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Comparing the functional and pasting properties of gari and the sensory attributes of the *eba* produced using backslopped and spontaneous fermentation methods

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Abstract: The possibilities of backslopped fermentation replacing spontaneous fermentation in gari production were evaluated by comparing the functional and pasting properties of gari and the sensory attributes of the *eba*. Backslopped cassava mash (BCM) was produced from 75 kg of TMS13F1343 cassava roots by pre-fermenting for 96 h. The BCM was mixed with fresh cassava mash (FCM) from another 75 kg of the same variety using design expert software developed blend ratios and processed to backslopped fermented gari (BFG). Another batch of 150 kg of the same variety was processed to gari by spontaneously fermenting for 24 h, 48 h, 72 h and 96 h (SFG). All the gari samples were analysed for functional, pasting and sensory properties and physical colour using standard methods. Results showed that a significant difference ($p < 0.05$) exists in the whiteness, dispersibility and water absorption capacity of the 24 h SFG compared to that of the BFG. All the pasting properties of the 48 h SFG were significantly different ($p < 0.05$) from that of the BFG. Only the texture differentiates ($p < 0.05$) the 96 h SFG *eba* from that of the

ABOUT THE AUTHOR

Awoyale Wasiu (Ph.D.) is a Lecturer in the Department of Food Science and Technology, Kwara State University, Malete, Kwara State, Nigeria, and a Postharvest Specialist (Consultant) in the Food and Nutrition Sciences Laboratory of International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State, Nigeria. Hakeem Oyedele (M.Sc.) works as a Research Associate in the Food and Nutrition Sciences Laboratory of the IITA, Ibadan, Oyo State, Nigeria. Adenitan Ayodele Adekemi (M.Sc.) was a Graduate Research Fellow in the Food and Nutrition Sciences Laboratory of the IITA, Ibadan, Oyo State, Nigeria. Emmanuel Alamu (Ph.D.) is an Associate Scientist in the Food and Nutrition Sciences unit based in Chelstone, Lusaka, Zambia. Busie Maziya-Dixon (Ph.D.) is a Senior Food and Nutrition Scientist and Head of the Food and Nutrition Sciences Laboratory of IITA, Ibadan, Nigeria. The outcome of this study will assist the cassava processors in the reduction of the period of gari production without a negative effect on the quality.

PUBLIC INTEREST STATEMENT

Fermentation, which is one of the critical control points in the production of gari contributes significantly to its sensory and quality attributes. There is a high variation in the qualities and the sensory attributes of the gari produced through the traditional spontaneous fermentation methods, and the fermentation process takes a longer time in some communities where highly sour gari is preferred. It is envisaged that the production of gari through backslopped fermentation may reduce the gari production time and as well increase the quantity produced per day without reducing the product quality, hence, the need to compare the functional, pasting and sensory properties of the gari produced from the backslopped and spontaneous fermentation. The information provided in this article may be of use to cassava processors in the production of an acceptable gari of different functional and pasting properties and eba of different sensory attributes, and whose quality may be comparable or better than that of the spontaneous fermented gari.

BFG *eba*. The outcome of this study may be used by cassava processors/value chain actors to produce an acceptable BFG of different qualities within a day, and whose quality may be comparable or better than the SFG.

Subjects: Sensory Science; Food Analysis; Evaluation/ Program Evaluation; Consumer Psychology

Keywords: Gari; backslopped fermentation; spontaneous fermentation; functional properties; pasting properties; sensory attributes

1. Introduction

Gari (a roasted, fermented cassava grits) is the most common food product in the diet of millions of West Africans (Ehirim, 2018; Olaoye et al., 2015). This is because gari is a convenient food with a short preparation time. Its cheapness, longer shelf-life, lower bulk, and ease of preparation for consumption account for its increasing popularity in the urban areas (Oluwafemi & Udeh, 2016; Yao et al., 2009). Gari is a lactic acid solid-state fermented product derived from the cassava root, which can be processed with or without the addition of palm oil depending on the geographical location (Olaoye et al., 2015). Gari is produced traditionally by peeling, grating, spontaneously fermented at ambient temperature, pressing, sieving and toasting. It is established that the smell, quality, hygiene and safety of gari result from the fermentative actions of lactic acid bacteria (LAB) and yeasts during the fermentation stage (Haakuria, 2005).

The fermentation of cassava mash for the production of gari is an essential operation in terms of taste, aroma, safety, and overall quality. The acceptability of gari is influenced by its sourness, which is related to the number of LAB present or the length of fermentation (Abass et al., 2012). Gari consumers in the South-east of Nigeria and most parts of Ghana prefer a mild, sour taste whereas in the South-west of Nigeria, they prefer an acidic taste. The cassava mash is fermented longer (72–120 h) to get the acidic taste in the South-west gari compared to gari in South-east Nigeria (24 – 48 h) (Abass et al., 2012). Cassava fermentation for gari production occurs through the activities of endogenous microorganisms, mostly LAB, producing lactic acid that reduces the pH of the fermenting mash. The LAB responsible for the acidification process of cassava mash for gari production is *Lactobacillus spp., Streptococcus, Corynebacterium* and *Leuconostoc* (Meraz et al., 1992). The longer the cassava mash is fermented, the more sour the gari becomes (Abass et al., 2012; Irtwange & Achimba, 2009). Some other flavour compounds that contribute to the smell of gari during roasting include pyrazines, aldehydes, esters, ketones and alcohols among others (Abass et al., 2012). In some fermentation process, the freshly harvested cassava root is grated to mash, which is inoculated with cassava liquor from a three-day-old fermented mash through backslopping fermentation at a rate of 1 l of liquor to 45 kg of mash (Haakuria, 2005). This reduces the fermentation time from 96 h to 24 h. The grated pulp is transferred to a jute sack and left to ferment in a solid-state.

To date, backslopping is still the preferred process to produce foodstuffs such as sauerkraut and sourdough (Harris, 1998). Backslopped fermentation has been used for cassava products such as fufu (Fayemi & Ojokoh, 2014), lafun (Adebayo-Oyetoro et al., 2017) and stored cassava chips gari (Uvere & Nwogu, 2011), but little or no information is available on the use of freshly prepared cassava mash and pre-fermented (backslopped) cassava mash for gari production. It is therefore very important to control and optimize the fermentation process of gari production to obtain an acceptable gari of comparable or better qualities to that of the different spontaneous fermentation periods. Therefore, this study aimed to compare the functional and pasting properties of gari and the sensory attributes of the eba produced from the backslopped and spontaneous fermentation methods.

2. Materials and methods

2.1. Materials

A total of 300 kg of cassava roots (TMS13F1343) were harvested from the IITA demonstration farm at Ago-owu, Osun State Nigeria, and processed (sorted, peeled, washed and grated) to the mash.

2.2. Methods

2.2.1. Production of backslopped cassava mash

About 75 kg of cassava root were processed into a mash. The mash was fermented for about 96 h in a black-covered plastic container before extraction and isolation of specific LAB (Abass et al., 2012). Samples were collected from the backslopped cassava mash, for the extraction of particular bacteria from cultured LAB plate, and subsequent isolation of the specific bacteria through the polymerase chain reaction method. This fermented cassava mash containing the specific LAB was then used as the backslopped cassava mash to produce *gari* in combination with the freshly grated mash.

2.2.1.1. Extraction of specific bacteria from cultured lactic acid bacteria plate. The method reported by Trindade et al. (2007) with modifications was used to extract the total nucleic acid from the cultured bacteria. A small amount of inoculum was scraped from the culture plate and emulsified in 500 µl T.E buffer (10 mM Tris-HCl, 1 mM EDTA, pH 8.0). About 15 µl of 20% SDS and 3 µl of 1.1 unit of proteinase K were added, and incubated for 1 h at 37 °C, then 100 µl of 5 M NaCl and 80 µL of a 10% CTAB solution in 0.7 M NaCl were added and mixed. The samples were then incubated for 10 min at 65 °C and kept on ice for 15 min. Then, an equal volume of chloroform: isoamyl alcohol (24:1) was added. The samples were incubated on ice for 5 min and centrifuged at 12,000 x g for 20 min and transferred to a new microcentrifuge tubes tube. About 0.6 ml of isopropanol was added relative to the aliquoted aqueous phase. The DNA pellets were precipitated at −20 °C for 1 h. The samples were spin at 12,000 x g for 10 min, and the supernatant was discarded. The pellet was washed with 500 µl of 70% ethanol twice, air-dried at room temperature and dissolved in 50 µl of sterile distilled water. The total nucleic acid concentration was quantified using a Nanodrop 1000 spectrophotometer (Thermo Fisher Scientific, USA).

2.2.1.2. Polymerase Chain Reaction (PCR). A total of 12.5 µl PCR reaction mix was set up at the following concentration; 0.25 µl of the 10 Mm dNTPs, 0.75 µl of 25 mM $MgCl_2$, 0.25 µl of 10 mmol 27 F and 1525 R primers, 0.06 µl of 5 U Taq DNA polymerase, 2.5 µl of the buffer, 6.44 µl of sterile distilled water and 2 µl of 1:50 template dilution. The 16S ribosomal RNA was amplified using sequence a specific forward primer 27 F AGAGTTTGATCMTGGCTCAG and a reverse 1525 R AAGGAGGTGWTCCARCC. The PCR was performed in thermal cycler using the following cycling conditions; 2 min at 94 °C, 2 min at 52 °C, 3 min at 72 °C; 35 cycles of 1 min at 94 °C, 1 min at 52 °C, 93 secs at 72 °C; followed by final extension of 5 min at 72 °C. The PCR products were analysed in 1% Tris-acetate-EDTA (TAE)-Agarose gels for the detection of amplicons (1600 bp product). Samples with positive amplification were further amplified, purified, and used for determining the sequence information. Both the DNA strands of the 1600 bp amplicons were sequenced using the Sanger sequencing method at the IOWA State University DNA Sequencing Facility (USA). The nucleotide sequence data were analysed using BioEdit and MEGA7 bioinformatics packages, and the consensus sequence generated was used for sequence similarity search in the NCBI GenBank database using the Blastn program. Based on the sequence similarity (99.9%) identity with the sequence in the NCBI database, the identity of the strain was established (Trindade et al., 2007).

The species identity was then confirmed as *Lactobacillus fermentum* based on the DNA-diagnostic method. The backslopped cassava mash (10:20) containing the *Lactobacillus fermentum* was mixed with fresh cassava mash (FCM) (70:90) from another 75 kg of the same cassava variety using the blend ratios developed through response surface central composite rotatable design (Table 1) of Design-Expert software (version 12) for the production of backslopped fermented gari.

2.2.2. Production of gari

The combinations shown in Table 1 were appropriately blended with a laboratory mixer to obtain a homogenous sample, after which they were bagged, dewatered, pulverized and roasted manually in the laboratory using a stainless steel roasting pan mounted on an electric cooker (Awoyale et al., 2020). The roasting temperature was monitored using an infra-red thermometer, and as much as possible maintained at between 68 °C and 70 °C for about 20 mins. A different batch of 150 kg of the same cassava roots genotype and location were harvested and processed, with the grated mash divided into four portions for different days of spontaneous fermentation (24 h, 48 h, 72 h, and 96 h). The grated cassava mash fermented for 24 h, 48 h, 72 h and 96 h were bagged, dewatered, pulverized, and roasted manually in the laboratory using the same temperature (68–70 °C) and time (20 min) as done above, after each of the fermentation periods (Awoyale et al., 2020). The moisture content of the backslopped and spontaneous fermented cassava mash was monitored to be between 28% and 30% before roasting.

2.2.3. Determination of physical colour and functional properties

2.2.3.1. Determination of physical colour. The physical colour was determined using a colour meter (Chroma meter CR-400, Konica Minolta, Inc., Japan). The colourimeter operates on the CIE (Commission Internationale de l'Eclairage) L*, a*, b* colour scheme. Multiple measurements of several points on samples were made. The instrument was first standardized (L = 93.24, a = 00.96, b = 02.75) with a sheet of Business Xerox 80 g/m2 white paper with 136 CIE whiteness D65. About 3 g of gari was put in whirl pack nylon, and the colour meter was placed on the sample by allowing the sensor to touch the sample. The reading was taken directly for L*. The instrument displays three-dimensional colour differences in uniform colour space (Lab) co-ordinates. Uniform colour space defines three directions, a light to dark direction, called L*, a red to green direction called a*, and a blue to yellow direction called b* (Shittu et al., 2009).

2.2.3.2. Bulk Density. Flour samples (10 g) were measured into a 50 ml graduated measuring cylinder and gently tapped on the bench 10-times to achieve a constant height. The volume of the sample was recorded and expressed as grams per milliliter (Ashraf et al., 2012).

2.2.3.3. Swelling power and solubility index. The method reported by Afoakwa et al. (2012)] was used for the determination of the swelling power (SWP) and solubility index (SI) of the samples. About 2.5% aqueous starch dispersion was put in centrifuge tubes, capped to prevent spillage, and

Table 1. Different proportions of the blends of freshly grated cassava mash and backslopped cassava mash to produce gari

Runs	Fresh cassava mash (g)	Backslopped cassava mash (g)
1	94.14	15.00
2	80.00	15.00
3	90.00	20.00
4	80.00	15.00
5	70.00	10.00
6	65.86	15.00
7	70.00	20.00
8	80.00	15.00
9	80.00	7.93
10	80.00	15.00
11	80.00	15.00
12	90.00	10.00
13	80.00	22.07

heated in a water bath with a shaker (Precision Scientific, Model 25: Chicago, USA) at a temperature of 85 °C for 30 min. The tubes were allowed to be cooled to room temperature and centrifuged after heating (Thelco GLC- 1, 60,647: Chicago, USA) at 3,000 rpm for 15 min. The paste was separated from the supernatant and weighed. The liquid above the sediment was evaporated in a hot air oven (Mmert GmbH+Co.KG: D-91,126, Germany) at a temperature of 105 °C, and the residue was weighed. All determinations were done in duplicates, and the SWP and SI were calculated as (Awoyale et al., 2020):

$$SWP = \frac{Wt\ of\ precipitated\ paste}{Wt\ of\ sample} - wt\ of\ residue\ insupernatant \times 100$$

$$SI = \frac{Wt\ o\ fresidue\ in\ supernatant}{Wt\ of\ sample} \times 100$$

2.2.3.4. Water absorption capacity. About 1 g of flour sample was weighed into a clean pre-weighed dried centrifuge tube and mixed adequately with distilled water (10 ml) by vortexing. The suspension was allowed to stand for 30 mins and Centrifuged (Thelco GLC-1, 60,647: Chicago, USA) at 3,500 rpm for 30 min. After centrifuging, the supernatant was decanted, and the tube with the sediment was weighed after removal of the adhering drops of water. The weight of water (g) retained in the sample was reported as the water absorption capacity (Oyeyinka et al., 2013)

2.2.3.5. Dispersibility. A sample of 10 g was dispersed in distilled water in a 100 ml measuring cylinder, and distilled water was added up to the 50 ml mark. The mixture was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was noted, and the percentage was calculated (Asaam et al., 2018; Kulkarni & Ingle, 1991).

$$Dispersibility(\%) = \frac{50 - volume\ of\ the\ settled\ particle}{50} \times 100$$

2.2.4. Pasting properties

The pasting properties of yam flour were measured using a Rapid Visco Analyser (Model RVA 4500, Perten Instrument, and Australia) equipped with a 1000 cmg sensitivity cartridge. Yam flour (3.5 g) was weighed into a dried empty canister, and 25 ml of distilled water was added. The mixture was thoroughly stirred, and the canister was fitted into the RVA as recommended. The slurry was heated from 50 to 95 °C at a rate of 1.5 °C/min, held at this temperature for 15 min, cooled to 50 °C. Viscosity profile indices recorded from the pasting profile with the aid of Thermocline for Windows Software connected to a computer were peak viscosity, trough, breakdown, final viscosity setback, peak time, and pasting temperature (Donaldben et al., 2020).

2.2.5. Preparation of eba and uncooked gari for sensory evaluation

The *gari* was made into *eba* using the modified method described by Udoro et al. (2014). *Eba* was prepared by adding about 100 g of *gari* to 195 ml of hot boiling water and continuously stirred to form a smooth thick paste. However, the sensory evaluation was carried out using twelve trained panelists from the staff and graduate students of the International Institute of Tropical Agriculture (IITA), Ibadan who consumes *eba* regularly based on parameters such as colour/appearance, texture, stretchability, mouldability, smell, mouthfeel, and overall acceptability. Uncooked gari was also evaluated for appearance (colour, smell and particle size), taste, and overall acceptability using the same panelist. The sensory acceptability of the *gari* and *eba* was evaluated using a 9-point hedonic scale; 1 corresponds to disliked extremely and 9 liked extremely (Iwe, 2002; Nkama & Filli, 2006). The authors of this study declare that the sensory evaluation followed the tenets of the Declaration of Helsinki promulgated in 1964 and was approved by the institutional ethical review committee. In addition, verbal consent was obtained from the participants.

2.2.6. Statistical analysis

The analysis of variance (ANOVA) of the data generated was analysed using the Statistical Package for Social Scientist (SPSS version 21). The t-test to check the level of significant difference (at 95%

significant level) between the backslopped and the spontaneously fermented gari was also done using the SPSS software, and the optimization was done using response surface central composite rotatable design of Design-Expert software (version 12).

3. Results and discussion

3.1. Physical colour and functional properties of backslopped and spontaneous fermented gari

The results of the physical colour and functional properties of the backslopped fermented *gari* (BFG) produced from different blends of fresh cassava mash (FCM), and backslopped cassava mash (BCM-containing *Lactobacillus fermentum*), as well as *gari*, produced from 24 h, 48 h, 72 h and 96 h spontaneous fermentation are shown in Table 2. The mean of the physical colour and functional properties of the BFG is whiteness 86.81, dispersibility 59.96%, water absorption capacity (WAC) 453.70%, bulk density (BD) 55.51%, swelling power (SWP) 29.22% and solubility index (SI) 2.07%. For the spontaneously fermented gari (SFG), the mean of the whiteness is 83.65, dispersibility 65.01%, WAC 477.90%, BD 61.05%, SWP 30.59% and SI 1.48% (Table 2). Comparing the physical colour and functional properties of the BFG with the 24 h, 48 h, 72 h and 96 h SFG using *t*-test, revealed that significant difference ($p < 0.05$) exists in the whiteness ($p = 0.000$), dispersibility ($p = 0.002$) and WAC ($p = 0.008$) of the 24 h SFG, with no significant difference observed in the BD ($p = 0.439$), SWP ($p = 0.667$) and SI ($p = 0.073$). It was only the whiteness ($p = 0.039$, $p = 0.025$) and the dispersibility ($p = 0.002$, $p = 0.000$) that were significantly different ($p < 0.05$) in the 48 h and 72 h SFG compared to the BFG. The 96 h SPG was significantly different ($p < 0.05$) from the BFG in terms of the dispersibility ($p = 0.000$) and SWP ($p = 0.026$). That is, of all the functional properties of the BFG compared to the SFG, it was only the dispersibility that was significantly different ($p < 0.05$) for all the fermentation periods (Table 2).

Among the BFG, the whiteness (L*) value was higher in 80%FCM: 7.93%BCM (89.44) and lower in 70%FCM: 10%BCM (83.47). This implies that the whiteness value decreased as the quantity of the BCM increased in the blends. The variation in the whiteness value of the *gari* may be attributed to the quantity of the BCM added to the freshly grated mash, although cassava variety, the period of harvest, and the temperature and time of roasting may affect the colour of the gari (Abass et al., 2012; Owuamanam et al., 2011). Even though there was no significant difference in the whiteness value of the gari produced from the different spontaneous fermented periods (24 h, 48 h, 72 h, and 96 h), gari produced from the 96 h fermentation (84.53) had the highest whiteness value and the 24 h fermented gari (83.09) had the least (Table 2). The whiteness of the BFG was not significantly different ($p = 0.154$) from the whiteness value of the 96 h SFG (Table 2). The Codex Alimentarius Commission does not give any specifications for colour (Codex Alimentarius Commission, 1985). This is based on the individual countries with respect to likeness. Sanni et al. (2005) reported that the colour of gari shall be yellow when palm oil is added or white without the addition of palm oil.

Dispersibility is a measure of the reconstitution of floury products in water, and the higher the dispersibility, the better the samples reconstitute in water (Awoyale et al., 2020; Kulkarni & Ingle, 1991). So, gari produced from 94.14%FCM: 15%BCM (66%) backslopped fermentation may reconstitute better in boiled water without lumps formation because of its high dispersibility. The gari produced from 65.86%FCM: 15%BCM (53.50%) may form lumps when reconstituted in boiled water due to low dispersibility. Though the way the gari is added to the boiled water and the stirring process may affect the formation of lumps during reconstitution (Awoyale et al., 2020). Results also depict that a higher quantity of FCM in the BFG favoured higher dispersibility. Amid the SFG, gari produced from the 72 h fermentation (83.75%) had higher dispersibility, and that of the 96 h fermentation (34.05%) had the least. This means that gari to be reconstituted in boiled water to *eba* should be spontaneously fermented for at least 72 h and not 96 h to reduce lumps formation (Awoyale et al., 2020; Kulkarni & Ingle, 1991). A significant difference ($p < 0.05$) exists between the dispersibility of the BFG and that of 24 h ($p = 0.002$), 48 h ($p = 0.002$), 72 h ($p = 0.000$) and the 96 h

(p = 0.000) SFG (Table 2). The dispersibility of the BFG of the present study was within the range of values (20.25–75.25%) reported by Awoyale et al. (2020) for gari produced from different cassava varieties using the spontaneous fermentation method. The dispersibility of the 72 h SFG was higher than the dispersibility reported by Awoyale et al. (2020). Conversely, the dispersibility of commercially available gari (39.95–43.22%) collected from different locations in Nigeria (Awoyale et al., 2017) was lower compared to the dispersibility of both the BFG and the SFG of this study.

The WAC of the gari produced from the backslopped fermentation was higher in 94.14%FCM: 15%BCM (519.89%) and lower in that of 65.86%FCM: 15%BCM (423.13%) (Table 2). The WAC is an essential property for most starchy foods and is a function of smaller granule sizes and, thus, higher solubility (Tian et al., 1991). Hence, gari produced from the 94.14%FCM: 15%BCM may be highly soluble in cold water compared to that produced from 65.86%FCM: 15%BCM. This result also revealed that gari of higher WAC could be produced from the backslopped fermentation by adding more of the freshly grated cassava to the blends. However, the age and type of cassava variety, harvesting period, the time and temperature of roasting and the particle size of the gari may affect the WAC (Abass et al., 2012; Owuamanam et al., 2011). In the SFG, the 24 h fermented gari (540.69%) had the highest WAC and the 48 h fermented gari (412.95%) had the lowest (Table 2). No significant difference was observed in the WAC of the 24 h fermentation gari and that of the 72 h fermentation, as well as that of the 48 h fermentation and the 96 h fermentation (Table 2). In essence, gari with higher WAC may be spontaneously fermented for either 24 h or 72 h. The result of the t-test depicts a significant difference (p = 0.008) between the WAC of the BFG and the 24 h SFG (Table 2). The WAC of the BFG and the SFG (except 24 h SFG) was in the range of values reported by Awoyale et al. (2017) for commercially available gari in Nigeria (450.46–514.70%) and gari produced from different cassava varieties (140.64–-693.18%) (Awoyale et al., 2020).

The lower the BD value, the higher the amount of the product that could be packaged in each volume of the container, and the reduction in the space occupied and the costs of packaging and transportation (Ikujenlola, 2008). The BD of all the gari produced from the backslopped and spontaneous fermentation was statistically the same. This is because the t-test showed that the p-values of the BFG and the 24 h (p = 0.439), 48 h (p = 0.760), 72 h (p = 0.682) and 96 h (p = −0.791) SFG are greater than 0.05 (Table 2). However, BFG from 90%FCM: 10%BCM (64.11%) had higher BD and that of 70%FCM: 20%BCM (55.25%) was lower (Table 2). Within the SFG, the 24 h fermented gari (65.34%) had the highest BD and that of the 96 h fermentation (58.84%) the least (Table 2). The statistical similarity of the BD of all the gari may be attributed to the same cassava variety used. The BD of gari reported for different varieties of cassava (40–70%) (Awoyale et al., 2020) was within the range of values observed for the BD of the BFG and the SFG. On the contrary, the BD of the SFG was higher compared to the BD (43.85–56.84%) of commercially available gari in Nigeria (Awoyale et al., 2017).

The SWP and SI provide evidence of the magnitude of the interaction between starch chains within the amorphous and crystalline domains. Also, a good quality gari is described as that which can swell to at least three times its original volume (Awoyale et al., 2020). The SWP was higher in gari produced from 94.14%FCM: 15%BCM (30.95%) backslopped fermentation and lower in that of the 80%FCM: 22.07%BCM (22.45%) (Table 2). This implies that to produce good quality gari of high SWP, more of the freshly grated cassava should be blended with less of the BCM containing *Lactobacillus fermentum*. Gari of higher SWP may also be produced by extending the spontaneous fermentation period to 96 h. This is because the SWP of the gari produced from the 96 h spontaneous fermentation (33.81%) was higher compared to that of the 24 h spontaneous fermentation (28.37%) (Table 2). The SWP of the BFG was significantly different (p = 0.026) from that of the 96 h SFG (Table 2). The SWP of the BFG and the SFG was higher compared to the range of values (8.23–12.74%) reported by Awoyale et al. (2020) for gari produced from different cassava varieties using the spontaneous fermentation method.

Table 2. Physical colour and functional properties of backslopped and spontaneous fermented gari

Samples	Whiteness	Dispersibility (%)	Water absorption capacity (%)	Bulk density (%)	Swelling power (%)	Solubility index (%)
Backslopped fermented gari (BFG) blend ratios						
94.14%FCM:15%BCM	84.24 ± 0.02 cd	66.00 ± 2.83bc	519.89 ± 0.48ab	61.91 ± 0.07ab	30.95 ± 1.36ab	2.99 ± 0.52a
80%FCM:15%BCM	87.52 ± 1.36a-c	60.60 ± 3.72 c-e	437.82 ± 44.44 c-e	58.83 ± 0.03ab	30.46 ± 1.16ab	2.18 ± 0.50a-c
90%FCM:20%BCM	86.24 ± 0.43a-d	64.50 ± 2.12 cd	485.30 ± 4.69a-d	61.56 ± 0.00ab	29.75 ± 0.03ab	2.45 ± 0.23ab
70%FCM:10%BCM	83.47 ± 3.79d	58.00 ± 0.00ef	450.06 ± 0.93b-e	61.55 ± 0.00ab	28.29 ± 3.00b	2.03 ± 0.73a-c
65.86%FCM:15%BCM	84.88 ± 3.62b-d	53.50 ± 3.54 f	423.13 ± 21.63de	59.35 ± 0.03ab	30.02 ± 0.17ab	2.60 ± 0.02ab
70%FCM:20%BCM	86.68 ± 0.42a-d	61.00 ± 1.41 c-e	441.29 ± 20.57 c-e	55.25 ± 0.03b	28.73 ± 1.21b	1.97 ± 0.23a-c
80%FCM:7.93%BCM	89.44 ± 1.24a	59.00 ± 1.41d-f	460.18 ± 1.31b-e	61.56 ± 0.00ab	30.20 ± 0.71ab	2.06 ± 0.12a-c
90%FCM:10%BCM	88.39 ± 0.52ab	56.50 ± 0.71ef	472.39 ± 18.19a-e	64.11 ± 0.04a	27.16 ± 5.79b	1.65 ± 1.45bc
80%FCM:22.07%BCM	87.57 ± 0.82a-c	58.00 ± 0.00ef	456.77 ± 1.10b-e	59.35 ± 0.03ab	22.45 ± 0.53 c	0.26 ± 0.10d
Mean	86.81	59.96	453.70	55.51	29.22	2.07
Spontaneously fermented gari (SFG)						
24 h fermentation	83.09 ± 1.32d	71.00 ± 2.83b	540.69 ± 19.93a	65.34 ± 0.02a	28.37 ± 3.82b	1.05 ± 0.56 cd
48 h fermentation	83.70 ± 0.52 cd	71.25 ± 1.77b	412.95 ± 0.83e	59.36 ± 0.03ab	29.93 ± 1.93ab	1.36 ± 0.26b-d
72 h fermentation	83.29 ± 1.61d	83.75 ± 1.77a	506.65 ± 4.89a-c	60.68 ± 0.03ab	30.25 ± 1.50ab	1.44 ± 0.14bc
96 h fermentation	84.53 ± 3.18b-d	34.05 ± 0.47 g	451.32 ± 26.59b-e	58.84 ± 0.00ab	33.81 ± 2.64a	2.08 ± 0.55a-c
Mean	83.65	65.01	477.90	61.05	30.59	1.48
T-test at 95% significant level						
p (BFG x 24 h SFG)	***	**	**	NS	NS	NS
p (BFG x 48 h SFG)	*	**	NS	NS	NS	NS
p (BFG x 72 h SFG)	*	***	NS	NS	NS	NS
p (BFG x 96 h SFG)	NS	***	NS	NS	*	NS

FCM-Fresh cassava mash, BCM-Backslopped cassava mash, ±standard deviation.

Means with different letters within the same column are significantly different ($p < 0.05$). All analyses were done in triplicate

Solubility is indicative of water penetration ability into starch granules of flours (Ikegwu et al., 2009). This means that the higher the solubility, the higher the dispersibility, and the higher the SWP of the starch granules. Hence, gari produced from 94.14%FCM: 15%BCM (2.99%) backslopped fermentation may disperse easily with higher swelling power because of its high SI compared to that of 80%FCM: 22.07%BCM (0.26%) gari due to its low SI (Table 2). Gari of higher SI may be produced by extending the spontaneous fermentation period to 96 h. This is because the SI of the gari produced from the 96 h spontaneous fermentation (2.08%) was higher compared to that of the 24 h fermentation (1.05%), although, no significant difference exists in the SI of the BFG and that of the 24 h (p = 0.073), 48 h (p = 0.190), 72 h (p = 0.240) and 96 h (p = 0.983) SFG, as shown in the t-test (Table 2). The SI of the gari produced from the 94.14%FCM: 15%BCM backslopped fermentation was not statistically different (p = 0.983) from that of the 96 h spontaneous fermentation (Table 2). Therefore, the quantity of BCM containing *Lactobacillus fermentum* should not be increased up to 22% in backslopped fermentation to achieve gari of higher SWP and SI. The SI (3.06–4.18%) of the commercially available gari in Nigeria was higher than the SI of the BFG and the SFG reported in this study (Awoyale et al., 2017). Also, the SI of the SFG was lower than the SI of gari produced from different cassava varieties (2.18–8.23%) (Awoyale et al., 2020).

3.2. Pasting properties of backslopped and spontaneous fermented gari

The pasting properties of gari are fundamental in predicting their behaviour during and after cooking, as these products may be reconstituted in hot water to eba before consumption (Adebowale et al., 2008). Table 3 depicts the results of the pasting properties of the BFG produced from different blends of FCM and BCM, as well as *gari* produced from 24 h, 48 h, 72 h, and 96 h spontaneous fermentation.

The mean of the BFG pasting properties is peak viscosity 369.68 RVU, trough viscosity 184.23 RVU, breakdown viscosity 185.46 RVU, final viscosity 301.78 RVU, setback viscosity 117.55 RVU, peak time 4.69 min and pasting temperature 77.90 °C. Likewise, the mean of the pasting properties of the SFG is peak viscosity 319.16 RVU, trough viscosity 192.28 RVU, breakdown viscosity 126.88 RVU, final viscosity 326.82 RVU, setback viscosity 134.54 RVU, peak time 5.06 min and pasting temperature 79.64 °C (Table 3). Relating the pasting properties of the BFG with the SFG using the t-test, the 24 h SFG was significantly different from the BFG in terms of only the setback viscosity (p = 0.016). All the pasting properties of the 48 h SFG were significantly different from that of the BFG except the trough (p = 0.810), final (p = 0.150) and setback (p = 0.062) viscosities, which were not significantly different. It was only the trough viscosity of the 72 h SFG (p = 0.621) that was not significantly different from that of the BFG. The trough viscosity (p = 0.005) and the peak time (p = 0.000) of the 96 h SFG were significantly different from that of the BFG (Table 3).

Ikegwu et al. (2009) stated that the peak viscosity is the maximum viscosity developed during or soon after the heating process, and which contributes to the good texture of the cooked starchy food. For the backslopped fermentation, gari of high peak viscosity could be produced from 80% FCM: 7.93%BCM (419.08 RVU), and that of low peak viscosity could be produced from 70%FCM: 10%BCM (298.46 RVU) (Table 3). This indicates that consumers who prefer the firm-textured *eba* may reconstitute 80%FCM: 7.93%BCM in boiled water because of its high peak viscosity. Also, consumers that prefer the soft textured *eba* may reconstitute 70%FCM: 10%BCM in boiled water due to its low peak viscosity. With the use of the spontaneous fermentation; firm-textured *eba* may be produced from the 96 h fermented gari (366.92 RVU) because of its high peak viscosity, and a soft textured *eba* may be produced from the 48 h fermented gari (283.92 RVU) due to its low peak viscosity (Table 3). Nevertheless, it is imperative to add that the texture of cooked starchy foods may depend on the quantity of water used during reconstitution and the temperature and time spent for gelatinization (Newport Scientific, 1998). The *t*-test shows a significant difference in the peak viscosity of the 48 h (p = 0.009) and 72 h (p = 0.035) SFG and that of the BFG (Table 3). The peak viscosity of the gari (129.17–241.30 RVU) available in the Nigerian markets was lower compared to the peak viscosity of the BFG and the SFG of this study (Awoyale et al., 2017). The range of values reported for the peak viscosity (371.69–680.99 RVU) of gari produced from different cassava varieties through the spontaneous fermented method (Awoyale et al., 2020) was higher than the peak viscosity of the BFG and the SFG.

The trough viscosity, also known as holding strength, is the ability of granules to remain undisrupted when the starch is subjected to a period of constant high temperature and mechanical shear stress (Olatunde et al., 2017). The trough viscosity of the gari produced from the backslopped fermentation ranged from 161.63 to 200.34 RVU, with the 80%FCM: 7.93%BCM gari having the highest and the 94.14%FCM: 15%BCM gari the least (Table 3). This result suggests that *eba* produced from 80%FCM: 7.93%BCM gari may not withstand mechanical shear stress, and the starch granules may be disrupted because of its high trough viscosity. The eba prepared from 94.14%FCM: 15%BCM with lower trough viscosity may withstand mechanical shear stress (Olatunde et al., 2017). The trough viscosity of the SFG, on the other hand, was higher in the 96 h fermentation (215.92 RVU) and lower in that of the 24 h fermentation (177.59 RVU). A significant difference (p = 0.005) exists in the trough viscosity between the BFG and the 96 h SFG (Table 3). The trough viscosity of the BFG produced from the 80%FCM: 7.93%BCM and that of the 96 h SFG was higher than the trough viscosity of the gari (104.03–185.75 RVU) collected from different markets in Nigeria (Awoyale et al., 2017). But the trough viscosity of the gari produced from different cassava varieties (239.79–385.71 RVU) was higher compared to that of the BFG and SFG (Awoyale et al., 2020).

Breakdown viscosity gives the fragility of starch upon the application of heat and shear force (Adebowale et al., 2008). That is, the higher the breakdown viscosity, the lower is the ability of the starchy food to withstand heating and shear stress during cooking (Adebowale et al., 2008; Awoyale et al., 2020). The 80%FCM: 7.93%BCM backslopped fermented gari (218.75 RVU) had the highest breakdown viscosity, and that of the 70%FCM: 10%BCM (124.17 RVU) had the lowest. This result corroborates the observation in the trough viscosity that the *eba* produced from the 80%FCM: 7.93% BCM gari may not withstand mechanical shear stress. This is because the breakdown viscosity of the gari produced from 80%FCM: 7.93%BCM was higher. In essence, *eba* produced from 70%FCM: 10% BCM gari may withstand mechanical shear stress with undisrupted starch granule because of its low breakdown viscosity (Table 3). Similarly, *eba* with undisrupted starch granule may be produced from the 48 h spontaneous fermentation (97.38 RVU) due to its low breakdown viscosity compared to that from the 96 h spontaneous fermentation (151.00 RVU), though, there was no statistically significant difference in the breakdown viscosity of all the spontaneously fermented gari. There was a significant difference in the breakdown viscosity amid the BFG and that of the 48 h (p = 0.002) and 72 h (p = 0.007) SFG (Table 3). The values of the breakdown viscosity (22.44–55.54 RVU) reported for the commercial gari in Nigeria (Awoyale et al., 2017) was lower than the breakdown viscosity of the BFG and the SFG. The breakdown viscosity of the BFG and the SFG of this study was within the range of values reported for the breakdown viscosity of gari produced from different cassava varieties (101.-66–406.67 RVU) (Awoyale et al., 2020).

The final viscosity is the pasting parameter most commonly used to determine the quality of a starchy product as it indicates the ability of the material to form a gel after cooking (Sanni et al., 2006). That is, the higher the final viscosity of gari, the better the quality, as the gelatinization process may be faster when reconstituted with boiled water to *eba*. This infers that for the backslopped fermentation; the 70%FCM: 20%BCM gari (321.63 RVU) may gelatinize faster when reconstituted in boiled water to *eba* because of its high final viscosity. Also, when the 94.14%FCM: 15%BCM gari (266.80 RVU) is reconstituted in boiled water to *eba* it may gelatinize gently due to its low final viscosity (Table 3). Amongst the spontaneously fermented gari, the final viscosity was higher in the 72 h fermented gari (337.55 RVU) and low in that of the 24 h fermentation (322.25 RVU), although the final viscosity of all the spontaneous fermented gari was not significantly different (Table 3). The t-test depicts a significant difference in the final viscosity between the BFG and the 72 h SFG (p = 0.025) (Table 3). The final viscosity of the BFG and the SFG was lower compared to the values (338.46–507.38 RVU) reported by Awoyale et al. (2020) for the final viscosity of the gari produced from different cassava varieties. Also,

Table 3. Pasting properties of backslopped and spontaneous fermented gari

Samples	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (min.)	Pasting Temperature (°C)
Backslopped fermented gari (BFG) blend ratios							
94.14%FCM:15%BCM	337.83 ± 30.41a-d	161.63 ± 11.38 c	176.21 ± 19.04a-c	266.80 ± 3.71 f	105.17 ± 7.66de	4.60 ± 0.00d	78.30 ± 0.07b
80%FCM:15%BCM	395.13 ± 37.95ab	189.51 ± 12.41a-c	205.62 ± 32.11ab	306.77 ± 19.07a-e	117.26 ± 13.77 c-e	4.65 ± 0.12 cd	77.73 ± 0.93bc
90%FCM:20%BCM	323.38 ± 10.19b-d	161.79 ± 0.30 c	161.58 ± 9.90a-c	279.46 ± 5.84ef	117.67 ± 6.13 c-e	4.77 ± 0.05 cd	78.28 ± 0.04b
70%FCM:10%BCM	298.46 ± 2.77d	174.29 ± 0.76bc	124.17 ± 3.54 cd	288.55 ± 5.83d-f	114.25 ± 6.60 c-e	4.87 ± 0.00bc	79.13 ± 0.11b
65.86%FCM:15%BCM	362.00 ± 6.25a-d	194.92 ± 2.83ab	167.09 ± 3.42a-c	292.46 ± 1.12 c-f	97.54 ± 1.71e	4.84 ± 0.05 c	78.33 ± 0.11b
70%FCM:20%BCM	385.30 ± 36.59a-c	191.25 ± 9.10ab	194.04 ± 27.52ab	321.63 ± 0.42a-c	130.38 ± 8.66a-d	4.67 ± 0.09 cd	77.45 ± 1.06bc
80%FCM:7.93%BCM	419.08 ± 35.71a	200.34 ± 8.72ab	218.75 ± 26.98a	319.21 ± 0.88a-d	118.88 ± 7.84b-e	4.57 ± 0.14d	76.35 ± 0.57 c
90%FCM:10%BCM	361.50 ± 34.65a-d	182.63 ± 5.59bc	178.88 ± 29.06a-c	318.34 ± 8.01a-d	135.71 ± 2.42a-c	4.60 ± 0.10d	77.58 ± 1.17bc
80%FCM:22.07%BCM	342.71 ± 59.93a-d	180.58 ± 28.64bc	162.13 ± 31.29a-c	302.88 ± 19.03b-e	122.29 ± 9.60a-e	4.84 ± 0.05 c	78.65 ± 0.64b
Mean	369.68	184.23	185.46	301.78	117.55	4.69	77.90
Spontaneously fermented gari (SFG)							
24 h fermentation	321.42 ± 79.90b-d	177.59 ± 20.27bc	143.84 ± 59.63b-d	322.25 ± 3.65a-c	144.67 ± 16.62ab	4.84 ± 0.05 c	78.75 ± 0.57b
48 h fermentation	283.92 ± 15.91d	186.54 ± 3.48bc	97.38 ± 12.44d	323.00 ± 4.24a-c	136.46 ± 7.72a-c	5.17 ± 0.05a	81.98 ± 1.80a
72 h fermentation	304.38 ± 11.73 cd	189.09 ± 9.07a-c	115.30 ± 2.65 cd	337.55 ± 11.84a	148.46 ± 20.92a	5.07 ± 0.09ab	79.10 ± 0.07b
96 h fermentation	366.92 ± 4.72a-d	215.92 ± 1.06a	151.00 ± 5.77b-d	324.50 ± 5.77ab	108.59 ± 6.84de	5.17 ± 0.14a	78.73 ± 0.67b
Mean	319.16	192.28	126.88	326.82	134.54	5.06	79.64
t-test at 95% significant level							
p (BFG x 24 h SFG)	NS	NS	NS	NS	*	NS	NS
p (BFG x 48 h SFG)	**	NS	**	NS	NS	***	***
p (BFG x 72 h SFG)	*	NS	**	*	**	**	*
p (BFG x 96 h SFG)	NS	**	NS	NS	NS	***	NS

FCM-Fresh cassava mash, BCM-Backslopped cassava mash, ±standard deviation, means with different letters within the same column are significantly different ($p < 0.05$). All analyses were done in triplicate

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lower final viscosity values (188.70–318.34 RVU) were reported by Awoyale et al. (2017) for commercially available gari in Nigeria compared to the final viscosity of the SFG in this study.

The setback viscosity is a stage where retrogradation or re-ordering of starch molecules occurs; thus, low setback viscosity during the cooling of the paste indicates greater resistance to syneresis/weeping (Adebowale et al., 2008; Awoyale et al., 2020). The BFG of 65.86%FCM: 15%BCM blends (97.54 RVU) may not weep or retrograde easily when prepared to *eba* due to its lower setback viscosity compared to *eba* produced from the 90%FCM: 10%BCM gari (135.71 RVU), which may weep easily because of its high setback viscosity. Likewise, good texture *eba* that may not retrograde easily may be produced from the 96 h spontaneous fermented gari (108.59 RVU) because of the low setback viscosity, and that of the 72 h fermented gari (148.46 RVU) may retrograde faster due to its high setback viscosity (Table 3). The setback viscosity of the 24 h (p = 0.016) and 72 h (p = 0.009) SFG was significantly different from that of the BFG as evidence in the t-test (Table 3). The setback viscosity reported by Awoyale et al. (2017) (84.67–133.02 RVU) was in range with the values for the setback viscosity of the BFG. Also, the setback viscosity of both the BFG and the SFG was within the range of values (74.92–177.58 RVU) reported by Awoyale et al. (2020).

The pasting temperature is a measure of the minimum temperature required to cook a given food sample, which has implications for the stability of other components in a formulation and as well indicates energy costs (Adebowale et al., 2008). The pasting temperature of the gari produced from the backslopped fermentation ranged between 76.35 °C for the 80%FCM: 7.93% BCM gari, and 79.13 °C for the 70%FCM: 10%BCM gari. Gari produced from the spontaneous fermentation has higher pasting temperature in the 48 h fermented gari (81.98 °C) and lower value in that of the 96 h fermentation (78.73 °C) (Table 3). The *t*-test revealed that the 48 h (p = 0.000) and 72 h (p = 0.044) SFG was significantly different from the BFG in terms of the pasting temperature. The pasting temperature of gari (60.14–84.55 °C) produced from different cassava varieties agreed with that of the BFG and the SFG of this study (Awoyale et al., 2020). Also, the pasting temperature of the BFG agreed with the values (69.58–80.40 °C) reported for the pasting temperature of gari available in Nigerian market (Awoyale et al., 2017). All the backslopped and spontaneously fermented gari may be reconstituted to *eba* below the boiling point (100 °C) of water in less than 6 min, hence, reducing energy cost (Adebowale et al., 2008). This observation agreed with the findings of Awoyale et al. (2020) on the peak time of gari produced from different cassava varieties. The peak time of the 48 h (p = 0.000), 72 h (p = 0.001) and 96 h (p = 0.000) SFG was significantly different from that of the BFG (Table 3).

3.3. Sensory attributes of backslopped and spontaneous fermented cooked gari (eba)

The expression of individual likes or dislikes for a product as a result of biological variation in humans and how the individual perceives the sensory attributes are known as sensory evaluation (Iwe, 2002). Consumers do check the appearance (colour, smell and particle size) and taste before purchasing uncooked *gari* in the open market, and the sensory attributes considered when the *gari* is reconstituted in boiled water to *eba* are the texture, colour, stretchability, mouldability, smell and mouthfeel (Adinsi et al., 2019), hence, the need for the sensory evaluation of the eba produced from the BFG and the SFG.

Table 4 depicts the sensory characteristics of the cooked *gari* (*eba*) prepared from the BFG and SFG. The results showed that the overall mean of the texture, colour, stretchability, mouldability, smell, mouthfeel and overall acceptability of the *eba* prepared from both the BFG and the SFG fall within the moderately liked range, except the texture (7.50) and the overall acceptability (7.67) of the SFG that fall within the very much liked range (Table 4). It was only the mouthfeel that differentiates the 24 h SFG *eba* (p = 0.020) from that of the BFG, as presented in the t-test. This is because the texture (p = 0.290, colour (p = 0.516), stretchability (p = 0.764), mouldability (p = 0.339), smell (p = 0.096), and overall acceptability (p = 0.375) of the eba prepared from the BFG and 24 h SFG were not significantly different except the mouthfeel (Table 4). The texture (p

= 0.029), mouldability (p = 0.027), mouthfeel (p = 0.006), and overall acceptability (p = 0.026) distinguish the 48 h SFG *eba* from that of the BFG. The texture (p = 0.000), colour (p = 0.050), mouldability (p = 0.027), mouthfeel (p = 0.023) and overall acceptability (p = 0.011) single out the 72 h SFG from the *eba* prepared from BFG. Likewise, only the texture (p = 0.006) differentiates the 96 h SFG eba from the BFG *eba* (Table 4).

It was reported by Ross et al. (2011) that texture is an important characteristic that impacts the consumer acceptability of products. Using the backslopped fermented method, the texture of the *eba* prepared from the 94.14%FCM: 15%BCM gari (6.83) was liked moderately and that of 70%FCM: 10%BCM (5.67) was slightly liked. This means that the 94.14%FCM: 15%BCM *eba* was more preferred than that of the 70%FCM: 10%BCM *gari* in terms of the texture. There was no significant difference in the texture of the *eba* prepared from all the BFG. For the spontaneously fermented method, the *eba* made from the 72 h fermented *gari* (8.25) was very much liked in texture compared to the *eba* made from the 24 h fermented *gari* (6.83), whose texture was moderately liked (Table 4). However, there was no significant difference in the texture of the *eba* prepared from all the SFG. The texture of the *eba* made from the 48 h (p = 0.029), 72 h (p = 0.000) and 96 h (p = 0.006) SFG was significantly different from that of the *eba* made from the BFG (Table 4).

Among the BFG, all the colour of the *eba* prepared from the blend ratios was moderately liked (6.67–7.42) (Table 4). Likewise, the colour of the *eba* from the 72 h SFG (7.83) was very much liked compared to the *eba* from the 48 h SFG (7.00) that was liked moderately (Table 4). It was only the colour of 72 h SFG *eba* (p = 0.050) that differs from that of the BFG compared to the other SFG *eba*, whose colours were not significantly different from that of the BFG (Table 4). The likeness of the colour of the eba agreed with the findings of Laya et al. (2018), who reported that the overall acceptability of gari was significant and positively correlated with the colour.

A good quality eba should be mouldable and not sticky (Teeken et al., 2020). In the BFG, the mouldability of the *eba* ranged from 5.75 to 7.67. *Eba* prepared from the 94.14%FCM: 15%BCM *gari* was very much liked and that of the 70%FCM: 10%BCM *gari* was slightly liked. Also, *eba* from the 48 h and 72 h SFG (7.83) was very much liked compared to the *eba* from the 96 h SFG (6.92) that was moderately liked in terms of mouldability (Table 4). The mouldability of the *eba* prepared from the 48 h (p = 0.027) and 72 h (p = 0.027) SFG was significantly different from the *eba* made from the BFG (Table 4).

For the BFG, the mouthfeel of the *eba* from the 90%FCM: 20%BCM gari (7.00) was moderately liked and the *eba* from the 70%FCM: 10%BCM (6.00) gari was slightly liked. Similarly, the *eba* prepared from the 48 h SFG (7.67) was very much liked, and that of the 96 h SFG (7.17) was moderately liked in terms of the mouthfeel (Table 4). The mouthfeel of the *eba* prepared from the 24 h (p = 0.020), 48 h (p = 0.023) and 72 h (p = 0.023) SFG differs significantly from the *eba* made from the BFG (Table 4).

Although all the *eba* prepared from the BFG were generally acceptable, *eba* from the 94.14% FCM: 15%BCM gari (7.67) was very much liked compared to the *eba* from the 80%FCM: 7.93%BCM gari (6.67) that was moderately liked. The overall acceptability of the *eba* from the 94.14%FCM: 15%BCM gari may be attributed to its texture and mouldability because these attributes were more accepted in the *eba*. Likewise, the overall acceptability of the *eba* from the SFG was more in the 72 h fermented gari (7.92) compared to that of the 24 h fermented gari (7.42) that was moderately liked (Table 4). The texture, colour and mouldability of the *eba* prepared from the 72 h SFG may be responsible for its overall acceptability. It is interesting to add that the overall acceptability of the *eba* made from the 24 h (p = 0.375) and 96 h (p = 0.251) SFG was not significantly different from that of the *eba* made from the BFG. Similarly, the overall acceptability of the 48 h (p = 0.026) and 72 h (p = 0.011) SFG was significantly different from that of the BFG (Table 4).

However, to get an optimum combination of the FCM and the BCM that will produce an acceptable backslopped fermented gari of comparable physical colour, and functional, pasting and sensory properties to that of the spontaneously fermented gari, there is a need for optimization of the FCM and BCM.

3.4. Optimization of fresh and backslopped cassava mash to produce backslopped fermented gari

Optimization is used to determine the values for process and formulation variables, which result in the product(s) with qualities that satisfy some specific predetermined values that make them acceptable to consumers (Galvez et al., 1995), using response surface methodology (RSM). The information from the RSM helps the product developer to understand ingredient interactions in the product, which guide the final product formulation and quality changes (Giovanni, 1983). So, the use of optimization in the production of gari of comparable physical colour, and functional, pasting and sensory properties to that of the spontaneously fermented periods may assist cassava processors to standardize the production process. The t-test was used to determine the level of significant difference in these properties between the BFG and the 24 h, 48 h, 72 h and 96 h SFG. The result of the *t*-test (Tables 2 and Tables 3) was then used for setting the criteria/goal for the numerical optimization of the responses. That is, the properties in the BFG that are significantly lower than those of the SFG were maximized; properties in the BFG that are significantly higher than those of the SFG were minimized, and parameters that are not significantly different between the BFG and the SFG were kept in range (Tables 5 and Tables 6).

3.4.1. Backslopped fermented gari of comparable physical colour and functional properties to that of the spontaneous fermentation

To produce BFG similar to the 24 h SFG; the whiteness value was minimized, dispersibility and WAC were maximized, BD, SWP and SI were kept in range, and the overall acceptability of both the uncooked gari and that of the *eba* was maximized because the consumers should accept the products. The FCM and BCM were kept in range as the independent variables during the optimization process. These criteria gave a solution of 0.57 desirability (Table 5). This infers that blending 90%FCM with 16.90%BCM in the backslopped fermentation method may produce gari of comparable physical colour and functional properties to that of the 24 h SFG in a day. That is, consumers of 24 h spontaneously fermented gari may get gari of comparable physical colour and functional properties by properly mixing 90%FCM with 16.90%BCM using the backslopped fermentation method in less than 24 h with the availability of the BCM, therefore reducing the gari production time.

To produce BFG similar to the 48 h and 72 h SFG; the FCM and BCM were kept in range as the independent variables, the whiteness was minimized, dispersibility was maximized, WAC, BD, SWP, and the SI were kept in range and the overall acceptability of the uncooked gari and eba was maximized. These criteria gave a solution of 0.57 desirability (Table 5). That is, consumers of the 48 h and 72 h spontaneously fermented gari may get gari of comparable physical colour and functional properties by properly mixing 90% of FCM with 16.88%BCM using the backslopped fermentation method in less than 24 h with the availability of the BCM, therefore reducing the gari production time.

Also, to produce BFG like that of the 96 h SFG, the physical colour, and all the functional properties were kept in range except the dispersibility that was maximized, and the overall acceptability was also maximized. The FCM and BCM were kept in range as the independent variables. These criteria gave a solution of 0.66 desirabilities (Table 5). Consequently, BFG, similar to that of the 96 h SFG, may be produced in a day by blending 90%FCM and 16.13%BCM (Table 5). This implies that, consumers of the 96 h spontaneously fermented gari may get gari of comparable physical colour and functional properties by properly mixing 90%FCM and 16.13%BCM using the backslopped fermentation method in less than 24 h with the availability of the BCM, therefore reducing the gari production time.

Table 4. Sensory attributes of *eba* produced from the backslopped and spontaneously fermented gari

Samples	Texture	Colour	Stretchability	Mouldability	Smell	Mouthfeel	Overall acceptability
Backslopped fermented gari (BFG) blend ratios							
94.14%FCM:15%BCM	6.83 ± 0.72bc	6.92 ± 0.79ab	7.00 ± 0.95a-c	7.67 ± 0.49a	6.50 ± 1.00a	6.83 ± 0.58a-c	7.67 ± 0.49a-c
80%FCM:15%BCM	6.70 ± 0.89bc	7.07 ± 0.84ab	7.18 ± 0.68ab	7.41 ± 0.65ab	6.75 ± 0.91a	6.68 ± 0.85a-c	7.33 ± 0.63a-d
90%FCM:20%BCM	6.08 ± 2.07 c	7.17 ± 1.70ab	6.17 ± 2.41bc	5.83 ± 2.41d	6.67 ± 2.23a	7.00 ± 1.04a-c	7.25 ± 1.14a-d
70%FCM:10%BCM	5.67 ± 1.72 c	7.25 ± 1.42ab	6.00 ± 2.04 c	5.75 ± 2.22d	6.75 ± 1.42a	6.00 ± 1.76 c	6.83 ± 0.83 cd
65.86%FCM:15%BCM	6.08 ± 2.15 c	6.67 ± 2.15b	6.25 ± 1.71bc	6.08 ± 2.07 cd	7.17 ± 1.11a	6.50 ± 1.68a-c	6.83 ± 1.27 cd
70%FCM:20%BCM	6.08 ± 1.88 c	6.92 ± 2.07ab	6.67 ± 1.50a-c	6.58 ± 1.78a-d	6.75 ± 1.29a	6.67 ± 1.50a-c	6.92 ± 1.44 cd
80%FCM:7.93%BCM	5.75 ± 1.96 c	7.42 ± 0.67ab	6.08 ± 1.38bc	6.17 ± 1.95b-d	6.92 ± 1.08a	6.33 ± 1.87bc	6.67 ± 1.50d
90%FCM:10%BCM	6.00 ± 2.09 c	7.08 ± 1.73ab	7.08 ± 1.38a-c	6.42 ± 1.88b-d	7.17 ± 1.03a	6.25 ± 1.82bc	7.00 ± 1.35b-d
80%FCM:22.07%BCM	6.75 ± 0.97bc	7.42 ± 0.79ab	7.08 ± 1.00a-c	6.83 ± 1.27a-d	7.00 ± 1.54a	6.92 ± 1.44a-c	7.17 ± 1.03a-d
Mean	6.37	7.09	6.79	6.79	6.92	6.61	7.15
Spontaneously fermented gari (SFG)							
24 h fermentation	6.83 ± 0.94bc	7.33 ± 0.89ab	6.67 ± 1.07a-c	7.25 ± 0.87a-c	7.42 ± 0.90a	7.50 ± 0.80ab	7.42 ± 0.67a-d
48 h fermentation	7.33 ± 0.98ab	7.00 ± 0.95ab	7.50 ± 1.17a	7.83 ± 0.83a	7.08 ± 1.08a	7.67 ± 0.98a	7.83 ± 1.11ab
72 h fermentation	8.25 ± 0.75a	7.83 ± 1.19a	7.25 ± 0.97ab	7.83 ± 0.72a	7.08 ± 1.38a	7.50 ± 1.38ab	7.92 ± 0.67a
96 h fermentation	7.58 ± 1.00ab	7.42 ± 1.08ab	7.17 ± 1.03a-c	6.92 ± 1.24a-d	6.42 ± 1.88a	7.17 ± 2.33a-c	7.50 ± 1.00a-d
Mean	7.50	7.40	7.15	7.46	7.00	7.46	7.67
T-test at 95% significant level							
p (BFG x 24 h SFG)	NS	NS	NS	NS	NS	*	NS
p (BFG x 48 h SFG)	*	NS	NS	*	NS	**	*
p (BFG x 72 h SFG)	***	*	NS	*	NS	*	*
p (BFG x 96 h SFG)	**	NS	NS	NS	NS	NS	NS

FCM-Fresh cassava mash, BCM-Backslopped cassava mash, ±standard deviation, means with different letters within the same column are significantly different ($p < 0.05$).

Table 5. Criteria for the numerical optimization of the physical colour and functional properties of gari, and the overall acceptability of the uncooked gari and *Eba*, and solutions

Type of gari	Constraints	Goal	Lower limit	Upper limit	Importance	Solution
24 h fermented	Fresh cassava mash	is in range	70.00	90.00	3	90.00
	Backslopped cassava mash	is in range	10.00	20.00	3	16.90
	Whiteness value	minimize	83.47	89.44	3	86.81
	Dispersibility	maximize	53.50	66.00	3	59.96
	Water absorption capacity	maximize	365.74	519.89	3	453.70
	Bulk density	is in range	55.25	64.11	3	59.43
	Swelling power	is in range	22.45	32.22	3	30.25
	Solubility index	is in range	0.26	2.99	3	2.14
	Uncooked gari overall acceptability	maximize	5.55	7.55	3	6.62
	Eba overall acceptability	maximize	6.67	7.67	3	7.51
	Desirability	-	-	-	-	0.567
48 h & 72 h fermented	Fresh cassava mash	is in range	70.00	90.00	3	90.00
	Backslopped cassava mash	is in range	10.00	20.00	3	16.88
	Whiteness value	minimize	83.47	89.44	3	86.81
	Dispersibility	maximize	53.50	66.00	3	59.96
	Water absorption capacity	is in range	365.74	519.89	3	453.70
	Bulk density	is in range	55.25	64.11	3	59.43
	Swelling power	is in range	22.45	32.22	3	30.25
	Solubility index	is in range	0.26	2.99	3	2.14
	Uncooked gari overall acceptability	maximize	5.55	7.55	3	6.62

(Continued)

Table 5. (*Continued*)

Type of gari	Constraints	Goal	Lower limit	Upper limit	Importance	Solution
	Eba overall acceptability	maximize	6.67	7.67	3	7.51
	Desirability	-	-	-	-	0.566
96 h fermented	Fresh cassava mash	is in range	70.00	90.00	3	90.00
	Backslopped cassava mash	is in range	10.00	20.00	3	16.13
	Whiteness value	is in range	83.47	89.44	3	86.81
	Dispersibility	maximize	53.50	66.00	3	59.96
	Water absorption capacity	is in range	365.74	519.89	3	453.70
	Bulk density	is in range	55.25	64.11	3	59.92
	Swelling power	maximize	22.45	32.22	3	30.39
	Solubility index	is in range	0.26	2.99	3	2.25
	Uncooked gari overall acceptability	maximize	5.55	7.55	3	6.62
	Eba overall acceptability	maximize	6.67	7.67	3	7.51
	Desirability	-	-	-	-	0.659

Table 6. Criteria for the optimization of the pasting properties of gari samples, and overall acceptability of the uncooked gari and *Eba*, and solutions

Types of gari	Constraints	Goal	Lower limit	Upper limit	Importance	Solution
24 h fermented	Fresh cassava mash	is in range	70.00	90.00	3	90.00
	Backslopped cassava mash	is in range	10.00	20.00	3	16.88
	Peak viscosity	is in range	298.46	427.34	3	369.68
	Trough viscosity	is in range	161.63	200.34	3	184.43
	Breakdown viscosity	is in range	124.17	231.75	3	185.46
	Final viscosity	is in range	266.80	321.63	3	301.78
	Setback viscosity	maximize	96.46	135.71	3	117.55
	Peak time	is in range	4.57	4.87	3	4.67
	Pasting temperature	is in range	76.35	79.13	3	77.90
	Uncooked gari overall acceptability	maximize	5.55	7.55	3	6.62
	Eba overall acceptability	maximize	6.67	7.67	3	7.51
	Desirability	-	-	-	-	0.624
48 h fermented	Fresh cassava mash	is in range	70.00	90.00	3	89.85
	Backslopped cassava mash	is in range	10.00	20.00	3	20.00
	Peak viscosity	minimize	298.46	427.34	3	369.68
	Trough viscosity	is in range	161.63	200.34	3	188.98
	Breakdown viscosity	minimize	124.17	231.75	3	185.46
	Final viscosity	is in range	266.80	321.63	3	301.78
	Setback viscosity	is in range	96.46	135.71	3	117.55
	Peak time	maximize	4.57	4.87	3	4.79
	Pasting temperature	maximize	76.35	79.13	3	77.90

(*Continued*)

Table 6. (*Continued*)

Types of gari	Constraints	Goal	Lower limit	Upper limit	Importance	Solution
	Uncooked gari overall acceptability	maximize	5.55	7.55	3	6.62
	Eba overall acceptability	maximize	6.67	7.67	3	7.42
	Desirability	-	-	-	-	0.561
72 h fermented	Fresh cassava mash	is in range	70.00	90.00	3	89.84
	Backslopped cassava mash	is in range	10.00	20.00	3	20.00
	Peak viscosity	minimize	298.46	427.34	3	369.68
	Trough viscosity	is in range	161.63	200.34	3	188.99
	Breakdown viscosity	minimize	124.17	231.75	3	185.46
	Final viscosity	maximize	266.80	321.63	3	301.78
	Setback viscosity	maximize	96.46	135.71	3	117.55
	Peak time	maximize	4.57	4.87	3	4.79
	Pasting temperature	maximize	76.35	79.13	3	77.90
	Uncooked gari overall acceptability	maximize	5.55	7.55	3	6.62
	Eba overall acceptability	maximize	6.67	7.67	3	7.42
	Desirability	-	-	-	-	0.567
96 h fermented	Fresh cassava mash	is in range	70.00	90.00	3	88.45
	Backslopped cassava mash	is in range	10.00	20.00	3	20.00
	Peak viscosity	is in range	298.46	427.34	3	369.68
	Trough viscosity	maximize	161.63	200.34	3	189.42
	Breakdown viscosity	is in range	124.17	231.75	3	185.46

(*Continued*)

Table 6. (*Continued*)

Types of gari	Constraints	Goal	Lower limit	Upper limit	Importance	Solution
	Final viscosity	is in range	266.80	321.63	3	301.78
	Setback viscosity	is in range	96.46	135.71	3	117.55
	Peak time	maximize	4.57	4.87	3	4.79
	Pasting temperature	is in range	76.35	79.13	3	77.90
	Uncooked gari overall acceptability	maximize	5.55	7.55	3	6.62
	Eba overall acceptability	maximize	6.67	7.67	3	7.40
	Desirability	-	-	-	-	0.675

3.4.2 Backslopped fermented gari of comparable pasting properties to that of the spontaneous fermentation

To produce BFG of similar pasting properties to that of the 24 h SFG; all the pasting properties were kept in range except the setback viscosity that was maximized. The overall acceptability of the uncooked gari and *eba* was maximized, and the FCM and BCM were kept in range as the independent variables during the optimization process. These criteria gave a solution of 0.62 desirability (Table 6). This means that blending 90%FCM with 16.88%BCM in the backslopped fermentation method may produce gari of comparable pasting properties to that of the 24 h SFG within a day. That is, consumers of the 24 h spontaneously fermented gari may get eba of comparable pasting properties by properly mixing 90% of FCM with 16.88%BCM using the backslopped fermentation method in less than 24 h with the availability of the BCM, therefore reducing the gari production time.

To produce BFG of similar pasting properties to that of the 48 h SFG, the FCM and BCM were kept in range as the independent variables. The peak and breakdown viscosities were minimized, and the trough, final, and setback viscosities were kept in range. The peak time and pasting temperature were maximized, and the overall acceptability of the uncooked gari and *eba* was maximized. The criteria showed that the best combination of the FCM and BCM that may produce BFG of similar pasting properties to that of the 48 h SFG is 89.85%FCM:20%BCM, with the desirability of 0.56 (Table 6). This means that consumers of the 48 h spontaneously fermented gari may get eba of comparable pasting properties by properly mixing 89.85% of FCM with 20%BCM using the backslopped fermentation method in less than 24 h with the availability of the BCM, therefore reducing the gari production time.

The BFG of comparable pasting properties to that of the 72 h SFG may be produced by minimizing the peak and breakdown viscosities, maximizing the final and setback viscosities, and also maximizing the peak time and pasting temperature. The overall acceptability of the uncooked gari and the *eba* were maximized, while the FCM and BCM were kept in range as the independent variables. The result gave desirability of 0.57, which depicts that mixing 89.84% of FCM and 20% of BCM may produce gari of similar pasting properties to that of the 72 h SFG within a day (Table 6). That is, consumers of the 72 h spontaneously fermented gari may get eba of comparable pasting properties by properly mixing 89.84% of FCM with 20%BCM using the backslopped fermentation method in less than 24 h with the availability of the BCM, therefore reducing the gari production time.

To produce BFG with comparable pasting properties to that of the 96 h SFG, the FCM and BCM were kept in range as the independent variables. The peak, breakdown, final and setback viscosities, and the pasting temperature were kept in range, the trough viscosity and peak time were maximized, and the overall acceptability of the uncooked gari and *eba* was equally maximized, which result in the desirability of 0.68. Meaning BFG of comparable pasting properties to that of the 96 h SFG may be produced within a day by blending 88.45%FCM with 20%BCM (Table 6). This means that consumers of the 96 h spontaneously fermented gari may get eba of comparable pasting properties by properly mixing 88.45% of FCM with 20%BCM using the backslopped fermentation method in less than 24 h with the availability of the BCM, therefore reducing the gari production time.

4. Conclusions

This study showed that gari of varying functional and pasting properties, and sensory attributes can be produced using the backslopped fermentation. The texture, colour, stretchability, mouldability, smell, mouthfeel and the overall acceptability of the *eba* prepared from both the backslopped (BFG) and spontaneous (SFG) fermented gari fall within the moderately liked range, except the texture and the overall acceptability of the SFG that fall within the very much liked range. However, a BFG of comparable physical colour and functional properties to that of the 24 h, 48 h, 72 h and 96 h SFG may be produced by blending 90%FCM with 16.90%BCM, 90%FCM with 16.88% BCM, and 90%FCM with 16.13%BCM respectively. Acceptable BFG of similar pasting properties to that of 24 h, 48 h, 72 h and 96 h SFG may also be produced by blending 90%FCM with 16.88%BCM, 89.85%FCM with 20%BCM, 89.84%FCM with 20%BCM and 88.45%FCM with 20%BCM respectively. Therefore, an acceptable BFG of different functional and pasting properties and eba of different sensory attributes can be produced within a day, and whose quality may be comparable or better than that of the SFG. This information may be of use to cassava processors/value chain actors in the production of gari.

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Data availability
All data will be deposited into the IITA data repository, and can be accessed through http://data.iita.org. The data could also be made available on request from the corresponding author.

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