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Mini Review

Effect of Selected Processing and Modification Methods on Quality of Cassava and its Starch

[1]Adewale Olusegun Omolola, [1]Patrick Francis Kapila and [2]Godwin Ainamensa Mchau

[1]Department of Agricultural and Rural Engineering, School of Agriculture, University of Venda, Private Bag X5050, 0950 Thohoyandou, Limpopo Province, South Africa
[2]Department of Horticultural Sciences, School of Agriculture, University of Venda, Private Bag X5050, 0950 Thohoyandou, Limpopo Province, South Africa

Abstract

The effect of processing on the quality properties of cassava and its starch was reviewed. Cassava (*Manihot esculenta* Crantz) is a broadly cultivated root crop and mostly consumed in developing nations. Cassava can be processed into flour, chips and starch for subsequent use in food production. Fermentation, boiling, drying, steaming, baking, blanching, frying and parboiling are some of the methods of processing cassava roots. These processes lead to a reduction in its cyanide content and other effects on cassava quality. The use of native cassava starch in food industry applications cannot be over emphasized; however, a major factor militating against its use is the finite imbalance in its structure and properties. As a result of this, native starch from cassava requires some form of modification to enhance its quality in terms of structure and functionality.

Key words: Cassava, cyanide, quality indices, cassava processing, phytochemicals, anti-nutrients, fermentation, fortification

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Corresponding Author: Adewale Olusegun Omolola, Department of Agricultural and Rural Engineering, School of Agriculture, University of Venda, Private Bag X5050, 0950 Thohoyandou, Limpopo Province, South Africa

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INTRODUCTION

Cassava (Fig. 1)[1] is extensively cultivated and utilized as a regular foodstuff in the tropical belt of most developing countries[2,3]. The 2010 globe production of cassava roots was predicted to be around 230 million tons, Nigeria being the largest producer followed by Brazil, Indonesia and Thailand[4]. The 2016 world cassava production increased by 3% (8 million tons) compared to 2015[4] world export and production of cassava are shown in Table 1 and 2, respectively. The humid content of cassava roots varies around 65% (w/w). Cassava roots are perishable with a shelf-life of 24 h, to no more than 72 h after harvest, if no special preservation measures are taken. Cassava variety includes the sweet and bitter types with high linamarin content being found to be responsible for the bitter taste observed in bitter cassava[5]. A huge number of food products, based on the processing of cassava root parenchyma exist worldwide. These include *Gari*, *Rale*, *Farinha*, *Carixi*, *Mingao*, *Cassareep*, *Kumkum* and *Fufu*[6-10,4]. Some are restricted to specific geographical regions, whereas some are widely spread across. In most cases the same product is named differently in different regions.

The presence of anti-nutrients, such as, linamarin and lotaustralin known as cyanogenic glucosides has greatly reduced the food use of cassava[11] since the consumption of cyanogens, which includes hydrocyanide, cyanogenic glucosides and cyanohydrins could lead to severe poisoning[11,12]. The degradation of cyanogenic glucosides to hydrocyanide requires cyanohydrins also known as cyanogenic intermediates[12,13].

The noxious effects of cassava can be minimized by processes, such as drying, soaking, frying, grating and fermentation, through the degradation of the toxic compounds by oxidation, reduction, or hydrolysis, or by reaction with other constituents-forming chemical bonds. Cassava is rich in carbohydrate but lacks protein and essential micronutrients[14,15]. Fortification of cassava with other protein-rich crops could be used to improve its nutritional quality, thereby, compensating for cassava's lack of protein and essential micronutrients. Cassava leaf, unlike the root, is nutritious but its utilisation as food is limited[16]. This paper summarize the quality of cassava and its starch as affected by processing by highlighting different processing and modification methods and their impacts on quality indices of cassava and its starch.

Fig. 1: Cassava roots[1]

Table 1: World export of cassava flour, starch chips and pellets

Countries	2012	2013	2014	2015	2016
Flour and starch (t)					
Thailand	6,163	6,686	7,919	7,657	6,900
Viet Nam	500	355	337	432	320
Others	367	350	333	316	250
Chips and pellets (t)					
Thailand	4,853	6,006	6,927	7,458	4,402
Viet Nam	2,386	2,700	2,565	3,081	2,280
Cambodia	722	361	350	420	300
Nigeria	-	-	20	150	100
Others	200	180	150	150	100

FAO, 2016

Table 2: World cassava production (t)

Countries	2013	2014	2015	2016
Nigeria	47,407	54,832	57,000	57,855
Congo DRC	16,500	16,817	15,300	15,200
Ghana	15,990	16,524	17,213	17,957
Angola	16,412	7,639	7,727	7,788
Brazil	21,484	23,242	22,784	22,410
Thailand	30,228	30,022	32,358	31,807
Indonesia	23,937	23,436	22,906	26,749
Viet Nam	9,758	10,210	10,674	10,201

FAO, 2016

IMPACT OF SELECTED PROCESSING METHODS ON QUALITY INDICES OF CASSAVA

Processing operations of cassava tubers include baking, steaming, frying, drying, parboiling, soaking, boiling, blanching and fermentation[17-21,2,6]. These processes usually lead to a great reduction in the cyanide content (antinutritional quality)[3] while other qualities (nutritional, microbiological and physicochemical) can also be affected by the different processing methods. A hand full of studies[17-21,2,3,6] has been done to determine the effects of the different processing methods on quality properties of cassava.

Baking: Baking is a food-processing method intended to modify the sensory qualities of food products, advance tastiness and widen the array of tastes, aromas and textures in food products. The process also eliminates enzymes and microbes and limits the water activity of food products, thereby, extending the storage life of foodstuffs[22]. A study, for example, on physical qualities of cassava-wheat bread as affected by baking time and temperature as investigated by Shittu *et al.*[23] revealed that baking time and temperature significantly ($p<0.05$) affected weight, loaf volume, specific volume, density, porosity, softness, crumb hardness, moisture, L* (lightness) and the brownness index of the bread. Furthermore, Ahza *et al.*[20] investigated enriched baked and fried-simulated chips as affected by a combination of cassava rice ratio and cooking time-temperature. The authors observed that physical, sensory and chemical qualities of the simulated chips were greatly affected by the mix ratio and cooking methods. Microstructure of the fried cassava rice chips was reported to be better as compared to baked chips. The optimum processing conditions reported for baked simulated cassava rice chips was 80% (cassava): 20% (rice) ratio, baked at 140°C for 14 min, while 60% (cassava): 40% (rice) ratio, fried at 150°C for 2.5 min was found suitable for fried cassava rice simulated chips.

Frying: Frying is a unit process usually carried out to impact characteristic colors, flavors and aromas in the outer layer of fried food products. These qualities are impacted by a mixture of Maillard reactions and compounds absorbed from the oil for eating enhancement. Thoroughly dried foods, for example, potato crisps, maize and other potato snack foods, by the frying process, have been observed to have a storage life of upto 12 months, at ambient temperature[22]. Pre-treatments, such as blanching or partial drying prior to frying can influence the amount of oil trapped within the food product and improve the eating qualities of foods. The influence of vacuum frying on the quality of cassava chips, as investigated by Garcia-Segovia *et al.*[2] showed that pre-blanching had a positive influence on the color of vacuum fried cassava chips coupled with less oil absorption. The authors concluded that the vacuum frying method for pre-blanched cassava chips can be a potential replacement for atmospheric frying method because of its positive influence on the chips in terms of color, oil gain and crispness. Blanching of food products usually leads to the disarrangement of hydrogen bonds between cell wall polymers[17]. This can further lead to the degradation and solubilization of pectins from the cell wall which in turn can result to loss of grip or friction between cells, hence damaging the cohesion of the membrane-facilitating water exchange[24,25].

Fermentation: The importance of fermentation in reducing the toxic compounds in cassava cannot be overemphasized. The removal of cyanogen from cassava tubers, through fermentation, can improve its value and creates new markets. Fermentation of cassava pulp by Corynebacterium leads to the production of lactic and formic acids and a pH reduction from 5.9-4.0. Elevated level of acidity increase the growth rate of *Geotrichum* spp. and reduces the toxicity of cassava roots by releasing gaseous hydrogen cyanide through hydrolysis of the cyanogenic glycosides present in the cassava[22]. Bradbury[26] and Cumbana *et al.*[27] observed that the entire cyanide content in cassava flour was limited by three or six folds when soaked in water in an open container for 5 h. Tivane *et al.*[18] revealed that flour made from material heap, fermented for 4 days prior to sun-drying had a total cyanogenic potential of 17 mg HCN equivalents kg^{-1} as compared to flour made solely from sun-dried cassava tubers which had a cyanogenic content of 158 mg HCN equivalents kg^{-1}. Padmaja and Steinkraus[28] similarly, noted that initial cyanide content (108 mg kg^{-1}) of cassava tubers was reduced to 60 and 3 mg kg^{-1} after soaking for 1 and 5 days, respectively.

Cooking: According to Montagnac *et al.*[29] cassava roots contain certain phenolic compounds (Table 3) which include gallocatechin, catechin and catechin gallate (3-flava-3-ols), hydroxycoumarins and the flavones 3-glycosides known as rutin and kaempferol 3-rutinoside. These phenolic compounds, however, can be affected by different cooking

Table 3: Compounds identified in cassava leaves and roots

Phytochemicals	References
Coumarins scopoletin (7-Hydroxy-6-methoxychromen-2-1)	Gnonlonfin *et al.*[19]
β-carotene	Carvalho *et al.*[30]
Terpenoids	Blagbrough *et al.*[14]
b-sitosterol, stigmasterol, campesterol and cholesterol	Sakai *et al.*[25]
Flavanols, (+)-gallocatechin, (+)-catechin and (+)-catechin gallate	Buschmann *et al.*[31]
Palmitic, oleic and linoleic acids	Sakai *et al.*[25]
Galactosyl diacylglycerides	Bayoumi *et al.*[32]

methods. Evaluation of the bio-accessibility of phenolic compounds and antioxidant activity of processed cassava using 3 different cooking methods (steaming, boiling and microwaving) was studied by de Lima *et al.*[21] The authors noted that the total polyphenols' content was significantly different after treatments, showing a variation of 25.81 (steaming) to 16.59 (boiling). The antioxidant activity determined by the (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) method differs significantly ($p<0.05$) in all cooking methods of cassava, wherein, boiling >microwaving> steaming. A reduction in the total phenolics composition and antioxidant activity was noticed for all cooking methods. A study on the content of carotenoids and the influence of various home-cooking processes on the preservation of β-carotene in yellow sweet cassava[30] revealed that the retention percentage of β-carotene varied according to cassava variety and cooking method. Bechoff *et al.*[33] studied the stability of carotenoid in yellow *gari* produced from bio-fortified cassava or with addition of palm oil during storage. They reported that carotenoid and vitamin A of the *gari* foodstuffs reduced greatly with time and temperature. The degradation of trans-β-carotene for bio-fortified *gari* displayed a good fit with Arrhenius model as observed by the authors. The authors further reported that the activation energies required for degrading trans-β-carotene in bio-fortified *gari* and red palm-oil *gari* were 60.4 and 81.0 kJ mol^{-1}, respectively. This is an indication that the shelf life of bio-fortified *gari* is shorter as compared to the red palm oil *gari* hence; the constancy of carotenoids in bio-fortified *gari* is less than in red palm-oil *gari*.

Drying: Drying is the elimination of moisture from agricultural foodstuffs with the crucial aim of reducing microbial activity, product deterioration and elongation of shelf life. Nearly all foods contain enough moisture to allow the action of native enzymes and microorganisms during storage and drying is essential to decrease their water activity and avoid microbial spoilage, in order to lessen weight and reduce costs of packaging, handling and transportation[34-38].

According to Gnonlonfin *et al.*[19], content of coumarin compound scopoletin (7-hydroxy-6-methoxychromen-2-one) in cassava after peeling, cutting into slices (chipping) and being subjected to drying for 6 days increased significantly ($p<0.05$). The mean content in fresh roots from four varieties varied between 4.1-11.1 mg kg^{-1}, while the content after 6 days rose to 242 mg kg^{-1} for the cultivar showing the highest increase. Pneumatic drying has been reported to be effective in cassava-starch production. Agglomeration of starch fractions into varying particle sizes usually takes place during pneumatic drying of cassava starch. These starch fractions are usually characterized by undesirable properties, which includes low enzyme or acid hydrolysis rate, low viscosity and high gelatinization temperature[39,40]. These agglomerated starch particles must then be subjected to reprocessing which leads to additional cost of production. In pneumatic drying operation, the product's dwelling time, which is more often than not determined by the pipe dimension and the air speed, ought to be systematically maximized in order to ensure an optimum product quality[41]. Chapuis *et al.*[41] designed a one dimensional model to study the drying of particles in a pneumatic conveying dryer using a water diffusion driven mechanism. The authors recommend that the use of drying pipes longer than 25 m with a limited air mass flow rate (i.e., low dilution ratio) can help to keep to product temperature low, so preserving its quality and ensuring energy efficiency.

CASSAVA STARCH MODIFICATION AND ITS EFFECT ON QUALITY OF CASSAVA STARCH

The industrial applications of native starch, from cassava have been identified by various researchers; however, it requires some form-modification to enhance its functionality, structure and quality. The influence of different modification methods on cassava starch, as conducted by various researchers are shown in Table 4 and 5. A study on ozone oxidation of cassava starch in aqueous solution with respect to different pH was carried out by Klein *et al.*[74]. They reported that the cross-linkages existing between the depolymerised starch molecules during ozonation were stable at pH 6.5 and 9.5. Cassava starch qualities such as, their breakdown, setback, peak viscosity and final viscosity were greatly reduced at pH 3.5. The morphology of the granule surface of the ozone-treated starch was indifferent when compared to cassava's native starch, according to the authors. Wang and Wang[75] pointed out that acetylated starches have been reported to be useful raw materials in the food industry due to their excellent characteristics in terms of physicochemical properties and storage stability. The process of starch acetylation, which is a way to advance the functional properties of starch, requires esterification of the hydroxyl functional groups of the starch[76]. Osundahunsi *et al.*[77] studied the effect of sulphur dioxide on acetylation and sorption isotherm of starches obtained from different cassava types. The authors observed that physicochemical properties such as solubility and swelling index of the acetylated starches increased as the addition of acetic anhydride proliferated. They also reported relatively high regression values ranging from 50-97% for water absorption and water activity of the acetylated starches.

Table 4: Effect of chemical and enzymatic modification on cassava starch

Modifications	Effects	References
Acid modification in aqueous solution	Decrease swelling power, increase solubility, increase and broaden gelatinization temperature, decrease retrogradation, polymorph change and increased crystallinity percentage	Sanguanpong *et al.*[42], Beninca *et al.*[43], Plata-Oviedo and Camargo[44]
Acid modification in methanol/ethanol environment	Increase water solubility	Cavallini and Franco[45]
Cationization	Reduce pasting viscosity and temperature	Han and Sosulski[46]
Oxidation	Reduce gelatinization temperatures and decrease pasting viscosity	Sangseethong *et al.*[42] and Beninca *et al.*[43]
Acetylation	Improves water solubility, decrease pasting viscosity, improves gelling power and decrease gelatinization temperature	Aiyeleye *et al.*[47], Agboola *et al.*[48], Agboola *et al.*[49], Moorthy[50] and Akingbala *et al.*[51]
Alkaline	Reduce amylose content and increase alkali number	Raja[52]
Cross-linking	Increase gelling power and water absorption, decrease gel cohesiveness and water solubility, reduce pasting and enzyme susceptibility and reduce swelling ability	Nabeshima and Grossmann[53], Jyothi *et al.*[54], Yussof *et al.*[55] and Tran *et al.*[56]
Bacterial and fungal lipases	Reduce enzyme susceptibility and increase onset temperature	Rajan *et al.*[57]
α -amylase of *Bacillus licheniformis*	Breaks granule into small particles; degradation of molecular components	Khatoon *et al.*[58]

Table 5: Effect of physical modification on cassava starch

Modifications	Effects	References
Blending with other starch	Reduce excessive cohesiveness	Karam *et al.*[59]
Thermal degradation	Liberates water molecules, amylose and amylopectin depolymerisation and carbonization reactions	Jankovic[60]
Annealing	Decrease swelling power and solubility, increase pasting properties, increase gelatinization and polymorph change	Gomes *et al.*[61] and Gomes *et al.*[62]
Heat-moisture treatment	Increase thermal stability and reduce swelling power and pasting viscosity	Klein *et al.*[63]
Microwave	Reduce pasting viscosity and rise in water solubility	Colman *et al.*[5] and Lan *et al.*[64]
Ultrasound	Increase swelling power and solubility and disruption of granules crystallinity	Manchun *et al.*[65]
Ball milling	Molecular structure breakdown, partial granule gelatinization, granule size reduction, glass transition temperature, reduce gelatinization temperature and rise in water absorption capacity	Che *et al.*[66], Huang *et al.*[67], Moraes *et al.*[68], Ren *et al.*[69], Sanguanpong *et al.*[42] and Zhang *et al.*[70]
Irradiation	Decrease swelling, viscosity and pasting and increase solubility	Bertolini *et al.*[71]
Pre-gelatinization by drum drying	Decrease apparent viscosity, increase swelling power, solubilization and water absorption	Perez-Sira and González-Parada[72]
Electric field modification	Decrease pasting viscosity and temperatures of gelatinization	Han *et al.*[73]

Madrigal *et al.*[78] observed that the plasticity of cassava starch amplified with decreased corn oil. According to these authors, hydrophilic-hydrophobic relationship between cassava starch and corn oil was responsible for the increased plasticity of cassava starch. Garcia *et al.*[79] examined the effect of whey protein concentrate on glass-transition temperature of cassava starch. The authors reported that glass-transition temperature of cassava starch reduced with the addition of whey protein concentrate, at constant moisture content. These authors note that a decrease in glass-transition temperature of cassava starch was due to more moisture being generated during the browning reactions in the cassava starch-whey protein blends. In a study on calorimetric glass-transition temperature of cassava starch as affected by sodium chloride, Farahnaky *et al.*[80] observed a decrease in the glass-transition temperature of cassava starch with the incorporation of sodium chloride.

Cassava native starch has been implicated in the production of starch foams. Nevertheless, cassava native starch foams have some restrictions and demerits which include reduced mechanical characteristics, frailty and increased water intake potential[81,82]. These demerits need to be extensively condensed so as to advance their quality and conceivably widen the functional application for starch foams. Starch foams primed from modified starch display enhanced perfunctory characteristics with an elevated water resistance compared to native starch foams[82,83]. Citric acid, glutaraldehyde, boric acid, glyoxal and epichlorohydrin are classical examples of chemical and reagents applicable for starch modification[84]. Among all the chemicals, citric acid seems to be better off as it is inexpensive and harmless[85,86]. Pornsuksomboon *et al.*[87] noted that blended foams of cassava native starch and citric acid modified cassava starch exhibit excellent water resistance potential coupled with good morphology in terms of cell size distribution.

SELECTED USES OF CASSAVA STARCH

Cassava pulp has been said to contain high quantity of starch. Cassava starch, together with certain acids, alcohols and oils can be used to preserve fruits, such as, mango and guava and can be hydrolyzed to glucose, which in turn could be utilized in the manufacture of chemicals, like ethanol, lactic acid and fumaric acid[88].

Sodium alginate and cassava starch have been utilized to conserve processed mangoes, hence stabilizing and enhancing the quality of mangoes[89]; higher lightness and failure stress as well as 41% reduction in respiration rate of the mango were observed, when a mango was coated with cassava starch with or without glycerol. The effect of cassava starch and cinnamon essential oil on physical, chemical and enzymatic properties of guava cv. 'Pedro Sato' has been studied by Botelho *et al.*[90]. These authors observed that the treatment of guava with cassava starch and cinnamon essential oil resulted in a reduction in mass and the preservation of the green color of the guava on the 8th day of storage as well as arise in soluble pectin content of the guava. Cassava starch has also been efficiently utilized for the manufacture of certain enzymes[91]. The optimization of amylolytic enzymes production in *Saccharomycopsis fibuligera* using cassava starch as a substrate was investigated by Gonzalez *et al.*[91] These authors reveal that glucoamylase and α-amylase production was greatly influenced by temperature, pH and oxygen saturation. A significant increase ($p<0.05$) in the production of α-amylase and glucoamylase which represents 9 and 3 fold increments, respectively, when compared to initial fermentation under non-optimal conditions, was also observed by the authors.

CONCLUSION

This review highlights different processing and modification methods applicable to cassava and their impacts on quality indices of cassava and its starch. The review discovered that supplementing cassava with other protein and essential micronutrients-rich agricultural products helps to improve its nutritional quality. Different types of processing methods have been applied to cassava tubers which are essential for the reduction of anti-nutrient (cyanogens) in cassava, to a safe level. Furthermore, the review revealed that quality of cassava native starch can be enhanced through diverse chemical, enzymatic and physical modification processes with a view of diversifying its use in the food industry. However, more research on the optimization of modification processes for cassava is required as it lacking in literature.

SIGNIFICANCE STATEMENTS

This study identifies the effect of selected processing and modification methods on quality of cassava. Processing methods such as baking, frying, fermentation, cooking and drying were observed to have significant effect on quality of cassava and its starch. The improvement of cassava native starch by chemical, enzymatic and physical modification methods can greatly help to enhance its functionality, structure and quality. Thus, diversification in industrial use of cassava starch may be achieved.

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