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Original Research Article

Effect of ascorbic acid and citric acid treatments on the functional and sensory properties of yam flour

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The study evaluated effect of ascorbic acid and citric acid treatments on the functional and sensory properties of yam flour. Yam (*Dioscorea rotundata*) tubers were washed, peeled and cut into thin slices of 1cm thickness. The slices were divided into 7 portions. The 1st portion served as control. The 2nd, 3rd, 4th and 5th portions were soaked in 2% (w/v) ascorbic acid, 4% ascorbic acid, and 0.5% citric acid and 1% citric acid solutions, respectively for 20 min. The 6th portion was soaked in a mixture containing 0.5% ascorbic acid and 0.5% citric acid while the 7th portion was soaked in a mixture containing 1% ascorbic acid and 1% citric acid. The slices were drained, sun dried, milled and sieved. The flours were analyzed for their functional properties. The yam flours were then used to prepare *amala* (yam flour dough) which were assessed for their sensory properties. The results showed that treatment of yam flour with ascorbic acid and citric acid improved the water absorption capacity, oil absorption capacity and least gelation concentration of the yam flour. However, the emulsion and foaming properties were not improved by the treatments. All the treatments significantly (P<0.05) improved the colour of the *amala* relative to the control. The taste, texture and flavour of the treated *amala* were not significantly different (P>0.05) from the control. The *amala* treated with 2% ascorbic acid was generally more preferred to the other *amala* samples.

Key words: Ascorbic acid, citric acid, yam flour dough, functional properties, sensory qualities.

INTRODUCTION

Yams are the edible tubers of various species of the genus *Dioscorea*. They are important staple foods of many tropical countries including Nigeria, Coted' Ivoire, Ghana, Togo, Burkina Faso, the Caribean, South America, India and South- East Asia (Amanze et al., 2011). Yam is a major contributor to food security in West Africa (FAO, 2008). West Africa remains the most important yam producing region in the world (Polycarp et al.,2012). Nigeria is the leading producer of yam with 54 million tones followed by Cote d' Ivoire (5.0 million tonnes), Ghana (3.9 million tonnes) and Benin (2.1 million tonnes) (FAO, 2008). Average yam consumption per capita per day is highest in Benin (364 kcal) followed by Cote d' Ivoire (342 kcal), Ghana (296 kcal) and Nigeria (258 kcal) (IITA, 2009).

The genus *Dioscorea* contains about 600 species but the main varieties of food yams belong to the species *Dioscorea rotundata*, *Dioscorea cayenensis, Dioscorea dumetarum* and *Dioscorea esculenta* (Asiedu, 1989). In Nigeria, there are about 50-60 species of yam but only 5 or 6 are important as food (Asiedu, 1989). Of all the yams generally cultivated in Nigeria, *Dioscorea rotundalt* is the most popular. It is the most suitable for the preparation of *fufu* or pounded yam due to the high viscosity of its starch (Osisiagu, 1973). Yams serve as one of the major staple foods for millions of people in Nigeria. They are consumed in substantial quantities as a fresh vegetable but a large proportion is processed. In Nigeria, the major processed product is yam flour (*elubo*) which is reconstituted by stirring in boiling water to form a paste (*amala*) and eaten with flavoured sauces (Eze, 1992). *Amala* is a common f ood item in Nigeria and other West

African countries. *Amala* is a menu that can be taken any time of the day with stew, vegetable or other types of soup, which differ with taste (Abulude and Ojediran 2006). Yam is also roasted and consumed in other forms such as boiled, fried and flaked, which could be milled into flour. Yam is also a useful source of good quality starch for man and livestock (Eka, 1985).

One potential problem in processed yam flour is the discolouration and darkening of the product (Onayemi and potter, 1974). This may be undesirable to many people. This has been attributed to enzymic browning reactions as a result of the presence of water soluble phenolic substances in yam (Onimawo and Akubor, 2012). Not withstanding the specific process employed in yam processing, one problem is how to achieve a flour of superior quality which reconstitutes into yam paste exhibiting the natural colour (Ngoddy and Onuoha, 1985). Various approaches have been employed in preventing browning of yam during processing into flours. These approaches include inactivating the phenolase (by blanching, use of inhibitors)(Akubor et al., 2008), rendering the conditions unfavourable to enzyme action (lowering pH),minimizing contact with oxygen and use of antioxidants such as ascorbic acid, sulphur dioxide e.t.c (Jiang and TU, 1998). In a study, the effect of fermentation of yam in reducing degree of browning in the reconstituted yam product was investigated (Achi, 1999). These treatments may affect the nutrient composition (Mbome, 1994) and functional properties of yam flour (Alinnor and Akalezi, 2010, Faboya and Asgbra, 1990). In most cases, the data on these effects are fragmentary (Akubor et al, 2008). Therefore, the objective of this study was to determine the effect of ascorbic acid and citric acid treatments on the functional and sensory properties of yam flour.

MATERIALS AND METHODS

Materials and sample preparation

Fresh yam (Dioscorea rotundata) tubers were purchased from a local market in Idah Township, Kogi State, Nigeria. The yam tubers were peeled manually with a sharp kitchen knife and then cut into thin slices (1cm thick). The slices were washed thoroughly in tap water contained in a basin and then divided into 7 portions. The first portion served as control. The 2nd, 3rd, 4th and 5th portions were soaked in 2% (w/v) ascorbic acid, 4% ascorbic, 0.5% citric acid and 1% citric acid solutions, respectively for 20 min. The 6th portion was soaked in a mixture containing 0.5% ascorbic acid and 0.5% (w/v) citric acid for 20 min. The 7th portion was soaked in 1% ascorbic acid and 1% citric acid mixture for 20min. The yam slices were drained for 5 min, sun dried to constant weight, milled in an attrition mill and sieved through 60 mesh sieve (British standard). The flours were packed in high density polyethylene bags prior to use. The flours were analyzed for their functional properties.

Sensory evaluation of *amala*

The sensory assessment was performed on the *amala* prepared from the untreated and treated yam flours. *Amala* was prepared by stirring 100g of yam flour into 500ml of boiling water (Achi, 1999). The paste was stirred continuously for 6min over low heat from a stove. The samples were wrapped in polyethylene pouches and allowed to cool to room temperature. The samples were presented to the panelists in 3- digit coded white plastic plates. The panelists consisted of 20 students and laboratory staff of the Department of Food Science and Technology, Federal polytechnic, Idah, who are familiar with *amala*. The *amala* samples were evaluated for colour, taste, texture, flavour and overall acceptability on a 5- point scale where 1 = disliked extremely, 3 = liked moderately and 5 = liked extremely (Ihekoronye and Ngoddy, 1985). The sensory evaluation was carried out in a sensory evaluation laboratory under controlled conditions of adequate light and ventilation. The order of presentation of the *amala* samples to the panelists was randomized. Clean tap water was provided for the panelists to rinse their mouths in between samples.

Evaluation functional properties of yam flours

Bulk density

Bulk density was determined according to the method described by Okaka and potter (1977). A fifty gram sample was put into a 100 ml graduated measuring cylinder. The cylinder was tapped several times on a laboratory bench to constant volume. The packed bulk density (g/ml) was calculated as weight of flour (g) per unit volume (ml).

Emulsion activity and stability

Emulsion activity and emulsion stability were determined by the method of Okaka and Potter (1977). The emulsion (1g flour, 10 ml distilled water, 10ml refined soybean oil) was rapidly blended in food blender for 5 min. The emulsion was transferred into a calibrated centrifuge tube and centrifuged in a centrifuge at 2000 x g for 5 min. The ratio of the height of the emulsion layer to the height of the liquid layer was calculated as the emulsion activity expressed in percentage.

The emulsion stability was estimated after heating the emulsion contained in a calibrated centrifuge at 80°C for 30 min in a water bath, cooling for 15 min under running tap water and centrifuging in a centrifuge at 2000 x g for 15 min. The emulsion stability, expressed as a percentage, was calculated as the ratio of the height of the emulsified layer to the height of the liquid layer.

Table 1. Functional properties of yam flours

	Yam flours						
Parameter	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Bulk density (g/ml)	0.63±0.09[a]	063±0.03[a]	0.59±0.10[a]	0.61±0.08[a]	0.66±0.01[a]	0.65±0.04[a]	0.63±.1[a]
Water absorption capacity (%)	127±0.12[g]	139±0.08[d]	235±0.14[b]	130±0.12[f]	131±0.1[e]	140[c]±0.02	246[a]±0.2
Oil absorption capacity (%)	137±0.12[e]	142±0.81[b]	141±0.24[c]	141±0.75[c]	140±0.31[d]	140±0.65[d]	228±0.4[a]
Foaming capacity (%)	27±0.21[c]	38±0.43[a]	31±0.14[b]	16±0.34[e]	14±0.52[g]	15±0.21[f]	21±0.1[d]
Foam stability (%)	13±0.35[b]	28±0.15[a]	5±0.14[d]	6±0.71[d]	5±0.18[d]	4±0.01[e]	6±0.29[c]
Emulsion capacity (%)	7.1±081[a]	5±024[c]	2.8±0.35[e]	6±0.44[b]	4.3±0.08[d]	1.4±0.21[f]	1.4±0.1[f]
Emulsion stability (%)	4.5±0.10[a]	2.8±0.01[b]	2.8±0.4[b]	1.4±0.11[c]	1.4±0.08[c]	1.0±0.1[c]	1.0±0.1[c]
Least gelation centration (%, w/v)	8[a]	8[a]	8[a]	8[a]	8[a]	8[a]	8[a]

The values are means of 3 replications. Means with in a row with the same superscript were not significantly different (P > 0.05) A = 0.5% citric acid treated, E = 1% citric acid treated, F = combination of 0.5% ascorbic acid and 0.5% citric acid treatment, G= combination of 1% ascorbic acid and 1% citric acid treatment.

Water and oil absorption capacities

Water and oil absorption capacities were determined by the method of Sosulski et al.,(1976). One gram flour samples of flour was mixed with 10ml distilled water or refined soybean oil and allowed to stand at room temperature (30± 2 °C) for 30 min, then centrifuged in a centrifuge 2000 x g for 15min. The water or oil absorption capacity was expressed as a percentage.

Least gelation concentration

The leas gelation concentration was determined as described by Sathe and Salunkle (1981). Flour dispersions of 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20% (w/v) were prepared in 5ml of distilled water in test tubes and heated for one hour in boiling water (100°C) bath. The heated dispersions were cooled rapidly under running tap water and then at 10± 2°C in a refrigerator for 2 hours. The least gelation concentration was determined as that concentration when the sample from the inverted tube did not slip.

Foaming capacity (FC) and foam stability (FS)

The FC and FS were determined as described by Okaka and potter (19771. A two gram flour sample was added to 50ml distilled water at 30± 2°C in a 100ml graduated cylinder. The suspension was mixed and shaken for 5 min to foam. The volume of foam at 30 seconds after whipping was expressed as FC using the following formula:

$$FC = \frac{\left(\begin{array}{c}\text{Volume of foam}\\ \text{after whipping}\end{array}\right) - \left(\begin{array}{c}\text{Volume of foam}\\ \text{before whipping}\end{array}\right)}{(\text{Volume of foam before whipping})} \times 100$$

The volume of foam was recorded one hour after whipping to determine FS as percent of the initial foam volume.

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) procedure (Steel and Torrie, 1980). Means where significant were separated by the least significant difference (Lsd) test. Significance was accepted of P <0.05. Analysis was carried out in three replicates.

RESULTS AND DISCUSSION

Functional properties of flours

Bulk density

The effect of treatments on the functional properties of yam flours are shown in Table 1. The bulk density of the untreated yam flour (control) was 0.63 g/ml and ranged from 0.59 to 0.65 g/ml for the variously treated yam flour samples. The bulk density of yam flour was not significantly (P>0.05) affected by the treatments. Bulk density is an indicator of the porosity of a product which influences package design and could be used in determining the type of packaging material and material handling in the food industry. Bulk density is also important in infant feeding where less bulk is desirable. The low bulk of the yam flour would be an advantage in the use of the flour for the preparation of complementary foods.

Water absorption capacity

All the treatments improved the water absorption capacity (WAC) of yam flour. The WAC of the untreated yam flour was 127%, a value which increased to a range of 130 to 146% for the treated yam flours. The WAC increased with increase in the levels of ascorbic acid and citric acid. The mixture of 1% ascorbic acid and 1% citric acid improved the WAC of the yam flour over the individual additives. The ascorbic acid and citric acid may have denatured the yam proteins, thereby exposing the hydrophilic sites of the

Table 2. Sensory properties of *amala* samples

Sample	Sensory properties				
	colour	**Taste**	**Texture**	**Flavour**	**Overall acceptability**
A	2.4^{b}	3.2^{a}	3.3^{a}	3.4^{b}	4.6^{a}
B	3.9^{a}	3.3^{a}	3.5^{a}	3.9^{a}	4.2^{a}
C	3.6^{a}	3.4^{a}	3.3^{a}	3.1^{b}	3.9^{b}
D	3.5^{a}	3.5^{c}	3.7^{a}	3.5^{b}	3.55
E	3.8^{a}	3.4^{c}	3.1^{a}	3.4^{b}	3.6^{b}
F	3.7^{a}	3.9^{a}	3.8^{a}	3.6^{b}	3.5^{b}
G	3.8^{c}	3.2^{c}	3.4^{c}	3.4^{b}	3.2^{b}

Means within a column with the same superscript were not significantly different (P > 0.05). Samples were evaluated on 5- point hedonic scale (1 = disliked extremely, 3= liked moderately and 5 = liked extremely). Abbreviations as defined in Table 1.

protein molecules which caused high water absorption. Denatured proteins bind more water than native proteins (Onimawo and Akubor, 2012). However, ascorbic acid exerted greater effect on this function than citric acid.

Oil absorption capacity

Like the WAC, all the treatments increased the oil absorption capacity (OAC) of yam flour. The treatments increased OAC from 137% in the control to values that varied from 140 to 228% for the treated flours. The OAC decreased with the concentration of ascorbic acid but was not affect by the citric acid level. Similarly, the combination of ascorbic acid and citric acid at the highest concentrations evaluated improved the OAC more than the individual additives. All the yam flours exhibited greater ability to absorb and retain oil than water. This was probably due to protein denaturation which might have unmasked the non-polar residues from the interior of the protein molecules (kinsella, 1987). The mechanism of oil absorption is known to be mainly due to the physical entrapment of oil by capillary action in the hydrophobic components of the proteins. The implication of the high WAC and OAC is that the treated yam flours would be good functional ingredients in food systems such as confectionery products where oil and water absorption is of prime importance. Fat increases the leavening power of the baking powder in the batter and improves the tenderness of the baked product. Good WAC is also required in *amala* where hydration to form stiff dough is desirable.

Emulsion, foaming and gelation properties

The untreated and treated yam flours have low emulsion and foaming properties, probably due to the low protein and high carbohydrate contents of yam flour. Kinsella (1987) have reported that the presence of carbohydrate adversely affected the emulsion capacity of groundnut flour. Only ascorbic acid treatment improved the emulsion activity of yam flour. None of the treatments improved the foaming capacity and foam stability of yam flour. Okaka and Potter (1977) reported that the foaming capacity of cowpea flour was influenced by the amount of the protein in the flour. Foam stability is related to the amount of native proteins (Kinsella, 1976), which was considered low in denatured proteins. Yams may have contained high concentration of highly ordered globular protein which is difficult to surface denaturations which give low foamability. Good foamability is linked with flexible protein molecule that can reduce surface tension. The low levels of emulsion activity and emulsion stability suggest that yam flours would not be useful for the preparation of sausages, cakes, mayonnaise and salad dressing because of the emulsion requirements of these products.

All the treatments did not increase the gel forming ability of yam flour. However, all the yam flours are required at low concentration (8%, w/v) to form gel. Gelation is an aggregation of denatured molecules. Protein concentration, especially globulin fraction, and interaction between proteins, carbohydrates and lipids are responsible for gelation capacity of flours. Yam is composed mainly of starch, with some proteins, lipids, vitamins and minerals (Asiedu, 1989). The main constituent of yam starch is amylopectin (Adiedu, 1989). Amylose occurs as 10-20% of the starch and influences the properties of the starch (Asiedu, 1989). D. *rotundata* is the most viscous of the yam species. It has also high gel strength. It is probably these characteristics that make D. *rotundata* for the production of pounded yam and *amala* for which stiff dough is required (Achi and Akubor, 2000).

Sensory characteristics of *amala*

The sensory properties of *amala* are presented in Table 2. The untreated *amala* was rated lower than the treated *amala* samples for colour. However, the scores for colour were not significantly different(p>0.05) among the chemically treated samples. Among the individual treatments, 2% ascorbic acid treatment gave *amala* with the highest score for colour. This was followed by the 1%

citric acid treated sample. Ascorbic acid may have acted as antioxidant by retarding pigments (melanoids) formation. Citric acid is used in suppressing browing in fruits and vegetables as a synergetic compound for antioxidants (Onimawo and Akubor, 2012). The ability of citric acid as a chelating agent contributed to stabilization of food colour, aroma and texture (Onimaaro and Akubor, 2012). However, when treatments were combined, *amala* treated with a mixture of 1% ascorbic acid and 1% citric acid had the highest score for colour. The scores for taste did not differ significantly (P>0.05) among the *amala* samples, though, the chemically treated *amala* samples received higher scores. The *amala* samples were not significantly different (P>0.05) in texture. However, the treated samples had higher scores for texture than the control. The *amala* treated with citric acid and mixture of ascorbic acid and citric acid had higher scores for texture than the other samples. The chemical treatments may have modified the constituents of the yam flour. Similarly, the scores for flavour were not significantly different (P>0.05) among the samples. However, ascorbic acid treatment improved the flavour more than the other treatments . There were no significant differences (p>0.05) between the untreated and the ascorbic acid treated *amala* for general acceptability. Indeed, the 2% ascorbic acid treated *amala* was more preferred to the control. The scores decreased with increased concentration of ascorbic acid. All the citric acid treated *amala* samples received lower scores for general acceptability than the control and ascorbic acid treated products. The scores decreased with the level of citric acid treatment.

Conclusion

Treatment of *Dioscorea rotundata* flour with ascorbic acid and citric acid improved the water and oil absorption capacities but decreased the emulsion and foaming properties of the yam flour. The treatments also improved the colour of *amala* prepared from yam flour. The taste and texture of the chemically treated *amala* were not significantly different (P>0.05) from the untreated *amala*. However, 2% ascorbic acid treatment produced a more acceptable *amala* than the other treatments. It is recommended that yam (*Dioscorea rotundata)* tubers for amala production should be treated with 2% ascorbic acid. Such treated yam flour could be used for preparation of bakery products.

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