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Refined cassava flour in bread making: a review

Harina de yuca refinada en panificación: una revisión

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ABSTRACT

Different studies have developed a variety of breads using cassava flour, with similar characteristics to wheat flour breads. The use of cassava flour in bread making is a convenient alternative for promoting the use of a local crop as well as reducing imports of wheat flour, promoting the production of high quality cassava flour, offering a gluten-free product and developing biofortified and fortified foods. Although the substitution level of cassava flour is limited, in some products, the incorporation of additives or flours from other crops improve the nutritional value and bread making quality of the baked foods. Several limitations have hindered the success of initiatives to promote, in some cassava producing countries, the intensive use cassava flour in bread making. Among these include the costs and efficiency of processing technologies, standards of the quality of cassava flour and lack of favorable policies. Further studies about bioavailability and retention of nutrients on baked foods and evaluation on the effects of processing cassava flour in relation to increasing the resistance starch are required to provide scientific evident for the health benefits of this flour.

Keywords: Cassava flour, composite flour, gluten-free, biofortification, resistant starch.

RESUMEN

Diferentes estudios han permitido desarrollar una variedad de panes utilizando harina de yuca, con características similares a los panes de harina de trigo. El uso de harina de yuca en productos de panificación es una alternativa conveniente para fomentar el uso de un cultivo local, reducir la importación de harina de trigo, promover la producción de harina de yuca de alta calidad, ofrecer un producto libre de gluten y desarrollar alimentos bio-fortificados y fortificados. Aunque el nivel de sustitución de harina de yuca es limitado, en algunos productos, la incorporación de aditivos o harinas de otros cultivos mejora el valor nutricional y la calidad panificable de los productos horneados. Varias limitaciones han impedido el éxito de iniciativas para promover, en algunos países productores de yuca, el uso intensivo de harina de yuca en panificación. Dentro de estas se incluyen costos y eficiencia de tecnologías de procesamiento, estándares de calidad de la harina de yuca y la falta de políticas favorables. Se requieren estudios adicionales sobre bio-disponiblidad y retención de nutrientes en productos horneados y evaluación de los efectos del procesamiento de la harina de yuca en relación a incrementar el almidón resistente para proveer evidencia científica de los beneficios para la salud de esta harina.

Palabras clave: Harina de yuca, harina compuesta, libre de gluten, bio-fortificación, almidón resistente.

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Introduction

Colombia is the third largest producer of cassava in Latin America after Brazil and Paraguay. In 2014, Colombia produced 2,1 million tons (MT), as compared with Brazil (23,2 MT) and Paraguay (3,0 MT). (FAO, 2016). Cassava is a staple food in many countries of Africa, Asia, Latin America and the Caribbean. This crop has great social value and cultural identity. Therefore, cassava plays an important role in food security and nutrition being a source of income for producers, processors and trades contributing substantially to poverty alleviation (IFAD & FAO, 2001). Among its main features stand out its great potential for the production of starch, tolerance to drought, its adaptation to difficult ecosystems such as acid soils of low fertility and its great flexibility on planting and harvesting adapting to different growing conditions (Cadavid, 2002). Both its roots and its leaves are suitable for human consumption; the first as a source of carbohydrates and the second as a source of protein, minerals and vitamins, particularly carotene, calcium and phosphorus (IFAD & FAO, 2004). Cassava is mainly grown by small producers, who use it for self-

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consumption, feed animals and generate income by selling in different markets (UNCTAD, 2015). One of the biggest challenges to the food industry in developing countries is changing processing techniques from traditional to modern ones. This transition depends on the type of food to be processed, consumption habits, supply of raw material and availability of equipment (Falade & Akingbala, 2011 and Ukwuru & Egbonu, 2013).

Cassava flour is one of derivatives from cassava roots whose processing technology is cheaper and easier than cassava starch production besides require less consumption of water and energy and produce smaller quantity of by-products and waste (Abass *et al.*, 1998). Cassava flour is traditionally obtained from receiving roots which later are washed and/or peeled and after that grated or chipped into slices or chips. These can be dried on concrete floors by the sun, on trays or in artificial dryers (rotatory, trays, fixed bed or flash). The commonest technique applied is drying cassava chips by the sun, which depends on sunny seasons and large spaces. The dried chips are milled and the flour is sieved to obtain refined flour which finally is packaged and stored. The production of cassava flour in Colombia is artisanal and small-scale. However one of the biggest limitations is drying technology (Alonso *et al.*, 2002).

Wheat and corn and its flours imports represent a major burden on the economy of importing countries including trade imbalance, overdependence on foreign foods, loss of foreign exchange, food insecurity, as well as displacement of local food, with detrimental effects on the agricultural and technological development of these regions (Ohimain, 2014). The need for strategic development and use of local resources for producing low cost foods, such as bread and baked foods has been recognized by organizations such as the Food and Agriculture Organization of the United Nations (FAO), the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA) and the Federal Institute for Industrial Research Oshodi (FIIRO). Inclusion of cassava flour as composite for production of foods such as noodles, breakfast cereals, cookies, breads, cakes, pastries, muffins and doughnuts among others could reduce costs and increase the production of these products locally (; Akinlonu, 2011; Falade & Akingbala, 2009 and Oyewole, 2002;). Measures to promote the use of cassava flour in tropical countries, particularly cereals importing countries, remain active however its implementation has not been consolidated. Brazil, in 2001, promoted the incorporation of 10% of cassava flour in wheat flour in bread making in order to absorb 50% of the country's cassava production (Rebelo, 2002). Nigeria, in 2003, established a policy to use 10% of cassava flour in bread making; however, 5% was used due to shortage of cassava flour. In 2012, the country imposed a tax to imported wheat flour, so bakeries were required to use 20% cassava flour. In addition, given the importance of cassava in diet Nigeria, proposals have been developed to biofortify cassava and reduce the deficiency of vitamin A which is a common problem in this country (UNCTAD, 2015).

In this study the contribution of scientific literature on the development of bread making products using cassava flour is analyzed. Three alternatives for the potential use of cassava flour are introduced including the elaboration of gluten-free products, biofortification and fortification of wheat-cassava composite flours, and techniques for increasing resistant starch in cassava flour products. Finally, the main challenges that must be overcome producing countries to achieve the extensive use of cassava flour in bread making are discussed to inspire actions and business models to exploit the comparative advantages of cassava flour in relation to wheat flour, boosting rural development in these regions.

Production of refined cassava flour

In 2001, the Latin American and Caribbean Consortium to Support Cassava Research and Development (CLAYUCA) and the International Center for Tropical Agriculture (CIAT), with support from the Colombian Ministry of Agriculture and Rural Development (MADR) supported the design of a pilot plant to obtain dried cassava chips for animal consumption. This initiative encouraged many industries in Colombia to design systems for drying cassava for both human and animal consumption; however the technologies designed did not have extensive application in the large scale production of cassava flour in Colombia, due to investment costs and operational problems among others (Silva *et al.*, 2002).

In 2006, CLAYUCA developed a research project to establish a pilot plant for continuous production of refined cassava flour titled sponsored by the MARD (García *et al.*, 2006). In this project, a modular pilot plant optimizing previous plant models was designed (Barona & Isaza, 2003) using improved methods of milling and refining. This technology has been recently improved in order to reduce the process time and energy consumption (Gallego & García, 2015).

The refined cassava flour production process comprises the steps of receiving, washing, chipping; drying, milling and refining.

- **Reception:** After harvesting cassava roots are transported to the processing plant. There the cassava is weighed to estimate its dry matter content using the technique of specific gravity (Toro & Cañas, 1983) which is possible also estimate the production yield. Subsequently, the roots are deposited in a feeding hopper which leads to a sand trap which rotates allowing that excess of impurities such as adhered soil, rootlets, and the peduncle are removed.

- **Washing:** The roots are driven by conveyor belt to a wash machine which consists of a horizontal cylinder with holes. The load on the machine is 200 kg. The roots are washed using water under pressure for about 5 minutes. On average 1 m^3 of water is required to wash 1 ton of cassava roots. The combination of water and friction between roots and the drum inner walls removes impurities and the thin outer peel. To improve the microbiological quality of cassava flour, at the end of the washing may be used a disinfectant solution of sodium hypochlorite at 10 ppm washing the roots during 2 minutes.

- **Chipping:** In this stage the size of cassava roots is reduced to increase the area of heat transfer and accelerate the drying process. The roots are chipped using a machine which has a vertical disc rotating with several fluted trapezoidal blades that turn at 1200 rpm. A typical cassava chip is a rectangular piece of about 0,5 cm^2 cross section area and 3 cm lenght, which has moisture content between 58-70 %. The drying time depends on the size of cassava chips.

- **Drying:** Cassava chips can be dried by sun or using artificial dryers to reduce moisture content (mc) to 10-12 %. Drying is a critical stage; it should be uniform to avoid fermentation problems or microbial contamination of the flour.

- **Milling and refining:** The dried cassava chips are milled through a hammer mill which has expanded mesh which reduces refine the flour rejecting small materials such as thin outer peel, and fiber pieces. The material that passes through the mesh enters a cylindrical mill-sieve, after which it is sucked by a centrifugal fan that transports the material to a pair of cyclones. The operating conditions of refining can be varied in accordance with the refinement requirements to obtain either refined flour or whole flour.

Subsequently, the refined cassava flour is packed into plastic bags and stored on wooden pallets in a place free of moisture, contamination and insect pests.

The FAO-WHO commission of the *Codex Alimentarius* defined the standard for edible cassava flour. Codex Stan 176 (Codex Alimentarius Commission, 1989).

Table 1. Requirements for edible cassava flour

Factor		Limit
Moisture content (mc)		Max. 13 %
Hydrogen cyanide content		Max. 10 mg/kg
Crude fiber		Max. 2,0 %
Ash		Max. 3,0 %
Abnormal flavours and odours		Exempt
Impurities and contaminants		Exempt
Food additives		Conform with legislation of the country in which the product is sold
Particle size	Fine flour	Min: 90 % shall pass through a 0,60 mm sieve (mesh 30)
	Coarse flour	Min: 90 % shall pass through a 1,20 mm sieve (mesh 16)

In general, the yield process for obtaining refined cassava flour is:

- 3 kg cassava roots: 1 kg dried cassava chips (12 % mc).
- 1,3 kg dried cassava chips: 1 kg refined cassava flour (12 % mc).

The conversion factor of cassava roots to refined cassava flour depends on the dry matter content of cassava roots as well as of levels of impurities in the raw material and losses occurring in the process.

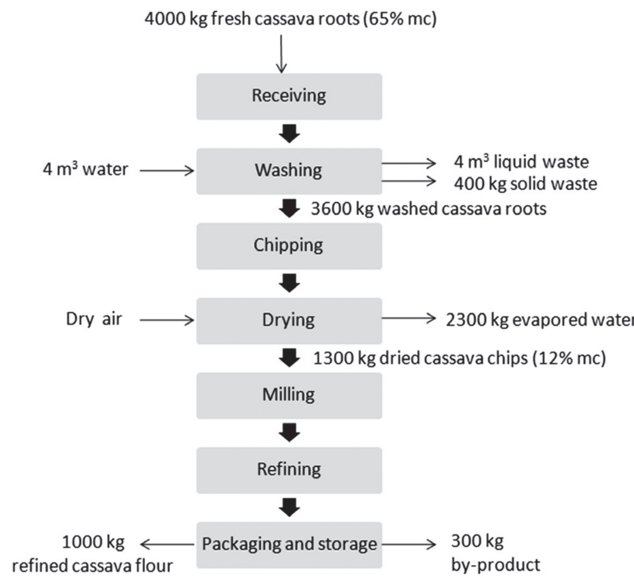

Figure1. Mass balance of production of refined cassava flour.

Cassava flour in baked food

One of the most popular uses of cassava flour in the world is in the manufacturing of baked products such as bread, cakes and pastries (Shittu *et al.*, 2008). Cassava flour as raw material for the bakery and pastry industry, as a substitute for wheat flour, can be used in the elaboration of products such as thickeners, dehydrated soups, noodles, extruded products, seasonings, breaded, baby food, sweets and processed meat (Adebayo *et al.*, 2010; Balagopalan *et al.*, 1988; Day *et al.*, 1996 and Fernández *et al.*, 1992;).

A number of studies have been conducted to use cassava flour in bread making. Most of the studies revealed that wheat flour can be replaced by 5 to 10 % cassava flour without significant effects on processing and the quality of bread (Dendy *et al.*, 1972; Giacco & Appolonia, 1977; Almazan, 1990; Defloor, 1995 and Eddy *et al.*, 2007). Substitutions of up to 30 % have been made to obtain acceptable breads (Defloor et al, 1993 and Jensen *et al.*, 2015). Some factors that influence the quality of bread made with wheat-cassava composite have been studied such as the type of variety of cassava (Eggleston *et al.*, 1993; Eduardo *et al.*, 2013; Eriksson *et al.*, 2014; IIT, 1986a; Henao & Aristizábal, 2009 and Shittu et al., 2007b), maturity of cassava of a same variety (IIT, 1986b and Defloor et al., 1994, 1995), the time and temperature of baking (Shittu *et al.*, 2007a) and absence of fertilizer on cassava roots (Shittu *et al.*, 2008). Akingbala *et al.* (2011) evaluated the effect of the maturity of the cassava root and shelf life of cassava roots and flour on the physico-chemical and sensory characteristics of cookies made with cassava flour. Studies have shown that cassava flour absorb a larger amount of water than wheat flour (Defloor et al., 1993; Eduardo *et al.*, 2013). Henao & Aristizábal (2009) found that using 10% of cassava flour the dough yield increased by 1,4%.

On the production of cookies, cassava flour can replace wheat flour in percentages of 20% (Mlingi *et al.*, 1998), 30% (Abass *et al.*, 1998; Oyewole, 2002 and Falola *et al.*, 2011) 40% (Eggleston *et al.*, 1992 and Onwuka & Bokanga, 1994) and 100% (Onabolu & Bokanga, 1998 and Oyewole *et al.*, 1996) with overall acceptability in terms of color, texture, crunchiness and flavor. Cassava flour substitutions from 30 to 100% has been evaluated in the production of cakes; as the proportion of cassava was increased, the firmness, chewing, and cohesiveness decreased, tendency that was remained in the time (Cueto *et al.*, 2011). Rangel *et al.* (2008) made cakes using 20% of cassava flour obtaining an acceptable product but with a lower specific volume.

Although cassava flour can replace wheat flour at levels above 20%, additives such as emulsifiers, enzymes, hydrocolloids and gums, lipids and proteins may be required to improve the quality of bread and increase the nutritional value (Houben *et al.*, 2012). However, using these additives may increase the cost of production of bread (Ohimain, 2014). Eduardo *et al.* (2013) evaluated the addition of pectin (1-3%) together with a 40% substitution of cassava flour resulting in a reduced crumb firmness of bread. Using 30% cassava substitution Khalil *et al.* (2000) achieved acceptable breads using malt while Owuamanam (2007) carried out a pre-treatment of cassava roots with citric acid solution before milling into flour. The addition of xanthan gum (Shittu *et al.*, 2009; Gambus *et al.*, 2007), and agar-agar (Alvarenga *et al.*, 2011) have been investigated to improve the functional properties of gluten-free breads. Moreover, substitutions of 100% cassava flour using egg white and extra virgin olive oil have been done (Pasqualone *et al.*, 2010).

Biofortification and fortification of wheat-cassava composite flours

The most conventional strategies used to address micronutrient malnutrition are supplementation, food fortification and biofortification (Berti *et al.*, 2014). Fortification is the addition of one or more nutrients to a staple food in order to improve its quality. On the other hand, biofortification is the process of increasing the content and/or bioavailability of essential nutrients in crops during plant growth through genetic and agronomic pathways (López, 2015).

Diverse mixtures can be designed and more nutritious products can be developed for local markets (Noorfarahzilah *et al.*, 2014). There are some varieties of cassava with high content in carotenoids, making these varieties a source of pro vitamin A. The total content of β-carotene can reach about 5 μg/g in yellow pulp cassava roots (Aniedu & Omodamiro, 2012 and Kimura *et al.*. 2007). Oven-drying of cassava roots rich in β- carotenes retained high content of β-carotene (71,9%) compared to drying shadow drying (59,2%) and boiling (55,7%). In addition, storage of cassava flour and chips in plastic bags using vacuum resulted in higher losses without application of vacuum. There is higher retention of β-carotene in cassava chips than cassava flour (Chávez *et al.*, 2007). The Harvesplus program lead the project "Combating hidden hunger in Latin-America: biofortified crops containing improved vitamin A, essential minerals and high quality protein" which increased the beta-carotene content of cassava roots making this crop more nutritious, contributing to the reduction of nutritional deficiencies of low income population in Colombia, Brazil and Nicaragua by developing food products such as soups, biscuits, breads, cakes, noodles and baby food (Ospina *et al.*, 2009).

Biscuits and cakes made from mixtures of cassava/soy flour in 50/50 proportion had high scores in sensory evaluation in all evaluated attributes: color, texture, flavor and overall acceptability (Akubor & Ukwuru, 2003). Akinwande *et al.* (2008) made biscuits with cassava flour using a substitution of 40% soy flour incorporating ginger powder as flavor agent which masked the taste of soy. Cakes made with soy/cassava/wheat flour in the ratio 20:30:50% respectively were comparable to cakes made with 100% wheat flour in terms of quality and acceptability for color, flavor, soft-mouth and texture (Ugwuona *et al.*, 2012). The inclusion of soy flour produces a significant emulsifying activity and increases the water absorption capacity, as well as contributing to increase protein content. In addition, due to the high water absorption capacity of soy proteins and its interactions with amylopectin may slow down the process of retrogradation of breads (Olaoye *et al.*, 2006). Cassava flour may be replaced by up to 30% with pumpkin seed flour to produce cookies without affecting the sensory qualities and increasing its nutritional value (Falola *et al.*, 2011). Polonium *et al.* (2012) produced a cake with cassava flour, 2% *Spirulina platensis* and 4% cassava fiber, enriched with chocolate, as a school meal. Acceptability trials were carried out with students at a public school in Brazil revealing an acceptability index of 98,8%. Ogunjobi & Ogunwolu (2010) developed cassava flour biscuits using cashew powder by up to 20%, as a source of vitamin C, protein and fiber. Jishua *et al.* (2010) produced muffins and cookies from cassava-based composite flour incorporating a mix of cereals/pulses and additives with fiber to increase the protein content by 4,5–5,6% (<1,0% in cassava flour). Other fortification sources include bovine plasma (Benítez *et al.*, 2008) and beans (Graham & Archbold, 1984; Cabal *et al.*, 2014; Chilungo, 2013). The increase of fiber in wheat-cassava flour composite has been evaluated (Jishua & Padmaja, 2008). Biscuits with cassava/cowpea flour in proportion 80/20 and wheat/cassava/cowpea flour in the ratio 35/35/30 did not have significant differences in comparison to wheat flour control (Olapade & Adeyemo, 2014).

Cassava products contain different amounts of resistant starch (RS). In cassava flour the resistant starch levels vary between 0,19 to 2,21% which depends on the cassava variety and the processing method (Buzati-& Leonel Pereira, 2014). The amount of resistant starch in foods can be modified by processing techniques. Certain types of processing, such as sterilization, drying in ovens, or drying at high temperatures increase the level of resistant starch (Sajilata *et al.*, 2006; Pereira, 2007; Walter *et al.*, 2005). The RS has similar properties to soluble fiber and evidence suggests that it has physiological benefits that contribute to the health of the gastrointestinal tract and the metabolic system in humans, as well as providing fewer calories and reduced glycemic load (Nugent, 2005). The characteristics of different types of resistant starch reflect the processing effect, the starch granule characteristics and the starch structure gelatinization (Hallström *et al.*, 2011). High amylose starches tend to be more resistant to digestion (Sharma *et al.*, 2008). Hamaker *et al.* (1991) evaluated the effect of dietary fiber and resistant starch present in cassava flour on the fecal composition of pre-school children. They determined that a portion of the RS was fermented in the large intestines and the fiber cassava produced an increase in the fecal bulk volume due to its high water-holding capacity. Korus *et al.* (2009) incorporated tapioca resistant starch (20%) in bakery products causing a decrease of starch gelatinization which was manifested by an increase of pasting temperature (76,8 °C) comparing with control (83,8°C) and decrease of the maximum viscosity (42,5 BU) while control was 81,5 BU. It was attributed to the rising amounts of dietary fiber, which acts as a neutral filler and dilutes starch lowering the viscosity. These changes were accompanied by reduction of the crumb initial hardness and besides by slower aging of bread. Gluten-free products tend to faster aging because the lack of gluten network as well as water migrates faster from crumb to the crust (Gallagher *et al.*, 2003).

Challenges to overcome for the widespread use of cassava flour in baked food

Despite considerable research done for many countries about using wheat-cassava composite flour in bread making there has been little impact in the market due to mainly high production costs, operational problems and quality of cassava flour. In the case of Nigeria, the largest producer of cassava in the world, the reasons for the failure of many initiatives to promote the use of cassava flour in bread making include: insufficient policy incentives; lack of favorable policies; low wheat flour prices relative to those of cassava flour; unreliable supply of and low demand for cassava flour; lack of market access; poor logistics; high cost of transportation and poor conditions of roads; dependence on weather for drying; lack of working capital (Ohimain, 2014). Other reasons that can be included are lack of willingness by the flour millers to comply with government policy; strong consumer preference for 100% wheat bread; lack of knowledge regarding the advantages of wheat-cassava bread (CIAT, 1998). In Nigeria, quality cassava flour is another common problem by the presence of impurities such as sand, foul odor and color problems, as well as high moisture content which generate significant variation in physico-chemical and functional properties of cassava flour (Adebowale *et al.*, 2011). Generally, cassava flour obtained by hand peeled of cassava roots has a yellow coloration and presence of odor as well as high microbial load which accelerates the bacterial fermentation (Sanni *et al.*, 2009). When cassava flour is obtained by drying cassava pulp, obtained by pulping the roots, previous dehydration is critical to prevent fermentation problems. This method limits the release of hydrocyanic acid due to its reduced area of heat transfer compared to chipped roots (Kolawole *et al.*, 2012). However, drying cassava chips by sun has limitations not only for dependence on weather and space (intensive, scarce, expansive and seasonal) but also poor microbiological quality (Abass *et al.*, 1998). If rotary or flash dryers are used the main problems encountered include high cost of production, ensuring high efficiency equipment, frequent breakdowns, lack of spare parts and excessive consumption of fuel and electricity, etc. (Ohimain, 2014). Because of the problems presented in the operations and maintenance of artificial dryers, other drying systems have been considered such as solar dryers, and use of fresh cassava roots or chips instead of cassava flour for the preparation of bread (Falade & Akingbala, 2009). Unless these challenges be effectively mitigated, current efforts in research and promotion of use of cassava flour in bread making cannot be successful.

Conclusions

There is enough scientific evidence that shows the effectiveness of using cassava flour to elaborate different kind of breads. The potential benefits of using cassava flour in bread making include reduction of dependence on wheat and wheat flour imports, foreign exchange savings, increase farming incomes, reduction food insecurity and boost of rural development by promoting cassava production. It is a fact that to achieve these goals is fundamental to promote policies to use cassava flour in the milling sector, doing association among cassava producers and processors, designing efficient processing technologies, and assuring quality standards, continuous supply and meet the needs of consumers.

Although the inclusion of cassava flour in baked products has limitations, it is possible increase the substitution level by incorporating additives and flour from other crops which improve the nutritional value and bread making quality. Strategies such as fortification or biofortification of staple foods increase the content of essential nutrients as well as address micronutrient malnutrition of low income population. In addition, baked products made out cassava flour offering food alternatives to celiac people who claim products gluten-free.

Further research is necessary to determinate the bioavailability and retention of nutrients in fortified and biofortified products after bread making process and evaluate the effects of processing techniques and storage on the increase of resistant starch in cassava flour in order to assess its health benefits.

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