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Studies On Microbiological Contents, Nutrient Composition and Functional Properties of Flour Produced from Fermented Acha (*Digitaria exilis*) And Iburu (*Digitaria iburua*)

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ABSTRACT

Flour was produced from *Acha* (*Digitaria exilis*) and Iburu (*Digitaria iburua*) to advance the use of nutritious and affordable indigenous crops in food processing. Flour samples were produced by steeping the grains in water for 5 days, dried, milled and sieved. Microbial counts and pH of the samples were assessed during steeping at day 0, 3 and 5. Proximate composition and functional properties of the flours were also determined using standard methods. The total viable count, lactic acid bacteria and fungi counts increased during the steeping period. The protein, fat, ash, crude fibre and carbohydrate content ranged from 9.08 to 9.43%, 3.74 to 5.30%, 0.83 to 1.33%, 0.22 to 0.28% and 84.27 to 84.97% respectively. Protein and fat contents of both Acha and Iburu increased during steeping while carbohydrate, crude fibre and ash contents decreased. The bulk density, water absorption capacity, oil absorption capacity, swelling power and dispersibility were in the range of 0.83 - 0.94 g/ml, 1.60 - 2.13 g/ml, 1.90 - 2.17 g/ml, 6.09 - 7.00 g/ml and 77.50 - 78.00% respectively. The results showed that the flours produced from both fermented Acha and Iburu could be useful for both domestic and industrial purposes. This will increase the demand for Acha and Iburu, proffer alternative for wheat flour in the production of snacks and ensure food security.

KEYWORDS

Flour
Acha
Iburu
Indigenous crops
Fermentation

1. INTRODUCTION

Acha (*Digitaria exilis*) is a tiny whitish cereal which originated from Africa. It is also known as hungry rice, fonio and fundi. It is a great crop of antiquity and one of the oldest crops of West African origin and its cultivation dates back thousands of years (Glew *et al.*, 2013; Malomo and Abiose, 2020). *Iburu* (*Digitaria iburua*), the black specie is also known as black fonio or petit mil.

The same size of these grains reduces the processing time thereby reducing loss of nutritional value during processing. It also contains a higher amount of sulphur-containing amino acid "methionine and cysteine" than maize, sorghum and millet and also contains a higher amount of calcium and phosphorus (Coda *et al.*, 2010).

Acha and *Iburu* are traditionally consumed in the form of porridges, *Acha jollof*, and couscous, and have been used in the production of composite flour in bread production (Satimehin and Philip, 2012).

One of the major challenges facing baking and confectionary industries in Nigeria is the cost of importation of wheat which directly affects the cost of products obtained from wheat flour. Researchers are working on cereals which could be used to substitute wheat wholly or partially to reduce over-dependency on wheat (Olapade and Oluwole, 2013; Malomo and Abiose, 2019). The acha grains have a high quantity of pentosan, which is important in the absorption of water for the production of viscous solution which is an attribute required for baking. *Acha* and *Iburu* have been named as nutraceutical foods that could prevent prediabetes and manage type 2 diabetes (Deriu, 2022).

Digitaria species do not contain glutenin and gliadin protein which causes celiac diseases (Ayo and Ayo, 2018). *Acha* and *Iburu* have lower glycemic index compared to cereals such as sorghum, rice and maize which make the grain suitable for diabetic patients and also contain resistant starch which could act as prebiotics for the beneficial probiotic microorganisms in the gut (Anderson, 2010).

The process of fermentation has been in practice since time immemorial. It improves the taste and aroma by producing carbonyl compounds, increases the digestibility of food by breaking down macromolecules present in food into simple products and also has a positive impact on the rheological properties of fermented products. Enzymes that break down non-digestible compounds such as cellulose and hemicellulose into digestible sugars which could be utilized in the body are also produced during the process of fermentation (Malomo *et al.*, 2019).

Many researchers have worked on *Acha* (Coda *et al.*, 2010; Ayo and Ayo, 2018; Malomo *et al.*, 2020) but there is still a dearth of information on the effect of fermentation on the chemical properties of *Acha* and *Iburu* flours. This research focused on fermentation for possible improvement of nutritional and functional properties of flours produced from *Acha* and *Iburu*.

2. MATERIALS AND METHODS

2.1. Procurement of materials

Acha and *Iburu* grains were purchased from Kaduna Central Market in Kaduna, Kaduna State and were stored in air-tight containers untill required for analyses.

2.2. Production of *Acha* and *Iburu* flours

One kilogramme each of the *Acha* and *Iburu* grains were weighed and washed with clean water. The grains were soaked in water in a ratio of 1:2 (w/v) for 3 and 5 days. Samples were picked from the steeped water and grain on days 0, 3 and 5 for microbiological analysis and pH determination. After the steeping period, the grains were rinsed with clean water, drained, thinly spread in trays and dried in the cabinet dryer at 50 °C for 8 h. The fermented grains were milled into flours and sieved using a sieve with a diameter of 0.02 mm according to the modified method of Malomo *et al.*, (2020).

2.3. Enumeration of microorganisms

Microorganisms were enumerated on days 0, 3 and 5. One milliliter of appropriate dilution of each sample was dispensed into well-labeled sterile petri dishes. Plate count agar (PCA), de Man

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Rogosa Sharpe Agar (MRS) and potato dextrose agar were prepared according to the manufacturer's instruction. The agars were cooled to 45 °C and 20 ml was poured over each sample and swirled in clockwise and anticlockwise directions to ensure even distribution of microbial cells. The MRS plates were incubated anaerobically, the PCA plates aerobically at 32 °C for 48 h and 24 h respectively while the PDA plates were incubated at 27 °C for 72 h. MRS was used for lactic acid bacteria count, PDA for fungi and PCA for total aerobic bacteria counts.

This was done for the selected days (0, 3 and 5) during the fermentation of the grains. The culture plates were examined after incubation and the colonies per plate were counted and recorded for the estimation of colony-forming units per ml (CFU/ml) of the original sample (Harrigan, 1998; Adepoju *et al*., 2016).

2.4. Determination of Proximate composition of *Acha* and *Iburu* flours

The moisture content, protein, fat, ash, crude fibre and Carbohydrates of the fermented *Acha* and *Iburu* flour were determined on days 0, 3 and 5 using AOAC (2005).

2.4.1. Moisture Content

Moisture cans were dried in a hot air oven at 100 °C for 1 h to obtain a constant weight and then cooled in a desiccator. Each of the samples (2 g) was weighed into different moisture cans, labelled and dried at 105 °C until a constant weight was obtained. The moisture content was calculated using Equation 1.

$$\text{Moisture content (\%)} = \frac{\text{Loss in weight of sample}}{\text{Original weight of sample}} \times 100 \quad (1)$$

2.4.2. Crude protein content

Each sample (5 g) was weighed into a digestion flask (AOAC, 2005). Kjeldahl catalyst (0.8g) was added to the sample already weighed into the flask and 15 ml of concentrated sulphuric acid was added. Each flask was heated on a pre-heated digester for about 4 hours in the fume cupboard. This was digested until a clear homogenous mixture was obtained. After digestion, the flask was removed from the heater, cooled and the content was diluted with about 50 ml of distilled water. The flask was then placed in the Kjeldahl analyser (distillation unit) where it received 5 ml of 40% NaOH automatically. The mixture was subsequently heated up to release ammonia which was distilled into a conical flask containing 25 ml of 2% boric acid for about 15 min. Two to three drops of methyl orange (indicator) were added to the Erlenmeyer flask and were titrated with 0.1 M HCl. During the distillation process, the ammonia combined with boric acid to form ammonium borate solution which was titrated against 0.1 M sulphuric acid until a purplish-grey endpoint was obtained.

$$\text{\% Gram Nitrogen} = \frac{0.28 \times A}{\text{Sample weight in gram}} \quad (2)$$

where A = volume(ml) of 0.1M H_2SO_4.

The protein content was attained by multiplying the % Nitrogen by a factor of 6.38. The experiment was carried out in duplicates for each sample and the average values were (AOAC, 2005).

2.4.3. Crude fat content

Crude fat content of *Acha* flour samples was determined using a soxhlet extractor containing a reflux condenser and a distillation flask which had been previously dried and weighed. Each sample (2.0 g) was weighed into a thimble and placed in the reflux flask. The distillation flask was filled to two-thirds capacities with n-hexane and boiled on a heating mantle for 4 h. Thereafter, n-hexane was recovered into a clean container by distillation. The remaining solvent in the distillation flask was evaporated in a hot air oven set at 70 °C. The flask was allowed to cool down in a desiccator after which the final weight of the flask was determined. The difference in the final and the initial weights of the distillation flask was recorded (AOAC, 2005).

$$\text{\% Crude fat} = \frac{\text{final weight of the flask} - \text{Initial weight of flask}}{\text{Weight of flask}} \times 100 \quad (3)$$

2.4.4. Total ash content

Total ash content was determined by using a muffle furnace (Carbolite AAF1100, United Kingdom) according to the method of AOAC (2005). Five grams (W_1) of the sample was weighed into an already weighed (W_2) ashing crucible and placed in the muffle furnace chambers at 550 °C until the samples turned into ashes usually within 5 h. The crucibles were removed, cooled in a desiccator and weighed (W_3). Total ash content was expressed as the percentage of the original sample as shown in equation 4.

$$\text{Ash content (\%)} = \left(\frac{W_3 - W_2}{W_1}\right) \times 100 \quad (4)$$

where W_1 = weight of sample, W_2 = weight of empty crucible, W_3 = weight of crucible + ash

2.4.5. Crude fibre content

Each sample (5 g) was weighed into a conical flask, 100 ml of 1.25% sulphuric acid was added and heated for 30 min while being rotated. The resulting mixture was filtered through Whatman 1 filter paper and rinsed with 50 ml boiling water. This was repeated with three 50 ml portions of water and subsequently sucked dry. The residue was boiled in a flask containing 1.25% NaOH and filtered, washed with 25 ml of 1% sulphuric acid, three portions of 50 ml water and 25 ml ethanol. It was then transferred into a crucible of known weight and dried in a hot air oven at 105 °C for about 4 h. The dried sample was ashed in a muffle furnace at 600 °C for 30 min, cooled and weighed (AOAC, 2005). The percentage of crude fibre in each sample was calculated as:

$$\text{\% Crude Fibre} \frac{\text{Loss in weight on ignition}}{\text{Weight of sample}} \times 100 \quad (5)$$

The carbohydrate content of each sample was obtained by difference using equation 6.

$$\text{Carbohydrate (\%)} = 100 - (\text{\% moisture content} + \text{\% crude fat} + \text{\% crude fibre} + \text{\% ash content} + \text{\% crude protein}) \quad (6)$$

2.5. Determination of functional properties of fermented *Acha* and *Iburu* flour

Bulk density, swelling power, dispersibility, water absorption capacity and oil absorption capacity were determined

2.5.1. Determination of water absorption capacity (WAC)

Distilled water (10 ml) was added to each flour sample and stirred for 5 min at 1000 rpm in a magnetic stirrer. The mixture was thereafter transferred into a centrifuge tube and centrifuged at 3500 rpm for 30 min. The supernatant was removed and measured by using a 10 ml measuring cylinder (Sathe *et al*, 1982). The water absorption capacity was calculated as:

$$\text{WAC (\%)} = \frac{\text{Volume of water absorbed}}{\text{Initial Weight of sample}} \times 100 \quad (7)$$

2.5.2. Determination of oil absorption capacity (OAC)

The method described by (Sathe *et al*, 1982) was used. Vegetable oil (10 ml) was added to each flour sample and stirred for 5 min at 1000 rpm in a magnetic stirrer. The mixture was thereafter transferred into a centrifuge tube and centrifuged at centrifuged at 3500 rpm for 30 min. The supernatant was

removed and measured by using a 10 ml measuring cylinder. The oil absorption capacity was calculated as:

$$\text{OAC} = \frac{\text{Volume of oil absorbed}}{\text{Initial Weight of sample}} \times 100 \quad (8)$$

2.5.3. Bulk Density

A known amount of sample was weighed into a 50 ml measuring cylinder. The sample was packed up by gently tapping the cylinder on the bench top 10 times from a height of 5 cm. The volume of the sample was then recorded.

$$\text{Bulk density (g/ml or g/cm3)} \quad \frac{\text{weight of sample}}{Volume\ of\ sample\ after\ tapping} \times 100 \quad (9)$$

2.5.4. Swelling Power Test

Each flour (1 g) was weighed into a 100 ml conical flask and 15 ml of distilled water was added and shaken for 15 min at low speed. It was transferred into the water bath and heated for 40 min at 80-85 °C with constant stirring. It was then transferred into a pre-weighed centrifuge tube and 7.5ml of distilled water was added. It was centrifuged at 2,200 rpm for 20 min and the supernatant was carefully decanted into a pre-weighed can and dried at 100 °C to constant weight. It was then cooled in a desiccator and weighed. The precipitate with the centrifuge tube was weighed.

$$\text{Swelling power} = \frac{\text{weight of sediment}}{sample\ weight - weight\ of\ soluble} \quad (10)$$

2.5.5. Dispersibility test

Each flour sample (10 g) was placed in a 100 ml measuring cylinder, distilled water was added to reach a volume of 100 ml. The mixture was stirred vigorously and allowed to settle for 3 h at room temperature. The volume of settled particles was recorded and subtracted from 100. The difference was reported as % dispersibility

2.6. Statistical analysis

Data obtained were subjected to analysis using Analysis of Variance (ANOVA) to determine significant differences at $p < 0.05$ and Means were separated using Duncans Multiple Range Test (DMRT) on the SPSS package (SPSS, Inc, Chicago, USA)

3. RESULTS AND DISCUSSION

3.1. Microbial counts of *Acha* and *Iburu* during steeping

The microbial counts for the 3rd and 5th days of fermentation are shown in (Figures 1 - 3). Total viable counts (TVC) of *Acha* and *Iburu* grains and steep water increased during steeping. Count was lowest in steeped *Acha* water (Sample AA) (3.565 to 8.188 log cfu/ml) and highest in steeped *Iburu* grains (Sample BI) (4.043 - 11.000 log CFU/ml). Ingbian and Agwu (2010) reported an increase in microbial population during the steeping of maize grain. This increase could be a result of the breaking down of complex molecules into simple compounds that can be easily utilized by microorganisms (Adepoju *et al.,* 2012).

Lactic Acid Bacteria count (LAB) of *Acha* and *Iburu* generally increased during steeping from 0 to 8.075 log CFU/ml (Figure 2). There was no viable LAB in steeped *Iburu* water (Sample AI) at day 0 while sample BI had a count of 0.507 log CFU/ml. This shows that LAB was more concentrated in the steeped grain and water (sample BI) than the steeped water (sample AI) at the beginning of steeping. Counts were higher in samples AI and BI (6.334 - 8.075 log cfu/ml) than in AA and BA (6.186 - 7.844 log CFU/ml) on days 3 and 5 respectively. LAB produce organic acid that imparts a sour taste on fermented products and also produces aromatic compounds that give fermented food products a desirable aroma (Malomo *et al.*, 2020).

Fungi counts of *Acha* and *Iburu* grains generally increased during steeping (Figure 3). Samples AA and AI had no count at day 0 while BA and BI had 2.300 log cfu/ml and 2.000 log cfu/ml respectively showing that fungi were introduced from the grain. Counts were also higher in samples AI and BI (7.611-7.699 log cfu/mL) than AA and BA (5.841 – 6.633 log cfu/ml) at day 3 and day 5 showing that LAB could utilize the nutrient in *Acha* than *Iburu*. A symbiotic relationship between yeasts and LAB has been reported by several researchers during natural fermentation (Gadaga *et al.*, 2001; Owuzu-Kwarteng and Akabanda, 2014; Malomo *et al.*, 2018).

The coexistence of different microorganisms has been observed at the beginning of fermentation, but as the process progresses, different metabolites will be produced by the fermenting microorganisms which could inhibit the activities of others and those that can withstand the food environment will become dominant. Some of these species are lactic acid bacteria which include genera *Leuconostoc, Lactobacillus, Streptococcus* and *Pediococcus*. *Micrococcus* and *Bacillus* species have also been identified as dominant microorganisms during the process of fermentation of *Acha* and *Iburu* sourdough (Coda *et al.*, 2010) and storage of *Fura* de Nunu (Adepoju *et al.*, 2012).

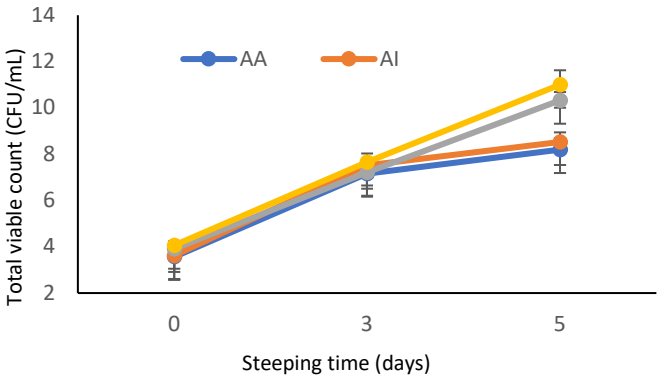

Figure 1. Total viable count of Acha and Iburu during steeping

AA: Steeped Acha Water;
AI: Steeped Iburu Water;
BA: Steeped Acha Grains and Water
BI: Steeped Iburu Grains and Water

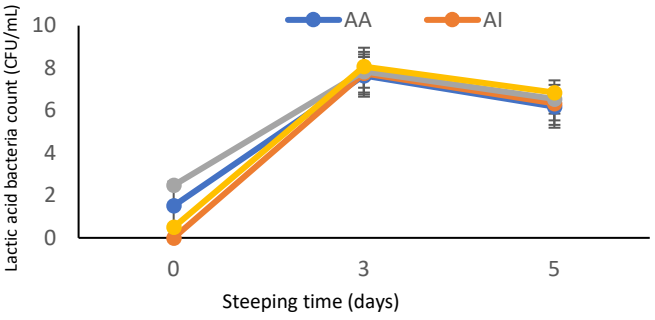

Figure 2. Lactic acid bacteria count of Acha and Iburu during steeping

AA: Steeped Acha Water;
AI: Steeped Iburu Water;
BA: Steeped Acha Grains and Water
BI: Steeped Iburu Grains and Water

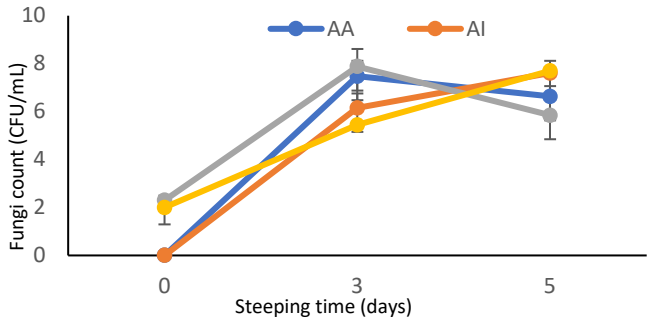

Figure 3. Fungal count of Acha and Iburu during steeping

AA: Steeped Acha Water;
AI: Steeped Iburu Water;
BA: Steeped Acha Grains and Water
BI: Steeped Iburu Grains and Water

3.2. Microorganisms isolated from *Acha* and *Iburu* during steeping

Twelve microorganisms were isolated from *Iburu* while 9 were isolated from *Acha*. *Serratia marcescens, Acinetobacter anitarus, Stapylococcus aureus* and *Escherichia coli* were dominant on day 0; *Bacillus subtilis*, *Leuconostoc mesenteroides, Pediococcus spp Streptococcus mutans* and *Micrococcus roseus* were the dominant microorganisms isolated in *Acha* on the 3rd and 5th days of steeping. *Proteus vulgaris, Enterobacter spp, Escherichia coli and Staphylococcus aureus* were dominant in *Iburu* at day 0. *Bacillus cereus, Bacillus subtilis, Listeria monocytogenes Aerococcus spp, Lactobacillus plantarum, Streptococcus agalactiae, Pediococcus spp Micrococcus varians* were the dominant organisms isolated on the 3rd and 5th days of steeping.

All pathogenic microorganisms isolated at the beginning of fermentation were not viable on the 3rd and 5th day. This could be due to the production of organic acid by LAB which reduced the pH of food thereby inhibiting the growth and activities of spoilage and pathogenic microorganisms. Studies also showed that antimicrobial substances known as bacteriocins which reduces the proliferation of some microorganisms are produced by LAB (Malomo *et al.*, 2018). *Pediococcus spp* and *Lactobacilli spp* were the dominant Lactic acid bacteria found in *Acha* and *Iburu* flours (Coda *et al*, 2010). Sanni *et al.* (2002) characterized the microbial flora present in natural fermentations of maize flours and found diverse species of *Lactobacillus, Leuconostoc, Saccharomyces, Debaryomuces, Candida, Bacillus, Micrococcus, Klebisella, Escherichia* and *Aspergillus* with *Lactobacillus* as the dominant species. Malomo *et al.* (2018) also reported the activities of *Bacillus* and *Micrococcus* during fermentation of *Acha* grains.

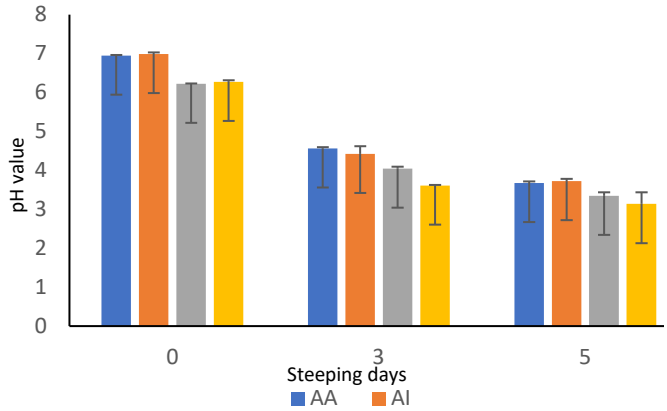

Figure 4. pH graph of the Fermented Grains during Fermentation

AA: Steeped Acha Water;
AI: Steeped Iburu Water;
BA: Steeped Acha Grains and Water
BI: Steeped Iburu Grains and Water

3.3. pH and Titratable acidity of *Acha* and *Iburu* grain during steeping

The pH graph of the fermented grains is shown in Figure 4. The hydrogen ion concentration ranges from 3.30 to 6.98. The pH of fermented *Acha* grains reduced with an increase in the period of fermentation. The pH of fermented *Iburu* grains reduced on the 3rd day of fermentation and increased on the 5th day. The reduction in pH value has been attributed to the activities of natural microbial floral in the grains which produce enzymes that hydrolyze starch into simple sugar, thereby producing metabolites and organic acids that reduce the pH of fermented foods (Adepoju *et al.*, 2012; Ishola *et al.*, 2018; Azeez *et al.*, 2022).

Table 1: Proximate Composition of flours from fermented Acha and Iburu (%)

Content (%)	A_3	A_5	I_3	I_5
Moisture	8.90 ± 0.10^{a}	8.82 ± 0.17^{a}	7.36 ± 0.05^{b}	7.35 ± 0.07^{b}
Protein	9.08 ± 0.03^{c}	9.23 ± 0.15^{b}	9.22 ± 0.05^{b}	9.43 ± 0.02^{a}
Fat	3.74 ± 0.20^{d}	4.92 ± 0.06^{b}	4.19 ± 0.04^{c}	5.30 ± 0.07^{a}
Crude Fibre	0.24 ± 0.10^{b}	0.22 ± 0.01^{c}	0.28 ± 0.01^{a}	0.27 ± 0.01^{a}
Ash	1.08 ± 0.04^{b}	0.83 ± 0.04^{d}	1.33 ± 0.03^{a}	0.99 ± 0.02^{c}
Carbohydrate	85.86 ± 0.14^{a}	84.78 ± 0.12^{b}	84.97 ± 0.02^{b}	84.27 ± 0.51^{c}

Mean values in the same row followed by different superscripts are significantly different at $p \leq 0.05$. A_3: flour from 3 days fermented *Acha*; A_5: flour from 5 days fermented *Acha*; I_3: flour from 3 days fermented *Iburu*; I_5: flour from 5 days fermented *Iburu*

3.4. Proximate composition of *Acha* and *Iburu* flours

The proximate composition of the fermented flour samples (A_3, A_5, I_3, and I5) are presented in Table 1. The moisture content of the fermented flour samples ranged from 7.35% to 8.90%. Sample I_5 had the lowest while A_3 had the highest moisture content. Moisture content was higher in A_3 and A_5 (8.82 - 8.90%) than I_3 and I_5 (7.35 - 7.36%). The moisture content of *Acha* was in the range of 8.62 - 8.79% reported by Ayo and Ayo (2018).

The protein content of the fermented flour samples ranged from 9.08% - 9.43% with I_5 having the highest value while A_3 had the lowest protein content. The concentration of proteins in fermented *Acha* and *Iburu* flours was higher than that of 7% reported for unfermented *Acha* and *Iburu* flour (Coda *et al*, 2010), and when compared with rice, millet, maize and sorghum but lower than that of wheat (Temple and Bassa, 1991). *Acha* protein content is comparable to rice but it has a higher content of sulphur-containing amino acid "methionine and cystine (Deiru *et al.*, 2011). Fermentation improves cereals' protein quality(Malomo *et al.*, 2020). Fermentation reduces non-nutritive content of a food such as anti-nutrients (Azeez *et al.*, 2022).

The fat content of the flour samples varied from 3.74% to 5.30% with A_3 having the lowest and I_5 the highest fat. The range of fat content obtained in this study is higher than the value obtained by Deriu *et al.* (2011) in unfermented *Acha* grain which indicates that fermentation increased the fat content of both *Acha* and *Iburu.*

The crude fibre content of fermented *Acha* and *Iburu* flours were between 0.22 and 0.28%. It was significantly higher in *Iburu* than *Acha* and generally higher on day 3 than on day 5. The carbohydrate content in *Acha* (84.74 - 85.86%) was significantly higher than *Iburu* (84.24 - 84.86%). It was also significantly higher ($p < 0.05$) in A_3 and I_3 than A_5 and I_5 showing that the increase in fermentation days led to a decrease in the carbohydrate content of both *Acha* and *Iburu.* The carbohydrate content of *Acha* was lower and Adepoju *et al.* (2016) attributed the decrease in carbohydrates to the activities of the fermenting microorganisms and their enzyme which break down starch to simple sugars and organic acids.

Fermentation did show a significant effect ($p < 0.05$) on protein, crude fat and carbohydrates of the fermented flour sample by the increase in their relative nutritive value. Moisture, ash,

crude fibre and carbohydrate contents of the fermented flour samples decreased with the increase in the fermentation period while the protein and fat content increased. The increase in protein and fat content was in agreement with the findings of Malomo *et al.* (2020). The range of the crude protein, fat and crude fibre was in agreement with Ballagoun *et al.* (2013).

Table 2: Functional properties of flours fermented Acha and Iburu grains.

Functional properties	A_3	A_5	I_3	I_5
Bulk Density (g/ml)	0.94 ± 0.04^{a}	0.94 ± 0.05^{a}	0.80 ± 0.03^{b}	0.83 ± 0.05^{b}
Water Absorption Capacity (g/g)	2.10 ± 0.10^{a}	2.13 ± 0.15^{a}	1.60 ± 0.10^{b}	1.87 ± 0.35^{a} b
Oil Absorption Capacity (g/g)	2.17 ± 0.15^{a}	2.07 ± 0.06^{a} b	1.90 ± 0.10^{b}	2.03 ± 0.06^{a} b
Swelling Power (g/ml)	7.00 ± 0.21^{a}	6.84 ± 0.10^{a}	6.25 ± 0.0^{b}	6.09 ± 0.23^{b}
Dispersibility (%)	78.00 ± 0.48 ab	78.50 ± 0.1 4^{a}	77.00 ± 0.4 6^{c}	77.50 ± 0.1 5^{bc}

Mean values in the same row followed by different superscripts are significantly different at $p \leq 0.05$. A_3: flour from 3 days fermented *Acha*; A_5: flour from 5 days fermented *Acha*; I_3: flour from 3 days fermented *Iburu*; I_5: flour from 5 days fermented *Iburu*

3.5. Functional properties of *Acha* and *Iburu* flours

The effect of different fermentation periods on the functional properties of flour samples produced from fermented *Acha* and *Iburu* grains are shown in Table 2.

The bulk density of A_3 and A_5 are not significantly different ($p > 0.05$) but are significantly higher ($p < 0.05$) than I_3 and I_5. This implies that the fermented flour obtained from *Iburu* (0.80 and 0.83 g/ml) on the 3rd and 5th day of fermentation had a lower bulk density than *Acha* flour (0.94 g/ml). The period of fermentation had no significant effect ($p > 0.05$) on the bulk density of both *Iburu* and *Acha* flours. The bulk density of fermented *Iburu* was lower than that of *Acha* which may offer a packaging advantage. Bulk density of flour is essential in packaging, handling and application of flour (Falade and Okafor, 2015; Ramashia *et al.*, 2017).

Water absorption capacity ranged between 1.90 to 2.17 g/ml. There was no significant difference ($p > 0.05$) between the WAC of fermented flour samples obtained on day 3 and 5. WAC of flours obtained from *Acha* on 3rd and 5th day of fermentation was significantly higher ($p < 0.05$) than flour obtained from *Iburu*. *Digitaria* will be a good raw material for bakers because it is high in pentosan which regulates water absorption in the dough (Ayo and Kajo, 2016).

Oil absorption capacity and swelling power decreased with the increase in the period of fermentation. Oil absorption capacities ranged from 1.90 to 2.17 g/ml with *Acha* having the highest and *Iburu* the lowest. OAC was higher in flour produced from *Acha* than flour produced from *Iburu* on 3rd and 5th day of fermentation. The OAC of flours has been reported to improve the flavour, taste and mouth feel of food (Klunklin and Savage, 2018).

The dispersibility values ranged between 77% to 78% and the values differ significantly between *Acha* and *Iburu*. It was higher in flours produced from *Acha* (78.00 and 78.50%) than *Iburu* (77.00 and 77.50%). The dispersibility of flour in water indicates it can be reconstituted easily. The range of dispersibility (45.50 - 51.0%) for maize, sorghum, millet and sorghum reported by Oluwole *et al.* (2016) was lower than the range (77.00 - 78.00%) obtained in this study. A higher value of the reconstitution index indicates that the sample will give a fine mixture during mixing (Eke-Ejiofor *et al.*, 2018).

The swelling capacity of fermented *Acha* is higher than that of fermented *Iburu*, which shows that *Acha* can swell more. *Acha* and *Iburu* samples had higher water absorption capacity and dispersibility on day 5 than on day 2.

Fermented *Acha* and *Iburu* flours can be used in the production of healthy and nutritious foods such as functional foods and dietary snacks which are specially made for those with specific dietary needs and preferences. Asides the effect of fermentation on nutritional properties, low-glycemic index of *Acha* flours makes it suitable for exploitation in the production of value-added innovative products such as low glycemic and gluten-free food products, confectioneries, snacks, dumplings, pasta for people with health conditions such as Celiac (gluten intolerance) and diabetes.

Acha and *Iburu* flours demonstrate a potential as a valuable supplement to conventional diets. Likewise, the absence of gluten in fermented flours of *Acha* and *Iburu* makes them suitable for consumption in people with celiac disease or gluten sensitivity. *Acha* and *Iburu* flours possess Fe and Zn significantly, which is similar to other cereals like wheat. Compared to other African grains (e.g., sorghum, millet and maize), *Acha* and Iburu contains higher levels of calcium and, especially, phosphorous. *Acha and Iburu* flour has been demonstrated to have high water absorption capacity, a property that contributes to its suitability for use in baked goods which could be attributed to the presence of appreciable amount of pentosan sugars. This will make the flours sample a probable substitute for wheat in the bakery industries. *Acha and Iburu flours also* exhibited less polyphenols compared to other African cereals like sorghum (*Sorghum bicolar*), hence, has high protein digestibility. Fermentation is known to enhance nutrient availability, improve digestibility and gut health.

Fermented *Acha* and *Iburu* flours offer new economic opportunities and niche markets, especially in the nutraceutical and gluten-free segments. Unlike wheat, farming which is resource-intensive and poses environmental challenges, *Acha* and *Iburu* have lower environmental impacts and promote sustainable agriculture especially in regions prone to drought and poor soil conditions. Often, refined wheat flour, which is less nutritious, is employed in baking. However, Fermented *Acha* and *Iburu* flours offer significant health benefits other than the nutritional ones which makes it superior to other flours in terms of nutritional profile, digestibility and gluten-free nature, hence a promising functional food ingredient.

4. CONCLUSION

Flour with good nutrient composition can be produced from both fermented and non-fermented *Acha* and *Iburu*. The flour produced may be useful for food production locally and industrially, especially in composite flour for baking and confectionary. This will advance the use of *Acha* and *Iburu* in promoting food security, and reduce over dependence on wheat.

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