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CSIR-FOOD RESEARCH INSTITUTE

VALIDATION OF PROCESSING METHODS AND GOOD MANUFACTURING PRACTICES (GMPS) USED BY MICRO-, SMALL AND MEDIUM-SCALE PROCESSORS IN GHANA FOR JUICE AND OTHER PRODUCTS FROM BANANA AND PLANTAIN

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Summary

An international workshop was organized in August 2007 in Accra by the CSIR-Food Research Institute in collaboration with the International Plant Genetics Research Institute and Bioversity International in France to document the best practices and unit operations used in several banana and plantain growing and consuming countries for transforming fresh bananas and plantains into commercial convenience products. This report is on the follow up validation of comparing the unit operations used by some selected micro-scale entrepreneurs in Accra and Kumasi, for the transforming fresh banana and plantains into processed products, to those documented practices as being used in the several other countries.

1. Introduction

Plantains and other cooking bananas are staple foods grown throughout the tropics. They form a major part of the carbohydrate food sources for millions of people in Africa, Caribbean, Latin America, Asia and the Pacific. In West and Central Africa, it is estimated that 70 million people derive as much as 25% of their total caloric intake from plantain (ref). Plantain is therefore one of the most important sources of food energy.

Bananas and plantains are grown in more than 120 countries in backyards or mixed cropping systems by small holders, and occasionally in monoculture (INIBAP, 1992). The total production is about 64 million tonnes with 23% being plantains, 15.6% as cooking bananas and 18% being highland cooking bananas and beer bananas. Table 1 presents data on the production and consumption of plantains and other cooking bananas in some producing countries.

In West Africa, the major plantain producing areas are Côte d'Ivoire and Nigeria. In Central Africa, Cameroon stands out tall in plantain production and therefore it is not surprising that it is the host of the Central and West Africa centre for research into banana and plantains. Although Ghana is not singled out in the report, its contribution cannot be completely ignored. It forms part of the total contribution from Africa. Interestingly, over the past five years, there have been significant increases in plantain production in the six regions where plantains are cultivated. These are the rain forest zones and the semi-deciduous regions of the country and include such regions as Ashanti, Brong Ahafo, Central, Eastern, Western and Volta.

The productions in Central and Eastern regions show a high level of consistency. However, those of Ashanti, Brong Ahafo, Western and Volta show significant increases. The reasons for such high significant increases are not readily available. However, the contribution that the introduction of disease resistant hybrids has made cannot be overlooked. It is obvious that those high production levels are helping meet energy needs in the producing areas and also in the non-producing areas alike.

In Ghana, plantains are consumed at five different stages of ripeness (green, half-ripe, ripe, fully ripe and over-ripe). Fully ripe plantains are often deep-fried or boiled and used in various dishes. Plantains and bananas are used as fufu, ampesi and as snack. They could also be processed into *tatale*, *kaaklo*, kelewale (spiced deep-fried chips), chips, flour and *ofam*. These traditional products of plantain are usually produced at the micro-scale level for sale at marketing centres, restaurant, and street foods. Over the last few years, there has been an increased commercial activity with the production of deep-fried plantain chips. This development is very like what happens in other plantain growing areas in world

Quite apart from the significant contribution that plantain makes in meeting the energy needs of the producing areas, by virtue of their high carbohydrate content, there are reported levels of such micronutrients as carotenes, (pro-vitamin A), ascorbic acid and minerals, particularly calcium and phosphorus (Ketiku, 1973; Fosseyth, 1986). There is also the possibility of high levels of other minerals such as iron (Fe), and zinc (Zn). The nutritional and public health significance of these minerals cannot be over emphasized. Iron is important in the obviation of various forms of anaemia, both in infant and the mothers. Zinc, an element which has received increased attention from scientists, although its determination in substances has not been without difficulties, since samples analyzed have not shown consistent results, has been associated with immunity to some diseases such as malaria, a disease that causes a lot of lost to people in the Sub-Saharan Africa and other tropical regions of the world.

In August, 2007, a 4-day international writeshop was organized by the CSIR-Food Research Institute of Ghana in collaboration with International Plant Genetics Research Institute and Bioversity International, France to document unit operations used for transformation of fresh banana and plantain into processed products in countries producing and consuming bananas and plantains. The writeshop attracted food scientists and technologists in the fields research and development of banana and plantain processing from India, Nigeria, Cote d'Ivoire and France. The validation was therefore carried out to verify whether the practices used by selected commercial producers of

plantain products in Ghana agree with the documented processes obtained from the writeshop.

2. Methodology

Preliminary visits were made to a number of producers of banana and plantain products for sale. Appendix 1 gives the questionnaire used.

2.2 Documented Processing Steps Used for Transforming Bananas and Plantains

The processing steps for the following plantain and banana products were documented.

2.2.1 Selected Products

- Deep-fried plantain chips starting with plantain of different initial ripening stages.
- Boiled plantain
- Roasted plantain.
- Banana Juice

2.2.2 Quality Requirements.

Fruits should be chosen which are acceptable in the market. They should have the following characteristics.

- Fruit free of physical damage.
- Free of unusual shapes or misshapen
- Colour and flavour characteristics
- Free of pesticides
- Appropriately packaged.

Appendix 2 gives the various processes which were documented for plantain and banana products during the international writeshop held in Accra in August 2007on processes for transforming banana and plantain into processed products.

3. FINDINGS & COMMENTS

3.1 Plantain Chips

Plantain chips are a product obtained by deep-frying thin sliced and spiced plantain in vegetable oil. There are two types. One is made from mature green plant and the second type is made from ripened plantain. They are all easily eaten as a snack only.

Table 3.1:
Unit Operations Used by Company A for the production of Plantain Chips

Flow Diagram Showing Unit operations	Comments
Fruit selection(Unripe and ripe *Apentu*) ↓ Washing ↓ Peeling ↓ Washing ↓ Slicing ↓ Frying (add spices) ↓ Draining ↓ Cooling ↓ Flavouring with salt ↓ Packaging ↓ Labeling ↓ Transporting and Marketing	**Strengths** • *Apentu* (falsehorn) plantains are used • Fruits are washed before and after peeling to reduce microbial load • Potable water is used • Spices (ginger, onion/garlic) are added during frying to improve flavour development **Weaknesses** • The slicers are not washed after each batch • The use of charcoal as source of heat may bring about uneven heat transfer. • Aluminium pans and stirrers are used for frying instead of stainless steel • Addition of salt after frying may bring uneven distribution of salt particles (specific amount per wt of chips)? • The oil used for frying is reused several times and new oil is added to make up for volume lost (rancidity) • No paper is used for draining the excess oil. • The fried chips are exposed to the atmosphere during cooling.

Fig. 3.1: Selection of fruits for chips preparation

Fig. 3.2: Washing and peeling of fruits

Fig. 3.3: Slicing of plantain into chips

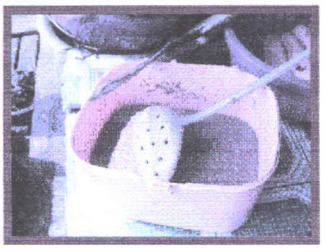

Fig.3.4: Spices added during frying of chips

Fig. 3.5: Deep frying of chips

Fig. 3.6: Draining of oil

Fig.3.7: Adding salt to fried plantain chips

Fig.3.8: Packaging of chips into plastic bags

3.2 Tatale

Tatale is a snack plantain product made from over-ripened plantain. It is made from slurry of wheat flour and over-ripened plantain. This slurry is shallow-fried in spoonfuls in a little hot palm oil until golden brown. Excess oil is drained on kitchen paper and served hot with cooked cowpea/bambara beans. It is eaten as a main meal.

3.2.1 Units Operations

Table 3.2:
Flow Diagram showing Unit Operations Used for the Preparation of Tatale, a fried plantain pancake by Company B

Unit operations	Comments
Fruit selection(over-ripe *Apentu*) ↓ Washing ↓ Peeling ↓ Blend with salt and ginger,onion,pepper and spices ↓ Add wheat flour to bind ↓ Mix with a ladle ↓ Ferment ↓ Frying (Add bits of palm oil) ↓ Draining ↓ Packaging in polythene bags ↓ Put in warmer ↓ Marketing	**Strengths** • Stainless steel bowls , spoons and frying pan are used • Blending as against pounding over -ripe plantains gives a better consistency. • Portions of Wheat flour are added to plantain mash to ensure the right texture. • Mash is left to ferment and expand. • The use of gas as a source of heat ensures uniform heat distribution. • The *tatale* is not deep-fried in palm oil (oil absorbed is minimal) • The frying pan was locally designed and fabricated from stainless steel. • Pwater is used for the unit operations **Weaknesses** • Paper is used in draining excess oil, making the product slightly soggy. • Burnt product may have acrylamide

3.2.2 Various Stages During Preparation of *Tatale*

Fig.3.9 Fruit selection for *tatale* preparation

Fig. 3.10 Washing of selected fruits

Fig. 3.11: Peeling and slicing of fruits

Fig. 3.12: Blending with spices

Fig. 3.13: Addition of wheat flour to blended fruits

Fig. 3.14: Fermentation stage

Fig. 3.15: Plantain and wheat slurry mixed with spices

Fig. 3.16: Frying of *tatale* with palm oil

Fig.3.17: Packaging of *tatale* for marketing

3.3 *Kakro*

Kakro is a product made from over-ripened plantain fruit mixed with corn flour, powdered chilies, salt and other spices. It is deep-fried in vegetable oil into oval shapes. It is eaten as a main meal with cooked cowpea and palm oil (with gari).

3.3.1 Unit Operations Used

Table 3.3:
Flow Diagram showing Unit Operations Used for the Preparation of Kakro, a fried plantain and corn flour product by Company C

Flow Diagram of Unit operations	Comments
Fruit selection (Over-ripe *Apentu* and *Apem*) ↓ Peeling ↓ Pounding ↓ Mix with roasted corn with pepper, ginger, salt and spices powder ↓ Frying ↓ Draining ↓ Cooling ↓ Marketing	**Strengths** • Both *Apentu* (falsehorn) and *Apem* (French) plantains are used. • Roasted corn flour is used to serve as a binder • Potable water is used • The frying is done at high temperatures. Therefore microorganisms cannot survive. Additionally, the high sugar content of the fruit gives a low water activity that hinders growth of micro-organisms **Weaknesses** • Plantains are not washed before peeling • The use of charcoal gives uneven distribution of heat. • Hands are used to mix the roasted corn flour and the mash. Though unhygienic, the high frying temperature takes care of microbes. • Use of wooden mortar and pestle for pounding. It is difficult to properly sanitize the mortar after use. • Aluminium pans, strainers, frying pans and stirrers are used instead of stainless steel. • The oil used for frying is reused several times and new oil is added to maké up for volume lost (rancidity) • Burnt product may have acrylamide

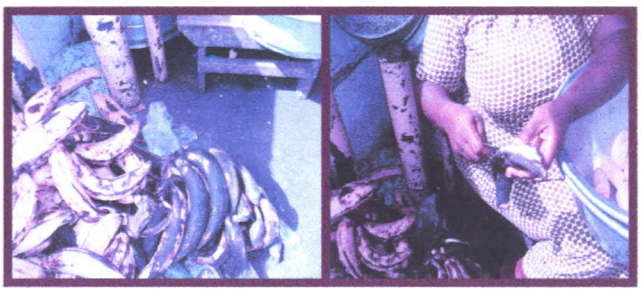

Fig. 3.18: Selection of over-ripe plantain for *kaakro* preparation

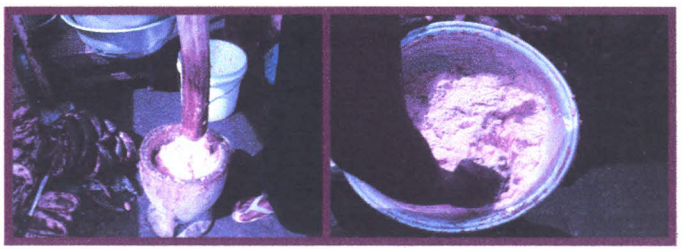

Fig. 3.19: Pounding of plantain and mixing with spices and corn flour

Fig. 3.20: Deep frying of *kakro*

Fig. 3.21: Draining oil from fried *kakro*

Fig. 3.22: Cooling and marketing of *kakro*

3.4 *Ofam*

Ofam is a baked plantain cake made from blended over-ripe plantain fruits mixed with powdered chilies, salt and other spices, palmoil and wheat flour. It is consumed as desserts and appetizers.

3.4.1 Unit Operations Used

Flow Diagram of Unit operations	Comments
Fruit selection(over-ripe *Apentu*) ↓ Washing ↓ Peeling ↓ Pound with wheat flour, pepper, ginger, salt and spices ↓ Add palm oil ↓ Put in baking sheet ↓ Bake ↓ Cooling Packaging ↓ Marketing	**Strengths** • Stainless steel pans were used • Temperature and time for baking were specific. Will ensure product uniformity • Spoons are used to mix and dish out the mash into baking pans. • Potable water is used. **Weaknesses** • Use of wooden mortar and pestle for pounding is unhygienic • Aluminium instead of stainless steel pans are used for baking. • Fruits are not washed after peeling.

3.4.2 Photographs of various unit Operations

Fig. 3. 23: Fruit selection for *ofam*

Fig. 3. 24: Washing of selected fruits

Fig 3.25: Peeling of fruits

Fig 3.26: Pounding fruits

Fig. 3.27: Addition of spices to pounded fruits

Fig 3.28: Addition of wheat flour

Fig 3.29: Addition of palm oil

Fig 3.30: Dishing out into baking pans

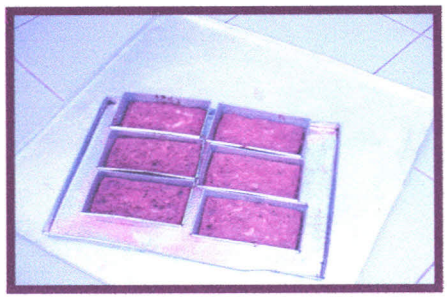

Fig 3.31: Baked *ofam*

Fig.3.32: Cooling stage

Fig 3.33: Final product

3.5 Banana Juice

There are two descriptions of banana juice in this section. In the first type, the banana is added as "adjunct" to give a banana-flavoured taste to a typical orange or pineapple juice. In the second type, the banana is the sole fruit used in preparing the juice.

3.5.1 Unit Operations of Orange/Pineapple and Banana Juice

Flow Diagram of Unit Operations	Comments
Fully ripe bananas free from moulds selected ↓ Peel into water solution (containing sodium metabisulphite) ↓ Pulp with a blender into orange/pineapple juice. ↓ Sieved through a fine mesh ↓ ↓ Pasteurize ↓ Filling into sterile bottles and cupped immediately ↓ Kept in cool dry place away from sunlight ↓ Marketing	**Strengths** • Fruits were washed in 1% sodium metabisulphite and citric acid to reduce microbial contamination. • All the working surfaces and items used were sterilized with 1% sodium metabisulphite and citric acid • Bananas were peeled into citric acid solution to prevent browning. • Head gear, laboratory coat gloves were worn. • A clean fine mesh was used in sieving to obtain a clear juice. • Preservatives were added. • Juice was filled hot into sterile bottles. • Temperature during sterilization was monitored. **Weaknesses** • An aluminium utensil instead of stainless steel is used during pasteurization.

3.5.2 Photographs of Various Stages of the Unit Operations

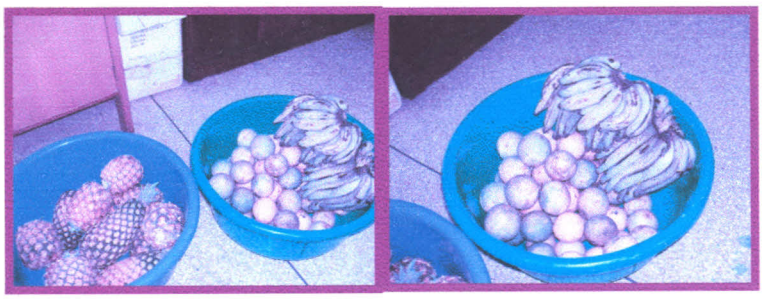

Fig. 3.34: Fruit selection for banana juice preparation

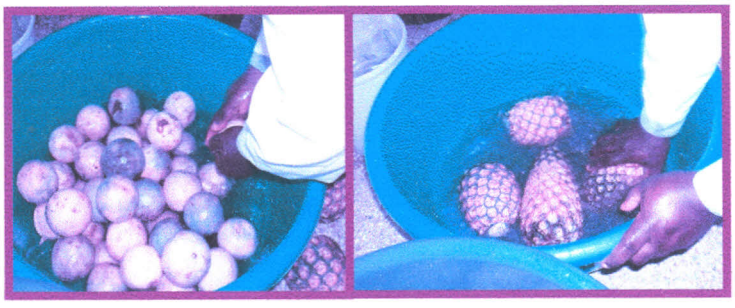

Fig 3.35: Washing of fruits

Fig. 3.36: Peeling of pineapple fruit

Fig. 3.37: Peeling of banana

Fig 3.38: Cutting of oranges for juice extraction

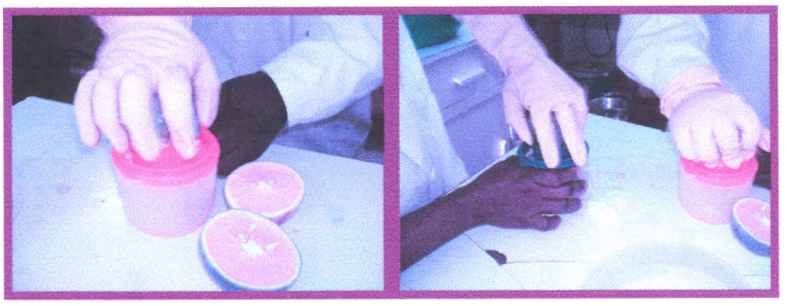

Fig 3.39: Juice extraction from orange

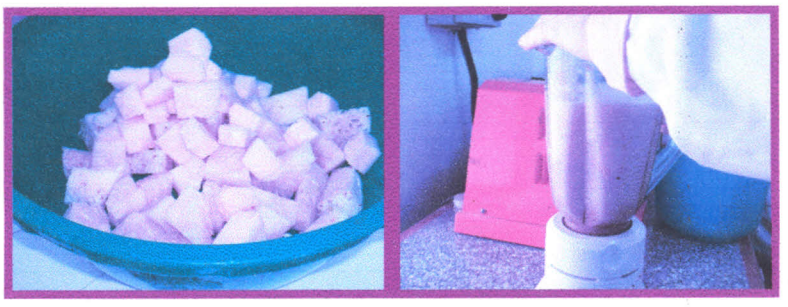

Fig 3.40: Extraction of pineapple juice

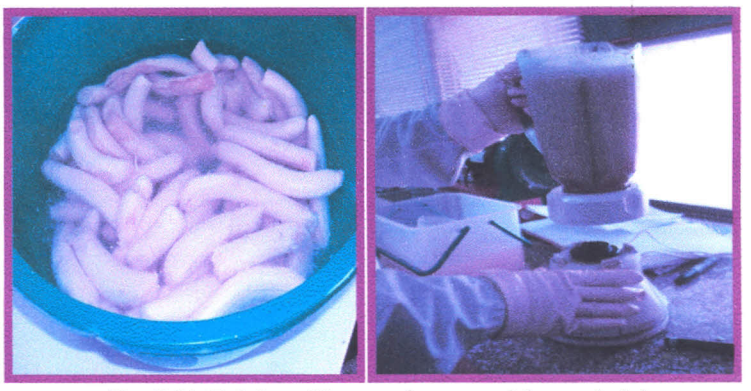

Fig. 3.41: Pulping of banana in orange/pineapple juice

Fig 3.42: Sieving of banana-orange/pineapple blend

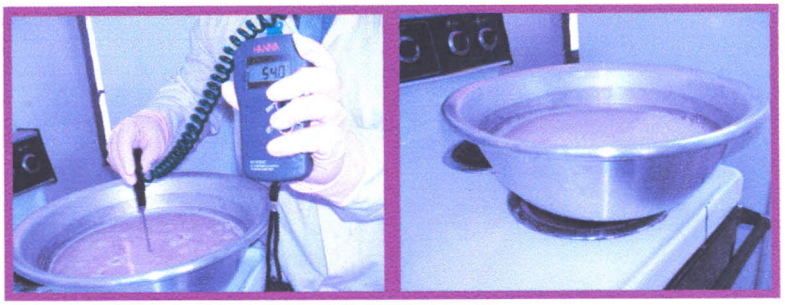

Fig 3.43: Pasteurization of banana-orange/ pineapple blends

Fig.44: Filling of bottles with banana-orange/pineapple juice

Fig 3.45: Marketing of juice

3.5.4 Unit Operations Used for Banana Juice

Flow Diagram of Unit Operations	Comments
Fully ripe bananas free from moulds selected ↓ Peel into water solution (containing sodium metabisulphite) ↓ Cut the banana into small chunks Pulp the banana with a blender ↓ Sieved through a fine mesh ↓ ↓ Pasteurize ↓ Filling into sterile bottles and cupped immediately ↓ Kept in cool dry place away from sunlight ↓ Marketing	**Strengths** • Fruits were washed in 1% sodium metabisulphite and citric acid to reduce microbial contamination. • All the working surfaces and items used were sterilized with 1% sodium metabisulphite and citric acid • Head gear, laboratory coat gloves were worn. • A clean fine mesh was used in sieving to obtain a clear juice. • Preservatives were added. • Juice was filled hot into sterile bottles. • Temperature during sterilization was monitored. **Weaknesses** • An aluminium utensil instead of stainless steel is used during pasteurization.

3.5.3 Photographs of Various Stages of the Unit Operations

Fig. 3.46 Sorting of raw material to remove those that are not at the right ripening stage for juice production.

Fig. 3.47 Washing of the fruits with potable water.

Fig. 3.48 Peeling of the washed fruits.

Fig. 3.49 Peeled banana pulps in a bowl. They are being immersed in a metabisulphite solution to prevent enzymatic browning. The use of hand gloves at the stage and the subsequent stages help to prevent contamination from personnel.

Fig. 3.50 Peeled fruits being taken out of the sodium metabisulphite solution. They are allowed to stay in a mesh so that the water get drained

Fig. 3.51 Peeled fruits reduced further into chunks to enhance the milling process in the blender.

Fig. 3. 52 The picture shows mashing of the fruit pulp into a mash in the process of making banana fruit juice/drink. There is the use of home-used blender. This is small. The blending will have to be done in very small batches and is time consuming. The operator has gloves and that is commendable. Though the operator wears a scarf, a proper sewn complete head cover will be more appropriate.

Fig. 3.53 Basic implements needed for turning the fruit pulp into a mash. There is a bowl, wooden ladle, blender and sauce pan. The wooden ladle is to help in scooping the mashed pulp from the blender. The sauce pan and the bowl are containers for carrying the pulp and the mashed pulp.

Fig. 3.54 Raking or second filtration. Filtration process aided by stirring with a wooden ladle.

Fig. 3.55 Pasteurization step. It is done in stainless steel pans on gas stove. It is a batch process. It will be time consuming and there is the possibility of recontamination.

Fig. 3.56: This is the labeling step in the banana fruit juice production. The fruit juice bottled in clean bottles are labeled with a stickers showing product name, basic ingredients, dates of production and time period within which the product is good for consumption.

Fig. 3.57 Fruit juice bottled in plastic bottles and being packaged in paper box. This is how they are packaged and distributed to sales points.

Appendix 1

QUESTIONNAIRE USED

This survey is an **IPGRI/Bioversity/FRI Plantain Project** to collate information on plantain and banana processing procedure in Ghana. The information accrue from the survey will be used in the development of the gallery of processing businesses.

A. BASELINE CHARACTERISTICS OF RESPONDENTS

1. Name of Company?.....
2. Which type of plantain/banana product do you process?.....
3. Which type(s) of plantain/banana cultivars do you use?.....
4. Where is your source of plantain/banana?.....
5. Which stage of ripeness of the plantain/banana do you use?.....
6. Mention the steps/unit operations you use for processing?.....

.....

.....

.....

7.Which of these step(s) is essential to ensure the quality of the product?.....

.....

8. Mention the type of equipment (s) you use for processing?

.....

9. What are some of the quality factor(s) affected during the steps/unit operations?.....10. Which source of water do you use?.....

11. How many times do you change the water for washing?.....

12. A question about GPH and GMP?

13. Which type of ingredient(s) do you add to product apart from Plantain/banana?.....

14. Which packaging materials do you use?.....

15. Do you have a label for your product?.....

16. Which method do you use to seal your packed product? a) Sealing Machine b) a stapler c) Ribbon.

17. Which type of oil do you use?

18. How do you drain the oil?

APPENDIX 1

Name of end product: chips,
Primary process used for transformation: Frying,
Most frequent cultivars: False horn (Apantu in Ghana, Agbagba in Nigeria)

State of ripeness of fruit: Ripening stage 1-4 (ripening chart of 10 peel colour points)

Essential unit operation	Optional unit operation	Change in state of fruit during step	Equipment used in unit operation	Labour skills used in unit operation	Quality factors affected during unit operation				
					Physical / chemical	microbiological	sensorial	Technological	Nutritional
Fruit selection		Dehanding, defingering, separation of ripening and broken, small fingers, split and twin fingers	Cement floor, raised platform, tarpaulin on the floor	Trained skilled, to be able to tell the difference between the stages of ripening and finger size	No physical and chemical factors are affected	No significant microbiological activity	Selection of right ripening stage will affect colour of product	Uniform size and ripening stage contribute to product quality , frying uniformity and labour efficiency	No change in nutritional content
Washing		Dirty to clean fruits, remove sand, makes peeling easier,	Basins (bigger sizes) , troughs, hand gloves to protect the hand, working space to make working comfortable, tables, basket	No special skills are	Fruits are washed to avoid contamination with sand	Eliminates any possible microbes that may be present in the bunch	No sensory quality is affected during this stage	Ensures production of hygienic product	No change in nutritional content
Peeling		Whole fruit to pulp separation is achieved and peel can be	Stainless steel knives, necessary to avoid reaction of the plantain	Skill is required to separate the pulp from the peel since	Peeled fruits are subject to enzymatic browning	No microbial activity is noticed at this stage,	No sensorial effects are noticed at this stage	Skill of making longitudinal line on the fruit before	No change in nutritional content

		used for soup, feed meal and biomass for plantain farms	with bad metals gloves	immature fingers are difficult to peel in comparison with matured fingers.	when kept beyond 2 hour from the time of peeling. Slicing should start as soon as possible to avoid browning	except when peeled fruit is left exposed for over 12 hours		separating the pulp from the peel without losing any part of the pulp material	
Slicing		Sliced pieces	Plantain Slicers, (using local knives will not produce uniform slices and would be time-consuming). Use of meat slicers with a rotating blade will give a more desired rounded chips	Skill in operating both manual and electrically operated rotating machine. Skill is also required in efficiency and safe handling of the equipment in order to avoid accidents.	Thickness should be between 1.2-1.5mm and must be uniform to achieve crispiness	No microbial activity when processed quickly. When delayed, enzymatic browning which will affect the final quality	Thickness levels that are lower than 1.5 would absorb more oil during frying, and would bend after frying. Thickness levels that are higher than 2mm would be very chewy	Thick slices would not result in uniform product, and would also not result in the desired crispiness, taste and colour. Efficiency of this depends on the skill of the operator	There would be losses in vitamins when slices are exposed to air for more than 30 minutes
Frying	Frying when the oil temperature is 170 – 180 °C	Soft slices become dried, fried, brittle and greasy and crunchy chips	Cooking stove, frying pan, perforated frying spoon, Deep fryers, industrial fryers. Draining baskets	Skill is required in monitoring the temperature of the oil before frying, (170 – 180 °C), duration of frying time,	Crispness and greasiness are the major physico – chemical factors affected	When properly drained and cooled there are no microbial threats	overfrying, overloading of the chips and underfrying will affect the crispness, taste and	Dehydration is necessary to avoid accumulation of fat and water for extension of shelf-life	Losses in nutrients, addition of fat from the drying medium

				turning of the slices and monitoring of end of turbulence for quick removal from oil to avoid high fat contents			colour of the end product.		
Draining		Drained chips	Strainers, sieves,	Unskilled labour	Fat content	E. coli, Coliforms		Removal of fat	This reduces the fat in the chips
Cooling		Cooled chips	Trays, paper	Unskilled labour	Moisture content	E. coli, Coliforms		Reduction of heat	
Packaging			High density polyethylene bags (HDPB),	Skilled in operating machine		E. coli, Coliforms		Preservation of product	
Labeling			Stamps, stickers, computer designed label	Computer literacy				Promotion of products	
Transporting and Marketing			Vans and cars	Knowledge in marketing,				Generation of income	

Name of end product: chips,
Primary process used for transformation: Frying,
Most frequent cultivars: False horn (Apantu in Ghana, Agbagba in Nigeria)
Acceptable substitute: French Horn and cutlivars very close to it (Onniba)
State of ripeness of fruit: Ripening stage of 4 - 5 (ripening chart of 10 peel colour points

Essential unit operation	Optional unit operation	Change in state of fruit during step	Equipment used in unit operation	Labour skills used in unit operation	Quality factors affected during unit operation				
					Physical / chemical	microbiologi cal	sensorial	Technological	Nutritional
Fruit selection		Dehanding, defingering, separation of fingers of ripening stage 4 - 5 and broken, small fingers.	Cement floor, raised platform, tarpaulin on the floor	Trained skilled, to be able to tell the difference between the stages of ripening and finger size	Fruit peel becomes yellow and pulp becomes less firm.	Possibility of fungal growth. Important to select fruit that don't show signs of fungal growth	Selection of right ripening stage will affect colour of product	Uniform size and ripening stage contribute to product quality , frying uniformity and labour efficiency	There is reduction of starch and increase in sugars
Washing		Dirty to clean fruits, remove sand, makes peeling easier,	Basins (bigger sizes) , troughs, hand gloves to protect the hand, working space to make working comfortable, tables, basket	No special skills are	Fruits are washed to avoid contaminati on with sand	Eliminates any possible microbes that may be present in the bunch	No sensory quality is affected during this stage	Ensures production of hygienic product	There is reduction of starch and increase in sugars
Peeling		Whole fruit to pulp separation is achieved and peel can be used for	Stainless steel knives, necessary to avoid reaction of the plantain with bad	Skill is required to separate the pulp from the peel since immature	Peeled fruits are subject to enzymatic browning when kept	No microbial activity is noticed at this stage is left	No sensorial effects are noticed at this stage	Skill of making longitudinal line on the fruit before separating the	There is reduction of starch and increase in sugars

		soup, feed meal and biomass for plantain farms	metals, gloves	fingers are difficult to peel in comparison with matured fingers.	beyond 2 hour from the time of peeling. Slicing should start as soon as possible to avoid browning	exposed for over 12 hours		pulp from the peel without losing any part of the pulp material	
Slicing		Sliced pieces	Plantain Slicers, (using local knives will not produce uniform slices and would be time-consuming). Use of meat slicers with a rotating blade will give a more desired rounded chips	Skill in operating both manual and electrically operated rotating machine. Skill is also required in efficiency and safe handling of the equipment in order to avoid accidents.	Thickness should be between 1.2-1.5mm and must be uniform to achieve crispiness	No microbial activity when processed quickly. When delayed, enzymatic browning which will affect the final quality	Thickness levels that are lower than 1.5 would absorb more oil during frying, and would bend or stick together after frying. Thickness levels that are higher than 2mm would be very chewy	Thick slices would not result in uniform product, and would also not result in the desired crispiness, taste and colour. Efficiency of this depends on the skill of the operator	There would be losses in vitamins when slices are exposed to air for more than 30 minutes
Frying	Frying when the oil temperature is 170 – 180 °C	Soft slices become dried, fried, brittle and greasy and crunchy chips	Cooking stove, frying pan, perforated frying spoon, Deep fryers, industrial fryers. Draining	Skill is required in monitoring the temperature of the oil (170 – 180 °C) before frying, duration of	Crispness and sogginess/ greasiness are the major physico – chemical	When properly drained and cooled there are no microbial threats	overfrying overloading of the chips and underfrying will affect the crispness,	Dehydration is necessary to attain right moisture level to prevent growth of microbes and spoilage.	Losses in nutrients, (fat soluble vitamins, ascorbic acid) addition of fat from the drying

			baskets	frying time, stirring of the slices and monitoring of end of turbulence for quick removal from oil to avoid high fat contents	factors affected		taste and colour of the end product.		medium
Draining		Drained chips, necessary to reduce fat.	Strainers, sieves,	Knowledge in proper draining is important	Proper draining results in fat reduction of the chips	E. coli, Coliforms when the drainng equipment is not clean	Reduction in greasiness	Removal of fat to prevent accumulation of fat in the packaged product	This reduces the fat in the chips, some fat soluble vitamins could also be lost
Cooling		Cooled chips	Trays, paper	No special labour is required. Necessary to cool to the right temperature	Moisture content	E. coli, Coliforms when exposed for too long without packaging		Reduction of heat, to avoid accumulation of moisture in the packaged material	There is no possible loss of nutrients
Packaging			High density polyethylene bags (HDPB),	Skilled in operating machine		E. coli, Coliforms		Preservation of product	Prevent nutritional losses that could arise from air, light and water
Labeling			Stamps, stickers, computer designed label	Computer literacy				Promotion of products	Promotion of nutritional content
Transporting and Marketing			Vans and cars	Knowledge in marketing,				Generation of income	Promotion of consumption of the plantain chips

Name of end product : Juice
Primary process used for transformation : Enzymatic liquefaction and pasteurization
Most frequent cultivars: Cavendish, check on what is available in West & Central Africa
State of ripeness of fruit: Fully ripe fruits

Essential unit operation	Optional unit operation	Change in state of fruit during state	Equipment used in unit operation	Labour skills used in unit operation	Quality factors affected during unit operation			
					Physical - chemical	microbiological	sensorial	Technological & Control
Harvest & store de-hand banana fingers on pallet. Inspect & Sort the bad from the good ones.	Purchase of ripe fruit	Ripening	Farm implements Sorting table	Farm skills Trained personnel	Peel colour as it ripens; Breakdown of chlorophyll, change in starch to sugar initiated loss in weight due to respiration and transpiration	No major	Colour & Increase in banana unique aroma,	(Bad refers those with cuts, deep bruises & other defects)
Ripening of fruit		Ripening	Ripening chamber or ethrel sprayer	Dehanding carefully to avoid injury to fruit	Change from raw fruit to ripe fruit, proper softening, conversion of all starches into sugars, loss in weight due to respiration and transpiration	Microbial spoilage of fruit due to attack by fungi like *Colletotrichum musae* and *Botryodiplodia theobramae* during ripening process.	Development of sweetness due to conversion of starch into sugars. Proper sugar : acid blend due to increase in acidity along with increase in sugars and development of aroma	Use of ripening aid like ethrel solution or ethylene gas would help in uniform ripening within short time. The quality of fruits ripened with ethylene/ethrel are better with complete degradation of starch to

								sugars.
Peeling		Protective coating of fruit skin is removed, hence easily prone to spoilage if kept for long time	No peeling machines are available for ripe banana. To be done manually using shape stainless steel knives.	Should use sterile hand gloves to prevent contamination of fruit pulp with microbes on bare hand.	Fruit pulp is exposed to air. Delay in further unit operation could lead to attack by spoilage organisms. Browning if kept for a long time (hours)	Prone to contamination by fungi like *Aspergillus niger* and bacteria like *Staphylococcus* sp, E.coli and other food borne patnogens.	No change in sensorial quality during peeling operation	This operation should be completed as soon as possible and the next unit operation started immediately. Damaged/Infected/Spoilt banana should be discarded
Pulping	Mashing	Soft solid fruit become semi-solid pulp or paste	A junior Pulper or a heavy duty mixer or blender based on quantity	Technician should be well trained. Chopping of peeled fruits would help in easy and faster pulping.	Quality of stainless steel used in pulper or mixer could affect the quality of solid pulp/ paste. The quality of steel should be of 304 grade or above to prevent reaction between the chemical content of solid pulp/ paste and the metal of pulper. Heavy metals like lead or arsenic could lead to contamination and spoilage at later stages of unit	100-200 ppm Potassium metabisulphite could be added to prevent microbial contamination of solid pulp/ paste	Heavy metal contamination from equipments could spoil the taste and sensory quality of pulp or juice. Potassium metabisulphite should be added to prevent browning of pulp due to oxidation of phenols.	Pulpers are available in varying capacities and can be tailor made by local manufacturers according to client's requirement. The time lag between pulping operation and subsequent unit operation should not be more 20 min. If it is more, it could lead

					operation.			to spoilage of pulp by oxidation and microbial fermentation. So it is better to use an efficient pulper of required capacity for improving the efficiency of unit operation. GMP & GHP require use of clean gloves at all times. All processing equipment should be stainless and cleaned thoroughly before and after use.
Pectolytic enzyme treatment and incubation. Time 2 h	No optional unit operation	The pulpy or semi solid paste separates into clear liquid juice and solids waste	Steam jacketed Kettle or incubation tanks with temperature control (between ambient and 100°C).	Careful and thorough mixing of pulp and pectolytic enzyme to bring out maximum juice yield.	Time and temperature control are very critical. The pulp and enzyme mixture has to be incubated between 45-50°C for proper reaction to take place between the	Too long incubation could lead to browning of pulp/juice.	The sweetness increases as all the soluble sugars separate into the liquid portion and insoluble pomace separates out.	Use of an temperature controlled incubator or an hot air oven could help in maintaining the temperature at desired

					enzyme and the pectinaceous material in the pulp. Normally 2 hours incubation time would suffice total break down of pulp into juice and pomace.			level. It improves the enzyme liquefaction efficiency.
Primary filtration using cloth filters	Centrifugation	The liquid juice and solid pomace are physically separated	Basket press or Basket Centrifuge	The incubated liquid – solid mixture has to be carefully handled to prevent spillage and loss of juice. The workers should use sterile hand gloves and clean filter cloth	The liquid juice is more concentrated material with more sugar. It should be handled carefully to prevent loss during filtration and juice extraction.	Chances of fermentation is more if holding time between filtration and subsequent unit operation is too long	The sensory quality improves over the pullp.	Use of basket centrifuge improves the efficiency of separation of juice and pomace. GMP & GHP
Raking or secondary filtration	Membrane filters	Separation of finely suspended particles of pulp from juice	Membrane filters or pressure filters or pasteurizing, bottling and raking at ambient temperature	Quick transfer of primary filtered juice to membrane filters of pressure filters or bottling for raking	The clarity and transparency of juice improves. No cloud or suspended particles will be visible	The contaminants also will get eliminated during membrane filtration. If pasteurized and raked the pathogens, if at all any, gets killed.	Clarity and appearance improves	Small businesses produced 50-100 litres per day may go for raking method as it is less expensive. If the volumes are more the membrane filters are more efficient.
Modify product by dilution to make beverage and adjustment of TSS	Concentration further for long distant transport or export.	The pure juice would be very sweet and thick in consistency which	Steel tanks or steel containers or steam jacketed kettle	The labour should know how to calculate the quantity of water	The consistency sweetness and acidity are the factors which get	Quality of water used for dilution can affect the microbiological	As the sweetness and acidity are affected due to dilution, it needs to be adjusted	The efficiency can be improved by using ready

and acidity.	Add citric acid to adjust the pH = 4.2	can not be consumed as such. It needs to be diluted to make it drinkable		to be added to adjust the total soluble levels and juice level based on brix meter or refractometer.	affected.	quality of the beverage. The water used should be potable, fit for drinking and free from metallic contaminants.	based on the sensorial acceptability of the clients or any statutory requirement of laws governing the food business	recknowers or charts for dilution and addition of sugar syrup or acid. Check the TSS by measuring the Brix Check the pH
Pasteurization at 80 - 90°C for 10 - 15 minutes	Fortification with extra vitamins or minerals Use of preservative, sodium benzoate @ 0.08%,? use of sodium metabisulphite	No change in the state of juice	Pasteurizer or steam jacketed kettle with pressure and temperature controls	Trained technician to be aware that while using steam jacketed kettle, there is the need to adjust the pressure level to get the required temperature for the pasteurization.	Slight evaporation during pasteurization would slightly change the physico-chemical composition of beverage. The TSS and acidity may increase slightly.	All the pathogenic microorganisms which would have gained entry would be killed during the pasteurization and the product is free from harmful pathogens.	Sweetness and acidity increase slightly which has to be adjusted based on experience gained in production of one batch of the juice.	Pasteurizers improves the efficiency. Pasteurization should always be done in stainless steel vessels using controlled flame or heating device. GMP & GHP Check the TSS by measuring the Brix Check the pH
Packaging. This could be via the ff: i. Bottling (Glass or plastic)	Immediate consumption after chilling or filling and sealing in	No change in state of juice	Semi automatic or automatic juice filling machine. If it is to be done on	The filling temperature should not fall below 80°C. The	No change in quality of the product during this operation	If the temperature falls below 80°C, the juice may get contaminated with	No change in sensorial quality occurs during this operation unless	Care should be taken to ensure that bottling is

(Bottles need to be sterilized just before filling) ii. Plastic Pouches (eg Tetra pak pouches) iii. Sachets	plastic pouches		very small scale manual filling and sealing can be done.	filling should be done in hot condition to prevent recontamination. It is a swift operation.		pathogens in air which would lead to shorter shelf life of the product.	contaminated by pathogens due to fall in filling temperature	done as aseptically as possible Filling and sealing machines improve the production efficiency as it fills correctly measured quantity of juice into the bottle or pouch
Sealing for bottles & sachets For tetra pak pouches, this will be done automatically through form and fill mechanism of the packaging machine.	Crown corking for bottle or roll on cap seals for plastic bottle or impulse heat sealing for pouches	No change in the state of juice	Crown corker, Impulse heat sealing machine	Improper sealing could result in breakage of bottle neck. Proper positioning of bottle on the sealing machine and its sealing is important	Leaky seals will result in spillage of product and spoil the quality of juice due to fermentation	Faulty sealing allows entry of microbes from air and leads to spoilage of the product	Flavour and taste get affected if the sealing is improper. Proper sealing ensures better quality of the product	For small businesses the crown corking machines would be ideal for improving the efficiency.

Name of end product: banana / plantain flour
Primary process used for transformation: drying
Cultivars*: almost all banana and plantain cultivars
State of ripeness of fruit: ripen fruits (3 - 5)

Essential unit operation	Optional unit operation	Change in state of fruit during step	Equipment used in unit operation	Labor skills used in unit operation	Quality factors affected during unit operation				
					Physical / chemical	microbiological	sensorial	Technological / control	nutritional
Purchased /stored bunches	No Option	No change			If there are cuts and /or deep bruises, browning will occur	If there are cuts and /or deep bruises, microorganism contamination occur	If there are cuts and improper handling, colour change and speeds ripening will occur	Careful handling to minimize damages	
De-handing	No Option		Knife						
Selecting fruits	No Option			Trained factory hand. Training in GHP and GMP very necessary for ensuring consistent quality				Remove all bad or cut fruits	
Washing	No Option	Entire fruit	Basin or washing bowl			Microorganism contamination from water		Use potable water and it should be changed frequently	
Peeling		Pulp	Knives*		Minimize the time between peeling and slicing in order to avoid browning			GPH (good personal hygiene) GMP (good manufacturing pratices)	
Slicing into sugar solution (20° Brix) water at 50°C for 20min under constant stirring. Slices sugar solution (1:4)		Pulp pieces (3 – 5mm)	Slicer* / knives					GMP (good manufacturing practices). The sugar solution should be used 2-3 times and new stock made	

Draining and rinsing under running water in order to remove the starch			Sieve					To avoid sticking of slices	
Drying at temperature between 55°C – 65°C and within 24 – 36h. Good air flow rate by fan speed			Dryer *	Trained technician. Training in GHP and GMP. Need for periodic review. Training to upgrade skills	Loss of weight, starch and hydro-soluble vitamins, increase in total soluble solid.		Light yellow colour enhanced, texture, aroma enhanced (caramelization due to Maillard reaction)	dry matter contain and water activity determined. Periodic calibration of dryer to verify the temperature	
Milling using a plate attrition mill (2 to 4 times to ensure less coarse particles)		Coarse to fine powder	Plate mill *		Reduction in dry matter through loss of moisture and other physical losses	Microorganism contamination if the machine is not constantly cleaned		Clean before and after use, sanitizing equipment periodically. Grounding teeth should be examined periodically and sharpened if warn out	
Sifting to uniform particle size to the range of 250 – 150µ		Uniform fine flour	Sifter *					Clean before and after use, sanitizing the equipment periodically. Periodically sieves must be examined and torn sieves replaced	
Packaging			Packaging machine *		Non enzymatic browning if not well packaged,			Use appropriate packaging material – note that the	

								packaging material must cut of light and moisture	
Storage									

Name of end product: Boiled plantain (Ampesi in Ghana)
Primary process used for transformation: Boiling
Most frequent cultivars: French plantain, *Onniaba*
Good substitutes: False horn (*Apantu* in Ghana, *Agbagba* in Nigeria), *Essammienu*.

State of ripeness of fruit: Green mature plantains

Essential unit operation	Optional unit operation	Change in state of fruit during step	Equipment used in unit operation	Labour skills used in unit operation	Quality factors affected during unit operation				
					Physical / chemical	microbiological	sensorial	Technological	Nutritional
Fruit selection		Dehanding, defingering, separation of ripening and broken, small fingers, split and twin fingers	Cement floor, raised platform, tarpaulin on the floor	Trained skilled, to be able to tell the difference between the stages of ripening and finger size	Right ripening stage (1-3) to ensure good cooking quality (i.e. firmness, water content)	No significant microbiological activity	Selection of green mature important to achieve boiled plantains of the right firmness	Uniform size and right ripening stage contribute to product quality uniformity and labour efficiency	Good selection of the right ripening stage ensures products of right carotenoids levels and other nuturients such as acids, sugars and starch
Washing		Dirty to clean fruits, remove sand, makes peeling easier	Basins (bigger sizes), troughs, hand gloves to protect the hand, working space to make working comfortable, tables, basket	No special skills are	Fruits are washed to avoid contaminati on with sand	Eliminates any possible microbes that may be present in the bunch	No sensory quality is affected during this stage	Ensures production of hygienic product	No change in nutritional content
		Whole fruit to	Stainless steel	Skill is	Peeled	No	No	Skill of	No change in

Peeling		pulp separation is achieved and peel can be used for soup, feed meal and biomass for plantain farms	knives, necessary to avoid cross contamination of the pulp with unacceptable metals, gloves	required to separate the pulp from the peel and scrape the outer thin layer of the pulp and fibers that may be on the pulp, and also to prevent cut on the pulp which could enhance water absosrption	fruits are subject to enzymatic browning when kept beyond 2 hour from the time of peeling. Slicing should start as soon as possible to avoid browning	microbial activity is noticed at this stage, except when peeled fruit is left exposed for over 12 hours	sensorial effects are noticed at this stage	making longitudinal line on the fruit before separating the pulp from the peel without losing any part of the pulp material	nutritional content
Slicing		Sliced pieces	Plantain Slicers, (using local knives will not produce uniform slices and would be time-consuming). Use of meat slicers with a rotating blade will give a more desired rounded chips	Skill in operating both manual and electrically operated rotating machine. Skill is also required in efficiency and safe handling of the equipment in order to avoid accidents.	Thickness should be between 1.2-1.5mm and must be uniform to achieve crispiness	No microbial activity when processed quickly. When delayed, enzymatic browning which will affect the final quality	Thickness levels that are lower than 1.5 would absorb more oil during frying, and would bend after frying. Thickness levels that are higher than 2mm would be very chewy	Thick slices would not result in uniform product, and would also not result in the desired crispiness, taste and colour. Efficiency of this depends on the skill of the operator	There would be losses in vitamins when slices are exposed to air for more than 30 minutes
Boiling	1. allow water to boil before adding the	Pulp is cooked due to	Cooking stove (gas, kerosene,	Knowledge of cooked pulp to avoid over	Pulp firmness, pulp of the	Addition of water after cooking	Over boiling could result	It important to ensure fuel and labour	Over boiling could result in significant

	pulp 2. arrange the pulp in pan, add water and put on fire	gelatinization of starch. Complete change from uncooked to cooked (i.e. boiled)	electric), coal pot, tripod	cooking and soaking of cooked pulp	colour, should be free of black spots	should be reasonably clean to avoid microbial contaminati on (E. coli, Coliforms)l	in soft pulp which is undesirabl e. Pulp should be firm and "crunchy"	efficiency and to reduce the extent of nutrient losses	losses of nutrients such as vvitamin C, change in carotenoid forms and losses, acids and pectins
Draining		Drained chips	Strainers, sieves,	Unskilled labour	Fat content	E. coli, Coliforms		It is important to prevent the cooked pulp from getting soaked with water	If the draining is unusually delayed, it could lead further losses in plantain nutrients
Cooling		Cooled chips	Trays, paper	Unskilled labour	Moisture content	E. coli, Coliforms		Reduction of heat	
Packaging			High density polyethylene bags (HDPB),	Skilled in operating machine		E. coli, Coliforms		Preservation of product	
Labeling			Stamps, stickers, computer designed label	Computer literacy				Promotion of products	
Transporting and Marketing			Vans and cars	Knowledge in marketing,				Generation of income	

Name of end product: roasted plantain
Primary process used for transformation: roasting

Most frequent cultivars: False horn (Apantu in Ghana, Agbagba in Nigeria, Batard/Big ebanga in Cameroon), saba used in Philippines
Special quality cultivar: Popolou (Cameroon)or Hawaiana (Nicaragua

State of ripeness of fruit: Ripening stage 1-6 (ripening chart of 10 peel colour points according to Dadzie and Orchard, 1997)

Essential unit operation	Optional unit operation	Change in state of fruit during step	Equipment used in unit operation	Labour skills used in unit operation	Quality factors affected during unit operation				
					Physical / chemical	microbiological	sensorial	Technological	Nutritional
Fruit selection		Dehanding, defingering, separation to different ripening stages, broken, small fingers, split and twin fingers	raised platform, shade, tarpaulin on the cement floor	Trained skilled, to be able to tell the difference between the stages of ripening and finger size	No physical and chemical factors are affected	No significant microbiological activity	Selection of right ripening stage will affect colour and textural properties of product	Uniform size and ripening stage contribute to product quality , frying uniformity and labour efficiency	No change in nutritional content
Washing		Dirty to clean fruits, remove dirt, makes peeling easier	Basins (bigger sizes) , troughs, hand gloves to protect the hand, working space to make working comfortable, tables, basket	Trained skilled, to be able to effectively remove any dirt that may affect the end product	Fruits are washed to avoid contamination with dirt	Eliminates any possible microbes that may be present in the bunch, use of potable water encouraged	No sensory quality is affected during this stage	Ensures production of hygienic product	No change in nutritional content
Peeling		Whole fruit to pulp separation is	Stainless steel knives, necessary to	Skill is required to separate the	Peeled pulps are subject to	No microbial activity is	No sensorial effects are	Skill of making longitudinal	No change in nutritional content

		achieved and peel can be used for soup, feed meal and biomass for plantain farms	avoid contamination of the plantain with bad metals, gloves should be used	pulp from peel effectively to ensure complete separation and removal of remaining fibre on the pulp surface.	enzymatic browning when kept for long the time of peeling. Slicing should start as soon as possible to avoid browning	noticed at this stage, except when peeled fruit is left exposed for over 12 hours	noticed at this stage	line on the fruit before separating the pulp from the peel without losing any part of the pulp material	
Slicing	The whole pulp could also be used	Pulp is sliced into two or three pieces per pulp, and shallow cuts made on the surface to ensure effective heat penetration to the core and for faster cooking	Stainless steel knives, mechanical slicers	Skill in operating both manual and electrically operated machine. Skill is also required in efficiency and safe handling of the equipment in order to avoid accidents. Skill in getting consistent sizes cut and whole pulp for efficient use of heat	Dry-cooking as a result of starch gelatinizatio n, reduction of moisture	No microbial activity when processed quickly. When delayed, enzymatic browning which will affect the final quality	No sensory quality changes here	Ensure similar sizes of pulp/cuts are roasted at the same time	There would be losses in vitamins when slices are exposed to air for long
Roasting		Change from raw to cooked pulp	Open top oven, mesh, charcoal, hand fan	Skill is required in To ensure even heat distribution,	Loss of moisture, starch gelatinizatio n	No microbial threats when properly	There is characteris tic roasted aroma, change n	Continuous and uniform distribution of heat for maximum	Losses in nutrients, especially heat labile vitamins

				effective loading and good turning to prevent over roasting or burning		roasted	colour and taste of the end product.	efficiency	
Packaging			High density polyethylene bags (HDPB), papers, transparent boxes	No special skill is needed		Contamination from microbes if allowed to sweat		Preservation of product	No nutrient loss

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