Academia Journal of Food Research 1(1): 001-013, February 2013
DOI: http://dx.doi.org/10.15413/ajfr.2012.0105
ISSN: 2315-7763

Review

Recent development in cassava-based products research

Accepted 1th February, 2013

ABSTRACT

Cassava is a plant that has been processed into many products and there are still emerging new products from cassava. These products have fed millions of people and others have economic value. This has elicited interest in cassava-based products. This paper therefore reviews recent development in cassava-based product research. Biofuel production, starch production and industrial utilization of cassava starch are treated. Similarly, glucose production and animal feed from cassava are reviewed. The paper highlights, the production of high quality cassava flour (HQCF) and their derivatives as well as iodine supplementation and protein enrichment of cassava product. This research attention on cassava-based products, has high potential for industrialization.

Ukwuru MU* and Egbonu SE

Department of Food Science and Technology, Federal Polytechnic, Idah, PMB 1037, Idah, Kogi State, Nigeria.

*Corresponding author. E-mail: ukwuru@yahoo.com.

Key words: Recent development, cassava-based products, biofuels, starch production, high quality cassava flour.

INTRODUCTION

Cassava (*Manihot esculenta* crantz, also known as manioc or yucca) is one of the leading food and feed plants in the world: it ranks fourth among staple crops with a global production of about 160 milllion tons per year (Lawrence and Moore, 2005). Most of these are grown in three regions, West Africa, and the Congo basin, tropical South America, and South East Asia (Kawano, 2003), while in Western countries it is not commonly used, because of the presence of cyanoglucosides (linamarin and lotaustralin). A great number of recent studies have reported many biotechnological approaches to improve the safety and quality of cassava flour (Santana et al., 2002; Shittu et al., 2007; Onitilo et al., 2007), and the effect of different processing modalities of the tuberous roots on the level of these toxic substances and functional properties has been assessed (Cooke and Maduagwu, 1978; Nambisan and Sundaresan, 1985; Udensi et al., 2005).

Cassava is a staple food that provides carbohydrates or energy, for more than 2 billion people in the tropics. Cassava is a higher producer of carbohydrate per hectare than the main cereal crops and can be grown at a considerably lower cost. Cassava also grows at a suboptimal conditions; it is tolerant of soil infertility and drought stress and can be stored underground for several months after maturation (Onabolu, 1988; Vlavonou, 1988). The crop is amenable to agronomic as well as genetic improvement, has a high yield potential under good conditions and performs better than other crops under suboptimal conditions. The adoption of disease and pest resistant varieties released by the international institute of tropical Agriculture (IITA) has increased cassava production in many African countries (IITA, 1990; Bokanga and Otoo, 1991).

Nigeria currently is the largest producer of cassava in the whole world with an annual output of over 34 million tons of tuberous root and it plays a dominant role in the rural economy in the southern agro-ecological zone (Adeniji et al., 2001). As a food crop, cassava fits well into the farming system of the small holder farmers in Nigeria because it is available year round, thus providing household food security. Cassava tubers can be kept in the ground prior to harvesting up to two years but once harvested, they begin to

Table 1. Some advantages of biofuel produced from cassava starch.

It is not poisonous
It does not cause air pollution or any environmental hazard
It does not contribute to the green house effect problem (CO_2 addition to the atmosphere, causing global warming)
It has a higher octane rating than petrol as fuel. That is, ethanol is an octane booster and anti-knocking agent
It is an excellent raw material for synthetic chemicals.
Ethanol provides jobs and economic development to rural areas.
Ethanol reduces country's dependence on petroleum and it is a source of non – oil revenue for any producing country
Ethanol is capable of reducing the adverse foreign balance trade.

deteriorate. To forestall early deterioration and also due to its bulky nature, cassava is usually traded in their processed form. The bulky roots contain much moisture (60-65%), making their transportation from rural areas difficult and expensive. Processing the tuber into a dry form reduces the moisture content and converts into a more durable and stable product with less volume which makes it more transportable (IITA, 1990; Ugwu, 1996). Over the years cassava has been transformed into a number of product both for domestic use (depending on local customs and preference) and industrial uses. Cassava in the fresh form contains cyanide which is extremely toxic to humans and animals and therefore needs to be processed to reduce the cyanide content to safe level (Eggelston et al., 1992).

Traditional cassava processing method involve several steps including peeling, soaking, grinding, steeping in water and left in air to allow fermentation to occur, drying, milling, roasting, steaming, pounding and mixing in cold or hot water. Specific combination of these steps leads to a myriad of different cassava products with acceptable taste to wide range of consumers (Bokanga and Otoo, 1991). Cassava processing by traditional method is labour-intensive but the application of improved processing technology has reduced processing time, labour and encourage further production (Adeniji et al., 2001). In Nigeria, almost all the cassava produced is used for human consumption and less than 5% is used in the industry.

One of the greatest challenges of food processing in the developing countries is the transformation of traditional or indigenous processing method into modern industrial operations. Indigenous processing techniques for making traditional food product differ within and between countries because of differences in food culture, available raw materials, and processing equipment utilized. Many traditional methods of food processing and preservation in Africa require review and upgrading for industrial production (Falade and Akingbala, 2011).

Cassava roots comprise of the peel and bulky storage root with a heavy concentration of carbohydrate of about 80% and only 2-4% crude proteins on dry weight basis (Falade and Akingbala, 2011). Like other roots and tuber crops, cassava has a high water content (65%) which is probably the major limitation in improving the utilization potential. The chemical composition of cassava roots shows that it is a principal source of carbohydrates for the consumers. It is therefore imperative to convert cassava into more utilizable products. Effort in this regard is gradually developing. Hence this paper reviews recent developments on the utilization of cassava for home and industrial application.

Biofuels Prodution

Ethanol is generally produced by fermentation of sugar, cellulose, or converted starch and has long history (Sanchez and Cardona, 2008). In Nigeria, local production of ethanol from maize, guinea corn, millet, and other starch substrate, and cellulose is as old as the country itself (Taiwo, 2006). Apart from food and pharmaceutical uses of starch, ethanol is finding itself alternative use for biofuel in most of the developed world for several reasons (Kosugi et al., 2009) (Table 1).

Cassava is a good feed stock to produce ethanol because it has high starch content and it is abundant in the southern provinces of China (Leng et al., 2008). Cassava starch can be converted readily to ethyl alcohol in a two-stage process involving the hydrolysis of starch slurry into glucose by liquefaction so that dextrin and subsequently fermentable sugar can be obtained. The glucose solution is diluted and converted to ethyl alcohol by the anaerobic action of yeast, ethanol of 95.6% w/w comes out through dehydration which is concentrated to 99.5% w/w (Ramasamy and Paramasamy, 2001; Kosugi et al., 2009). Thus cassava-based fuel ethanol is produced and it is usually denatured by small volume of gasoline or other materials added preventing people from drinking it, (Leng et al., 2008). The ethanol produced is of high quality similar to cereal alcohol (Taiwo, 2006). The cassava chips can be used instead of the tuber in which case the chips are ground, cooked to release the starch etc (Ajibola, 1988). Saccharification can be accomplished either by hydrolytic process or the biological process. The hydrolytic process uses hydrochloric acid or sulphuric acid. Yields are low and continuous use of acid causes equipment corrosion and is dangerous to handlers. The biological process uses amylolytic enzymes, which can be obtained from barley malt and moulds that grow on rice or wheat bran. This process results in higher yields than the

Table 2. Major industries using modified cassava starch and its products in Nigeria.

Industry	State of the raw material utilization
Flour mill	major
Sugar	major
Brewery	major
Gin/spirit industry	major
Soft drink and carbonated water	minor
Bakeries	major
Pharmaceutical	minor
Textile mills	minor
Paper mills	minor

Source: Daramola and Falade (2006).

acid process (Sanni, 1991; Ceballos et al., 2008).

Starch production

Starch is one of the most abundant substance in nature, renewable and almost unlimited resources (Jenkins and Donald, 1995; Pandey et al., 2000). Starch is produced from grain and root crops. It is mainly used as food but it is also readily converted chemically, physically and biologically into many useful products to date (James and West, 1997; Matsui et al., 2004). Starch is used to produce such diverse product as food, paper textile, adhesives, beverages, confectionary, pharmaceuticals and building materials (Daramola and Osanyinlusi, 2005).

Cassava starch has many remarkable characteristics, including high paste viscosity, high paste clarity, and high freeze – thaw stability, which are advantageous to many industries (Gomes et al., 2005; Nzigamasabo and Ming, 2006; Zaidul et al., 2007). Cassava starch is produced primarily by wet milling of fresh cassava roots but in some countries such as Thailand, it is produced from dry cassava chips (Larotonda, 2002; Ceballos et al., 2006). Starch is the main constituent of cassava; about 25% starch may be obtained from mature, good quality tuber. About 60% starch may be obtained from dry cassava chips and about 10% dry pulp may be obtain per 100 kg of cassava roots. The development of both the food and non food uses of cassava starch has made much progress and continues to have a bright future (Abraham et al., 1984; Srirotha et al., 1999; Jyothi et al., 2007). Both old and important new product, such as modified starches, starch sugar, starch based plastics and fuel alcohol, have been reviewed briefly (Blennow, 2003). Table 2 indicates the extent of utilization of modified starch by industries in Nigeria.

Native starch

Native starches are produced through separation of naturally occurring starch from either grain or root crops such as cassava, maize and sweet potato, and can be used directly in producing certain foods such as noodles (Wang et al., 1993). The raw starches produced still retain the original structure and characteristics and are called “native starch” (Ene, 1992). Native starch is the basic starch product that is marketed in the dry powder form under different grades for food, and as pharmaceutical, human and industrial materials. Native starch has different functional properties depending on the crop source and specific types of starch are preferred for certain applications.

Native starches have limited usage, mainly in the food industry, because they lack certain desired functional properties. The native granules hydrate easily when heated in water. They swell and gelatinize, the viscosity increases to a peak value, followed by a rapid decrease, yielding weak boiled, stringy, and cohesive paste of poor stability and poor tolerance to the acidity with low resistance to shear pressure, as commonly employed in modern food processing (Balagopalan et al., 1988). However, food metallurgic, pharmaceutical, paper and cardboard, and textile industries among others use native starch in its traditional form.

Modified starch

For those characteristics which are maintainable with native starch, modified starch can be used for other industrial applications through a series of techniques, chemical, physical and enzymatic modification (Feuer, 1998). Thus, modified starch is native starch that has been changed in its physical and/or chemical properties. Modification may involve altering the form of granule or changing the shape and composition of the constituent amylose and amylopectin molecules. Modification is therefore carried on the native starch to confer it with properties needed for specific uses in many industries such as food, pharmaceutical, textile, petroleum and paper pulp

Table 3. Some of the positive attribute of modified starch.

To modify pasting attributes
To decrease the 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).

industries (Fringant et al., 1996; Curvelo et al., 2001). The reasons why native starch is modified include: modifying cooking characteristics (gelatinization); to reduce retrogradation and paste stability when cooled or frozen; to increase transparency and texture of pastes and gels; and to improve adhesiveness between different surfaces such as in paper applications (Table 3).

Utilization Of Cassava Starch In The Industries

Paper industry

The paper industry uses various types of starches for different purposes. Currently, the most common starches used for paper manufacture are from maize, potato and cassava. Cassava starch has very good properties that are highly desirable for the paper manufacturer. Cassava starch, as a dominant source of starch in Nigeria, posses a strong film, clear paste, good water holding properties, and stable viscosity (Srirotha, 1999). It should be the most suitable material for the paper industry in West Africa. In the paper and board industries, starch is used in large quantities at three points during the manufacturing process.

- At the end of wet treatment, when the basic cellulose fiber is beaten to the desired pulp to increase the strength of the finished paper and to impart body and resistance to scuffing and folding.
- At the size press, when the paper sheet or board has been formed and partially dried, starch generally oxidized (or modified) is usually added to one or both sides of the paper sheet or board to improve the finished product appearance, strength and printing properties.
- In the coating operation, when a pigment coating is required for paper, starch acts as coating agents and as adhesive.

Cassava starch has been widely used as tube size and a beater size in the manufacture of paper in the past mainly on account of its low price. A high colour (whiteness), low dirt and fiber content and above all, uniformity of lots are needed in this instance. An important new application of starch is in the machine coating magazine paper, formally done exclusively with caseins (Essers, 1994). There are indications that cassava is particularly well-suited to the purpose, however, definite specification for the starch still has worked out.

Textile industry

In the textile industry, the properties of the starch used are abrasion resistance, flexibility, ability to form a bond to the fiber, to penetrate the fiber bundle to some extent and to have enough water holding capacity so that the fiber itself does not rob the size of its hydration. Textile printing or the impression of the design on fabrics requires a carrier for the dyes and pigment and modified starches have found special uses in this application. Printing pastes are high viscosity of media that preferably will not change on ageing and will not resist the effect of added acids or alkalis as required by the colour agent. A sharp image is required and thus a short non stringy paste. Modified starches are frequently mixed with other industrial gums to give the required viscosity and paste characteristics (Balagopalan et al., 1988).

Adhesive industry

Starch is a popular base for adhesives, particularly those designed to bond paper in some form to itself or to other materials such as glass, mineral wool, and clay. Starch can also be used as a binder or adhesive for non paper substance such as charcoal in charcoal briquettes, minerals wool in ceiling tiles and ceramics before firing. The starches most commonly used for the manufacturing of adhesives are from maize, potato and cassava, (Graffham et al., 1998) of this, cassava starch appears more suitable in several respects.

Cassava starch adhesives are more viscous and smoother for working. They are fluid, stable glues of neutral pH that can be easily prepared and can be combined with many synthetic resin emulsions (Dziedzoave et al., 1999). For top quality work, cassava starch is thought to be ideal, because it is slightly stronger than potato starch adhesive while being odourless and tasteless, excellent as an adhesive for postage stamps, envelope flaps, and labels (Graffham et al., 1998). Certain potato pastes have bitter tasting properties while cereal starch exhibit a cereal flavour.

Satisfactory texture or slip properties may be achieved via cross-linking. Properties required include low shear resistance or “slip” permitting the paper to be aligned precisely without losing contact with the substrate, good open time (range of tack), and slow setting speed (Delcour et al., 2000). To meet these requirements, it is important that the starch should have little or no tendency to retrograde in the dried film. Using starches low in amylose can readily achieve this property and/or by subjecting the starch to retrogradation inhibiting treatment on base starches such as cassava, potato, or waxy cereal starches which are the preferred approaches.

Glucose Production (Monosodium Glutamate)

Cassava tubers processing for large scale production of starch result in solid and liquid waste (Balagopalan et al., 1987). The fibrous slurry constitute about 15-20% of the cassava chips/tuber processed, which contain about 50-70% starch on dry weight basis. The residue from cassava tubers are naturally rich in organic matters which render it suitable as a good substrate for microorganisms for the production of different product like organic acids, flavour and aroma compounds (Adriane-Medeiros et al., 2000; Pandey et al., 2000, Nair et al., 2011). In view of the high starch content, various starch-derived products like maltose, malto-dextrin, corn syrup solids, etc. can also be produced from cassava residues (Ghildyal and Lonsane, 1990; Pandey et al., 2000). Monosodium glutamate (MSG), the sodium salt of L-glutamic acid is a popular flavour enhancer and an additive for foods. It was used primarily in Asian foods but its use is now widespread (Jyothi et al., 2005). The product is used extremely in many parts of the continent in powder or crystal form as a flavouring agent in food such as meats, vegetables, sauces, and gravies. Cassava starch and molasses are the major raw materials used in the manufacture of monosodium glutamate in the Far East and the Latin American countries (Sanni et al., 2005). The starch is usually hydrolyzed into glucose by boiling with hydrochloric or sulphuric acid solution in closed converters under pressure. The glucose is filtered and converted into glutamic acid by bacterial fermentation. The resulting glutamic acid is refined, filtered and treated with caustic soda to produce monosodium glutamate, which is then centrifuged and dried in drum driers. The finished product is usually at least 99% pure (Sanni et al., 2005).

Animal Feed

During recent years, there has been a remarkable increase in livestock production in the third world. Because of this, the requirement for animal feed materials also is increasing. The spiraling price hike of cereals has necessitated the search for alternative source of energy for animals (Balagopalan et al., 1988). Being a cheap carbohydrate source capable of supplying adequate calories, cassava tubers offer great potentials as an animal feed. Cassava is widely used in most tropical areas in feeding pigs, cattle, sheep and poultry. Dried peel of cassava roots are fed to the sheep and goats, and raw or boiled root are mixed into a mash with protein concentrate such as maize, sorghum, groundnut or oil palm kernel meal and mineral salts for livestock feeding (Onuma et al., 1983).

Cassava is similar to feed grain as it consist almost entirely of starch and its easy to digest. The roots are, therefore especially suited to feeding young animals and fattening pigs. Many feeding experiments have shown that cassava provide a good quality carbohydrate, which may be substituted for maize or barley and that cassava rations are especially suitable for swine, diary cattle and poultry (Nzigamasabo and Ming, 2006). However cassava cannot be used as a sole feedstuff because of its deficiency in protein and vitamins, but must be supplemented by other feeds that are rich in these elements (Ajibola, 1988; Charles et al., 2004).The maximum cyanide content that can be ingested safely depends not only on the cyanide content of the dried cassava chips but also on the level of inclusion of the cassava meal in animals diet and the age of the animal (Taiwo, 2006). The composition of the compound animal feed varies according to the animal (cattle, pigs and poultry) as well as the kind of production (diary meat or egg). There are many constituent that could be used to supply the main element in the compound feed, such as starch, protein, fat, mineral and vitamins. Cassava can be incorporated in practical ration at levels of 20-30% for broiler (0-8 weeks) and 30-40% for growing pigs weaning to market weight, (Gomez and Valdivieso, 1984). The amount of cassava used in animal feed production have not been estimated but with the Nigeria Federal Government regulation on local sourcing and the need to use cheaper energy sources, the inclusion of cassava in animal feed formulation becomes urgent (Taiwo, 2006).

Proper formulation of the diet is equally important to make the feed nutritionally balanced, since animal performance is highly dependent on it. Cassava leaf meal is a highly nutritious protein-rich ingredient that offers a vast scope for inclusion in root meal diets. However the leaves have to be properly detoxified by drying prior to its inclusion in compound feeds. Cassava leaves have been found to contribute substantially to the energy requirement of poultry, swine and ruminants (Balagopalan, 2002).

Cassava Flour (High Quality Cassava Flour)

High quality cassava flour (HQCF) is simply unfermented cassava flour. The IITA production process minimize the capital investment requirement for flour production by making use of simple equipment already used for garri processing (Onabolu, 1988). This technique is suitable for preparing cassava flour from both sweet and bitter varieties. Mini chippers are also tried in place of the mechanical grater but is found to be unsuitable for bitter varieties because of the concentration of cyanogenic glycosides which is not reduced sufficiently during processing (Abass et al., 1998; Onabolu and Bokanga, 1998).

Table 4. Level of inclusion and the benefits of use of cassava flour in specific product made by home caterers, bakers and industrial users.

Cassava product	User	Level of inclusion of high quality cassava flour in the product (%)
Bread	Bread bakers	5-25
Biscuits	Biscuit factory	10-50
Noodles	Pasta factory	10
Cake	Caterers	5-100
Maize semovita	Restaurant	18.0
Chips	Confectionery	not specified
Pies	Caterer	10-100
Cookies	Caterer	10-100
Chin-chin	Caterer	25-100
Flakes	Confectionery	not specified

HQCF is made within a day of harvesting the root. It is very white, has a low fat content; not sour like the traditional fermented cassava flour, does not give a bad smell or taste to food product and can be mixed very well with wheat floor for use in bread or cake (IITA, 2005). The most promising market to develop is HQCF and its use as a replacement for wheat flour in the bakery sector, in plywood manufacture and also as an alternative or component in traditional cassava product e.g. instant *fufu* in Ghana, fermented *fufu* in Nigeria (Adebayo et al., 2010). The main reason for focusing on HQCF are that value can be added at the rural household level by processing of the intermediate product (cassava grits or waste paste), thereby increasing income for farmers, the requirement for the capital investment is lower and less environmental damage is caused than starch manufacture; and many farmers already know how to create the basic raw materials for HQCF (grated cassava). Therefore, a huge technology leap at the farmer level is not required to attain the development objectives (Adebayo et al., 2003; Adebayo et al., 2010). Consequently, HQCF offers the easiest entry point, benefits the most small holder farmer/processor in the immediate and provides a spring board for investment in other product.

Drying has been identified as the major tool for expanding the processing of cassava into HQCF. Various options have been considered so far in cassava project at IITA (IITA, 2005). Local processors expose cassava mash on polythene sheet directly to the sun. This is referred to as "sun drying". The project observed that drying in rural or domestic levels cannot be done artificially because of the high capital investment in equipment and energy required and hence, natural sun drying is done. Sun drying is beset by several inherent draw backs, such as susceptibility to damage due to inclement weather, slow drying rates and contamination. In view of these limitations, the high cost and low utilization of more efficient traditional dryers, the adoption of a modified sun drying process, solar drying have been considered for drying HQCF in rural areas (IITA, 2005; Sanni et al., 2009).

Using the IITA process, peeled roots are washed and grated. The grated mash is subsequently pulverized into particulates and then sun-dried or mechanically dehydrated using solar, cabinet, rotary or flash driers. The dried material is then finely milled into flour, sieved and packaged into moisture proof high density polythene bags and sealed (Abass, 1993; Onabolu et al., 1998). Table 4 indicates the usage of flours.

Cassava chips

Chipping (using a modified IITA mini chipper) is found to be the best option for processing cassava roots with low cyanogens. This option proved to be cheaper, less labour intensive, resulted in lower microbial load and less loss of starch when compared to grating (Graffham et al., 1999).

Tapioca grit is a partially gelatinize dried cassava starch, which appears as flakes or irregular shaped granule. It is consumed in many parts of West Africa and widely accepted as a convenient diet (Raji et al., 2008). It is the cheapest form of storable cassava. They are typically popular in transitional and savannah areas where sun drying is relatively easier than forest zones. Peeled chips are often slightly molded or fermented to a certain degree, according to climatic conditions, local taste, and consumption habit. They are milled or pounded into (fermented) flour that does not comply with standards for replacing wheat.

The fermentation alters the sensory characteristics of the roots in a way that is often appreciated by local consumers. The process is mainly manual and offers some potential for mechanization for short and medium term in dry areas or seasons. The reduction of chip size by a slicer or shredder can speed up drying, thereby avoiding fermentation and moldiness and after milling, chips can be turned into flour. The faster drying of intact cassava pieces means that this accelerated process should be applied only for non consumable product, e.g. as a glue – extender in the plywood industry (Sanni et al., 2009). High quality chips and flour could be prepared under rural condition at lower cost when compared to centralize processing. However, conversion of chips into flour in lager quantities would be a bottle neck for rural processors. A better option would be to transport the dry chips from rural areas to a centralize processor for conversion into flour (Graffham et al., 1999).

Cassava bread

Bread and other bakery products like doughnuts, pies, cakes, etc, have become important item in the diet of many people living in towns and cities. The major raw material used in this bakery product is wheat flour, which has become increasingly expensive because it is imported.

The use of cassava flour as a raw material for the bakery and pastry industries is fast growing and gaining recognition as reliable partial substitute for wheat (Balagopalan et al., 1988; Day et al., 1996; Adebayo et al., 2010). Using high quality cassava flour particularly is suitable since it has no fat content which is important for storage life. Other possible advantages include its bland taste offering no foreign odour or flavour. It is impossible to increase the level of non wheat flour considerably without great change in the bread characteristics, provided certain bread improvers as calcium stearyl lactylate is added or relatively high percentage of fat and sugar is used (Ajibola, 1988; Taiwo, 2006). Mechanical leavening rather than bulk fermentation for the ripening of the dough and a blend of 60% wheat flour, 30% cassava starch, and 10% soybean flour, produced a bread of good quality almost equal to the normal wheat flour bread in volume, appearance and eaten quality (Taiwo et al., 2002).

In spite of the considerable research on bread making and the use of composite flour, there has been little impact in commercial practice except where government control the importation of wheat in Nigeria in the year 2002 to 2008 (Adebayo et al., 2010). Different wheat flours have been diluted with various proportions of cassava starch and flour (Shittu et al., 2007, Shittu et al., 2008). Defloor et al. (1993), Defloor et al. (1994, 1995), Khalil et al. (2000), specifically reported that inclusion of cassava flour into wheat flour up to about 30% could still give an acceptable fresh loaf depending on the source of the flour. Bread containing 20% fresh minced cassava showed higher sensory evaluation rating (Crabtree et al., 1978). Federal Institute of Industrial Research Oshodi (FIIRO) Nigeria, has developed cassava bread with 20% high quality cassava flour substituted with 80% wheat flour, which gives similar characteristics of bread produced with 100% wheat flour both in sensory and nutritional properties. This technique has the advantage of eliminating the need for energy consuming drying stage and should be of special interest to bakeries in rural areas of the developing world where fresh cassava is readily available. If cassava is to be processed to dry flour before incorporation into bread, low temperature drying at 50°C is recommended to ensure that the flour is light in colour. The use of composite flour will enable the developing countries to save some scarce foreign exchange expanded on importing flour (Ogunsua, 1989).

Cassava pies

The International Institute for Tropical Agriculture (IITA) has been promoting the production of high quality cassava flour (HQCF) which is used increasingly as substitute for wheat flour in meat or fish pies (12.5%); bread-making (5-20%); and other cassava food products (Abass *et al*., 1998). These newer uses of cassava are generating more income for local cassava processors. Akinlonu (2011) investigated the nutritional quality and sensory properties of some products from fresh cassava roots and high quality cassava flour (HQCF) from which cassava meat pies and cassava sausage roll were produced. Proximate, mineral and cyanide composition of all the products were determined using standard analytical procedures. The proximate composition showed that there was no significant difference (P>0.05) in the moisture content of HQCF products and the cassava flour. HQCF products with the highest protein were meat pie (7.68%) and also had the highest iron content (4.89 mg/100 g). The cyanide composition of all the products was between 0.95-4.09 mg/100 g which is lower than the acceptable limit by codex standard of 10 mg/kg for HQCF and 50 mg/kg of fresh cassava root. Sensory acceptance scores showed that all the products were generally acceptable (Akinlonu, 2011). Oyewole (2002) and Akinlonu (2011) reported that HQCF could be used to produce safe, nutritious and acceptable food products, and also recommended that the products should be further enriched in order to meet the nutritional requirements of people of different age groups and also to be used for nutrition intervention programmes.

Cassava cookies

Cookies are flat, dry, and sweet biscuits. Research into the use of tropical crops has shown that cookies could be made from flours of locally available crops such as sweet potato, cassava, corn, millet, sorghum etc (IITA, 1985; Falade and Akingbala, 2008). Cookies are convenient food product dried to very low moisture content, taken among young people and adult to provide energy (Okaka and Potter, 1997). It is produced from a mixture of flour and water which may contain fat, sugar and other ingredients mixed together into dough which is rested for a period and passed between rollers to make a sheet (Drake et al., 1989). It provides an excellent means of improving the nutritional quality of foods through incorporation of less expensive high quality protein, mineral, vitamins and has been employed in food product enrichment (Okafor et al., 2002). The consumption of cookies is steady and increasing in Nigeria. It is however relatively expensive, being made from imported wheat that is not cultivated in the tropics for climatic reasons (Falola et al., 2011). Wheat importation represents an immense drain on the economy while also suppressing and displacing indigenous crops, with a resultant detrimental effect on agricultural and technological development. The need for strategic development and use of inexpensive local resources in the production of popular foods such as cookies has been recognized by organizations such as the Food and Agricultural Organization (FAO), the International Institute for Tropical Agriculture (IITA), Nigeria and the Federal Institute for Industrial Research Oshodi (FIIRO), Nigeria (Falola et al., 2011). Research at IITA has shown that cassava flour (100%) can be used to prepare bakery products such as cookies and doughnuts (Onabolu and Bokanga, 1998). The resulting products are readily available and sold in Nigeria, thus helping to improve food and livelihood security.

Cassava biscuits

Cassava flour proved effective as a partial substitute for imported wheat flour in biscuits. High quality cassava flour can substitute for up to 30% of wheat flour in sweet dough biscuit and 40% in hard dough biscuit, without consumers being able to detect any adverse change in colour, taste or texture when compared to 100% wheat flour control (Abass et al., 1998; Oyewole, 2002). At higher levels (>40%) of substitution the flour texture was found to be too light. These could be overcome with additional margarine, but this caused an unacceptable increase in production cost (Graffham et al., 1999). Consumers found biscuit containing >40% cassava flour to be less crispy, bland in flavour and susceptible to crumbling. Biscuits containing a minimum of 40% cassava flour had very low microbial counts and cyanogens levels that are below the limits of detection after baking.

Cassava flakes

Cassava flakes also known as tapioca grit is a partially gelatinized dried cassava starch which appears as irregularly shaped flakes (Adebowale et al., 2008). It is consumed in most part of West Africa and widely accepted as a convenient diet (Cheeke, 1995; Mac-Mahon et al., 1995). In the traditional method, the moist starch flour is roasted over an open firewood flame in a large, shallow stainless steel pan for 20 min at temperature range of 120 – 150°C with constant stirring using a piece of stainless steel plate. Vegetable oil is used to rub the pan before roasting to prevent stickiness and burning (Adebowale et al., 2006). The roasted tapioca appears as irregular lumps called flakes or perfectly round beads (Sanni et al., 2009). The processing steps are very labour-demanding and make the product quite expensive. The sorption characteristics tapioca produced using the rotary dryer are different from the traditional roasting method, but the sorption characteristic of the tapioca grits produced using the rotary dryer roasting method are significantly dependent on the cassava variety (Adebowale et al., 2006). Such information could be useful for process development and optimization, drying time prediction, packaging production and modeling moisture changes, which occur during storage and predicting shelf life stability of tapioca.

Cassava noodles

Among the popular cassava products in Nigeria such as *gari*, *fufu* and *lafun*, cassava flour is the easiest and cheapest to make, and the highest income generator (Abass et al., 1998). The use of cassava flour in food rations has clear advantages. The inclusion of cassava in composite flour for the production of fast food would reduce cost and enhance the production of noodles, breakfast cereals, and pastries among others (Falade and Akingbala, 2009). Apart from the industries, bakers, caterers and individuals also produce and purchase cassava flour for home use for the preparation of chin-chin, pie (meat and fish), buns and cake among others (Falade and Akingbala, 2008). Inclusions of cassava flour at 10% in wheat flour have been used for producing acceptable noodles.

Cassava cakes

Several kinds of traditional food which are usually prepared from wheat flour, rice flour or maize starch are made using cassava flour as a partial or total substitute for these ingredients. The basic procedure for cake preparation is mixing of sugar, egg and a leavening agent. Composite flour and melted margarine are then added and mixed thoroughly into dough. The dough is poured into a pan already swiped with margarine and coated with wheat flour, then baked for approximately 30 min. Acceptable cake can be made from varying replacement of wheat flour with cassava flour. There are many flavours of cake such as coconut cake, palm sugar, pineapple etc (Table 5).

Iodine Supplemented Cassava Product

Iodine is an essential trace element of great importance in human nutrition. The element is an integral part of the thyroid hormones (Dunn and Dunn, 2001). Iodine deficiency due to iodine decrease or loss during processing

Table 5. Summary of Recent developed Industrial cassava-based products and their applications.

Cassava-based products	Industrial applications
Biofuel (ethanol)	Distilleries
Starch	Paper, Textile, Adhesives, Breweries, Pharmaceutical Industries
Glucose	Sugar Industry
Animal feed	Feed Industry
HQCF products (chips, bread, noodles, biscuits etc.)	Confectionery, Caterers, Flour mills, Pasta Industries

Table 6. Iodine and moisture content of cassava and its products.

Cassava and its product	Moisture content (g%)	Iodine content (µg/100g dry matter)
Fresh cassava tuber(edible portion)	58.25±1.18[a]	592.50±8.22
Cassava flour (*lafun*)	14.15±0.22 [b]	216.90±1.23
Cassava meal (*Gari*)	18.32±0.38 [c]	366.03±3.82

Values in the same column with the same superscript are not significantly different from each others. Source: Salau et al., 2010.

or cooking is still a major public health problem in several areas of the world, especially in developing countries (Wisnu, 2008; Ozedemir et al., 2009).

The absorption and/or utilization of iodine are inhibited by components of certain foods, these food component called goitrogenic compounds are found primarily in cruciferous vegetables (e.g. cabbage and broccoli), soy-beans product, cassava roots, peanuts, mustard and millet. Over consumption of these food may lead to thyroid problems by reducing the amount of available iodine for the manufacture of thyroids hormones (Kontras et al., 2002; Soetan, 2008). It is believed that cooking can inactivate the goitrogenic compounds in these foods, thereby eliminating their negative impact on iodine status (Kontras et al., 2002). Salau et al. (2010) reports that the result of moisture and iodine content of cassava and its products shows that the two processed products (Cassava flour and cassava meal) were significantly lower ($p<0.05$) in iodine content when compared with the raw edible portion (Table 6). The least reduction in iodine content was observed in *gari* (38.22%) while *lafun* had the highest reduction (63.39%).

Protein Enriched Cassava Product

Gari (fried fermented cassava flour), is the most popular cassava product consumed in West Africa and the most important food products in the diet of millions of Ghanaians and Nigerians (Kordylas, 1990; Oduro et al., 2000; Edem et al., 2001). It forms a significant part of the diet in many countries such as Cameroon, Sierra Leone, Zaire and Brazil where it is called *Farinhade moniaca* (Lancaster et al., 1982). Although cassava is high in linamarin (Vasconcelos et al., 1990), about 83% of the total cyanogenic glucosides (Linamarin and Lotaustralin) are detoxified during the processing of tuber into *gari* and 98% of the cyanide is lost when it is cooked into *eba* (Mahungwu et al., 1987). However, cassava and its products are low in protein and deficient in essential amino acids, and therefore have low protein quality, with a protein content of between 3.6 and 4.4% dry weight (Oboh and Akindahunsi, 2003). Thus, continuous dependence on *gari* without supplementation with meat, fish and/or other protein-rich sources would result in protein deficiency (Agbon et al., 2010). However, because of the high cost of animal proteins, majority of the population cannot afford such fortification for *gari*, hence the need to search for cheaper and good quality protein sources that are readily available for the fortification of *gari*. Soybean, a protein rich legume with essential amino acid profile, is potentially the most useful protein source for complementing and enhancing the nutritional value of *Gari*.

Soybean (*Glycine max* Merr), an inexpensive protein source, is readily available in many countries where starchy tubers are consumed in large quantities. In comparison with most other legumes, soybean is much higher in protein 38.9% -41.8% (Nagata et al., 1998; Kumar et al., 2006; Redondo-Cuenca et al., 2006). Soy protein is reported to lower cholesterol level in the blood (Nagata et al., 1998; Henkel, 2000), and its amino acid content is considered key in its ability to control blood pressure, and this appears to be related to calcium conservation (Dadson and Noureldin, 2001). Supplementation of soy proteins to *gari* is therefore

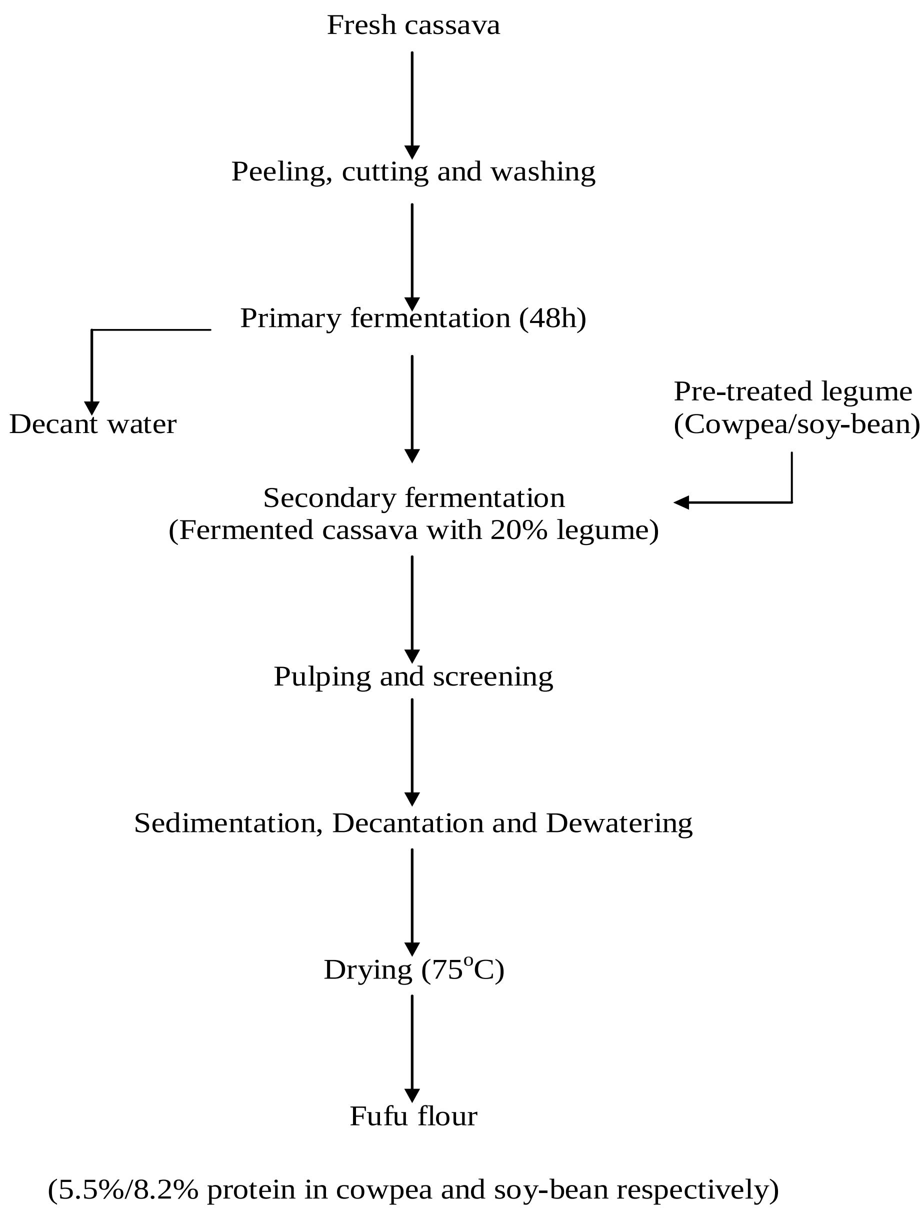

Figure 1. Scheme for the co-fermentation of cassava with legumes to produce enriched *fufu*, (Oyewole and Aibor, 1992).

expected to enhance its protein quantity and quality as well as improve its health promoting benefits. However acceptability of *gari* depends on the final texture and sensory attributes after processing and these vary based on the extent of souring/acidification during fermentation and the starch behaviour during heat processing.

Afoakwa et al. (2010) reports that fortification of cassava dough with 20% soy-beans caused only minimal and insignificant variation in the acid generation relative to the unfortified cassava *fufu* after 48 h of fermentation. Increasing the soy concentration to 30% cause significant increase in acid production, with consequential significant reduction in starch content which would have negatively affected the flavour, colour and texture of the product. Starch pasting characteristics is also affected by the soy fortification but the effect is insignificant at the 20% soy fortification level. These suggest that cassava dough could be effectively co-fermented for 48 h with soybean up to 20% concentration without significant effect on acid production and starch pasting characteristics of resulting product (Afoakwa et al., 2010). This would improve the nutritional quality of the product without affecting the process development and/or product quality characteristics.

Agbon et al. (2010) also reported that cassava-cowpea *fufu* which underwent 48 h of fermentation had better sensory rating than cassava *fufu*, and with development of newly cassava-cowpea *fufu* (Figure 1), it will provide viable alternatives for dwellers in various developing countries of Africa including Nigeria, who consume fermented cassava *fufu* during the three meals of the day. *Fufu* from cassava-cowpea mixtures contain higher amount of protein and micronutrients than the commonly consumed cassava *fufu*.

CONCLUSION

Cassava has the potential to be processed into different products. Production of biofuel through fermentation has been identified as a source of economic wealth. Native and modified starches are used for various purposes in the industry such as paper, textile and adhesive industries. Monosodium glutamate and animal feeds can be obtained from cassava. There is currently high focus on cassava flour (HQCF) and derivatives such as cassava chip, cassava bread, cassava pies, cassava cookies, cassava biscuits, cassava flakes, cassava noodles and cassava cakes may be obtained. Iodine supplementation and protein enrichment of cassava products are been evaluated. Cassava is a rich source of many products.

REFERENCES:

Abass AB, Onabolu AO, Bokanga M (1998). Impact of the high quality cassava flour technology in Nigeria. In: root crops in the 21st century. Compiled by Akoroda, M.O. & Ngeve, J.M. Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root

Crops-Africa Branch (ISTRC-AB). Centre International des Conferences, Cotonou, Benin, 11-17 October, 1998.

Abraham TE, Raja KCM, Manoharan EP, Mathew AG (1984). Effect of heat-moisture treatment on textural characteristics of cassava flour. Cereal Chem. 60:7-8.

Adebayo K, White JL, Morris MJ, Dipeolu AO, Ayinde IA, Wandschneider TS, Sanni LO, Oyewole OB, Tomlins K. Westby A. (2003). Innovativeness and stakeholdership in the fufu processing systems in southwest Nigeria. Agriculture, Soc. Science, Environ. Technol. Series A 3(4):15-27.

Adebayo K, Abayomi L, Abass A, Dziedzoave NT, Forsythe L, Hillocks RJ, Gensi R, Gibson RW, Graffham AJ, Ilona P, Kleih UK, Lamboll RI, Mahende G, Martin AM, Onumah GE, Orr AW, Posthumus H. Sanni LO. Sandifolo V. Westby A (2010). Sustainable Inclusion of Smallholders in the Emerging High Quality Cassava Flour Value Chains in Africa: Challenges for Agricultural Extension Services. J. Agric. Ext. 14(1):1-10.

Adebowale AA, Sanni LO, Kuye A (2006). Effect of roasting methods on sorption isotherm of tapioca grits. Electron. J. Environ. Agric. Food Chem. 5(6):1649-653.

Adebowale AA, Sanni LO, Onitilo MO (2008). Chemical composition and pasting properties of tapioca grits from different cassava varieties and roasting methods. Afr. J. Food Sci. (2):77-82.

Adeniji AA, Ega LA, Akoroda MO, Ugwu BO, Balogun A (2001). Global strategy for cassava development. Nigeria: A country case study.

Department of Agriculture, Federal Ministry of Agriculture and Natural Resources. AvailableDevelopments of new techniques for gari production: www.globalcassavastrategy.net/Africa/nigeria/n0000e05.htm.

Adriane-Medeiros BP, Carlos ES, Pandey A (2000). Aroma production by *Kluyveromyces marxianus* in solid state fermentation. In: Paper presented at ISOTUC III: international symposium on tropical root and tuber crops.

Afoakwa EO, Kongor EJ, Annor GA, Adjonu R (2010). Acidification and starch behaviour during co-fermentation of cassava (Manihot esculenta Crantz) and soybean (Glycine max Merr) into gari, an African fermented food. Int J Food Sci Nutri, 61(5):449-462.

Agbon AC, Ngozi EO, Onabanjo OO (2010). Production and Nutrient Composition of Fufu Made From a Mixture of Cassava and Cowpea Flours. J. Culinary Sci. Technol. 8(2-3):147-157.

Ajibola OO (1988). New technique in cassava processing. A paper presented at a seminar held at Federal Institute of Industrial Research Oshodi Nigeria, 10th-13th April.

Akinlonu EO (2011). Nutritional and sensory qualities of novel dishes from cassava. A Dissertation submitted to the Department of Nutrition and Dietetics, College of Food Science and Human Ecology, University of Agriculture, Abeokuta.

Balagopalan C, Padmaja G, Nanda SK, Moorthy SN (1988). Cassava nutrition and toxicity. Hillocks RJ, Trsh JM. Belloti AC.ed. In: *Cassava in Food, Feed and Industry*. Boca Raton, FL: CRC Press. pp. 13-36.

Balagopalan C, Padmaja G, Nanda SK, Moorthy SN (1987). Cassava based industries. In: cassava in food, feed industry. Boca Raton, Florida: CRC Press Inc. 169-172.

Balagopalan C (2002). Cassava utilization in food, feed and Industry. R J., Hillocks, JM., Tresh, and A C., Belloti, eds. Cassava, biology, production and utilization. Cali, Colombia: CIAT pp. 301-318.

Blennow A (2003). Towards predictable functionalization of starch. Starch, 50: 58-64.

Bokanga M, Otoo E (1991). Cassava based foods: how safe are they? In: F Ofori & S. K, Hahn Ed. Tropical root crops in a developing economy Proceedings of the 9th Symposium of the International Society for Tropical Root Crops. Accra, Ghana pp. 225-232.

Charles AL, Chang YH, Ko WC, Sriroth K, Huang TC (2004). Some physical and chemical properties of starch isolates of cassava genotypes. Starch/Starke 56:413-418.

Ceballos H, Sanchez T, Morante N, Fregene M, Dufour D, Smith A, Denyer K, Perez J, Calle F, Mestres C. (2006). Discovery of an Amylose-free Starch Mutant in Cassava. (*Manihot esculenta* Crantz. J. Agric. Food Chem. 55(18):7469 -7476.

Ceballos H, Fahrney K, Howeler R, Ospina B (2008). Cassava Potential for Bioethanol. Symposium-Biofuels in Developing Countries: Opportunities and Risks pp. 625-628.

Cheeke PR (1995). Alimentación y nutrición del conejo. Acribia: Zaragoza.

Cooke RD, Maduagwu EN (1978). The effects of simple processing on the cyanide content of cassava chips. Journal of Food Technology, 13: 299-306.

Crabtree J, Kramer EC, Baldry J (1978). The bread making potential of products of cassava as partial replacements for wheat flour. J. Food Technol. 13:397-407.

Curvelo AA, De Carvalho AJF, Agnelli JAM (2001). Thermoplastic starch-cellulosic fibers composites: preliminary results. Carbohydr. Polym. Bark. 45:183-188.

Dadson RB, Noureldin NA (2001). Soybeans in Egypt: Research, production, economics, nutrition and health. Bethesda: University Press of Maryland pp 143-169.

Daramola B, Folade KO (2006). Enhancement of agronomic values: upstream and downstream opportunities for starch and starch adjuncts. Afr. J. Biotechnol. 5(5):2488-2494.

Daramola B, Osanyinlusi SA (2005). Production, characterization and application of banana (Musa spp.) flour in whole maize. African J. Biotechnol. 5(10):992-995.

Day G, Graffham,JA, Amoako M (1996). Market potential for cassava based flours and starches in Ghana, NRI Report. Natural Resources Institute, Chatham United Kingdom.

Defloor I, Nys M, Delcour JA (1993). Wheat starch, cassava starch, and cassava flour impairment of the bread making potential of wheat flour.

Cereal Chem. 78:525-530.

Defloor I, De Geest C, Schellekens M, Martens A, Delcour JA (1994). Impact of genotype and crop age on the bread making and physiochemical properties of flour produced from cassava (*Manihot esculenta Crantz*) planted in the dry season. J. Sci. Food Agric. 66:193-202.

Defloor I, Leijskens R, Bokanga M, Delcour JA (1995). Impact of genotype, crop age and planting season on the breadmaking and gelatinization properties of flour produced from cassava (*Manihot esculenta Crantz*). J. Sci. Food Agric. *68*:167-174.

Delcour JA, Vansteelandt J, Hythier MC, Abe'cassis J (2000). Fractionation and reconstitution experiments provide insight into the role of starch gelatinization and pasting properties in pasta quality. J. Agric. Food

Chem. 48(9):3769-3773.
Drake DL, Gephardt SE, Matthew RH (1989). Composition of food: cereal grains and paster. Lake publishers England 14:20.
Dunn JT, Dunn AD (2001). Update on intrathyroidal iodine metabolism. Thyroid 11: 407-414.
Dziedzoave NT, Osei-Yaw A, Mensah BA, Degraft-Yartey JW, Gyato C (1999). Project R6504. Expanded markets for locally produced cassava flours and starches in Ghana. Final Report of the FRI/NRI Cassava Flour Project, Food Research Institute Report, Food Research Institute, Accra, Ghana. p. 47.
Edem DO, Ayatse JOI and Itam EH (2001). Effect of soy protein supplementation on the nutritive value of 'gari' (farina) from Manihot esculenta. Food Chem. 75:57-62.
Eggleston G, Onwaka PE, Ihedioha OD (1992). Development and evaluation of products from cassava flour as a new alternative to wheat bread. J. Sci. Food Agric. 59:377-385.
Ene LSO (1992). Prospects for processing and utilization of root and tuber crops in Africa. Proceedings 4th Triennial Symposium, International Society for Tropical Root Crops-Africa Branch Kinshasa, Zaire, December 5–8, 1989. pp. 23-32).
Essers AJ (1994). Making safe flour from bitter cassava by indigenous solid substrate fermentation. Acta Hortic. 375:217-224.
Falade KO, Akingbala JO (2008). Improved Nutrition and National Development hrough the Utilization of Cassava in Baked Foods. International Union of Food Sci. Technol. 1-12.
Falade KO, Akingbala JO (2011). Utilization of cassava for food. Food Rev. Internat. 27:51-83.
Falola AO, Olatidoye OP, Balogun IO, Opeifa AO (2011). Quality characteristics of cookies produced from composite flours of cassava and cucurbita mixta seed. J. Agric. Vet. Sci. 3:1-12.
Feuer BI (1998). Methods of making starch acetate using an acid catalyst. USA Patent no. 5, 710, 269.
Fringant C, Desvrieres J, Rinaudo M (1996). Physical properties of acetylated starch-based materials: relation with their molecular characteristics. Polymer, 37(13):2663-2673.
Ghildyal NP, Lonsane BK (1990). Utilization of cassava fibrous residue for
the manufacture of value added products: an economic alternative to waste treatment. Process Biochem, 3:5-9.
Gomes G, Valdivieso M (1984). Effects of sun drying on a concrete floor and ovendrying on trays on the elimination of cyanide from cassava whole root chips. J. Food Technol. 19:703-710.
Gomes A, Mendes da Silva C, Ricardo N (2005). Effects of annealing on the physicochemical properties of fermented cassava starch (polvilho azedo). Carbohydr. Polym. 60:1-6.
Graffham AJ, Ababio JT, Dziedzoave N, Day G, Andah A, Budu A, Ayernor GS, Gallat S, Westby A. (1998). Market potential for cassava flours and starches in Africa. J. trop. Agric. (Trinidad) 75:267-270.
Graffham AJ, Dziedzoave N T, Ayernor, GS (1999). Crop Post Harvest Programme, Expanded markets for locally produced cassava flours and starches in Ghana. Final Technical Report, 1 January 1996 - 31 March 1999.
Henkel J (2000). Soy: Health claims for soy protein, questions about other components. FDA Consumer. Available online at: www.cfsan.fda.gov; accessed July 21, 2007.
IITA (1985). IITA research brief 6(3):8.
IITA (1985). Common African pests and diseases of cassava, yam, sweet potato and cocoyam. Int. Instit. Trop. Agric. Ibadan, pp. 30-36.
IITA (2005). Pre-emptive management of the virulent cassava mosaic disease in Nigeria. Annual report, July 2003-June, 2004. International Institute of Tropical Agriculture, Ibadan, Nigeria.
IITA (1990). Cassava in tropical Africa-A reference manual. Ibadan, Nigeria: International Institute of Tropical Agriculture.
James N, West L. (1997). Starch modification: challenges and prospects. Starch/ Starke 49(2):127-131.
Jenkins PJ, Donald AM (1995). The influence of amylase on starch granule structure. Int. J. Biol. Macromol., 17 (6): 315- 321
Jyothi AN, Sasikiran K, Nambisan B, Balagopalan C (2005). Optimization of glutamic acid production from cassava starch factory residues using *Brevibacterium divaricatum*. Process Bioch. 40:3576-3579.
Jyothi AN, Kiran KS, Wilson B, Moorthy SN, Nambisan B (2007). Wet Storage of Cassava Starch: Use of Sodium Metabisulphite and Acetic Acid and the Effect on Starch Properties. Starch/Stärke 59:141-148.
Kawano K (2003). Thirty years of cassava breeding for productivity – Biological and social factors for success. Crop Science, 43: 1325-1335.
Kontras DA, Matovinovic J, Vought R. (2002). The ecology of iodine In: Stanbury; J. B Hetzel BS (eds). Endemic goiter and endemic cretinism. New York John Wiley publisher pp.185-195.
Khalil AH, Mansour EH, Dawood FM (2000). Influence of malt on rheological and baking properties of wheat-cassava composite flours. Lebensmittel Wissenchaf Technol. 33:159-164.
Kordylas JM (1990). Processing and preservation of tropical and subtropical foods. London: Macmillan.
Kosugi A, Kondo A, Ueda M, Murata Y, Vaithanomsat P, Thanapase W, Arai T, Mori Y (2009). Production of ethanol from cassava pulp via fermentation with a surface engineered yeast strain displaying glucoamylase. Renew. Energy, 34:1354-1358.
Kumar V, Rani A, Solanki S, Hussain SM (2006). Influence of growing environment on the biochemical composition and physical characteristics of soybean seed. J. Food Comp. Anal. 19:188-195.
Lancaster PA, Igran JS, Lim MY, Coursey DG (1982). Traditional cassava based foods. Survey of processing techniques. Econ. Bot. 36:12-45.
Larotonda FDS (2002). Desenvolvimento de biofilmes a partir da fe´cula de mandioca. Dissertac¸a˜o de Mestrado. Departamento de Engenharia Quı´mica e Engenharia de Alimentos. Universidade Federal de Santa Catarina.
Lawrence JH, Moore LM (2005). United States Department of Agriculture Plant Guide. Cassava, Manihot esculenta Crantz. USDA: Washington, DC, 2005, http://plants.usda.gov/plantguide/doc/pg_maes.doc (accessed March 24, 2008).
Leng R, Wang C, Zhang C, Dai D, Pu G (2008). Life cycle inventory and energy analysis of cassava-based Fuel ethanol in China. J. Clean. Prod. 16: 374-384.
Mac-Mahon JM, Warda LB, Sayre RT (1995). Cyanogenesis in cassava (*Manihot esculenta* Crantz). J. Exp. Bot. 46:731-741.
Mahungwu NM, Yamaguchi Y, Almazan AM, Hatin SK (1987). Reduction of cyanide during processing of cyanide of cassava into some traditional
African foods. J. Food Agric. 1:11-15.
Matsui KN, Larotonda FDS, Paes SS, Luiz DB, Pires ATN, Laurindo JB (2004). Cassava bagasse-Kraft paper composites: analysis of influence of impregnation with starch acetate on tensile strength and water absorption properties. Carbohydr. Polym. 55(2004):237-243.
Nagata E, Takatsuka N, Kurisu Y, Shimizu H (1998). Decreased serum total cholesterol concentration is associated with high intake of soy products in Japanese men and women. J. Nutr. 128(2):209-213.
Nair MPD, Padmaja G, Moorthy SN. (2011). Biodegradation of cassava starch factory residue and using a combination of cellulases, xylanases and hemicellulases. Biomass and Bioenergy 35(1):1211–1218.
Nambisan B. and Sundaresan S (1985). Effect of processing on the cyanoglucoside content of cassava. J. Sci. Food Agric. 36:1197-1203.
Nzigamasabo A, Ming ZH (2006). Traditional Cassava Foods in Burundi-A Review. Food Rev Internat, 22 (1): 1-27.
Oboh GO. and Akindahunsi AA (2003). Biochemical changes in cassava products (flour & gari) subjected to Saccharomyces cerevisae solid media fermentation. Food Chem. 82:599-602.
Oduro I, Ellis WO, Dziedzoave NT, Nimako-Yeboah K (2000). Quality of gari from selected processing zones in Ghana. Food Control 11:297-303.
Ogunsua AO (1989). Total cyanide levels in bread made from wheat cassava composite flours. International J. Food Sci. Technol. 24:361-365.
Okafor JN, Ozumba AU, Solomon HM (2002). Production and Acceptability of chinchin fortified with Oyster mushroom. Niger. Food J. 18:19-20.
Okaka JC, Potter NN (1997). Functional and storage properties of Cowpea powder – wheat flour blends in bread making. J. Food Sci. 42:828-833.
Onabolu A (1988). Sweet Cassava-A food for all seasons. United Nations Children's Fund, Household Food Security and Nutrition Program.
Onabalu A, Bokanga M (1998). The promotion of cassava as a commodity for the food industry: A case study in Nigeria. Presented at the CFC workshop on local processing and vertical diversification of cassava in Southern and Eastern Africa, 15-19 June 1998. Mukono, Uganda.
Onitilo MO, Sanni LO, Oyewole OB, Maziya-Dixon B (2007). Physico-chemical and functional properties of sour starches from different cassava varieties. Int. J. Food Proper. 10:607-620.

Onuma O,Kosikowski FV, Markakis P (1983): Cassava as a food, C R C Critical Reviews in Food Sci. Nutr. 17(3):259-275.
Oyewole OB, Aibor AM (1992). Fermentation of cassava with cowpea and soy-bean for an enriched *fufu.* Trop. Sci, 33:9-15.
Oyewole OB (2002). The powers at the roots: Food and its Microbials Allies. 15th Inaugural lecture University of Agriculture, Abeokuta-Nigeria.
Ozedemir Y, Olcay S, Sefik K (2009). Estimation of iodine loss from iodized salt during different storage and cooking conditions. 3rd International Congress on Food and Nutrition 22-25 April 2009 Antalya, Turkey.
Pandey A, Nigam P, Soccol CR, Soccol VT, Singh D, Mohan R (2000). Advances in microbial amylases. Biotechnol. Appl. Biochem. 31:135-152.
Raji AO, Kanwanya N, Sanni LA, Asiru WB, Dixon A, Ilona P (2008). Optimisation of Cassava Pellet Processing Method. Int. J. Food Eng. 4(2):1-13.
Ramasamy A, Paramasamy G (2001). Production of ethanol from liquefied cassava starch using Co-immobilized cells of *Zymomonas mobilis and Saccharomymes diastaticus.* J. Biosci. Bioeng 92(6):560-564.
Redondo-Cuenca A, Villanueva-Suarez MJ, RodrIguez-Sevilla MD, Mateos-Aparicio I (2006). Chemical composition and dietary fibre of yellow and green commercial soybeans (*Glycine max*). Food Chem. 101:1216-1222.
Sanchez OJ, Cardona CA (2008). Trends in biotechnological production of fuel ethanol from different feedstocks. Bioresour. Technol. 99:5270-5295.
Salau BA, Ajani EO Odufuwa KT, Adegbesan BO, Soladoye MO (2010).Effect of processing on iodine content of some selected plants food. African J. Biotechnol. 9(8):1200-1204.
Sanni OM (1991). Gari processing in Ibadan metropolis: Factors controlling quality at the small scale level, In: F Ofor, SK. Hahn, Tropical root crops in a developing economy Proceed. 9th Sympos. Int. Soc. Trop. Root Crops, Accra, Ghana, October 20–26. pp. 256-258.
Sanni LO, Maziya-Dixo B, Akanya CI, Alaya Y, Egwuonwu CV, Okechukwu RU, Ezedinma C, Akoroda M, Lemchi J, Ogbe F, Okoro E, Tarawali G,Mkumbira J, Patino M, Ssemakula G, Dixon A. (2005). Value addition to cassava in Africa: Challenges and Opportunities. Afr. Crop Sci. Conf. Proceed. 583-590.
Sanni LO, Onadipe OO, Ilona P, Mussagy MD, Abass A, Dixon AGO (2009). Successes and challenges of cassava enterprises in West Africa: a case study of Nigeria, Bénin, and Sierra Leone. IITA, Ibadan, Nigeria 19:4-7.
Santana MA, Vásquez V, Matehus J, Aldao RA (2002). Linamarase expression in cassava cultivars with roots of low- and high-cyanide content. Plant Physiol. 129:1686-1694.
Shittu TA, Sanni LO, Awonorin SO, Maziya-Dixon B, Dixon A (2007).Effect of genotype on the flour making properties of some CMD-resistant varieties of cassava. Food chem. 101;1634-1643.
Shittu TA, Dixon A, Awonorin SO, Sanni LO, Maziya-Dixon B (2008). Bread from composite cassava–wheat flour. II: Effect of cassava genotype and nitrogen fertilizer on bread quality. Food Res. Int. 41:569-578.
Soetan KO (2008). Pharmacological and other beneficial effects ofzantinutritional factors in plants, A Review. Afr. J. Biotechnol. 7:4713-4721.
Srirotha K, Santisopasrib V, Petchalanuwatc C, Kurotjanawonga K, Piyachomkwand K, Oates CG (1999). Cassava starch granule structure-function properties: influence of time and conditions at harvest on four cultivars of cassava starch. Carbohydr. Polym. 38:161-170.
Taiwo KA, Oladepo WO, Ilori MO, Akanbi CT (2002). A study on the Nigerian food industry and the impact of technological changes on the small-scale food enterprises. Food Rev. Int. 18(4):243-262.
Taiwo KA (2006). Utilization Potentials of Cassava in Nigeria: The Domestic and Industrial Products. Food Rev. Int. 22(1):29-42.
Udensi EA, Ukozor AUC, Ekwu FC (2005). Effect of fermentation, blanching, and drying temperature on the functional and chemical properties of cassava flour. Int. J. Food Properties 8:171-177.
Ugwu BO. (1996). Increasing cassava production in Nigeria and prospects for sustaining the trend. Outlook on Agric. 25(3):179-185.
Vasconcelos AI, Twiddy DR, Westby A, Reilly RJA (1990). Detoxification of cassava during gari preparation. Int. J. Food Sci. Technol. 25:198-203.
Vlavonou BM (1988). Cassava processing technologies in Africa In N. D. Hahn (Ed.), In praise of cassava Proceedings of the Interregional Experts' Group Meeting on the Exchange of Technologies for Cassava Processing Equipment and Food Products, IITA, Ibadan, Nigeria, April 13–19, 1988. New York: UNICEF House pp. 19-25.
Wang YJ, White P, Pollak Jane JL (1993). Characterization of starch structures of 17 maize endosperm mutant genotypes with Oh 43 inbred line background. Cereal Chem. 10:171-179.
Wisnu C (2008). Determination of iodine species content in iodized salt and foodstuff during cooking. Int. Food Res. J. 15:325-330.
Zaidul ISM, Yamauchi H, Kim SJ. Hashimoto N, Noda T. (2007). RVA study of mixtures of wheat flour and potato starches with different phosphorus content. Food Chem. 102:1105-1111.

Cite this article as:

Ukwuru MU and Egbonu SE (2013). Recent development in cassava-based products research. Acad. J. Food. Res. 1(1): 001-013.

Submit your manuscript at
http://www.academiapublishing.org/journals/ajfr