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Review

Enhancement of agronomical values: upstream and downstream opportunities for starch and starch adjuncts

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Majority of the starch crops harvested in the tropical African countries are wasted to post-harvest losses, while minority are consumed locally with insignificant quantity being processed for down stream applications, with no evidence for up stream process applications. Consequently, the natural resources are under utilized but deserve value enhanced utilities. In view of these necessity, this review pooled together information on tropical agricultural starch crops endowment with respect to types, present status of utilization, possibility for value enhancement and illustrations on prospects for utilization of value-added starch based products and adjuncts in food and non-food products with view to provoke interest on enhancement of agronomical benefits of tropical African countries starch crops.

Key words: Tropical countries, starch crops, under utilization, utilization constraints, value added opportunities.

INTRODUCTION

Nigeria is endowed with lot of agricultural resources among which crop farming is the most favoured. Over 80% of Nigerian population engaged in farming but survey showed that majority of the starch crops harvested are wasted to post-harvest losses, while minority are consumed locally with insignificant quantity being processed for down stream applications with no evidence for up stream application. This underutilization trend may not be too different from what is obtained in other tropical African countries.

Therefore, it suffice to assert that the natural resources are underutilized, but deserve value enhance derivatives. Considering applicabilities of the crops using advanced technology, it is anticipated that the natural resources can be of great potentials for economic and technological development if properly managed. The anticipation serves as impetus to this review. Therefore, this review pooled together information on types, present status of utilization, and possibility for enhancement and prospects for utilization of the value-added starch products in Nigeria with view to provoke interest on optimization of agronomical benefits of the crops.

Starch, the most important reserve carbohydrate in the plant world (Wang et al., 1993) belong to a class of polysaccharides which consist of several hundreds of glucose units joined by α-1-4 and α-1-6 glucosidic bonds. In term of commerce, starches as a group is the cheapest and the most important polysaccharide hydrocolloid (Bahnasey and Breene, 1994). In addition, starch is one of the most abundant organic chemicals on earth (Jane et al., 1994). In terms of quantity, starch ranks third behind wood and vegetable oil. They are widely used in a variety of food and non-food products.

The principal sources of starch in Nigeria are roots and tubers (cassava, yam, cocoyam and potato), cereals (maize, sorghum, millet and rice) and fruits (banana, pla-

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ntain and breadfruit). Although all the starch crops are enormously produced in Nigeria, but the present status of amount of production of cassava and yam by Nigerians in the world informed our chosen the two for discussion on present utilization of the crops.

CURRENT APPLICATIONS OF CASSAVA AND YAM

Cassava is an important food crop. This is informed by its amiable characteristics namely, high carbohydrate content, an energy-source food component, and availability of the crop all the year round. Other desirable attributes are ability to withstand adverse conditions such as tolerance to poor edaphic factors and resistance to drought, pests and diseases, and relatively simple primary processing method involved.

Although, virtually all food products from cassava are known to all Nigerians irrespective of their ethnic origin, but some products appeared to be native to some regions. The major food products processed form cassava has been reviewed by Ihekoronye and Ngoddy (1985). Cassava processing operations in Nigeria can be classified into 5 categories: household (cottage), micro, small, medium and large. Small and medium processing operations are very sparse at present. Large-scale cassava processing is virtually non-existent in Nigeria. The assertion was based on definition of large scale operation as an enterprise employing 10 - 30 or more labourers.

It has been reported (anonymous) that estimation of industrial application of cassava in Nigeria in the year 2001 was 16% of cassava root production. About 10% was used as chips in animal feed, 5% was processed into a syrup concentrate for soft drinks and less than 1% was processed into high quality cassava flour used in biscuit and confectionary, dextrin, pre-gelled starch for adhesives, starch and hydrolysates for pharmaceuticals and seasonings. This evaluation leaves 84% of production for food consumption. Ever since, there has not been an increase in industrial utilization of cassava in Nigeria. Unfortunately, comparable time series data describing cassava processing and utilization at the national, regional and state level is virtually non-existent.

However, information on preliminary analysis of the first national consumption survey of Nigeria since the early 1980s is available in Ministry of Health and Nutrition of Nigeria. The largest acreage and greatest amount of yam production is in West Africa, where over 95% of the total world production takes place. The major yam producing countries in West Africa are Nigeria, Ivory Coast, Ghana and Togo. Nigeria alone accounts for 78 percent of world production of yam (Asiedu, 1989). There are about 60 yam species; the notable varieties are *D rotundata, D cayenesis, D alata, D dumetorum* and *D esculenta.* Presently, uses of yam are still at domestic level and sparsely dried for production of chips or processed to flour, both of which are important for local commerce.

Considering the quantitative descriptive data stated earlier, cassava and yam are the most favoured in term of production. Nigeria is currently the largest producer of cassava and yam in the world. Even with the high level of the nation's endowment of starch crops, processing of the crops is still at informal state. Traditional processing has a number of undesirable attitudes; it is time consuming, provides low yield and lacks storage capacity. Depending on the class of starch source, means of production of starch can be low technology as in extraction of starch from root/tuber crops like cassava where the major unit operations essentially involved are peeling, washing, grating, sieving, sedimentation and decantation/starch recovery (Leach, 1965; Osunsami et al., 1989). Some of the major constraints hypothesized for under utilization of the crops and the necessities for enhancement of agronomical benefits are outlined in Tables 1 and 2 respectively. Details of potentials industries using starch and starch products in food and allied industries are shown in Table 3.

TRANSFORMATION OF STARCH TO VALUE-ADDED PRODUCTS

Characteristics of cook of native starch irrespective of source are undesirable for many industrial applications. This is because they are susceptible to retrogradation, syneresis, undesirable viscosity and un-ordered gelation. This is as a result of their inability to withstand the typical industrial processing conditions such as extreme temperature, pH, high shear rate, and freeze thaw variation encountered during manufacture of food and allied products. As a result of these undesirable phenomena there is need for modification.

Modification significantly improved positive attributes of starches and negative characteristics are tremendously reduced (James and West, 1997). Some of the important positive attributes conferred on starch when modified are presented in Table 4.

The principal biochemical components of starch are amylose and amylopectin, and these have been pioneer target for modification. Modification had been accomplished using chemical action, physical and genetic modifications (Table 5). In a previous review, James and West (1997) indicated that each starch is unique in terms of granule organization and structures of its constituent polymers. The paper stressed that definition of starch properties based on generalized chemical structure, source of the starch may not be adequate to explain the behavioral properties of starches as granule ultrastructures differ from one plant source to another and even from location to location within a single plant. The variations lead to differences in terms of formation, development or derivation of new products with wider industrial application (James and West, 1997).

Table 1. Present constraints to enhancement of agronomical value.

- Low and inconsistent quality of starch crops
- Present poor status of technological developments
- High price of home-made product compared to imported products
- Sub-quality of product compared to high quality of imported products
- Lack of processing inputs (in terms of skill labour, power supply and storage facilities)
- In-availability of government subsidies
- Lack / Inadequate of producers incentives

Table 2. Necessities for the enhancement of agronomical benefits

- Better incentives for hard labour of agricultural produce farmers
- Reduction of post harvest losses
- Enhancement of food security and attainment of food sufficiency
- Amount of starch and starch based products imported in Nigeria for industrial use.
- Present interest of Federal Government in boosting non-oil sectors particularly agriculture-sector.
- Reduction in degree of dependence on foreign products
- Present predicament of sourcing scarce foreign exchange.
- Loans and other forms of agricultural inputs are being disbursed to stake holders in the sector - particularly farmers. This has been supported by some non-governmental agencies (NGO) such as ERAP, ADP.
- Maximization of utilization of natural resources with respect to agricultural crops.

Table 3. Major industries using starch and starch products in Nigeria

Industry	Status of the raw material at utilization
Flour mill	Major
Sugar	Major
Brewery	Major
Gin / Spirit industry	Major
Soft drink and carbonated water	Minor
Bakeries	Major
Pharmaceuticals	Minor
Textile	Minor
Paper mill	Minor

Table 4. Some of the positive attributes of modified starch.

* To modify pasting attributes
* To decrease retrogradation crystallinity
* To decrease gelling tendencies of paste
* To increase freeze-thaw stability of paste
* To decrease paste and or gel syneresis
* To improve paste and or gel clarity / sheen
* To improve paste and or gel texture
* To improve film formation
* To improve adhesion.
* To add hydrophobic groups for emulsion stabilization.

Source: James and West, (1997).

APPLICATIONS OF STARCH

Down stream applications of crude, refined and specialty starch

Starch component of agricultural crops is endowed with high energy for human and animal nutrition. They are, therefore, relied on for our daily energy derivation whether supply from domestic cooking or from institutional catering or industrial (confectionery) products. Although, crops such as cassava may not be suitable for production of some foods especially bakery products (like bread), but they have been found to be a substrate for composite flour formulation for varieties of bakery/snacks foods at some pre-determined level with awesome economic benefits (Table 6).

Partially refined and treated starches can be used to modifying texture of gum, pastilles and jellies. Some other specialty starches have been tailored to impact neutral taste, and low viscosity in products like salad, creams, and mayonnaises. Native starches can be modified in order to form granular cold water gel or viscous mass on addition of water even at room temperature (28°C). Such value added starch that thickens without the applications of heat, find applications in preparation of food products such as instant puddings and cold dessert mixes. Others are powdered soups and easy mixed sauces (Trimble, 1983). A number of procedures for preparation of these starches had been reported by Baik et al. (2001) and Jane and Chen (1994). Other spe-

Table 5. Modification methods and probable attribute conferred.

Types of modification	Probable attribute conferred
I. Chemical modification	
A. Derivatization	
1. Monostarch substitution (etherification and esterification, includes polymer grafting)	Improved paste clarity
2. Cross linking (via distarch esterification)	Increase paste stability , lower tendency to retrograde
	Increase water solubility
B. Acid-thinning /hydrolytic depolymerization	Improved water solubility
C. Dextrinization (depolymerization and transglycosylation	
D. Oxidation (bleaching and depolymerization)	Increase clarity
E. Hydrolysis (maltodextrins, glucose syrup, glucose etc. – both acid and enzyme –catalyzed).	
II. Physical modification	Increase in digestibility
A. Pre-gelatinization process	Cold water solubility
B. Preparation of cold-water-swelling starch	
III Genetic	
A. Waxy starch	Variable quality profile
B. High –amylose starch	

Table 6. Level of inclusion and the benefits of use of cassava flour in specific products made by home caterers, bakers and industrial users.

User	Product	Level of inclusion of high quality cassava flour in the products (%)
Bread bakers	Cassava-wheat bread.	5 – 25
Bread bakers	Cassava-whole wheat bread	95.5
Biscuit factories	Biscuits	10 – 50
Noodle factory	Noodle	10
Caterers	Cake	5 – 100
Indomie factory	Indomie	80 – 92
Restaurant	Cassava-maize semo	18.0
Home caterers	Chinchin	25 – 100
"	Fish/meat pie	10 – 100
"	Buns	10 – 12.5
"	Fish rolls	10 – 12.5
"	Puff –puff	10 – 25

Source: NIFST Food Forum (2004).

cialty starches of amiable attributes include, heat stability and resistance to change in pH. These qualities make starch a functional raw material for products like baby meal, pudding and sauce for canning fruits. The major multifunctional properties of native and modified starches that made them to be useful for production of the mentioned and other designer foods are presented in Table 7.

Specialty starch as a natural strategy for management of physiological disorder

Starch can sometimes exhibit the property of non-digestible carbohydrate, if designed to exhibit such property. With regard to rate and extent of digestibility or nutrition, starch can be group into three classes namely, rapidly digestible starch, slowly digestible starch and resistant starch (Englyst et al., 1992). Slowly digestible starches are important for treatment and prevention of some glucose dependent diseases. Elevated plasma glucose and insulin levels after a glucose load are associated with non-insulin dependent diabetes (Krapt and Nosal, 1975) and cardiovascular diseases (Elodin, 1986). Prolonged digestion and absorption of carbohydrates are favorable for the dietary management of metabolic disorders such as diabetes and hyperlipidemia (Asp, 1994; Wursch, 1994). In addition, starch plays an important role as a component of carbohydrate-based fat replacers, one of the strategies to manage influential disease of hypercholestromia. Stable starch-lipid composite can be prepared by co-jet cooking starch, lipid and water in excess steam.

Table 7. Functions of starch in foods.

Function	Application
Adhesion	Breaded products
Binding	Formed meat, extruded food
Clouding	Cream filling, drinks
Dusting	Bread, gum
Flowing aid	Baking powder
Antistaling	Bakery foods
Gelling	Gum drops
Glazing	Nuts
Moulding	Gum drops, candies
Shaping	Beverages, salad dressing
Thickening	Gravies, pie-fillings

Source: Ihekoroye and Ngoddy (1985).

The products are useful in preparation of ice- cream and chocolate chip cookies. Consequently, slowly digestible starch and dietary fibres are gaining recognition as a component in formulation of a functional cereal and meat products (Goff et al., 2001).

Pectic substances, cellulose, hemicellulose and lignin are the major components of the plant cell wall and collectively referred to part of what is called dietary fibre (Southgate, 1979). Pectic substances have important physiological and nutritional effects such as hypocholesterolemic effect, increased excretion of faecal sterols and lipids. Others are binding of bile salts and polyvalent cations.

Similarly, it is also now well established that the main physiological effects of dietary fiber are improved bowel function and improved carbohydrate and lipid metabolism (Kay and Truswell, 1977). Takahashi et al. (1999) indicated that dietary fiber was effective for counteracting obesity, diabetes, hyperlipidemia, colon disease and constipation. Burkitt (1973) and Trowell (1972) have also epidemiological demonstrated the benefit of consumption of dietary fibre-rich ration, as a management tool for controlling certain diseases associated with consumption of low fibre extraction rate foods.

Manufacture of starch sugar and chemicals

Starch sugar can be obtained from the action of dilute acid on starch. It is a very important raw material in brewing industry and spirituous liquors. Other sweetening agents that can be produced from starch include D-glucose and maltose. The sweetener is excellent because, the products are not associated with all the physiological abnormalities identified with consumption of cane sucrose. Therefore, the product is a delight in confectionery (Radley, 1976).

Heavy chemicals such as ethanol, butanol, acetone, glycerol and other organic chemicals notably acetic, citric, itaconic, gluconic and lactic acids can be produced from starchy materials using fermentation processes. Fermentation process utilizing starch based substrates can be used to produce complex organic chemicals that may not be easily synthesized through chemical pathways. Some of the organic chemicals include antibiotics, amino acids, vitamins notably riboflavin, cobamides, carotene and enzymes.

Biopolymer based packing materials

There is great interest in replacing synthetic (plastic) packaging materials with those made from biopolymers, since they are biodegradable. And of all biopolymers, starch has been the most favoured for application in production of the biodegradable packages (Bhatnagar and Hanna, 1996; Gennadios et al., 1978). Hanna et al. (2005) in their report stated that due to low cost, availability and total degradability of starch after usage, it is a well preferred candidate material for replacement of petroleum-derived synthetic polymers to decrease environmental pollution.

Added to this, production of edible film, a new development in packaging technology, uses starch as one of the components for its manufacture. Some of the desirable attributes of edible films are: renewable nature of their components, among which starch is chief. Its films have ability to function as carriers of food additives (e.g. flavourants, antioxidants) and as selection barrier to transport vapours and gases in living foods (George et al., 1995).

Starch derivatives can also be tailored for paper Industries. The derivatives can function as wet end additives, surface sizes, coatings and binders (Gebre-Mariam, 1996).

Vehicle for bio-active components

Starch has been used as a carrier of active components in drugs and fertilizer. The idea is that the active components can be released at the target over a period of time at a controlled rate (Chen and Jane, 1995). By this, the active agents released at a controlled rate provide a continual but constant concentration, consequently, exerting steady action during period of release. The advantage of this mechanism of therapy over that of traditional method of application is that loss of active agents by degradation, leaching, evaporation or surface-run-off are reduced (Boydston, 1992; Fleming et al., 1992).

Similarly, pesticides can be encapsulated within starch solid matrices with view to control rate of release, decomposition, leaching, ground water contamination, dermatoxicity and other uncertainties associated with application of therapeutic active agents (Carr et al., 1991; Shasha, 1980; Schreiber and Shasha, 1988).

Other non-food applications of value added starch

Specialty starch also finds utilization in oil-well drilling

Table 8. Expectations on enhancement of value of indigenous starch and adjuncts.

- Increment in generation of revenue / income to producers
- Creation of employment opportunities
- Development of import substitution products
- Enhancement of technological advancement / development
- Creation of market for auxiliary inputs
- Reduction and conversion of waste to utilities
- Motivation of primary producers (farmers)
- Food and raw-materials, security / self sufficiency
- Industrial growth and development.

muds, formulation of cosmetics notably hair dressings, wave sets and other hair treatments. Other uses are in production of plastics and resins, building materials such as wall boards and acoustic tiles. Value-added specialty starches are also effective raw materials in manufacture of soapy and soapless detergents. Treated starch conjugated to nitrates is prominent component of some explosives. Starch products also find application in photographic industry as coat for fibres and plates. Dialdehyde starch possesses certain characteristics which make them valuable as adhesive and binders. The starch is characterized with formation of water-resistant films with high binding capacity (Mehltretter and Roth, 1971).

The bonding characteristics of starch can be harnessed for manufacture of briquettes. One of the advantages of briquettes over petroleum products is that its burnt-products contain lesser pollutants such as dust, tar, carbon monoxide nitrogen monoxide, or hydrocarbon releases (Ludwig, 1995). In addition, briquetting may possess some cost-benefit in comparison to other fuel-petroleum products in Nigeria where the burden of subsidizing petroleum product is becoming unbearable and can no longer be tolerated. Other benefits derived from upstream and down stream processing of starch and spent products are presented in Table 8.

CONCLUSION

Considering the fact that starches have inexhaustible applications and that it is obtained from renewable raw materials is advantageous. As economics of starch is becoming more remunerative, expectation is on high note that more effort shall be concerted towards mechanized farming to boost yield of starch crops. The future is fertile for demand for starch and its derivatives. Nigeria and other tropical African countries are endowed with assorted agricultural starch rich crops that are under-utilized. Agronomical benefits of the crops can be enhanced by upstream and down stream processes to yield value added products for domestic and industrial applications.

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