



The Effect of Ascorbic Acid on the Physical and Proximate Properties of Wheat-Acha Composite Bread

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This work studied the effect of different proportions of ascorbic acid on the physical and proximate properties on wheat-acha composite bread. Bread was produced from wheat (*Triticum aestivum*) and acha (*Digitaria exilis*) composite flours. The wheat: acha ratios used were 100:0, 90:10 and 80:20. The proximate, and functional properties of the flours were analysed. The dough improver, ascorbic acid was added at 80, 100 and 120ppm during the bread making process and the proximate, physical and sensory properties of the bread was analysed. Flour sample with 20% acha had the significantly highest values for bulk density ($0.744\text{g}/\text{cm}^3$), water absorption capacity ($1.5\text{g}/\text{g}$), oil absorption capacity ($1.564\text{g}/\text{g}$), foam capacity (11.32%) and swelling index (1.24). There was no significant difference in the crude fat and ash content of all bread samples. Significant difference was observed in the volume and specific volume of the bread samples, with 100% wheat flour giving the highest values of 431.33 ml and 3.16 ml/g respectively. However, addition of ascorbic acid significantly improved these parameters with no significant difference between the 100ppm and 120ppm bread samples. Also the bread samples produced with 100:0 and 90:10 wheat: acha flours showed no significant difference in their sensory properties. The 80:20 composite bread gave significantly lower sensory scores for all the sensory parameters.

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1. INTRODUCTION

Bread is a baked dough product made from cereal grains, commonly wheat [1]. Bread is one of the popular staple foods consumed by humanity and today, there are few countries in the world where bread is not made or eaten. The term 'bread' is used to describe a range of products of different shapes, sizes textures, crust, colour, softness, eating qualities and flavours (Stanley, 2007).

The basic recipes for bread making include wheat flour, yeast, salt and water. If any of these ingredients is missing, the acceptable product cannot be prepared. Other ingredients are optional, for example, fat, sugar, milk and milk products, malt and malt products, oxidants (such as ascorbic acid) surfactants and anti-microbial agents [2].

Bread requires wheat flour and water to form gluten to trap the gas generated by the yeast (Stanley, 2007). Wheat flour is the main ingredient in bread production. It is primarily responsible for bread structure and bite characteristics [2]. However wheat is not grown in most tropical countries like Nigeria. So in order to reduce the foreign exchange spent on wheat importation, several developing countries have encouraged the initiation of a program to evaluate the feasibility of utilising alternative locally available flours as a substitute for wheat flour.

In Nigeria, wheat flour needed for making bread, rolls and pastry goods has to be imported, since the climatic conditions and soil do not permit commercial wheat production locally. Although there are varieties of wheat that are more adaptable to tropical climate, they are to be tested in Nigeria. For these reasons, the government has developed keen interest in replacing some portions of wheat with locally manufactured or cultivated cereals, legumes and tuber crops. Several researchers have produced acceptable bread products using composite flours made with wheat and other foods ([3,4]; Idowu et al 1996; FAO 2006; Onuegbu et al., 2013; [5-8]).

Acha (*Digitaria exilis*), also known as Fonio, Findi, Hungry rice, petit millet and white fonio, is a small grain indigenous to West Africa [9]. Acha belongs to the family of granule and originated in Africa, it is grown in various parts of the Nigeria,

Sierra Leone, Ghana, Guinea Bissau and Benin Republic on poor sandy soils which may not sustain the growth of the other more demanding cereals, however, with nutritional supplementation there is the possibility of other crops.

Acha is one of the most nutritious grains, because its seed is very rich methionine and cysteine (amino acids) which are vital to human health. It is high in digestible energy but low in oil and minerals. Acha protein is reported to be unique due to its greater methionine content than other cereals [10].

The use of composite flours, containing wheat and non-wheat flours in bread making comes with its attendant problems. This is because of the low gluten content of non-wheat flours. Gluten comprises the proteins gliadin and glutenin which are responsible for the strength and extensibility of the dough when water is added to the flour. This quality produces through the oxidation and reduction reactions resulting in the formation of –S-H and –S-S bonds within and between the protein chains. This enables the formation of the gluten network that retains the CO₂ which is released during dough proofing, thus giving the bread good volume and crumb texture after baking. Since the non-wheat flours do not contain enough of the gluten components, it is necessary to aid the oxidation-reduction process by addition of dough improvers [11].

Ascorbic acid is one of the naturally occurring substances that are used as dough improvers. They help to speed up the dough development process when added to dough during bread making (Okorie et al., 2013). Ascorbic acid is a reducing agent. During dough development, it is first converted to dehydroascorbic acid catalysed by ascorbic acid oxidase contained in the flour. This helps to form disulphide bridges between protein molecules as well as rearrangement of intramolecular disulphide bonds as a result of the oxidation/reduction activities which were enhanced by the presence of the ascorbic acid. New disulphide bonds are formed in the gluten structure which enables the dough to retain carbon dioxide released by the yeast.

The aim of this work therefore is to determine the effect of addition of different levels of ascorbic acid on the wheat-acha composite bread. The

data obtained will enable better utilization of the acha seeds which until now has remained lesser-known, with no commercial product made from them. It will also be useful in reducing the production cost spent on wheat importation.

2. MATERIALS AND METHODS

The wheat flour (Honeywell brand) and acha seeds used for this work were purchased from Eke-ukwu market in Owerri, Imo State, Nigeria. The baking ingredients: salt, yeast, shortening and sugar were also purchased in the same market. The ascorbic acid (99% purity) was purchased from Chemisciences Laboratory located at Owerri, Imo State. All chemical and physical analyses were carried out in Food Science and Technology Laboratory, Federal University of Technology, Owerri. The Acha (Fonio) grain was milled using a locally fabricated attrition mill, and sieved (using 425 µm aperture size sieve) to obtain the flour.

The wheat : acha composite flour samples were prepared in the following ratios, 100:0, 90:10, 80:20, based on the outcome of preliminary analysis. The different flours were stored in airtight containers and used for the subsequent analyses as well as the bread making process.

2.1 Proximate Analysis

The procedures described by Association of Official Analytical Chemists [12] were used to determine the proximate composition of composite flour and the bread samples.

2.2 Determination of the Functional Properties of Flour Samples

2.2.1 The bulk density

The method described by Onwuka (2005) was followed. A 10ml graduated measuring cylinder was weighed and filled gently with the weighed flour samples. The bottom of cylinder was tapped gently on laboratory bench several times until there was no further diminution of the sample level after filling to the 10ml mark. The bulk density was calculated as:

$$\text{Bulk density} = \frac{\text{weight of sample(g)}}{\text{Volume of sample(ml)}}$$

2.2.2 Emulsion capacity

Two grams of flour sample and 25ml of distilled water were blended for 30s using a warring

blender at 1600rpm (Onwuka, 2005). After complete dispersion deodorized vegetable oil was added continuously through a burette until emulsion breakpoint and blended again for 30secs. It was transferred to a centrifuge and centrifuged at 1600rpm for 5mins. The volume of the oil separated from the sample after centrifuging was read directly from the tube. The emulsion capacity was expressed as millimeter of emulsified oil per gram of flour.

$$\text{Emulsion Capacity} = \frac{\text{Height of emulsified layer}}{\text{Height of whole solution in the centrifuge tube}}$$

2.2.3 Swelling index

The method of Abbey and Ibeh [13] was employed. One gram of each flour sample was weighed into 10ml graduated measuring cylinder. Five milliliters of distilled water was carefully added and the volume occupied by the sample was recorded. The sample was allowed to stand undisturbed in water for 1hr and the volume was again recorded. The swelling index was calculated as the ratio of the volume occupied after swelling to the volume before swelling.

$$\text{Swelling index} = \frac{\text{Volume of sample after swelling}}{\text{Volume of Sample before swelling}}$$

2.3 Water and Oil Absorption Capacities

The water/oil absorption Capacity was determined using the method described by Carcea [14]. One gram of each flour sample was stirred in 10ml of distilled water/oil for 1min by manual shaking. The mixture was then allowed to stand at room temperature for 30mins and then centrifuged at 1,500 rpm for 30mins. The supernatant was decanted and the volume in the measuring cylinder was noted and converted to weight (in grams) by multiplying by the density of oil (0.902g/ml) and water (1g/ml) respectively. The oil/water absorption capacities were expressed as grams of oil/water absorbed per gram of flour sample.

2.4 Foam Capacity

The foaming capacities of flour samples were determined according to Onwuka (2005). Two grams of samples was blended with 100ml distilled water in an electric blender for 30min. The mixture was transferred into a 250ml measuring cylinder and the volume after 30secs was recorded. The foam capacity was expressed as percent increase in volume using the formula:

Foam Capacity = ((Volume after whipping – volume before whipping) / Volume before whipping) X 100

2.5 Wettability

The method described by Onwuka (2005) was used. One gram of the sample was weighed into a graduated cylinder of 25ml with a diameter of 1cm and a cover was used to cover the open end of the cylinder. It was inverted and clamped at a height of 10cm from the surface of a 600 ml beaker filled with 500 ml of distilled water. The cover was removed to allow the sample to be dumped. The wettability is the time required for the sample to become completely wet.

2.6 Bread Production

The bread samples were produced using the knock back method (Stauffer, 1990).

The list of ingredients were as follows:

- Flour (100:0, 90:10, 80:20 combination Wheat:Acha)...100g
- Yeast....0.9g
- Water...60ml
- Margarine....5g
- Sugar... 10g
- Salt....0.5g
- Ascorbic acid (80,100 and 120 ppm)

The dry ingredients were first mixed and the margarine was added. After proper mixing the water was added followed by further mixing and kneading. Bulk proofing was done for 30 minutes and the dough was knocked back. It was then kneaded, divided, scaled, rounded and put into a greased baking pan. The dough was further proved for 2 hours and then baked in a preheated oven at 240 °C for 15 minutes. The bread was removed from the oven and allowed to cool to room temperature.

2.7 Evaluation of Bread Characteristics

Bread quality was evaluated by measuring loaf volume, specific loaf volume and organoleptic properties.

2.8 Loaf Volume

Loaf volume was measured 50minutes after loaves were removed from the oven using rape seed displacement method as described by

Onwuka (2005). However, millet grains were used in place of rape seed.

2.9 Specific Volume

The weight of the loaf was determined using a weighing balance. The specific volume was obtained by dividing the loaf volume by its corresponding loaf weight.

$$\text{Specific volume} = \frac{\text{Volume of loaf (cm}^3\text{)}}{\text{Weight of loaf (g)}}$$

2.10 Sensory Evaluation of Baked Bread

Sensory evaluation was done using a 10-man semi-trained panelist to access the quality attributes of the bread samples. The quality attributes accessed includes: texture, taste, aroma, crumb colour, crust colour and overall acceptability.

The panel members were selected randomly from staff and students of the university community. The panelists were instructed to rate the samples based on 9-point hedonic scale ranging from 9 = like extremely to 1 = dislike extremely. The raw scores were assembled and statistically analysed using the method described by Ihekoronye and Ngoddy [15].

3. RESULTS AND DISCUSSION

3.1 The Proximate and Functional Properties of the Flours

Slight differences were observed in the proximate composition of the wheat flour and acha flours (Table 1). The wheat flour had a higher protein (10.6%) and ash (1.3%) content as against 8.5% and 0.6% in acha flour respectively. However the carbohydrate content was higher for the acha flour (80.9%) than the wheat flour (75.65%). With only these minor differences observed in the proximate composition of the two grains, it is expected that the differences in the behavior of the flours during baking will be as a result of the gluten in the wheat and the differences in the carbohydrate composition.

Slight differences were recorded in the bulk density of the flours with values ranging from 0.739 to 0.745 g/cm³ (Table 2). The bulk density is an important property since higher bulk density enables a higher amount of material to occupy a

smaller volume [16]. It is influenced by particle size and it is a relevant consideration in determining the packaging requirement of flours [17].

There were increases in the water absorption, oil absorption and the foaming capacities as the proportion of acha in the sample increased with values ranging from 1.25 to 1.5, 1.35 to 1.56 and 2.86 to 11.32 respectively. Baking quality is a function of water absorption capacity of the flour (Shittu et al., 2008). The oil absorption index is also an important index of quality since oil acts as flavour retainer and increases the mouth feel of foods, improvement of palatability and extension of shelf life particularly in bakery or meat products where fat absorptions are desired [18]. The major chemical affecting oil absorption index is protein, which is composed of both hydrophilic and hydrophobic parts. Non-polar amino acid side chains can form hydrophobic interactions with hydrocarbon chains of lipid [19] and has implication in functional properties of flours.

The foam capacity increased significantly ($p < 0.05$) from 2.86 for 100% wheat to 11.32 for 20% acha composite flour. Higher foam capacity indicates that the flour may be useful in fluffy food products like cakes. The wettability of the samples also increased with increase in substitution with acha flour. The time required for the flour to be completely wet reduced from 186 seconds, to 126 seconds and then to 71 second as the percentage acha increased from 0 to 10 and 20% respectively, while the swelling index increased 1.15 to 1.24. Swelling power is often related to their protein and starch properties (Woolfe, 1992). A higher protein content in flour may cause the starch granules to be embedded within a stiff protein matrix, which subsequently limits the access of the starch to water and restricts the wettability and swelling power [20]. The amylopectin is primarily responsible for granule swelling, the increased the swelling power of composite flour may be related to a higher amylopectin content (Tester and Morrison, 1990). Moorthy and Ramanujam [21] reported that the swelling power of granules is an indication of the extent of associative forces within granule.

The emulsion capacity ranged from 57.51 to 62.51%. While no particular trend was observed, the 10% acha sample gave the highest value. Emulsion properties play a significant role in many food system where the proteins have the

ability to bind fat such as in meat products, batter, dough and salad dressing (Sathe and Salkhe, 1981).

3.2 Properties of Bread Samples

Slight differences were observed in the proximate composition of the bread samples produced with different composite flours (Table 3). The moisture and crude fibre contents of the bread samples increased as the percentage of acha while the protein, ash and carbohydrate decreased.

The moisture content ranged from 34.667 to 39.50%. The shelf life of products depend on their moisture content and higher moisture contents are associated with high spoilage rate. The 0, 10 and 20% acha composite bread had protein values of 8.883, 8.283 and 4.860% and 0.833, 0.333 and 0.333% ash. This may be related to the low levels of these components in the acha flour.

There was a reduction in loaf volume and specific volume of the bread as proportion of acha flour increased (0, 10 and 20%) with values ranging from 347.0 to 384.333ml and 2.294 to 3.163ml/g respectively (Table 4). However the values increased as the proportion of ascorbic acid in the dough increased. The mean loaf volume was 347.00, 267.667 and 384 333ml and mean specific volume values were 2.515, 2.647 and 2.754 ml/g for bread samples produced with 80ppm, 100ppm and 120ppm ascorbic acid respectively (Table 5). This suggests that though the specific volume was reduced by the addition of acha to the flour, the addition of the ascorbic acid increased the specific volume. This is due to the improved dough development process by addition of the ascorbic acid (Okorie et al., 2013).

The sensory scores are shown on Table 6 and some significant differences ($p < 0.05$) were observed between some of the values. The samples compared favorably with the 100% wheat flour bread. No significant difference ($p \geq 0.05$) was observed in the taste, aroma, crumb colour and crumb texture of the 100% and 90% wheat flour samples, demonstrating that there is no rejection of the combinations. The bread sample produced from 90:10 wheat – acha composite bread with 100ppm ascorbic acid had the highest value for taste, and the sample with 20% acha and 100ppm ascorbic acid had the least. This indicates that the acha taste is most acceptable in the bread when used at lower

percentage (10%). The 80:20 wheat:acha composite bread gave lower values for crumb colour and crumb texture, which can interfere with sales. The overall acceptability scores for all the samples ranged from 6.5 to 8.3 on a nine-point hedonic scale. The lowest score was given by 80:20 wheat:acha composite flour with added 100ppm ascorbic acid, while the highest score was given by the 100% wheat flour with 100ppm ascorbic acid addition.

Interestingly, no significant difference was observed between the values obtained for the taste, aroma, crumb colour and texture for all the samples. These are very important parameters that affect repeated purchase of any bread product. No wonder then that the overall acceptability scores were high and within a close range. This suggests that the product will compete favourably with already existing brands in the market.

Table 1. Results of proximate analysis of wheat and acha flour

Component	Wheat flour	Acha flour
Moisture (%)	9.5	8.5
Protein (%)	10.6	8.5
Fat (%)	1.5	1.0
Crude fibre (%)	1.4	2.0
Ash (%)	1.35	0.6
Carbohydrate (%)	75.65	80.19

Mean on the same column with different superscripts are significantly different at ($p < 0.05$)

Table 2. Functional properties of composite flour samples

Flour samples(wheat : acha)	Bulk density (g/cm ³)	Water absorption Capacity (g/g)	Oil absorption capacity (g/g)	Foam capacity (%)	Wettability (g/s)	Swelling index	Emulsion capacity (%)
100:0	0.739 ^b	1.250 ^b	1.352 ^c	2.86 ^c	186 ^a	1.15 ^b	58.75 ^b
90:10	0.745 ^a	1.283 ^b	1.476 ^b	9.26 ^b	126 ^b	1.24 ^a	62.51 ^a
80:20	0.744 ^a	1.500 ^a	1.564 ^a	11.32 ^a	71 ^c	1.24 ^a	57.50 ^c

Mean on the same column with different superscripts are significantly different at ($p < 0.05$)

Table 3. Effect of flour composite on proximate composition of bread samples

Flour Samples (wheat:acha)	Moisture Content (%)	Crude Protein (%)	Crude Fat (%)	Crude Fibre (%)	Ash (%)	Carbohydrates (%)
100:0	34.66 ^c	8.68 ^a	9.33 ^a	1.66 ^d	0.83 ^a	49.58 ^a
90:10	38.28 ^d	8.28 ^b	10.33 ^a	2.33 ^{ab}	0.33 ^a	39.97 ^b
80:20	39.50 ^a	4.86 ^c	7.33 ^a	2.83 ^a	0.33 ^a	45.85 ^a

Mean on the same column with different superscripts are significantly different at ($p < 0.05$)

Table 4. Effect of composite flour on physical properties of bread samples

Flour samples	Loaf volume (ml)	Loaf weight (g)	Specific volume (ml/g)
Wheat:Acha (100:0)	431.33 ^a	136.36 ^c	3.16 ^a
Wheat:acha (90:10)	343.00 ^d	138.93 ^d	2.46 ^d
Wheat:acha (80:20)	324.66 ^d	141.50 ^a	2.2 ^d

Mean on the same column with different superscripts are significantly different at ($p < 0.05$)

Table 5. Effect of Ascorbic acid on the physical properties of bread samples

Ascorbic acid content	Loaf volume (ml)	Loaf weight (g)	Specific volume (ml/g)
80ppm	374.00 ^b	137.86 ^c	2.515 ^b
100ppm	367.66 ^{ab}	139.20 ^b	2.64 ^{ab}
120ppm	384.33 ^a	139.73 ^a	2.75 ^a

Mean on the same column with different superscripts are significantly different at ($p < 0.05$)

Table 6. Result of sensory evaluation

Samples wheat: acha ratio/ascorbic acid (ppm)	Texture	Taste	Aroma	Crumb colour	Crust colour	Overall acceptability
100:0; (80ppm)	8.0 ^a	7.7 ^a	7.3 ^{ab}	7.8 ^a	7.9 ^a	8.0 ^{abc}
100:0; (100ppm)	7.8 ^{ab}	7.7 ^a	7.7 ^{ab}	8.0 ^a	8.0 ^a	8.3 ^a
100:0; (120ppm)	7.4 ^{abc}	7.6 ^a	7.8 ^a	8.0 ^a	8.0 ^a	8.1 ^{ab}
90:10; (80ppm)	7.7 ^{ab}	7.6 ^a	7.4 ^b	7.4 ^a	7.3 ^{ab}	7.5 ^{bcd}
90:10; (100ppm)	7.9 ^a	7.8 ^a	7.4 ^{ab}	7.3 ^{ab}	7.3 ^{ab}	7.7 ^{abc}
90:10; (120ppm)	7.8 ^{ab}	7.3 ^{ab}	7.3 ^{ab}	7.2 ^{ab}	7.2 ^{ab}	7.3 ^{ab}
80:20; (80ppm)	6.7 ^{cd}	7.0 ^{ab}	6.9 ^{ab}	6.5 ^{bc}	6.3 ^{bc}	6.8 ^{de}
80:20; (100ppm)	6.1 ^d	6.5 ^b	6.9 ^b	5.9 ^c	6.1 ^c	6.5 ^e
80:20; (120ppm)	7.0 ^{bc}	7.0 ^{ab}	7.2 ^{ab}	6.1 ^c	6.3 ^{bc}	6.8 ^{de}

Mean on the same column with different superscripts are significantly different at ($p < 0.05$)

4. CONCLUSION

The proximate composition and the functional properties of the different flours were different from one another and this affected the quality of bread produced using them. Addition of 100 and 120ppm ascorbic acid significantly improved the volume and specific volume of the bread samples produced. The bread samples produced with 100:0 and 90:10 wheat: acha flours (at all levels of ascorbic acid addition) showed no significant difference in their sensory properties. The 80:20 composite bread gave significantly lower sensory scores for all the sensory parameters, which will possibly affect sales.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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