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Effect of traditional and modified grain-soaking methods on physicochemical characteristics and consumers' acceptability of sorghum *ogi*

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The influence of traditional and modified soaking methods and varietal difference of sorghum [*Sorghum bicolor* (Linn.) Moench] grains on the physicochemical properties and consumers' acceptability of *ogi* was investigated. Three sorghum varieties (SAMSORG-14, SAMSORG-41 and SAMSORG-42) were used for the study, and each was subjected to three grain-soaking methods (SGW-72, PBW-24 and IBG5-24) after which *ogi* was produced and then oven-dried (55°C for 18 h). The pH of sorghum *ogi* prepared from IBG5-24 method was statistically higher ($p < 0.05$) than those from others while it exhibited a correspondingly lowest total titratable acidity. The water absorption capacity (252 to 293%) of *ogi* also varied with respect to the grain varieties and soaking methods applied. The pasting properties of *ogi* samples gave significantly varied values ($p < 0.05$) with respect to grain varieties and soaking methods, and these include peak viscosity (560 to 1311 cP), breakdown viscosity (117 to 317 cP), final viscosity (801 to 1571 cP) and setback viscosity (358 to 577 cP). The lightness index (L^* -value) of *ogi* from IBG5-24 method was statistically lower ($p < 0.05$) than that of others while both the swelling capacity and solubility index of *ogi* samples exhibited increasing values with the elevation of temperature of heating. The sensory quality rating of sorghum gruel (re-constituted and boiled *ogi*) revealed that *ogi* from 'SAMSORG-42 (PBW-24)' was rated the highest in terms of colour, taste, consistency, aroma and overall acceptability though not significantly different ($p < 0.05$) from samples of 'SAMSORG-14 (PBW-24)' and 'SAMSORG-41 (PBW-24)'. Grain-soaking methods and varietal difference have therefore been shown to influence the physicochemical characteristics and consumers' preference of sorghum *ogi*.

Key words: Sorghum, *ogi*, drying, physicochemical, soaking technique.

INTRODUCTION

Sorghum (*Sorghum bicolor* (Linn.) Moench) is a group member of small seeded cereal used for food or feed,

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and is sometimes called miscellaneous cereal or coarse grain (Kent and Evers, 1994). It has many cultivars widely grown sorghum grains is particularly important in the semi-arid tropics (SAT) where it provides appropriate calorie needs for the people in the region (Belton and Taylor, 2004). Sorghum cultivation has a special peculiarity with respect to its unique in Africa and Asia continents (Dicko et al., 2006). The ability to tolerate and survive under harsh climatic conditions of temporary logging, continuous or intermittent drought (Kent and Evers, 1994). Globally, sorghum grains have been observed of increasingly becoming a major food crop in Africa and India, and an important livestock feed in the developed countries (Felix et al., 2015). In many parts of Africa, sorghum grains plays an essential role in the attainment of food security for a lot of households while its commercial processing into value-added food and beverage products serves as income generating activities and an important driver for economic development (Taylor, 2004).

Several food products can be obtained from sorghum grains, particularly from Africa, and these include *ogi*, *kunu*, *eko* and *tuwo* (Obilana, 1982), malted and fermented beverages such as *mahewu* (Bvochora et al., 1999), porridge, *couscous* and *dolo* (Dicko et al., 2006), *injera*, *kisra* and *ugali* (Blandino et al., 2003), among others. *Ogi* is essentially a traditionally-extracted starch from maize, sorghum or millet through wet-milling of any of these cereal grains (Akingbala et al., 1987; Modu et al., 2005). It is this extracted starch called *ogi* that is converted to various other products such as *eko*, *agidi*, *akamu*, and *koko* depending on the locality and form in which it is consumed. When *ogi* is gelatinized into a stiff gel, it is called *eko* or *agidi* which is commonly consumed by adults with any of the local vegetable soups, '*moinmoin*' or '*akara*' (Oluwamukomi et al., 2005).

When gelatinized into gruel, it is called '*eko mimu*', *akamu*, or *koko* which is popular among infants as a weaning food and amongst adults as a breakfast meal and as a food for the convalescents (Teniola and Odunfa, 2001). The colour of *ogi* varies and depends on the type of cereal used for its production: white to yellow for maize, reddish-brown to gray for sorghum, and dirty-grey for millet (Onyekwere et al., 1989). The consumption of *ogi*-based food products cuts across different ethnic and economic classes along the West African coastal region where such products are given diverse local names (Teniola and Odunfa, 2001). Some of the problems associated with *ogi* production include limited shelf-life, inability to achieving a controlled fermentation with pure cultures and low nutritional quality (FAO, 1992).

A great number of research works had been carried out specifically on the production of *ogi* from sorghum grains. Akingbala et al. (1981) investigated the physical, chemical and sensory quality of *ogi* prepared from sorghum of differing kernel characteristics while the possibility of producing *ogi* from dry-milled sorghum

grains was evaluated by Adeyemi (1983). The enhancement of nutritional quality of sorghum '*ogi*' with leguminous protein sources was also investigated (Oyeleke et al., 1985; Nnam, 2001; Sanni et al., 2001; Adelekan and Oyewole, 2010; Akanbi et al., 2010; Makinde and Lapido, 2012; Ajanaku et al., 2012). Other research works include a comparative assessment of the nutritional quality of *ogi* prepared from three different cereal grains (sorghum, maize and millet) (Oyarekua and Eleyinmi, 2004), nutritional enhancement of sorghum *ogi* by using pawpaw for its fortification (Ajanaku et al., 2010), the effect of drying methods on selected properties of sorghum *ogi* (Esther et al., 2013), and dietary fortification of sorghum *ogi* using crayfish as supplements in infant feeding (Ajanaku et al., 2013).

One particular unit operation peculiar to the utilization of sorghum for most food production is the soaking of the grains. During soaking operation, grains are highly hydrated and the kernel softened to make grinding or cooking easier (Addo et al., 2006). Soaking can also cause the breakdown of several components, within the grains, into simpler compounds which are capable of causing alterations in the texture, flavour, aroma and taste of the final products (Parveen and Hafiz, 2003).

In West Africa, the traditional soaking method for cereal grains in the course of '*ogi*' production essentially involves soaking of the grains for up to 72 h at ambient temperature (25 to 35°C) after which the softened grains are wet-milled. However, a modification to the traditional grain soaking method was suggested by Nago et al. (1998) which involved initial mild boiling of the grains at 95 to 100°C for 10 min preceding soaking for 12 to 48 h at ambient temperature (25 to 35°C) followed by wet-milling. Some research works that are related to soaking of cereal grains during '*ogi*' production had also been reported.

Apotiola (2013) examined the effect of soaking period on '*ogi*' powder produced from sorghum while changes induced by soaking period on the physical properties of maize grains (Bolaji et al., 2014) and functional properties of maize '*ogi*' (Bolaji et al., 2017) were also investigated.

The present study, therefore, was aimed at examining the influence of varietal difference and grain soaking techniques, traditional and modified, on the physicochemical properties and acceptability of sorghum *ogi*; and this is the general objective of the work.

MATERIALS AND METHODS

Three varieties of sorghum (SAMSORG-14, SAMSORG-41 and SAMSORG-42) used in this study were obtained from the Institute of Agricultural Research (IAR), Samaru, Zaria, Nigeria.

Grain soaking procedures and '*ogi*' production

The soaking of sorghum grains was carried out using three different traditional methods:

Soaking of grains in tap water for 72 h at ambient temperature (SGW-72 method)

1 Kg of sorghum grains from respective variety was soaked in 10 L of tap water at ambient temperature ($29\pm 2^\circ\text{C}$). The soaking was done for a total period of 72 h during which the soaking water was being replaced at 12 hourly interval to slow down the fermentation process that could lead to over-souring. At the end of the soaking period, the water was drained off, the grains washed and wet-milled using a disc mill. The milled slurry was sieved using a fine mesh sieve to remove the over-tails which was discarded. The milky filtrate obtained was allowed to sediment for 18 h at ambient temperature ($29\pm 2^\circ\text{C}$) after which the souring water was decanted. The 'ogi' sediment was drained with the aid of muslin cloth and oven dried at 55°C for 18 h and sorghum 'ogi' powder obtained was stored.

Pouring of boiled tap water on the grains and allowing it to cool down for 24 h at ambient temperature (PBW-24 method)

10 L of boiled tap water (100°C) were poured onto 1 kg of sorghum grains of respective variety in a plastic bowl for the grains to be fully submerged. Both the soaking grains and the hot tap water were left in that position for 24 h during which they cooled down naturally to assume ambient temperature ($29\pm 2^\circ\text{C}$) after few hours. At the end of the steeping period, the water was drained off, the grains washed and wet-milled using a disc mill; while subsequent unit operations were similar to those carried out for 'SGW-72 Method' as explained earlier.

Initial boiling of sorghum grains for 5 min followed by cooling at ambient temperature for 24 h (IBG5-24 method)

10 L of tap water was initially brought to boiling in a stainless steel bowl to which 1 Kg of sorghum grains were added. Both were then allowed to boil for further 5 min after which they were brought down from cooking fire and then left in that position for 24 h during which they cooled down naturally to assume ambient temperature ($29\pm 2^\circ\text{C}$) after few hours. Thereafter, the subsequent unit operations carried out were similar to those done for 'SGW-72 Method' as explained.

pH determination of sorghum ogi

The pH of sorghum *ogi* was determined using a pH meter (model WPA CD70, India). After each determination, the pH probe was rinsed with distilled water and blotted dry (Sadler and Murphy, 2010). Triplicate determinations were made in all cases while the pH meter was calibrated using pH 4.0 and 9.0 buffers.

Determination of total titratable acidity of sorghum 'ogi'

The total titratable acidity (TTA) of sorghum *ogi* was determined by the method described by Sadler and Murphy (2010). 2 g of each sample were taken into a separate conical flask, and 20 ml of distilled water was added to each sample and shook properly on addition of an indicator (phenolphthalein). The mixture was further shaken properly and titrated against 0.1M NaOH, and the percentage acidity was expressed as lactic acid equivalent.

Evaluation of water absorption capacity of sorghum 'ogi'

The water absorption capacity (WAC) of sorghum *ogi* was evaluated by the method described by Sathe et al. (1982). 1 g of the sample was weighed into a tarred 20 ml centrifuge tube, and 10 ml of distilled water was added. The suspension was stirred for 5 min followed by centrifugation (Etek centrifuge, MP 400R, Electrocraft, India) at 3000 rpm for 30 min. The supernatant was decanted and the volume of water determined. The water absorbed by the dried sorghum *ogi* was calculated as the difference between the initial water used and the volume of supernatant obtained after centrifuging. The result was expressed as percentage of water absorbed by the dried sorghum *ogi*.

Determination of swelling power and solubility index of sorghum 'ogi'

The swelling power and solubility index of sorghum *ogi* were determined by using the method of Leach et al. (1959). Sorghum *ogi* (1 g, dry basis) was weighed into centrifuge tubes and 50 ml distilled water added. These tubes were immersed in a temperature-controlled water bath at temperature range of 50 to 90°C at 20°C interval for 30 min and thoroughly, and constantly stirred with glass rod during the heating period. The tubes were removed, cooled to room temperature and centrifuged (Etek centrifuge, MP 400R, Electrocraft, India) at 3,000 rpm for 15 min. The supernatant was carefully transferred into weighing petri dishes and evaporated over a steam bath and finally dried in an air oven at 105°C for 4 h. The weight of the dissolved solids was taken as a measure of solubility index of sorghum *ogi* samples. The sedimented slurry obtained after centrifugation was also weighed to get the weight of the swollen flour particles. The values were expressed as percentages of total swollen flour particles (swelling power) with respect to the original weight of the flour sample used.

Evaluation of pasting properties of sorghum 'ogi'

The pasting properties of sorghum *ogi* were evaluated using a Rapid Visco-Analyzer, RVA-Series 4, with the aid of a Thermocline for Windows, version 2.2 software (Newport- Scientific, 1998). A sample of 4.0 g sorghum *ogi* flour (14% moisture-basis) was transferred into a canister and approximately 25 ± 0.1 ml distilled water was added (correction factor was used to compensate for 14% moisture-basis). The slurry was heated to 50°C and stirred at 160 rpm for 10 s for thorough dispersion. The slurry was held at 50°C for up to 1 min followed by heating to 95°C over about 7.5 min and held at 95°C for 5 min, and finally cooled to 50°C over about 7.9 min. The parameters generated from the pasting curve include the peak viscosity, pasting temperature, time to peak, breakdown, holding strength or trough, setback, and final viscosity.

Determination of colour characteristics of sorghum 'ogi'

The colour of sorghum *ogi* samples was measured using a colour measuring instrument (ColorTec-PCM, model SN 3000421, USA) and the values expressed on the L^* , a^* , and b^* tristimulus scale. The L^* -value indicates lightness index while the positive a^* value indicates the red direction, negative a^* value is the green direction; positive b^* value is the yellow direction, and negative b^* value is the blue direction (Wojdylo et al., 2009). The instrument was first standardized ($L^*=93.24$, $a^*=-0.96$, $b^*=-2.75$) with a business duplicating white paper (80 g/m^2). About 3 g of *ogi* sample was put

Table 1. pH, total titratable acidity and water absorption capacity of sorghum *ogi* obtained from different grain soaking methods¹.

| Source of sorghum 'ogi' | pH | Total titratable acidity (TTA) (%) | Water absorption capacity (%) |
|-------------------------|--------------------------|------------------------------------|-------------------------------|
| SAMSORG-14 (SGW-72) | 4.38±0.17 ^e | 1.06±0.04 ^a | 280±2 ^b |
| SAMSORG-14 (PBW-24) | 4.46±0.06 ^e | 0.81±0.03 ^c | 282±2 ^b |
| SAMSORG-14 (IBG5-24) | 4.65±0.11 ^d | 0.75±0.05 ^{cd} | 293±4 ^a |
| SAMSORG-41 (SGW-72) | 4.66±0.12 ^d | 1.07±0.07 ^b | 258±2 ^{de} |
| SAMSORG-41 (PBW-24) | 4.88±0.08 ^{bc} | 0.82±0.06 ^c | 261±2 ^d |
| SAMSORG-41 (IBG5-24) | 5.02±0.07 ^{ab} | 0.72±0.04 ^d | 271±1 ^c |
| SAMSORG-42 (SGW-72) | 4.84±0.05 ^c | 1.02±0.05 ^a | 252±3 ^f |
| SAMSORG-42 (PBW-24) | 4.91±0.08 ^{abc} | 0.83±0.03 ^c | 255±2 ^{ef} |
| SAMSORG-42 (IBG5-24) | 5.06±0.06 ^a | 0.82±0.02 ^c | 261±1 ^d |

¹Results are mean values of triplicate determinations ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$.

(SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

in a clean paper and the colour meter was placed on the sample by allowing the sensor to touch the sample. The reading was taken directly, and the results from three replicates per sample were averaged (McGuire, 1992).

Preparation of sorghum gruel (re-constituted and boiled *ogi*)

Sorghum gruel (re-constituted 'ogi') was prepared from each dried 'ogi' sample obtained from different soaking techniques. The gruel was prepared from dried 'ogi' (10.1 to 10.5%, moisture content) at overall ratio of dried 'ogi' to water of 1:10 (w/v). Cold slurry of the dried 'ogi' was first prepared by mixing 40% of the desired quantity of dried 'ogi' (100 g) with 40% of the desired quantity of water (1000 ml). This was followed by bringing 40% (400 ml) of the required quantity of water into boiling and the cold slurry initially prepared was added to this boiling water coupled with vigorous stirring, using a wooden flat spoon, to form a pap-like consistency. The remaining 20% of water (200 ml) was finally added to the pap-like consistency with vigorous stirring which was then allowed to cook for about 3 to 5 min after which it was ultimately stirred to ensure smoothness of the gruel. The final product so obtained is called sorghum gruel (re-constituted and boiled *ogi*).

Sensory evaluation of sorghum gruel (re-constituted and boiled *ogi*)

Sorghums gruel prepared from each of the dried sorghum 'ogi' from different varieties were evaluated for their sensory qualities and general acceptability. A scoring test was used which was designed to determine which of the products was most preferred. A 50-member semi-trained taste panel was requested to carry out the rating of gruel samples. The panelists were all familiar with the food product while they were also instructed on the use of sensory evaluation procedures. The sorghum gruel was presented to each panelist when its temperature was 38 to 42°C. Each of the panelists was asked to rate the samples on the basis of colour, taste, consistency, aroma and overall acceptability using a nine-point hedonic scale (that is, 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). The scores from the rating were subsequently subjected to analysis of variance (ANOVA), and the

means separated using Duncan Multiple Range test (IFT, 1981; Lawless and Heymann, 2010).

Statistical analysis

All determinations carried out were done in triplicates. A mean value and standard deviation were calculated in each case. ANOVA was also performed and separation of the mean values was by Duncan's Multiple Range Test at $p < 0.05$ using Statistical Package for Social Scientists (SPSS) software, version 16.0.

RESULTS AND DISCUSSION

Influence of grain soaking methods and variety on the pH, total titratable acidity and water absorption capacity of sorghum *ogi*

Table 1 presents the pH, TTA and WAC of dried sorghum 'ogi'. The pH of dried 'ogi' from SAMSORG-14 (4.38-4.65), SAMSORG-41 (4.66-5.02) and SAMSORG-42 (4.84-5.06) varied significantly ($p < 0.05$) with respect to the grains soaking methods adopted. The pH of 'ogi' from SGW-72 method was significantly the lowest which implies that the fermentation process during the soaking period was most severe. It had earlier been observed that during cereal grain soaking, a succession of naturally-occurring microorganisms would result in a population dominated by lactic acid bacteria (LAB) which are capable of producing organic acids with subsequent lowering of the pH of the fermenting material (Omemu, 2011).

The significance of pH of a food product is that it could determine the ability of microorganisms to grow in such product (Sadler and Murphy, 2010). Similarly, the pH of 'ogi' from IBG5-24 method was significantly ($p < 0.05$) the highest. The initial severe boiling of sorghum grains prior

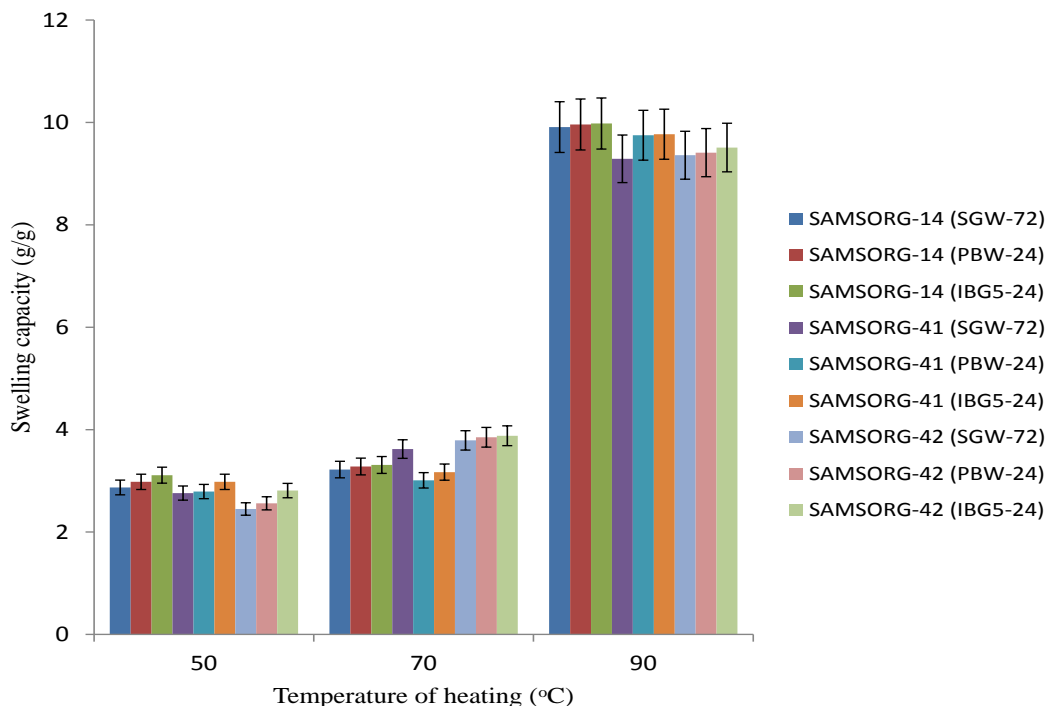


Figure 1. Swelling capacity of sorghum *ogi* obtained from different grain soaking methods. (SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

to soaking might be implicated to have caused a seeming delay in the fermentation process thereby leading to relatively high pH values. There were variations in the TTA of dried sorghum '*ogi*' obtained from SAMSORG-14 (0.75-1.06%), SAMSORG-41 (0.72-1.07%) and SAMSORG-42 (0.82-1.02%). The TTA of '*ogi*' from SGW-72 was observed to exhibit the highest value. This might also be attributed to a relatively intense fermentation process that gave rise to highest concentration of organic acids. The significance of TTA in a food product is connected with its ability to influence the flavour of such product (Sadler and Murphy, 2010).

The water absorption capacity (Table 1) of dried sorghum '*ogi*' produced from SAMSORG-14 (280–293%), SAMSORG-41 (258–271%) and SAMSORG-42 (252–261%) also exhibited variation with respect to the grain soaking methods applied. Sorghum '*ogi*' from IBG5-24 method was observed to have the highest water absorption capacity (WAC) while those from SGW-72 method exhibited the lowest values. The implication of these observations is that an intense fermentation process, as reflected in SGW-72 method due to its lowest pH values, might be responsible for such lowest WAC. Fermentation tends to decrease the capacity of the site for holding water in sorghum flour/starch (Elkhalifa et al., 2005). The significance of WAC of cereal-based flour/starch is that higher WAC suggests its usefulness in

the formulation of food product where a water holding attribute is an important consideration (Olayinka et al., 2008). However, lower WAC is desirable for making thinner gruels (Elkhalifa et al., 2005).

Swelling capacity and solubility of sorghum '*ogi*'

The swelling capacity of dried sorghum '*ogi*' obtained from different grain soaking methods is shown in Figure 1. There were variations in the swelling capacity of the samples at different temperatures of heating with a higher temperature giving greater swelling capacity values. At 50°C, the swelling capacities were SAMSORG-14 (2.87 to 3.11 g/g), SAMSORG-41 (2.76 to 2.98 g/g), and SAMSORG-42 (2.45 to 2.18 g/g); with respect to the grain soaking methods used. However at 90°C, the swelling capacities significantly increased ($p < 0.05$) which were SAMSORG-14 (9.91 to 9.98 g/g), SAMSORG-41 (9.29 to 9.77 g/g), and SAMSORG-42 (9.36 to 9.51 g/g). The higher swelling capacity of '*ogi*' samples at an elevated temperature could be attributed to the seeming weakening of the associative binding forces within the starch granules thereby causing a progressive hydration and subsequent swelling (Pal et al., 2002; Peroni et al., 2006). Figure 2 shows the solubility index of dried sorghum '*ogi*' samples obtained from different grain

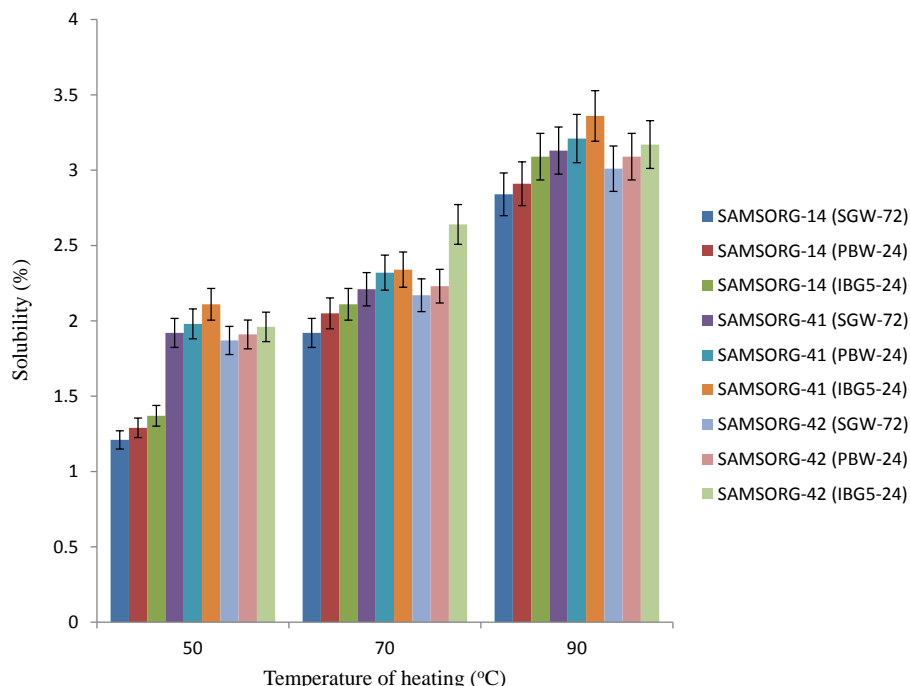


Figure 2. Solubility index of sorghum *ogi* as influenced by different grain soaking methods.

(SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

soaking methods. The solubility index was also observed to be dependent on temperature as higher temperature of heating led to greater solubility index. At 50°C, the solubility indices were SAMSORG-14 (1.21 to 1.37%), SAMSORG-41 (1.92 to 2.11%), and SAMSORG-42 (1.87 to 1.96%); with respect to the grain soaking methods applied. At higher temperature of 90°C, the solubility indices were higher and these include SAMSORG-14 (2.84 to 3.09%), SAMSORG-41 (3.13 to 3.36%), and SAMSORG-42 (3.01 to 3.17%). Sorghum 'ogi' from SAMSORG-41 seemed to exhibit greatest solubility index than other varieties. The higher solubility index at an elevated temperature had earlier been explained to be due to the weakening of intragranular binding forces within a starch molecule thereby causing the motional freedom of starch chains with subsequent increase in the solubility of the starch (Lawal, 2011).

Pasting properties of sorghum 'ogi' as influenced by varietal difference and grain soaking methods

Table 2 shows the pasting properties of oven-dried sorghum 'ogi'. The peak viscosity of SAMSORG-14 (560 to 942 cP), SAMSORG-41 (1043 to 1251 cP) and

SAMSORG-42 (1251 to 1311 cP) showed significant variations ($p < 0.05$) with respect to the grain soaking methods applied. Sorghum 'ogi' obtained from IBG5-24 method generally exhibited the lowest peak viscosity across the varieties which may be attributed to the severe boiling of the grains at the beginning of the soaking. The initial boiling might have caused partial gelatinization of the starch granules thereby leading to the formation of sorghum 'ogi' containing pre-gelatinized granules. The partially gelatinized starch granules seemed to have lowered the attainment of peak viscosity (Hidalgo et al., 2008; Pongjaruvat et al., 2014). The reduction in peak viscosity in 'ogi' from 'IBG5-24' method also indicated that the pre-gelatinized starch granules within the matrix caused retardation in the swelling of the granules during heating (Ragaei and Abdel-Aal, 2006). The breakdown viscosity of oven-dried sorghum 'ogi' from SAMSORG-14 (117 to 170 cP), SAMSORG-41 (189 to 342 cP) and SAMSORG-42 (295 to 317 cP) also exhibited significant variation ($p < 0.05$). Lower value of breakdown viscosity indicates increased paste stability during processing of the food product (Zaidul et al., 2007).

The final viscosity of 'ogi' from SAMSORG-14, SAMSORG-41 and SAMSORG-42 ranged from 801 to 1204, 1140 to 1561 and 1480 to 1571 cP, respectively.

Table 2. Pasting properties of sorghum *ogi* as influenced by different grain soaking methods.

| Source of sorghum 'ogi' | Pasting factor ¹ | | | | | | |
|-------------------------|----------------------------------|----------------------|---------------------|-----------------------|---------------------|------------------------|-----------------------|
| | Peak viscosity (cP) ² | Trough (cP) | Breakdown (cP) | Final viscosity (cP) | Setback (cP) | Pasting temp (°C) | Peak time (min) |
| SAMSORG-14 (SGW-72) | 942±6 ^f | 781±12 ^e | 161±7 ^e | 1204±18 ^d | 423±13 ^d | 87.7±0.1 ^d | 7.0±0.2 ^a |
| SAMSORG-14 (PBW-24) | 879±6 ^g | 709±5 ^f | 170±5 ^e | 1105±15 ^f | 396±7 ^e | 93.5 ±0.1 ^b | 7.0 ±0.1 ^a |
| SAMSORG-14 (IBG5-24) | 560±5 ^h | 443±10 ^g | 117±9 ^f | 801±11 ^g | 358±9 ^f | 94.8±0.2 ^a | 5.7±0.1 ^c |
| SAMSORG-41 (SGW-72) | 1251±10 ^c | 1047±12 ^a | 204±10 ^d | 1561±19 ^a | 514±14 ^b | 87.6±0.1 ^d | 5.4±0.1 ^d |
| SAMSORG-41 (PBW-24) | 1207±14 ^d | 1018±21 ^b | 189±16 ^d | 1510±18 ^b | 492±17 ^c | 92.8±0.1 ^c | 6.5±0.2 ^b |
| SAMSORG-41 (IBG5-24) | 1043±5 ^e | 701±8 ^f | 342±6 ^a | 1140±15 ^e | 439±9 ^d | 94.9±0.2 ^a | 5.2±0.1 ^d |
| SAMSORG-42 (SGW-72) | 1311±7 ^a | 994±8 ^c | 317±8 ^b | 1571±17 ^a | 577±10 ^a | 86.3±0.1 ^e | 7.0±0.2 ^a |
| SAMSORG-42 (PBW-24) | 1286±5 ^b | 980±10 ^c | 306±6 ^b | 1506±17 ^{bc} | 526±11 ^b | 93.1±0.1 ^b | 6.9±0.1 ^a |
| SAMSORG-42 (IBG5-24) | 1251±7 ^d | 956±10 ^d | 295±7 ^c | 1480±14 ^c | 524±11 ^b | 94.5±0.2 ^a | 5.4±0.1 ^d |

¹ Results are mean values of triplicate determinations ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$. (SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

²cP = centipoise.

Lowest final viscosity was observed in sorghum 'ogi' from IBG5-24 method across the varieties. Final viscosity is essentially an index of the stability of cooked paste in actual use as a higher final viscosity value implies greater paste stability (Ragae and Abdel-Aal, 2006). The setback viscosity of sorghum 'ogi' varied significantly ($p < 0.05$) across the varieties which are SAMSORG-14 (358 to 423 cP), SAMSORG-41 (439 to 514 cP) and SAMSORG-42 (524 to 577 cP). The setback viscosity is usually used as an indicator of retrogradation tendency of the paste and the lower the value, the smaller the retrogradation tendency coupled with minimal syneresis (Sandhu et al., 2007).

Sorghum 'ogi' from all the varieties exhibited significant variations ($p < 0.05$) in their pasting temperature which are SAMSORG-14 (87.7 to 94.8°C), SAMSORG-41 (87.6 to 94.9°C) and SAMSORG-42 (86.3-94.5°C). Higher pasting temperatures were observed for sorghum 'ogi' from both PBW-24 and IBG5-24 methods. This may be attributed to the presence of partially-pregelatinized starch granules in these samples as a result of preliminary higher temperature of soaking. The pre-gelatinized granules seemed to serve as a resistant to gelatinization thereby causing the elevation of pasting temperature (Pongjaruvat et al., 2014). The variation in the pasting temperatures is basically an indication that sorghum 'ogi' samples exhibited different gelatinization temperatures (Newport-Scientific, 1998). The pasting temperature also serves as an indication of minimum temperature to cook a given sample with a concomitant implication for energy utilization (Ragae and Abdel-Aal, 2006).

The peak time for sorghum 'ogi' samples also varied in values which are SAMSORG-14 (5.7 to 7 min), SAMSORG-41 (5.2 to 6.5 min), SAMSORG-42 (5.4 to 7

min). Lowest peak time was generally observed for sorghum 'ogi' obtained from IBG5-24 method. The significance of peak time is that it serves as an index of the total time taken by each 'ogi' sample to attain its respective peak viscosity. Sorghum 'ogi' sample with a lower peak time would cook faster than that with a greater peak time.

Colour characteristics of sorghum 'ogi'

The colour characteristics of oven-dried sorghum 'ogi' prepared through different grain soaking methods are presented in Table 3. There were significant variations ($p < 0.05$) in the lightness index (L^* -value) of the samples and these are SAMSORG-14 (78.6 to 86.3), SAMSORG-41 (76.7 to 84.7) and SAMSORG-42 (79.7 to 83.7); with respect to the grain soaking methods used. Sorghum 'ogi' samples from IBG5-24 method were observed to exhibit the lowest L^* -value. This observation may be attributed to the soaking method used that involved an initial 5-minute boiling. This initial boiling of the sorghum grains might have caused a severe non-enzymatic browning within the endosperm of the grains thereby contributing to the lowering of the lightness index of 'ogi' produced from them. An earlier postulation by Horrobin et al. (2003) had stated that colour development in boiled/steamed cereal grains is essentially a resultant effect of interplay between moisture uptake by the grains undergoing such thermal application and gelatinization within the endosperm which could lead to a non-enzymatic browning reaction. The lowest L^* -value associated with IBG5-24 method also indicated that boiling of sorghum grains in the course of soaking had a high tendency of reducing the lightness index of product emanating from

Table 3. Colour characteristics of sorghum *ogi* as influenced by different grain soaking methods.

| Source of sorghum 'ogi' | Colour variable ¹ | | |
|-------------------------|------------------------------|-----------------------|-------------------------|
| | L* | a* | b* |
| SAMSORG-14 (SGW-72) | 86.3±2.1 ^a | 8.1±0.8 ^a | 13.2±1.1 ^a |
| SAMSORG-14 (PBW-24) | 82.3±1.4 ^{abc} | 5.4±0.5 ^b | 12.5±1.1 ^{ab} |
| SAMSORG-14 (IBG5-24) | 78.6±2.3 ^{cd} | 4.1±0.4 ^{cd} | 11.3±1.0 ^{abc} |
| SAMSORG-41 (SGW-72) | 84.7±1.6 ^{ab} | 7.9±0.2 ^a | 12.8±1.9 ^{ab} |
| SAMSORG-41 (PBW-24) | 81.2±2.8 ^{bc} | 6.1±0.2 ^b | 11.4±1.3 ^{abc} |
| SAMSORG-41 (IBG5-24) | 76.7±2.0 ^d | 3.5±0.3 ^d | 10.4±0.8 ^{bc} |
| SAMSORG-42 (SGW-72) | 83.7±2.8 ^{ab} | 7.7±0.5 ^a | 11.7±1.2 ^{abc} |
| SAMSORG-42 (PBW-24) | 82.4±1.9 ^{abc} | 5.5±0.3 ^b | 10.7±1.4 ^{bc} |
| SAMSORG-42 (IBG5-24) | 79.7±1.7 ^{cd} | 4.4±0.2 ^c | 10.1±0.9 ^c |

¹ Results are mean values of triplicate determinations ± standard deviation. Mean values within the same column having the same letter are not significantly different at $p < 0.05$. (SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

Table 4. Sensory quality rating of re-constituted sorghum *ogi* produced from different grain soaking techniques.

| Re-constituted sorghum 'ogi' sample | Sensory factor ¹ | | | | |
|-------------------------------------|-----------------------------|-------------------|-------------------|------------------|-----------------------|
| | Colour | Taste | Consistency | Aroma | Overall acceptability |
| SAMSORG-14 (SGW-72) | 7.8 ^b | 6.4 ^c | 6.1 ^f | 6.5 ^c | 6.6 ^d |
| SAMSORG-14 (PBW-24) | 8.1 ^a | 8.0 ^a | 7.8 ^a | 7.9 ^a | 8.1 ^b |
| SAMSORG-14 (IBG5-24) | 7.3 ^c | 8.1 ^a | 7.4 ^b | 7.1 ^b | 7.5 ^c |
| SAMSORG-41 (SGW-72) | 7.9 ^{ab} | 6.6 ^c | 6.4 ^e | 6.5 ^c | 6.5 ^d |
| SAMSORG-41 (PBW-24) | 8.2 ^a | 8.1 ^a | 7.9 ^a | 8.0 ^a | 8.1 ^b |
| SAMSORG-41 (IBG5-24) | 7.4 ^c | 7.8 ^{ab} | 7.2 ^{bc} | 7.1 ^b | 7.6 ^c |
| SAMSORG-42 (SGW-72) | 7.8 ^b | 6.5 ^c | 6.8 ^d | 6.6 ^c | 6.7 ^d |
| SAMSORG-42 (PBW-24) | 8.2 ^a | 8.1 ^a | 8.0 ^a | 8.2 ^a | 8.4 ^a |
| SAMSORG-42 (IBG5-24) | 7.2 ^c | 7.7 ^b | 7.6 ^b | 7.3 ^b | 7.7 ^c |

¹ Results are mean values from 50 panelists. Mean value within the same column having the same letter are not significantly different at $p < 0.05$. The sensory quality rating was carried out using a nine-point hedonic scale (i.e. 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely). (SGW-72) = Method involving soaking of sorghum grains in tap water for 72 h at ambient temperature; (PBW-24) = Method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature; and (IBG5-24) = Method involving the initial boiling of sorghum grains for 5 min followed by natural cooling at ambient temperature for 24 h.

the grains. The '±a-value' is essentially a measure of the degree of redness and greenness while '±b-value' stands for the degree of yellowness or blueness in a material (Giese, 2000). These two factors, however, may not be useful indices for explaining the colour characteristics of sorghum 'ogi' in this study as grain colour of the varieties is somewhat gray. These factors are popular in the visual colour evaluation in fruit ripening (Ferrer et al., 2005).

Organoleptic quality of sorghum gruel (re-constituted and boiled *ogi*) as influenced by grain soaking methods and varieties

The sensory quality rating of re-constituted sorghum 'ogi'

is presented in Table 4. It was observed that sorghum gruel prepared from 'SAMSORG-42 (PBW-24)' was rated the highest in terms of colour, taste, consistency, aroma and overall acceptability. The rating, however, was not significantly different ($p < 0.05$) from 'SAMSORG-14 (PBW-24)' and 'SAMSORG-41 (PBW-24)'. The quality assessment revealed that the products with the highest sensory rating were all from 'PBW-24' soaking technique. The implication of this is that the consumers seemed to prefer sorghum gruel emanating from the grain soaking technique that involved the initial pouring of hot water on the grains and allowing it to cool down naturally for 24 h at ambient temperature. Another inference from this quality assessment is that sorghum gruel from 'SGW-72' soaking technique was significantly ($p < 0.05$) rated the

lowest. Variations in the grain soaking methods and sorghum varieties had shown to influence consumers' preferences.

Conclusion

It could be drawn from this study that grain soaking techniques as well as varietal difference of sorghum grains did have a great influence on the ultimate properties of sorghum 'ogi' derived from the kernel. These include variations in the pH, total titrable acidity and water absorption capacity. Other parameters that were influenced were the pasting properties, swelling capacity, solubility index and colour characteristics of 'ogi' samples. The sensory quality rating of sorghum gruel (re-constituted 'ogi') revealed that the most preferred product came from 'PBW-24 soaking technique' which is a method involving pouring of boiled tap water on the sorghum grains and allowing it to cool down naturally for 24 h at ambient temperature. The practical relevance of these findings is that the desired physicochemical characteristics and consumers' acceptability of sorghum 'ogi' could be influenced by both the grain soaking methods and variety.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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