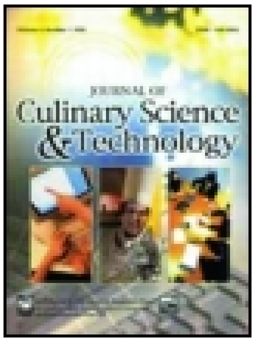

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Comparing Backslopped and Spontaneous Fermentation Based on the Chemical Composition and Sensory Properties of Gari

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ABSTRACT

The backslopped cassava mash (BCM) produced by pre-fermenting grated cassava for 96 h was mixed with fresh cassava mash from the same variety using different blend ratios and processed to backslopped fermented gari (BFG). Another batch of the same variety was fermented for 24 h, 48 h, 72 h, and 96 h to get spontaneous fermented gari (SFG). Standard methods were used to analyze the chemical composition and sensory properties of the samples. Results showed that the moisture, fat, and CNP contents, and the pH value of the 96 h SFG were significantly different ($p < .05$) from that of the BFG. The overall acceptability of the BFG was not significantly different ($p > .05$) from those of the 24 h and 72 h SFG. The information presented in this study may help the processors produce consistent quality gari for different end-users.

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Cassava; gari; backslopped fermentation; spontaneous fermentation; chemical composition; sensory properties

Introduction

Gari is a granulated, white, or yellowish product, the most popular form in which cassava root is consumed by several millions of people in West Africa (Abiodun, Ayano, & Amanyunose, 2020). Gari can be consumed as a snack, a refreshing light meal when soaked in cold water and eaten with coconut, banana, smoked fish or peanut (Oluwafemi & Udeh, 2016)). The consumption of gari as a principal meal (when made into *eba* and eaten with preferred African soups) make it the most popular diet amongst the rich and the poor, with acceptability cutting across the various socio-economic and multi-ethnic groups in Africa (Awoyale, Oyedele, Adenitan, Alamu, & Maziya-Dixon, 2021).

However, one of the critical control points in gari production is the fermentation of the mash obtained after grating the peeled cassava root. This is because fermentation contributes significantly to the sensory and quality attributes of

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gari. Traditionally, the cassava mash used for gari production is spontaneously fermented between 48 h and 96 h depending on its quality. During fermentation, grated cassava mash is softened, and there is the disintegration of tissue structure which cause the interaction between the linamarin and the linamarase enzyme located in the cell wall. This leads to the hydrolysis and subsequent production of glucose and cyanohydrins easily broken down to ketone and hydrogen cyanide (Halake & Chinthapalli, 2020). Flibert, Abel, and Aly (2016) reported that fermentation improves food preservation, nutritional value, energy density, and sensory attributes of foods. Additionally, the fermentation process takes a longer time in some communities where highly sour gari is preferred, reducing the quantity of gari produced within a specific period. The use of the back-slopped method of fermentation, where portions of the previously fermented cassava mash or its liquor are added to a freshly prepared cassava mash to act as an inoculum, allows for the gradual selection of lactic acid bacteria and an accelerated fermentation (Uvere, Onyekwere, & Ngoddy, 2010).

Backslopping is a way to use a selected culture to shorten the fermentation process and produce gari of improved and consistent quality. This was necessary since the end product's quality and the fermentation time are dependent on the microbial load. 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), stored cassava chips gari (Uvere & Nwogu, 2011). Recently, Awoyale et al. (2021) worked on the functional and pasting properties of gari and the sensory attributes of the eba produced using backslopped and spontaneous fermentation methods. The safety in terms of the chemical composition of the uncooked gari was not reported in the study.

Therefore, this study aimed to comparatively evaluate the chemical composition and the sensory properties of the gari produced from backslopped and spontaneous fermentation methods.

Materials and methods

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.

Production of backslopped cassava mash

About 75 kg of cassava root was processed into a mash. The mash was fermented for about 96 h in a black-covered plastic container before extraction and isolation of specific lactic acid bacteria (LAB). Samples were collected from the backslopped cassava mash to extract bacteria from cultured lactic acid bacteria (LAB) plate and subsequent isolation of the specific bacteria through the polymerase-chain reaction method (Trindade, Eder, Biaggioni, & Álvares, 2007). This fermented cassava mash containing the typical LAB was then used as the backslopped cassava mash to produce *gari* combined with the freshly grated mash.

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 of Design-Expert software (Version 12) reported by Awoyale et al. (2021).

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., 2021). 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. The grated mash was 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

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

fermentation periods. The dry matter content of backslopped and spontaneous fermented mash was controlled to be between 28% and 30% before roasting (Awoyale et al., 2021).

Chemical composition

Moisture content

The moisture content (MC) was determined using AOAC (2000) method. About 3 g of samples were weighed into a pre-weighed clean dried moisture can, after which the can was placed in a well-ventilated oven (Memmert GmbH+co.Kg, Oven model D-91126 Schwabach FRG, Germany) maintained at 105 ± 2°C for 16 h. The loss in weight was recorded as moisture content.

Ash content

This was determined using the method of AOAC (2000). It involves burning off moisture and all organic constituents at 600°C for 6 h in a furnace (Ney Vulcan ™ furnace model 3–1750, USA). The weight of the residue after incineration was then recorded as the ash content.

Fat content

The percentage fat content of the sample was determined by the conventional Soxhlet (Soxtec 800; Foss China) extraction method with hexane as the solvent, according to AOAC (2000).

Protein content

This was determined by the Kjeldahl method using Kjeltec™ model 2300, as described in the FOSS Manual (Foss Analytical AB, 2003). The technique involved digestion of the sample at 420°C for 1 h to liberate the organically bound nitrogen in the form of ammonium sulfate. The ammonia in the digest (ammonium sulfate) was then distilled into a boric acid receiver solution, then titrated with standard hydrochloric acid. A conversion factor of 6.25 was used to convert from total nitrogen to percentage crude protein.

Starch and sugar contents

Starch and sugar content was determined by the method described by Onitilo, Sanni, Daniel, Maziya-Dixon, and Dixon (2007). This involves weighing 0.02 g of the sample into a centrifuge tube with 1 ml ethanol, 2 ml distilled water, and 10 ml hot ethanol. The mixture was vortexed and centrifuged at 2000 rpm for 10 min. The supernatant was decanted and used for determining sugar content, while the sediment was hydrolyzed with perchloric acid and used to estimate starch content. Phenol and sulfuric acid reagents were used for color development, and glucose standards were used to estimate sugar. The absorbance was read with a spectrophotometer (Genesys 10S UV-VIS, China) at 490 nm.

pH-value

The pH of the gari samples was determined using the method of AOAC (2000). Ten grams of the sample was put into a 100 mL beaker, and 100 mL of distilled water was added. The pH was analyzed using a standardized pH meter (Mettler Toledo GmbH; 8606 Greifensee, Switzerland). Triplicate values were obtained, and the mean was taken as a pH value.

Cyanogenic potential

Thirty grams of gari was milled and homogenized with 250 mL of 0.1 M orthophosphoric acid. The homogenate was centrifuged. The supernatant was taken as the extract; 0.1 mL of the enzyme was added into 0.6 ml of the extract. The 3.4 mL of the acetate buffer (pH 4.5) was added and stirred to mix. After this, 0.2 mL of 0.5% chloramines-T and 0.6 mL of color reagent was added and allowed to stand for 15 min. for color development. The absorbance value was obtained at 605 nm against blank similarly prepared to contain all reagents and 0.1 mL phosphate buffer added instead of KCN (Essers, Bosveld, Van der Grift, & Voragen, 1993).

Sensory evaluation of gari

The gari was evaluated for the overall acceptability based on the appearance/color, smell, taste, and particle size using twelve trained panelists from the staff and graduate students of the International Institute of Tropical Agriculture (IITA) Ibadan who consumes *gari* regularly. The sensory acceptability of the *gari* 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. Also, verbal consent was obtained from the participants.

Statistical analysis

The analysis of variance (ANOVA) of the data generated was analyzed using the Statistical Package for Social Scientist (SPSS version 21). The t-test to check the significant difference between the BFG and the SFG was also done using the SPSS software. The optimization was done using the response surface central composite rotatable design of Design-Expert software (version 12).

Results and discussion

Chemical composition of gari

The chemical composition of the different gari samples is shown in Table 2. The mean of the chemical composition of the backslopped fermented gari (BFG) was moisture 10.17%, ash 1.52%, fat 0.13%, amylose 29.64%, sugar 2.94%, starch 77.47%, cyanogenic potential (CNP) 2.87 mg HCN/kg, protein 1.04% and pH value 4.15. The mean of the chemical composition of the spontaneously fermented gari (SFG) was moisture 9.37%, ash 1.55%, fat 0.12%, amylose 29.75%, sugar 3.04%, starch 78.54%, cyanogenic potential (CNP) 2.92 mgHCN/kg, protein 1.09% and pH value 3.99 (Table 2). The ash, fat, starch and CNP contents, and the pH value of the 24 h SFG were significantly different ($p < .05$) from those of the BFG. The moisture, ash and protein content and pH value of the BFG were significantly different ($p < .05$) from 48 h and 72 h SFG. Also, the 96 h SFG was significantly different ($p < .05$) from the BFG in terms of the moisture, fat, and CNP contents and the pH value (Table 2).

The lower the initial moisture content of a product to be stored, the better the storage stability (Awoyale et al., 2020). Among the BFG, gari produced from 70%FCM: 10%BCM (12.96%) had the highest moisture content, and that of the 80%FCM: 7.93%BCM (7.33%) had the lowest. The variation in the blend ratios may be responsible for the differences in the moisture content of the gari samples. The moisture content of the SFG was higher in the 24 h fermentation (9.17%) and lower in the 72 h fermentation (4.71%) (Table 2). Irtwange and Achimba (2009) observed that a very poor relationship exists between the moisture content of gari and the period of fermentation. These authors then concluded that the moisture removal in gari is a function of many factors such as temperature, time, and relative humidity. The available moisture in gari depends solely on the degree of dryness during roasting. However, the moisture content of all the SFG is lower than the 10% stipulated by the Codex Alimentarius Commission (1989) and maybe more shelf-stable, compared to the 70%FCM: 10%BCM BFG, with higher moisture content. The moisture content of the BFG of this study agrees with the observation of Awoyale et al. (2020) on the moisture content (7.32–15.49%) of gari produced from different cassava varieties using the spontaneous fermented method. Conversely, the moisture content of the SFG was lower compared to the moisture content (10.94–13.40%) reported for different types of commercial gari available in Nigeria markets (Abass, Awoyale, & Alamu, 2018). However, it is essential to properly package and stores the products during marketing to avoid moisture absorption and possible mold growth (Abass et al., 2018).

Baah, Maziya-Dixon, Asiedu, Oduro, and Ellis (2009) stated that ash content reflects the mineral status of a sample even though contamination during processing could indicate a high concentration. The ash content of the BFG

Table 2. Chemical composition of backslopped and spontaneous-fermented gari.

Samples	Moisture	Ash	Fat	Amylose	Sugar	Starch	CNP	Protein	pH-value
Backslopped fermented gari (SFG)									
94.14%FCM:15%BCM	10.18 ± 0.12b–d	1.59 ± 0.02a–c	0.14 ± 0.04a-d	28.35 ± 0.11a	3.35 ± 0.03a	80.58 ± 0.15b-d	2.14 ± 0.51de	1.41 ± 0.11a	4.35 ± 0.07a
80%FCM:15%BCM	9.65 ± 0.90 cd	1.54 ± 0.08a–d	0.14 ± 0.04a–c	30.24 ± 1.56a	3.20 ± 0.45ab	76.70 ± 1.97fg	2.73 ± 0.55 cd	1.05 ± 0.18 c	4.16 ± 0.11b
90%FCM:20%BCM	11.65 ± 0.08ab	1.54 ± 0.06a–d	0.12 ± 0.01a–d	29.92 ± 0.11a	2.33 ± 0.08 c	81.86 ± 0.42bc	2.73 ± 0.17 cd	1.03 ± 0.07 c	4.16 ± 0.01b
70%FCM:10%BCM	12.96 ± 0.24a	1.43 ± 0.03d	0.12 ± 0.02a–d	29.92 ± 0.11a	2.83 ± 0.06a–c	72.04 ± 0.29 h	2.57 ± 0.49 cd	0.99 ± 0.02 c	4.16 ± 0.01b
65.86%FCM:15%BCM	11.28 ± 0.10bc	1.52 ± 0.01b-d	0.18 ± 0.01a	29.69 ± 0.00a	2.59 ± 0.07bc	77.04 ± 0.02e–g	2.75 ± 0.01 cd	1.01 ± 0.02 c	4.09 ± 0.01b
70%FCM:20%BCM	9.74 ± 0.20 cd	1.49 ± 0.10 cd	0.13 ± 0.02a–d	28.50 ± 0.11a	2.80 ± 0.06a–c	79.40 ± 0.28 c–f	2.94 ± 0.09b–d	0.91 ± 0.05 c	4.03 ± 0.01bc
80%FCM:7.93%BCM	7.33 ± 0.22e	1.51 ± 0.01b–d	0.11 ± 0.01a–d	29.88 ± 0.06a	2.42 ± 0.07 c	79.68 ± 0.29c–e	3.77 ± 0.44b	0.94 ± 0.03 c	4.38 ± 0.02a
90%FCM:10%BCM	9.52 ± 1.24d	1.43 ± 0.05d	0.08 ± 0.01b–d	29.29 ± 0.11a	3.10 ± 0.05ab	76.50 ± 0.26fg	3.48 ± 0.01bc	0.86 ± 0.03 c	4.14 ± 0.01b
20%FCM:22.07%BCM	11.25 ± 1.28bc	1.60 ± 0.00a–c	0.09 ± 0.02b–d	28.54 ± 0.17a	2.85 ± 0.06a–c	76.44 ± 0.29 g	3.23 ± 0.14bc	1.11 ± 0.05bc	3.93 ± 0.02 c
Mean	10.17	1.52	0.13	29.64	2.94	77.47	2.87	1.04	4.15
Spontaneously fermented gari (SFG)									
24 h fermentation	9.17 ± 0.91d	1.68 ± 0.03a	0.07 ± 0.00 cd	30.08 ± 0.11a	3.22 ± 0.06ab	86.64 ± 0.44a	4.84 ± 0.05a	1.10 ± 0.01bc	3.75 ± 0.02d
48 h fermentation	6.90 ± 0.04e	1.67 ± 0.02a	0.15 ± 0.01ab	29.88 ± 0.06a	3.33 ± 0.00a	82.98 ± 0.30b	3.10 ± 0.15bc	1.07 ± 0.12bc	3.55 ± 0.01e
72 h fermentation	4.71 ± 0.10 f	1.64 ± 0.02ab	0.13 ± 0.01a–d	30.32 ± 0.11a	3.45 ± 0.07a	80.07 ± 0.29 cd	2.79 ± 0.13 cd	1.33 ± 0.04ab	3.22 ± 0.03 f
96 h fermentation	6.30 ± 0.09e	1.61 ± 0.09a–c	0.07 ± 0.01d	30.24 ± 0.33a	3.47 ± 0.07a	78.39 ± 0.44d–g	1.63 ± 0.07e	1.49 ± 0.09a	3.27 ± 0.01 f
Mean	9.37	1.55	0.12	29.75	3.04	78.54	2.92	1.09	3.99
T-test at 95% significant level									
p (BFG × 24 h SFG)	NS	**	*	NS	NS	***	***	NS	**
p (BFG × 48 h SFG)	**	*	NS	NS	NS	*	NS	**	***
p (BFG × 72 h SFG)	***	*	NS	NS	NS	NS	NS	*	***
p (BFG × 96 h SFG)	**	NS	*	NS	NS	NS	**	NS	***

FCM-Fresh cassava mash, BCM-Backslopped cassava mash, *p*-significant level ($p > 0.05$ is not significantly different), NS-Not significant, ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$. Means with different letters within the same column are significantly different ($p < 0.05$).

ranged from 1.43% (70%FCM: 10%BFG and 90%FCM: 10%BFG) to 1.60% (80%FCM: 22.07%BCM). The differences in the blend ratios of the fresh and backslopped cassava mash may be attributed to the variation in the ash content of the gari samples. The ash content of the SFG ranged between 1.61% and 1.68%, with the 24 h fermentation having the highest and the 96 h fermentation the least (Table 2). The decrease in the ash content of the gari as the fermentation period increases may be due to the leaching of soluble mineral elements into fermenting medium (Abiodun et al., 2020). Since the stipulated ash content for gari by the Codex Alimentarius Commission (1989) is 1.50%, it means the BFG produced by blending 70%FCM with 10%BFG and 90%FCM with 10%BFG are within the safety range, compared to the SFG with higher ash content. The ash content of the BFG and the SFG of this study is within the range of values reported by Awoyale et al. (2020) for the ash content of gari produced from different cassava varieties using the spontaneous fermentation method. The ash content of the SFG was higher than the ash content (1.30–1.56%) of different gari collected from Nigeria markets (2018).

It has been established that cassava and its value-added products are very low in fat and protein contents, except if fortified or supplemented with fat/protein-rich foods (Etudaiye et al., 2009). The 65.86%FCM: 15%BFG (0.18%) had the highest fat content, and 90%FCM: 10%BFG (0.08%) had the lowest among the BFG. Gari fermented for 24 h and 96 h (0.07%) have the lowest fat content, and that fermented for 48 h (0.15%) had the highest fat content within the SFG (Table 2). Awoyale et al. (2020) reported a fat content of between 0.28% and 1.55% for gari produced from different cassava varieties using the spontaneous fermented method, which was higher than the fat content of the BFG and the BFG of this study. The protein content of the BFG ranged from 0.86% in 90%FCM: 10%BCM to 1.41% in 94.14%FCM: 15%BCM. Similarly, the protein content of the SFG ranged from 1.07% to 1.49%, with gari produced from the 96 h fermentation having the highest and that of the 48 h fermentation the lowest. The microbial activities in the 96 h fermented gari may be responsible for the high-protein content (Oyeyinka et al., 2020). The protein content of the SFG (0.17–0.88%) reported by Awoyale et al. (2020) for different cassava varieties was lower compared to the protein content of the SFG in this study. Varietal differences may be responsible for the variation in protein content of the gari.

The starch content is one of the vital quality indices, which controls cooked gari pastes (*eba*) (Oyeyinka et al., 2020). The BFG produced from 90%FCM: 20%BCM (81.86%) had the highest starch content, and that of 70%FCM: 10% BCM (72.04%) had the least. Among the SFG, the 96 h fermentation (78.395) had the lowest starch content, and the 24 h fermentation (86.64%) had the highest (Table 2). This implies that consumers that prefer *eba* with a firm texture may use the 24 h SFG because of the high starch contents. However, in places where gari are fermented for 48 h or 96 h, the BFG produced from the

90%FCM: 20%BCM the 48 h SFG may be used to prepare firm-textured *eba* due to their starch content (Table 2). The 70%FCM: 10%BCM gari and the 96 h SFG may be used in places where light-textured *eba* is consumed because of their low starch content (Oyeyinka et al., 2020). The starch content of the commercially available gari in the Nigeria market (53.60–61.53%) (Abass et al., 2018) was lower than the starch content of the BFG and the SFG of this study. Also, the BFG starch content was lower than the starch content (82.62–92.00%) of gari produced from different cassava varieties using the spontaneous fermented method (Awoyale et al., 2020).

The sugar content of the BFG ranged from 2.33% to 3.35%. Gari produced from 94.14%FCM: 15%BCM had the highest sugar content, and that of 90% FCM: 20%BCM had the lowest. The SFG sugar content was higher in the 96 h fermentation (3.47%) and lowered in that of the 24 h fermentation (3.22%) (Table 2). This implied that the conversion of starch into sugar during fermentation in gari production was higher in the 94.14%FCM: 15%BCM BFG and 96 h SFG, but lower in the 90%FCM: 20%BCM BFG and 24 h SFG (*27*). The sugar content of the BFG and the SFG of this study was within the range of values (2.78–4.39%) reported by Awoyale et al. (2020) for gari produced from different varieties using the spontaneous fermented method.

Awoyale, Sanni, Shittu, and Adegunwa (2015) reported that the amylose content determines the stability of the viscous solution formed when starch is heated. The higher the amylose content, the higher the rate of retrogradation of the starch molecules after cooking. The behavior of all BFG and the SFG samples after cooking may be the same since there was no statistically significant difference ($p > .05$) in their amylose content (Table 2).

A limiting factor for human consumption of value-added cassava products is the toxicity of cyanogenic potential (CNP) content if the cassava roots are not adequately processed before consumption (Awoyale et al., 2020). The CNP content of the BFG ranged between 2.14 mg HCN/kg and 3.77 mg HCN/kg, with gari produced from the 94.14%FCM: 15%BCM having the lowest and the gari from 80%FCM: 7.93%BCM the highest. Also, the 24 h fermented gari (4.84 mg HCN/kg) had the highest CNP content and gari from the 96 h fermentation had the lowest (1.63 mg HCN/kg) among the SFG (Table 2). The CNP of different gari (6.65–8.77 mgHCN/kg) collected from Nigeria markets (Abass et al., 2018) was higher than the CNP of the BFG and the SFG of this study. However, the CNP of all the gari samples was very low compared to the standard set by the Codex Alimentarius Commission (1989) of 10 mg HCN/kg. This implied that there might not be an issue with cassava toxicity using the backslopped fermentation method in gari production, although the CNP content of the fresh cassava variety matters.

The pH value is a measure of the degree of acidity or alkalinity of fermented foods (Awoyale et al., 2020). It is imperative to add that the period and temperature of the solid-state fermentation and the climatic condition may affect the pH values of the gari. Within the BFG, the pH value was higher in 94.14%FCM: 15%BCM (4.35) and lower in 80%FCM: 22.07%BCM (3.93). The SFG had the highest pH value in the 24 h fermentation (3.75) and the lowest in the 72 h fermentation (3.22). However, there was no significant difference in pH value between the 72 h and 96 h fermented gari (Table 2). The breakdown of starch in the fresh roots by *Corynebacterium manihoti* and *Lactobacillus fermentum*, among other microorganisms to produce lactic and formic acids, could be responsible for the low pH values in all the products (Awoyale et al., 2020). Keeping other factors constant, consumers of sourer gari may patronize SFG produced from the 72 h and 96 h fermentation because of their significantly ($p < .05$) lower pH values. In contrast, consumers of slightly sour gari may patronize the BFG produced from 94.14%FCM:15%BCM (4.35) and 80% FCM:7.93%BCM (4.38) due to their significantly ($p < .05$) higher pH values. Abass et al. (2018) reported that the pH value of gari collected from different Nigeria markets ranged from 5.73 to 6.52, which was higher compared to the pH values of the BFG and the SFG of this study. The differences in the cassava varieties, period of harvest, and the processing method may be responsible for the gari changes in pH values (Abass et al., 2018). The pH values of the BFG agrees with the range of pH values (4.05–6.55) reported by Awoyale et al. (2020) for gari produced from different cassava varieties using the spontaneous fermented method. The pH values of the SFG of this study was lower than the pH values reported by Awoyale et al. (2020).

Sensory properties of gari

The results of the sensory properties of the BFG and SFG showed that the appearance, taste, and overall acceptability were within the likeness range (Table 3).

Among the BFG, the gari's appearance produced from 80%FCM: 22.10% BCM (7.64) was very much liked compared to gari made from the 94.14% FCM: 15%BCM (5.18) that was neither liked nor disliked. The variation in the gari's likeness may be attributed to the different quantities of the BCM added to the freshly grated cassava in the backslopped fermentation. The appearance of the 96 h SFG (7.73) was very much liked compared to the gari produced from the 24 h spontaneous fermentation (5.45), which was neither liked nor disliked. This suggests that consumers may prefer the gari's appearance that is spontaneously fermented for 96 h than that of 24 h. Although there was no significant difference ($p > .05$) in the appearance of the SFG produced from the 96 h, 72 h, and 48 h spontaneous fermentation. The appearance of the 24 h and 96 h SFG differentiate ($p < .05$) them from that of the BFG, but there was no difference in the appearance of the BFG and that of the 48 h and 72 h SFG (Table 3). The appearance of the BFG was negatively correlated ($p > .05$) with all the chemical composition (moisture, ash, amylose, sugar, starch, and pH

Table 3. Sensory attributes of gari produced from backslopped and spontaneous fermentation.

Samples	Appearance	Taste	Overall acceptability
Backslopped fermented gari (BFG) blend ratios			
94.14%FCM:15%BCM	5.18 ± 2.23 c	5.55 ± 2.38 c	5.55 ± 2.70 c
80%FCM:15%BCM	6.55 ± 1.95a–c	6.20 ± 1.97bc	6.78 ± 1.73a–c
90%FCM:20%BCM	6.18 ± 2.27a–c	5.55 ± 1.69 c	6.09 ± 1.92bc
70%FCM:10%BCM	6.18 ± 1.66a–c	6.36 ± 1.50a–c	6.55 ± 1.86a–c
65.86%FCM:15%BCM	6.82 ± 1.60a–c	7.09 ± 1.45a–c	7.55 ± 1.51ab
70%FCM:20%BCM	7.18 ± 1.17ab	5.82 ± 2.14 c	6.45 ± 2.02a–c
80%FCM:7.93%BCM	7.18 ± 1.17ab	5.36 ± 2.42 c	6.36 ± 1.57a–c
90%FCM:10%BCM	6.73 ± 1.79a–c	6.09 ± 1.51bc	6.55 ± 1.37a–c
80%FCM:22.07%BCM	7.64 ± 0.81a	6.45 ± 1.97a–c	7.09 ± 1.22a–c
Mean	6.60	6.10	6.62
Spontaneously fermented gari (SFG)			
24 h fermentation	5.45 ± 2.16bc	6.00 ± 2.19bc	5.73 ± 2.45 c
48 h fermentation	6.45 ± 1.69a–c	8.00 ± 0.89a	7.73 ± 1.19ab
72 h fermentation	6.82 ± 2.09a–c	7.64 ± 1.50ab	7.45 ± 1.57ab
96 h fermentation	7.73 ± 1.10a	7.73 ± 1.19ab	7.91 ± 1.04a
Mean	6.61	7.34	7.20
t-test at 95% significant level			
p (BFG × 24 h SFG)	*	NS	NS
p (BFG × 48 h SFG)	NS	**	*
p (BFG × 72 h SFG)	NS	*	NS
p (BFG × 96 h SFG)	*	**	*

FCM-Fresh cassava mash, BCM-Backslopped cassava mash, *p*-significant level ($p > 0.05$ is not significantly different), NS-Not significant, **$p < 0.01$, *$p < 0.05$. Means with different letters within the same column are significantly different ($p < 0.05$)

value), except for the CNP, which had a significant positive correlation with the appearance of the BFG ($p < .05$, r = 0.77) (Table 4a). The appearance of the SFG, on the other hand, had a significant and negative correlation with the starch ($p < .05$, r = −0.98) and the CNP ($p < .01$, r = −0.99) contents (Table 4b).

The taste of the BFG produced from 65.86%FCM: 15%BCM (7.09) was moderately liked, and that of the 80%FCM: 7.93%BCM gari (5.36) was neither liked nor disliked. Amid the SFG; the 48 h gari (8.00) was very much like compared to that of the 24 h gari (6.00), which was slightly liked (Table 3), though, there was no significant difference ($p > .05$) in the taste of the 48 h SFG and that of the 72 h and 96 h SFG (Table 3). The taste of the BFG distinguishes ($p < .05$) it from that of the 48 h, 72 h, and 96 h SFG, but there was no significant difference $p > .05$) in the taste of the 24 h SFG and that of the BFG, as shown in the t-test (Table 3). The taste of the BFG was negatively correlated but not significant ($p > .05$) with all the chemical compositions except for the moisture, amylose and sugar contents, which are positively correlated ($p > .05$) (Table 4a). The correlation between the taste and all the chemical composition of the SFG was negative ($p > .05$), except for the amylose and sugar contents which are positive and not significant ($p > .05$) (Table 4b).

For the BFG, gari produced from the 65.86%FCM: 15%BCM (7.55) was very much accepted, and that of the 94.14%FCM: 15%BCM (5.55) was slightly accepted. The 96 h SFG (7.91) was very much accepted, and that of the 24 h spontaneous fermentation (5.73) was accepted somewhat. However, there was

Table 4. (a) Pearson correlation of the chemical composition and sensory attributes of backslopped fermented gari. b. Pearson correlation of the chemical composition and sensory attributes of spontaneously fermented gari.

Parameters	Moisture	Ash	Amylose	Sugar	Starch	CNP	pH-value	Appearance	Taste	Overall acceptability
(a)										
Moisture	1.00									
Ash	−0.05	1.00								
Amylose	0.03	−0.37	1.00							
Sugar	−0.04	0.10	−0.39	1.00						
Starch	−0.45	0.50	−0.25	−0.25	1.00					
CNP	−0.60	−0.27	0.14	−0.39	−0.01	1.00				
pH-value	−0.48	−0.03	0.25	0.05	0.34	−0.06	1.00			
Appearance	−0.26	−0.06	−0.02	−0.40	−0.17	0.77*	−0.58	1.00		
Taste	0.52	−0.11	0.12	0.07	−0.66	−0.13	−0.62	0.28	1.00	
Overall acceptability	0.20	−0.10	0.25	−0.22	−0.52	0.29	−0.64	0.67*	0.87**	1.00
(b)										
Moisture	1.00									
Ash	0.65	1.00								
Amylose	−0.55	−0.70	1.00							
Sugar	−0.90	−0.92	0.65	1.00						
Starch	0.85	0.94	−0.59	−0.99**	1.00					
CNP	0.75	0.91	−0.40	−0.94	0.97*	1.00				
pH-value	0.94	0.87	−0.72	−0.99*	0.96*	0.87	1.00			
Appearance	−0.72	−0.95	0.48	0.94	-o.98*	−0.99**	−0.87	1.00		
Taste	−0.78	−0.53	0.00	0.75	−0.77	−0.83	−0.70	0.76	1.00	
Overall acceptability	−0.78	−0.68	0.11	0.83	−0.86	−0.92	−0.77	0.87	0.98*	1.00

CNP-Cyanogenic potential, *$p < 0.05$, **$p < 0.01$

no significant difference ($p > .05$) in the overall acceptability of the gari produced from the 96 h, 72 h and 48 h spontaneous fermentation. The overall acceptability of the 48 h and 96 h SFG was significantly different ($p < .05$) from that of the BFG, but there was no difference ($p > .05$) in the overall acceptability of the BFG and that of the 24 h and 72 h SFG (Table 3). The overall acceptability of the BFG had a negative but not significant correlation ($p > .05$) with the ash, sugar and starch contents and the pH value. In contrast, the correlation between the overall acceptability of the BFG and the moisture, amylose and CNP contents was positive and also not significant ($p > .l05$) (Table 4a). However, a significant and positive correlation exists between the overall acceptability of the BFG and the appearance ($p < .05$, r = 0.67) and the taste ($p < .01$, r = 0.87) (Table 4a). Also, the correlation between the overall acceptability of the SFG and all the chemical composition was negative ($p > .05$), except for the amylose and sugar contents, which have a positive correlation ($p > .05$) (Table 4b). Just like the BFG, the overall acceptability of the SFG was positively correlated with the appearance ($p > .05$, r = 0.87) and the taste ($p < .05$, r = 0.98) (Table 4b).

Optimization of fresh and backslopped cassava mash to produce gari

To use the backslopped fermented method in the production of gari within a day of comparable chemical composition to that of the spontaneously fermented methods, the t-test was used to determine the level of significant difference in the chemical properties between the BFG and the 24 h, 48 h, 72 h and the 96 h SFG. The result of the t-test (Table 3) was then used for setting the criteria/goal for the numerical optimization of the responses.

The numerical optimization of the chemical composition of the gari samples showed that the starch content and the overall acceptability of the gari need to be maximized, and all the other parameters need to be kept within the range, including the independent factors (FCM and BCM); to get gari within a day of similar chemical composition to that of the 24 h, 48 h, and 72 h SFG. These criteria gave a solution of 0.63 desirability, which implied that blending 90% FCM with 16.88% BCM may produce gari of similar chemical composition to that of the 24 h, 48 h and 72 h SFG (Table 5). This means that consumers of the 24 h, 48 h and the 72 h spontaneously fermented gari may get gari of comparable chemical composition and sensory acceptability 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.

The criteria set for the responses of the 96 h fermentation was similar to that of the 24 h, 48 h and 72 h fermented gari, except that all the responses were kept within the range including the independent factors while maximizing only the overall acceptability. These criteria gave a solution of 0.67 desirability. Surprisingly gari of similar chemical composition to that of the 24 h, 48 h, 72 h,

Table 5. Criteria for the numerical optimization of the chemical composition and sensory acceptability of backslopped fermented gari and solutions.

Type of gari	Constraints	Goal	Lower Limit	Upper Limit	Solution
24 h, 48 h & 72 h fermented	Fresh cassava mash	is in range	70.00	90.00	90.00
	Backslopped cassava mash	is in range	10.00	20.00	16.88
	Moisture content	is in range	7.33	12.96	10.49
	Ash content	is in range	1.43	1.66	1.52
	Fat content	is in range	0.08	0.20	0.13
	Amylose content	is in range	28.35	31.50	29.64
	Starch content	maximize	72.04	81.86	77.47
	Cyanogenic potential	is in range	2.14	3.77	2.45
	Protein content	is in range	0.86	1.41	1.04
	pH value	is in range	3.93	4.38	4.18
	Gari overall acceptability	maximize	5.55	7.55	6.62
	Desirability	-	-	-	0.63
96 h fermented	Cassava mash	is in range	70.00	90.00	90.00
	Starter culture	is in range	10.00	20.00	16.87
	Moisture content	is in range	7.33	12.96	10.49
	Ash content	is in range	1.43	1.66	1.52
	Fat content	is in range	0.08	0.20	0.13
	Amylose content	is in range	28.35	31.50	29.64
	Sugar content	is in range	2.33	3.96	2.94
	Starch content	is in range	72.04	81.86	77.47
	Cyanogenic potential	is in range	2.14	3.77	2.45
	Protein content	is in range	0.86	1.41	1.04
	pH value	is in range	3.93	4.38	4.18
	Gari overall acceptability	maximize	5.55	7.55	6.62
	Desirability	–	–	–	0.67

and 96 h spontaneous fermented gari could be produced by blending 90% of FCM with 16.9% BCM, in less than 24 h with the availability of the BCM. However, combining the functional, pasting, and chemical composition of the gari with the sensory attributes of the dough may change the optimum combinations of the FCM and the BCM in the production of BFG that will be similar to the 24 h, 48 h, 72 h and the 96 h spontaneously fermented gari.

Conclusion

This study showed that both the backslopped and spontaneous fermentation methods might be used to produce gari based on the end-user preferences, quantity demanded per day, and the availability of raw materials, as each has a peculiar chemical composition and sensory properties. Gari of similar chemical composition and sensory acceptability to that of the spontaneously fermented gari may be produced using the backslopped fermentation method by blending 90% FCM with 16.9% BCM for the 24 h, 48 h,72 h, and 96 h gari Although combining the functional, pasting, and chemical composition of the gari with the sensory attributes of the dough may change the optimum combinations of the FCM and the BCM in the production of BFG that will be similar to the 24 h, 48 h, 72 h and the 96 h spontaneously fermented gari. The information presented in this article may help the cassava value chain actors in the production of consistent quality and quantity of gari for different end-users.

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Authors' contribution

Wasiu Awoyale, Hakeem Oyedele & Busie Maziya-Dixon design the work; Wasiu Awoyale, Hakeem Oyedele & Ayodele Adenitan collected the data; Wasiu Awoyale, Hakeem Oyedele & Ayodele Adenitan performed the laboratory analysis, data analysis and interpretation; Wasiu Awoyale, Emmanuel Alamu & Busie Maziya-Dixon drafted the article, as well as the critical revision and final approval of the version to be published.

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