rd cycle)**	**Intensive system (1st cycle)**
Production			
Number of plants sown	900	900	1666
% of harvested plants	95	40	90
Weight of cluster (kg)	9,3	8,0	8,0
Production (kg)	7 951	2 880	11 995
Value (FCFA)	**214 677**	**77 760**	**323 865**
Changing price			

Drops			
Number	900	225	1666
Value (F CFA)	45 000	11 250	83 300
Insecticide			
Quantity (kg)	0	0	33
Value (F CFA)	0	0	82 500
Total cost (FCFA)	**45 000**	**11 250**	**165 800**
Gross (1) (FCFA)	**169 677**	**66 510**	**158 065**
Labour (days)*			
Clearing	25.0	7.0	0.0
Making holes	15.6	4.0	29.0
Sowing	9.4	2.3	17.3
Weeding	22.5	15.6	41.7
Treatment	0.0	0.0	1.3
Harvest	40.6	17.0	71.5
Total (2) (F CFA)	**113.1**	**45.9**	**160.8**
Productivity per working day	**1 500**	**1 449**	**983**

(1)(2) (F CFA)			

***Note**: Technical coefficients are derived from surveys under actual conditions. The cost retained for plantain is 27 CFA/kg, average price over the production period from September to May at the field border 100 FCFA = 2 FF (French Francs). The duration of a working day is 5 hours. The time of clearing (semi-mechanical) is 51 working days spread over 3 years. Drops or losses are defined as number planted per hectare in the first cycle and number of replacements per hectare Fr the second cycle.

Source: TEMPLE et. al., 1993

The requirement for labour per hectare for the plantain is smaller than that required for most tropical species (See Table 6).

Table 6. Labour requirement for tropical crops

	Plantain	Cassava	Maize	Rice
Day labour /ha	80	310	122	162
Days work/ton	20	31	122	62

Source: Johnston, 1958

The most extensive systems of production could hardly challenge in the short term the present forestry system (TEMPLE and al., 1993).

Table 7: Evolution of plantain production in the most important producing countries between 1971 and 1979 (in thousands of tons) (*)

					% variation
	1971	1977	1978	1979	(1971-1979)
World	16 05	19 536	20 275	20 584	28
Africa	10 404	12 640	13 011	13 285	28
Cameroon	694	950	950	955	38
Gabon	807	1100	1150	1200	48
Guinea	177	212	220	222	25
Côte d'Ivoire	653	750	800	800	23
Kenya	168	205	215	225	34
Nigeria	1635	2000	2100	2150	30
Rwanda	1656	1896	2043	2127	28
Tanzania	539	746	733	746	38
Uganda	2650	3100	3192	3192	19
Zaire	1191	1433	1405	1420	18
North and Central America	1237	1418	1519	1464	18
Cuba	60	130	134	134	123
Dominican Republic	529	531	610	550	4

Haiti	189	198	198	162	5
Honduras	110	153	160	162	47
Puerto Rico	101	102	101	100	35
South America	3210	3897	4255	4336	35
Bolivia	100	153	165	173	73
Colombia	1619	1844	2192	2236	38
Equador	445	770	796	790	77
Peru	654	700	705	742	13
Venezuela	363	406	372	369	2
Asia	1197	1577	1486	1495	25
Burma	406	501	404	425	5
Philippines	402	270	270	270	(-33)
Sri Lanka	389	806	775	800	105

(*) Countries producing more 100,000 tons per year. Source FAO, 1979.

In many producer countries, plantain is used for consumption. Global data often conceal the importance of consumption in certain regions. Consumption is generally highest in producing zones (Melin and Djomo, 1972; Guillemot, 1976). Recent studies indicate that consumption is increasing in urban areas, except within principal production regions (Sery, 1988).

Table 8: Plantain and cooking banana production and utilisation world-wide by region and Africa by country (FAO, 1985)

REGION/COUNTRY	PRODUCTION (`000 t)				
	Total	Export	Feed	Food	Processed
AFRICA	12867,0		28,9	8194,5	2387,6
Cameroon	970,0			630.0	
Central African Republic	65.0			52.0	
Congo	62.0			55.8	
Gabon	170.0			161.5	
Ghana	450.0			585.0*	
Guinea	235.0			188.0	
Guinea Bissau	25.0			20.0	
Ivory Coast	850.0			680.0	
Kenya	225.0			216.8	
Liberia	32.5			29.9	
Malawi	17.5			15.8	
Nigeria	1420.0			1420.0	
Rwanda	2200.0			534.0	1600.0
Sierra Leone	25.0			23.8	

Tanzania	1000.0		20.0	730.0	100.0
Uganda	3410.0			1700.0	511.5
Zaire	1480.0		8.8	1147.0	176.1
ASIA	1718.0			1288.3	
N/C AMERICA	1615.1	23.9	87.9	1119.0	
S AMERICA	4036.9		311.1	3258.3	
OCEANIA	1.3		0.3	0.8	

*Numbers includes imports.

Table 9- Estimated annual per-person consumption of starchy staples in many countries of the tropics (FAO. 1971)

Country	Per-person consumption (kg/year)			
	Plantain*	Cassava	Yam	Maize
Brazil	39,3	55,5	--	19,2
Cameroon	76,5	104,0	39,8	48,6
Colombia	61,5	21,4	6,0	16,6
Costa Rica	31,2	6,2	--	54,9
Congo	24,6	241,7	--	3,3
Dominican	143,4	27,4	4,5	7,0

Republic				
Ecuador	65,0	12,4	--	7,3
Gabon	153,6	192,8	52,5	3,6
Ghana	80,7	104,8	97,2	35,5
Haiti	75,1	23,2	4,3	47,3
Ivory Coast	99,5	71,7	166,3	38,7
Puerto Rico	27,0	1,9	4,2	2,3
Rwanda	296,8	15,8	--	12,8
Tanzania	86,8	19,5	--	50,7
Uganda	237,2	95,7	51,6	14,7
Zaire	62,7	264,4	16,2	15,0

* Numbers for Costa Rica, Dominican Republic, Rwanda, and Uganda include banana.

1.3 Primary product

The traditional consumption almost represents the usual form of utilisation. Plantain is consumed regardless of its ripening stage. The green or ripe fruit is boiled in water, chopped up or pounded into a homogeneous paste and may mixed up with peanuts, cassava or yam.

Riper plantain is fried in oil after being chopped, mashed or mixed with wheat, cassava or maize flour. The pulps may be cooked by wrapping them in banana leaves. Plantain can also be toasted or dried up.

There is an abundance of recipes for plantain. Naturally certain plantain varieties are preferred to others for different dishes. For example, True and false Horn with bigger fingers are mashed more often than French plantain. The latter are used in recipes that call for chopped plantain. The ripe fruits are used in making traditional wines in Central Africa.

Beyond the usual alimentary utilisation, the different parts of the plant or the fruit are used in traditional medicine in West Africa:

- The coal obtained from the burnt skin of the fruit is used to cure dysentery;

- The juice obtained after cooking the green fruits is recommended for urinary incontinence;

- The ashes of the burnt skin, after being mixed with some water and strained with a low fire, provide a potash which is used in medicines, soap works, and in sauces.

Industrial level chip manufacturing is done in Latin America (Badia, 1985). Chips are more and families in Africa make more. These are sold in the streets or by small and medium companies, which deliver them to supermarkets.

The pulps can be transformed into flour and may be used in various dishes such as nursing porridge (Kiyingi, 1985). The pulps of the ripe fruit can be used in making industrial alcoholic drinks such as wines and liquors.

1.5 Requirements for export and quality assurance

Quality criteria are taken into account when fixing prices at all stages of commercialisation. Quality is judged by objective and subjective criteria, which are likely to change from one region to the other. The opinions of the specialists in the field cover characteristics:

- Cooking flavour and eating habits;

- The physiological maturity at harvest (for example, the degree of filling of the fingers).

The perception of quality will also affect commercial activity:

- Producers prefers high yielding plantains cultivars which have greater resistance both to pests and to drops caused by wind and hurricanes;

- Intermediaries focus on degree of maturity, transport distances and the distribution deadlines. The plantain crops already ripe at the producer level are depreciated because they will be too mature before delivery at the urban market.

The characteristics at harvest and the state of freshness are two basic criteria taken into consideration in the commercialisation value of the plantain.

Traditional criteria identify quality through reference marks of the level of filling, the degree of roundness of the fingers and the colour of the pulp.

Three qualities that define decreasing commercial values are:

- The well filled cluster with well-coloured pulp (Quality 1) (See Figure 9a+b);

- The cluster with medium filling and pulp coloration (Quality 2);

- The lean cluster with a poorly coloured pulp (Quality 3).

Cross and lengthways sections of median portions of corresponding fingers (cultivar *Orishele,* a «*False Horn*» plantain) are shown in Figure 10a-c.

Sometimes professionals add another parameter, which they call «drop» made up of very early and immature clusters from fallen trees (hurricanes, winds). Sometimes these crops are sold when supply is very weak during the low production season (Sections of fingers are shown in Figure 11a+b).

Figure 9a+b: 
Well developing bunches of plantain (quality 1). Showing caracteristics of freshness. First cultivar French clair ("French"). Second cultivar Orishele (false "Horn"); See the splited finger in first hand showing a well coloured pulp

Figure 10a-c: 

Medium portions of fingers (cultivar Orishele) showing criteria of increasing qualities. From left to right: quality 3, 2 and 1

Figure 11a+b:  

Lengthwise (first) and cross (second) section of pulps from cultivar French Sombre showing increasing qualities. From left to right: "drop", qualities 3, 2 and 1

On the banana and the plantain tree, one can notice an increase of the weight of the cluster, of the filling of fingers and the coloration of the pulp during the development of the bunch.

Quality 1 corresponds to the well-advanced physiological maturity and homogeneous filling;

Quality 2 has an intermediary filling and pulp coloration;

Quality 3 comprises clusters of various characteristics:

- Lean fingers with coloured pulp. The plantain is quite advanced in physiological maturity but its yield is low to poor, following bad growth and development conditions (nutritional deficiencies, unfavourable bioclimatology, pest attacks);

- Lean fingers and pale pulp indicating homogeneous physiological maturity resulting from a too early harvest or taken from a banana tree fallen before successful development of the bunch.

The degree of filling is the simplest parameter to observe at markets, because it can be detected from a distance of several meters. It is not necessary to break a finger. The pulp coloration can confirm for the client the maturity of the cluster.

The impact of quality on the commercial value is undeniable. Reports of prices at all stages of the market showed that the clusters of Quality 2 and 3 are worth when compared to those of Quality 1 around 30 percent and 45 percent to 55 percent respectively (N'da Adopo and al. 1997).

When buyers and sellers are bargaining about the maturity of a cluster, freshness is ranked second. The green fresh cluster (See Figure 9a+b) has:

- Brilliant and clean appearance;

- Peducles, which are, firm and can still support fingers in an erect position;

- A shaft which shows a white or whitish-coloured humid wound when it is cut.

The cluster which has lost freshness (See Figure 12) shows:

- A dirty appearance. There are traces of shocks and wounds inflicted during the various manipulations. These marks are apparent, dark-coloured or black further aggravated by heat and dehydration;

- A dry, soft shaft;

- Falling fingers.

Figure 12: 

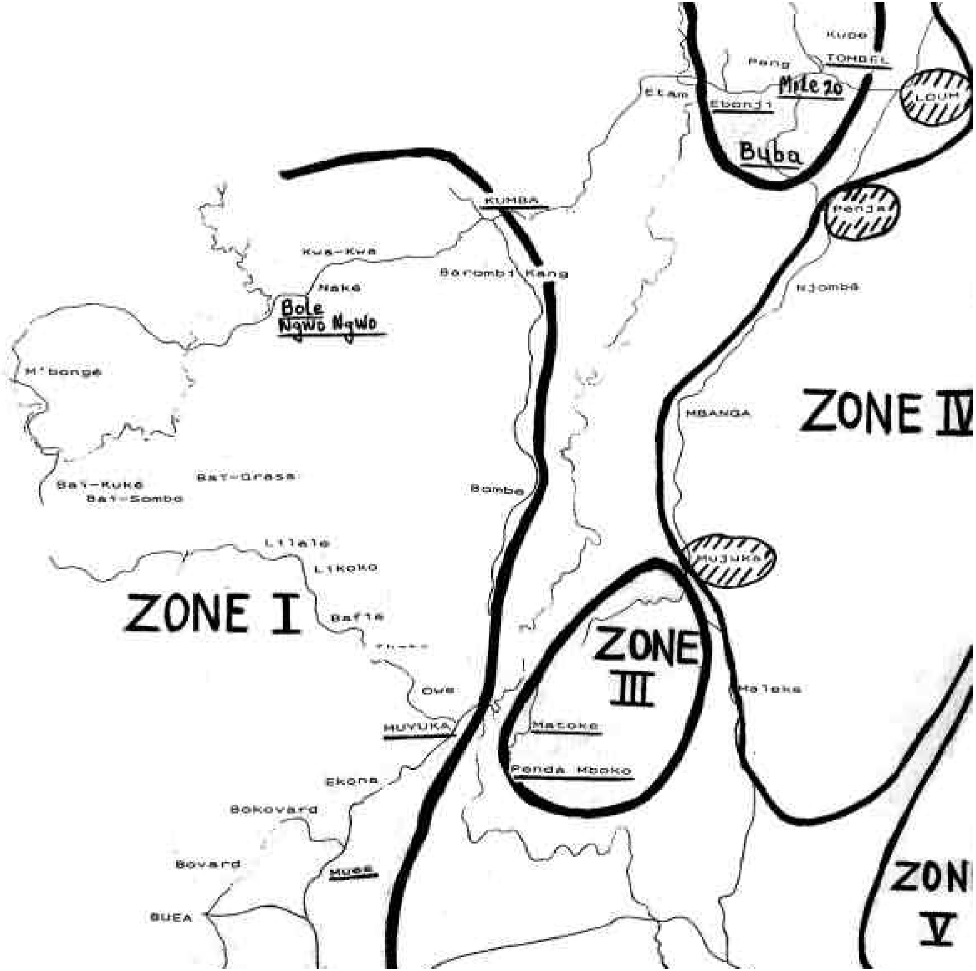
Type false "Horn" bunches showing signs of loosing freshness.

A study initiated in 1992 in Douala (Cameroon) and in the main zones of the Coastal and Southwest districts which supply towns with plantains, translated the seasonal variations of quality perception by the local producers (N'da Adopo and al., 1992).

These two districts were supplying respectively 63,500 and 245,000 tons (Source: Minpat, Direction of Planning, 1985) or 6.4 and 30 percent of the production of the country. 70 percent of the plantain consumed in Douala comes from the Southwest (Lendres, 1990; CRBP, 1996).

Producers and intermediaries in rural zones generally recognise the rainy season as being the period during which clusters are of best quality. The rainy season corresponds in fact to the period during which the banana tree gets a lot more water. The alternate rain-sun pattern creates good conditions to fill and mature the fingers of the bunches. The study concluded that quality is synonymous with good development, good filling and turgid characteristics of the cluster.

Table 10 (a, b and c) presents the periods and percentages of the clusters of Quality 1 cited by the producers of Zones I, II and III (See Figure 13). Zones IV and V have not been studied, as their production is marginal compared to the first three.


Kupe
TOMBEL
Peng
Mile 20
Etam
Ebonji
LOUM
Buba
KUMBA
Penja
Kwa-Kwa
Barombi Kang
Nake
Njombe
Bole
Ngwo Ngwo
M'bonge
MBANGA
ZONE IV
Bai-Kuke
Bai-Sombo
Bombe
Lilale
Likoko
ZONE I
Bafia
Mujuka
ZONE III
Owe
MUYUKA
Matoke
Penda Mboko
Ekona
Bovard
Muea
BUEA
ZONE V

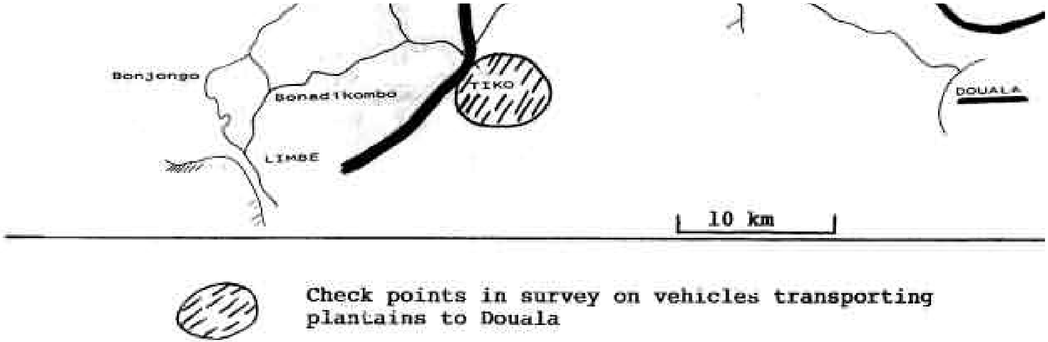


Figure 13: Borders of the major areas of South-West and Coastal Districts which provide Doulas with plantains

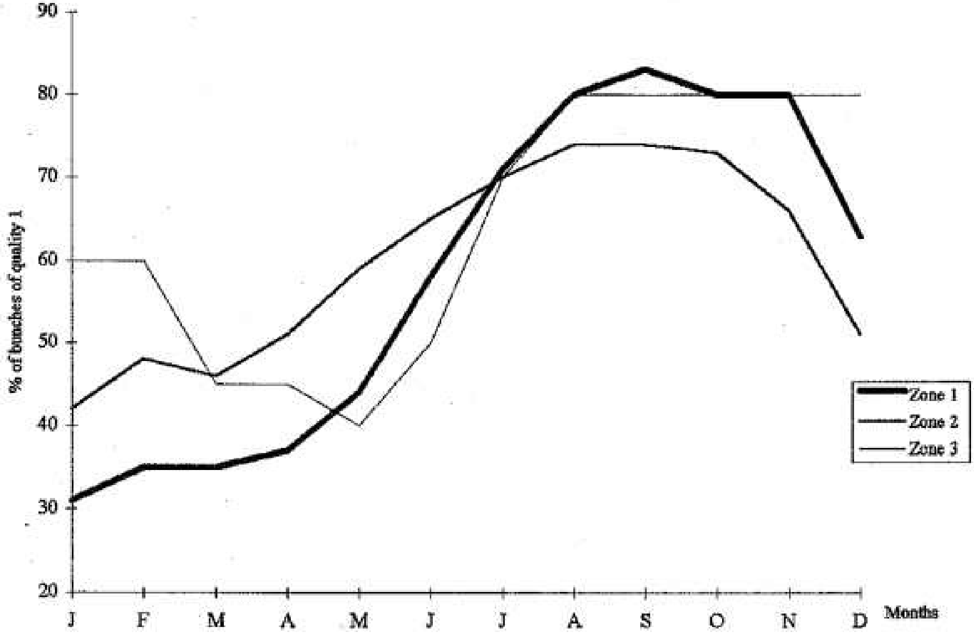


Figure 13b: Calender of quality and percentage of its distribution according with the perception of producers in the major areas providing Douala with plantains (N'Da Adopo et al., 1992)

Consumers in Douala in their majority designated the dry season, as the period during which the rate of Quality 1 clusters is the highest. The dry season (December to March) corresponds to the peak production period (up to 2 times more plantains than in rainy season). During this peak period, banana trees often suffer from heat and a certain proportion of clusters do not reach maximum filling.

In the rainy season (June to September), conditions are more conducive for better development of the fruits; but production is weaker. Producers often harvest when filling is still insufficient, because they are sure to sell the cluster.

Table 10: Calendar of quality and percentage of its distribution during the year in the surveyed production zones

+ = Period of large proportion of banana plantain of Quality 1

- = Period of small proportion of banana plantain of Quality 1

a) Regions of Kumba, Muyuka and Muyenge (Zone **I**)

Areas	J	F	M	A	M	J	J	A	S	O	N	D
Muyenge	- 20 à 30						+	+			+	50 à 90
Liliale	- 20 à 40					-		+			+	+ + 60 à 85
Likoko	- 20 à 40					-				+	60 à 80	- - -

Bafia	- 25 à 30		-			+	50 à 90	- + -
Muyuka	- 25 à 35		-	-	-			- 50 à 90
Yoke	+	- 30 à 70		-			+	+ + 50 à 90
Owe	-	- 30 à 40		-	-			+ + + 50 à 90
Kumba	+	- 25 à 40		-	-			+ + 50 à 90
								+

Mabanda	+	+	-20 à 40					-	-			- 80 à 90
Molyko	- 30 à 50					-	+			+	+ 50 à 90	+ + + +
Mutengene	+	+	-	40	-	+	+	65 à 85				+ +
Tiko	+	-	-	20	-			+	50 à 90			+

B) Region of Tombel (Zone **II)**

Areas	J	F	M	A	M	J	J	A	S	O	N	D
Buba 1	- 40					+	+			50 à 70		+ +
Buba 3	- 25 à 50						+			+	80 à 90	+ - -
Ebonji		-	45	-	+	+	75 à 95					+ +
Ngap **(_)**	+	80	+	+	-	30 à 50					-	+

Mile 20	-							+ 90			+	-
Bulutu	-	30	-			+	+	70	+	+	+	-
Mahole	-	30	-			+	+ 50 à 70					+ +
Ehom	-	40	-			+	+	75	+	+		-

(_) The soils of this area contain often-excess water during wet season.

c) Region of Penda Mboko (Zone **III**)

Areas	J	F	M	A	M	J	J	A	S	O	N	D
Penda Mboko		-	- 40			-			+	+	80	+ +
Matouke	+	+	-	50	-			+	+	+	+	+

Banana plantain has not been covered by well-defined international criteria, as is the case for export banana. One may adapt existing specifications to plantain, on the basis of current methods and data. Côte d'Ivoire specifications concerning banana plantain for export (NI 01.02.001) mainly applies the regulations of fresh bananas intended for export.

Fingers should:

- Be normally developed, full, firm, fresh, green and free from ripeness marks, black spots and rust marks;

- Be healthy without scratches, wounds and no symptoms of sunburn. Crops should be free of storage pests or marks affecting the commercial value;

- Be clean, free from processing products or visible foreign matter and dust;

- Held by healthy peduncles which are not broken, twisted or mouldy. Fingers should not be missing inside hands.

In the traditional sector, ripeness for harvest of several cultivars of reduced or medium size (Corne 1 and 4 in Côte d'Ivoire, French Sombre and Bâtard of Cameroon, Orishele of Nigeria) is reached between 75 to 95 days after discovery of the last female hand.

The formula of thermal sums used to forecast the harvest of export bananas (Ganry, 1978) was tested on plantain at CRBP (N'da Adopo, 1993).

The daily thermal sum is equal to:

(0.4 X t_ maxi + 0.6 X t_ mini) - 14

Is defined with a threshold of 14_C, the temperature threshold for growing bananas.

The corresponding features with the French sombre cultivar between the calculated thermal sums, the intervals since flowering (stage of last female hand discovered), the weight of clusters, the degree of fingers filling and pulp coloration (in accordance to IRFA colour scale on banana, Figure 14a) and quality criteria defined by professionals of the traditional sector, is summarised in Table 11.

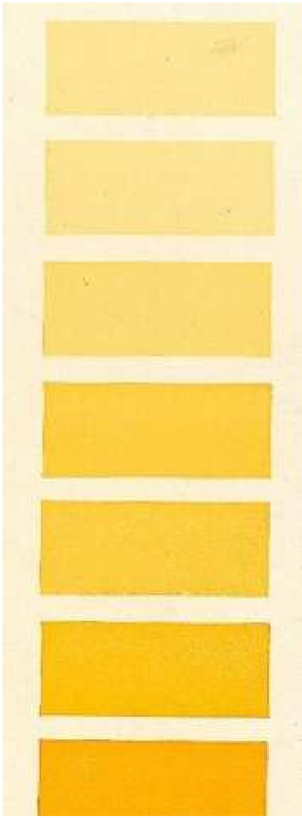
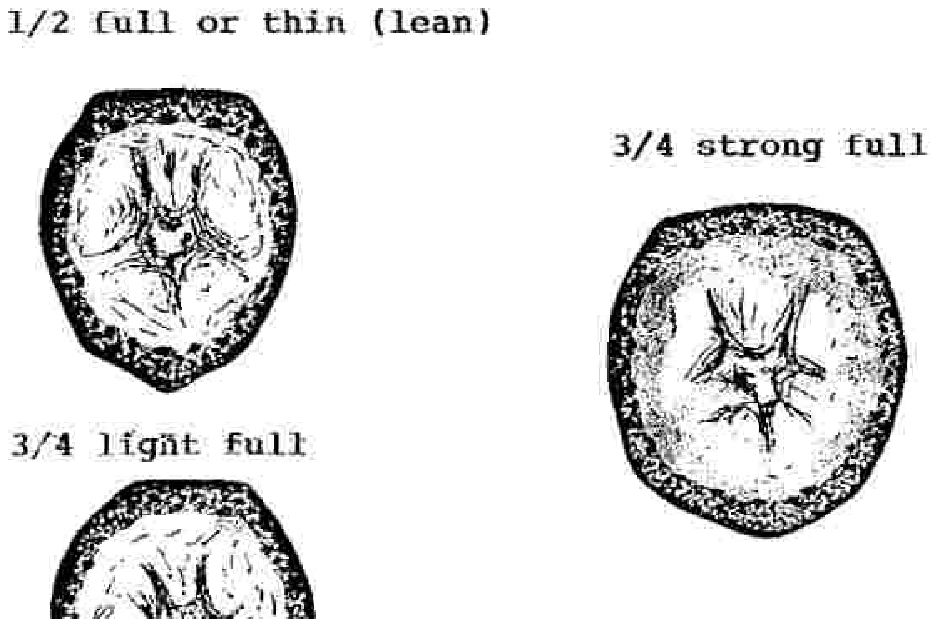


Figure 14a: Colorchart of banana pulp according with french norm for export (IRFA, 1980)

Figure 11a+b and Table 11 present increasing characteristics of filling (in accordance to Figure 14) and coloration observed during this trial.



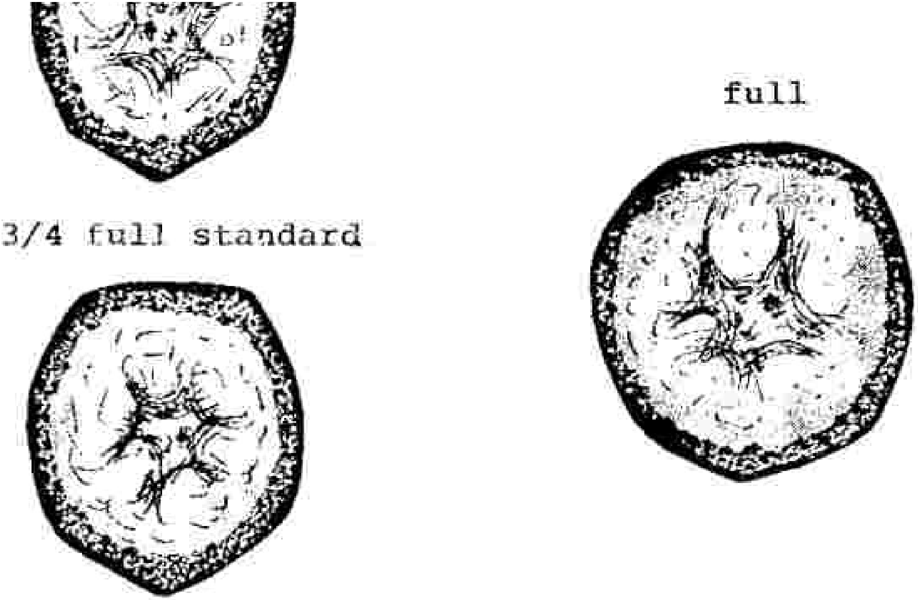


Figure 14: Schematic cross section of banana according to different levels of development (IRFA, 1980)

Table 11: Quality at harvest of the French sombre cultivar in the traditional sectors (characteristics per official regulations)

Quality	«Drop»	3	2	1
Thermal sum (_C)	800	900	1000 à 1100	1200

Interval flowering-harvest (days)	61	69	77 to 84	94
Level of filling	< 3/4	3/4 lean	3/4 light to 3/4 full	3/4 full to 4/4
Pulp coloration	< 5	5 to 5,5	6 to 6,5	7 to 8
Medium weight of clusters (kg)	13	15	17	17,2
Medium living leaves at harvest	6,4	6,4	5,47 to 5,08	4,14

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CHAPTER XIII PLANTAIN CASE STUDY: POST-HARVEST OPERATIONS

2. Post-Production Operations

Banana plantain belongs to climacteric fruits characterised by temporary increase of respiration (Cheftel, 1976). This sudden increase of respiration is called climacteric phase or crisis, which precedes or coincides with observed changes during ripening of plantain:

- Progressive fading of the green colour of the skin;

- Brutal decrease of the hardness of the pulp;

- Occurrence of aromatic flavour.

During its development on the tree, the hardness of the pulp of banana reaches a maximum point that is approximately 2/3 of the growth cycle of the fruit. Then hardness decreases continuously until harvest (Deullin, 1966).

Hardness measurements of the pulp of the plantain on French sombre and Orishele cultivars during their development indicate a permanent decrease of the pulp breaking strength from 65 to 70 days after dropping of female flowers. This stage corresponds to hardness pics for a growing and development cycle of the cluster of about 100 days (corresponding to the maximum yield) (Sery, 1985).

The change of the colour of the skin from green to yellow, the softening of the fruit and characteristic odours, constitute the most practical and fastest physical characteristics signalling the ripening of the plantain.

The decrease of the hardness of fingers (the pulp breaking strength), practically nil at the climacteric stage, has a very important consequence for the fruit as it is subjected to brutal handling in the traditional sector. After harvest, the finger, even if it is still very green, softens continuously and becomes less and less breakable compared to the freshly picked. This phenomenon considerably reduces the number of fingers broken or removed normally encountered during loading and unloading operations.

The period of green life or pre-climacteric phase is closely linked to the harvest stage. The time between harvest and ripening decreases as harvesting is delayed.

In the commercialisation sector, clusters are often harvested when they have nearly reached the ultimate stage of development. In these conditions (air temperature from 24 to 35_C, hygrometry from 70 to 90 percent), ripening occurs in 5 to 7 days. This corresponds very often in the traditional sector to the length of time between harvest and delivery to the most distant urban markets (400 to 700 km).

Traditional cropping provides the most important share of production (at least 80 percent of commercialised clusters). In this production system, the offer is not regular. One can consider as very good the selling on a weekly basis of 10 to 20 clusters by a producer after his self-consumption needs. The gathering by intermediaries can last from 2 to 4 days. The cluster, which has reached the consumption market then, has a potential of green life duration that is quite limited.

If intermediaries can choose the plantain in the stages of filling they want, they cannot control the accelerated loss of freshness in a system where goods are not carefully handled, are piled-up and finally exposed to direct sunshine directly on the floor or the tarmac (See Figure 15).

Figure 15: 
Poor storage conditions meaning quick decreasing of initial commercial value of clusters

Cluster protection is easier at the producer level: waiting for the arrival of buyers, the plantain can be placed under the shade of banana trees and covered with their large leaves. This type of product storage under good conditions without any cost, has the advantage of banana leaves cut at the same time as the cluster are laid down to avoid scratching crops against the floor during harvest

(See Figure 16). This process also allows the farmer to slow down ripening of the cluster for a few days, pending the arrival of the buyer. Intermediaries are more at ease to bargain for reduced prices when damage is obvious or when there are important signs of loss of freshness of the product.

Figure 16a-d: 
Harvesting for sale by the producer

When the buyer abides by his collection calendar, plantain is removed from the producer at green stage. The ripening will occur only at the level of the intermediary, during transport or on the stalls in the consumption market.

If one thinks that after harvest, ripe clusters are more likely to bring about post-harvest losses than green clusters, one should recognise that in the current traditional system, methods to reduce possible losses are relatively more efficient at the level of producers than at the level of intermediaries. Post-harvest manipulations with intermediaries are the same in all the producing countries and this brings about the same effects on plantains, that is ripening and a quick loss of commercial value (Mihailov, 1986; Kuperminc, 1985; N'da Adopo, 1993).

Rapid ripening of the product during commercialisation may be attributed to several factors:

1- Harvest stage and harvest techniques;

2- Packaging mode and type of transport;

3- Storage and conservation modes.

Generally, the cluster that is in the commercial process will follow one of these two patterns:

- Ripening before loss of freshness;

- Ripening after loss of freshness.

(See Table 12).

Table 12: Aspect of the clusters found on markets of different traditional channels in Cameroon, Côte d'Ivoire and Ghana, according to levels of filling of fingers and commercialisation duration from harvest

	Early or medium stage of harvest	Advanced stage of harvest
Distribution deadline 1 to 3 days	* green cluster* fresh or withered	* green or ripe cluster* fresh
Distribution deadline 4 to 6 days	* green cluster* withered	* well ripened cluster
Distribution deadline 7 to 9 days	* green or ripe cluster* withered	* well ripened or rotting cluster* withered

The cluster which has reached maturity and which is ready for harvest presents certain external characteristics:

- Rounded and very little angular finger lines (the earlier the harvest, the more angular the lines);

- Increase of green pigmentation of apex of fruits;

- Drying of finger tips;

- Drying of floral pieces;

- Presence of cracked fingers or ripe fingers (generally at the level of the first hands).

At this stage, the plant presents only 4 to 6 living leaves maximum against 8 or more at the beginning and middle of the growth and development of the cluster.

The degree of filling for harvest varies according to eating habits, cooking and destination of clusters. Harvest for immediate domestic consumption in Côte d'Ivoire, could produce ripe fingers whereas for sale the cluster will be full and green. The Horn and false Horn plantains are often more rounded than those of French type at harvest.

At the cutting stage (75 to 95 days) of medium size cultivars (Corne 4 and French sombre comprising 5 to 8 hands), many big clusters comprising at least 10 hands (for example cultivar Essong in Cameroon) often present angular fingers, due to the reduced number of leaves which are alive and capable of ensuring an important photosynthetic activity for quick filling of so many fingers (Osafo, 1986).

Tables 13 and 14 present data at harvest obtained from Orishele and French sombre cultivars. Hardness of the pulp is measured at the level of median transversal cut of fingers using a crossbow penetrometer of Cosse type (6 mm diameter nozzle).

Table 13: Pulp hardness in kg/cm²

Harvest stage (days after loss of flowers)	65 à 71	75 à 80	85 à 95
Orishele	2 - 1,8	1,8 - 1,6	1,5 - 1,2
French Sombre	4,6 - 4,3	4,3 - 4	4,1 - 3,2

Table 14: Pulp/skin weight ratio

Harvest stage (days after loss of flowers)	65 à 71	75 à 80	85 à 95
Orishele	1,3 - 1,5	1,5 - 1,65	1,6 - 1,7
French Sombre	1,15 - 1,3	1,3 - 1,5	1,5 - 1,7

2.2 Harvesting

Harvest is done for self-consumption (1 to 3 clusters per week), for sale to possible buyers alongside the road or village track (about 10 clusters maximum) or on request of intermediaries. The number of clusters in the later case depends on demand and supply of the producer compared to the clusters, which have reached physiological maturity.

Harvest is performed to avoid or reduce damages (See Figure 16). A technique often used in Latin America and Africa is to do use a big knife commonly utilised for fieldwork called a *machete*. An oblique wound of 6 to 8 cm is made in the wrong trunk at approximately 0,8 to 1,5 m under the level of the last hands in the axis of the cluster.

The depth of the wound in the wrong trunk should be reduced inversely by the size of the cluster. One can slightly shake the plant by kicking at the level of the wound with the back of the machete. Placing a fork under the stave can also monitor the fall of the cluster. The cluster will be held in the middle by its rachis before being separated from the tree.

When this technique is mastered, the product does not suffer from any shock. The operation requires a maximum of 30 seconds. There are practically no losses in the field due to post-harvest practices.

Harvest for self-consumption, in the field or behind the hut is incidentally done by both sexes. Harvest of larger quantities of clusters (about 10) for sale are generally undertaken by men (the husband, a planting agent, etc.).

The length on which the stave is cut often depends on the destination of the product:

1) Show the freshness of the cluster. It will then be possible later on to cut it one or many times according to the length of sale, in order to present a fresher section to the clients and convince them that the cluster has been harvested that day or for a few hours only;

2) Identify the owner of the cluster, the producer or intermediary puts marks or writes initials on it).

2.3 Transport

In the traditional channel, the plantain is generally transported in clusters from the field to the farm and from one intermediary to the other. The cuttings into hands, bunches or fingers occurs at the last stage of commercialisation with the detailers.

The type of transportation varies according to the number of clusters to be carried, the distance to run and local removing methods:

- Carried by people (1 to 3 clusters);

- Trolley pushed or pulled by people (15 to 25 clusters);

- Bicycle or motorcycle (1 to 7 clusters);

- On the roof of travellers' transport van (50 to 60 clusters);

- Truck (400 to 700 clusters);

- By railway (more than a thousand clusters).

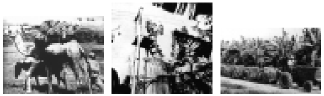
Clusters are thrown into the vehicle, piled-up one on top of the other, without any care. The major concern is to convey maximum of the product while occupying all the available space. One overloads the vehicle in order to make one trip only. These careless operations bring about twisting of peducules, breaking and dropping of many fingers (Figure 5c, 17 and 18). The practice in general in Africa (Mihailov, 1986).

Figure 17: 

View of a lorry (7 tons) full of bunches at arrival at the urban market. Approximately 500 bunches are piled into the vehicle.

Figure 18: 

Pile of brocken and removed fingers during handling and transport, collected below the lorry. According to the lot of bunches in the left, these fingers are equivalent to 50 bunches.

Figure 18a-c: 

Transport in the past (Simmonds, 1959)

Most commonly, the carrier is not the owner of the clusters; he is only charged with the responsibility to transport goods to destination. To load or unload 7 to 8 tons (450 to 650 clusters) requires at each destination, 3 to 4 specialised goods handlers apart from the carrier. These goods handlers are real auxiliaries of the channel. These goods handlers wait on the premises where the collected plantains are gathered at he level of producers and on the markets of destination of the clusters. The work is done in sequence:

- A loader «a specialist>> is charged with arranging the clusters in the truck following a process that he masters. One makes sure to arrange the clusters tightly, sometimes breaking them or twisting the fingers;

- Another «specialist» loader (the identifier) in urban market arranges on the fruits in lots, referring to the initials marked by intermediaries on the staves;

- The last goods handlers transmits to the first ones the clusters in one direction or the other, according to loading and unloading situation.

Five to 6 seconds are necessary to throw a cluster into a truck and place it tightly that makes approximately 1 hour for all the collected goods. The identification of clusters and their classification on arrival in town requires as much time. It takes a total of 2 hours to load and unload 500 clusters. The cost of loading or unloading of a cluster including its identification and sorting was 10 F CFA per cluster in the Southwest district of Cameroon (N'da Adopo, 1992). The transport of the cluster per truck (7 to 8 tons) of this district up to Douala cost 180 F CFA. Compared to the costs in abundant periods, 500 F CFA/cluster at the producer level, 915 and 1000 F CFA respectively for wholesaler and detail sale, revenues and charges are shown in Table 15.

Table 15: Gains estimates (F CFA) of the various actors according to the type of circuit: Road Tombel (Zone II) to Douala in high production season (December 1990 to February 1991). Reference: 500 clusters, medium weight _15 kg/cluster.

Type of circuit	Producer himself	Retailer (supplying from	Wholesaler (supplying from	Retailer (supplying from

		the producer)	the producer)	the wholesaler in town)
Buying cost from the producer		250.000	250.600	
Individual transport Douala-Ngoussi-Douala	5.000	5.000	5.000	
Collection:-loader	5.000	5.000	5.000	
Collection - other handlers	5.000	5.000	5.000	
Transportation of clusters	90.000	90.000	90.000	
Unloading- off loaders-	5.000	5.000	5.000	
Unloading identifier	5.000-	5.000	5.000	-
Charges	110.000	115.000	115.000	-
Gross return	-	-	365.000	-
Selling price (wholesale) (Douala)	457.500	-	458.330	458.330 (buying in bulk from wholesaler in town)

Net return (wholesale) (Douala)	347.500 less production cost	-	93.330 (186 F/bunch)	
Return (retailer)	-	365.000	-	-
Retail selling price	500.000	500.000	-	500.000
Net return in retail in clusters in Douala	390.000 less production cost	135.000 (270 F/cluster)	-	42.000 (84 F/cluster)

Source: (N'Da Adopo, 1992)

Although product losses during transportation are scarce, this stage is the most delicate and risky of distribution. The harvested plantain can be lost totally or in part in the following situations:

- Lack of respect for the appointment or collection deadline of the harvest by the intermediary;

- Mechanical failure or accident of the vehicle during transportation, immobilising goods for several days.

2.7 Packaging

Plantains are not placed in particular packaging in the traditional channel inside the country of production or between neighbouring countries in Africa. This happens for export to more remote markets, from Africa to Europe, and from South America to North America (Lescot, 1993). Packaging and all other operations try to follow the methods of the international commercial distribution of bananas.

More caution is taken for products destined for export:

- 2 people to harvest a cluster (one to cut, the other one to receive on a back with a foam carpet);

- Take the harvested product to the spot where it is going to be cut near the field or packaging warehouse, hang it on a gantry;

- Cut into hands or fingers with adapted tools («banacut» to remove hands, special knife, etc.);

- Wash and possibly soak in a fungicide;

- Package into cartons for transportation.

An analysis of packaging coast has been carried out, in hypothesis that 500 clusters (according to Table 15) are cut up and packed in cartons, in a field or on a farm and conveyed for sale in Douala (N'da Adopo, 1992):

- The shaft represents approximately 9 percent of the weight of the bunch. So the net weight of a bunch being able to pack is 13.65 kg, net weight of the 500 clusters is 6,825 kg (hands and fingers);

- The usual packages (cartons used to export bananas) are full at optimum with 19.0 kg of plantains;

6,825 kg require # 359 cartons;

- Handling and packaging;

. Cutting up.

The time required for this task is 1 minute per cluster per person. Therefore 500 clusters require 8.33 hours. It is necessary to recruit 9 handlers to complete cutting in 1 hour. Eight other packers are required to wash and clean the fruits before packaging.

To package requires 2 minutes per carton per person, or 3 hours per person for 359 carton It is advisable to recruit 3 persons. There is a requirement for 28 persons (8 for harvesting and 20 for cutting up and packaging) to finish these operations in 1 hour. The pay for agricultural labour is 110 F CFA /hour /person in the area of this study (Zone III, Figure 13), or 3 080 F CFA in total.

Loading the 359 cartons in the lorry requires 3 handlers, which 20 F CFA in total per carton (See Table 15), or 7 180 F CFA.

Total theoretical charge minimum is 10 260 F CFA (loading would require only 10 000 F CFA in the traditional circuit).

How many cartons are in the lorry?

- The dimensions (in meter) of the trailer of usual lorry (7 tons) are 5 (L) X 2.18 (W) X 0.26 (H) # 19 m3

- The dimensions of banana carton are 0.45 (L) X 0.35 (W) X 0.26 (H) = 0.04 m3.

A lorry can so contain 19/0.04 = 475 cartons. One needs 116 other cartons (and 162 clusters) to complete the

Loading, that is to say 662 clusters in total: for the same coast, it is cheaper to transport 662 corresponding to 475 cartons than 500 clusters.

But this method requires buying cartons. The coast of a carton is # 600 F CFA, that is to say an initial input of

285 000 F CFA. One carton can be used only for 4 to 5 trips in loading and unloading. In addition to these charges, it needs also workers to collect the cartons and keep them in the market places during marketing!

2.8 Storage

The producers harvest for self-consumption or an imminent sale. Contrary to the case of rice or maize, one doesn't stock so perishable product on the farm: There are no storage coasts at the farm level (See Table 16).

Harvesting takes place little by little according to the self-consumption needs. When these needs are satisfied and there are no buyers, the clusters are not harvested and plantain can ripen on the trees. The salesman provides his stand with clusters little by little according to the market. The objective is not to stock because the plantains will loss their freshness and their value.

Because the demand for well-ripened plantain is high, many sellers cover the fruits to accelerate ripening. They also use chemical products, which generate ethylene to obtain the same result (See Figure 23).

Figure 19: 

In urban markets plantains are usually covered by salers to accelerate ripening. See the little girl behind watching the stall.

Table 16: Handling Costs (NGN/t of plantain)

	Producer	Wholesaler	Retailer
Transportation	16	43	39
Storage	0	91	15
Handling	16	134	54
Transportation cost as % of handling	100	32	72
Storage cost as % of handling	0	68	28

Source: Njoku J.E. and Nweke F.I., 1985

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CHAPTER XIII PLANTAIN CASE STUDY: POST-HARVEST OPERATIONS

3. Overall losses

Two types of infections must be discerned:

1) Those which act on the plant by causing a bad development of the bunch;

2) Those which affect the fruits directly before or after the harvest.

Bad nutrition and poor soils cause a delay in the filling of the fingers in conformity with the age of the bunch. The fruits are thin and the pulp is coloured or even with an advanced coloration (yellow dard in some cases in the phenomenon of "yellow pulp").

The bunches often display a poor appearance. Ripening frequently happens on the plant before the harvest stage.

Water outages in the soil and continued droughts lead to similar effects.

Parasites and spoilers: Attack of underground organs

Weevils and nematodes attack respectively the stumps (formation of galleries) and the roots of the banana trees. The incidences on vegetation and the profits are disastrous (Kehe, 1985; Sarah, 1985):

- Section and breaking of the tubes conducting the sap;

- Early destruction of the bulb;

- Section and destruction of the roots.

The consequences are:

- A bad water and nourishing alimentation from the soil; banana trees remain puny and they vegetate. The production becomes inadequate and the plantation gets old quickly.

- The plants fall down with the least wind blow, chiefly from the flowering period when the fruits start to be filled and when they begin to increase in weight.

- The bunches from those banana trees can be classified as Quality 3.

Aerial agents

Black Sigatoka, a fungi disease of the foliaceous system causes falls of the production that can reach more than 50 percent. There's a defect of filling with the fruits of affected plants and they can no more reach their optimum size. Some attacks cause an important destruction of the plantations in Central America, reducing practically to nothing plantain exportations from affected plantation in Honduras (Stover, 1985). Bunches coming from those plantations can no more satisfy the minima requirements in quality and size. Moreover, they grow ripe too early when they're being transported (Bustamente, 1985).

Two types of infections must be discerned:

1) Those which act on the plant by causing a bad development of the bunch,

2) Those which affect the fruits directly before or after the harvest.

Bad nutrition and poor soils cause a delay in the filling of the fingers in conformity with the age of the bunch. The fruits are thin and the pulp is coloured or even with an advanced coloration (yellow dard in some cases in the phenomenon of "yellow pulp").

The bunches often present a dim aspect. Ripening of the fruits frequently happens on the plant before the stage of habitual harvest.

Water outrages in the soil, continued droughts, and lead to similar effects.

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Water outrages in the soil, continued droughts, and lead to similar effects.

In some areas fall in plantain production leads to increases in food prices (Mouliom Pefoura, 1985).

In the usual traditional plantain crop system, it is impractical for the producer to resort to fighting pests with chemical products suited for banana or plantain plantations intended for exportation (Foure, 1985). Those methods require:

- The use of systematic fungicides by pulverisation or spreading;

- Aerial treatment.

The impact of the disease on the commercial level appears more pronounced in industrial plantations (in particular for exportation) than on the traditional market:

- Lack of average (norms);

- The affected bunches are classified in the category corresponding to the filling level and to their pulp coloration and then sold or consumed by people without any other quality concerns.

When fruits are attacked they become enormously undervalued:

- Tip disease;

- Dry rots of the ends of the fingers;

- Black spots; at an advanced stage of development, the skin is ready to crack;

- Anthracnose leads to black marks. The development of the disease causes the rottenness of the fruit when getting ripe during the maturity period).

Fungi attacks are particularly noticeable during the wet season. They cause quicker ripening of the fruit before harvest. Direct infections on bunches which provoke a rather repulsive aspect of the fingers are the only causes of rejection of the crop in that traditional channel. Removing the residual floral pieces of the tips of fingers with the casing of the bunch in a plastic protection at the end of the flowering period, treatment with fungicides, work to fight those diseases.

If removing residual floral pieces can't be done (a few minutes maximum per bunch) by the traditional producer himself, by means of a ladder (which he can make by himself), the buying of plastic protection cases and treating products and their employment, may not be profitable when taking into account the prices of banana plantain in the traditional channel.

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5. Economic and social considerations

When we speak of rapid ripening of plantain in the system, the first thought is post-harvest losses. People then try to use another system, which is much more liable to reduce loss. A commonly recommended solution is to initiate methods to keep fruit unripened for as long as possible.

This principle conflicts with several problems:

- Actors are mostly interested in well-filled and high weight and short green life of the clusters. They know that filling of fingers (See Figure 20) and weight of bunch increase more and more with age. They seem to have no concern about the issues of diminishing green life of clusters;

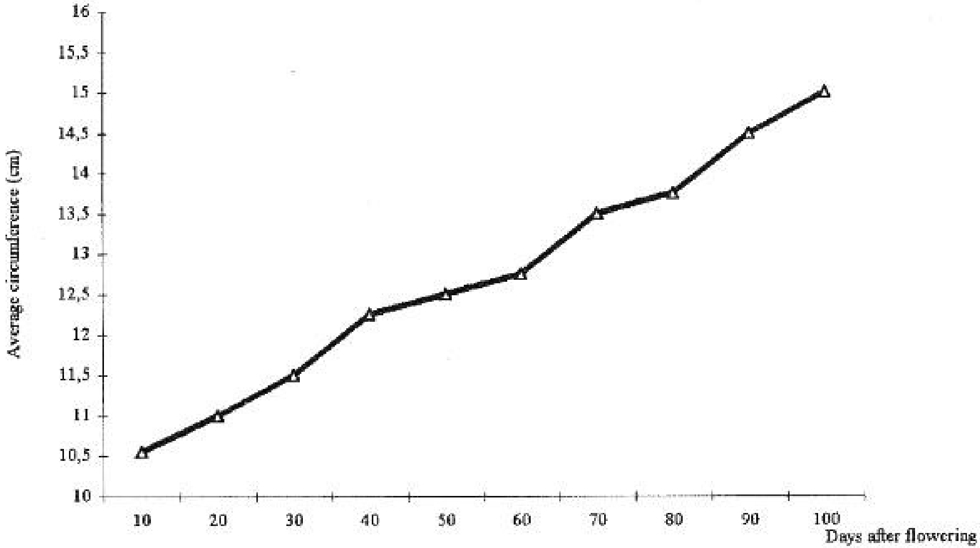


Figure 20: Increasing of medium cross section of fingers (second hand, Orishele) during development

- The physical post-harvest losses are relatively low;

- Ripe plantains are demanded at the markets.

The price of ripe banana is at least equal to that of unripe plantain. The ratio of ripe fruit to unripe fruit can reach 1,5 and 2 in some regions, particularly during periods of less production. Figure 21 describes the price evolution of two bunches (one is Quality 1, the other is Quality 3) during commercialisation in an urban market place (N'da Adopo, 1996): the value of a well ripening cluster increases and after decreases at stage of super-ripening. The fact that sellers select their goods to accelerate ripening illustrates this point (See Figure 19).

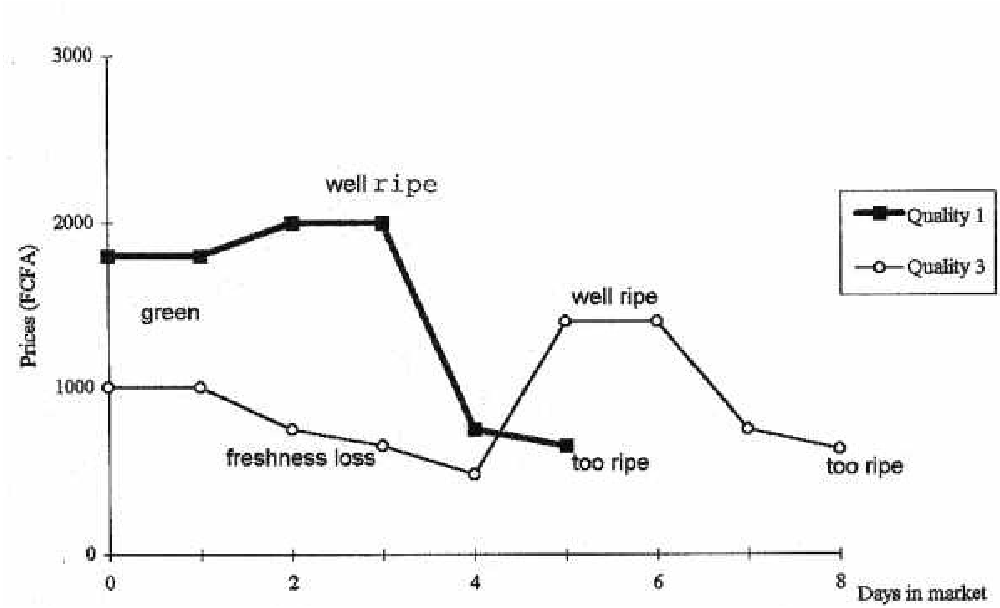
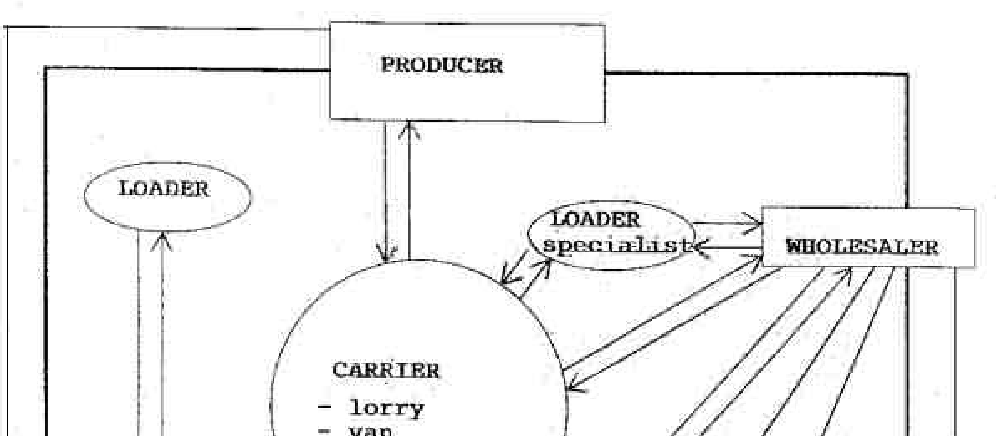


Figure 21: Evolution of the prices of two clusters (quality 1, quality 3) in accordance with their ripening stage (N'Da Adopo, 1996)

Whatever the process used the technology of keeping the unripened fruit allows the increase of price, and mobilises the capital of the seller without any guarantee of sales at a later time. Along the same lines, the cutting bunches and packaging them in boxes causes an unacceptable level of expenses. The final cost of the fruit becomes inaccessible for the typical consumer.

The informal sector is very developed in producing countries and all the range of small jobs result from practices found in the usual network.

The "loader" (See Figure 22) earns 10 FCFA per bunch loaded into the lorry (For example, 5000F CFA for 500 bunches placed in a lorry of 7 tons) (See Figure 17). After transport, the "identifier", who arranges the bunches during unloading in the main urban market, earns the same amount. Generally, the "identifier" prefers to remove one finger per bunch. He sells these fingers retail in the marketplace. The other packers also share 10 FCFA per bunch.



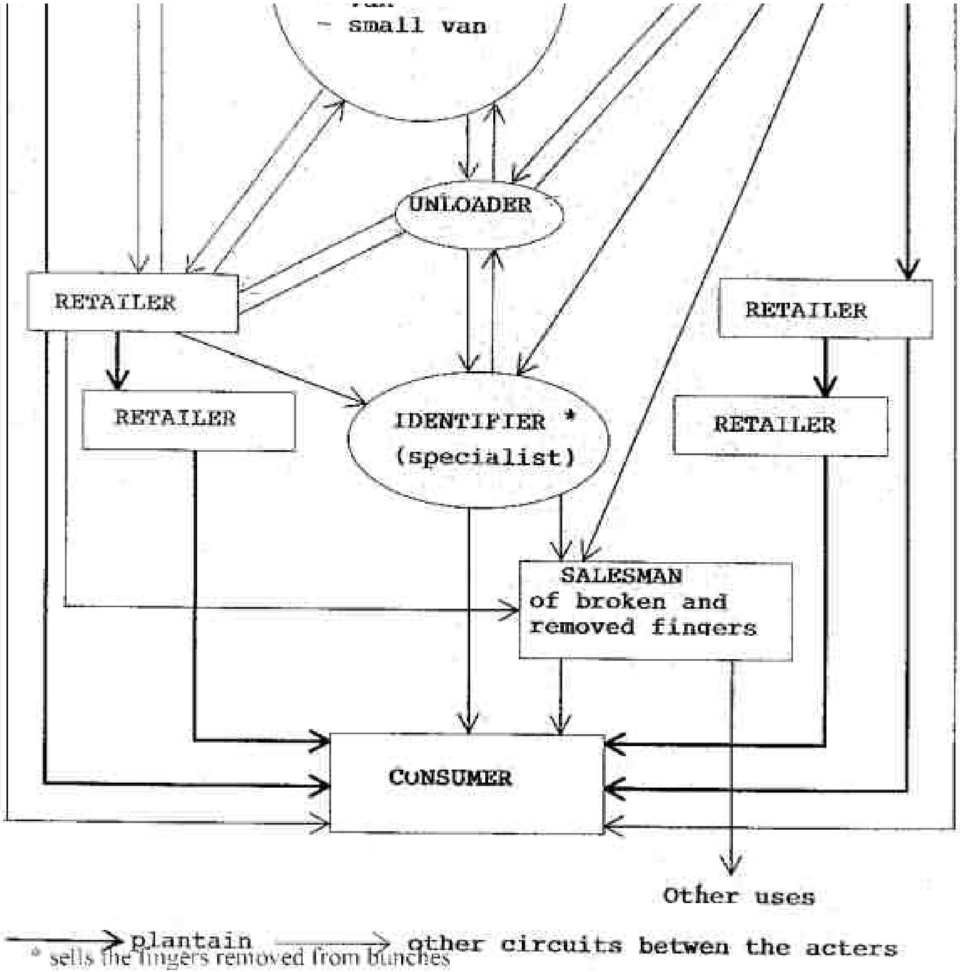

- small van
UNLOADER
RETAILER
RETAILER
RETAILER
RETAILER
IDENTIFIER *
(specialist)
SALESMAN
of broken and
removed fingers
CONSUMER
Other uses
plantain
other circuits betwen the acters
* sells the fingers removed from bunches

Figure 22: An example of the complex commercialization channel providing Douala (Cammeroon) with plantains (N'Da Adopo, Fruits, Vol. 48, no 2, 1993))

At a rate of two or three lorries per week or eight to twelve lorries per month, these auxiliaries can earn 60 to 80 000 F CFA per month. This amount represents an important income in these producer regions of developing countries. One or several broken or uprooted parts during the transportation of plantain is not very significant during the wholesale process. These broken parts are useful as they are sold once the lorry is unloaded. This enables the wholesaler to pay off some permanent fees:

- Pay the one who arranges fruits once in the lorry and other packers, recover fees of loading;

- Pay the diverse municipal taxes on the market;

- Amortise the cost of transportation of bunches.

The fingers broken during transportation represent rather additional earnings for the wholesaler rather than post-harvest losses. These fruits are distributed at sale prices, obviously advantageous to consumers who cannot buy the best plantains or unbroken fruits.

5.4 Improved techniques

The earnings of the participants can be improved by decreasing the numbers of bad clusters that are harvested. These mediocre qualities are the result of bad cultivation, poor soil and diseases. The solutions are the concern of agronomic training taking place in the farms and the fields.

Improved handling and storage conditions can reduce the high proportions of clusters, which are sold at a discount by those transporting plantain in particular, the intermediaries. It is recommended that:

PRACTISES OBSERVED	ACTORS CONCERNED	RECOMMENDATIONS
Non-Harvested Bunches		favour exchange between
Or Post-Harvest Losses In		the various actors by
Field Or In Farm		creating markets or collec-
caused by :		ting points in rural zones
low prices due to excess bunches or		
intermediaries blackmails		develop processing
very lean bunches due to poor soils,		group the actors in coope-
pests and cropping system	Producers	rative
no vehicle to transport bunches		improve communication

to		
regional or urban markets		routes
no buyers		develop low price
		methods to improve
		cropping system
Rough Handling And Poor	Intermediaries	build shelters in the markets
Storage Condition Meaning		
Decrease Of Value Of		
Bunches		
	Producers	Create an information
	Intermediaries	network for plantain (quantities
	consumers	for sale by area, prices, qualities
		and export possibilities)
		make training on quality
		of foods

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CHAPTER XIII PLANTAIN CASE STUDY: POST-HARVEST OPERATIONS

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CHAPTER XIV BANANA PLANTAIN: Post-harvest Operations

1. Introduction

Plantains and other cooking bananas, staple foods grown throughout the tropics, constitute a major source of carbohydrates for millions of people in Africa, the Caribbean, Latin America, Asia and the Pacific. Due to the perishable nature of the fruits, the rate of plantain post-harvest losses varies from one country to another according to the organisation of market chains and modes of consumption. In many producing countries, there are no data on post-harvest losses. The assessment of these post-harvest losses is rather complex because green mature plantains are consumed as well as overripe fruits. However, some factors are likely to depreciate quality and provoke post-harvest losses. These include poor transportation and distribution facilities in the production areas, harvest at maturity close to fruit ripening, and poor storage conditions.

In Cameroon, the most evident post-harvest losses are registered at the producer level in enclave sites during the rainy season (N'da Adopo, 1993). These losses should be less than 35 percentage) in developing countries as previously estimated by FAO (1987).

In plantain production, labour distribution according to sex varies with producer traditions and the economic role of production. In Cameroon, men and boys over 12 years olds are generally in charge of land clearing, land preparation and planting. Women and girls over 15 years old step in go to the planting site and to monitor crop growth. Men and women both perform the transport and sale of products.

1.1 Economic and social impact

Plantains (AAB) as well as other cooking bananas (AAB and ABB), East Africa cooking bananas, beer bananas (AAA) and dessert banana (AAA) belong to the Musa genus. Figure 1 shows great diversity among plantains and cooking bananas.

Figure 1: 
Bunches of plantains and cooking bananas from the germplasm collection of CRBP in Njombé, Cameroon (Photo R. Achard)

Bananas and plantains are grown in more than 120 countries, in backyards or in mixed cropping systems by smallholders, and occasionally in monoculture (INIBAP, 1992). The total production is about 64 million tons with 23 percentage of AAB plantains, 16.5 percentage of cooking bananas, and 18 percentage of highland cooking bananas and beer bananas. The most prevalent combination of mixed cropping systems is cultivating plantains with coffee and cocoa. In Latin America for example (Colombia, Costa Rica, Venezuela), mixed cropping with coffee is common, but association with cocoa and pure stand of plantains are also found (Costa Rica and Panama). Table 1 presents some data on the production and the consumption of plantains and other cooking bananas in some producing countries.

Table 1 **: Main producing and consuming countries of plantains and other cooking bananas**

Countries	Yearly Production (x 1,000 tons)	Consumption (kg/person/year)	Plantain Calories Consumption (Calories/person/day)
Africa	600	67	111
Burundi*	1000	81	195
Cameroon	1000	81	194
Côte d'Ivoire	1530	49	112
Democratic Rep.of Congo	1800	-	-
Nigeria	6700	150	348
Uganda*	2150	91	222
Rwanda*	1350	-	-
Tanzania			
Latin America	2463	82	197
Colombia	960	-	-

Ecuador	600	70	135
Venezuela	580	-	-
Peru	105	-	-
Bolivia			
Asia	1150	66	115
Philippines	-	65	137
Sri Lanka			

* These countries produce mainly cooking and beer bananas.
Sources : FAO (1989), United Nations (1991), Ganry (1990) and Lescot (1993).

According to Treche (1997), 69.4 percentage of plantains and other cooking bananas are used for human consumption while 8.0 percentage are used for animal feed. Post-harvest losses and transformed quantities in the world are 11.5 percentage and 11 percentage, respectively. In most cases plantains are locally consumed. Plantain also shows great adaptation to urban consumption and exportation to specific markets. This will vary from one country to another because of prevailing eating habits:

- Ripe or unripe plantain pulp cooked in water or vapour;

- Pastry from unripe plantain cooked in water and pounded in a mortar;

- Elastic pastry prepared from plantain flour and boiling water;

- Ripe or unripe plantain pulp roasted on charcoal fire;

- Unripe plantain pulp cooked with water, meat or fish, palm oil, salt and various spices;

- Slices of unripe or ripe plantain pulp fried in palm oil or other vegetable oils.

The available food energy (AFE) from plantains and other cooking bananas in some producing countries is shown in Table 2 (Treche, 1997).

Table 2 : Available food energy (AFE) from plantain and other cooking bananas in selected producing countries

Countries	AFE from plantains and other cooking bananas (Kcal/inhabitant/day)
Uganda	436
Gabon	432
Rwanda	422
Côte d'Ivoire	189
Cameroon	173
Ghana	172
Colombia	169
Dominican Republic	142
Guinea	140

Ecuador 119

1.3 Primary product

Boiled plantain

The fingers of ripe plantain or unripe plantain are peeled and cooked in boiling water or in vapour for 20 to 50 minutes depending on the cultivar and ripening stage of the fruit. Plantains boiled in this way are consumed with various sauces or other accompanying dishes. This mode of cooking and eating is quite common in most plantain producing countries in Africa.

Green mature fruits after peeling can be cooked in water mixed with palm oil, goat or cow meat, salt and diverse spices (*condre* in Cameroon). It is a classical dish for the people of West Cameroon during weddings, funerals and other traditional ceremonies. The pulp of unripe plantains cut into pieces can also be cooked with water, salt, palm or groundnut oil, groundnut paste, tomatoes and spices, fresh or smoked fish or meat. This makes a porridge or one-course meal.

Plantain pastry

Unripe plantain pulp after cooking in water or vapour is pounded in a wooden mortar to be transformed into a homogenous flexible pastry. The addition of a few pieces of cooked cassava can be needed to improve the elasticity of the pastry. This food called "*ntuba*" in Cameroon (Figure 7), "*foufou*" in Côte d'Ivoire, "*fufu*" in Nigeria and Ghana is always eaten with a sauce which is somewhat rich in proteins. It is a staple food in certain regions of these countries.

Figure 7: 

Plantain pastry (*ntuba*) prepared in Cameroon from the pulp of plantain boiled and pounded (photo S. Morelle)

Plantain Pastry lined with green leafy vegetables

Plantain fingers, generally of the horn or false horn type, are cooked in water with leafy vegetables (pumpkin leaves, amaranth leaves, etc.). After cooking, the plantains are peeled and pounded hot in a mortar. Vegetables, which were before hand washed in cold water and drained by hands are then added to the pastry as well as salt, pepper and unrefined palm oil. All of this is well mixed and served for eating.

Plantain pastry mixed with beans

The preparation is the similar to the preceding recipe, except cooked kidney beans are substituted for vegetables. The people in the West Cameroon prepare this recipe.

Roasted Plantains

The entire pulps of unripe or half-ripe plantains are roasted on heated charcoal. About fifteen minutes is enough to prepare simultaneously 2 to 4 fingers of plantain depending on the customers. Women on the roadside generally sell this plantain which is consumed warm with other delicacies (roasted plums, avocado, roasted fish, meat kebab). The cooking and selling of roasted plantain constitutes a major commercial activity for some women in Cameroon, Côte d'Ivoire and other plantain producing countries.

Fried plantains

Ripe or unripe plantain are peeled and cut into slices and fried in palm oil or other vegetable oil for 4 to 5 minutes at 160-180_C. Roasted fish, chicken or meat kebab are sometimes served. Fried ripe plantain or *aloko* in Côte d'Ivoire, *red-red* in Ghana and *dodo* in Nigeria is a meal well cherished by children and in restaurant. Fruits of certain cooking bananas (Topala, Pelipita, Popoulou, Kalapua N_2, etc) also produce good quality fried plantains.

Plantain fritters

The pulp of over ripe plantains are pounded and mixed with a small quantity of maize or other local cereal flour (about 1/4 of pulp weight) and salt to form a homogeneous pastry. The fritters obtained by deep frying of small pastry balls in palm oil (160-180_C for 4 to 5 minutes) are eaten hot or warm alone or with other dishes (sauce, spices, fried beans, etc). Over ripe fruits of dessert or cooking bananas can also be used.

Plantain Chips

Plantain chips are the most popular plantain products in Nigeria (Onyejegbu and Olorunda, 1995). They are prepared by frying round slices of unripened or slightly ripened plantain pulp in vegetable oil (Figure 8). Best quality plantain chips have been obtained in Cameroon by frying round slices of pulp (2 mm thick) in refined palm oil between 160 and 170_C for 2 to 3 minutes (Lemaire et al, 1997). These generally absorb less frying oil than chips from cooking banana and dessert banana.

The antioxydising treatment (soaking in citric acid solution) which is indispensable to inhibit the action of polyphenoloxydase responsible for the browning of the pulp of dessert banana before frying is not necessary when making chips from plantains and certain cooking bananas (Lemaire et al, 1997). The plantain chips prepared in this way and packed in plastic sachets or in hermetic aluminium sachets (Figure 10) can stay crispy and conserve all their quality for more than 4 months at room temperature and away from light. They generally contain less than 35 percentage of fats and between 1 to 3 percentage residual humidity.

The production and marketing of plantain chips in Africa (Cameroon, Nigeria, Ghana, and Côte d'Ivoire) is principally a feminine activity, which has greatly developed these past years. They are generally eaten as snack food. Industries producing banana and plantain chips have equally been developed in Cameroon and Colombia to give more value to this perishable food product. These industrial or semi-industrial units use various equipment making it possible to mechanise certain activities in the production chain. The "robot-coupe" (models R 502, R 602, or R 602 VV) used for the rapid slicing of banana or plantain pulp into round sizes of uniform thickness is an example (Figure 9). In industry, frying can be done using continues or discontinues electric or gas deep fryers, whereas vacuum packaging with appropriate apparatus is welcome.

Green mature plantain bunches

↓

Separation into individual fingers

↓

Washing and manual peeling

↓

Slicing into round pieces (2 mm thick)

↓

Salting (optional)

↓

Frying in vegetable oil

↓

(Refined palm oil, 2 to 3 minutes at 160-170_C)

↓

Plantain chips (golden colour)

↓

Draining and cooling

↓

Hermetic packaging

↓

(Plastic or aluminium sachets)

↓

Storage and commercialisation

Figure 8: Flow chart for the preparation of plantain chips (Lemaire et al., 1997)

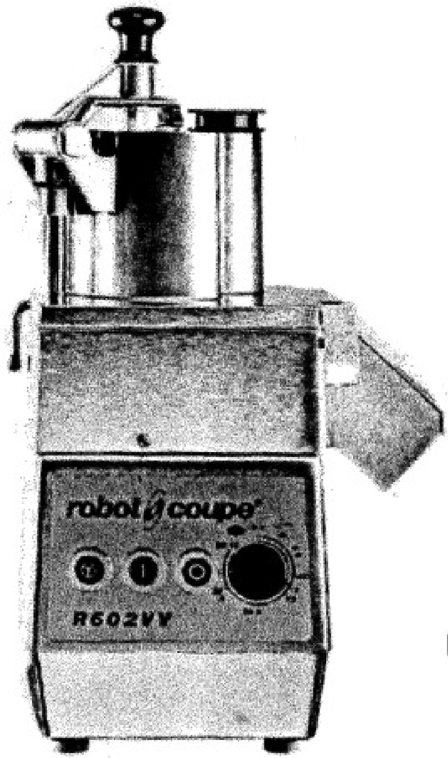


Figure 9: A "robot-coupe" used for rapid slicing of banana and plantain pulp into round sizes of uniform thickness (reproduced from the catalogue of ROBOT-COUPE S.N.C., France).

Figure 10: 

Traditional and industrial packaging of plantain chips produced in Cameroon (photo. J. Tchango Tchango)

Green mature plantain bunches

↓

Separation into individual finger

↓

Washing and manual peeling

↓

plantain pulp

↓

Blanching
(80_C for 5 minutes)

↓

Slicing into round pieces
(2 mm thick)

↓

Slicing into round pieces (2 mm thick)		Antioxidant treatment (3 minutes in critic acid solution)

↓ Drying
(for some days in the sun, 65_C for 48 hours in an oven)
↓
Grinding
↓
Plantain flour
↓
Packaging and storage

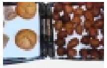
Figure 11: Plantain flour production flow chart (Ngalani, 1989)

Unripe plantain is traditionally processed into flour in Nigeria (Ukhum and Ukpebor, 1991) and in other west and central African countries. This traditional technology is equally present in Amazonian Bolivia. The preparation method consists of peeling of the fruits with the hands, then cutting the pulp into small pieces, and air drying them for few days. The dried pulp is then ground in a wooden mortar or a corn grinder. The flour produced is mixed with boiling water to prepare an

elastic pastry (*alama* in Nigeria and *foufou* or *fufu* in Cameroon) which is eaten with various sauces. The colour of the flour obtained is more or less dark due to the action of browning enzymes. Some improvement of this traditional method (Figure 11), by blanching the plantain pulp at 80_C for 5 minutes and cutting them into round pieces (or by soaking the round pieces for about 3 minutes in a sodium metabisulfite solution (41 g/1) containing 3 g citric acid, followed by draining and drying in a drying oven at 65_C for 48 hours or in the sun for some days resulted in the production of a more or less whitish flour (Ngalani, 1989). Plantain flour containing 10 percentage of residual humidity and hermetically packed in plastic sachets can be kept for many months without deterioration of its qualities. Plantain flour can be used in different ways.

Flour made from ripe plantain (stage 4 to 5 of ripeness) has been used in making bread, biscuits and instant flour (Ngalani and Crouzet, 1995). Bread obtained by partial substitution of wheat flour by 7.5 percentage plantain flour was not significantly different from that made with wheat flour alone. Extruded biscuits had equally been made with a mixture of millet flour (33.2 percentage), plantain flour (17 percentage), groundnut cake (25 percentage), sucrose (20 percentage) coconut (4 percentage) and sodium chlorite (0.8 percentage). The rehydration properties of instant flour obtained by grinding extruded biscuits were comparable to those of commercial flour, with initial absorption rates two to three times higher (Ngalani and Crouzet, 1995). The *soyamusa*, a baby food from plantain flour (60 percentage), full fat soybean flour (32 percentage), sucrose (8 percentage), fortified with 0.15 percentage of multivitamins and 0.85 percentage calcium carbonate have been made and used in Nigeria (Ogazi et al., 1991; Ogazi, 1996). Recent work carried out at CRBP Njombé (Cameroon) have defined simple formulations for fritters and cakes from plantain flour (Figure 12) well appreciated by consumers (Morelle, 1997). The cakes were obtained by cooking a homogeneous pastry in the oven at 150_C for about 50 minutes. Pastry for cakes was made from

100 g plantain flour, 60 g sugar, 40 g fresh semi-skimmed milk, 10 g butter, 5.5 g baking powder, 3 g of pieces of lemon peel and 1 egg. The pastry for fritters can be made with either a mixture of 250 g plantain flour, 100 g fresh semi-skimmed milk, 75 g sugar, 50 g butter, 5.5 g baking powder, 2 g of pieces of lemon peel, 0.5 g salt and 3 eggs ("*beignets merveillés*") or 63 g water, 32 g plantain flour, 25 g butter, 7 g sugar, 0.5 g salt and 1 egg (*"beignets soufflés*"). The fritters are thus obtained by frying small balls of these homogeneous pastries in refined vegetable oil (palm, groundnut and cotton) at 140-150_C for about 10 minutes. The quantities of the ingredients in the mixture for the various fritters and cakes can be modified and adapted according to the taste of the consumers.

Figure 12: 

"*Beignets merveilles*" and cakes from plantain flour produced in Cameroon (photo. J. Tchango Tchango)

1.4 Secondary and derived product

Other uses of plantains

Jams, marmalades, juice, vinegar, beer and alcohol can be made from ripe plantain fruits. In some towns and villages in the region of Ife in Nigeria, a non-alcoholic drink called "*sekete*" is prepared by women. They take ripe plantain fruits that have been peeled and soaked in water for 2 to 3 days, then filter this mixture to obtain a drink which is bottled and sold locally (Ohiokpehia, 1985). Also in Nigeria, Ogazi (1996) reported the production of beer from over ripe plantain pulp with alcoholic content of 5 percentage v/v and specific gravity between 0.998 and 1.0034. These uses are

however more typical of banana than plantains. In Uganda and other East African countries (Burundi and Rwanda) for example, beer bananas are very often used for the domestic production of beer frequently consumed in these regions (Davies, 1993).

1.5 Requirements for export and quality assurance

Bunches or fruit qualities of plantains are judged by important criteria at all stages in the market chain irrespective of the cultivars (N'da Adopo, 1993). Different standards are applied by individuals in the distribution network to assess plantain quality: (1) bunches with well filled fingers and sufficiently round fruits at the time of harvest, (2) fresh fruits without cracks, (3) fruits without mechanical damage, (4) well defined orange rose pulp, and (5) fruits without pest or fungal attacks.

Besides market trends, it was noticed in Cameroon that other factors affect the price of a bunch of mature green plantains (N'da Adopo et al., 1996). These factors include bunch quality at harvest (size, weight, level of finger filling and the colour of the pulp) and its freshness given transportation and storage conditions. A good bunch can cost twice the price of a poor bunch.

Plantains for exportation are carefully handled and transported to preserve the original fruit quality. Handling of those sold locally contrasts sharply with the fragile and perishable nature of the product.

Certain diseases significantly affect fruit qualities. Cercospora diseases caused by Mycosphaerella fijiensis and M. musicola reduce the filling of fingers resulting in about 30-percentage yield reduction. (Momambo, 1993). All known plantain cultivars are susceptible to these fungi. Good

disease control can be achieved with fungicides belonging to triazole and benzimidazole groups. As costs continue to rise, the need for resistant hybrids becomes imperative. Cultural practices used to control such diseases include good drainage (Jeger et al., 1995) and frequently stripping off the leaves with necrotic tissues. Some fungi are responsible for post-harvest diseases, which affect the quality of the banana and plantain fruits. For example anthracnose caused by Colletotricum musae provokes the decay of fruits during ripening. Incidence of anthracnose may be reduced by removal of inoculum laden banana and plantain trash from packing areas and by avoiding injury to fingers and pedicels during harvesting and packing (Jeger et al., 1995). Anthracnose may also be controlled chemically after harvest with spray or dip treatments using fungicides (thiabendazole, imazalil, etc). Cigar-end rot disease caused by Trachysfera fructigena and Verticillium dahliae renders fruits unsatisfactory for consumption. Placing polythene sleeves over the stems before the hands come out (Jeger et al., 1995) effectively controls cigar-end rot disease.

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CHAPTER XIV BANANA PLANTAIN: Post-harvest Operations

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2. Post-Production Operations

2.1 Pre-harvest operations

Plantain is a climacteric fruit. During their growth, there is an increase in size of the fruits and

accumulation of starch. This increase in size stops when the fruits reach total physiological maturity.

Theoretical determination of the harvesting stage of Cavendish banana (Ganry, 1978) showed that increased fruit diameter in the absence of limiting soil factors is a function of the total daily temperature from the appearance of the last hand of the bunch up to the harvest stage (3/4 full or 34 mm grade). The total daily temperature is defined from a 14 ºC threshold, which represents the minimum temperature permitting the growth of bananas. The total daily temperature is equal to [(0,4 x T max) + (0,6 x T min)]-14. In optimal conditions without constraints other than temperature, a total cumulative temperature of 900º C is required to obtain the theoretical optimum harvest stage of dessert bananas. The same growth model applied to French Sombre plantain (N'da Adopo, 1992) confirms that bunches of this plantain cultivar at the 3/4 filling stage are obtained at total cumulative temperature between 900 and 1000ºC. Bunches harvested at full maturity (bunches with well filled fingers and some few ripe fingers) correspond to a total cumulative temperature of 1200ºC. In practice, this model is not apparent to most plantain producers who usually don't work in optimal farming conditions.

In practice, harvest maturity of fruits will depend mostly on the target market. Plantains for local markets are harvested at a more advanced stage of maturity than those for exportation. The maturity indices are based on the age of the bunch, the interval between flowering and harvesting (IFH), the filling of the fingers or the colour of the skin and pulp. The filling of the fingers is the criterion mostly used. This standard is typically completed by other visual criteria like the evolution of the peel colour of the fruits. Most of these criteria depend on the cultivar. If the filling of the fingers was combined with the colour of the pulp, evaluating harvest maturity could become more objective (Marchal, 1993). This leads to the definition of three stages of fruit maturity: non-angular

fruits with pale and whitish pulp (stage 1), rounded fruits with well-coloured pulp (stage 3), and stage 2 between stage 1 and 3. The interval between flowering and harvesting (IFH) is also an objective criterion, which can be grounds for harvest decision. Using the practical IFH and the evolution of average temperature, it is possible to define in each ecological zone an IFH chart according to the seasons and cultivars.

Other maturity indices like pulp to peel ratio, fruit firmness, diameter and length of the fruits reported by Thompson and Burden (1993) are less useful for traditional plantain producers.

Investigations on the best standards to address yield requirement, bunch quality and the conservation of green mature plantain by analysing stages of harvesting remains a priority in producing countries.

2.2 Harvesting

The usual method of harvesting plantains is to partly cut through the pseudostem approximately 2 m from the ground or at upper thirds with a machete. This allows the plant to bend over under the weight of the bunch. The bunch is then cut off and taken away while the pseudostem is left in the plot. The pseudostem is then cut into pieces to reconstitute the organic matter. The stages involved in harvesting a bunch of plantain are shown in Figure 2. This mode of harvesting exposes the fruits to mechanical damage, especially when no precautions are taken to prevent the bunch from falling on the ground (Wainwright and Burdon, 1991; Dadzie, 1994). In the case of dwarf types, bunches can directly be cut off and removed from the pseudostem without cutting it into sections.

Figure 2a-2d: 

Stages involved in harvesting a bunch of plantain without mechanical damage (photo J. Tchango Tchango)

The use of plastic forms is recommended to protect bunches of plantain during harvesting and transportation to the packaging site in the same manner as exportation from industrial plantations. This reduces mechanical damage and avoids reduction of fruit quality of plantains for exportation.

2.3 Transport

The handling techniques of plantains before marketing are generally less adapted to the fragile and perishable nature of the product. In the producing countries of central and west Africa, hands or entire bunches of plantains are combined with other agricultural products in baskets and pans and carried on top of a person's head home or to sell by the roadside. Hands or single fingers can also be packed with other agricultural products in bags to facilitate transportation. Generally in Cameroon, men transport plantains on their heads, behind their bicycles or motorbikes or in rickshaws to their houses or to be sold. Packages of 2 to 3 bunches of plantain are jointed to each other. Women in certain regions of Cameroon carry bunches of plantains in baskets hung on their backs from the plantation to their homes or selling points (Figure 3).

Figure 3: 

Transportation of bunches of plantains to the market by women in the region of mile 20 in the South West province of Cameroon (photo J. Tchango Tchango)

In markets located in the production zones, the bunches of plantains bought from the villages are piled up on one another (Figure 4), then loaded in bulk in trucks (Figure 5) or vans for travel to big distribution and consumption centres situated at times hundreds of kilometres away. The bunches are piled up to maximise loading and to expedite transportation. They are unloaded without caution at the destination. These different modes of packaging and transportation expose the fruits to damage and low market quality (Marchal, 1990; Wainwright and Burdon, 1991; Dadzie, 1994; N'da Adopo et al, 1996).

Figure 4: 

Bunches of plantains piled on one another while awaiting loading in truck at the Mile 20 market in the South West province of Cameroon (photo J. Tchango Tchango)

Figure 5: 

Loading bunches of plantains in bulk in trucks at the Mile 20 market in the Southwest province of Cameroon for transportation to urban centres (photo R. Achard)

2.7 Packaging

Figure 6: 

Reusable plastic cages, which could be used for packaging and transportation of plantain hands (photo J. Tchango Tchango)

Dehanding plantains in the field and packaging the hands in reusable plastic cages reduce mechanical damage and preserve the fruit quality during transportation. An example of reusable plastic cages, which could be used, is shown in Figure 6. The utility of this packaging is not obvious in many producing countries as peasants and intermediate wholesalers are accustomed to bunches. In addition, they are not prepared to bear additional costs or extra investment to buy plastic cages for local sales.

Bunches of plantains exported by ship from Cameroon to Gabon are transported in bulk by ship, without any particular care similar to those sold locally since the trip is about 48 hours.

Plantains exported to Europe and North America are superior quality compared to those sold locally. A high grade of false horn type plantains is in great demand in these countries. In Cameroon, plantains exported to Europe by air are harvested at normal maturity and packed under perforated plastic film in well-ventilated cartons. This method is used to export dessert bananas. Plantain exported by ship in containers or in refrigerated docks (12-14_ C) should be harvested much earlier to avoid ripening during transportation (about 15 days). They are handpacked under perforated plastic film in cartons after soaking them in a solution to avoid the development of fungi during transportation. Studies are underway at the CRBP bananas and plantains regional research centre in Cameroon to determine the optimal harvest period of fruits for plantain cultivars (Big Ebanga, Bâtard and French Clair). This study intends to ensure crop conservation at 12-14_C in the mature green stage during transportation to Europe. Export by ship would enable participants:

To compete with the higher costs of transportation by plane in Cameroon and in other producing countries;

To increase the profit margin;

Promote the development of the production of plantains to ensure high export tonnage.

In Central America, the false horn Cuerno and the bâtard Dominico-harton are the most exported cultivars to North America (United States) and Europe (FHIA, 1993; Lescot, 1993). Single fruits are packed in normalised cartons after soaking in a fungicide solution containing 35 ppm of thiabendazole (0.0035 percentage) and 1000 ppm of imazalil (0.1 percentage). Afterwards the cartons are placed into pallets and transported in refrigerated containers (8 to 9_C) to North America and Europe (FHIA, 1993). In the European market, plantains from Latin America seem to be of inferior quality since they ripen poorly during marketing compared to those transported by plane or by ship in optimal conservation conditions (12 to 14_C and 85 to 95 percentage HR).

2.8. Storage

In producing zones and at the local distribution market, bunches of plantains are generally stockpiled in bulk (Figure 4). However, simple methods intended to reduce the desiccation and the evapotranspiration rate of fruits are occasionally used within the traditional distribution channel to maintain a certain level of freshness and an acceptable quality for a number of days. These measures include precautions to limit mechanical damage to fruits, stocking bunches under shades shielded from the sun and protection of piles of plantains with leaves of banana or bags regularly

moistened with water.

Studies carried out in Côte-d'Ivoire have shown that bunches of plantains (Offoto and Orishele cultivars) harvested at normal maturity stage can be kept green in peasant farms for 14 to 20 days at 302_C and 24 to 27 days at 202_C. This assumes that bunches are harvested when fingers are well filled or rounded and wrapped in plastic bags (8/100 mm) mixed with powder of dry cocoa leaves or rice husk. They will be preserved without remarkable modifications of their organoleptic characteristics (Agbo et al, 1996)

Traders who want to sell their plantains at the ripe stage generally induce the ripening process by stocking them in baskets, drums or other containers covered with plastic bags or jute bags to maintain heat among fruits. These containers are ventilated by removing the covers after 2 to 4 days.

Studies carried out on the conservation of plantains recommend that they be packaged in suitable plastic bags to reduce air circulation. In addition, the use of low temperatures (12 to 14_C) to extend the green life span and maintain the fresh quality of fruits is advised (Hernandez, 1973; Ngalani, 1986; Marchal, 1990; Collin, 1991). These modern techniques of conservation require an investment (purchase of appropriate plastic bags and storage equipment, installation of positive cold store, electricity bills, etc.). Traditional plantain producers and traders would hardly adopt them. All storage attempt to prolong the shelf life of mature green plantain should be preceded by an economic analysis of the system in place: network type, stage of harvest, market value and price after conservation (N'da Adopo et al; 1996). The use of refrigerators or appropriate plastic bags would then be necessary only in the long distribution channel to great distances to supply the non

producing zones where selling plantains at a higher price will justify the establishment of such a technology.

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CHAPTER XIV BANANA PLANTAIN: Post-harvest Operations

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5. Economic and social considerations

Research and development programmes for the post-harvest systems of plantain focus essentially on the improvement of conservation and transformation techniques of the product, and the reduction of post-harvest losses for a more consistent supply. In the analysis of a post-harvest systems, technical description (presentation of methods, tools or innovations) alone is not sufficient and should therefore be complemented by socio-economic evaluation. The idea behind this approach is to appreciate the technology at the disposal of the operator, proposed technology, the technical constraints, but also the economic and social constraints. In most cases, the operator has at his disposal the methods and expertise, which correspond to his environment.

The evaluation of the advantages and disadvantages of the current procedures must be the first step in the intervention process (Nago et al., 1993). All interventions to improve an existing system (introducing modern conservation or stocking techniques, etc) must be preceded by an socio-economic evaluation.

To evaluate a technique, it is advisable to define criteria from the beginning (Guéneau, 1994). The measures often adopted are:

- Efficiency

- Impact

- Viability/reproducibility

- Participation/satisfaction of the operators.

The significance of each standard will depend on the specific methodology considered. The measure of the efficiency of a technique compares the results obtained to the financial, human and material means available. Following the identification, assessment and cost-benefit analysis, the probability for its adoption is then determined. For instance, the cutting up of bunches into hands, followed by packaging in reusable cages is a technique that reduces mechanical damages and improves fruit quality. However, it appears that this technique leads to supplementary investment which operators are not ready to incur. There is no certainty that consumers will accept a plantain price increase sufficient to gain the return of investment.

Analysis of the viability of a technique consists of estimating the capacity of the operator to master and carry forward the technique. The challenge is to overcome not only the technical constraints but also the economic ones. Can a success with a new technology be sustained and repeated?

The analysis of the impact of a technique consists of appreciating the effects that this can have on the environment in its broadest sense:

- Technical impact (improving traditional techniques or introduction of new techniques);

- Economic impact (creation or loss of employment and the increase or decrease of income);

- Social impact (effects of this technique on the operator prestige, on social cohesion and harmony,

and on social organisation of labour);

- Ecological impact (destruction or protection of the environment).

The participation and satisfaction of the operators contributes to the evaluation of the technique at the operator levels. For more complete information on this point, the opinion of potential operators who refuse the technique should be collected. Possible unfavourable effects that the technique could have on certain groups should not be concealed.

5.3 Proposed improvements

Plantains and other cooking bananas produced throughout the humid tropics constitute a major source of carbohydrates and contribute to the food security for millions of people in Africa, the Caribbean, Latin America, Asia and the Pacific. The modes of consumption vary from one country to another depending on the eating habits. Production systems are mostly of traditional type and are dominated by mixed cropping of plantains with other agricultural products (coffee, cocoa, yams, cocoyams, etc). In some countries, plantain monoculture is reported. The improvement of the production systems of these food-stuffs must permit not only the increase in the quantities produced but also the improvement of the fruit quality. This can be achieved through the development of techniques for a better management of pests and diseases as well as a harmonious and durable land use.

All programmes for the improvement of post-harvest systems in plantain should be aimed at objectives defined on the basis of technical criteria (improvement of production technique,

improvement of packaging, handling and transportation methods, development of appropriate preservation techniques), social (reduction of laborious operations), economic (income improvement and market reinforcement). The programme generally includes 4 phases:

- A diagnostic phase to understand the technical system and identify variables that need innovation. This essentially consists of technical and socio-economic evaluation of the system (its functional advantages and constraints, achievements, the expectations and the means of the operators). This next leads to an action plan used as a basis to search for solutions.

- A phase in search for technical solutions which takes into account the objectives of different actors of the system, their environment and their resources. The options to be investigated are not always adapted to the different situations. It is necessary to adjust them or to conceive new ones.

- An experimentation phase carried out with different actors under normal conditions. Experimental demonstrations with actors should be considered as training phase. For example, when testing an equipment, training on installation, functioning and maintenance should be organised.

- A follow up and evaluation phase for the gathering of information on the improved system. The information is then treated and technical options can be adjusted for real situations.

- An improvement programme based on such procedures enables within record time to effectively support the existing dynamics and to actually meet the expectations of operators.

Any study aimed at improving the post-harvest system of plantain should consequently take into account the contribution of the government (repairing roads and tracks in the production areas,

dissemination of research finding and results, subsidising of fertilisers and pesticides, organising the market, etc) as well as the other operators in the plantain network (producers, wholesalers and retail traders, transporters, consumers, etc).

The "commodity chain" approach seems to be better for the global analysis of the system. This global and multidisciplinary approach will include a socio-economic aspect to understand the motivations and logic of the actions of the different actors in the chain (researchers, producers, transporters, retailers, consumers and manufacturers), and a technical aspect to evaluate the technical characteristics and to determine the variables for the development of the production and the improvement of the post-harvest system.

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CHAPTER XV COCONUT: Post-harvest Operations

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1. Introduction

In beauty and utility no other tree can surpass the coconut tree. It is the most extensively grown nut in the world, the most important palm. It provides people basic needs such as food, drink, shelter, fuel, furniture, medicine, decorative materials and much more. They are a necessity and a luxury. It is the "heavenly tree", "tree of life", "tree of abundance" and "nature's supermarket."

1.1 Economic and Social Impact of Coconut

Total world coconut area in 1996 was estimated at 11 million hectares and around 93 percent is found in the Asian and Pacific region. The two biggest producers Indonesia and the Philippines have about 3.7 million ha and 3.1 million ha respectively. India is the third largest producer. In the South Pacific countries, Papua New Guinea is the leading producer. In Africa, Tanzania is the largest producer while in Latin America Brazil accounts for more than one half of the total coconut area of that region. (See Table 1.).

Table 1. WORLD: Area of Coconut 1992-1996 (In 1000 Ha)

C o u n t r y	1992	1993	1994	1995	1996
A. Asian and Pacific	10261	10244	10427	10555	10642
F.S. Micronesia	17	17	17	17	17
Fiji	65	65	65	64	65
India	1529	1538	1635	1714	1796
Indonesia	3599	3636	3681	3724	3745
Malaysia	315	310	305	290	280
Papua New Guinea	260	260	260	260	260
Philippines	3077	3075	3083	3064	3093
Solomon Islands	59	59	59	59	59
Sri Lanka	419	419	419	419	419
Thailand	389	336	397	412	377
Vanuatu	96	96	96	96	96
Vietnam	220	215	186	19	190
Western Samoa	46	50	55	75	75
Palau	14	14	14	14	14

Bangladesh	31	31	31	32	29
Myanmar	29	30	31	32	33
French Polynesia	50	50	50	50	50
Kiribati	27	25	25	25	26
Others	19	18	18	18	18
B. Africa	444	446	466	460	460
Benin	12	12	12	12	12
Comoros	17	17	18	18	18
Ghana	28	30	46	40	40
Ivory Coast	33	33	32	32	32
Madagascar	33	33	33	33	33
Tanzania	305	305	310	310	310
Others	16	16	15	15	15
C. America	484	448	456	459	476
Brazil	236	228	232	238	258
Mexico	165	141	143	139	135
Jamaica	35	35	35	35	35
Venezuela	23	22	23	23	23
Others	25	22	23	24	25

T o t a l	11189	11138	11349	11474	11578

Source: Statistical Year Book 1996, Asian and Pacific Coconut Community (APCC)

Table 2: World Production of Coconuts (Measured in Nut Equivalent) 1992-1996 (1000 nuts)

C o u n t r y	1992	1993	1994	1995	1996
A. Asia and Pacific	42113805	43671709	45462211	48295884	47934625
F.S. Micronesia	40000	40000	40000	40000	40000
Fiji	195000	198000	196200	196040	196400
India	10080000	11241000	11975000	13300000	13968000
Indonesia	12376000	13030000	13245000	13521000	13595000
Malaysia	883000	800000	787000	748000	722000
Papua New Guinea	980000	1058000	840000	869000	960000
Philippines	11405000	11328000	11207000	12183000	11935000
Solomon Islands	262000	267000	272000	280000	287600
Sri Lanka	2296000	2164000	2622000	2755000	2546000
Thailand	1103000	1128000	1849000	1898000	1130000
Vanuatu	327000	317000	317000	317000	346000

Vietnam	1010000	1000000	978000	1054000	1065000
Western Samoa	122000	144000	159000	160000	160000
Palau	70000	70000	70000	70000	70000
Others	964805	886709	905011	904844	9136
B. Africa	2129145	2230674	2181004	2196295	2193000
C. America	3352218	3097368	3487416	3522878	3469929
T o t a l	47595168	48999750	51130631	54015056	53597554

Source: Statistical Yearbook 1966, Asian and Pacific Coconut Community (APCC)

The average annual production of coconut during 1992-1996 was estimated to be 50 billion nuts, or 10 million metric tons of copra equivalents. (APCC 1996, Table 2).

Of the world production of coconut, more than 50 percent is processed into copra. While a small portion is converted into desiccated coconut and other edible kernel products, the rest is consumed as fresh nuts. The coconut palm also provides a series of by-products such as fibre, charcoal, handicrafts, vinegar, alcohol, sugar, furniture, roofing, fuel among others, which provide an additional source of income. Diversified local uses of the coconut palm number over 200. (See Figures 1 and 2).

Figure 1 - Potential Products from the Coconut Palm

T H E C O C O N U T P A L M

TRUNK FRUIT INFLORESCENCE FROND

FUEL LEAF SPINE
NUT HUSK SYRUP

TIMBER CHARCOAL
FIBRE MATTING FUEL

WATER FLESH SHELL FUEL BEVERAGE DISTILLATION

PRODUCTS

BAVERAGE POWDER
FILLER DUST SUGAR

COOKING Fresh Dry
MILK Process Process

FOOD Peel CHARCOAL COIR

BRIQUETTES
ACTIVATED

WHITE FLESH TESTA CARBON SOIL CONDITIONER

DRY COPRA

Aqueous Dry HARDBOARD
Process Process STOCK ROOFING

FEED

Ultra-fine Shred Gasification
Shredding Extraction

DESICCATED

COCONUT PRODUCER GAS HEAT
Separation

Synthesis ELECTRICITY

EDIBLE CREAM
MEAL METHANOL or

EDIBLE CRUDE AMONIA
NATURAL OIL BRISTLE FIBRE YARN

dry OIL STOCK

FEED
refine

DRY FOOD
PRODUCTS BLAND INDUSTRIAL OIL BRUSHES MATTRESSES TWINE

COOKING OIL

refine BROOMS RUBBERIZED ROPE
COIR

DAIRY MILK Process
SUBSTITUTE COCO CHEMICALS CONCRETE

SOAP REINFORCING

VEHICLE/

AIRCRAFT SEATS
MILK YOGURT CHEESE ICE CREAM ETC
POWDER

Products are expressed in upper case and processes in lower-case letters.

Source: Proceedings of XXXIII COCOTECH Report 1991, APCC

Figure 2. Coconut Tree of Life - Its Parts and end

1.2 World Trade

A wide range of coconut products are internationally traded. There are more than 50 unprocessed, semiprocessed or processed coconut products entering the international markets in small and big quantities. Aside from copra and coconut oil, other exports which have a significant volume are desiccated coconut, copra meal, cocochemicals (fatty acids, fatty alcohol, methyl ether), shell charcoal and activated carbon, fibre products, coconut cream, milk, powder and nata de coco.

Although global production continues to increase, the growth rate of domestic use was faster therefore reducing the exportable supply of kernel products to about one third of the production. However there has been a sizeable increase in the export of non-traditional products in recent years. Both copra and coconut oil are traded internationally. In the past, the main export was copra.

In the 1960s over 1 million tons of copra was traded world-wide per annum. The volume declined to about 900000 tons a year in the 1970s further declining to an annual average of 350000 tons in the 1980s. This immense drop occurred when the producing countries established domestic copra processing plants in response to their desire to obtain more value-added products. In 1994 copra exports further dropped to 234874 tons with Papua New Guinea at 53767 tons followed by Indonesia, Vanuatu, Philippines, Solomon Islands and Malaysia with exports below 40000 tons

each. The downtrend in copra exports is likely to continue.

In contrast, coconut oil exports increased marketedly. World trade in coconut oil during the period 1964-1968 averaged only 506000 tons a year. This rose by 75 percent during the next decade to reach an average volume of 888000 tons. The market further improved to an average of 1.2 million tons in 1980s and 1.5 million tons in 1990-1994. 1995 was a peak year for coconut oil when exports rose to 1.8 million tons. The world annual tonnage of coconut oil and copra exported for 1990-1994 averaged 1.6 million tons of oil with about 55 percent from the Philippines. Coconut oil is imported by 100 countries. The United States of America and Western European countries absorbed about 70 percent of total imports.

1.3 Primary Products

The main coconut product, copra (dried kernel), and its derivatives coconut oil, copra cake, plus desiccated coconut represent a major source of foreign exchange. For several small nations, especially in the Pacific, copra is the principal source of foreign exchange.

Coconut oil is the leading commercial product which contributes nearly 7 percent of the total supplies of vegetable oils in the world. The world's production of coconut oil reached 3.1 million tons in 1996.

Traditionally, the coconut is dried to produce copra and the oil is then obtained from the copra by expression or prepress solvent extraction methods. The residual product after the oil extraction coconut meal contains 18-25 percent protein, but is too fibrous for use in monogastric diets.

Consequently its main use is ruminant feeding.

Desiccated coconut is the dried, white, particulate or shredded food product manufactured from freshly peeled coconut kernels. The world production of desiccated coconut is around 200,000 mt a year, the bulk of which is exported and is the second next most significant coconut product in global trade. In 1996 the total volume of desiccated coconut imported was 174,000 mt tons mainly purchased by Europe and the United States.

Coconut Processing

Though coconut can be processed into many products, the next part focuses on the processing of coconut oil, highlighting the dry-process of coconut oil extraction and two improved coconut oil extraction technologies which have proven to be adaptable at the village level, namely: a) The Hot-Oil Immersion Drying Technology; and b) The Ram Press Coconut Oil Extraction Technology. These technologies were selected as the most practical. Though their viability is site-specific, women and members of the farming family may run the technology.

Coconut Oil Processing - The Dry Process

Coconut oil is one of the main traditional products derived from the meat or kernel. It is a mixture of chemical compounds called glycerides containing fatty acids and glycerol. The different fatty acids present in coconut range from C6-C18 carbon atom chains.

Coconut oil processing methods or technologies are classified into two (2) major types: the dry and the wet processes. The oil extraction technology which starts with copra as the raw material is

termed as the dry process, while the method that uses fresh coconuts as starting material is generally called the wet process.

Dry processing of meat for oil production involves the conversion of coconut meat into copra prior to expelling and refining. This process is however done off-farm, in an oil mill. From the farm, the copra goes through a series of traders. Storage in warehouses range from two weeks to two months. At the mill, the copra undergoes the following steps, (Figure 12):

1) Cleaning: Copra is transferred from the warehouse to a mill by a series of floor conveyors, rotor-lift and overhead conveyors. Copra is cleaned of metals, dirt and other foreign matter manually by picking or through the use of shaking or revolving screens, magnetic separators and other similar devices;

2) Crushing: Copra is broken into fine particle sizes of about 1/16" to 1/8" by high speed vertical hammer mills to facilitate oil extraction;

3) Cooking/Conditioning: The crushed copra that has about 5-6 percent moisture is passed through a steam-heated cooker. This brings the temperature of the copra to the conditioning temperature of about 104^{o}C (220^{o}F). At the conditioner, the copra is maintained at about 104-110^{o}C (220-230^{o}F) for about 30 minutes to insure uniform heat penetration before oil extraction. Moderately high temperature facilitates the expelling action. Oil is able to flow out more easily due to decrease in viscosity proteins and other substances present in the copra. Heating dries and shrinks these substances. Moisture content of copra is about 3 percent when it leaves the conditioner.

4) Oil extraction: In the expeller, the milled copra is subjected to high-pressure oil extraction, first by a vertical screw, and finally by a horizontal screw. To control the temperature during extraction, the main shaft is provided with water-cooling and cooled oil is sprayed over the screw cage bars. The temperature of the oil should be kept at about 93-102^{O}C (200-215^{O}F) to produce light coloured oil and effect good extraction.

5) Screening: The oil extracted in the expeller flows into the screening tanks to remove the entrained foots from the oil. The foots settle at the bottom and are continuously scooped-out by a series of chain-mounted scrapers which lift the foots to the screen on top of the tank. While travelling across the screen, oil is drained out of the foots. The filtered oil flows into a surge tank from where it is finally pumped to the coconut oil storage tank.

6) Filtration: The oil is passed through a plate and frame filter press to further remove the solids in the oil. Two filter presses are provided - one on duty while the other is being cleaned and dressed. Maximum filtering pressures reach about 60 psi. The filtered oil flows into a surge tank from where it is finally pumped to the coconut oil storage tank.

Coconut oil produced from good quality copra is clear, low in fatty acid and has good coconut aroma. However crude coconut oil from bad quality copra is dark; turbid; high in free fatty acids (FFA), phosphatides and gums; has an unpleasant odour. To render this oil edible, it has to undergo a refining process. Typically, 5 percent of the weight of the crude oil is lost in refining but the loss can be as high as 7.5 percent.

Figure 12: Dry Process of Coconut Oil Manufacture

NaOH-_ _ Soapstock

Filtered crude oil

Crude coconut oil

suspended solids

copra cake

Refining consists of neutralisation, bleaching and deodorising. Neutralisation reduces the FFA to improve the taste and appearance of the oil. It is done by reacting sodium hydroxide with free fatty acid to form an oil-insoluble precipitate called soapstock.

The amount of sodium hydroxide required to neutralise is 1.418 kg NaOH per 1 percent FFA content per ton of crude coconut oil. In actual practice, it is reported that 10 percent excess is added to ensure complete neutralisation. This amounts to 1.50 kg NaOH per ton of crude coconut oil per 1 percent FFA.

The soapstock is then removed once it settles out. This is either converted into either acid oil by treatment with sulphuric acid or into soap by complete saponification.

Phosphotides and gums are removed by physical refining in which the first stage involves treating the oil with phosphoric acid. These are then separated from the oil either by centrifugation or decantation.

Bleaching takes out most of the dissolved or colloidal pigments responsible for the colour of crude oil. Either activated carbon or bleaching earth such as bentonite (1 to 2 percent) or a combination of both are added to neutralised the oil under vacuum while heating it to 95-100^{o}C. Afterwards, the bleaching agents are removed by passing the oil through a filter press.

Deodorisation removes volatile odours and flavours as well as peroxides that affect the stability of the oil. It is done by heating the oil to a temperature between 150-250^{o}C and contacting with live steam under vacuum conditions (29 psig pressure).

Coconut Oil Extraction: The Hot Oil Drying Technology (HOID)

The Hot Oil Immersion Drying (HOID) technology or the `fry-dry' process is a method of extracting coconut oil from fresh coconut meat (wet process). The process involves grating and then drying the freshly cut coconut kernel by immersing it in hot oil. The dried residue is subsequently removed from the hot oil, drained and passed through a screw press where the oil is extracted under pressure leaving a dry cake. (See Figure 13).

Figure 13. Process Flow of the Hot-Oil Drying Technology (HOID) of Extracting Coconut Oil

to be sold

HOID or `fry-dry' process is indigenous to West and North Sumatra, North Slaws in Indonesia and is currently practised all over the country. It was reported that a few areas in the Philippines have used the technology but not many are fully knowledgeable of its application. It is believed that

there are good prospects and a wider scope for the introduction and application of the HOID technology not only in other parts of Indonesia but also in many areas in Asia and the Pacific, especially in medium and large scale operations.

The HOID technology is an alternative method of producing coconut oil. The oil is generally of a better quality and preferred by certain segments of the population, especially in Indonesia, because of its distinctive coconut flavour. The HOID oil can be used directly as cooking oil, without chemical refining. In certain parts of Indonesia, HOID oil is sold at prices higher than that of refined palm oil.

The method of HOID oil production involves the following steps:

1) The fresh coconut meat is delivered to the processing plant where it is inspected, washed and cut into pieces with a hammer mill or a grater.

2) The grated kernel is then fried in the pan of hot coconut oil at approximately 120^{o}C for 20-45 minutes depending on the oil temperature and ratio of fresh meat to coconut oil used. Care must be exercised not to add too much meat at once during the frying because the immersion of the cut coconut kernel results in a rapid evolution of steam which can result in oil spillage. Stirring of the grated coconut is occasionally done during the frying. The drying process is completed when there is no more steam produced, the coconut meat becomes yellowish to brown and the temperature of the coconut oil in the pan increases;

3) The fried particles are then taken out of the oil by means of perforated spoon affixed to the end of a long wooden handle. The meat is then dumped in a filter box and the oil is allowed to drain

through a meshed plate at the base of the container.

4) The drained, cooked brown coconut particles, rich in coconut oil, are then fed to the hopper whence it is fed to the screw press. The expelled oil is passed through a mesh plate and settled in a tank before it is pumped or poured into the main settling tank.

5) The oil is then clarified by settling the oil in the tank. Sometimes a filter press is used. Once clarified, the oil can be sold directly in the market as cooking oil without further chemical refining.

The main equipment used in a small HOID processing plant are as follows: a) hammer mill or grater - this is used to cut the fresh coconut kernels. In some areas in Indonesia, the kernel is grated; b) drying pans-either circular or rectangular in shape. These pans are equipped with wooden stirrers and spoons for removing out the dried meat manually, c) furnace - is used to heat the pans by burning the wood, coconut shell or husk in the combustion chamber; d) screw press - this is used to extract oil from cooked, brown coconut meat; e) filter press or setting tank; and f) a draining tank and other handling equipment such as scooper, tray, metal and rattan baskets.

The viability of the process is most sensitive to the price of the raw material, price of oil and the oil yield. Thus, it is important that the plant must be designed and operated to minimise oil losses and maximise returns from efficient operation of the whole system. The viability of the process is also dependent on the site.

Ram Press Coconut Oil Extraction

Ram press coconut oil extraction is a method of expelling oil from dried coconut either in the form

of dried fresh coconut gratings, copra or dried residue from aqueous coconut processes.

The ram press also called the Bielenberg press was developed by the Appropriate Technology International, a Washington based NGO, in 1985 through its Village Oil Press Project in Tanzania. It is manually operated, low-cost piece of equipment which was originally designed to be used by smallholder farmers to process soft-shelled sunflower seed to obtain scarce cooking oil. The original design of the Ram Press was arduous to use and took two men to operate.

Recently, the Natural Resources Institute (NRI) of the UK has carried out some work on improving small scale coconut oil extraction methods using the participatory approach, particularly involving women in the rural areas in Asia, the Pacific and Africa. One of the design advancements of the Ram Press is a version that is smaller and easily operated by a woman.

The newly designed Ram Press has a long, pivoted lever which moves a piston backwards and forwards inside a cylindrical cage constructed from metal bars spaced to allow the passage of oil. At the end of the piston's stroke an entry port from the feed hopper is opened so that the oilseed or the squeezed coconut gratings (called chicha in Tanzania) can enter the cage. When the piston is moved forward, the entry port is closed and the chicha is compressed in the cage. (See Figure 14, 15 and 16).

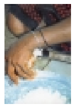
Figure 14: Villager Using the Traditional Coconut Grater in Tanzania 

Figure 15: Rotary Coconut Grater 

Figure 16: Ram Press Operated by Women in Zanzibar 

The compressed chichi is pushed through a circular gap at the end of the cage. The width of this gap, which can be varied using an adjustable choke, controls the operating pressure of the press. The lever mechanism of the press is such that it can operate pressures greater than those obtained in most manually-operated presses, and as high as those in small-scale expellers. While the Ram Press has a low seed throughput, it has the advantage of continuous operation.

Laboratory and field trials conducted by the NRI in Tanzania indicated that the Ram Press was suitable for pressing sundried squeezed coconut gratings or chicha. The oil extraction efficiency achieved was 60-70 percent. Although more arduous to use when processing chicha than when processing sunflower seed, women users in the villages of Zanzibar found that the ram press is easy to operate, especially when several changes in operation were made.

Desiccated Coconut

Desiccated coconut is the dehydrated, shredded white kernel of the coconut. It is produced from fully ripe coconut kernel under strict hygienic conditions for human consumption. It is used both in household foods and processed foods particularly in ready-to-cook mixes and in packaged and canned foods. In the bakery and confectionery industries desiccated coconut is a preferred product.

Nutritionally desiccated coconut is not different from fresh coconut kernel. It retains all the characteristic features of the wet kernel including the original nutrients. Good desiccated coconut is crisp, snow white in colour with a sweet, pleasant and fresh taste of the wet kernel.

The production of desiccated coconut involves dehiscing of fully matured coconut. This involves detailing without breaking the kernel, removing the brown test and slicing the pared kernel into two halves to release the nut water. Next comes washing and sterilising the kernel pieces either by passing them through boiling water or subjecting the pieces to live steam. Stabilising the sterilised kernel pieces is done by immersion in a solution of sulphur dioxide. Finally the kernel is disintegrated or shredded into standard or fancy cuts. The final stage the kernel is dried, cooled, graded and packaged in moisture and odour proof containers.

In the desiccating process the wet kernel is shredded into nine different cuts. These cuts are grouped under three broad categories such as granular cuts, shred cuts and speciality cuts. The cuts are further processed at the destinations to satisfy specified end use requirements. The more common products so produced are (1) sweetened coconut (2) toasted coconut (3) coloured coconut and (4) creamed coconut. The proximate composition of selected types of desiccated coconut is given in Table 7.

Table 7: Proximate Composition (in percent) of Selected Types of Desiccated Coconut

Component	Desiccated	Sweetened	Toasted
Moisture	2.50	11.50	0.50
Fat	66.00	39.00	46.50

Non-fat solids	31.50	20.00	22.50
Added sugars	-	27.00	30.00
Propylene glycol	-	2.00	-
Salt	-	0.50	0.50

Source: Franklin Baker (1971)

1.4 Secondary and derived product

In major coconut producing countries, several products and by-products are processed for export. They are coconut fibre: coir and coir products, mats, mattings, brushes, brooms, rubberized coir mattresses; shell products: charcoal, activated carbon; coconut-based food products: coconut milk, cream, nata de coco, coconut jam, young tender coconut. For coconut-based oleochemicals including fatty alcohol, fatty acids, methyl esters, tertiry amines, alkanolamides and glycerine there has been a growing demand in the world market

Today, technologies exist for many other value-added products from the coconut tree, its fruit as well as the wastes generated. These technologies are not centred in any one country but are scattered across the major coconut growing regions.

Coconut food processing technologies that are adaptable by individuals or groups of coconut farmers will be featured here. These coconut-based technologies require very simple locally available materials, and their operation is quite easy to follow. The coconut-based products that

are derived from these technologies may be consumed by the farming family or sold in the domestic market. Thus, adding value to the coconut, and enabling the farming family to earn additional income. These technologies include a) Coconut Vinegar Making; b) Moulded Coconut Sugar; c) Coconut Jam; and d) Nata de coco; e) Soap making; f) Coconut Shell Charcoal Making; and g) Coconut Fibre Products.

Coconut Water-Vinegar

Coconut water vinegar is a natural product resulting from the alcoholic and acetos fermentation of sugar-enriched coconut water. It contains 3-4 percent acetic acid and is used as an indispensable commodity in any household.

Vinegar derived from fermenting coconut water can be produced either on a commercial scale or as a village cottage industry. As a non-synthetic food product, coco water vinegar is widely preferred as table seasoning, or as ingredient in food processing.

Cocoa water vinegar is processed by allowing filtered coconut water, mixed with other substances, to undergo fermentation and acetification at ambient temperature (28-32^{o}C). The first step of the process is done by straining the coconut water through filter cloth. The sugar content of coco water is then adjusted to 15 degrees Brix (162 grams per liter) by adding refined sugar into it. The mixture is pasteurised by heating to boiling point. The boiled mixture is then cooled and inoculated with the active dry yeast at one-half gram per litre. The mixture is then allowed to undergo alcoholic fermentation for five to seven days. After the fermentation process, alcoholic coconut water is then transferred to another container with a faucet at its bottom. Mother vinegar or a starter culture is

then added to about 1/4 its volume. The container is only filled up to 3/4 its capacity to provide headspace for effective acetic acid fermentation. The mixture is then stirred thoroughly, covered with clean cloth and allowed to undergo acetification for seven days.

The coco water vinegar is harvested by opening the faucet or by siphoning. The amount of vinegar harvested is equivalent to the amount of alcoholic coconut water added. The remaining vinegar will then serve as the starter for the next batch of alcoholic coconut water acidification. Since the process involves fermentation care must be taken to ensure that all fermentation containers are either made of plastic or stainless steel.

The process produces a natural product, which is highly acceptable, based on flavour, aroma and general acceptability. It contains 4.0 percent acetic acid, which conforms to the Food and Drug Administration requirements.

The technology is simple, economic and an accelerated method of coconut water vinegar production. It can be easily adopted in the rural areas since no sophisticated equipment is needed and very little capital investment is required.

The utilisation of coconut water which is considered a waste material in copra making or in desiccated coconut factories will certainly give an added income to the rural families in the coconut farming communities. It will provide productive use of the time and employment to the women in the coconut countryside.

Toddy Vinegar

When the coconut inflorescence is tapped, a very sweet juice or sap exudes from it. This is called coconut toddy in Malaysia, Sri Lanka, India and other countries. The coconut toddy contains as high as 16 percent sucrose and can be had throughout the year.

A characteristic of coconut sap is its spontaneous and rapid fermentation. No yeast is needed since there is a ready source of very active "wild" yeast in the environment. The coconut sap starts alcoholic fermentation right away and becomes completely fermented within a day.

Fresh coconut toddy can be used as a beverage. However, it becomes unpalatable if allowed to ferment for more than 24 hours. After this period, acetic fermentation converts the alcohol into vinegar. In the traditional method of vinegar production, toddy is allowed to ferment in large acetifying vats for 10 to 14 weeks. When the vinegar reaches the maximum strength of about 4 to 7 percent acetic acid, the clear supernatant liquid or vinegar is then transferred to closed casks for ageing up to six months. The aged vinegar is then bottled for household or commercial purposes.

Alcoholic Beverages from Coconut Sap

Sweet toddy or fresh sap undergoes spontaneous fermentation producing a common alcoholic drink `fermented toddy'. The toddy becomes stale when the fermentation exceeds 24 hours. Normally, the toddy is consumed within 12 hours after the sap is collected. The nutritional value of toddy for thiamine and riboflavin resides mainly in the yeast-free fluid portion. Toddy also contains small amounts of protein, fat and other nutrients.

Fermented toddy on distillation yields a strong alcoholic drink known as arrack or lambanog. (See

Figure 17). The range of recovery is 15-18 per cent of the original toddy. Normally, sweet toddy is allowed to undergo fermentation in loosely covered wooden or plastic container for 3-5 days before it is distilled. Reports revealed that analysed, samples of arrack collected from several location had average value of total soluble solids of (^{O}Brix) 13.52, a pH of 3.92 and alcohol content of 42.65 (Vol. percent).

Figure 17: Arrack and Lambanog 

Home-Made Moulded Coconut Sugar

Moulded coconut sugar is edible sugar made from fresh coconut sap. Produced by small-scale cottage industries, moulded coconut sugar is used for edible purposes essentially as a sweetening agent in many traditional food preparations and food products especially in Indonesia. The concentration of total sugars in moulded coconut sugar is 80 percent total soluble solids. (See Figure 18).

Figure 18: Moulded coconut sugar 

The process of producing moulded coconut sugar starts from tapping or collection of coconut sap. But before this is done, the collection vessels are first washed with clean water, followed with hot water and then dried. Alternatively, the clean vessels are smoked using firewood for 10-15 minutes. The treatments are used to reduce microbial loads of vessels.

To prevent spoilage of sap during tapping, the collection vessels are added with tablespoon in the form of paste, a few pieces of mangosteen bark or other natural preservatives such as special varieties of leaves. Once treated, the collection vessels are then ready to be used for tapping the coconut sap.

Collection of coconut sap from the palm is done twice a day at 6 to 7 in the morning and at 4 to 5 in the evening. Although it is not a common practice by home processors, it is desired that the collected sap be tested for acidity using a pH indicator paper. This is because the fermented or spoiled coconut palm sap is no longer suitable for brown sugar manufacture.

The collected coconut sap is then filtered through a muslin cloth to remove insects, ants and other contamination. It is then transferred into a cooking vessel.

The next step involves evaporation of water from the sap to increase the concentration of the sap. Thus, the filtered sap is boiled in a cooking vessel at a temperature of 100-110^{o}C for 3 hours. The material will then turn into a thick liquid. During boiling, foam will be formed. This should be discarded from the vessel. A few drops of cooking oil or grated coconut are added to the mash to prevent excessive foam formation.

The mash is heated for another one hour with occasional stirring. To avoid caramelisation of sugars, heating should be done slowly. When the mash has become very thick and suitable for moulding, the cooking vessel is lifted from the stove and cooled to 60^{o}C. The cooled mash is then poured into clean halves coconut shell or bamboo vessels for cooling and setting.

Home-Made Coconut Jam

Referred to as coconut caramel spread (siamu popo) by some South Pacific countries, especially in Samoa, coco jam is actually coconut milk cooked in brown sugar and glucose. Coco jam is the `butter' in many coconut producing countries and it is commonly taken as a spread, biscuit sandwich, pancake syrup, sponge cake filling, doughnut spread, ice cream topping, fruit dessert topping and as marinade syrup for meat. (See Figure 19). The concentration of total sugars in coconut jam is 75-76 percent total soluble solids.

Figure 19: Coconut caramel spread (siamu popo) 

To produce good quality coconut caramel spread, one starts with choosing 100 fully matured coconuts which are devoid of cracks or any damage. The selected nuts are dehusked, cut into halves and grated immediately. Freshly grated coconut meat has the characteristic coconut smell and must not have any off odour. It is also important that all containers used are thoroughly clean and the working place completely sanitary.

Once the grated coconut is ready, (33.3 kg) coconut milk may then be extracted by adding water in the proportion of 1 part grated coconut to 0.5 part water (if pressing to be done manually). However, no water is needed if pressing is done mechanically.

Strain or filter the coconut milk through cheesecloth to remove any solid particle or foreign matter from the milk. Weigh the coconut milk (12 kg) and determine the amount of brown sugar (2.13 kg)

and glucose (1.06 kg) needed. Mix the sugar the glucose with one-half of the total volume of the coconut milk and boil slowly to dissolve the brown sugar and the glucose. Stir continuously for about 10 minutes and maintain the cooking temperature at about 78-80 degrees C.

Add the remaining half of the coconut milk extract when almost thick and boil for another 35 minutes until the temperature reaches to 100-102 degrees C. Stir the mixture frequently or almost continuously to prevent burning continue to boil until done. The end point is reached when a drop of the mixture forms a soft ball in cold water. Strain the cooked mixture through a clean wire mesh and pack while hot. Packing is best done using clean and sterilised bottles for longer shelf life. Cool the bottles, label and seal.

Nata-de-Coco Production

Nata de Coco is a white, gelatinous food product obtained from the action of micro- organism Acetobacter xylinum on coconut water or coconut milk mixed with water, sugar and acetic acid. Quality nata is smooth, clear and chewy. It is sweetened by boiling it in sugar-water solution.

Nata de Coco is popular primarily for its food uses. It can be sweetened as desserts or candies. It is an excellent ingredient for sweet fruit salads, pickles, fruit cocktails, drinks, ice cream, sherbets and other recipes. Nata de coco also has some industrial uses.

The process flow in the production of nata de coco is:

1. Preparation of ingredients - Measure all ingredients in the formulation, properly from the 28 litres of tap water, get approximately 3 litres for dissolving sugar and 2 litres for extracting the

coconut milk from the freshly grated coconut meat.

2. Milk extraction: Place the coconut meat in the basin and add half of the water set aside for extraction. Mix thoroughly and squeeze grated meat in water. Filter through a piece of cheesecloth. Repeat extraction using the remaining water and filter. Add second extract to the first.

3. Filtration of dissolved sugar: Filter dissolved sugar to remove impurities that might have entered accidentally into the sugar in stock.

4. Mixing: To the remaining 23 litres of water, add the extracted coconut milk, dissolved sugar, glacial acetic acid and mother liquor. Stir thoroughly with a wooden ladle to get a homogenous mixture. Set aside a small portion as mother liquor for the next mixing.

5. Filling: Distribute the rest of the mixture into nata moulders at a level of approximately 3 centimetres high.

6. Fermentation: Arrange the nata moulders in the nata fermentation room. Cover with newspapers or similar materials. To maximise space, nata moulders can be placed one on top of the other to obtain several layers. Fermentation is completed after 8-10 days, depending on environmental conditions. Optimum temperature for nata production is between 23-32^{o}C.

7. Harvesting: Harvest by separating nata from the spent liquor.

8. Scraping: Clean nata by scraping the cream and the thin, white layer at the bottom part using a

blunt piece of plastic or bamboo.

9. Soaking: Place clean nata in a plastic container and keep immersed in water.

10. Syrup of Nata de Coco: To cook nata de coco in syrup, cut clean nata into cubes approximately 1 cm3 or according to the customer specifications. Soak the nata for one or more days in several changes of water to remove the sour taste and smell. Drain the nata and boil in water for 5 to 10 minutes. Check if acid is totally removed.

Add sugar equal to the weight of drained nata. Mix thoroughly and set aside overnight. The next day, stir the mixture to disperse any undissolved sugar. Add a small amount of water. Heat the mixture to boiling point, stirring occasionally. Add flavouring, if desired. Set aside overnight and repeat the heating process until the nata is fully penetrated with sugar as evidenced by the clear and crystalline appearance of the sweetened nata.

Pack the sweetened nata 2/3 full into sterilised preserving jars. Add syrup leaving a 1/4 inch air space. Cover jar immediately with PVC lined caps. Sterilised bottled nata by immersing in boiling water for 30 minutes.

Remove bottled nata and tighten the caps. Cool the jars in inverted position to further sterilise the caps and check for leakage. Wash cooled jars and wipe them thoroughly, place plastic seal and label. Store in cool dry place.

Soap Making

Mixing oil with a solution of caustic soda in water makes soap. When the caustic soda is mixed with oil, a chemical reaction occurs and all the component fatty acids of the oil are changed into sodium salts, known familiarly as "soap".

The oil, caustic soda and water used to make the soap have to be mixed together in correct proportions to ensure that the finished soap contains no excess alkaline which would cause a burning reaction on the skin. The oils used for soap making fall into two categories. In the first category are oils that are obtained from the kernels of different types of palms. The most commonly known oils in this category are coconut oil and palm kernel oil. They are known are "lauric oils" because lauric acid is the major fatty acid that they contain. These fats make hard soap which produces fast foaming lather.

To make soap by the cold process follow the following steps. Weigh one kilo of NaOH and two kilos of water, and pour the NaOH flakes in water and stir constantly until dissolved. Avoid inhaling the vapour over the solution as the mixture will become very hot and. Set aside for cooling to a temperature of about 96^{o}F.

Prepare six kilos of coconut oil and slowly pour this into the caustic soda solution, while constantly stirring the mixture in one direction. The mixture is kept stirred until it thickens to a desired consistency, approximately after 40 minutes to 1.75 hours. Add any desired colour or essence. Stir and immediately pour into moulders and leave for about 24 hours for saponification.

Cut into desired sizes and dry or age for at least one week to complete the chemical reaction. Wrap if required and use the soap only after one week of ageing.

Coconut Shell Charcoal Making

Charcoal making is based on the principle that coconut shell, wood and other carbonaceous materials can be converted into charcoal by incomplete burning. Limiting the amount of air used during the burning process produces incomplete burning. Thus, the quantity and quality of charcoal depend largely on how well the amount of air is regulated in the charcoal chamber.

Charcoal making started with simple methods such as those employed in the backyard to make charcoal for household use. As demand increased, more sophisticated methods were developed to produce charcoal in commercial scale. Today, small backyard and commercial kilns are being used.

The two types of kiln used in charcoal making are the primitive or modified pit and the drum.

Primitive or modified pit - A simple pit is dug in the ground just enough to accommodate the desired number of coconut shells to be made into charcoal. The process mainly involves simple drying of coconut shells arranged in the hole and burned. Some farmers cover the pit from time to time while the shells burn. To control the fire, sprinkle the flame with enough water so as to put the fire totally out. The charcoal produced out of the modified pit method is suitable only for household use due to its poor quality.

-Drum - A 55-gal drum open on one end, and punched with four holes at the bottom is used in this method. This is then raised from the ground by two pipes to allow air entry through the holes. As a starter, remove the cover from the drum, place and burn a shovel full of shells on it. When already burning strongly, throw the shells into the drum. Throw in just enough fresh shells to put the

flames but not the fire. Feed shells continuously at the top to assure that they will not burn fiercely. Slow burning gives the highest charcoal yield and the least ash. When burning reaches the top pile of shells, cover the drum with banana stalks or wet sack plastered with sand or mud. Never allow sand or mud to get inside the drum. The charcoal-filled drum should be left to cool overnight. It takes about for hours of shell burning to fill one drum. When properly attended to, one drum can yield 75-90 kg charcoal. Generally, it takes 3 tons of shells to make 1 ton of charcoal.

Uses of Coconut Shell Charcoal Activated Carbon:

Activated carbon from coconut shell charcoal is a manufactured carbonaceous material having a porous structure and a large internal surface area. It can absorb a wide variety of substances. Activated carbon particles are capable of attracting molecules to their internal surface area and are therefore called adsorbents.

The main characteristic of activated carbon is the extent of their internal pores. Among other products with internal pores used as adsorbents on a commercial scale are silica gel, zeolites, alumina and molecular sieves. The main difference between these adsorbents and activated carbon is the ability of activated carbon to adsorb an extremely wide spectrum of adsorbates. This is because activated carbon has different types and/or sizes of pores.

Generally, coconut shell charcoal-based activated carbon is microporous and depending on the size of the pores predominant, it will exhibit affinities for molecules of different sizes. Activated carbon is used for a wide array of purposes which include water, air and food purification; solvent recovery, pharmaceutical industry and catalyst support. The examples of use of coconut shell

charcoal activated carbon in air purification are their uses in gas masks, cooker hoods and other filters.

Other uses of coconut shells

Coconut shell is exploited in small-scale industries, e.g. manufacture of novelties. It has been in demand when ground into a "flour" for mosquito coils (insect repellent) and as filler for articles made of synthetic resin-plastics. With the present shortage of fuels, the shell itself and the charcoal made from it are gradually taking the place of liquefied petroleum gas (LPG) for home cooking.

Coconut Fibre Products

Coconut husk is the raw material for the coir industry. (See Figure 20A). The coir fibre is extracted either by natural retting (microbiological process) or mechanical means.

Figure 20a: Mechanical extraction of the coconut husk 

Roughly 10 percent of the global annual production of coconut husks is used to extract coir fibre resulting in 480,000 M.T. of coir approximately. An average of 100,000 tons of this total production (21 percent) enters into the world trade. Majority of exports take the form of fibre that is then processed in consuming countries. Coir product exports take the form mainly of mats, matting, brushes and a very small quantity of needled felt and rubberised coir.

Extraction Process of Coconut Fibre

There are two distinct varieties of coir fibre, white fibre and brown fibre. The fibre extracted from green coconut husk by the natural retting process is known as "white fibre" whereas fibre extracted mechanically from dry coconut husk is "brown fibre".

Retting of coconut husk for the production of white fibre is biological process which softens the husks paving way for easy extraction of fibre manually by beating with wooden mallets. (See Figure 21). It is normally done in the saline back waters that are bestowed with a gentle natural tidal action. There are three process of retting: Net retting, Pit retting and Stake retting. In the areas where very good quality fibre is produced, Net retting is practised. In this process, the husks are filled inside a net made out of coir yarn and toyed to the retting field. The bundles are then weighed down using mud. Stake retting is practised where there is a heavy current and fear of husks being washed off. In this method, husks are filled in the enclosures made out of bamboo stakes and covered with mud. In Pit retting, the bottom of the pits are covered with mud and sides with plated coconut leaves or coir yarn nets. The entire pit or nets are filled with fully matured green husk. The bundles are piled appropriately in such a manner and they are not disrupted and left for a period varying from 4-12 months. After about 4 weeks of soaking the water gets warm up, becomes cloudy and yellowish white covering is formed on the surface. Exhale of gas bubbles is observed with the smell of hydrogen sulphide which subsides after a period of approximately 4 months. The retted husks are taken out from the soaking pits and beaten manually by wooden mallets to separate the fibre from the embedded pith. The extracted fibre is cleaned properly and dried under shade for further processing. (See Figure 22). The fibre is graded in accordance with its colour, length of fibre and other factors. Women of coconut farming families are greatly involved in these activities.

Figure 21: Manual extraction of coco fibre by beating with wooden malletsk 

Figure 22: Flow Chart of Processing in the Production of Coir

Coconut Palm

Plucking of Coconut

Dehusking

Green Husks Dry Husk

Natural Retting Crushing

Manual Extraction Soaking
of White Fibre
Mechanical Extraction
Spinning of Different
Types of Yarn/Rope Decortation Defibering

Decorticated Bristle Mattress
Weaving Coir Mats, Fibre Fibre Fibre
Mattings, Carpets, Ropes

Curled Coir Curled Coir
Rubberised Coir
Needled Felt

1.5 Requirements for Export and Quality Assurance

Export of coconut oil and copra are governed by the standards of the National Institute of Oilseed Production (NIOP), the Federation of Oilseed, Fats and Oils (FOSFA) and the Asean Vegetable Oil Club (AVOC). For aqueous coconut products, the Asian and Pacific Coconut Community (APCC) formulated a set of standards which its member countries have accepted as reference material. Trade in other products are conducted on terms mutually agreed by buyer and seller. Export of copra and copra meal to EU is governed by the regulations formulated in 1991 which set the limit for aflatoxin.

Copra Classification Standards

The oil content, the colour and appearance, and the moisture content are variable. These characteristics are demonstrated in the grades and standards used for copra.

In the Philippines there are four recognised classes of copra designated A, B, C and D. The classification is based on the method of drying. Under each class are seven grades, from 1 to 7, based on moisture content. The classes are given in Table 3 and the grades in Table 4. These tables show the 3 types of copra drying in existence: sun drying, smoked tapahan drying and hot air drying. It is also indicates among the grades, as high as 22 percent moisture content (Corriente) is

traded. The best grade copra contains no more than 6 percent moisture.

Table 3: Quality Standard for Copra in the Philippines: Classes of Copra (Based on Method of Drying and Appearance)

Class	Name/Designation	Requirement (Appearance)
A.	Hot air, kiln or mechanically dried	Clean, whitish or pale; free of smoke, moulds and dirt
B.	Sun dried	Dull white; low in dirt, mould and decay; free of smoke
C.	Smoked or tapahan	Tinged with soot; low in mould, dirt a decay; not unduly charred or burned
D.	Mixed	Low in mould, dirt, soot and decay

It must be noted however, that trading of copra is essentially based on moisture content. In the Philippines where roughly 90-95 percent of total production is sold to the village trader, copra with 20-25 percent moisture content are bought at a discounted price. This is referred to as the "pasa system" of copra buying where a discount on the copra price is based on moisture. Thus, copra is classified according to its moisture content even at the first point of sale. (See Table 4). Since moisture meters are not readily available in the villages, moisture content determination is done visually or by cracking or splitting the copra by hand and feeling. Experienced and highly skilled copra buyers do this.

Table 4: Grades of Copra Used in the Philippines (Based on Moisture Content)

Grade	Name/Designation	Moisture Content	Requirements
1	Resecada Bodega	6.0 percent	Free from noticeable mixture of copra from unripened nuts
2	Resecada	7.5 percent	Free from noticeable mixture of foreign materials
3	Semi-Resecada	9.0 percent	Free from noticeable mixture of foreign matter
4	Buen Corriente Mejorado	12.0 percent	Reasonably free of vermin
5	Buen Corriente	15.0 percent	Reasonably free of weevils and other insects
6	Corriente Mejorado	20.0 percent	No objectionable odour or putrefaction
7	Corriente	22.0 percent	No objectionable odour or putrefaction

In India standard contract terms for milling copra were specified in as early as 1949. Since then, these form the basis of transactions in the domestic market. The terms apply to sundried and smoke dried copra, but the smoked copra cannot be tendered against a contract for sundried copra. The following are the details of contract terms for milling copra.

Table 5. Contract Terms for Trading Copra in India

Based on Moisture Content and Appearance

1. Moisture	Basis 6 percent	- with mutual allowance
	Below 6 to 5 percent	-allowance to seller equal to 1.5 times less moisture
	Below 5 percent	-allowance to seller at the rate of 1.25 percent for every 1 percent less of moisture
	Over 6 to 8 percent	-rebate to buyer equal to 1.25 times the excess
	Over 10 percent	-rejection at buyer's option
2. Dirt and Foreign Matter	Basis 0.5 percent	- with mutual allowance
	Below 0.5 percent	- proportionate allowance to seller
	Over 0.5 to 2.0 percent	- rebate to buyer equal to 1.25 times the excess
	Over 2.0 percent	- rejection at buyer's option
3. Mouldy	5 percent free	

In Papua New Guinea (PNG), copra intended for export is classified into the following grades (See Table 6.).

Table 6: Copra Classification in Papua New Guinea

Grade	General Appearance
A. (Hot-Air Dried Copra)	Clean; of good colour; free from smoke, excess mould or insect infestation, charred pieces or foreign matter; free from an unreasonable admixture of copra from germinated nuts; not exceeding 6 percent moisture content (MC) ; not exceeding 3 percent free fatty acid (FFA) content.
C. (Smoke Dried Copra)	Clean and of uniform colour, not burned or tarry; free from excess mould or insect infestation, charred pieces or foreign matter; free from an unreasonable admixture of copra from germinated nuts; not exceeding 6 percent MC; not exceeding 3 percent FFA.
D. (Mixed Copra)	Copra of exportable quality which cannot be reconditioned to a higher grade; not exceeding 7 percent MC and not exceeding 4 percent FFA.

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Organisation: Asian and Pacific Coconut Community (APCC) (http://www.apcc.org.sg)
Author: P.G.Punchihewa and R.N. Arancon
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CHAPTER XV COCONUT: Post-harvest Operations

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2. Post-Production Operations

Bearing coconut palms produce nuts throughout the year, although yields may vary with the season. A normal-bearing, adult palm produces at least one matured ready-to-harvest bunch of coconuts every month. Depending on the variety, the number of nuts per bunch can vary from 5 to 15. The theoretical number of bunches per palm that can be harvested annually is about 14 from tall coconut varieties and 16 from the dwarf species.

2.1 Pre-Harvest Operations

It usually takes 12 months for a nut to mature from pollination to harvest. Husk colour is the best indicator of coconut maturity. To attain good quality products, it is advisable that coconuts be harvested at the right maturity. Thus, only nuts that are partially or completely brown should be harvested. Nuts harvested at the tenth month or colour-break stage, should be stored or seasoned for some time to increase copra and oil yield.

To obtain maximum copra and oil recovery, nuts must be harvested when fully ripe. At this age of maturity, the estimated age is from 11 to 12 months. Although this stage is ideal for copra-production, in practice, green and immature nuts (about ten months old) are sometimes included during harvest especially as harvesters are paid on a per nut basis in certain countries.

Immature nuts when converted into copra will produce rubbery copra with low oil recovery. Rubbery copra is also susceptible to insect and mould attack due to its high moisture content. Immature nuts should therefore be segregated for seasoning for about two to four weeks. Seasoning is done under a shed, preferably with a concrete or wooden floor.

2.2 Harvesting

In practice, the harvesting cycle varies from 45 to 60 or 90-day periods. However, considering the hired labour cost, the recommended harvesting cycle is every 45 days for practical and economic reasons. Two to three bunches of coconuts could be harvested from each palm if this cycle is followed. This harvesting cycle has been found to yield a good number of mature nuts with high

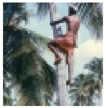
copra and oil recovery.

2.2.1 Methods of Harvesting

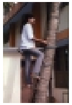
The methods of harvesting coconuts vary among countries or even among provinces within the same country. Producers from certain countries, especially in the Pacific, do not harvest their coconuts. Mature nuts are just left to fall on the ground and gathered by the farmer or the members of the farming family at regular intervals.

There are two common methods of harvesting coconuts. These are the pole and the climbing method. A third method is only practised in Thailand, Malaysia and Indonesia. This procedure involves harvesting of mature coconuts using of trained monkeys.

The pole method of harvesting is common in many countries in the region. In this case a harvesting scythe attached to the end of a long bamboo pole is used. (See Figure 3).

Figure 3: Climbing Method of Harvesting Products Coconut 

The palm-climbing device is useful and advantageous for harvesting operations in places where traditional palm climbers are not available. (See Figure 4). The device is more efficient than manual climbing. With its use around 80 trees are harvested a day. There is also no risk of falling from the tree. In research stations and seed farms, the gadget could be useful for breeding purposes.

Figure 4: Palm Climbing Device in India 

Although both the pole and the climbing method of harvesting require considerable experience and skill to be performed safely and efficiently, each has its own advantages and disadvantages. Harvesting using bamboo poles is generally faster, more efficient, less tedious, and less dangerous when compared with climbing. With bamboo poles, a harvester could also harvest more nuts per unit of time from more trees. On the other hand, the advantage of harvesting by climbing is that the climber/harvester could clean and inspect the crown of the palm for pest and disease attack. However, the cuts made to construct steps in the trunk in certain countries to facilitate climbing make the trees less suitable for timber purposes and fractures serve as entry points for pests.

Harvesting coconuts by using trained monkeys is considered efficient and cost-effective especially in areas where labour has become scarce.

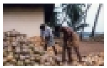
Coconut Dehusking and Splitting

After harvesting, the succeeding operations are collection of the nuts, ripening, and dehusking. Harvested nuts are usually gathered together on a single layer on the ground. If the soil is moist, there is always the tendency for the nuts to germinate. Hence, nuts are not allowed on the damp ground for a long time, but are moved to a drier place. As mentioned earlier, the nuts are kept for about a month to ripen on the ground. This practice promotes desirable changes in the greener or somewhat less mature nuts: the coconut meat is said to grow thicker and harder thus producing a better quality copra if copra is desired, or a more suitable material for desiccated coconut

production. Immature nuts tend to produce rubbery copra. Producers claim that seasoning or storage of 10-11 month old green nuts for one month or so improves the coconut kernel. This reduces the tendency to produce rubbery copra. Also dehusking is easier.

Coconuts in the husk are very bulky. They are dehusked first before being transported in trucks or carts.

Dehusking is a manual procedure. The principal part of the dehusker is a sharp-pointed shard of steel (a part of the native plow) positioned vertically with the point up and the broader part firmly placed on the ground. The farmer-operator impales the coconut on the sharp point with a strong determined downward movement. A few impaling strokes loosen the husk, making it come off (usually) in one piece. (See Figure 5). Impaling requires accuracy and nerve. Hence it has been difficult to get dehuskers in countries that are still trying to set up coconut plantations.

Figure 5: Coconut Dehusking Tool 

Since dehusked coconut is an important article of commerce locally, husking therefore becomes mandatory. The coconut husks are left with the farmer. In the places where there is a coir fibre industry, the husks may be sold to this industry. Most often the husks are not sold but are used as fuel for drying copra. If little or no copra is made, there is an accumulation of coconut husks.

Since the coconut meat is found well inside the nut and is firmly attached to the shell, certain steps are necessary before drying the coconut kernel.

Nut Splitting

After the coconut is dehusked, the hard but brittle shell is exposed and can be split open into two halves using a machete. The coconut water is drained off leaving the cups ready for the drying stage. The meat is still attached to the shell. During the drying process, the meat shrinks and is easily detached or scooped out from the shell. These cups of coconut meat are then dried further.

Some farmers also practice nut splitting using a heavy machete even without dehusking the coconut. After nut splitting, the water is allowed to drain off. With meat still attached to the shell and the shell to the husk, the halved nuts are dried under direct sunlight. During the drying process the meat becomes detached or is scooped out from the shell with a scooping knife. The cups of meat are then further dried into copra.

2.5 Copra Processing

Copra is produced after drying the coconut kernel. Copra and the coconut oil as well as the cake derived from it are a major source of foreign exchange for many coconut growing countries in Asia, the Pacific, and Africa.

The quality of copra and copra cake is influenced by the method and the manner of drying the coconut kernel. Improperly dried copra gives rise to certain moulds, the most harmful of which is the yellow green mould called *Aspergillus flavus* and other aflatoxin related moulds. Aflatoxin is harmful both for man and animals.

It is therefore extremely important that the coconut kernel be properly dried to prevent the attack

of aflatoxin related moulds. Processing of mature nuts to copra has several problems. Improper processing results in low oil yield and incidence of aflatoxin. Proper post-harvest practices, as well as proper drying and storage can increase the oil yield to about 20 percent. Proper drying of coconut results in copra with lower moisture content and lower incidence of aflatoxin.

Copra is mainly produced by small coconut holders using sun drying or smoke-kiln methods. Hot-air dryers are also used to a limited extent.

Copra making involves different steps between harvesting and marketing of the produce. Of these, drying the coconut kernel or reducing its moisture content from 50 percent to 6 percent most influences the quality of the product.

The following are ten guidelines for producing aflatoxin-free copra:

1) Harvest only fully matured (brown) nuts. These are the 12-month old or older nuts;

2) Do not pay the harvester for immature (green) nuts; instead penalise them for picking green nuts;

3) For producers selling husked nuts to desiccated coconut factories, segregate the "fouls" for processing into copra. Never mix the "regular copra" with the copra from "foul" nuts. They tend to have high mould growth;

4) When preparing copra, split the nuts and expose the meat only when certain that drying can start immediately or within four hours from splitting (exposure) to prevent mould formation. When

there is the threat of bad weather, defer nut splitting;

5) If the weather suddenly turns bad during the sun-drying period and is expected to remain so for some time, use of mould inhibitors is recommended;

6) For producers practising sun drying, maintain cleanliness in the drying area. Clean pavement or floors before spreading fresh coconut meat. Make sure that soil and other extraneous matters are not mixed with the meat. Plastic sheeting may be used under the coconut meat to avoid direct contact with the ground;

7) Have on hand a portable cover (plastic sheeting) to protect coconut meat from rain and dew. These are shaped like roofing (inverted Vs) to allow aeration. On extended downpours, heat and dry the copra within 24 hours;

8) Continuous sun drying for four to five days (in good sunlight) shall achieve 6 percent moisture content;

9) For producers using smoke, kiln dryers, and other types of dryers, a drying temperature of 35^{o}C to 50^{o}C should be maintained for the first 16 hours of drying followed by 50^{o}C during the next phase until a final moisture content of 6 percent if reached. It is important that drying should begin four hours after the nuts are split to prevent mould contamination;

10) Pressing the copra between the thumb and forefinger, the thumb against the whitemeat is a quick test for 6 percent moisture content. If the copra kernel (white portion) does not stick to the

thumb, and readily drops when released, the 6 percent (approximately) moisture level has been achieved.

2.5 Drying

There are several methods and practices in drying the coconut kernel or in making copra. The methods vary from that which is considered primitive and traditional to one that adheres to certain scientific principles of drying.

The three common methods of drying are: a) sun drying or solar drying; b) kiln drying which is either direct on semi-direct drying; and c) indirect drying using hot-air dryers.

2.5.1 Sun Drying

Where weather conditions permit, sun drying can produce good quality copra. This method is used only during the dry season and when drying only small quantities of nuts. (See Figures 6 and 7).

Figure 6: Sun Drying Copra 

Figure 7: Coconut Dehusking Tool 

Since sundrying requires no expenses for fuel, the overall drying cost is considerably cheap compared to other copra drying methods using fuel-fed dryers. Fuel saved could mean possible

additional farm income when sold or transformed into high value products like coconut shell charcoal, activated carbon, coir, etc., leading to the maximum utilisation of farm resources. Because the dryer is capable of producing clean, white and edible copra, copra produced should command a premium price. Moreover, its adoption could promote a high degree of consciousness in the production of superior quality export products.

2.5.2 Kiln Drying

There are two types of smoke dryers commonly used by coconut farmers, namely: the direct and semidirect types. Primarily, both types have the same heating principle but differ only in design and manner of firing or charging fuel. The direct dryer is designed in such a way that the fire bed is directly located below the copra bed.

On the other hand, the design of semidirect dryer is superior to the direct type. The hearth where fuel charging/feeding is done is located on one side of the dryer, connected to the drying bed by a tunnelike flue.

Direct Smoke Copra Dryer

The direct smoke dryer is a commonly used by coconut farmers in many coconut producing countries in the world. The smoke dryer has a grill-platform usually of split bamboo which constitutes the drying area. Halved nuts in the shell are placed on this grill. Underneath the platform is a fire hearth where coconut shells and husks are burned slowly to provide the heat for vaporising the water from the coconut meat. Generally, there is no chimney. (See Figure 8). The

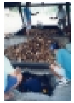
coconut meat shrinks upon drying and may be removed or scooped out from the shell. The meat is then further dried in the smoked dryer.

Figure 8: Direct Smoke Copra Dryer 

The basic features which make the direct smoke dryer preferred by farmers are the high thermal efficiency of the dryer (the coconut meat is directly heated), the low cost of construction (the component parts are available on the farm), the simplicity of the design and the low cost of fuel. However, copra produced from this dryer are usually dark, sooty with smoke and at times scorched. Since the fuel is burned inside a pit underneath the drying bed, the dryer has to be attended when it is in operation to prevent the dryer from burning.

Semi-Direct Copra Dryer

It is a simple structural design, cheap and easy to build. The dryer has a combustion pit located about 3 feet away from the drying bed. The hot combustion product is channelled to the drying bed via an underground tunnel. The dimension of the excavation pit is 6 feet in width, 12 feet in length and a depth of 4 feet. The pit floor of the firing chamber is slightly inclined upward toward the end portion, which is designed to direct the flow of heated air. Dry coconut husks are used for fuel. It has a capacity of 2,000 nuts which are dried after 20 to 25 drying hours with resultant moisture of 6 percent. (See Figure 9).

Figure 9: Semi-Direct Smoke Copra Dryer 

Due to the ease of structural design and operation, needing only inexpensive and locally available construction materials, this dryer is deemed to be socially adaptable and economically ideal for small coconut farmers. Since the total construction cost is within the reach of small coconut farmers with minimal fuel costs , the over-all production cost per kilo of copra would be much cheaper. Reflecting that fuel consumption per batch is approximately 50 percent of nut capacity, the savings per coconut husk (50 percent) plus coconut shell has a higher commercial value. This would mean additional financial benefits for the coconut farmers.

2.5.3. Copra Drying Using Hot-Air Dryers

In drying copra using hot-air dryers, the coconut meat is dried by means of uncontaminated hot air that passes through the copra bed. Since the smoke does not come in contact with the kernel, the copra produced is clean and white. If properly done, copra-drying using hot-air dryers produces good quality copra with 6 percent moisture content.

There are quite a few hot-air dryer designs. The common ones are a) The Modified Kukum Hot-Air Dryer and b) The Cocopugon or the Brick Hot Air Dryer.

The Modified Kukum Dryer

The Modified Kukum Dryer is an indirect natural draught dryer measuring 1.83 m in width, 3.66 m in

length and 2.13 m in height. About 2000 nuts (average size) can be accommodated (volume of drying bed: 2.8 m3). Its heat exchange is made up of three standard oil drums welded together with five semi-circular baffles installed alternately inside the drums at distance of 0.46 m. The furnace measures three feet in length and two feet in width and is made of steel plastered with 6 cm thick cement-ash mixture inside. The furnace is provided with a slanting grate and door to regulate air entry. A butterfly valve is also provided at the chimney to control the temperature. (See Figure 10).

Figure 10: Modified Kukum Hot-Air Copra Dryer 

About 30 hours are needed to dry one batch to 6 percent moisture content. Based on a 10 hours operation time per day, drying takes three days. About 8.7 minutes are needed to produce one kilo copra with the modified Kukum dryer.

The Modified Kukum dryer produces good quality copra. However, maintenance and repair costs are the high. The metal parts of the dryer, which start to corrode as soon as the dryer is being constructed. Frequent use of the dryer will reduce corrosion, but never stop it. Since copra is a low price product, the use of stainless steel or even the application of primer is not economical. The exposure to high temperatures, aggressive fumes and water induce corrosion of the metal dryer components.

Cocopugon Hot-Air Brick Copra Dryer

The Cocopugon is a further improvement of the modified Kukum Dryer. Instead of using metal

drums as the heat exchanger common in Kukum Dryers, the Cocopugon uses bricks. Bricks are known for their high strength, durability and dimensional stability.

The proportions of the Cocopugon are 260 cm in width, 360 cm in length and 200 cm in height. Standard fire bricks and 2.5" crown bricks are used for the chimney and the heat exchanger, respectively. The dryer can accommodate 2,000 average sized nuts per batch (volume of drying bed: 3.33 m3). To facilitate ease of loading and unloading, the right side of the drying bed wall is removable. A one step stair and platform is also provided on the same location. (See Figure 11).

Figure 11: Cocopugon Hot-Air Brick Copra Dryer 

Unlike dryers with metal heat exchangers, this dryer needs to be preheated. Firing should be done first before loading the split nuts. The burner can accommodate about 200 to 300 husks. Refuelling has to be done every 3 to 5 hours. The heat stored in the bricks will be released slowly after the last firing on the first drying day, such that drying will continue for several hours without adding fuel (husks).

After a preheating time of 3.5 hours and a loading time of two hours, the average temperature in the bottom layer is 66.3ºC. The burner then has to be fed five to seven times for the whole drying period. Formerly, this could only be accomplished in one day at a feeding interval of about three to four hours assuming a constant fuel feed rate. Unloading could be done after the dryer has cooled down on the second day. If operated on a two days schedule, five firings are needed on the first day and another two to three firings on the second day. Unloading will be done the next morning to

utilise the heat stored in the bricks. If the baffle in the chimney is closed during nighttime, embers can still be found inside the burner on the following morning making it easy to continue firing. The temperature curve for the burner has several small peaks indicating the maximum temperature per feeding interval. The effect on the drying bed temperature is minimal, thus having an almost constant drying temperature. Even if the burner is fully loaded, the resulting temperature in the drying bed does not exceed 90 to 95ºC, thus eliminating the risk of producing scorched copra.

Since the heat exchanger or the burner covers almost the whole area inside the dryer body, the temperature distribution is very uniform. The difference in temperature between the highest and lowest value is less than 5º Kelvin. A standard deviation of 3º Kelvin indicates a very constant temperature.

During operation, the dryer operator spends two hours per batch at the dryer, meaning the labour requirements are cut down by more than 50 percent to 4.1 minutes per kilogram copra compared with the modified Kukum dryer. The farmer can therefore leave the dryer in between fuel feedings and use his time for other activities.

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