Effect of Alkaline Soaking and Cooking on the Proximate, Functional and Some Anti-Nutritional Properties of Sorghum Flour

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Abstract

The effect of nixtamalization on the functional, proximate, and anti-nutritional properties of sorghum flour was studied. Flour samples were produced from soaked sorghum grains and cooked sorghum grains. A portion of sorghum grains were soaked in water and 1% lime solution for 24 hours and some were cooked for 30 minutes in both water and 1% lime solution. At the end of soaking and cooking, the grains were sundried; milled; sieved with a 0.25 mesh screen; and packaged. Alkaline cooking of sorghum resulted in flour with significantly higher protein; water and oil absorption capacity; pH; hygroscopicity; phytate and trypsin inhibitor and significantly lower ash; tannins and cyanide content than flours from untreated and water treated sorghums, while alkaline soaking resulted in flour with significantly higher carbohydrate; water and oil absorption capacity; and pH and significantly lower packed bulk density and hydrogen cyanide than flours from untreated and water treated sorghum.

Keywords: *Nixtamalization, functional properties, anti-nutritional properties, soaking, cooking.*

Introduction

Nixtamalization refers to a process of preparing maize (corn) in which the grain is cooked and soaked in alkaline solution, usually lime solution, and then dehulled (Ocheme *et al*. 2010). The term 'nixtamalization' also refers to the removal of the pericarp from any grain using an alkaline process. The basic process begins by cooking whole grains in water with lime and steeping the cooked grains for 12-16 hrs in large tanks. The steeped grain is called 'nixtamal' and the cooked steep liquid, rich in maize solids, is called 'nejayote' (Sahai *et al*. 2000).The process of nixtamalization is popular in Mexico and Central America and has been applied to corn for centuries (Bressani *et al.* 1990). Grains subjected to nixtamalization process have several benefits over unprocessed grains for food preparation: they are more easily ground; their nutritional value is increased; flavour and aroma are improved and mycotoxins are reduced (Sefa-Dedeh *et al.* 2003). These benefits make nixtamalization a crucial preliminary step for further processing of grains into food products. Unleavened bread (tortilla) is a common food in central and South America produced from sorghum cooked in lime solution (Asiedu 1989). In nixtamalization, dried cereal grains are cooked in an alkaline solution at or near its boiling point. After cooking, the grains are steeped in the cook liquor for a length of time. Cooking and soaking varies according to local tradition and type of food to be prepared. During cooking a number of chemical changes take place in the grains: the kernels soften and their pericarp loosen causing the plant cell wall including hemicelluloses and pectin to become soluble; the grain is hydrated and absorbs the alkali used from the cooking solution; starches swell and gelatinize and some disperse into the liquid. After steeping, the alkaline liquid (*nejayote*) containing dissolved components of the maize, is discarded. The kernels are washed thoroughly of the remaining *nejayote* which has an unpleasant flavour (Wacher 2003). The kernels are then dehulled to remove the pericarp and the germ. The grain is called *nixtamal* and it has many uses contemporarily and historically. Whole *nixtamal* may be used fresh or dried for later use.

Sorghum is a popular grain in many areas of Africa. Sorghum grains serve as an ingredient for many unique indigenous foods and beverages. Food preparation methods generally differ from region to region. A porridge or stiff paste, a basic diet in most of east Africa, is prepared by adding pounded flour to hot water. In Ethiopia and Sudan sorghum flour may be made into a flat cake or the grain may be popped or boiled whole. In West Africa, sorghum is used to prepare many foods. In Nigeria, particularly in the northern region, it is utilized mainly in the preparation of *tuwo* - a thick dough prepared by mixing sorghum flour in hot water and allowing the paste to cool and gelatinize which is then eaten with soup. *Akamu, koko* or *pap* is prepared by soaking the grains in cold water, milling and filtering through a cloth and the expressed mass is reconstituted in cold water after which boiling water is added to it. Sorghum beer is very popular. It may be drunk as *burukutu* - an alcoholic gruel; or as *pito* when the sediment is removed. In most parts of Asia, particularly India, sorghum grain is ground, made into dough and baked as flat unleavened bread. Preparation of sorghum flour is influenced by grain type. Traditionally, grains are usually ground using a milling stone and the flour is mixed with cassava or sweet potato to make a palatable food. The grain may also be malted by soaking in water, mixing with ash and germinating. It maybe pounded to remove the radicle and then dried. The soaking removes some anti-nutritional factors and germination results in production of sugar so that a sweet porridge is made.

This research work is aimed at investigating the effect of soaking and cooking sorghum in lime solution (nixtamalization) on the proximate, functional and anti-nutritional factors of sorghum flour with a view to improving food products derived from sorghum flour.

Materials and Methods

Sorghum (*Sorghum bicolor*) grains were purchased from Minna Central Market, Minna, Niger State, Nigeria. Analysis of functional properties and proximate composition took place in the Food Science and Nutrition Laboratory, Federal University of Technology, Minna while analysis of anti-nutritional factors were carried out at the Root and Tuber Crops Research Institute, Umudike, Abia State, Nigeria.

Preparation of Samples

Sorghum grains were manually cleaned to remove husk, stems, damaged and discoloured seeds. This was achieved by winnowing, hand picking and washing with tap water after which they were dried in a hot air oven at a temperature of 60^{o}C for 90 min.

Preparation of Untreated Sorghum Flour

400g of sorghum grains were dry milled, using a disc attrition mill and then sieved using a 0.25mm mesh screen. The flour was then packaged in a white high density polyethylene bag and stored in the refrigerator at a temperature of 4^{o}C.

Preparation of Flour from Soaked Sorghum Grains

400g of sorghum grains were soaked in 2000ml of 1% lime solution while another 400g was soaked in tap water for 24h after which the grains were thoroughly washed with tap water and drained. The grains were then dried in a hot air oven at a temperature of 60^{o}C for 90 min. The grains were dry milled using a disc attrition mill after which they were sieved using a 0.25mm mesh screen. Both flours were then packaged using a white high density polyethylene bag and stored in a refrigerator at a temperature of 4^{o}C.

Preparation of Flour from Cooked Sorghum Grains

Four hundred grams of sorghum grains were boiled/cooked in 2000ml of 1% lime solution while another 400g was boiled/cooked in tap water for 30min after which they were steeped in plastic containers for 24h. After steeping, the grains were thoroughly washed to remove the pericarp. They were then dried in a hot air oven at 60^{o}C for 90min and then dry milled using a disc attrition mill. Both flours were sieved using a 0.25mm mesh screen and then packaged in white high density polyethylene bag and stored in a refrigerator at a temperature of 4°C.

Analysis of Functional Properties

The loose and packed bulk densities of the flours were determined using the methods described by Akpapunam and Markakis (1981) and Okaka and Potter (1979) respectively. The oil and water absorption capacities were determined using the methods described by Okezie and Bello (1988). The hygroscopicity and swelling power were determined using the procedures of Bhatty (1988) and Ooraikul and Moledina (1981) respectively. The emulsion capacity and stability of the flours were determined using the method of Yatsumatsu *et al*. (1972).

Analysis of Proximate Composition

The moisture, ether extract, crude protein, crude fibre, ash, carbohydrate and pH values of the flours were all determined using the method of AOAC (2000).

Analysis of Anti-nutritional Factors

The trypsin inhibitor and cyanogenic glucoside (hydrogen cyanide) contents of the flours were determined using the method described by AOAC (1990) while the tannin and phytate contents were determined using the method of Pearson (1976).

Statistical Analysis

All determinations were carried out in triplicates and the means were subjected to one-way analysis of variance by means of MINITAB 14 statistical software.

Results and Discussion

Table 1 shows the proximate composition of sorghum flours. The protein content ranged from 15.99% to 21.69% with flour from sorghum soaked in lime having the lowest value and flour from sorghum cooked in lime having the highest value. Lime treatments significantly ($p<0.05$) increased the protein content. Bressani and Scrimshaw (1958) reported small increase in nitrogen content of *nixtamals* which was attributed to a concentration effect. Gomez *et al.* (1987) and Serna Saldivar *et al*. (1987), reported an increase an increase in protein when alkaline cooked corn products were compared to original grain. Fat content values ranged from 7.48 to 12.45% with the control sample having the lowest value and flour from sorghum soaked in water having the highest. Lime treatment did not significantly ($p>0.05$) increase the fat content. Ash values ranged from 1.13 to 3.39% with flour from sorghum cooked in water having the lowest value and flour from the untreated sorghum having the highest values. Lime treatments significantly ($p<0.05$) decreased the ash contents. This may be due to the nixtamalization process which removes the seed coat of the grain in which the inorganic materials are concentrated. It may also be due to leaching of the inorganic elements into the soaking or cooking medium. Crude fibre values ranged from 4.82 to 10.18% with flour from untreated sorghum grains having the lowest value and flour from sorghum grains cooked in water having the highest value. Lime treatment significantly ($p<0.05$) increased the crude fibre content of the sample. This may be because the soaking and boiling operations caused some interactions between other components of the grain thereby increasing the crude fibre content of the flour sample. Carbohydrate values ranged from 57.03 to 64.52% with flour from sorghum cooked in water having the lowest value and flour from untreated sorghum having the highest value. The carbohydrate content was significantly ($p<0.05$) decreased by soaking in lime solution. The variation in the carbohydrate contents of the flours is probably due to the increases and decreases that took place in the other components of the flours as a consequence of the processing variables. Since carbohydrate values are obtained by difference it means its values depend on factors responsible for the values of other components. Table 2 shows the results of the functional properties of sorghum flours. The water absorption capacity values ranged from 2.94 to 4.76g/g with flour from untreated sorghum having the lowest value and flour from sorghum soaked in lime having the highest value. Lime treatments significantly ($p<0.05$) increased the water absorption of the flours. Water absorption gives an indication of the amount of water available for gelatinization. The different trends observed in water absorption of lime treated flours could be attributed to the effect of gelatinization as well as Ca^{2+} and OH^- starch interactions (Sefah Dedeh *et al.* 2003). It may also be due to larger pore spaces in the structure of the carbohydrates (starches) of the lime treated samples than that of the untreated and water treated samples. Oil absorption values ranged from 1.33 to 2.34g/g with flour from untreated sorghum having the lowest value and flour from sorghum cooked in lime having the highest value. Lime soaking and cooking significantly ($p<0.05$) increased the oil absorption capacity. The ability of flours to absorb oil may help to enhance sensory properties such as flavor retention and mouth feel given that fats and oils contribute to satiety value of foods. The differences observed might be due to the effect of lime absorption on oil of flours. Packed bulk density values ranged from $0.63g/cm^3$ to 0.73g/g with flour from untreated sorghum having the highest value and flour from sorghum soaked in lime solution having the lowest value. Loose bulk density values ranged from $0.50g/cm^3$ to $0.57g/cm^3$ with sorghum cooked in lime having the highest and sorghum soaked in water and lime respectively having the lowest values. Lime soaking significantly ($p<0.05$) decreased the packed bulk density. The density of particulate materials (especially flours) under mixing, storage, packaging and transportation is an important functional parameter in the processing of flours into different products. The low values observed in lime treated samples indicate that more of the flour will be needed to yield a particular consistency relative to that with a higher bulk density. This will translate into more nutrients for the consumer. pH values ranged from 6.36 to 10.10 with flour from sorghum cooked in lime having the highest value and flour from sorghum soaked in lime having least value. Lime soaking and cooking significantly ($p<0.05$) increased the pH (lowered acidity) of the flour sample. The increase in pH values of lime treated samples is probably due to absorption and retention of lime by the soaked and cooked grains given that lime is alkaline, its absorption and retention in a food system will result in a higher pH (low acidity). The pH of flours is an important parameter which affects flavour and shelf life of products. The lower the pH of a product the better it keeps. This implies that nixtamalized products may not keep well compared with non-nixtamalized products. The emulsion capacity values ranged from 18.00% to 26.50% with flour from untreated sorghum having the lowest value and flour from sorghum soaked in lime having the highest value. Emulsion stability values ranged from 19.5 to 26.5% with flour from untreated sorghum having lowest value and flour from sorghum cooked in water having the highest value. Lime soaking significantly ($p<0.05$) increased the emulsion capacity and stability of the flour samples while lime cooking significantly ($p<0.05$) increased emulsion capacity only. This increase may be due to the concentration and solubility of the proteins. Achinewhu (1983) stated that the efficiency of emulsion by flour varies with concentration and solubility of protein. This increase implies that nixtamalized products may be more easily incorporated into oil-water mixtures. Hygroscopicity values ranged from 19.00% to 40.00% with flour from untreated sorghum having the lowest value and flour from sorghum cooked in lime having the highest value. Lime soaking and cooking significantly ($p<0.05$) increased the hygroscopicity of the flour samples. This increase may be due to the same reasons that caused the nixtamalized flour samples to have relatively higher water absorption capacity. Given the nixtamalized flour samples' affinity for water and their high pH values (low acidity), they may be more prone to spoilage than the unnixtamalized flour samples. Swelling power values ranged from 2.55 to 8.66g/g with flour from untreated sorghum having the lowest value and flour from sorghum cooked in water having the highest value. Both lime soaking and cooking significantly ($p<0.05$) increased the swelling power of the flour samples just like water-soaking and water-cooking did.

Table 3 shows the results of the anti-nutritional factors of sorghum flours. Phytate content ranged from 43.45 mg/100g to 112.10 mg/100g with flour sorghum cooked in lime having the highest value and flour from sorghum cooked in water having the lowest value. Lime soaking significantly (p<0.05) decreased the phytate content but lime cooking significantly (p<0.05) increased it. The reduction in phytic acid as a result of lime soaking may be due to degradation of phytic acid by the enzyme phytase which is usually activated by soaking. The increase in phytic acid as a result of lime cooking is probably due to the relatively high protein content observed in the flour. Since phytic acid readily forms complexes with proteins it is likely that an increase in protein will may also result in an increase in phytic acid. The increase in phytic acid in lime cooked samples may also be due to interactions between phytic acid and absorbed Ca^{2+} which may have stabilized the phytic acid. Tannin content ranged from 0.70g/kg to 2.92g/kg with flour from sorghum cooked in water having the lowest value and flour from sorghum cooked in lime having the highest value. Lime treatment significantly (p<0.05) reduced the tannin content of the flour samples. Price *et al.* (1980) observed that tannin content of sorghum flour decreased when mixed into batter with a further reduction on cooking. Furthermore, Price *et al.* (1977) reported that moisturizing grains with alkali several hours to processing or utilization was found to be quite effective in inactivating or detoxifying tannins in bird resistant sorghum. Though flour sample from sorghum cooked in lime was lower than that of the control sample, it seems cooking in ordinary water is more effective since the flour sample from sorghum cooked in water had the lowest tannin content. It is possible that the calcium and hydroxide (Ca^{2+} and OH^-) ions in the lime solution had a stabilizing effect on the tannin. Trypsin inhibitor activity ranged from 1.58 to 12.05mg/g with flour from sorghum cooked in water having the lowest value and flour from sorghum cooked in lime having the highest value. Lime cooking significantly (p<0.05) increased the trypsin inhibitor activity while water and lime soaking significantly (p<0.05) decreased it. Cooking, soaking and traditional methods of processing cause significant reduction in trypsin inhibitor activity (Akinyele 1989; Egbe and Akinyele 1990). The increase in trypsin content of flour from sorghum cooked in lime may be due to its increased protein content and binding between Ca^{2+} and trypsin inhibitor. Cyanide content ranged from 8.63mg/100g to 18.25mg/100g with flour from sorghum soaked in lime solution having the lowest value and flour from untreated sorghum having the highest value. Lime soaking and cooking significantly (p<0.05) decreased the cyanide contents of sorghum flour samples. The reduction in cyanide content of the flour samples may have been due to the effect of soaking and cooking which could have caused hydrogen cyanide to be lost during cooking and soaking.

Conclusion

Alkaline cooking of sorghum resulted in flour with significantly higher protein; water and oil absorption capacity; pH; hygroscopicity; phytate and trypsin inhibitor and significantly lower ash; tannins and cyanide content than flours from untreated and water treated sorghums, while alkaline soaking resulted in flour with significantly higher carbohydrate; water and oil absorption capacity; and pH and significantly lower packed bulk density and hydrogen cyanide than flours from untreated and water treated sorghum.

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Table 1. Proximate composition of sorghum flours.

Parameters	USF	WSSF	LSSF	WCSF	LCSF
Dry matter	88.49±0.49^{a}	88.73±0.09^{a}	88.17±0.24^{a}	90.00±0.13^{b}	88.49±0.00^{a}
Protein	19.77±0.13^{b}	19.62±0.00^{b}	19.62±0.00^{b}	19.44±0.10^{a}	21.69±0.18^{c}
Fat	7.48±0.33^{a}	12.45±0.36^{b}	8.51±0.00^{a}	12.22±0.50^{b}	8.66±0.00^{a}
Ash	3.39±0.10^{d}	2.29±0.00^{b}	2.26±0.25^{b}	1.13±0.00^{a}	2.93±0.25^{c}
Crude fibre	4.82±0.21^{a}	7.86+0.25^{c}	6.71±0.40^{b}	10.18±0.00^{d}	6.79±0.20^{b}
Carbohydrate	64.52±0.83^{b}	57.33±0.36^{a}	66.53±0.34^{c}	57.03±0.48^{b}	59.93±0.15^{ab}

Table 2. Functional properties of sorghum flours.

Parameters	USF	WSSF	LSSF	WCSF	LCSF
Water absorption capacity (g/g)	2.94±0.00^{a}	3.12±0.02^{a}	4.76±0.06^{c}	4.35±0.05^{b}	4.54±0.02^{a}
Oil absorption capacity (g/g)	1.38±0.00^{a}	1.23±0.15^{d}	1.98±0.15^{c}	1.31±0.10^{a}	2.34±0.25^{b}
Packed bulk density (g/cm^{3})	0.73±0.20^{b}	0.71±0.20^{b}	0.63±0.10^{a}	0.72±0.10^{b}	0.68±0.10^{ab}
Loose bulk density (g/cm^{3})	0.73±0.20^{b}	0.71±0.20^{b}	0.63±0.10^{a}	0.72±0.10^{b}	0.57±0.15^{bc}
pH	7.07±0.05^{c}	6.36±0.00^{e}	8.01±0.10^{d}	6.90±0.15^{b}	10.10±0.01^{a}
Emulsion capacity (%)	19.50±1.50^{a}	21.50±0.50^{a}	25.00±0.00^{b}	26.50±0.50^{b}	24.50±1.50^{b}
Emulsion stability (%)	18.00±0.00^{a}	23.50±0.50^{ab}	26.50±1.50^{b}	25.00±1.00^{b}	24.50±2.50^{ab}
Hygroscopicity (%)	19.00±2.01^{a}	25.00±1.10^{b}	33.00±0.00^{bc}	31.00±1.50^{c}	40.00±0.00^{d}
Swelling power (ml/g)	2.55±0.06^{a}	4.10±0.15^{d}	3.61±0.15^{c}	8.66±0.00^{c}	3.51±0.25^{b}

Table 3. Anti-nutritional factors of sorghum flours.

Parameters	USF	WSSF	LSSF	WCSF	LCSF
Phytate (mg/100g)	80.30±0.90^{b}	64.72±0.50^{c}	50.19±0.49^{d}	43.45±0.00^{e}	112.10±2.00^{a}
Tannins (g/Kg)	2.92±0.72^{a}	2.10±0.12^{b}	1.48±0.00^{c}	0.70±0.00^{d}	2.46±0.24^{b}
Trypsin inhibitor (mg/g)	8.90±0.88^{b}	7.26±0.00^{b}	3.75±0.45^{c}	1.58±0.30^{d}	12.05±0.30^{a}
Cyanide (mg/100g)	18.25±0.50^{a}	13.70±0.25^{c}	8.63±0.15^{e}	12.41±0.00^{d}	15.35±0.30^{b}

Values are means and standard deviations of triplicate determination. Means in the same row not followed by the same superscript are significantly different ($p<0.05$).

Key:
USF = Flour from untreated sorghum grains;
WSSF = Flour from sorghum grains soaked in water;
LSSF = Flour from sorghum grains soaked in lime solution;
WCSF =Flour from sorghum grains cooked in water;
LCSF = Flour from sorghum grains cooked in lime solution.