Research Journal of Food Science and Nutrition
Volume 9(2), pages 52-60, April 2024
Article Number: 87A331342
ISSN: 2536-7080
https://doi.org/10.31248/RJFSN2024.171
https://integrityresjournals.org/journal/RJFSN

Full Length Research

Effect of processing methods on the nutritional composition and sensory properties of two African mango (*Irvingia gabonensis*) seed varieties

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Received 28th February 2024; Accepted 17th March 2024

ABSTRACT: The objective of this study was to determine effects of processing methods on the nutritional composition and sensory properties of two African mango (*Irvingia gabonensis*) seed varieties- *Irvangia gabonensis var. gabonensis* and *Irvingia gabonensis var. wombolu.* Four processing methods (boiling, soaking, blanching and defatting) were used to treat the samples. The treated and untreated African mango locally called '*ogbono'* in Nigeria were processed into flours, and used to prepare soups, and results analyzed. Proximate, viscosity and sensory properties of the soups were determined, as well as the proximate, mineral and phytochemical contents of the flours. The moisture, ash and crude fibre content of the flours ranged from 6.20-8.91%, 1.25-1.98% and 1.10-1.70%, respectively. The mineral content of the flours ranged from 262.79-801.25 mg/100g for calcium, 1.48-6.90 mg/100g for iron, 255.13-754.24 mg/100g for sodium and 173.14-285.69 mg/100g for magnesium. Results revealed that the various treatment methods reduced the phytochemical contents of the treated flours. Hydrogen cyanide content of the untreated flours ranged from 3.66-4.06 mg/kg as against the treated samples which ranged from 2.23-3.76 mg/kg. The sensory properties of the soups were evaluated. Sample A0 recorded the highest (7.61) for taste, 7.50 for thickness, and overall acceptability of 7.48. The highest sensory score for drawability was recorded by sample A2 with 7.45, while sample B4 had the lowest sensory score (2.40) for drawability. Sample B4 also recorded the least sensory score for thickness (2.65), while the least score for appearance (3.40) and overall acceptability (3.76) was recorded in sample A4. Sample A2 had the highest viscosity (76.71 Pa.s) while sample B4 recorded the least viscosity (19.63 Pa.s). This study reveals that processing methods like boiling, soaking, blanching and defatting on the seeds improved the proximate and mineral compositions of the flours, reduced the phytochemical contents of the flours and maintained the drawability of the soups prepared with the two varieties.

Keywords: African mango, ogbono soup, processing methods, drawability, *Irvingia gabonensis.*

INTRODUCTION

Irvingia gabonensis grows wild in forests of tropical Africa. According to Gbadamosi *et al*. (2021), it is a species of African tree that grows at elevations between 200 and 500 m (660 and 1640 feet) and is also known as the wild mango, African mango, bush mango, 'dika, or ogbono'. It is truly a multipurpose tree as it provides food, fuel, fibre, medicine and timber. Its fruits are edible, having yellow pulp, it seeds contain oil used in different culinary processes. The wood is hardy and green having resistance to termites. The bark is used as medicine for arthritis, dropsy, swelling, edema, gout, eye treatment, and stomach trouble. This plant offers considerable scope for enhancing the nutritional and economic security of subsistence farmers. It is now recognized for its various food and medicinal uses. This plant produces seeds rich in fat, which is traditionally used as a soup thickener (Yamoneka *et al.,* 2015).

There are roughly seven different *Irvingia* species found in Africa: *Irvingia excels* and *Irvingia grandiofolia* (both in Central Africa), *Irvingia gabonensis*, *Irvingia robur* and *Irvingia smithii* (both in West and Central Africa), *Irvingia wombolu* (both in West and Central Africa), and *Irvingia malayana* (both in Southeast Africa). Two of these species, *Irvingia gabonensis* and *Irvingia wombolu*, are primarily found in Nigeria. Because of its mango-like fruits, *Irvingia spp*. are often known as African/bush/wild mangoes (Matos *et al*., 2009; Ngondi *et al*., 2005). The kernels are used as a condiment in Nigeria and are prized for their ability to thicken food (Ndjouenkeu *et al.,* 1996) while making "Ogbono" or draw soup. *I. gabonensis* kernels are widely sold in Cameroon (Ndoye *et al.,* 1997) and constitute a significant diet that provides protein, oil, and carbohydrates to improve nutrition and health. Although bitter and acrid with a turpentine flavour, the pulp, kernel, and fruit are palatable to both humans and animals (Atangana *et al*., 2001). The fruits are rich in oil and can be used in making bread, chocolate, cheese, butter, soap and feed cake. The kernels of the fruits are considered to be the most valuable component for various reasons. They are rich source of fat, oil and protein and are used widely as condiments in thickening of sauce (Matos *et al*., 2009). *Irvingia gabonensis* and *Irvinga wombolu* are similar and are often difficult to differentiate from herbarium specimens alone (Harris, 1996). However, the edibility of the fruit mesocarp can help distinguish between the two. Additionally, listed as diagnostic characteristics by Harris (1996) were the amount of mucilage in the cotyledons, the size of the endosperm, the height of the first branching, the disc-shaped unfertilized flowers, and the shape of the tree. Fruit from *Irvingia gabonensis* can be consumed naturally. The delicious pulp can be utilized to make juice, smoothies, jam, jelly, and wine. The seeds can be crushed to make margarine or vegetable oil. The dried 'dika nut' seeds can be ground and used for preparing "*ogbono*" soup, stew, chocolate and 'dika' bread. Ngondi *et al.* (2005) opined that *ogbono* seed is capable of reducing fasting blood glucose levels in obese beings.

The aim of this study was to determine the effects of boiling, soaking, blanching and defatting on the nutritional composition and sensory properties of the flour of two African mango (*I*. *gabonensis*) and (*I*. *wombolu*) varieties.

MATERIALS AND METHODS

The two varieties of ogbono (*Irvingia gabonensis*) were purchased from an Ogbono farm in Uyo, Akwa Ibom State, Nigeria. Other ingredients such as crayfish, pepper, dry fish, salt, etc. were purchased at Mile 3 Market in Port Harcourt, Rivers State, Nigeria. Chemicals and reagents were sourced from the Biochemistry Laboratory, Department of Food Science and Technology, Rivers State University, Port Harcourt and they were all of the analytical grade.

Sample preparation

Preparation of Ogbono seed flour

As described by Akusu and Kiin-Kabari (2003) with modifications, 2 kg of each Ogbono seed varieties were cleaned, sorted and divided into four portions. A portion was boiled for 30 minutes at 100°C, a portion was soaked for 24 hours at room temperature (27°C), and the third portion was blanched for 1 minute at 70°C before oven drying at 55°C for 24 hours in a hot air fan oven (Model QUB, 305010G, Gallenkamp, UK), grind using a laboratory mill (Numex Pep Grinding Mill, India); and screened through a 0.25 mm British Standard sieve (Model B5410, Endecotts Ltd, London UK). The fourth portion was milled before defatting by cold pressing, and oven dried, then milled to produce various batches of ready-to-cook Ogbono flour. The processing of the treated and untreated ogbono flours is shown in Figure 1.

Preparation of Ogbono soup

As described by Ogunbusola *et al*. (2014) with modifications, 100 g each of the ground Ogbono seed flour that has been air-tight-sealed in ziplock bags, was removed at intervals and used in the preparation of Ogbono soups, based on the recipe in Table 1. The dry fish was steamed for 25 minutes and put in a clean bowl. Ogbono seed flour was poured in slightly heated palm oil, and mixed thoroughly. The fish was then added to the mix, and water was added. Other ingredients were then added and allowed to boil for 20 minutes, and ogbono soup was ready to be served.

Proximate analysis

The proximate composition of the two varieties of ogbono flours and soups was determined according to the methods described by AOAC (2016). Carbohydrate content was determined by difference.

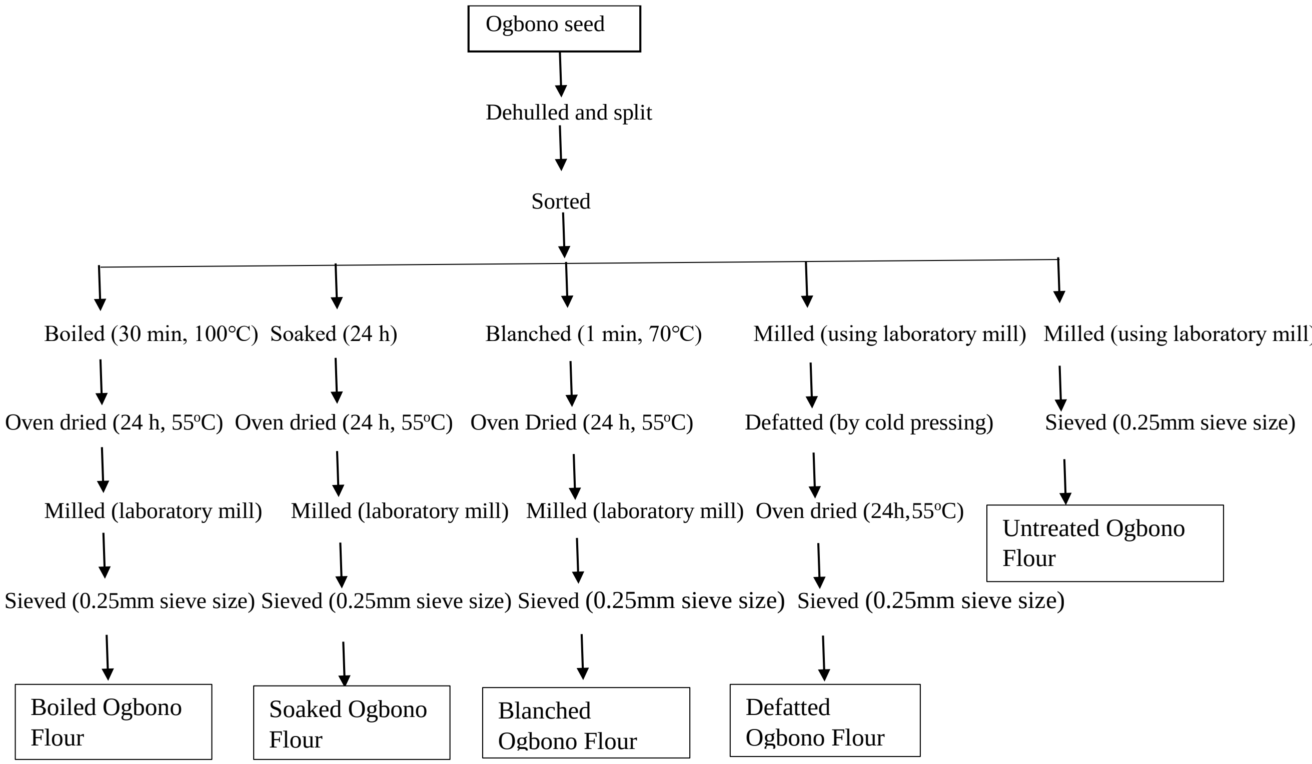

Figure 1. Processing of treated and untreated Ogbono flour.

Table 1. Recipe for preparation of Ogbono soups.

Ingredients	*Irvingia gabonensis*	*Irvingia wombolu*
Grind Ogbono (g)	100	100
Palm oil (ml)	60	60
Water (ml)	500	500
Dry fish (g)	50	50
Onion (g)	10	10
Dry pepper (g)	2	2
Salt	To taste	To taste

Mineral content analysis

As described by Gbadamosi *et al.* (2021), 1 g of each sample was digested with 10% HNO_3 after ashing. The sample was filtered after digestion and the filtrate was made up to 100 mL of distilled deionized water. Atomic Absorption Spectrometer was used to determine the concentration of Iron, Magnesium and Calcium while Flame Photometry was used for the determination of Sodium.

Viscosity determination

Fifty grams (50 g) of the soup was weighed, 40 ml of water was added and treated to boiling. The soup was allowed to cool to room temperature and the viscosity was determined with the aid of a Rotary Digital Viscometer (NDJ-8S). Using spindle number 4 at 3 rpm. The content of the beaker was introduced onto the rotating spindle and values of the viscosity were displayed on the LCD screen in Pa.s and taken as the viscosity of the soup as described by AOAC (2016).

Phytochemical analysis

As described by Nbaeyi-Nwaoha and Onwuka (2014), determinations of alkaloid, flavonoid and saponin contents were done by Alkaline Precipitation Gravimetric,

Gravimetric and Double Solvent Extraction Gravimetric methods respectively. Tannin content was determined by the Folin Denis Colourimetric method. Hydrogen cyanide (HCN) determination was carried out with the Alkaline Picrate Colorimeter method.

Sensory evaluation

A semi-trained panel of 20 consumers consisting of staff and students of the Department of Food Science and Technology of Rivers State University, Port Harcourt, Rivers State, Nigeria was selected based on experience and familiarity with Ogbono soup for sensory evaluation of appearance, colour, taste, flavour, drawability, thickness and overall acceptability based on a 9-point Hedonic scale (Iwe, 2010). The sample rating ranged from 1 (dislike extremely) through 5 (neither like nor dislike) to 9 (like extremely). The soup was served warm, and water was provided to rinse the mouth between evaluations.

Statistical analysis

All the analysis was carried out in duplicate. Data obtained was subjected to Analysis of Variance (ANOVA). Difference between means was evaluated using Turkey's Multiple comparison tests with 95% confidence level. The statistical package SPSS software version 26 was used.

RESULTS AND DISCUSSION

Effect of processing on the proximate composition of soups from differently processed Ogbono seeds

Table 2 shows the proximate composition of soups prepared from two ogbono seed varieties with different processing methods. The result of the proximate composition showed a significant ($p<0.05$) increase in moisture (71.35 – 86.85%), fat (4.91 – 17.59%), crude protein (2.00 – 5.34%) and carbohydrate (1.20 – 6.84%). The moisture content showed the lowest value (71.35%) in sample A0 while the highest (86.85%) in sample A4. The percentage protein content of the soups increased. This increase from (2.00 – 5.34%) may be due to the processing methods, which is in line with the work of Ekpe *et al.* (2007), who opined an increase in protein content as a result of the processing method of fermentation of seeds. It can also be as a result of other ingredients used. There was no significant difference ($p>0.05$) in the ash content of the samples, as sample A1 had the highest value (2.23%) and B4 had the least value (1.47%). The values obtained are a bit lower than those reported by Idowu *et al*. (2013), and this may be as a result of the variety of kernels used in this study. The crude fat content ranged from (4.91–17.59%), with sample B4 having the least value (4.91%) and sample B1 having the highest (17.59%). There was no significant difference ($p<0.05$) between the untreated and boiled samples in their fat content. Samples with low fat contents were observed to have high moisture content, and this agrees with Eke-Ejiofor et al. (2023) who reported a reduction in the moisture content of seafood preserved with spice oleoresins as a result of the increase in fat content. The carbohydrate value of the samples was moderately ranged (1.18 – 6.84%), having a significant difference ($p<0.05$), and differs from the result (11.91% carbohydrate) earlier reported by Oladimeji and Fasuan (2018). This may be as a result of variations in ingredients used in preparing the soups.

Effect of processing on the proximate composition and viscosity of flours from differently processed Ogbono seeds

Table 3 shows no significant difference ($p>0.05$) in the moisture (6.20 -8.09%) and crude fibre (1.10 – 1.70%) and with an increase in the carbohydrate content (16.86 – 40.91%). The moisture content showed the lowest value (6.20%) in sample A0 while the highest (8.09%), in samples A3 and B2 respectively, which is moderate for a seed flour. The moisture contents reported here were higher than 2.25-4.35% reported by Obasi *et al.* (2023) when studying effect of drying temperatures on the proximate composition of African bush mango seed flour and the physicochemical properties of the oil. This may be as a result of differences in flour processing methods. However, the lower the moisture content of a product, the better the shelf stability of such product (Sanni *et al.,* 2018), because low moisture ensures shelf stability in dried products. Ash content of the sample ranged from 1.25-1.98%, with the least value recorded in sample B1 while sample A3 had the highest (1.98%). Ash content is an indication of the mineral content of a food (Ndife and Obieguna, 2013). There was no significant ($p>0.05$) difference in the ash content of the samples. However, there was an observed increase in the ash content of the blanched samples (A3 and B3), which agrees with Rindiani *et al*. (2018) who reported an increase in the ash content of okra flour after blanching. The protein content showed no significant difference ($p>0.05$) in all the samples ranging from (7.07 – 9.34%). In this study, soaking decreased the crude protein of ogbono flour from 8.52 to 5.61%. This could be as a result of leaching loss and solubility of nitrogen as obtained in cowpea study by Groeneveld *et al.* (1998). There was a significant difference ($p>0.05$) in terms of carbohydrates, with moderate values (16.86-40.91%). The percentage crude fiber values ranged from 1.10 – 1.70%. From this study, sample A2 had the highest crude fibre value (1.70%) and sample B2, had the least (1.10%) indicating no significant difference between them. The fat content of the samples ranged from 41.50 – 62.00%. The fat content of the

Table 2. Proximate composition (%) of soups prepared from differently processed Ogbono seeds.

Samples	Moisture	Ash	Fat	Crude protein	Carbohydrate
A0	$71.35^{d}\pm1.06$	$1.98^{a}\pm0.16$	$15.24^{a}\pm1.21$	$4.63^{ab}\pm0.02$	$6.80^{a}\pm0.63$
A1	$76.66^{cd}\pm1.56$	$2.23^{a}\pm0.03$	$14.57^{a}\pm1.38$	$5.34^{a}\pm0.35$	$1.20^{c}\pm0.02$
A2	$81.92^{abc}\pm0.84$	$1.73^{a}\pm0.21$	$8.45^{b}\pm0.07$	$3.24^{bc}\pm0.17$	$4.66^{abc}\pm0.53$
A3	$78.89^{bcd}\pm5.99$	$2.14^{a}\pm0.74$	$8.34^{b}\pm2.28$	$3.78^{bc}\pm1.11$	$6.84^{a}\pm1.86$
A4	$86.85^{a}\pm0.16$	$1.60^{a}\pm0.56$	$6.74^{bc}\pm0.95$	$2.00^{d}\pm0.01$	$2.81^{bc}\pm1.69$
B0	$72.92^{cd}\pm1.01$	$1.77^{a}\pm0.54$	$16.82^{a}\pm2.01$	$4.92^{a}\pm0.17$	$3.57^{bc}\pm1.00$
B1	$73.99^{d}\pm4.53$	$1.84^{a}\pm0.25$	$17.59^{a}\pm3.45$	$4.44^{ab}\pm0.81$	$2.14^{c}\pm0.01$
B2	$80.02^{abcd}\pm0.83$	$2.05^{a}\pm0.09$	$7.87^{b}\pm0.33$	$3.49^{bc}\pm0.17$	$6.57^{ab}\pm0.24$
B3	$82.06^{abc}\pm0.16$	$1.90^{a}\pm0.06$	$9.08^{b}\pm0.54$	$3.82^{bc}\pm0.04$	$3.13^{abc}\pm0.60$
B4	$84.35^{ab}\pm0.16$	$1.47^{a}\pm0.16$	$4.91^{c}\pm0.41$	$2.57^{cd}\pm0.24$	$4.78^{abc}\pm3.37$

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$). **Keys:** A0 = Untreated *I.ganonensis*, A1 = Boiled *I.ganonensis*, A2 = Soaked *I.ganonensis*, A3 = Blanched *I.ganonensis*, A4 = Defatted *I.ganonensis*, B0 = Untreated *I. wombulo*, B1 = Boiled *I. wombulo*, B2 = Soaked *I. wombulo*, B3 = Blanched *I. wombulo*, B4 = Defatted *I. wombulo.*

Table 3. Proximate composition (%) and Viscosity (Pa.s) of differently processed ogbono flour.

Samples	Moisture	Ash	Fat	Crude protein	Crude fibre	Carbohydrate	Viscosity
A0	$8.09^{abcd}\pm0.10$	$1.55^{ab}\pm0.21$	$59.33^{ab}\pm0.63$	$7.21^{a}\pm0.07$	$1.47^{ab}\pm0.17$	$22.35^{bc}\pm1.63$	$74.63^{a}\pm2.11$
A1	$7.38^{cd}\pm0.53$	$1.33^{b}\pm0.11$	$55.00^{b}\pm4.24$	$8.05^{a}\pm1.73$	$1.20^{b}\pm0.00$	$27.04^{b}\pm1.89$	$65.37^{b}\pm4.48$
A2	$7.48^{abc}\pm0.67$	$1.43^{ab}\pm0.25$	$49.00^{bc}\pm6.36$	$7.07^{a}\pm2.06$	$1.70^{ab}\pm0.14$	$32.79^{b}\pm8.19$	$76.71^{a}\pm1.42$
A3	$8.00^{abcd}\pm0.00$	$1.98^{a}\pm0.32$	$62.00^{a}\pm1.41$	$8.54^{a}\pm0.18$	$1.60^{ab}\pm0.28$	$17.82^{c}\pm1.01$	$56.70^{c}\pm2.97$
A4	$6.20^{c}\pm0.07$	$1.33^{b}\pm0.11$	$43.00^{cd}\pm1.41$	$7.60^{a}\pm0.22$	$1.30^{ab}\pm0.14$	$40.67^{a}\pm1.15$	$21.80^{e}\pm0.24$
B0	$6.41^{c}\pm0.25$	$1.31^{b}\pm0.17$	$61.32^{a}\pm0.48$	$8.20^{a}\pm0.32$	$1.52^{ab}\pm0.01$	$21.24^{bc}\pm1.27$	$69.34^{ab}\pm0.96$
B1	$6.33^{d}\pm0.45$	$1.25^{b}\pm0.21$	$49.50^{bc}\pm2.12$	$8.48^{a}\pm0.27$	$1.30^{ab}\pm0.14$	$33.13^{ab}\pm2.37$	$42.36^{d}\pm3.01$
B2	$8.00^{abcd}\pm0.00$	$1.90^{a}\pm0.00$	$52.00^{b}\pm1.41$	$9.34^{a}\pm0.07$	$1.10^{a}\pm0.42$	$27.65^{b}\pm1.90$	$54.14^{c}\pm5.03$
B3	$6.33^{c}\pm0.45$	$1.58^{ab}\pm0.18$	$65.50^{a}\pm0.71$	$8.22^{a}\pm0.42$	$1.50^{ab}\pm0.14$	$16.86^{c}\pm0.64$	$60.09^{bc}\pm0.69$
B4	$6.33^{c}\pm0.45$	$1.48^{ab}\pm0.39$	$41.50^{d}\pm0.71$	$8.47^{a}\pm0.78$	$1.30^{ab}\pm0.14$	$40.91^{a}\pm1.06$	$19.63^{e}\pm0.25$

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$).

blanched samples recorded higher fat contents and agrees with Rindiani *et al.* (2018) who reported increase in fat content of okra flour after blanching. The defatted samples however recorded the least fat content. The high fat content of the flour can be attributed to the seed which has been classified as an oil seed (Idowu *et al.,* 2013). The viscosity of the differently processed ogbono seed and the untreated ranged from 19.63 – 76.71 Pa.s, with sample A2 having the highest value (76.71 Pa.s) while sample B4 had the lowest value (19.63 Pa.s). Results showed that defatting reduced the viscosity of Ogbono seed flour, which agrees with the findings of Ortiz-Gomez *et al.* (2022) who reported a reduction in the viscosity of *Quinoa hyperprotein*- defatted flour. The untreated samples (A0 and B0) recorded higher viscosity.

Mineral composition of flours prepared from differently processed ogbono flour

Calcium, iron, sodium and magnesium were found to be present in the two varieties of the treated and untreated ogbono flour samples as shown in Table 4. Calcium content of the ogbono flour samples ranged from 262.79 mg/100g in sample B1 to 801.25 mg/100g in sample B4. Calcium in addition with other micro minerals and proteins helps in bone formation, with calcium acting as principal contributor (Kiin-Kabari *et al.,* 2017). There was an observed increase in the calcium content of the defatted (657.84 mg/100g for A4 and 801.25 mg/100g for B4) and soaked (669.11 mg/100g for A2, and 796.03 mg/100g for B2) samples of the two varieties. The calcium content here was similar to Emojorho *et al.* (2023) who also reported increase in calcium content of boiled and defatted orange seed flours. Iron content of the samples ranged from 1.48 mg/100g in sample B2 to 6.90 mg/100g in sample A1, and were similar to the iron contents of different types of wheat flours reported by Qureshi *et al.* (2002). The different treatment methods seem to have reduced the iron content of the two flour varieties, only samples A1 and A2 (boiled and soaked samples of *I. ganonensis,* respectively) recorded increased iron content. Similarly, Emojorho *et al*. (2023) had reported increase in iron content of orange seed flours boiled at different time intervals. Sodium

Table 4. Mineral composition (mg/100g) of differently processed ogbono flour.

Samples	Calcium	Iron	Sodium	Magnesium
A0	332.41^{d}±16.35	6.25^{a}±0.36	5.24^{a}±20.33	192.33^{de}±12.31
A1	596.31^{c}±10.16	6.90^{a}±0.92	5.13^{a}±40.47	266.92^{ab}±14.23
A2	669.11^{b}±19.28	6.59^{a}±0.23	5.13^{a}±79.03	187.19^{de}±16.31
A3	288.69^{d}±11.95	4.79^{b}±0.35	5.19^{a}±36.78	285.69^{a}±18.33
A4	657.84^{b}±17.35	3.70^{c}±0.42	5.39^{a}±13.35	189.03^{de}±2.04
B0	302.28^{d}±14.00	5.00^{b}±0.28	5.03^{ab}±18.51	217.63^{c}±1.05
B1	262.79^{d}±6.44	3.98^{bc}±0.14	5.11^{a}±17.61	224.85^{c}±14.68
B2	796.03^{a}±9.14	1.48^{d}±0.13	5.13^{a}±51.61	173.14^{e}±6.49
B3	579.82^{c}±3.60	4.29^{bc}±0.38	4.63^{b}±20.18	240.41^{bc}±19.71
B4	801.25^{a}±4.23	3.64^{c}±0.20	5.13^{a}±15.74	215.78^{cd}±6.43

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$).

Table 5. Phytochemical properties (%) of two varieties of ogbono seed flour prepared with different processing methods.

Samples	Alkaloids	Flavonoids	Saponins	Tannins	Hydrogen cyanide (mg/kg)
A0	3.47^{a}±0.03	1.02^{a}±0.32	0.99^{a}±0.00	2.13^{a}±0.17	4.06^{a}±0.41
A1	3.19^{b}±0.17	0.74^{b}±0.00	0.74^{a}±0.14	1.69^{b}±0.04	3·52^{a}±0.17
A2	2.28^{c}±0.03	0.65^{b}±0.21	0.65^{b}±0.07	1.15^{c}±0.09	2.85b±0.03
A3	3.22^{ab}±0.04	0.85^{ab}±0.13	0.85^{a}±0.01	1.75^{b}±0.11	3.58^{a}±0.17
A4	3.40^{a}±0.06	0.90^{a}±0.01	0.82^{a}±0.06	1.93^{ab}±0.10	3.76^{a}±0.01
B0	3.33^{ab}±0.00	0.79^{b}±0.14	0.81^{a}±0.03	2.03^{a}±0.08	3.66^{a}±0.00
B1	3.02^{b}±0.21	0.50^{b}±0.02	0.60^{b}±0.11	1.58^{b}±0.03	2.64^{b}±0.15
B2	2.17^{c}±0.11	0.30^{c}±0.03	0.63^{b}±0.13	1.40^{b}±0.07	2.23^{bc}±0.06
B3	3.15^{b}±0.08	0.66^{b}±0.30	0.78^{a}±0.07	1.65^{b}±0.17	2.70^{b}±0.09
B4	3.20^{b}±0.13	0.70^{b}±0.16	0.81^{a}±0.16	1.95^{ab}±0.03	3.03^{ab}±0.05

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$).

content of the flour samples ranged from 4.63 mg/100g in sample B3 to 5.39 mg/100g in sample A4. The processing methods did not have significant difference ($p<0.05$) in the sodium content. The magnesium content of the flour samples ranged from 173.14 mg/100g (sample B2) to 285.69 mg/100g (sample A3). Onojah *et al.* (2018) reported magnesium content ranging from 40.07-48.2 mg/100g for two varieties of ogbono seeds, while Okagu *et al.* (2021) reported magnesium content of 11.99 and 18.65 mg/kg for *I. wombolu* and *I. gabonensis* respectively. Soaking and defatting showed to have reduced the magnesium content of the flours. Emojorho *et al.* (2023) however reported that defatting increased the magnesium content of orange seed flour. Magnesium helps in the proper functioning of the muscles. It also serves as an activator in many enzymes systems (Okoye and Egbujie, 2018). The mineral content found in Ogbono (Fe, Na, Ca and Mg) respectively are known to be good for tissue functioning and also necessary as a dietary requirement for human nutrition and growth (Soetan et al., 2010).

Effect of different processing methods on the phytochemical properties of soup prepared with two varieties of Ogbono seed flour

The phytochemical properties of two varieties of ogbono seed flour prepared with different processing methods are shown in Table 5. The different processing methods reduced the phytochemical contents of the flours of both varieties of *Irvingia gabonensis* and *I. Wombolu.* The alkaloid content of the untreated and treated ogbono seed flour varieties ranged from 2.17-3.47% with sample B2 recording the least, and the highest alkaloid content recorded by sample A0. Ezeabara and Ezeani (2016) had reported alkaloid contents of 1.84% and 1.76%, respectively for *Irvingia gabonensis* and *I. wombolu* which differs from the 3.47 and 3.33% recorded in this research. Flavonoid content of the samples ranged from 0.30% (sample B2) to 1.02% (sample A0). The defatted samples recording the highest flavonoid content (0.90% in sample A4 and 0.70% in sample B4) when compared to the control

Table 6. Mean sensory scores of soups prepared from differently processed ogbono seeds.

Samples	Appearance	Taste	Thickness	Flavor	Drawability	Overall Acceptability
A0	7.44^{a}±0.04	7.61^{a}±0.14	7.50^{a}±0.12	7.63^{a}±0.15	7.32^{a}±0.03	7.48^{a}±0.21
A1	7.45^{a}±0.32	7.50^{a}±0.47	7.30^{a}±0.24	7.80^{a}±0.23	7.30^{a}±0.09	7.47^{a}±0.14
A2	7.40^{a}±0.14	6.55^{ab}±0.18	6.75^{a}±0.17	7.15^{ab}±0.18	7.45^{a}±0.14	7.06^{ab}±0.25
A3	7.15^{a}±0.11	6.35^{b}±0.23	6.35^{a}±0.25	6.75^{abc}±0.25	6.25^{b}±0.28	6.58^{b}±0.21
A4	3.40^{b}±0.02	5.00^{c}±017	3.50^{b}±0.15	4.65^{d}±0.16	2.40^{c}±0.09	3.76^{c}±0.08
B0	6.67^{a}±0.39	6.99^{ab}±0.22	6.63^{a}±0.13	6.71^{bc}±0.13	6.25^{b}±0.23	6.51^{b}±0.22
B1	6.75^{a}±0.17	6.30^{b}±0.20	6.50^{a}±0.18	7.50^{ab}±0.27	6.20^{b}±0.17	6.64^{b}±0.25
B2	6.75^{a}±0.28	6.90^{ab}±0.32	6.60^{a}±0.36	6.40^{bc}±0.23	6.15^{b}±0.18	6.55^{b}±0.22
B3	6.85^{a}±0.17	7.35^{ab}±0.17	6.15^{a}±0.25	6.65^{bc}±0.11	6.50^{ab}±0.15	6.70^{b}±0.17
B4	3.90^{b}±0.05	4.35^{c}±0.29	2.65^{b}±0.17	5.95^{c}±0.24	2.40^{c}±0.17	3.83^{c}±0.29

Mean values are of duplicate determinations. Mean values within a column with different superscripts are significantly different at ($p < 0.05$).

(samples A0 and B0) respectively. Flavonoids are free radical scavengers and are super antioxidant as phenolics which are water soluble and prevent oxidative cell damage and have strong anti cancer properties (Salah *et al.,* 1995). The flavonoid content of the flour supports its ethnomedical use (Gbadamosi *et al.,* 2021). Flavonoids also show antimicrobial properties (Cushnie and Lamb, 2009) and anti-cancer properties (Paul *et al.,* 2012). Saponin and tannin content of the samples ranged from 0.60% (sample B1) to 0.99% (sample A0) and 1.15% (sample A2) to 2.13% (sample A0) respectively, and were similar to (Eze and Obinwa, 2014) who reported saponin (0.214-0.374%) and tannin (0.833-1.250%) content of the leaves and seeds of *Nauclea Latifolia*. The hydrogen cyanide content of the flours ranged from 2.23 mg/kg (sample B2) to 4.06 mg/kg (sample A0). Ezeabara and Ezeani (2016) reported hydrogen cyanide of 4.78 mg/kg for *Irvingia gabonensis* and 3.21 mg/kg for *I. wombolu.* Processing methods can reduce the hydrogen content of foods (Ezeabara and Ezeani, 2016), hence the reduction in the hydrogen contents of the samples as seen in this research.

Effect of different processing methods on the sensory properties of soup prepared with two varieties of ogbono seed flour

Sensory analysis is an important criterion for assessing quality in the development of new products and for meeting consumer requirements. Appearance as evaluated by the panelists indicated different preferences for all the samples. The panelist scores for appearance of the samples ranged from 3.40 to 7.45 with sample A1 as the most prefer and sample A4 as the least prefer. The defatted sample recorded the least appearance scores (3.40-3.90), and were similar to appearance scores (4.67-5.33) of ogbono soup mix reported by Fasogbon *et al*. (2017). The attribute for taste showed a range of scores from 4.35 to 7.61 with sample A0 being most preferred and sample B4 least preferred. There was no significant difference ($p<0.05$) between the control and the boiled samples of the various varieties. For flavour, the sample A1 with highest score of 7.80 was most preferred while sample A4 having 4.65 value was least preferred. Result showed that boiling seemed to have improved the flavour of the soup samples, as panelists scored samples A1 and B1 highest when compared to their control scores. Bi *et al*. (2019) observed that boiling increased the content of several unsaturated aldehydes, alcohols, and benzene derivatives while studying the effect of cooking on aroma profiles of Chinese foxtail millet and its correlation with sensory quality. Thickness ranged from 2.65 to 7.50 with the least score recorded in sample B4 while sample A0 had the highest. The panelists scored the defatted samples the lowest for thickness. For drawability, sample A2 was most preferred with mean score of 7.45 and A4 and B4 were least preferred with mean score of 2.40. The result for drawability were higher than Fasogbon *et al*. (2017) who reported 4.87-5.47 for ogbono mix, only the defatted samples reported in this study (3.76-3.83) scored lower. Oladimeji and Fasuan (2018) however recorded drawability of 7.39 while studying the characterization of *Irvingia gabonensis* (ogbono) soup and optimization of process variables. The result of the overall acceptability showed a significant difference ($p<0.05$) amongst the samples which ranged from 3.83 in sample B4 to 7.48 in sample A0. The scores for overall acceptability did not differ much from Bamidele *et al.* (2015) who reported overall acceptability score of 4.60-6.07 for instant ogbono mix powder.

Conclusion

This study has introduced new processing methods such as blanching, boiling, soaking and defatting in the processing of ogbono seed flour. The different processing methods reduced the moisture contents of the samples, while defatting reduced the fat content of the samples. The phytochemical contents of the samples reduced after treatments, with the soaked samples recording the least phytochemical contents. Sensory evaluation revealed that the boiled flour samples gave a better flavour score when used to make soup, compared to the control and other treated samples. The drawability of the soups was affected by defatting as samples A4 and B4 recorded the least drawability scores, while samples A1 and B1 compared favourably with their various controls (sample A0 and B0 respectively) in their overall acceptability.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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