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Effects of sprouting and dehulling on the proximate composition and anti-nutrient contents of Okpa prepared from three Bambara nut varieties

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Abstract
Okpa is a traditional dish prepared from milling Bambara nut into flour. It is a popular savoury Nigerian delicacy originating from the South-Eastern part of Nigeria, particularly Enugu State made from ground Bambara nut. It serves as a staple cuisine among the inhabitants of the Eastern region of Nigeria for breakfast or as a snack. It has a firm texture, typically steamed in banana leaves or nylon bag with palm oil, pepper and salt. This study was designed to investigate the effects of sprouting and dehulling on the proximate composition, phytochemical, and organoleptic properties of Okpa prepared from flours of three different Bambara groundnut (Vigna subterranea) varities namely: cream, black and red. Samples of the three varieties were obtained from Cereal Research Institute Bida and were transported in airtight containers to the Food Science and Technology Laboratory of the Department of Food Science and Technology University of Maiduguri where they were subjected to sprouting and dehulling at ambient temperatures prior to their milling into flours. The proximate composition and anti-nutrients analyses of flours and Okpa were carried out using the Standard Analytical Techniques, whereas the organoleptic properties were evaluated by twenty semi trained panelists made up of students and staff who were familiar with the Okpa using 9-point hedonic scale under controlled laboratory conditions. The results of the proximate composition, expressed in percentages, showed significant differences ($p \leq 0.05$) between protein and fat contents of the sprouted red and black varieties, the mean values were 22.7±82.43% and 8.70±3.74%, respectively; and the mean crude fiber contents of the dehulled cream variety was 13.07±0.41%. The results also showed a significant decrease ($p \leq 0.05$) in the phytochemical contents of both the sprouted and dehulled samples of the flours and the Okpa produced from the flours. On the organoleptic qualities, the results obtained suggested that the dehulling resulted in an improvement in color, texture, taste, and aroma, as evidenced by the higher mean values observed in the dehulled black Bambara groundnut Okpa samples; whereas the sprouted samples recorded higher mean values in terms of overall acceptability of Okpa produced from the flours of the three Bambara groundnut varieties. The study therefore, recommended that households should be encouraged to use the red and black Bambara groundnut varieties as they contain higher nutrients when compared with the cream variety.

Keywords: *Okpa*, dehulling, sprouting, anti-nutrients, organoleptic properties

Introduction

Bambara groundnut (*Vigna subterranea (L.) Verdc),* is an indigenous African legume mainly grown for its seeds. It has become increasingly recognized as a staple food in rural regions across the African Continent (Khan *et al*., 2021). The locals favor the Bambara groundnut since it is thought to have more nutrients than many other legumes (Lin Tan *et al*., 2020). However, Bambara groundnut is still largely unexplored and underutilized, despite being widely cultivated in Nigeria and being a widespread staple crop in semi-arid regions of Africa (Bamshaiye *et al*., 2011). The best utilization of Bambara as a food source has been found to be hampered by issues including the presence of beany flavors, processing challenges (particularly its requirement for extended cooking times), and its content of a high anti-nutrient agent (Aminu *et al*., 2021).

Moreover, a renewed interest has emerged recently in Bambara groundnut cultivation in arid savannah zones. The dried, ripe seeds are usually milled into flour or boiled and eaten as pulses. Freshly picked pods or seeds are shelled, prepared and consumed as snacks in Nigeria (Nnenna *et al*., 2022). In addition, the seeds are roasted and salted, to prepare a snack known as "*ngangala*" among the Kanuri tribe in Northern Nigeria, or the nut is ground into a flour and then tumbled to a tick nutritious paste to make "*Okpa*," a popular dish among the Igbo tribe in Eastern Nigeria, which is an analog of "*moin moin*" (Ogunmuyiwa *et al*.,2017).

Despite its many nutritional advantages, Bambara groundnut has been reported to be similar to many other legume seeds in that it contains many anti-nutritional factors such as tannins, phytates, and trypsin inhibitors (Ikokoh *et al*., 2019). Furthermore, high quantities of phytates, which are known to reduce the bioavailability of cations, especially calcium, have also been reported to be present in Bambara groundnut (Nwanna *et al*., 2005).

The current study seeks to determine how sprouting and dehulling would affect the chemical and organoleptic qualities of *Okpa* made from three varieties of Bambara nuts.

Materials and Method

1. Materials.

1.1 Acquisition of the Bambara Nut Seeds

The three cultivars of Bambara nuts (*Vigna subterranea*) namely black, cream, and red were purchased, in enough quantities, directly from the Cereal Research Institute Bida, Niger State, Nigeria. The samples were transported to

Processing Laboratory of the Department of Food Science and Technology, University of Maiduguri in airtight containers for their preparation and subsequent processing into *Okpa*. Three sets of samples were prepared for each of the processing methods: sprouting or dehulling, while the third set served as control. The third batch of seeds was cleaned and ground into flour in a blender (Bardefu stainless blender Model: QC 11); the flour was then stored in a plastic container that was tightly closed until it was needed.

2. Methods

2.1 Experimental Design

The experiment was laid out on a Completely Randomized Design (CRD) where the three (3) Bambara groundnut types (black, cream and red) were the main factors and three sets of each factor formulated into three making a total of nine treatments. Each of the treatments were replicated three times and analysis of variance (ANOVA) was used to evaluate the effects of the three processing methods and their interactions

2.2 Production of Flours from Sprouted, Unsprouted and Dehulled Nuts

The flow charts for the sprouted, unsprouted and dehulled Bambara ground nut flours are shown in Figures 1 to 3, respectively. The sprouting process was carried out in accordance with the method described by Shah *et al*. (2011), with minor modifications (Figure 1). In this process, the seeds were first soaked for 24 hours at room temperature in distilled water and then sprouted for three (3) consecutive days, using different containers. The sprouted seeds were then sun-dried for two days, before milling into flours. For the unsprouted experiment, the nuts were dried to a moisture content of 12% (Mubaiwa *et al*., 2018), before milling (Figure 2), this served as the control. Whereas in the dehulling exercise, the procedure outlined by Adamuyan *et al*. (2012) was followed (Figure 3). In each of the experiments, two (2) kilograms of each of the three Bambara ground varieties: cream, black, and red, were used and the experiments were carried out in triplicates using plastic containers covered with muslin cloth.

The nuts obtained from the three separate experiments sprouted, unsprouted and dehulled, were milled using a Blender (Bardefu stainless blender Model: QC 11), and the flours obtained were sieved through a 300 µm mesh into previously cleaned plastic buckets which were properly closed and then stored until used.

3. Preparation of the *Okpa* Samples

The *Okpa* samples were prepared from the flours obtained from each of the three Bambara ground nut varieties following the procedures outlined by Barimalaa *et al*. (2005), as illustrated in Figure 4. Ingredients such as red pepper, onion, salt, palm oil (Table 1) and hot water were added and thoroughly mixed with either the sprouted, unsprouted, or dehulled

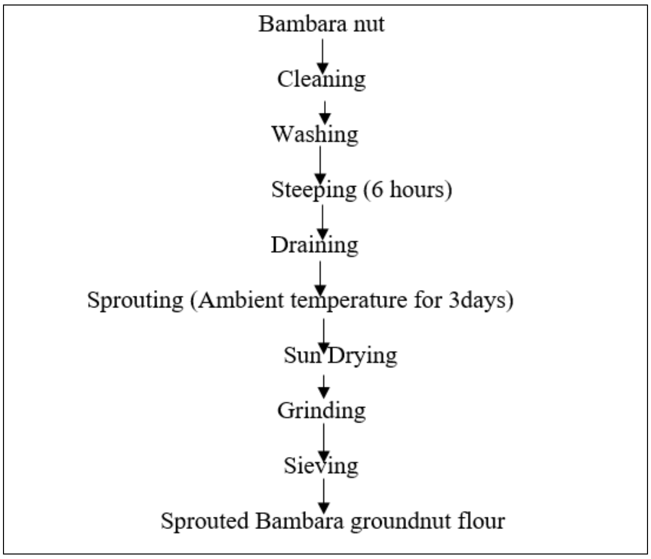

Fig 1: Flow Chart for Production of Sprouted Bambara nut Flour (Modified from Shah *et al.,* 2011)

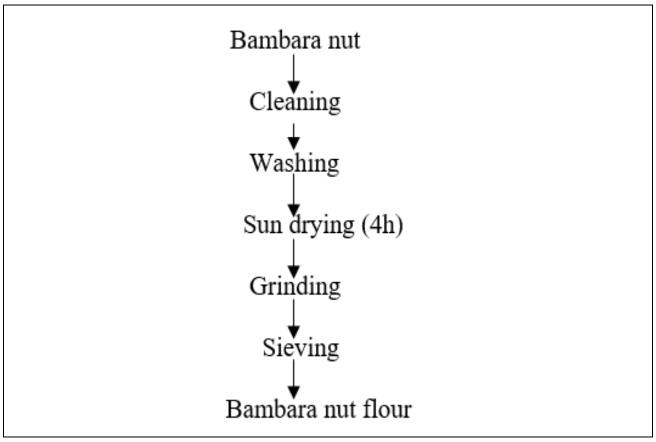

Fig 2: Flow Chart for Production of Bambara Nut Flour (Modified from Mubaiwa *et al.,* 2018).

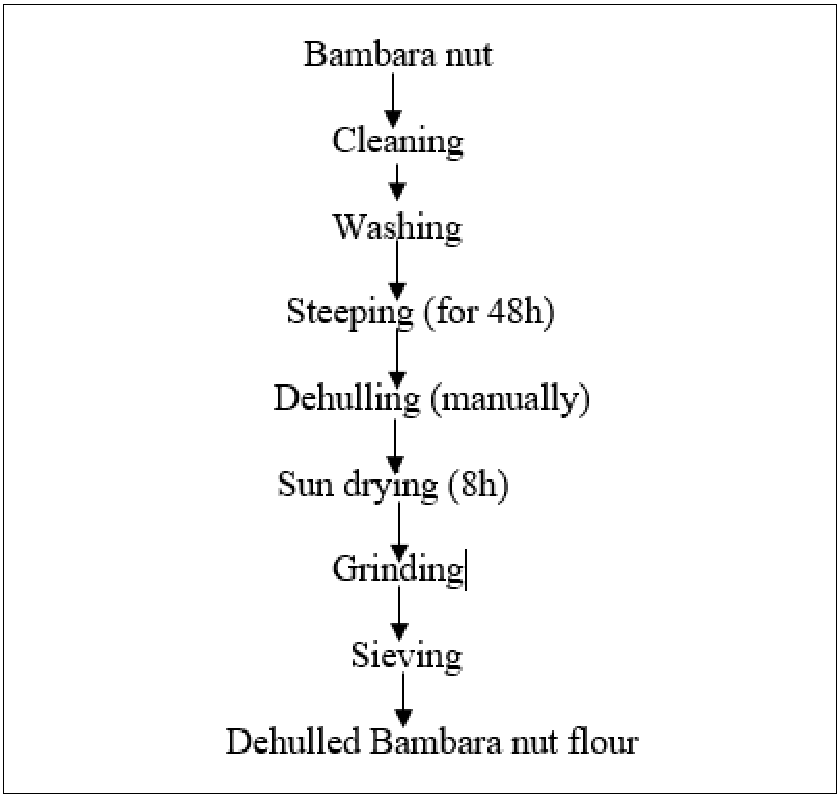

Fig 3: Flow Chart for the Production of Dehulled Bambara Nut Flour (Modified from Adamuyan *et al.*, (2012).

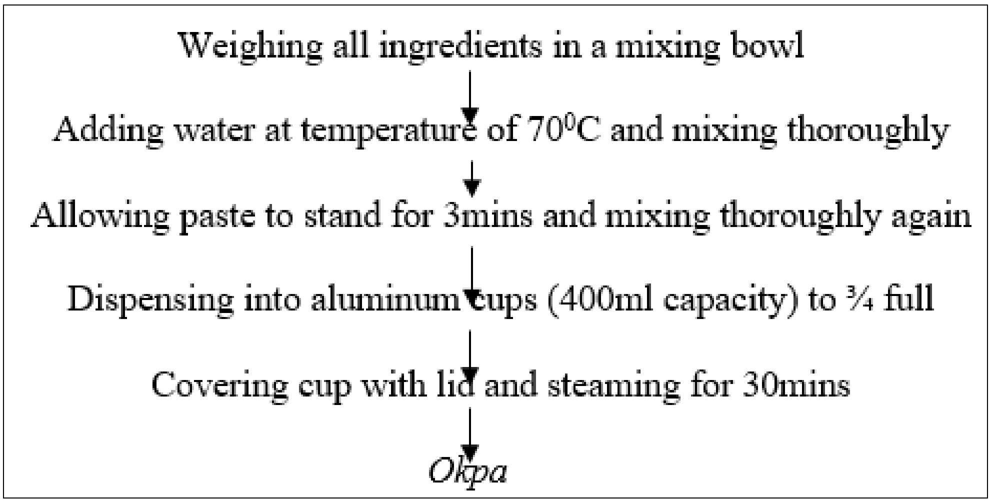

Fig 4: Flow Chart for the Preparation of *Okpa* (Barimalaa *et al.*, 2005)

Bambara nut flours from each of the varieties. The resulting semi-tick slurry was then steamed for 30 minutes, cooled and then stored until analyzed. A control sample was also prepared in the same way, using unprocessed Bambara nut flour.

Table 1: Formulation and Recipe for *Okpa* preparation

Sample Code[1]	**Ingredients**				
	Flour (g)	**Palm Oil (ml)**	**Salt (g)**	**Water(ml)**	**Red Pepper (g)**
R_C	500	350	5	500	10
S_C	500	350	5	500	10
D_C	500	350	5	500	10
R_B	500	350	5	500	10
S_B	500	350	5	500	10
D_B	500	350	5	500	10
R_R	500	350	5	500	10
S_R	500	350	5	500	10
D_R	500	350	5	500	10

[1]R_C = Raw Cream; S_C = Sprouted cream; D_C = Dehulled Cream; R_B = Raw Brown; S_B = Sprouted Brown; D_B = Dehulled Brown; R_R = Raw Red; S_R = Sprouted Red; D_R = Dehulled Red.

4. Proximate Analysis of the Samples

Determination of the proximate composition (protein, fat, carbohydrate, ash, and moisture) was conducted following the procedures outlined in the American Association of Cereal Chemists (AACC, 2000; Nielsen, 2019).

5. Determination of the Anti-nutrient Contents

Phytic acid was determined using the method reported by Anhwange *et al*. (2015) while for oxalates, the titration method described by Day and Underwood (1986) was used with slight modifications. The method reported by Kirk and Sawyer (1998) was adopted for tannin quantification, where standard calibration curve was prepared and the absorbance against concentration of tannins at specific wavelength was estimated. The gravimetric method of Adeniyi *et al*. (2009) was adopted for alkaloid analysis.

6. Sensory Evaluation

The organoleptic properties were evaluated by twenty semi trained panelists made up of students and staff who were familiar with the *Okpa* using 9-point hedonic scale under controlled laboratory conditions. In this process, the *Okpa* samples were scored from 1-9, with 9 being liked extremely, 8 (liked very much), 7 (liked moderately), 6 (liked slightly), 5 (neither liked nor disliked), 4 (disliked slightly), 3 disliked moderately), 2 (liked very much) and 1 (disliked extremely); and the sensory attributes evaluated were: colour, taste, aroma, texture, and overall acceptability.

7. Statistical Analysis

The one-way analysis of variance (ANOVA) was used to compare the means of the variables and significantly different means were separated using Turkey's Honestly Significance (HSD) at 5% level of probability using Statistical Tool.

Results and Discussions

1. Effects of Sprouting and Dehulling on the Proximate Composition of *Okpa* Produced from the Bambara Groundnut Flours

The results obtained from the proximate analysis of the *okpa* produced using the sprouted and dehulled cream, black, and red varieties of Bambara groundnut flours are presented in Table 2. It can be observed that sprouted cream *Okpa* exhibited the highest mean moisture content of 30.70±0.52% while the raw black variety had the lowest value of 22.17±0.23%. The addition of water as an ingredient prior to the cooking of mix is thought to be responsible for the significant variations ($p \leq 0.05$) in the moisture content of the *okpa* from the three Bambara groundnut flours. This result is comparable to Ugwu *et al*. (2022) [1] findings on African yam bean and Bambara groundnut pudding, where the average moisture content was observed to be 18% and 22%, respectively; however, the *Okpa* produced in this study showed higher moisture levels. The moisture contents reported by Adumanya *et al*. (2012) [2, 14] and Davidson *et al*. (2019) [3], were however, higher than the values observed in this study.

Table 2: Effect of Sprouting and Dehulling on Proximate Composition (%) and Energy value (kcal) of the *Okpa* from three Bambara Groundnut Varieties.

Sample Code [2]	Parameters (%)[1]						Energy (kcal)
	Moisture	Protein	Fat	Crude fiber	Ash	Carbohydrate	
RCOK	27.24^{b} ±0.43	14.01^{a} ±0.01	9.74^{b} ±0.05	8.19^{d} ±0.17	3.11^{b} ±0.00	38.65^{b} ±0.12	298.30
SCO	25.06^{a} ±0.02	17.56^{c} ±0.05	11.30^{c} ±0.00	7.67^{e} ±034	4.01^{a} ±0.01	33.93^{a} ±0.12	307.03
DCOK	30.70^{c} ±0.52	11.00^{f} ±0.00	6.78^{a} ±0.04	7.03^{f} ±0.06	2.91^{d} ±0.02	40.90^{c} ±0.20	265.68
RBOK	22.17^{a} ±0.23	16.07^{d} ±0.06	8.53^{d} ±0.49	6.33^{g} ±0.35	4.00^{a} ±0.00	42.02^{d} ±0.00	309.13
SBOK	29.82^{d} ±0.27	14.01^{e} ±0.99	10.87^{e} ±0.04	6.06^{h} ±0.13	3.09^{b} ±0.08	36.00^{a} ±0.00	297.87
DBOK	28.00^{e} ±0.00	13.92^{e} ±0.00	10.12^{f} ±0.00	5.01^{a} ±0.01	2.06^{e} ±0.02	40.76^{e} ±0.21	309.80
RROK	24.25^{a} ±0.17	19.01^{b} ±0.01	9.19^{g} ±0.11	3.03^{a} ±0.04	3.00^{c} ±0.00	41.01^{f} ±0.02	322.79
SROK	29.95^{f} ±0.05	23.85^{a} ±0.06	6.29^{a} ±0.43	2.14^{a} ±0.12	3.01^{c} ±0.00	34.97^{a} ±0.06	291.89
DROK	27.47^{e} ±0.11	19.28^{b} ±0.06	8.48^{a} ±0.49	2.00^{a} ±0.00	1.11^{f} ±0.02	41.59^{g} ±0.07	319.80

[1]Values are means ± standard deviation of three determinations. In any column, means bearing similar superscripts are not significantly different ($p \geq 0.05$);

[2]RCOK = Raw cream *Okpa*; SCOK = Sprouted cream *Okpa*; DCOK =Dehulled cream *Okpa*; RBOK=Raw black *Okpa*; SBOK =Sprouted black *Okpa*; DBOK =Dehulled black *Okpa*; RROK =Raw red *Okpa*; SROK =Sprouted red *Okpa*; DROK =Dehulled red *Okpa*.

The cooking process was observed to have resulted in a reduction in protein levels across all the *Okpa* samples. The dehulled *Okpa* samples, particularly those from the cream variety, exhibited a significant decrease ($p \leq 0.05$) from 14.01±0.01% to 11.00±0.00%; whereas that of black *Okpa* decreased from 16.07±0.06% to 13.92±0.00%. In contrast to this observation, cooking had a positive impact on the protein contents of *Okpa* produced from sprouted cream and red Bambara groundnuts, the values increased from 17.56±0.05% and 23.85±0.06%, respectively. The values of protein recorded in this are in line with the findings of many other researchers including Davidson (2019) [3], Olapade and Adetuyi (2007) [4, 22] and Omorodion and Alobari (2022) [5, 16].

Lipids, or fats, are secondary plant products known for providing more energy per gram than carbohydrates and proteins. In the case of *Okpa* from sprouted Bambara groundnut, the sprouted cream variety displayed the highest fat content of 11.30±0.00%, while the sprouted red variety exhibited the lowest value of 6.29±0.43%. In a study by China *et al*. (2019) [6], a higher fat content was recorded, whereas Amoshogha and Peter (2021) reported a higher fat content in *Okpa* prepared and enriched with three leafy green vegetables. Fat content is crucial for the shelf-life stability of food products due to the potential rancid flavor formation. Both sprouted and dehulled *Okpa* from the various varieties could however, be good sources of energy and fat-soluble vitamins for the body. The fat content recorded in this study is in line with the findings of Ugwu *et al*. (2022) [1] and is also close to the results obtained by Aniebet and Olarenwaju (2018) [13] for moin-moin made from cowpea and Bambara groundnut.

A significant decrease ($p<0.05$) was observed in crude fiber contents of the processed *okpa* samples, ranging from 8.19±0.17% to 7.03±0.06% and from 6.33±0.35% to 5.01±0.35% in the cream and black varieties respectively. This is likely due to the heat exposure during the cooking process. Dehulled cream and black varieties had lower fiber contents when compared with the sprouted cream (7.67±034%) and sprouted black *Okpa* (6.06±0.13%). The fiber content in dehulled cream is close to the values reported by Adumanya *et al*. (2012) [2, 14] and Davidson *et al*. (2019) [3].

The dietary fiber content in both sprouted and dehulled *Okpa* exceeded that of Akara from prepared from Bambara groundnut and cowpea flours. This is in line with the findings of Ebube and Maduka (2022) [15] in their studies on proximate composition of main African Legumes. Also, the fiber content of both sprouted and dehulled red Bambara groundnut is close to the values recorded by Omorodion and Olabari (2022) [5, 16] on steamed Bambara groundnut pudding (*Okpa*).

Furthermore,the *Okpa* produced from the sprouted cream variety recorded the highest mean ash content (4.01±0.01%), while the lowest mean value (1.11±0.02%), was observed in *Okpa* from the dehulled red Bambara groundnut. Both the sprouting and dehulling processes resulted in a significant decrease ($p\leq0.05$) in the ash content of *Okpa* prepared from cream and black Bambara groundnut varieties.

Generally, the ash content of a food item is reflective of the mineral content present in that food. The results obtained in this study showed that the sprouted cream variety had a higher ash content when compared with the sprouted black and red varieties. The ash contents obtained in this study are lower than those reported by Adumanya *et al*. (2012) [2, 14], Asomugha and Peter (2021), and Ugwu *et al*. (2022) [1] in Bambara nut pudding. On the other hand, the ash content reported by Anosike *et al*. (2019) [8] in maize flour and African yam pudding were lower than that observed in this study.

A decrease in the carbohydrate level was observed which may be attributed to the water-to-flour ratio used during the preparation of the Okpa. According to Adeyanju and Abimbola (2015) [9], the hydrophilic groups in carbohydrate molecules have the tendency of absorbing moisture in a manner that is proportionate to the relative humidity of the of the food environment. This characteristic behavior may lead to moisture uptake and an apparent reduction in the percentage of carbohydrates in the food.

The okpa samples prepared from the Red Bambara (RB) and Sprouted Cream (SC) varieties had the lowest (40.02±0.00%) and the highest (42.02±0.00%) mean carbohydrate values, respectively. The Okpa samples produced through the two processing methods using the three varieties of Bambara groundnut exhibited a significant difference ($p\leq0.05$) when they are compared with the control samples. On the other hand, the *okpa* from three dehulled Bambara nut varieties recorded a higher carbohydrate content when compared with the sprouted samples. The carbohydrate content of dehulled *Okpa* in this study is higher than the values reported by Okereke *et al*., (2022) [10] and Ugwu *et al*. (2022) [1] from Bambara groundnut pudding. A diet rich in carbohydrates is usually considered as beneficial because it supplies the energy required for physical activities (Ijeh *et al*., 2010) [11]. However, individuals with diabetes, who need minimal carbohydrate intake, find advantages in low-carbohydreate diets.

2. The Effect of Sprouting and Dehulling on Phytochemical contents of *Okpa* from the three Bambara Ground Nut Varieties

The results presented in Table 3 reveal the phytochemical contents of *okpa* samples from three different varieties. The highest phytate contents (480.33±2.08 mg/g), was found in the raw red sample while the lowest (125.67 ±2.52mg/g), was observed in the dehulled cream sample. The results also indicate that sprouting caused a significant decrease ($p\leq0.05$) in the cream, black, and red varieties; the mean values were 168.67±2.08 mg/g, 218.66±0.57 mg/g, and 213.67±2.52 mg/g, respectively. A similar trend was observed in the dehulled samples, where decreases were recorded in all the samples. This reduction could likely be attributed to the cooking process, which resulted in a decrease in the antinutrient levels.

The results of the analysis for the oxalate contents of *Okpa* indicated a decrease across the samples following sprouting and dehulling processes. The oxalate levels of *Okpa* from raw cream and red varieties decreased from 2.51±0.07 mg/g to 2.38±0.06 mg/g, and 4.01±0.02 mg/g to 0.60 ±0.05 mg/g, respectively, after dehulling. Sprouting also resulted in a decrease in oxalate contents from 2.51 ±0.07mg/g to 1.48±0.01 mg/g, 1.24 ±0.02mg/g to 0.26±0.06 mg/g and 4.01±0.02 mg/g to 0.60 ±0.05 mg/g in cream, black, and red Bambara groundnut varieties, respectively. The observed reductions in the oxalate levels across the samples after processing were statistically significant ($p\leq0.05$). The highest levels of oxalate (2.51±0.07 mg/g) were found in raw red *Okpa* and the lowest level (0.26±0.06 mg/g) was in sprouted black *Okpa*.

Heating may lead to losses in oxalic acid, phytic acid, and tannins, and leaching during soaking and cooking may also be a contributing factor. The results recorded in this study are in line with that of Siddhuraju and Becker (2001) [12], who observed reductions of 4 – 8 % of phytic acid due to leaching in *mucuna* beans. The authors suggested that low molecular weight and ionic forms of phytic acid are more prone to leaching. Additionally, the heat applied during cooking may decrease phytic acid through the formation of insoluble complexes with other components like phytate-mineral, phytate-protein, and phytate-protein-mineral complexes (Siddhuraju and Becker, 2001) [12].

Table 3: Comparison between the Anti-nutrient Contents of *Okpa* Processed from the three Bambara Groundnut Cultivars.

Sample Code[2]	Phytochemicals (mg/g)[1]				
	Phytate	**Oxalate**	**Tannin**	**G/ cyanide**	**Alkaloids**
R_C	$294.00^{a} \pm 13.99$	$4.95^{b} \pm 2.12$	$19.80^{b} \pm 0.67$	$0.86^{sb} \pm 0.05$	$0.01^{b} \pm 0.00$
S_C	$226.30^{a} \pm 23.71$	$3.63^{a} \pm 0.85$	$20.05^{c} \pm 0.14$	$0.15^{a} \pm 0.01$	$0.00^{a} \pm 0.00$
D_C	$177.30^{a} \pm 16.01$	$4.44^{c} \pm 1.10$	$19.85^{d} \pm 0.95$	$0.75^{c} \pm 0.34$	$0.00^{a} \pm 0.00$
R_B	$423.18^{b} \pm 35.47$	$4.23^{d} \pm 0.55$	$19.81^{e} \pm 0.91$	$0.90^{d} \pm 0.00$	$0.02^{c} \pm 0.00$
S_B	$260.23^{c} \pm 13.53$	$2.23^{a} \pm 0.55$	$12.54^{a} \pm 0.62$	$0.78^{e} \pm 0.01$	$0.00^{a} \pm 0.00$
D_B	$346.93^{d} \pm 21.18$	$3.98^{a} \pm 0.39$	$18.34^{f} \pm 0.54$	$0.73^{f} \pm 0.00$	$0.01^{d} \pm 0.00$
R_R	$541.60^{e} \pm 52.65$	$6.19^{e} \pm 3.96$	$21.75^{g} \pm 0.97$	$0.56^{a} \pm 0.05$	$0.02^{e} \pm 0.00$
S_R	$272.7^{a} \pm 82.65$	$2.46^{a} \pm 0.33$	$14.89^{a} \pm 0.93$	$0.25^{a} \pm 0.01$	$0.00^{a} \pm 0.00$
D_R	$424.46^{f} \pm 32.01$	$5.03^{f} \pm 0.47$	$13.94^{a} \pm 0.99$	$0.14^{a} \pm 0.03$	$0.00^{a} \pm 0.00$

[1]Values are means ± standard deviation of three determinations. In any column, means bearing similar superscripts are not significantly different ($p \geq 0.05$);

[2]R_{COK} = Raw cream *Okpa*; S_{COK} = Sprouted cream *Okpa*; D_{COK} =Dehulled cream *Okpa*; R_{BOK}=Raw Black *Okpa*; S_{BOK} =Sprouted Black *Okpa*; DBOK =Dehulled Black *Okpa*; RROK =Raw red *Okpa*; SROK =Sprouted red *Okpa*; D_{ROK} =Dehulled red *Okpa*.

The decrease in detectable tannins during cooking may be attributed to the formation of complexes like tannins, tannin-protein, tannin polysaccharide, and tannin-mineral, as suggested by Oyeyinka *et al*. (2019) [17] in their study in Bambara groundnut infant puree, and by Sinha *et al*. (2013) [18] and Mustapha *et al*. (2014) [19] in their studies on Moimoi. The present study also observed a reduction in glyosidic cyanide post-cooking, with raw black *Okpa* having the highest (0.35 ±0.01mg/g) and dehulled red sample the lowest (0.03±0.00 mg/g); while alkaloid content was not detected in the *Okpa* across all the samples, even when heating was minimal. Alkaloids are known for their hormonal action prolongation and stimulant properties (Majola *et al*., 2021) [20].

3. Results of the Sensory Evaluation of the *Okpa* produced from the three Bambara Groundnut Varieties

The results of sensory evaluation showed that the *Okpa* produced from the sprouted cream bambara groundnut flour had the highest mean acceptability score (8.0±0.94); when compared with that of raw black *Okpa* which had the lowest acceptability score of 5.7±2.05 (Table 4). The difference in overall acceptability between the three products may be attributed to the color of the raw materials. Nti (2009), observed that removing highly pigmented seed coats of Bambara groundnut through pre-treatments like dehulling, roasting, germination, and fermentation can enhance the appearance, texture, and taste of products; and that addressing the challenge of long cooking time, especially for dried seeds, can be overcome through milling. In this study, it was observed that sprouted cream *Okpa* and dehulled black *Okpa* had the same mean score of 7.10±1.59 for the aroma and the least preferred for this sensory attribute was observed in dehulled cream *Okpa*. Similarly, the *Okpa* from raw cream and dehulled black samples was scored highest in terms of taste, whereas for color and texture, *Okpa* from dehulled black scored highest mean values of 7.60 ±2.31 and 7.20±3.0, respectively.

The results of this study indicate that removing the seed coat through dehulling played a role in enhancing the attractive appearance of the produced *Okpa*. The sprouted red *Okpa* showed the lowest mean score (4.90±2.16) for texture, while dehulled red *Okpa* scored a mean value of 4.60±2.67 for color. The process of dehulling had a positive impact on the *Okpa*, contributing to its overall appeal. These results are in line with the findings of Olapade and Adetuyi (2007) [4, 22] from their research on the impact of steam blanching, hot blanching, and cold water soaking, and roasting on Bambara groundnut *Okpa*. The outcomes of this study exceeded those reported by Adamunya (2012) in a sensory evaluation of *Okpa* prepared from fluted pumpkin and scent leaves.

In general, the present study suggests that dehulling led to improved color, texture, taste, and aroma, as evidenced by the higher mean values observed in the dehulled black Bambara groundnut *Okpa* sample. Furthermore, sprouted samples demonstrated higher mean values in terms of overall acceptability across *Okpa* produced from the three Bambara groundnut varieties.

Table 4: The Mean Scores of Sensory Evaluation of *Okpa* from the Three Varieties of Bambara Groundnut Flours recorded in this Study

Sample Code[2]	Sensory Parameter[1]				
	Colour	**Texture**	**Taste**	**Aroma**	**Overall Acceptability**
R_{COK}	$5.40^{bc} \pm 1.77$	$6.50^{abc} \pm 2.06$	$7.00^{a} \pm 1.56$	$6.30^{ab} \pm 1.25$	$6.3^{b} \pm 1.76$
S_{COK}	$7.40^{a} \pm 1.35$	$7.10^{ab} \pm 1.85$	$6.20^{ab} \pm 2.48$	$7.10^{a} \pm 1.59$	$8.00^{a} \pm 0.94$
D_{COK}	$5.50^{bc} \pm 2.06$	$5.30^{abc} \pm 2.58$	$4.70^{bc} \pm 2.05$	$4.40^{c} \pm 2.17$	$5.7^{b} \pm 2.05$
R_{BOK}	$5.40^{bc} \pm 1.83$	$5.40^{abc} \pm 1.89$	$5.20^{bc} \pm 2.04$	$4.60^{c} \pm 1.43$	$5.9^{b} \pm 1.66$
S_{BOK}	$6.60^{ab} \pm 1.71$	$6.00^{abc} \pm 2.26$	$5.90^{ab} \pm 1.72$	$5.90^{abc} \pm 1.10$	$7.1^{ab} \pm 1.28$
D_{BOK}	$7.60^{a} \pm 2.31$	$7.20^{bc} \pm 1.81$	$7.00^{a} \pm 1.56$	$7.10^{a} \pm 1.66$	$6.8^{ab} \pm 1.47$
R_{ROK}	$7 \pm 20^{ab} \pm 30$	$5.20^{bc} \pm 1.98$	$4.80^{bc} \pm 1.68$	$4.80^{bc} \pm 2.25$	$6.8^{ab} \pm 1.68$
S_{ROK}	$6.54^{ab} \pm 1.91$	$4.90^{c} \pm 2.16$	$4.18^{c} \pm 1.9$	$4.90^{bc} \pm 1.64$	$6.45^{b} \pm 2.20$
D_{ROK}	$4.60^{c} \pm 2.67$	$5.50^{abc} \pm 2.87$	$5.70^{abc} \pm 2.11$	$6.00^{abc} \pm 2.66$	$6.1^{b} \pm 2.37$

[1]Values are means ± standard deviation of twenty panelist. In any column, means bearing similar superscripts are not significantly different ($p \geq 0.5$);

[2]R_{COK} = Raw cream *Okpa*; S_{COK} = Sprouted cream *Okpa*; D_{COK} =Dehulled cream *Okpa*; R_{BOK}=Raw black *Okpa*; S_{BOK} =Sprouted black *Okpa*; D_{BOK} =Dehulled brown *Okpa*; R_{ROK} =Raw red *Okpa*; S_{ROK} =Sprouted red *Okpa*; D_{ROK} =Dehulled red *Okpa*

Conclusion

Based on the findings of this study, sprouting and dehulling of Bambara groundnut seeds resulted in an increase in nutritional quality. An increase in the moisture contents and a decrease in the carbohydrate contents were observed in the *Okpa* samples across the three varieties. Similarly, a further decrease in the antinutrients contents was observed in the *Okpa* samples made from the three Bambara groundnut varieties. Therefore, households should be encouraged to use the red and black Bambara groundnut varieties as they contain higher nutrients compared with the cream varieties as confirmed in this study.

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