

Review

Value-adding post harvest processing of cooking bananas (*Musa* spp. AAB and ABB genome groups)

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Accepted 8 December, 2010

Cooking bananas (including plantains) are among the major commodities used in Sub Saharan Africa to combat food insecurity. It is estimated that more than 30% of the banana production are lost after harvest. The losses are mostly due to the rapid ripening of the fruits, poor handling, inadequate storage and transportation means, and poor knowledge of food processing options. Processing the fresh fruits into food products with a longer shelf life can provide a major outlet to use surpluses and to exploit a greater number of marketing options. In this paper, we provide ingredients and recipes for food products made by the International Institute of Tropical Agriculture (IITA) from its improved hybrids of cooking bananas to decrease post harvest losses, diversify the industrial potentials of bananas, and add value to farmers' products. Some of these processing methods can be used by farmers and rural entrepreneurs in their communities to ensure food security and raise their incomes, or upgraded by the private sector in a value chain approach to curb production losses in bananas.

Key words: Bananas, food security, post harvest, food processing, value addition.

INTRODUCTION

Commercial bananas are notoriously known as table or dessert fruits, but the bulk of the bananas grown throughout the tropics cannot be eaten without cooking (through boiling or frying), fermenting, or drying, according to the cultivar. There are several kinds of these bananas, including the East African highland bananas (*Musa* spp. AAA-EA group), the West African plantains (*Musa* spp. AAB group) and the predominantly Asian cooking banana (*Musa* spp. ABB group).

Bananas for cooking are among the major starchy staples of sub-Saharan Africa, representing about one third of estimated 100 million tons of bananas produced annually in the world. The plantain types of cooking bananas are traditionally grown as part of a staple diet, or for processing into more durable products such as flour that can be stored for later use. In East Africa, most of the cooking bananas produced are the East African highland bananas that are used in a similar way to the plantain type, and constitute the major staple food for some 20

million people in East Africa and part of Central Africa (Ssemwanga et al., 2000). Many traditional dishes are prepared in the region from the green to over-ripe stages (Hemeng et al., 1996; Rubaihayo, 1991; Seenappa et al., 1986). In West Africa a wide range of processing operations are employed before plantain is consumed and they include boiling, roasting or baking, frying and drying (Dadzie and Wainwright, 1995; Adeniji et al., 1997; Agbor, 1996; Echibiri, 1996; Abiose and Adedeji, 1992).

Bananas are highly perishable, with a significant proportion of the harvested crop being lost from the farm gate to the market place, owing to poor handling, storage and transportation of the fresh fruits. Additionally, non-harvesting losses may occur in peak production periods when farmers do not harvest the entirety of their production because of saturated markets. Put together, an estimate of 35% loss of the production of bananas was reported for developing countries (FAO, 1987). Cooking bananas are used in a wide range of food dishes of varying regional importance. There appears to be a potential market for a wider range of snack products produced from these commodities in the target countries, including the production of several popular alcoholic

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and non-alcoholic banana based beverages in East Africa.

The nutritional composition of plantain and banana has been elucidated, starch being the predominant carbohydrate in green fruit. The fruits provide some essential minerals and contribute substantial amount of vitamin C and carotene (pro-vitamin A), which are among the six vitamins included in the Recommended Daily Allowances of the Food and Nutrition Board of the National Research Council (Ogazi, 1996). Bananas are easy to digest and, since they are similar in chemical composition to the mucus of the stomach lining, they have a soothing effect in the treatment of gastric ulcers and diarrhea (INIBAP, 2003). The major sugars in bananas are glucose and fructose. Glucose is the most easily digestible sugar, which gets into the bloodstream rapidly and can be utilized for a quick release of energy, while fructose is absorbed more slowly, and thus it provides a more lasting fuel release. Bananas are famous as a good source of potassium, a mineral involved in proper muscle contraction.

The International Institute of Tropical Agriculture (IITA) has developed improved varieties, which are disease and pest resistant, high yielding with good post harvest processing qualities, from landraces of cooking bananas. The new varieties are being currently disseminated to farmers in West and Central Africa (WCA) and East and Southern Africa (ESA), together with new post harvest processing options. The conversion of cooking bananas into flour, wine, beer, and weaning food products (extruded and high protein, low cost) is a means of adding value to the fruits as well as extending the shelf life of derived foods (Echibiri, 1996; Chukwu et al., 1998; Adeniji and Empere, 2001). The manufacture of local soap using banana peels or skin is a complementary value adding option (Nwaiwu et al., 1998). The present report provides laboratory procedures and recipes for banana flour, chips, juices and wine generated at IITA in order to curb post harvest losses, add value to fresh fruit products, and enhance industrial potentials of bananas.

PRODUCTION OF FLOUR FROM COOKING BANANAS

Flour is an important raw material in the baking and confectionery industry. The demand for flour in bakery products is increasing globally and banana flour is currently being exploited in baking and complementary weaning foods (Ogazi, 1996; Adeniji and Empere, 2001; Baiyeri, 2004). Flour has a longer shelf life than the raw fruits because of the reduced moisture content. Converting fresh banana fruits to flour also adds value to them. Banana flour is prepared from green unripe fruit and is therefore characterised by high starch content (Crowther, 1979; Thompson, 1995). Usually, banana fruits are hand-peeled, which often proved difficult and takes time to

achieve. Crowther (1979) reported that fruits may be soaked in hot water before peeling, but this method rarely helps, and with experience, hand-peeling untreated fruit can be quite successful. The stage of maturity and the nutritional qualities are important factors in the production of banana flour and its uses in various food preparations. It has been reported that stage of fruit ripeness affects the quality of chips and the physical properties of cooking banana flours (Onyejegbu and Ayodele, 1995; Lemaire et al., 1997). The colour of the flour produced is dependent on the quality of the raw material and the temperature of drying, which is very critical for flour acceptability (Ogazi, 1989). Light coloured, non-gelatinised flour is produced when the fruits are at the green or turning point stage, and dried at temperature below 65°C (Ogazi, 1989). Dark coloured, gelatinised flour resulted when the temperature is raised above 75°C, which is as a result of Maillard reaction (reaction between reducing sugars and amino acids) that takes place at high temperature. Changes in particle properties (moisture content and particle size) and storage conditions may influence the capability of the flour particles to flow (flowability). In that regard, small changes can have significant effects. The storage conditions include temperature, exposure to humidity of air, storage time, and consolidation (Fitzpatrick et al., 2004; Teunou and Fitzpatrick, 1999). Dried banana slices may be stored and only be converted to flour when needed because the flour tends to lose its flavour over time or may absorb moisture (hygroscopic) and become mouldy (Dadzie and Orchard, 1997), especially when stored without proper packaging. Crowther (1979) and Thompson (1995) reported that after milling, it is ideal to leave the flour or powder to cool before packaging in moisture proof bag for storage and marketing. Ogazi and Jones (1988) reported on various treatments and drying procedures for the production of dried plantain cubes, while Ogazi and Jones (1990) focused on pilot-scale dehydration of the fruit pulp for flour production.

Banana fruit slices may be dried in the sun by spreading out the slices on mats on bamboo framework, on cement floors, or on a roof or sheets of corrugated iron or simply on a swept-bare ground (Dadzie and Orchard, 1997). Banana flour produced using sun drying or simple cabinet dryer is often heavily infested with insects, sand and filth, and is therefore of limited commercial value (Crowther, 1979). Ogazi and Jones (1990) demonstrated a pilot-scale drying of unripe plantain pulps for flour production; if the pulps are not properly dried, the flour will agglomerate on the sieves and make sieving difficult. Dadzie and Orchard (1997) reported that various designs of solar dryers can be employed in plantain pulp dehydration or they may be dried in ovens, oven fires, in cabinet dryer or tunnel dryer. Different designs of solar dryers, cabinet dryers, tunnel dryers may be employed in banana flour

production. Sweet bananas have higher water content (75%) than cooking bananas and plantain (66%) according to Dadzie (1998). The high moisture content of banana which affects dry matter content must be taken into account when deciding which types or varieties of bananas are best suited for making flour or beverage. Therefore, based on moisture and dry matter content, most cooking bananas can be better for making flour while most sweet bananas are better for making juice. Some of the improved hybrids produced by the international institute of tropical agriculture have differentials in water contents that may rank them in either classes for flour, juices, and liquors.

Banana flour processing methods

Harvest green bunches and detaches the fruits from the peduncle. De-finger each fruit from the hands into a bowl containing water and wash to remove dirt and possible chemical residue and latex (which exuded from the cut surface of the crown). Peel the fruit manually with the aid of stainless kitchen knife and keep in a bowl containing water, and allow to remain in water until the peeling process is complete to prevent browning of the resultant flour. Ensure proper peeling to ensure total removal of the peel. Slice the pulps longitudinally to about 15 mm thickness with stainless steel knife to further prevent discoloration and to enhance dehydration. Dry the slices in a moisture extraction oven (for instance the Forced-Air Sanyo Gallenkamp) at 60°C for about 48 h. Mill the resultant dried pulp slices to obtain a fine powder. Sieving is not required if appropriate machine with sieve of fine mesh size is used. This will help to prevent loss of flour and ensure very fine particle flour that can be easily amenable to mixing. The dried pulp slices may be stored and only converted to flour when needed since the flour tends to lose its flavour rapidly or the flour being hygroscopic in nature may absorb moisture and become moldy. Banana flour can be used in many different ways; in Africa, plantain is beginning to be used in total (e.g. in cakes) or partial (bread, meat pies, chin-chin, and other snacks) substitution for wheat flour in the baking industry (Ogazi, 1996). Traditionally the gruel can be reconstituted in hot water to make thick dough commonly eaten with vegetable soup in many parts of Nigeria. Pancake can be processed by reconstituting two parts of the flour with half part of water to produce a paste, which is then mixed with other ingredients and fried in vegetable oil until brown.

PRODUCTION OF BANANA CHIPS

Chips or crisps are hard, brittle fried products abruptly releasing energy that gives rise to characteristic sound

effects when they are bitten. They are the most popular post harvest processed products of cooking bananas in East Africa (CTA, 2007) and West Africa (Onyejegbu and Olorunda, 1995). They are one of the most important foods usually fried in the form of crisps (thin circular) or sometimes in form of French fries (stick). They are prepared by deep-frying round slices of unripe or slightly ripened plantain pulp in vegetable oil, and can be preserved for a long time given adequate packaging and storage facilities. Several studies have been conducted on the use of *Musa* species fruits for chips making (Adeniji and Tenkouano, 2007; Dzomeku et al., 2006; Adeniji, 2005; Yomeni et al., 2004; Adeniji et al., 1997; Ferris et al., 1996; Ogazi, 1996). 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 min (Lemaire et al., 1997). The plantain chips prepared in this way and packed in plastic sachets or in hermetic aluminium sachets can stay crispy and conserve all their quality for more than 4 months at room temperature and away from light. Adeniji (2005) also reported that plantain chips can be stored for up to six months with adequate packaging and storage in dark experimental cupboard to exclude light.

Cooking bananas chips produced from some improved varieties contain appreciable levels of iron, zinc and total carotenoids (Adeniji and Tenkouano, 2007). The estimated daily contribution of iron from average servings of 45 g plantain chips at 31.1 and 23.0% for adult male and female, respectively (Adeniji and Tenkouano, 2007). An average serving of 45 g chips per day from some improved varieties provide 14.6 and 20.1% zinc to adult male and female, respectively. Consumption of an average serving of 45 g banana chips can contribute 2.61 retinol equivalents (RE) daily, if a small packet (45 g) is consumed based on Recommended Daily Dietary Allowances. Since plantain chips are snacks, they can be consumed in between meals as much as desired, which could hitherto make provision for substantial amount of micronutrient in the diet. Deep-fried plantain and banana chips may potentially be used in intervention programmes to combat micronutrient deficiencies, by virtue of their iron, zinc and total carotenoid content. The fat content of chips may increase the carotenoid bioavailability (Jalal et al., 1998), though, may also reduce product shelf life due to lipid oxidation Min and Schweizer (1983).

The production and marketing of plantain chips in Africa is principally a feminine activity, which has greatly developed these past years in Cameroon, Côte d'Ivoire, Ghana, and Nigeria. Industries producing chips from cooking bananas have equally been developed in Cameroon and Colombia to give more value to this perishable food product. These industrial or semi-industrial units use equipment that makes the mechanization

possible in certain activities in the production chain. The "robot-coupe" (for example 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. In industry, frying can be done using continuous or discontinuous electric or gas deep fryers, whereas vacuum packaging with appropriate apparatus is welcome.

Banana chips processing methods

Cooking bananas chips are produced by deep-frying green unripe or partially ripe pulp slices. Wash the fruit, peel neatly and slice using a plantain slicer (kitchen wonder) into disc or longitudinal shapes. The fruit may be salted before or after slicing and then deep-fry in vegetable oil until crisp. To prevent sticking of pulp slices, the peeled fruit can be salted whole and then slice directly into the heated oil. The chips should be removed as soon as crisp and golden yellow colour (in case of plantain chips) is attained. Drain the chips and leave to cool at room temperature. Select the chips to remove broken ones and then pack in a polyethylene bag and seal with electric sealer. The shelf life of plantain chips is greatly reduced when exposed to air and light. The typical golden yellow colour of plantain chips fades away gradually, and turns white. Greater improvements have been made on plantain chips production in Nigeria (Adeniji and Tenkouano, 2008; Adeniji and Tenkouano, 2007; Ogazi, 1996). The use of electric fryer and improved packaging materials is being encouraged to meet both domestic and export markets.

PRODUCTION OF BANANA JUICE

Juices are more convenient to consume and usually have a longer shelf life than fresh fruit from where it is usually derived. Fruit juices usually contain a complex mixture of nutrients which are beneficial to the maintenance of good health and they have intrinsic disease risk reduction properties (IFU, 2005). In addition to the major nutrients that are inherent in the fruit itself, juices also contain phytochemicals, which are often referred to as phytonutrients that are derived from the fruit. Photochemicals act as antioxidants, stimulating the immune system, positively affecting hormones, and acting as antibacterial and anti-viral agents. The major raw materials for juice production include carefully selected ripe fruit of the highest quality in terms of colour and freedom from diseases or flecks. Water obtained from a clean source, industrially certified as free from germs is also required. Other ingredients include sweeteners such as sodium cyclamates (in some instances), sugar or fructose syrup.

Preservatives like sodium benzoate, sodium nitrite, nitrates, sulphur dioxide, carbon dioxide, copper carbonate and benzoic acid may be needed to extend the shelf life of fresh juice. Banana juice may be packaged in different types of materials such as protective paper packages, bottles, spectra packages, and plastics. All these packaging materials are effective in keeping dust, microorganisms and contaminated air away from the fruit juices. Canning of juice involves the use of agitate, spiral or helical retorts. Filling is done at high speed with a weighed amount done mechanically or using automatic filling machines. The cans are exposed to steam or hot water to create space at the top. Filled and exhausted cans are sealed automatically. Hermetic sealing ensures that no air enters. Oxidation is one of the most important free radical-producing processes in food, chemicals and even in living systems. Free radicals play an important role in food and chemical material degradation, contributing also to more than one hundred disorders in humans (Ye and Song, 2008; Tribble, 1999). In fruit juices, oxidation may result in discolouration, resulting in low quality products with short shelf life. The use of 3% benzoic acid for preserving fruit juice for at least one month has been reported (Akpan and Kovo, 2005). At refrigerated temperatures (4°C), most micro-organisms do not multiply as rapidly as they do at room temperature, suggesting the need for juice refrigeration to increase shelf life. Improvements in the methods of fruit juice preservation will make it possible for the successful feeding of populations in countries unable to produce their own fruits. This will hitherto help to provide varied and better balanced diets.

Banana juice processing methods

Fruits could be ripened artificially with the aid of ethylene to ensure uniformity in fruit colour. Detach ripe fruit from the bunch, wash and hand peeled followed by pulping using a warring blender. Peeled fruit could also be mashed with hands to obtain slurry. Add three parts of boiling water to one part of the macerated pulp in a bowl with the addition of few drops of lime juice or unripe lemon or other citrus fruit. Keep the slurry open to prevent discolouration. The addition of lime juice was to facilitate juice extraction as pulp coagulates due to the presence of acid. Lime juice enhances the flavour of the juice and probably act as preservative for its high citric acid content. Leave for about 15 to 20 min and filter the slurry through a muslin (white, fine filter) cloth to obtain a clear bright juice by removing suspended fruit particles. Sweeten the filtrate with granulated sugar and flavoured with vanilla powder to improve the sensory qualities of the juice. Apply E102 Tartrazine and E110 Sunset Yellow FCF food colourings (e.g. made by Preema International

Ltd., UK) to the extracted juice to improve its colour. Make a master solution by dissolving 9 g of the powders in water and make up to 1 litre. Add the solution to the juice sparingly. Add Vanilla Powder Favouring, for example PIO47), a product of Rayner Essence Group Limited, Bull Lane N18 ITQ (which country) to improve the flavor of the juice. Transfer the juice into washed, sterilized glass bottles and pasteurized by heating filled bottles in boiling water for 5 to 10 min depending upon the size of the bottles.

PRODUCTION OF COUNTRY WINE FROM BANANAS

True wine is known as a product of grape. Wine can also be produced from native fruits, berries and flowers, which are usually referred to as country wine, capable of standing comparison with commercial wines of similar type. Wines come in two major categories, red and white, depending on the variety of grape used in winemaking process (Berry, 1992). Similarly to the fruits mentioned above, overripe bananas can be used for the production of country wines.

Banana wine processing methods

Overripe bananas have been found useful in country wine making because of the presence of high level of sugar in the fruit. Other ingredients required included the peels, which complement the pulp in providing the nutrient required for yeast and impart natural colour to the resultant wine. Extracted juice from Roselle (*Hibiscus sabdariffa*) may be used as part of the recipe in wine-making to improve colour and flavour. Wine yeast is commonly applied, however natural yeast obtained from matured palm wine has been found useful. Water, sugar and yeast nutrient are also required in varying quantities. To produce about 1 gallon of wine, 2 kg of dessert or cooking banana pulp, and $\frac{1}{4}$ kg of the peel is required, in addition to 1.5 kg of granulated sugar, 4.5 litres of water and few drops of yeast extract. Juice of one grape, one lemon, and sweet orange may be required to serve as yeast nutrient.

The processing methodology for banana wine involves the use of mashed ripe or overripe pulps and peels of bananas. The resultant mash should be kept in a clean, sterilized white cloth bag or calico cloth. Then tie the bag and place into a saucepan (preferably aluminum) with water and boiled and then allowed to simmer for about 10 to 15 min. Pour the hot water used in boiling the mashed pulp-peel mixture over granulated sugar in a fermenting can. Then apply pressure on the cloth to extract more juice as the bag became cold, which should also be added to the liquid in the can. Add the yeast when the temperature of the juice is about 27 to 30°C, since yeast will be killed at high temperatures (temperature of 38°C is definitely not ideal). Alternatively yeast culture may be

prepared ahead of time to facilitate fermentation. Cover the mouth of the fermenter tightly with calico cloth until the first stage (primary or aerobic) of fermentation is over. Primary fermentation is always vigorous, producing some froth, while the second stage is rather quieter, but longer. The must (extracted slurry and the ingredients) should be allowed to stand for 7 to 10 days in a room temperature. Agitate the jar twice daily to boost the fermentation.

To initiate the secondary (aerobic) fermentation, plug the mouth of the fermenter with fermentation trap with few drops of water or sterilizing solution in the U shape of the trap and a small cotton wool at the mouth of the trap. This is necessary to prevent air into the fermenter and thereby ensuring aerobic fermentation in addition to preventing fruit flies from turning the fermenting liquor into vinegar. Keep the bulk to ferment until bubbles is no longer noticed, which indicates end of fermentation. Rack the fermenting liquor occasionally by siphoning the wine off the lees of yeast and deposited solids. Secondary fermentation may last for 2 to 4 months or even longer. The wine should be allowed to clear on its own accord, given time, but it could be filtered if it does not. Certain chemicals may also be added for clarity, but it is advisable to allow wine to clear on its own. Keep the wine bulk together as long as practicable, and bottle as required as this ensures adequate maturation and aging, which improves the quality of the wine. The resultant wine should be filled into sterilized bottles and corks and store in a rack or bin or in a refrigerator.

Preparation of a starter bottle or culture as an ingredient for making wine

Juice from any fruit can be used to prepare the culture. Culture should be prepared about 48 h before it is likely to be required because this allows time for the starter fermentation to get underway. To 500 ml of fruit juice, add 30 g of granulated sugar and sterilize by boiling in an aluminum or sound enamel saucepan. Allow the juice to cool before adding yeast. Plug the neck of the bottle with cotton wool or cover with a thick cloth and keep in a comfortably warm place for the yeast to get going. Shake the bottle occasionally, and after a while tiny bubbles will be seen. After about two or three days, the starter bottle should be in full ferment. Tiny bubbles rise to the surface and you need to shake well to disperse the yeast thoroughly in the liquid. Pour the starter into the bulk of liquor already prepared for wine making. One such starter bottle should be enough for 5 to 10 gallons of liquor.

CONCLUSION

The International Institute of Tropical Agriculture (IITA) is

playing a leading role for sustainable agricultural development in sub-Saharan Africa through its research programs. In its cooking banana programs, the institute is working mostly with national research systems to release the improved varieties bred at the institute. These new varieties have several agronomic and nutritional qualities, and are amenable to various forms of food processing at any stage of ripeness, depending on product type, taste desired. The processing provided in the present work helps to transform perishable fresh fruits into high-value food products with a longer shelf life. Following the current distribution and acceptance of improved cooking bananas hybrids with increased levels of micronutrients at IITA, the diversification of their processing potentials is required as a means to providing the baseline for industrial application. For instance the uses of ripe banana fruit in juice making and processing of beverages are economically viable investments for both local and export markets. Banana flour is used for bread and cake making among other products, either in partial or total substitution. This technology is being currently disseminated to farmers and food processors in Sub Saharan Africa as part of new cooking banana hybrids delivery initiative.

With increasing urbanisation and population growth in Africa, new products are being developed that take into account the different tempo of urban compared with rural life. As reported by Ferris (1998) food processing has a great potential in the marketing chain, but considerable improvements should be made in the technologies used for drying, frying, juice extraction, storing and quality to enable local enterprises develop and expand before they can create more income and generate jobs. As cooking bananas commands such a stronghold in developing countries in the tropics, it is appropriate to conduct more research to identify new markets for processed products and find technologies to supply high-quality products at acceptable prices.

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