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Cocoyam Processing: Food Uses and Industrial Benefits

James Abiodun Adeyanju, Grace Oluwakemi Babarinde, *Adekanmi Olusegun Abioye, Ajekigbe Sola Olajire, Ifeoluwa Damilola Bolarinwa

Abstract - Cocoyam (*Colocasia* spp) is one of the major five tuber crops produced in Nigeria for local consumption alongside yam, cassava, Irish potato, and sweet potato. In many developing countries, roots and tubers such as cassava, sweet potato, yam, and cocoyam are important household food security and income crops. They all contain starch and fiber that can provide energy and satiate the consumer. Generally, cocoyam is a tuber crop that is usually cultivated in West Africa. They are important food crop for more than 400 million people worldwide. Several studies have shown that cocoyam contains digestible starch, protein of good quality, vitamin C, thiamin, riboflavin, niacin, and high scores of amino acids. However, one major limiting factor in the utilization of cocoyam is the presence of oxalates, which impart acrid taste or cause irritation when foods prepared from them are eaten. Ingestion of foods containing oxalates has also been reported to cause caustic effects, irritation to the intestinal tract and absorptive poisoning. Oxalates are also known to interfere with the bioavailability of calcium. Food and feed usage of cocoyam is restricted because of the acrid nature of the corms that irritate upon ingestion and lowers palatability. This has reduced the possibilities for processing. Processes for stabilizing and adding value to cocoyam is by converting it to semi-finished and finished products through boiling, roasting, fermenting, baking, frying in oil, pasting, milling and pounding. Cocoyam has various applications such as flour, chips, poi, syrup and starch production. Cocoyam starch is an important product with physical and functional properties for industrial application. These properties include particle size, pasting, and amylose content. The particle size of starch of cocoyam sets them apart distinctly from more familiar commercial starches. Therefore, this paper reviews various value-added products from cocoyam in order to reduce postharvest losses and food insecurity. The paper further examines other potential utilization of cocoyam for shelf life extension.

Index Terms: Antinutritional factors, cocoyam, processing, food-uses, root-crops, starch

1 Introduction

Cocoyam (*Colocasia* spp) is a taproot, starchy and globular fleshy food of edible aroid family (*Araceae*) that grows well in sandy, loamy soil that is not water-logged. It performs better in loamy soil with a good water retention capacity. Notably, cocoyam cultivation is for over a long period to meets the nutritional needs of about 400 million people around the world especially among populations in developing countries of the world which include Asia, the Pacific Islands and West Africa sub-region [1]. Nigeria and Ghana are the world's leading countries in the production of cocoyam [2] where it is commonly grown amongst smallholder farmers and contributes immensely to address problem of food insecurity.

- *James Abiodun Adeyanju is a Lecturer in the Department of Food Engineering at Ladoke Akintola University of Technology (LAUTECH), PMB. 4000, Ogbomoso, Nigeria. E-mail: jaadeyanju@lautech.edu.ng*
- *Grace Oluwakemi Babarinde is a Lecturer in the Department of Food Science at LAUTECH, PMB. 4000, Ogbomoso, Nigeria. E-mail: gobabarinde@lautech.edu.ng.*
- *Adekanmi Olusegun Abioye (Corresponding author) is a Lecturer in the Department of Food Engineering, LAUTECH, PMB. 4000, Ogbomoso, Nigeria.* E-mail: aoabioye@lautech.edu.ng
- *Ajekigbe Sola Olajire, is a Research Assistant in the Department of Food Engineering, LAUTECH, PMB. 4000, Ogbomoso, Nigeria. E-mail: olajiresola@ yahoo.com*
- *Ifeoluwa Damilola Bolarinwa is a Postgraduate Student in the Department of Food Science at LAUTECH, PM.B. 4000, Ogbomoso, Nigeria.*

Cocoyam is rich in calories mainly derived from complex carbohydrates [3] with some quantities of fats and proteins. Their protein level is nearly the same levels as that of yam, cassava, and potato. It is one of the major sources of dietary fibers and thus adds essential value to the human nutritional assortment. Several studies have reported that apart from carbohydrates (starch) which are easily digestible due to the small size of the starch granules Cocoyam contains vitamin, thiamin, riboflavin, and niacin) and minerals (calcium, phosphorus, e.t.c.) in reasonable amount [4], [5]. These nutrients give cocoyam nutritional advantages over other numerous roots and tubers.

Cocoyam can be processed using different unit operations such as boiling, roasting, frying, and milling. It can be converted to *fufu*, soup thickeners, porridge, and specialty food for gastrointestinal disorders, among others. They are either eaten boiled or fried to make crispy chips. The leaf stalks can be prepared like other vegetables and consume with solid foods [6]. Cocoyam can further be processed into poi, flour, sun-dried slices, grits, and drum-dried flakes. Proper processing of cocoyams will give a good source of starch for industrial applications which can give corms good potentials for new product development. Cocoyam crops when properly stabilized will add market value, and this will greatly improve its utilization in countries that are producing cocoyam above the human food consumption need.

However, cocoyam also contains oxalate, which gives acrid taste to the food when prepared which limits its utilization.

Antinutrient such as oxalates, when present in the food cause caustic effects, irritation to the intestinal tract and absorptive poisoning and also interfere with the bioavailability of calcium in the material [7]. Mechanical damage to the corms during harvest leads to microbial attack which causes high post-harvest loss of the corms during storage. Cocoyams contained, on the average, 25% starch (wet weight basis) with A-type structures characterized by small granule size (<1.5 μm) [8]. Non-starch polysaccharides in cocoyams lead to gummy properties of the starch. However, mishandling of raphides (crystals of calcium oxalate and other components) during harvest produces a negative effect with several levels of discomfort on the human system when it is consumed raw.

Despite the hardness of cocoyam corms compared with other root and tuber crops, they are very susceptible to physical injury during harvesting and post-harvest operations. These are responsible for losses that were estimated to be around 15% approximately. Incidence of pests invasion is at a high rate; such case is the snail reducing losses by up to 60% in worst-affected areas [9]. In spite of the huge nutritional importance of cocoyam, its corm is highly prone to being perishable due to poor harvesting, lack of appropriate storage facility and nature of cocoyam itself; i.e., its moisture content speeds up the activity of pests and diseases. Processing of cocoyam to stable products is a way of reducing its post-harvest losses and increasing its potentials in food and industrial applications. Therefore, this paper reviews cocoyam utilization and also makes recommendations on innovations that can extend its shelf life.

1.1 Nutritional Facts of Cocoyam

Cocoyam, like other roots and tubers, contains dietary energy which is mainly carbohydrate. It has more carbohydrate than potatoes, about 100 g provides 112 calories. It has low protein content 1-2%, like other root crop proteins, which means that sulfur-containing amino acids are relatively small [10]. However, it contains very low fat and protein than in cereals and pulses. The levels of protein are almost the same as that of yam, cassava, potato, and banana. Despite their high starch content, cocoyam has a higher content of protein and amino acids than many other roots and tuber [11]. The nutritional values of cocoyam are presented in Table 1. The protein content of cocoyam is higher (1.12% for taro and 1.55% for tannia) when compared to other tropical root crops [12]. Cocoyam, however, is gluten-free and contains high-quality phyto-nutrition profile comprising of dietary fiber, and antioxidants with a moderate quantity of minerals, and vitamins. Valuable B-complex group of vitamins is also present in cocoyam which includes; pyridoxine (vitamin B_6), folate, riboflavin, pantothenic acid, and thiamine. Also, the corms contain some important minerals like zinc, magnesium, copper, iron, and manganese.

de Castro *et al*. [13] and Monte Neschich *et al*. [14]. Studied two major globulins from corms of taro by The authors observed the existence of two unrelated globulin families during root development; a G2 and G1 protein which accounts for up to about 80% of total soluble tuber proteins. Cocoyam is very rich in thiamine, riboflavin, phosphorus and zinc and also sources of vitamin B_6, vitamin C, and niacin. It contains valuable B-complex groups of vitamins such as pyridoxine, folates, riboflavin, pantothenic acid, and thiamine [15]. Cocoyam is prone to microbial attack and deterioration because of its high water content which contributed to the short shelf life of the corm. The leaves are used in feeding pigs because of their nutritive values [6]. The leaves are good sources of vitamins A and C and contain a reasonable amount of protein than the corms. Cocoyam's richness in B_6 makes it good for controlling high blood pressure and protects the heart. Cocoyam contains some dietary fiber, which helps in regulating bowel health, lowering cholesterol levels and controlling blood sugar levels. Cocoyam flesh of about 100 g provides 4.1 g or 11% of recommended daily dietary fiber. The presence of slow-digesting complex carbohydrates leads to a gradual rise in blood sugar levels.

Cocoyam leaves have some phenolic flavonoid pigment anti-oxidants such as β-carotene along with vitamin A, which help to maintain healthy mucous membranes and vision. The corms provide minerals like zinc, magnesium, copper, iron, and calcium. It has low fat, and sodium content and this crop when eaten can aid the prevention of hardening of the arteries, which is attributed to eating foods that are high in cholesterol [15]. Drying can be used to dry aroids into flour for *fufu*, commonly eaten in Nigeria with stew. In Nigeria, most especially in the southeastern region, some quantity of Tannia is used in soup thickener when boiling and pounding to obtain a consistent paste. Young taro leaves are used for vegetable in South Pacific, also with coconut cream to prepare a dish called "luau," that are eating with boiled or roasted taro, breadfruit, and banana.

1.2 Cocoyam Anti-nutritional Factors

The presence of acrid in cocoyam restricts its use because of the nature of the corms that irritates upon ingestion and lowers its palatability [16], [17]. The acridity when eaten raw causes swelling of the lips, mouth, and throat and also leads to scratchiness in the mouth and throat. Anti-nutritional and off-taste problems are always common to needle-like raphides of calcium oxalate crystals and other acidic proteinaceous factors [18], [19], [20], [21], [22]. Lawal [23] and Bradbury and Nixon [22] have explained the acid level of cocoyam which can result in mechanical or sharp raphides in puncturing the soft skin. Paull *et al*. [24] also explain the presence of one or more chemical irritants on raphide surfaces. Owusu-Darko *et al*. [12] reported that calcium oxalate raphides decrease from outer to the inner of the corm and can be more concentrated in distal sections than apical [11].

Effects of cocoyam anti-nutritional factors include; reductions of food and feed intake, which leads to depression, weight gain, and pancreatic hypertrophy in experimental animals [26], [27], [28]. Trypsin inhibitors, α-amylase inhibitors, and sapotoxins are other anti-nutritional factors present in cocoyams. Philipy *et al*. [29] concluded that the levels of phytate in cassava is lower (0.133%) than in taro (0.169%). However, corms that are boiled or roasted can be consumed alone or with stew. Taro flours have special properties such as small starch granules and high mucilage content. It makes it a better substitute to be used

Table 1: Nutritional content of the major edible aroids per 100g edible portion

Constituent	Taro (*Colocasia esculenta*)			Tannia (*Xanthosoma sagittifolium*)		
Major nutrients	Corms	Leaf	Stalk	Corms	Leaves	Shoots
Calories	102	94	24	133	34	33
Protein (g)	1.8	202	0.5	2.0	2.5	3.1
Fat (g)	0.1	0.4	0.2	0.3	1.6	0.6
Carbohydrate (g)	23	21	6	31	5	5
Fibre (g)	1.0	0.8	0.9	1.0	2.1	3.2
Calcium (mg)	51	34	49	20	95	49
Phosphorus (mg)	88	62	25	47	388	80
Iron (mg)	1.2	1.2	0.9	1.0	2.0	0.3
Vitamins						
β-carotene equiv. (μg)	Trace	Trace	180	Trace	3300	
Thiamine (mg)	0.10	0.12	0.02	0.10	-	-
Riboflavin (mg)	0.03	0.04	0.04	0.03	-	-
Niacin (mg)	0.8	1.0	0.4	0.5	-	-
Ascorbic acid (mg)	8.0	8.0	13	10	37	82

Source: Opara [25]

instead of corn or wheat starch in weaning foods. Extrusion cooking and addition of whey protein to cocoyam significantly reduced gummy properties of mucilage during the production of cocoyam flours [30].

1.3 Uses of Cocoyam

Cocoyam tubers are used in the same ways like other root and tuber (yam, potato, and cassava) and they can be converted into other product and can be used industrially. Processing into stable shelf food and adding values to cocoyam could be done using the following process; boiling, roasting, baking, frying in oil, pasting, milling, and pounding. Arnaud-Vinas and Lorenz [31] have also suggested the production of pasta from blends of wheat and taro flours. The common example is the Ghanaian *fufu* - a pounded form of boiled cocoyam. Other uses include soup thickeners and baking flours, beverages, porridge and as foods for people with gastrointestinal disorders. Subhadhirasakul *et al*. [32] stated that taro starch could be used instead of maize as a binding agent in the manufacture of tablets. Lawal [23] also stated that cocoyam starches could be modified as for other industrial starches. The high digestibility and small size of taro granules make it suitable for baby foods. Boiled corms are mashed to form a weaning diet in West Africa. Onwulata and Constance [30] have suggested the process of formulation of weaning food with taro flour blended with whey protein concentrate, whey protein separate and lactalbumin. Onwuka and Enneh [33] produced beer from cocoyam and reported that the product tasted better when assessed by local assessors.

2. Potentials of Cocoyam

2.1 Processed foods

Cocoyams had been processed into several food forms more than any other root crop. The processed form of cocoyam includes poi (fresh paste), cocoyam flour, beverage powders, chips, sun-dried slices, grits, and drum-dried flakes. Corms may further be processed into roasted, boiled, baked, steamed and fried. Cocoyam can be processed into more stable food so that shelf-life can be extended and to process it into more consumable forms. These include poi (fresh or fermented paste), cocoyam flour, cereal base, chips, sun-dried slices, grits, and drum-dried flakes.

2.2 Cocoyam paste

Poi, a purplish-gray paste made from taro, is sold commercially in plastic bags, jars, or cans in Hawaii [34]. Easily digested and practically non-allergic, it is an excellent food for patients with specific health problems and recommended to patients with food allergies. Patients allergic to certain grains can eat poi with no adverse reaction [10]. The preparation of poi from taro involves pressure cooking of the corms, washing, peeling, trimming, grinding, straining out the fibrous material, and blending with water to 30 percent total solids (ready-to mix poi). This process changes the distribution of the starch components. Lactobacilli fermentation of the poi is usually very rapid within the first twenty-four hours of manufacturing, during which time the pH decreased from a pH of 6.3 (fresh ground taro corms) to a pH of 4.5. After that, the acidity increases gradually, and the pH dropped to 3.8 by the third day. The shelf life of unrefrigerated poi is three to four days. Refrigeration makes its texture rubbery, and changes the eating quality; thus it is not usually used.

Canned fresh poi (ready-to-eat poi) is an unfermented product containing 18% total solids. To maintain a quality standard of 566 g can, the heat process requires about 100 minutes of cooking time at 116 ºC. Canned-acidified poi is one of the unfermented products usually less than 4 hours old to which 1% w/w commercial grade lactic acid (50% lactic acid) has been added. It usually contains 18% or more total solids, with a shelf life that is comparable to other canned foods [35]. When subjected to gamma-radiation, at a minimum of 7 kGy increase the shelf life of poi to 7-10 days. Poi made by freeze-drying with high dehydration quality which has acceptable nutritional status has been reported [7]; however, this process is costly and required high capital.

2.3 Cocoyam slices and chips

Cocoyam chips prepared by deep-fat frying like that of potato chips can also be marketed. The criterion in making acceptable cocoyam chips is the choice of a variety that will lose the acridity factor during frying. In Nigeria, raw cocoyam corms or cormels are cleaned, washed, boiled, peeled, cut into half-moon slices about 1 cm thick, and sun-dried or smoked. They are packed in clay pots shielded with dry leaves and sealed with a mixture of smoked banana stems and clay. The dried or smoked slices are then stored in warm dry places until needed for eating.

2.4 Cocoyam flour

Flour can be produced in different ways but the common unit operations employed are peeling of fresh or pre-cooked corms and cormels, slicing, drying and grinding into flour. In commercial practice, the flour is produced by peeling the corms and cormels, slicing them, and washing them thoroughly with water to remove specks of dirt. Pretreatment is done by immersion in 0.25% sulfurous acid for 3 hr. Finally, blanching of the slice in boiling water for 4 – 5 minutes and dried thoroughly at 57 – 60 °C, after which the dried slices are milled into flour which can be used in making *fufu*.

2.5 Industrial Uses of Cocoyam

Industrial use of cocoyam is very limited although the starch content of cocoyam, for instance, accounts for nearly 78% of its carbohydrate fraction. The granules of the cocoyam starch grains (1 - 4 µm) make them readily digestible as food material, but unsuitable as a source of industrial starch. The special quality attributes of cocoyam starch, which are important for industrial application, include particle size, pasting temperature, and amylose content. The particle size of starch of cocoyam sets them apart distinctly from more familiar commercial starches. Comparison of the results of microscopy and laser light scattering studies showed that several taro varieties have particle size of 1.0 to 6.5 µm mean diameter, compared with rice starch at about 5 µm which is the finest of the commonly available starch. Thus, taro starch can be used in place of other commercial starches. Contrarily, the starch of tannia has large grains with diameter of 17-20 µm. Cocoyam, therefore, covers a uniquely wide range of particle sizes. In addition to particle size, pasting or gelation temperature of starch is also important during processing and industrial applications. Starch application technology highlights specific areas in which cocoyam properties of the starch can be applied in commercial industries. These areas include syrups, gums, modified atmosphere packaging film, fillers/modifiers for plastics, and renewable energy.

2.6 Syrup production

World production and demand for industrial syrup has increased considerably in the last few decades and is predicted to continue in the future. Like other vegetable starches, the starches present in cocoyam could be processed into High Fructose Enriched Syrups (HFES) which is a liquid sugar (sweetener) made from starch. The nutritional value of HFES is the same as that of sucrose, and it is desirable, inexpensive, and an easy to use sweetener. Hence, facilities for production can be built in areas where starch is available in sufficient amounts and inexpensive. Local uses include canning, jams, jellies, and soft drinks.

2.7 Gum production

Cocoyam contains a gum-like substance, which swells in water and becomes hydrated. This gum has potential usefulness as an emulsifying, thickening, and smoothing agent for creams, suspensions, and other colloidal food preparations. Extraction of the gum would also alter cocoyam properties of the products and reduce their stickiness and viscosity.

2.8 Modification of plastics

Starch can make up to 40% of plastic compounds based on polymers such as polystyrene, polyethylene, polyvinyl chloride (PVC). The addition of modest amounts of starch will not affect the original physical properties of the plastics. Cocoyam starch is biodegradable, and when used in the appropriate formulation for the production of plastics, it accelerates the biodegradability of the parent polymer. Furthermore, the starch content does not exclude the possibility of recycling the majority of plastics composition. With the increasing global demand and utilization of food and raw materials in general, biodegradability has become increasingly an important requirement in agro-industrial waste management. Taro has small sizes of starch granules (about one-tenth of the size of maize starch granules); this makes it superior to other starches when used for the production of biodegradable plastics.

2.9 Cocoyam-based edible films for Modified Atmosphere Packaging (MAP)

MAP technology utilizes the permeability characteristics of films and other packaging materials to influence the exchange of air mainly to control the degree of ripening and other physiological activities of fresh food products inside a package. Starch-filled polyethylene films gave a significant decrease in gas permeability with increasing starch content. This effect is associated with the high degree of crystallinity of the starch filler material; a property that is also shared by mineral fillers [10]. The low fixed gas permeability of starch obtained from cocoyam makes it a potential candidate in developing appropriate MAP technologies, especially in the tropical root and tuber regions where the production of root crops is a major part of agricultural production. A cocoyam-based packaging film has been successfully developed but was found expensive compared to low-cost synthetics.

2.10 Renewable Energy Source

There is a global concern on the depletion of non-renewable energy sources and the deleterious effects of fossil fuel on environmental degradation. In underdeveloped countries, low-energy input is often a major limitation to increasing agricultural productivity and overall rural development. Many countries could reduce the rate of importation of oil appreciably by replacing part of their petroleum consumption with alcohol from sugar or starch-containing crops. Due to its favourable domestic economy, cocoyam would serve well as a feed material for energy generation. The quantity of alcohol produced from taro is lower than that of cassava and other cereal crops, but the percentage is higher than that of sugarcane and sweet corn. The accepted starch-to-alcohol conversion ratio is about 1.67 kg of starch to 1 litre of alcohol, and in the USA alcohol production cost from taro is considered similar to cassava or sugarcane [10].

3 Conclusion

Cocoyam can be processed into more stable food so that shelf-life can be extended and to process it into more consumable forms. These include poi (fresh or fermented paste), cocoyam flour, cereal base, chips, sun-dried slices, grits, and drum-dried flakes. Cocoyam can be used industrially in making syrups which can be used in jams, jellies, and soft drinks. Proper processing method to stabilizing corms and cocoyam flours could resolve the problem of food security in cocoyam producing areas.

As a result of various potentials of cocoyam, this crop can ameliorate the problems of food insecurity in most developing countries. The industrial application will also help in boosting the economy of most countries. Modern technology can be used in processing cocoyam to meet the international standards, hence facilitate exportation of some of cocoyam products. These applications will yield better quality product in terms of nutrients retention and control of enzymatic reaction and microbial attack.

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