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Effect of Pretreatment on the Physicochemical, Technological and Glycemic Properties of Plantain (*Musa paradisiaca*) Flour: Review Paper

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ABSTRACT

Plantain is an important source of energy for many in sub-Saharan Africa. It is however highly perishable and its transformation to flour after drying helps prolong its shelf life. Drying has been associated with loss of nutrients and organoleptic quality such as color, texture and aroma. Diverse individual or combined pretreatment techniques have been largely used to improve the flour color, and texture, reduce drying time and nutrient loss during drying. There has been increasing attention on food processing methods, because food transformation can alter the nutritional, technological and physiological fate of food components. In this review, the various pretreatment techniques applied in production of plantain flour have been discussed. In addition, the impact on the nutritional, technological, properties of plantain were reviewed.

Key words: Plantain, pretreatment, Flour, Nutritional properties, technological properties

1. INTRODUCTION

Plantain, cultivated in over 120 countries in the tropical and sub-tropical countries constitute a major staple food for millions of families as well as providing a valued source of income for local and international trade [1]. Over 80% of plantain is harvested between September and February and there is much wastage at this time due to the short shelf life. This results in seasonal availability and limitations on the use by urban population. As such, it is processed into many products at different stages of physiological maturity; unripe, ripe, overripe or using a number of processing methods such as frying, grilling, boiling and drying for transformation into flour [2-3]. Amongst these products, flour is the most shelf-stable product due to the reduced water activity. The most commonly used drying method includes sun drying, convectional air drying, vacuum drying [4]. Drying method and processing conditions affect significantly the color, texture, nutritional content, density and porosity and sorption characteristics of the material. The product may end up completely different from raw material depending on the type of drying method and conditions applied [4-5]. However, consumers demand for processed foods that preserve their original properties. This sometimes requires the development of operations that minimize the adverse effects of food processing [6]. Many studies have been carried out to improve the physical and nutritional quality of the dried products. The application of blanching before drying fruits and vegetables has been frequently used to interrupt enzymatic activity, modify texture, preserve color, flavor and nutritional value and remove trapped air. Hot water and steam are the most commonly used heating media for blanching as pretreatment prior to the drying process [6-8]. However, some adverse effect on the macro as well as micronutrient content [1, 9-10] as well as affect the functional properties [11-12] have been observed due to leaching. Some studies have employed the sulphiting to minimize color degradation [13] or combined blanching and sulphiting [14] in plantain. However, sulfites may cause asthmatic reactions in a small portion of the asthmatic population [15].

Interestingly, OD as a pretreatment applied on many other food materials have been reported to be very efficient in obtaining nutritious products, and improve sensory and functional properties of food without changing its integrity [16 -19]. It is effective even at ambient temperature, so heat damage to texture, color and flavor of food is minimized hence, energy efficient and improves storage quality [20-21]. Literature on the use of osmotic dehydration as a pretreatment of plantain largely focuses on process kinetics [22-23] and structural change [24]). Furthermore, few studies were focused on the modeling of OD process [25-26]. [27] reported best pasting characteristics, water activity and moisture content (low) and least browning color for osmo-dehydrated plantain flour compared to the blanched sample. These different studies reported sucrose as osmotic agent used in the osmotic dehydration (OD) process with the use of ripe plantain. The resulting product may not be good for diabetics because the use of sucrose coupled with the high sugar content of ripe plantain may contribute in raising the glycemic index (GI) of food and consequently, blood sugar level.

Also, many research works have reported on the effect of processing technique on alteration in the starch fraction and digestibility and consequent glycemic properties of food products [28-30]. Interestingly, the impact of some treatment techniques on plantain on the digestibility, and control of blood sugar level has been reported by some authors [31-33]. Therefore, this review is aimed at highlighting the various pretreatment techniques that have been commonly used in the production of plantain flour and their impact on some of the properties of plantain flour.

2. Effect of pretreatment on the physicochemical properties of plantain

2.1 Effect of pretreatment on Nutrient composition of plantain flour

2.1.1 Moisture content

Research carried out by [34] revealed higher moisture content value of non-treated plantain flour than that of blanched (80°C for 10min), metabisulphite and combined blanched/ sodium metabisulphite flours. According to the author, this is probably because the unblanched ample was not subjected to any form of pretreatment which would speed up the rate of drying of food samples. On the contrary, [35] reported higher moisture values in blanched (100^{o}C for 10min) plantain flours (10.46-10.50) (peeled and unpeeled) than the unblanched samples (9.20-9.81%). Previous investigation by [26] subjected French and false horn plantain slices (10mm thick), to various pretreatments: citric acid (1% w/w) for 1 min, sodium metabisulphite (21g/l) for 1 min and steam blanching for 10 min. The study revealed higher moisture content in blanched samples for both the French and False Horn than non-treated, other pre-treated samples. The high moisture content in the blanched samples was associated to gelatinization of plantain starches, resulting in resistance to moisture migration from within the material to the surface during air-drying of the blanched samples. In addition, this correlated with low moisture diffusivity values (D_{eff}) for the blanched samples. Interestingly, this value was lower in blanched French Horn followed by citric acid treated, control and sodium metabisulphite compared to the false horn. This result corroborates with the findings of [35]. Generally, when starch or starch-based foods are heated in water beyond a critical temperature (characteristic of a particular starch), the granules absorb a large amount of water and swell to many times their original size and the starch undergoes an irreversible process known as gelatinization [12]. This critical temperature for plantain ranges between 75 - 81.95 ºC [12, 35-36]. Blanching at temperature lower the gelatinization temperature (60 °C for 10 min), [11] reported faster and higher moisture loss in blanched plantain samples than in the unblanched, and attributed it to increased permeability of cell walls due to blanching favoring faster water migration to the surface for easier dehydration. Thus, low moisture content for plantain flour blanched at temperature above the gelatinization temperature is a strange observation which needs to be looked into.

2.1.2. Carbohydrate content

Result obtained from studies by [34] revealed decreased crude fibre content in pretreated samples; blanched/Sodium metabisulphite flour (1.10 %) and sodium metabisulphite flour (1.25 %) relative to the unblanched plantain flour (2.09 %). Also, there was observed decrease in total carbohydrate content in blanched plantain flour (77.4 %), blanched/sodium metabisulpnite flour (74.64 %) compared to the unblanched plantain flour (78.1 %). This decrease carbohydrate was attributed to decrease fiber resulting from slight break down of the high-molecular weight polymer structure consequence of the blanching process. Only the sodium metabisulphite treated flour had higher carbohydrate content (80.80 %). On their part, [35] observed increase carbohydrate content in blanched plantain samples. The observed increase was associated with increase fiber content due to blanching treatment, because of lose in soluble components [37-38] found significantly high ($p<0.05$) amylose content after 5 min blanching at 100°C (23.11) and least after 10min (19.62%) compared to the control (22.31%). Increased amylose content with increased temperature has been reported in chestnut [39]. This suggests change in starch conformation. The decrease after a long duration at high temperature could be due to swelling and bursting of starch granules followed by release into the blanching medium.

2.1.3. Protein content

There have been reports of low protein contents in unblanched plantain flour (5.15%) and higher protein content (8.10%) in sodium metabisulphite pretreated plantain flour [34]. The higher protein content reported was attributed to lose of catalytic activity of proteases (which hydrolyze peptide bonds of proteins) which was very present and active in the unblanched flour [40]. [35] obtained results of decreased protein contents in blanched plantain flour samples. The decreased protein content was attributed to leaching of the water-soluble nutrients such as protein during the process. Given that proteins are water soluble substances and the high temperature at which the blanching processes were carried (80-100°C for 10min) it is possible to witness leaching. However, the possibility of protease activity in unblanched plantain flour even after drying at 60 for 24h as is the case here is low given that enzymes are destroyed at that temperature.

2.1.4. Lipid content

[34] reported none significant difference in percentage fat between the blanched and

unblanched (2.42%) plantain flour. However, the combined pretreatment of blanching/Sodium metabisulphite (3.82%) and Sodium metabisulphite (3.75%) resulted in flour with increase lipid content. This high fat content in the flour samples could be attributed to the low moisture contents reported by the author following the various pretreatments. The authors explained that the high fat content of the flour makes the flours prone to be to rancidity and could impact negatively on storage stability.

2.1.5. Mineral content

Findings by [9] showed unblanched plantain flour samples had higher iron content (1.18 to 1.25 mg/100g) and richer in calcium (4.23 to 4.34) compared to blanched (60°C for 10 min) flour samples (iron content 1.09 - 1.16 mg/100g and calcium 3.33 - 3.35 mg/100g). The results also revealed significant decrease in potassium content with blanching. On the other hand, blanching pretreatment on the plantain improved the phosphorus and zinc contents of the blanched samples (13.03 and 0.31mg/100g respectively) compared to the unblanched (10.07 and 0.25 mg/100g). Similar results of decreased calcium, iron and potassium contents in blanched plantain flours (both peeled and unpeeled blanched) were obtained by [35]. The findings as well revealed decreased sodium, zinc and magnesium content in blanched samples. This mineral reduction could be attributed to hot water blanching process which enhances leaching of minerals via dissolution into water. On the other hand, thermal processing (blanching) could facilitate the rupture of bonds linking certain mineral ions to food constituent hence increasing their bioavailability.

2.2. Effect of pretreatment on phytochemical composition of plantain

Phytochemicals are secondary metabolites produced by plants [41]. Their presence in plant gives it its medicinal value and produce physiological action in human body. Their concentrations in plant structures, vary depending on the genetic, environmental, pre- and post-harvest treatments and analytical methodologies [42].

Research works by [43-44] reported significant quantities of phytochemicals in unripe plantain flour including saponins, flavonoids, alkaloids and tannins. This was confirmed by [45] indicating these polyphenol compounds in plantain. Qualitative and quantitative analysis by [31] revealed major phenolic compounds in varied quantities for different unripe plantain products. The study showed that the raw flour contained the highest quantity of apigenin, myricetin, luteolin, capsaicin, and isorhaemnetin. The boiled elastic paste flour contained the highest quantity of caffeic acid while the roasted flour had highest quantity of kampferol and quercetin and boiled flour the highest quantity of p-hydroxybenzoic acid, shogaol, glycitein and gingerol.

Boiled plantain samples had higher extractable polyphenols (EPP) levels (Unripe Unboiled: 5.74, Unripe boiled 6.46 mg/g; Fully ripe unboiled: 2.84 mg/g, fully ripe boiled 4.16) than the raw fully ripe samples (dry sample) [44]. Noteworthy is the fact that samples boiled with the peel had significantly higher values of EPP and hydrolysable polyphenol (HPP). The increase soluble polyphenols in the boiled samples were attributed to alterations in chemical structure/composition, causing them to be more readily detected in the supernatants of the extract. On the other hand, the higher hydrolysable polyphenols contents in almost all the processed samples were attributed to the heat effect of boiling which breaks hydrogen bonds between the hydroxyl groups on the polyphenol and the oxygen atoms of the sugar in the polysaccharide cell wall liberating polyphenols.

Also, significant decrease in total polyphenol content (TPC) was observed in blanched plantain flour samples (10.50 to 20.00 µgGAE/100g) compared to that of unblanched flour samples (25.50 to 30.00 µgGAE/100g) [9]. [35] made similar observation while investigating the impact of blanching on polyphenol content in plantain. The authors reported 1.48±0.01 (peeled unblanched) to 2.69±0.06 (unpeeled unblanched) while the value was 1.25 mg/g (peeled blanched) and 2.45 (unpeeled blanched) plantain flour samples. The tannin content varied between 8.50±0.07 (peeled unblanched) and 8.20±0.04 (peeled blanched) but were observed to be 10.95±0.50 (unpeeled unblanched) and 10.55±0.02mg/g for the unpeeled blanched flour. Flour from peeled, blanched plantain (PBF) thus, had the least values while flour from unpeeled, unblanched plantain (UUF) had the higher values. The reduction observed was attributed to the degradation of phenolic compounds by heat or it's leaching out from plantain slices into the blanching water. [46] made similar observation reported that some phenolic compounds are known to be insoluble and in combination with plant cell wall components. They explained that during blanching (heat application), disruption of the cell wall of the plant occurs leading to leaching of the soluble phenolic compounds.

Table 1: Phenolics content as affected by processing techniques of plantain (mg/100 g).

Polyphenols	Raw	Boiled/dried	Roasted	Boiled	Blanched	Authors
Shogaol	$8.39x10^{-3}$	$4.58x10^{-3}$	$4.81x10^{-3}$	5.18		[31]
Glycitein	$1.02x10^{-3}$	$3.50x10^{-3}$	$3.60x10^{-3}$	4.03		
Gingerol	$2.00x10^{-2}$	$1.20x10^{-2}$	1.00x10	14.38		
Caffeic acid	$1.82x10^{-1}$	1.48	$1.52x10^{-3}$	$1.61x10^{-2}$		
Apigenine	4.29	1.62	2.89	$1.84x10^{-3}$		
Kaempferol	3.83	3.32	4.86	$3.88x10^{-3}$		
Myricetin	4.74	3.13	2.91	$1.41x10^{-2}$		
Luteolin	6.63	$5.73x10^{-3}$	1.61	$1.03x10^{-2}$		
Capsaicin	16.61	$1.46x10^{-2}$	12.13	$1.71x10^{-2}$		
Quercetin	$7.82x10^{-3}$	$6.89x10^{-3}$	4.88	$8.07x10^{-3}$		
Isorhamnetin	$7.82x10^{-3}$	$6.38x10^{-3}$	4.16	$7.84x10^{-3}$		
Total polyphenol	0.026-0.030				10.50-20.00	[9]
	148 - 269				1.25 - 2.45	[35]
Tannin	8.50 – 10.95				8.20 -10.55	[35]

2.3. Effect of processing on Antioxidant activity of plantain

According to [47], aqueous extracts of boiled and raw unripe plantain ("False Horn") flours exhibited hydroxyl (OH·) and DPPH radical scavenging activity in a dose-dependent manner. However, boiled extract had the highest OH· and DPPH scavenging ability considering the very low EC_{50} values of 4.35 and 24.76 respectively. According to the researchers, the DPPH radical scavenging ability exhibited by the boiled flour correlates with its high quantity of P-hydroxybenzoic acid content which has been reported to exert antifungal, antimutagenic, anti-sickling, and antimicrobial activities. However, the raw unripe extract had the highest Fe^{2+} chelating ability and inhibitory effect on lipid peroxidation in isolated pancreas tissues. Both correlated with the vitamin C content of the flour. On their part, [44] reported a positive correlation between antioxidant capacity and extractable polyphenol content in plantain flour. In addition, they observed increased radical scavenging capacities for the boiled samples of unripe plantains (unripe raw 67µg/ml, and unripe boiled 56µg/ml) while marked increase in free radical scavenging capacity for the ripe plantains was only observed in the boiled with peel (ripe boiled 59µg/ml) sample.

In vitro study by [31] on the antioxidant potential of aqueous extracts of unripe plantain (Raw flour and 'amala' flour) revealed that the 'amala' flour extract (boiled plantain flour paste extract) had higher DPPH scavenging ability than the raw flour extract correlating with the phenolic content. On the other hand, the raw flour extract demonstrated greater Fe^{2+} chelating ability (EC50=6.10 mg/mL) and $OH^{\bullet}$

radical scavenging ability (EC50= 4.92 mg/mL) than the 'amala' flour extract. This high Fe^{2+} chelating, OH• radical-scavenging ability and DPPH free radical-scavenging activity are of immense importance in the protective ability of antioxidant phytochemicals against oxidative stress. This shows heat application helped in unleashing polypnemol hence enhancing DPPH scavenging activity but reduced Fe^{2+} chelating and OH• radical-scavenging ability probably due to loss of vital components during boiling of the plantain to obtain amala flour.

With respect to application of blanching process, [9] reported higher chelating ability and FRAP in unblanched plantain flour samples than the blanched samples. The low chelating ability of the blanched flours was attributed to reduction of some metals by leaching during blanching. On the other hand, there was no significant effect of blanching on the DPPH scavenging ability of flour samples.

2.4. Influence of pretreatment on structural changes of plantain

Osmotic dehydration carried out at 80°C gave least moisture loss due to gelatinization of starch which prevented out flow of water [24]. This was attributed to starch swelling in inter-mycelium amorphous areas, which are less organized due to water absorption, resulting to reduced water outlet. In addition, the rapid impregnation of tissues leads to structural changes at cellular level with an increase in true density (ρ*b*), a reduction in porosity (ε) and consequently, reduction in pore diameter. The same phenomenon was reported by [12] during blanching process of plantain. The authors explained that, when starch or starch-based foods are heated in water beyond a critical temperature (characteristic of a particular starch), the granules absorb a large amount of water and swell to many times their original size and the starch undergoes an irreversible process known as gelatinization. This impedes water loss during subsequent drying and contributes to high moisture in plantain flours blanched at high temperature (75 - 81.95 ºC). On the other hand, [11] reported that blanching plantain slices at low temperature (60°C for 10min) brought about changes in the cell structure that enhanced permeability of cell walls due to favoring faster water migration to the surface for easier dehydration.

3. Effect of pretreatment on functional properties of plantain flour

The functional properties of foods and flours are influenced by the components of the food material, especially the carbohydrates, proteins, fats and oils, moisture, fiber, ash, and other ingredients or food additives, such as sugar alcohols [48], as well as the structures of these components. Some of the important functional properties that influence the utility of most starchy staples include the drying characteristics, water absorption capacity, emulsion capacity, oil absorption capacity, whipability, foam stability, viscosity, and swelling capacity. The functional properties determine the applications and uses of food materials for various food products. Most of the process foods undergo initiate the onset of some functional properties. This section of the review focused on the common functional properties evaluated in plantain flour and the links between the functional properties and process technique and flour components such as starch, protein, fats and oils, moisture, sugars.

3.1. Emulsion capacity (EC)

Emulsion capacity (EC), of foods is associated with the amount of oil, non-polar amino acids residues on the surface of protein, water, and other components in the food [48]. [49] found the EC of the blanched samples (hot water and ash infusion and blanched with peels) to be lower than that of the unblanched sample. Also, [11] reported lower values of emulsion capacity and stability in blanched compared to the unblanched samples of plantains and equally stated that this effect increased with blanching temperature and time and associated the observation to the heat of blanching. [48] explained that an increase number of non-polar amino acids residues on the surface of protein will reduce the energy barrier to adsorptions which depends on the protein structure. Thus, it can be said that blanching reduces the protein content of blanched samples via leaching and consequently EC of flours.

3.2. Foaming capacity

The foaming capacity of a food or flour is measured as the amount of interfacial area created by whipping the food or flour. Good foam capacity and stability are desired attributes for flours intended for use in the production of various baked products such as angel cakes, muffins, *akara*, cookies, etc. [48]. [49] reported significantly high value of foaming capacity of unblanched plantain flour (3.91%) relative to the blanched (hot water without peel; 0.98% and ash infusion 2.70%). [48] pointed out that protein is mainly responsible for foaming and explained that foaming capacity and stability generally depend on the interfacial film formed by the proteins, which maintains the suspension of air bubbles and slows down the coalescence rate. [50] reported that foaming increased progressively with increase in protein concentrates of wheat / plantain flour enriched with bambara groundnut protein concentrate. It therefore implies the low FC observed in blanched samples are related to decrease protein content which can be attributed to leaching during the blenching process.

3.3. Swelling capacity

The swelling capacity is the measure of the starch ability to absorb water and swell, and also reflects the extent of associative forces in the starch granules. Swelling capacity is regarded as quality criterion in so many formulations such as bakery products [48]. [51] explained that flours with low swelling power have slow rates of digestion and consequently recommended for control of blood glucose. According to [52], high swelling capacity values are associated with higher starch content whose complex molecule will demand more water during hydrolysis than foods or flours with lower starch contents. Investigating the effect of different pre-treatments on the functional properties of unripe mature green horn plantain flour [53] reported reduced swelling capacity with blanching, Citric acid, Potassium metabisulphite pretreatments However, they reported a corresponding increase value in the blanching/Citric and blanching/Potassium metabisulphite compared to the none-treated. Similar observations were made by [12, 34-35]. The difference in swelling power observed amongst the flour samples could be due to internal arrangement of the starch granules. [11] explained that blanching causes the structure of the flour to become firmer, due to retro-gradation thus reducing its capacity to absorb water compared to the unblanched flour.

3.4. Water absorption capacity (WAC)

Water absorption capacity (WAC), is the amount of water taken up by food/flour to achieve the desirable consistency and create quality food product. Very low or excessive water absorption can negatively affect the quality of food products [48]. The hydration process is achieved when molecules of starch and protein create hydrophilic interactions and hydrogen bonds with water molecules. The water absorption capacity is important in the formulation of ready to eat foods and highwater absorption capacity may assure product cohesiveness [54]. Assessing the effect of temperature and blanching time on the functional properties of flour obtained from plantain (Musa AAB), [53] observed higher WAC in all pretreated sample (Citric acid, Potassium metabisulphite, Blanching and

Citric acid, Blanching/Potassium metabisulphite) compared to the untreated plantain flour. Also, research study by [34] on the effects of pre-treatment on the proximate composition and functional properties of plantain flour revealed lower water absorption capacity for the unblanched plantain flour (220%) compared to the all pretreated samples; blanched (310%), blanching/sodium metabisulphite (320%) and Sodium metabisulphite (340%). On the contrary, [11, 35, 49] reported higher water absorption capacity values for unblanched than blanched flour samples of plantain. [11] attributed this phenomenon to some thin cell membranes rupture during blanching that facilitated partial gelatinization of starch granules. They further explained that starch gelatinization was enhanced by hot air drying resulting in decrease water binding capacity. According to [55] high water absorption capacity of flours is attributed to the difference starch granules of the flours and to the presence of greater number of hydrophilic constituents like soluble fiber and lower amount of fat content in plantain flour which are normally leached out during blanching. While [3, 52] associates high values to the amount and nature of the hydrophilic constituents. Thus, the high WAC of the pretreated samples can be attributed to high amounts of hydrophilic constituents with a complex molecule that demand more water during hydrolysis. [12] however, reported no significant differences in WAC of the control and blanched samples ($P > 0.05$) except for samples blanched at 60°C which recorded lower values. Thus, the blanching time, and temperature associated with variations in amount and nature of hydrophilic constituents in different varieties could be the origin of divergence observed on the effect of blanching on WAC.

3.5. Oil absorption capacity (OAC)

According to [56], good oil absorption capacity of flour samples suggest that they may be useful in food preparations that involve oil mixing like in bakery products, where oil is an important ingredient. Absorption of oil by food products improves mouth feel and flavor retention of a product. Assessing the effect of temperature and blanching time on the functional properties of plantain flour, [12] indicated that, blanching time did not have any significant difference in oil absorption capacity at each chosen temperature compared to the control (unblanched). On their part, [53] indicated there was no significant difference in OAC between blanched and unblanched samples but observed increased value as a result of Citric acid, Potassium metabisulphite, blanching/Citric acid, blanching /Potassium metabisulphite pretreatments. High oil absorption capacity could suggest the presence of a large proportion of hydrophobic groups as compared with the hydrophilic groups on the surface of protein molecules [55]. This implies Citric acid, Potassium metabisulphite, blanching/Citric acid, blanching/Potassium metabisulphite pretreatments enhanced the exposure of hydrophobic constituents on proteins compared to simple blanching. [11] and [49] reported higher oil absorption capacities in unblanched plantain flour samples than the blanched. The mechanism of fat absorption is attributed mainly to the physical entrapment of oil and the binding of fat to a polar chain of the protein [57]. According to [58], oil absorption capacity in starchy food materials rely predominantly on physical entrapment of oil within the starch structure as starch does not possess sites compared to those found on proteins. Thus, a more organized starch structure in the unblanched appears to entrap lipid better than the disorganized structure in blanched sample due to thermal effect. Consequently, the duration of blanching and the operating temperature may result in varied effect on OAC.

3.6. Bulk density

Significant difference in bulk density of untreated (control) and pretreated plantain flour samples (Citric acid, Potassium metabisulphite. blanching/Citric acid, and blanching/Potassium metabisulphite) [53]. However, there was a significant reduction in bulk density following blanching pretreatment. Similarly, [12, 34-35] reported higher BD values for unblanched plantain flour (0.77g/ml, 0.420 g/ml and 0.53 g/ml respectively) as opposed to the blanched plantain flour (0.67, 0.140 and 0.51 g/ml respectively). On the contrary, [11] reported increased bulk density for blanched unripe plantain flour sample compared to the control (unblanched). [19] explained that lower values of bulk density during drying are indicators of lower shrinkage and better retention of textural properties.

Bulk density is controlled by a number of factors including starch content, the geometry of particles, particle size, method of measurement as well as the initial moisture content of the flour. Thus, variations in bulk density of flour samples as observed by the different research could be as due to the variation in any of the above-mentioned factors not detailed in the studies. Higher starch content has been attributed to increase in bulk density. Bulk density can be improved when the particles are smaller, and properly tapped/vibrated [48].

3.7. Wettability

Wettability is a function of the ease of dispersion with respect to the displacement in the water of the sample. The sample with lowest wettability time would dissolve in the water more rapidly than samples with higher wettability [59]. According to [60], a powder is considered wettable if its wettability time is less than 60s and very wettable if it is less than 30s. [53] revealed no significant difference in the wettability of blanched, citric acid and Potassium metabisulphite pretreated plantain flours (1.34min) with an observed increase in the parameter in the blanched/Citric acid and blanched/potassium metabisulphite pretreated flours (2.34min). Thus, single pretreatment techniques improve on the ability of the plantain flour to dissolve wettatbility and may be very essential for the production of instant plantain flour important for infant formulas.

4. Effect of pretreatment on glycemic properties of plantain

There has been increasing attention on food processing methods, because food transformation can alter the physiological fate of food components. Given the central role of food processing in food production, processed foods have become a major part of our daily diets. Food starch is derived from cereals, tubers, legumes and fruits like plantain and bananas and constitutes our major daily source of carbohydrates and energy intake. Research works by [61] reported on the influence of processing on the starch fraction and digestibility in wheat flour. [28], on their part reported on the impact of processing methods (drying, fermentation, boiling and steaming) on starch hydrolysis, digestibility, absorption and glycaemic index (GI) of cassava based traditional food. This section of the review is aimed at searching information available on the impact of pretreatment techniques on the glycemic properties of plantain.

In vitro study by [47] revealed that aqueous extracts of unripe plantain (Raw flour and ‘amala’ flour) inhibited α-amylase and α-glucosidase activity in a dose dependent manner. However, the ‘amala’ flour extract had higher inhibitory activity on both enzymes than the raw flour extract with EC_{50} (extract concentration causing 50% enzyme inhibition) values (6.81±0.95 and 7.44±0.60 on α-amylase) and (4.10±7.17 and 6.55±4.09 on α-glucosidase). [62] explains that inhibition of α-amylase and α-glucosidase is a pointer to the anti-diabetic potentials of unripe plantains, by slowing down the breakdown of starch and disaccharide to simple glucose, hence reducing the amount of glucose absorbed in the blood.

On the other hand, [33] reported significant reduction in blood glucose levels in Alloxan-Induced diabetic Wistar Rats when given dried, boiled and roasted unripe plantain extracts respectively (boiled 3.25, roasted 12.82, dried 9.32mmol/L). Thus, the boiled plantain extract had the highest hypoglycemic effect while the roasted extract had the least; thus, confirming the ability of unripe plantain to ameliorate hyperglycemia. According to the authors, this indicated moist heating improves the strength of the food substance to enhance the effect of hyperglycemia than drying.

5. CONCLUSION

This review focused on various pretreatment techniques employed in the processing of plantain to flour. Blanching, sulphiting, boiling and parboiling pretreatment have been used in the processing of plantain to flour. The use of combined pretreatment techniques has as well been reported. Generally, these techniques improve the sensory quality (color and flavor), and reduce energy consumption during drying. However, reports on their effects on the nutritional, technological, phyto-chemical, antioxidant activity and digestibility vary. The application of osmotic dehydration pretreatment on plantain has been essentially on the kinetics with very minimal information on the optimization, and modeling of the process. On the other hand, sucrose has been the main osmotic dehydrating agent employed with the raw material been ripe plantain. Furthermore, studies on OD were limited at obtaining plantain chips, whereas information on the suitability of the process for flour production, its influence on nutritional, phytochemical and technological properties and physiological fate are rare in literature. This can result in product with improved properties as well as ameliorate their nutritional quality. As such, this brief review highlighted the various pretreatment used in processing of plantain to initiate further work in developing benchmarks for specific plantain flour for specific end usage.

6. Suggestions for future work

With regard to the pretreatment of plantain for flour production, the increasing demand for more specific methods of processing that are tailored to meet specific end-usage demands the use of alternative osmotic dehydrating agents with low caloric value, the modeling and optimization of the process. It is also essential that OD and its impact on the nutritional, technological and physiological impact be considered. Non-thermal methods like OD have attracted considerable attention recently for maintaining a balance between quality and shelf life of dehydrated products thus more systematic research is required to fully utilize the potential of OD for novel plantain flour destined for specific end-use.

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