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Influence of Drying Methods and Soaking Media on *Lafun* Processed from Cassava Chips

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Authors' contributions

This work was carried out in collaboration between all authors. Authors KAT, SOG, CTA designed the study. Authors SOG, EOI, AAF performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors SOG, EOI, AAF, ROA, managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study investigated the influence of drying temperature and soaking media on *lafun* processed from dried cassava chips. Fresh cassava tubers were processed into dried chips by sun drying and oven drying (50 and 70°C). The sundried and oven-dried chips were each divided into three portions; the first portions were milled into powder form, the second portions were soaked in water at an initial temperature of 60°C and the third portions were soaked in four-day old liquor (4DOL). Swelling power (SP), bulk density, least gelling concentration, pasting properties and sensory evaluation of the flour samples were conducted. The pH of the soaking medium decreased with increased soaking time from 4.90 to 4.08, gelling concentration ranged between 13-15% and pasting temperature of the samples were between 48.81-49.66°C. Drying temperature did not

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influence the pH of the *lafun* samples. However, samples soaked in water had significantly (p<0.05) lower pH values than those soaked in 4DOL. The SP (99.76 to 553.09%) increased with increased temperature.

Sensory evaluation showed that *lafun* samples from dried chips were preferred more than the commercial sample. Soaking in water at an initial temperature of 60℃ gave the better results than soaking in 4DOL. The study concluded that *Lafun* of good sensory and pasting properties can be processed from dried cassava chips.

Keywords: Lafun; soaking; cassava chips; temperature.

1. INTRODUCTION

Lafun is a fine powdery fermented product of cassava that is commonly consumed in the Western states of Nigeria. Peeled cassava roots are immersed in water for 3-5 days during which the fresh tubers undergo fermentation and become soft. The softened tubers are mashed manually, the wooden fibre removed and the mash dewatered. The dewatered mash is sun dried on mats, concrete floors, racks or any other appropriate site for 1-3 days depending on the weather [1]. The dried crumbs are milled into flour which is referred to as *lafun* flour. It is prepared, before eating by reconstituting the flour in boiling water with constant stirring until a smooth thick paste is formed. The paste is served and eaten with soups [2].

Nigeria is the world's largest producer of cassava with production currently estimated at about 49 million tons a year - almost 19% of total world production [3]. Cassava in fresh form contains cyanide and once harvested begins to deteriorate and cannot be stored for more than a few days. They are bulky with about 70% moisture content which makes transportation and distribution of the tubers to urban markets difficult and expensive. Thus, there is a need for rapid processing of the tubers into various products that have increased shelf life, are easier and cheaper to transport and market, and contain less cyanide [4,5]. Processing the tubers into chips reduces the moisture content to a very low level, reduces the cyanide content, facilitates transportation, improves the shelf life and reduces postharvest losses [6,7].

Dried cassava chips, is a product of industrial value which serves as a vital raw material in the livestock feed, alcohol, textile, confectionery, wood, food and soft drink industries [8]. In Nigeria, chips are mostly used in animal feed production even though it has potentials for human consumption which has not been fully explored [9]. Some studies have shown that cassava chips can be reconstituted and converted to desired traditional food products such as *gari* and *fufu* [10-12] however, not much work has been done on *lafun* in this regard.

Chips, unfermented dried products of cassava, are made to undergo fermentation during conversion to desired fermented products. Several media of fermentation (which includes the use of old liquor, seeding with fresh cassava mash, etc.), have been used in the conversion of dried (unfermented) cassava chips to fermented products such as *gari* and *fufu* [12]. [10] fermented cassava chips by rehydrating and seeding with fresh cassava mash which were processed to *gari.* [9] fermented dried chips using liquor from previous fermentation and water at room temperature and 45℃. They reported that chips soaked in water at room temperature gave no yield at all but chips soaked in old liquor gave *gari* yield comparable to that of fresh tubers. This finding is in conformity with that of [11] in a study on the processing of *fufu* from dried cassava chips. Chips steeped in four-day old liquor (4DOL) yielded *fufu* but those soaked in portable water gave no yield. They reported that the absence of fermenting microbes in water resulted in no yield. They further explained that the purpose of using 4DOL was to jump start the fermentation process because it was expected that micro organisms in the liquor will begin the retting and fermentation processes in the chips. The studies of [11] and that of [9] further revealed that fermenting chips using 4DOL at 45℃ gave no yield. It was those fermented at room temperature in 4DOL that yielded *fufu* and *gari*.

Due to the dearth of literature with respect to the use of dried chips in *lafun* production, this study explored the possibility of converting cassava chips into *lafun*. The influence of experimental variables (drying condition to produce the chips, soaking medium and temperature of soaking) on the processing of *lafun* from dried cassava chips were evaluated and compared with those processed from fresh cassava tubers.

2. MATERIALS AND METHODS

2.1 Materials

Bitter variety (*Manihot esculenta* Crantz) of freshly harvested cassava tubers (10-12 months old) were purchased from the Teaching and Research farm on Obafemi Awolowo University Campus, Ile-Ife. All chemicals used were of analytical grade.

2.2 Preparation of Dried Cassava Chips

The method described by [13] was used with slight modifications in preparing the chips. Freshly harvested cassava tubers were sorted to remove bruised or rotten tubers and then washed with water to remove extraneous materials such as plant scraps, stones, sand and dirt. The washed cassava tubers were peeled and diced manually into chips of 2.0±1.0 mm thickness using a sharp knife and thickness was measured using a vernier calliper. The diced cassava tubers were divided into three portions. The first part was sun dried by spreading thinly on perforated stainless steel trays in the sun (32℃±2℃, relative humidity 55%) until no more changes in weight were recorded (average of 3 days). The second and third parts were dried in the oven (DK- 500WT, MRC LTD, Israel) between 50℃ and 70℃, respectively for 48 h to a moisture content of about 10±2%. The cassava chips obtained were allowed to cool, packed in polythene bags and sealed. Fig. 1 shows the flow chart for the production of cassava chips.

2.3 Preparation of *Lafun* from Dried Cassava Chips

The three categories of dried chips were soaked using tap water heated to starting temperature of 60℃ (this is to simulate the traditional practice of adding hot water to the soaking medium) and 4DOL at room temperature. Initially soaking with warm water is expected to activate the enzymes and microbes (the temperature was not kept constant at this temperature but gradually reduced to ambient temperature). Fig. 2 shows the flow chart (designed) for the processing of *lafun* from dried cassava chips. The methods of [11] for *fufu* and [12] for *gari* were modified for *lafun* production.

2.4 Preparation of Four Day Old Liquor (4DOL)

The method described by [11] was employed with slight modifications.

Fresh cassava tubers were peeled, washed, cut and soaked in water. Cassava to water ratio was 1:3 weight/volume in a bucket, covered and allowed to stand for four days at room temperature. The liquor obtained is referred to as 4DOL.

2.5 Swelling Power of *Lafun* Flour

Swelling power of *lafun* samples (from both fresh and dried cassava) was determined by a modification of the method described by [14]. About 1 g of the sample was weighed into a previously tared 20 ml centrifuge tube and 15 ml of distilled water with temperature ranging between 60℃ and 90℃ added. The mixture was stirred with a glass stirring rod for 60 s and allowed to stand for 10 min. The suspension was then centrifuged (0502-1 Centrifuge, HOSPIBRAND, USA) at 3500x g for 15 min. The supernatant was decanted and the tube allowed to drain at 45° angle for 10 min and then weighed. Swelling power was expressed as percentage increase of the sample weight.

2.6 Pasting Properties of *Lafun* FLOUR

The pasting characteristics were determined using a Rapid Visco Analyzer (RVA) (Newport Scientific Pty. Ltd) according to the method described by [11].

2.7 Properties of the Fermenting Medium

2.7.1 pH

The pH of the fermenting media was determined using the method of [15]. A l0 ml portion of the fermenting medium was removed daily and its pH determined using a HANNA pH meter (HANNA Instruments, Italy) model HI96107. The test was done in triplicates.

2.7.2 Electrical conductivity (EC)

The EC of the fermenting medium was determined by inserting a digital EC metre (ATAGO, USA) DEC-2 for about 10 s into the medium and the reading was taken.

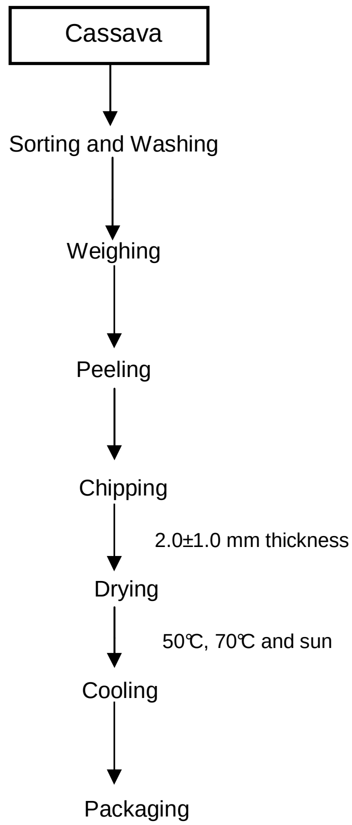

Fig. 1. Flow diagram of cassava chips production

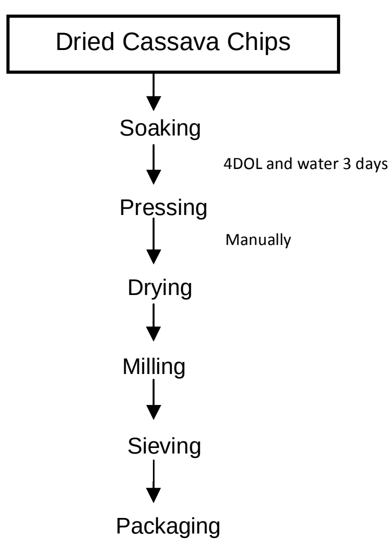

Fig. 2. Flow diagram of *lafun* production from dried cassava chips

2.7.3 Titratable acidity (TTA)

The TTA (expressed as percentage of lactic acid) of the fermenting media was determined by titrating 25 ml of the fermenting media against 0.1N NaOH using 1ml of phenolphthalein indicator. TTA was determined as the product of the titre value and 0.09 which is the lactic acid factor [10,16].

2.8 Bulk Density of *Lafun* Flour

The bulk density of *lafun* samples was determined according to the method of [17]. A 10 ml graduated cylinder, was gently filled with the sample, the bottom of the cylinder was gently tapped on a laboratory bench several times (about 50) until there was no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/cm^3).

2.9 Gelling Concentration

The method of [14] was employed in determining the least gelling concentration of the *lafun* flour samples. Sample suspensions of 3, 5, 7, 9, 11, 13 and 15% (w/v) were prepared in 5 ml distilled water and the test tubes were heated in a boiling water bath for 1 h, this was followed by rapid cooling under running cold tap water. The test tubes were further cooled for 2 h at 4℃ in a refrigerator. Least gelling concentration was determined as that concentration when the sample from the inverted test tube did not fall down or slip.

2.10 Sensory Evaluation

The sensory evaluation of the samples was carried out using hedonic scale of 7. Samples for sensory (*Lafun* dough) was prepared by reconstituting the flour samples processed from dried cassava chips in boiling water with constant stirring over gentle heat till cooked.

2.11 Statistical Analysis

All experiments were conducted in triplicate. Data reported are averages of three determinations. Analysis of variance (ANOVA) was performed and differences in mean values were evaluated using Duncan`s test at $p < 0.05$ [12].

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of the Soaking Medium

The results of pH, TTA and EC of the fermenting medium during soaking of the chips are presented in Table 1. The pH of the fermenting media ranged between 4.02 and 4.80 during soaking of the chips. The values in this study are similar to those (3.90-4.65) reported by [12] for *gari* obtained from chips. The initial pH (4.9) of the 4DOL dropped in all the experimental samples for the starting temperatures and the temperature at which the chips were dried. This is an indication that fermentation occurred during soaking of the chips. The breakdown of starch in fresh cassava tubers by cassava bacterium *Corynebacterium manihot* to simple sugars and its subsequent fermentation to produce lactic and formic acids has been reported to be responsible for the drop in pH of the fermenting medium [18]. Since lactic acid is the main bye product of the fermentation process, the pH of the fermenting medium and product is always lower than 5 [19]. This explains the initial pH (4.9) of 4DOL used in soaking some of the chips. Influence of time was such that the pH dropped up to 48 h after which it either remained stable or increased although the increase was not significant ($p<0.05$). According to [19] the fermentation process takes a few days and the bacterial population stabilizes around 48 h. The pH of the medium containing sundried chips was higher than the pH of the medium containing oven dried chips but the difference was not significant ($p<0.05$). The results suggest that pre-drying and drying methods or conditions did not affect the pH of the fermenting medium (i.e. either the drying to get the chips or drying to produce the *lafun* flour). During fermentation, the chips absorb water resulting in swelling. In this soaked state, the chips are susceptible to microbial activities which results in starch breakdown, acid production, etc which would in turn affect the pH of the medium [12].

The observed decrease in pH could be attributed to further activities of cassava microbes on the substrate (starch in the dried chips) and the low pH further encouraged the growth of a fungus *Geotrichum candidum* which brought about further acidification [18]. However, the pH slightly increased at 72 h. This increase in pH at 72 h was also reported by [11].

Many researchers have reported that the trend in pH is opposite to that of titratable acidity [20-22]. The TTA ranged between 0.19 and 0.74. Sample 70W (70℃ oven dried chips, soaked in water at 60℃ initially) had the lowest TTA value at 24 h while SDL (sun dried chips, soaked in 4DOL at room temperature) at 48 h had the highest TTA value. Samples soaked in 4DOL at RT had significantly higher ($P>0.05$) TTA values than those samples soaked in warm water. This suggests the soaking conditions affected reactions which in turn affected the TTA of the soaking medium. More specifically, medium of dried chips soaked in 4DOL had higher TTA than those soaked in water at elevated temperature. The change in pH and TTA observed in the fermenting medium can be attributed to the activity of microorganisms converting sugars and starch in the tubers into organic acids [20]. Some microorganisms identified to be involved in the fermentation of cassava include *Lactobacillus* spp*., Lactococcus* spp*., Leuconostoc* spp*., Corynebacterium* spp*., Streptococcus* spp., *Candida tropicalis,* and *Geotrichum candidum* [23]. The commonest organisms are acid-forming bacteria such as genera lactic acid bacteria (LAB) accompanied by the production of lactic and acetic acids with decrease in pH and increase in titratable acidity [19,24]. The results obtained in this study show that the processing variables (drying method for the chip, type of rehydrating medium and rehydrating temperature) studied did not influence the pH of the fermenting medium during soaking/rehydration of the chips.

Data on Table 1 suggests that the Electrical Conductivity (EC) of the fermenting media was not affected by prolonged soaking time. The EC measures the flow of electrical charges from the food samples during soaking or cooking. The EC values increased slightly but not significantly ($p<0.05$) different. The EC of samples rehydrated at RT were significantly ($P<0.05$) lower than those rehydrated at initially warm temperature (60℃).

3.2 Physicochemical Properties of *Lafun* Flour

The results of the pH, EC and bulk density of *lafun* flour processed from dried chips and fresh cassava tubers are shown in Table 2. The pH ranged from 3.72 to 5.07 with *lafun* flour processed from chips dried at 50℃ and soaked in water (50 W) having the least pH value and *lafun* processed from fresh cassava tubers, dried at 70±C which was significantly ($P>0.05$) higher than all other samples, had the highest pH value.

It was observed that the pH of all *lafun* samples processed from dried chips were lower than those processed from fresh cassava tubers. This could be attributed to the more rigorous (drying first, soaking and drying again) processing which the chips were subjected to during production of *lafun* unlike those processed from fresh tubers which were subjected to a more convenient process of production. [12], reported pH values of 4.03–6.80 for *gari* (a fermented product of cassava) and that all the experimental samples (processed from chips) showed a sharp drop in pH with increase in fermentation days.

Comparing the pH values of the flour to those of the soaking medium at the end of 72 h showed that the flours had lower pH values than the medium. It is probable that biochemical/microbial reactions and activities continued in the samples even after the medium was removed. The pH of *lafun* flour from fresh cassava was higher than those made from chips. The multiplication of microorganisms in food is greatly influenced by the inherent (intrinsic factors) and environmental characteristics of the food. Fermentation is usually carried out in a moist solid state involving contact with appropriate microorganism at the ambient temperatures [25]. In general, microorganisms multiply mostly rapidly in moist, nutritionally-rich, pH-neutral and warm, oxygen-rich environment [26].

The difference in the drying temperature of the chips did not show a distinct influence on the pH of the end product however the results indicated that the fermenting medium influenced the pH of the samples. The samples soaked in warm water (initial temperature of 60℃) had a lower pH than those soaked in 4DOL (irrespective of the initial temperature) for all the samples dried at different temperatures. This may suggest higher microbial activities in the samples in 4DOL than those soaked in water hence the lower pH. The contents of hydrocyanic (prussic) acid (HCN) in the final product may have contributed to the pH of the flour samples in water. HCN was expected to be present at higher levels in *lafun* made from chips soaked in water and since it is highly soluble in water, it releases its hydrogen ion which contributes to increased acidity of the medium as reflected in lower pH values [27]. A trend similar to that of pH was observed in the EC of the samples. However, the EC of the samples processed from dried chips were higher than those processed from fresh tubers. This further corroborates the fact that the rate of leaching of water soluble substances such as prussic acid, sugars, etc. was higher in *lafun* samples produced from chips soaked in water. The bulk density of the samples was between 0.54 and 0.70 g/cm^3. The bulk density of *lafun* from dried chips compared favourably with those from fresh cassava tubers. The results showed that the drying temperatures of the chips significantly ($p>0.05$) influenced the bulk density of the *lafun* samples with those dried at 70℃ having the highest and those dried in the sun having the least bulk densities respectively. The bulk density value (0.68 g/cm^3) of *lafun* flour reported by [28] was within the range obtained in this study. The values obtained in this study are also comparable to the range (0.56–0.69 g/cm^3) reported by [29] for flour processed from breadfruit. The high volume per gram of flour material is important in relation to its packaging. Increase in bulk density is desirable in that it offers greater packaging advantage, as a greater quantity of product may be packed in a standard volume [30].

3.3 Least Gelling Concentration (%) of *Lafun* Flour

Gellation is a functional property of food materials which affects its texture. The percentage least gelling concentration (LGC) is shown in Table 3. The least gelling concentration varied from 9 to 15% w/v. The gelatinization process is a property of the starch granule found in cereals and tuber crops [31]. The least gelling concentration indicates the amount of *lafun* per volume of water that will be required to prepare the gelatinized (ready-to-eat meal) form. It was observed that most of the samples gelled at and about 13% w/v. This is higher than the values of 8–10% w/v reported by [29] for breadfruit flour. The difference in the LGC observed in all the *lafun* samples implies that the experimental variables influenced the gelling ability of the *lafun* samples. However, from the results obtained in this study, it can be said that *lafun* chips (50L) exhibited similar gelling abilities as *lafun* from fresh tubers.

Lafun flour from fresh samples had higher gelling ability than *lafun* flour from chips. Amongst the chip samples, the higher the drying temperature of the chips the lower the gelling ability which means it gelled at a higher concentration implying that it required more flour to form a gel. The soaking medium (water or 4DOL) did not appear to affect the LGC. *Lafun* flour from fresh cassava showed gelation signs from about 7% concentration while *lafun* flour from chips although were partially gelled at 9% concentration complete gelation occurred between 13 and 15% concentrations. Flour from sundried chips gelled faster than *lafun* flour obtained from oven dried cassava chips. It is probable that the gelling rate is affected by the rate of drying of the chips.

3.4 Swelling Power (SP) of *Lafun* Flour

Swelling power (SP) of *lafun* flour as a function of temperature is shown in Table 4. Swelling power (SP) is the ability of the flour to swell for improved consistency in food when dissolved in water at higher temperature. It is desirable in food systems to improve yield, consistency and give body to the food [32]. The samples from different processing conditions exhibited swelling capacities ranging from 99.76 to 553.09% across the investigated temperatures. In all samples, it was observed that the swelling power increased with temperature. At elevated temperatures, the molecules are subjected to random movement causing the intermolecular and intramolecular forces to be broken and the material in question will imbibe greater volume of water [10]. At these temperatures, the swelling power of *lafun* flour processed from chips was significantly ($p<0.05$) higher than those processed from fresh tubers. Swelling capacity of starches is a function of several parameters such as size, shape, conformational characteristics, hydrophilic and hydrophobic balance in the molecule, carbohydrate associated with proteins, thermodynamic properties of the system and the solubility of starch molecules [28]. The values obtained in this study can be said to be slightly higher (at 90℃**)** than the values (219.92 – 459.31%) reported for *gari* by [12]. This increase could be because *lafun* flour is highly viscose (when mixed in warm water) and upon gelatinization, it swells and causes the expansion of starch granules as well that of some other structural components [33]. The results denote that *lafun* processed from dried cassava chips exhibited higher swelling capacities than *lafun* flour processed from fresh cassava tubers.

3.5 Pasting Properties of *Lafun*

The pasting properties of *lafun* flour processed from dried cassava chips and fresh cassava tubers are presented in Table 5. The application of heat to starchy foods in the presence of water brings about a series of changes known as gelatinisation and pasting which influence the quality, aesthetic and processing considerations in the food industry, as it affects the texture and digestibility of the foods [34].

The peak viscosity (PV) indicates the water binding capacity of the *lafun* samples. It is often correlated with the final product quality and also provides an indication of the viscous load likely to be encountered when converting starch based foods to their gelatinized form. The peak viscosity ranged from 352.50 for flour from sundried samples to 424.84 RVU for flour from fresh cassava dried at 70℃. Peak viscosity occurs at the equilibrium point between swelling and polymer leaching which cause an increase in viscosity, rupture and polymer alignment which cause it to decrease (Flores – Farias et al., 2000). The peak viscosity of *lafun* flour from fresh cassava tubers were significantly higher ($p> 0.05$) than the peak viscosity of *lafun* flour from dried chips. This indicates that drying to make chips reduced the peak viscosity of the *lafun* samples however the values obtained for *lafun* from dried chips were higher than the PV (342.92) of yam flour and compared with PV (362.07) of *lafun* reported by Babajide and Olowe [28]. High peak viscosity is an indication of high starch content which also relate to water binding capacity of starch [35].

Trough viscosity is known as the minimum viscosity at constant temperature phase of the RVA profile and the ability of the paste to withstand breakdown during cooling. *Lafun* samples processed from 70℃ oven dried chips (soaked in 4DOL at room temperature and oven dried at 70℃) had the lowest (116.34 RVU) trough viscosity and *lafun* processed from fresh tubers (soaked in water at room temperature and oven dried at 70℃) had the highest (266.63 RVU) trough viscosity. The samples from fresh cassava tubers exhibited significantly higher ($p> 0.05$) trough viscosities than *lafun* processed from chips. The values obtained in this study compared with those (89.67–177.42) reported by [12] for *gari* from dried cassava chips.

The breakdown viscosity (BV) which is a measure of stability of cooked flour ranged from 152.42 to 242.33 RVU. The BV of the samples from dried chips (except 50L) was found to be significantly higher ($p> 0.05$) than the BV of *lafun* from fresh tubers. This implies that the *lafun* from fresh tubers is more stable to heat and mechanical shear than the *lafun* from dried chips. The values obtained for *lafun* from dried chips were higher than the BV (142.08) of yam flour and compared with BV (170.10) of *lafun* reported by Babajide and Olowe [28].

Table 1. pH, TTA and EC of soaking medium (24 hrs interval)

	pH			TTA			EC		
Samples	**24 h**	**48 h**	**72 h**	**24 h**	**48 h**	**72 h**	**24 h**	**48 h**	**72 h**
SDL	4.59±0.02[a]	4.10±0.06[c]	4.25±0.04[cd]	0.70±0.10[a]	0.74±0.02[a]	0.40±0.02[a]	7.9±0.83[a]	7.8±0.61[a]	7.9±1.01[a]
SDW	4.59±0.01[a]	4.10±0.15[c]	4.30±0.25[c]	0.25±0.04[c]	0.33±0.03[d]	0.30±0.02[c]	4.8±0.75[c]	4.8±0.32[c]	5.0±0.84[c]
50 L	4.24±0.01[c]	4.24±0.18[a]	4.29±0.21[c]	0.57±0.04[b]	0.51±0,01[b]	0.40±0.01[a]	8.0±1.20[a]	7.9±0.41[a]	8.0±0.96[a]
50 W	4.30±0.02[b]	4.02±0.09[d]	4.37±0.32[b]	0.24±0.01[c]	0.34±0.01[d]	0.34±0.02[bc]	4.7±0.05[c]	4.9±0.05[c]	5.1±0.56[c]
70 L	4.21±0.01[c]	4.20±0.38[ab]	4.43±0.05[a]	0.61±0.05[b]	0.42±0.04[c]	0.36±0.01[b]	7.1±0.72[b]	7.2±0.27[b]	7.3±0.92[b]
70 W	4.48±0.03[ab]	4.18±0.04[b]	4.20±0.07[d]	0.19±0.02[d]	0.28±0.01[e]	0.25±0.03[d]	3.7±0.06[d]	4.1±0.09[d]	4.4±0.34[d]

**initial pH at 0 h = 4.9; *initial EC at 0 h = 7.0; *initial TTA at 0 h = 0.23*

SDL, Sun dried chips (soaked in 4DOL at room temperature and sun dried); SDW, Sun dried chips (soaked in water at 60℃ initially and sun dried); 50L, 50° C oven dried chips (soaked in 4DOL at room temperature and oven dried at 50℃); 50 W, 60℃ oven dried chips (soaked in wa ter at 60℃ initially and oven dried at 50℃)
70 L, 70℃ oven dried chips (soaked in 4DOL at room temperature and oven dried at 70℃); 70 W, 70℃ ov en dried chips (soaked in water at 60 ℃ initially and oven dried at 70℃); Values with similar letters within the same column are not significantly ($p < 0.05$) different

Table 2. Physicochemical properties of *lafun* flour

Samples	**pH**	**EC**	**Bulk density (g/cm^3)**
FSD	4.85±0.07[d]	1.00±0.02[ab]	0.59±0.00[cd]
F50	4.70±0.21[d]	1.00±0.015[ab]	0.60±0.001[d]
F70	5.07±0.14[e]	1.10±0.01[abc]	0.70±0.013[f]
SDL	3.92±0.03[ab]	1.50±0.03[e]	0.54±0.002[ab]
SDW	3.77±0.01[ab]	1.10±0.011[abc]	0.55±0.004[b]
50 L	4.29±0.14[c]	1.30±0.01[bcd]	0.58±0.015[c]
50 W	3.72±0.01[a]	0.90±0.01[a]	0.54±0.002[a]
70 L	4.02±0.01[b]	1.40±0.03[de]	0.66±0.004[e]
70 W	3.95±0.07[ab]	1.00±0.001[ab]	0.65±0.012[e]

FSD, Fresh tubers (soaked in water at room temperature and sun dried); F50, Fresh tubers (soaked in water at room temperature and oven dried at 50℃); F7 0, Fresh tubers (soaked in water at room temperature and oven dried at 70℃); SDL, Sun dried chips (soaked in 4DOL at room temperature and sun dried); SDW, Sun dried chips (soaked in water at 60℃ initially and sun dried); 50 L, 50℃ oven dried chips (soaked in 4DOL at room temperature and oven dried at 50℃); 50 W, 60℃ oven dried ch ips (soaked in water at 60℃ initially and oven dried at 50℃); 70 L, 70℃ oven dried chips (soaked in 4DOL at room t emperature and oven dried at 70℃); 70 W, 70℃ oven dried chips (soaked in water at 60℃ initially and oven dried a t 70℃); Values with similar letters within the sam e column are not significantly ($p < 0.05$) different

Table 3. Least gelling concentration (%/vol) of *lafun* flour

Samples	3	5	7	9	11	13	15
FSD	-	-	±	+	+	+	+
F50	-	-	±	±	+	+	+
F70	-	-	-	-	-	+	+
SDL	-	-	-	±	±	+	+
SDW	-	-	-	-	-	+	+
50 L	-	-	±	+	+	+	+
50 W	-	-	-	±	±	±	+
70 L	-	-	-	±	±	±	+
70 W	-	-	-	±	±	±	+

FSD, Fresh tubers (soaked in water at room temperature and sun dried); F50, Fresh tubers (soaked in water at room temperature and oven dried at 50℃); F7 0, Fresh tubers (soaked in water at room temperature and oven dried at 70℃); SDL, Sun dried chips (soaked in 4DOL at room temperature and sun dried); SDW, Sun dried chips (soaked in water at 60℃ initially and sun dried); 50 L, 50℃ oven dried chips (soaked in 4DOL at room temperature and oven dried at 50℃); 60/W/60, 60℃ oven dried chips (soaked in water at 60℃ initially and oven dried at 50℃); 70 L, 70℃ oven dried chips (soaked in 4DOL at room t emperature and oven dried at 70℃); 70W/70, 70℃ ov en dried chips (soaked in water at 60℃ initially and oven dried a t 70℃); - Not gelled;±Partially gelled; + Complet ely gelled

Table 4. Swelling power of *lafun* flour

Samples	RT	60°C	70°C	80°C	90°C
FSD	100.48±3.51^{a}	113.14±1.78^{a}	141.58±1.40^{cd}	371.95±10.68^{e}	500.24±159.36^{a}
F50	99.76±2.45^{a}	110.23±1.80^{a}	129.04±16.33^{abc}	253.22±18.56^{cd}	289.00±32.53^{a}
F70	104.45±0.71^{ab}	114.64±1.81^{a}	121.29±0.10^{ab}	195.03±16.08^{ab}	496.08±11.19^{a}
SDL	103.99±0.72^{ab}	119.86±3.58^{ab}	122.57±2.38^{ab}	240.36±19.18^{cd}	405.64±174.04^{a}
SDW	113.14±6.62^{c}	132.88±12.19^{c}	138.00±9.19^{bc}	277.01±14.40^{d}	515.22±155.25^{a}
50 L	109.45±0.01^{bc}	127.61±2.46^{bc}	130.52±0.94^{abc}	216.10±22.77^{bc}	553.09±46.93^{a}
50 W	120.35±2.18^{d}	146.79±0.70^{d}	155.04±6.44^{d}	224.55±20.15^{bc}	478.58±173.12^{a}
70 L	109.46±2.11^{bc}	109.88±0.03^{a}	118.14±5.30^{a}	155.96±0.34^{a}	294.90±191.83^{a}
70 W	110.97±2.08^{bc}	110.92±0.74^{a}	113.63±0.35^{a}	210.47±24.71^{bc}	481.63±30.87^{a}

FSD, Fresh tubers (soaked in water at room temperature and sun dried); F50, Fresh tubers (soaked in water at room temperature and oven dried at 50℃); F7 0, Fresh tubers (soaked in water at room temperature and oven dried at 70℃); SDL, Sun dried chips (soaked in 4DOL at room temperature and sun dried); SDW, Sun dried chips (soaked in water at 60℃ initially and sun dried); 50 L, 50℃ oven dried chips (soaked in 4DOL at room temperature and oven dried at 50℃); 50W, 60℃ oven dried chi ps (soaked in water at 60℃ initially and oven dried at 50℃); 70L, 70° C oven dried chips (soaked in 4DOL at room temperature and oven dried at 70℃); 70W, 70℃ oven dried c hips (soaked in water at 60℃ initially and oven dried a t 70℃); Values with similar letters within the sam e column are not significantly ($p < 0.05$) different

Table 5. Pasting properties of *lafun*

Sample	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown viscosity (cP)	Final viscosity (cP)	Setback viscosity (cP)	Peak time (min)	Pasting temp. (°c)
FSD	388.46±2.06^{d}	217.25±12.02^{e}	171.21±14.09^{ab}	278.92±4.83^{f}	61.67±7.19^{c}	4.97±0.03^{ef}	48.81±0.92^{a}
F50	401.92±6.48^{e}	249.50±0.71^{f}	152.42±5.78^{a}	322.46±4.07^{g}	72.96±3.36^{d}	5.09±0.05^{f}	49.41±0.07^{ab}
F70	424.84±0.12^{f}	266.63±5.48^{g}	158.21±5.60^{ab}	341.09±1.53^{h}	74.46±3.95^{d}	4.82±0.01^{e}	49.51±0.07^{ab}
SDL	352.50±4,36^{a}	148.50±1.77^{b}	204.00±2.59^{cd}	189.17±0.35^{b}	40.67±2.12^{a}	4.03±0.06^{bc}	49.36±0.01^{ab}
SDW	377.80±8.31^{c}	153.21±3.95^{b}	224.59±12.25^{de}	198.92±1.29^{c}	45.71±2.65^{ab}	3.92±0.09^{ab}	49.46±0.14^{ab}
50 L	361.84±0.12^{ab}	186.71±12.90^{d}	175.13±13.02^{b}	241.92±5.07^{e}	55.21±7.83^{bc}	4.83±0.09^{e}	49.51±0.21^{ab}
50 W	370.38±5.13^{bc}	161.17±4.48^{bc}	209.21±9.60^{cd}	222.67±1.77^{d}	61.50±2.72^{c}	4.53±0.10^{d}	49.51±0.07^{ab}
70 L	358.67±0.83^{a}	116.34±2.35^{a}	242.33±3.18^{e}	175.29±0.30^{a}	58.96±2.06^{c}	3.78±0.04^{a}	49.61±0.07^{ab}
70 W	371.34±4.36^{bc}	173.63±9.02^{cd}	197.71±4.65^{c}	234.63±5.37^{e}	61.00±3.65^{c}	4.12±0.07^{c}	49.66±0.14^{b}

FSD, Fresh tubers (soaked in water at room temperature and sun dried); F50, Fresh tubers (soaked in water at room temperature and oven dried at 50℃); F7 0, Fresh tubers (soaked in water at room temperature and oven dried at 70℃); SDL, Sun dried chips (soaked in 4DOL at room temperature and sun dried); SDW, Sun dried chips (soaked in water at 60℃ initially and sun dried); 50L, 50℃ o ven dried chips (soaked in 4DOL at room temperature and oven dried at 50℃); 50W, 60℃ oven dried chip s (soaked in water at 60℃ initially and oven dried at 50℃); 70 L, 70 ℃ oven dried chips (soaked in 4DOL at room tempera ture and oven dried at 70℃); 70 W, 70℃ oven dried chips (soaked in water at 60℃ initially and oven dried a t 70℃); Values with similar letters within the sam e column are not significantly (p < 0.05) different

Table 6. Sensory analysis of *lafun*

Sample	Color	Aroma	Taste	Elasticity	Mouldability	Overall acceptability
FSD	5.67±0.45^{cd}	5.13±0.29^{bcde}	5.33±0.39^{c}	5.33±0.21^{b}	4.87±0.36^{bc}	5.60±0.21^{de}
F50	5.93±0.37^{cd}	6.07±0.18e	5.60±0.32^{c}	5.00±0.37^{ab}	5.80±0.26^{c}	6.27±0.23^{e}
F70	5.60±0.38^{cd}	4.93±0.43^{bcd}	4.87±0.39^{bc}	4.67±0.41^{ab}	5.07±0.46^{bc}	4.80±0.37^{bcd}
SDL	4.80±0.30^{c}	4.13±0.35^{abc}	4.60±0.42^{bc}	5.13±0.31^{b}	5.27±0.30^{c}	4.73±0.42^{bcd}
SDW	5.13±0.26^{cd}	5.13±0.32^{bcde}	5.00±0.29^{bc}	5.20±0.30^{b}	5.20±0.43^{c}	5.33±0.33^{cde}
50 L	5.20±0.38^{cd}	5.20±0.44^{cde}	4.93±0.36^{bc}	4.73±0.37^{ab}	4.80±0.48^{bc}	4.93±0.43^{bcd}
50 W	6.00±0.43^{d}	5.67±0.27^{de}	5.20±0.34^{c}	4.73±0.33^{ab}	4.67±0.54^{abc}	5.33±0.37 ^{cde}
70 L	3.47±0.39^{b}	4.07±0.34^{ab}	3.93±0.44^{ab}	3.93±0.44^{a}	3.53±0.40^{a}	3.87±0.42^{ab}
70 W	3.60±0.38^{b}	4.20±0.35^{bc}	4.67±0.40^{bc}	4.93±0.32^{ab}	5.27±0.33^{c}	4.40±0.43^{bc}
Comm	2.13±0.36^{a}	3.13±0.42^{a}	3.07±0.43^{a}	4.67±0.44^{ab}	3.87±0.46^{ab}	2.87±0.36^{a}

FSD, Fresh tubers (soaked in water at room temperature and sun dried); F50, Fresh tubers (soaked in water at room temperature and oven dried at 50℃); F7 0, Fresh tubers (soaked in water at room temperature and oven dried at 70℃); SDL, Sun dried chips (soaked in 4DOL at room temperature and sun dried); SDW, Sun dried chips (soaked in water at 60℃ initially and sun dried); 50 L, 50℃ oven dried chips (soaked in 4DOL at room temperature and oven dried at 50℃); 50W, 60℃ oven dried chi ps (soaked in water at 60℃ initially and oven dried at 50℃); 70 L, 70 ℃ oven dried chips (soaked in 4DOL at room tempera ture and oven dried at 70℃); 70 W, 70℃ oven dried chips (soaked in water at 60℃ initially and oven dried a t 70℃); Comm: Commercial sample.; Values with simi lar letters within the same column are not significantly (p < 0.05) different

The final viscosity of the samples was between 175.29 and 341.09 RVU. Final viscosity is one of the most common parameters used to define the quality of a particular starch-based sample, as it indicates the ability of the material to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear force during stirring [36,37]. The final viscosity of *lafun* flour from fresh cassava tubers were significantly higher ($p > 0.05$) than the final viscosity of *lafun* from dried chips.

The index of retrogradation during cooling is known as setback viscosity (SV). The SV ranged between 40.67 and 74.46 RVU. *Lafun* flour from fresh tubers had higher values for SV than the samples from dried cassava chips but not completely significantly ($p < 0.05$) different for all of the samples especially those from oven dried chips. This implies that in terms of SV, *lafun* from oven dried chips compared favourably with *lafun* from fresh cassava tubers. Higher SV of a product, indicates that retrogradation will be slower during cooling and a lower staling rate of the product made from the flour [36]. Sundried chips had lower SV values compared to flour from oven dried chips. This suggests that drying at higher temperatures affected starch structure and form which would later affect the retrogradation properties.

The peak time of all the samples followed a similar trend observed in the breakdown viscosity discussed above.

The pasting temperature, an indication of the first detectable viscosity, compared favourably in all the samples. The pasting temperature ranged between 48.81℃ (FSD) and 49.66℃ (70 W). The pasting temperature provides an indication of the minimum temperature required to cook a given sample and also has implications for energy costs [29]. This results suggest that the processing variables had no significant effect ($p<0.05$) on the amount of energy that would be required to cook any of the *lafun* samples.

3.6 Sensory Analysis of *Lafun* Dough

Using a hedonic scale of 7, the result of sensory evaluation of the *lafun* dough i.e. flour samples processed from dried cassava chips reconstituted in boiling water with constant stirring over gentle heat till cooked and a commercial sample is shown in Table 6.

<u>3.6.1 Colour</u>

The commercial sample ranked lowest (2.13) and sample F50 *lafun* processed from fresh tubers soaked in water at room temperature and oven dried at 50℃ ranked highest (5.93). It can be noted that at specific drying temperatures, the *lafun* samples soaked in water scored higher than those soaked in liquor even though they were not significantly ($p<0.05$) different. Thus the soaking medium did not significantly ($p<0.05$) influence the color of the samples. An almost similar trend was observed for the drying temperature except for chips dried at 70℃ soaked in liquor (70 L) and water (70 W) which ranked next to the commercial sample and were significantly ($p<0.05$) lower than the other experimental samples. Aroma and taste: The scores for the aroma of the samples ranged from 3.13 to 6.07 and score for taste ranged between 3.07 and 5.60. The commercial samples ranked lowest and sample F50 ranked highest. It implies that *lafun* from dried chips had a better taste and aroma than the commercial samples on sensory evaluation.

Elasticity and mouldability are important quality attributes of *lafun* dough and the two attributes are interrelated. The elasticity of the samples ranged from 3.93 to 5.33 and mouldability varied between 3.53 and 5.80. Sample 70L (70℃ oven dried chips soaked in 4DOL at room temperature and oven dried at 70℃) had the least scores and F50 (fresh tubers soaked in water at room temperature and oven dried at 50℃).

This suggests that *lafun* dough from sun dried flour gave better elasticity and mouldabilty than those from oven dried samples although the analysis of variance showed that there was no significant ($p<0.05$) difference in the elasticity of all the samples. It can therefore be said that the soaking medium and temperature of drying did not significantly influence the elasticity of the *lafun* samples.

The overall acceptance of the *lafun* ranged between 2.87 and 6.27. The commercial sample ranked lowest and F50 (fresh tubers soaked in water at room temperature and oven dried at 50℃) ranked highest. A more critical look at the results in Table 6 showed that in all the quality attributes (except elasticity and mouldability) assessed, the samples dried at 70℃ had the least scores followed by sun dried and 50℃. At each of the investigated temperatures, those soaked in water obtained higher scores than those soaked in 4DOL, Table 1 further confirms this point which showed that the pH and TTA of the soaking water is lower than that of the 4DOL. The lower preference of the samples soaked in liquor could be due to the metabolic activity of microbes in the liquor (during its preparation) which gives it the characteristic sour smell. This could in turn have an impact on the color, taste, aroma and most importantly the overall acceptability of the product by consumers. The poor ranking of the commercial samples when compared to the experimental samples could be as a result of the production environment. The experimental samples were processed in a controlled (hygienic) environment but that may not be the case of the commercial sample which during production has been exposed to the atmosphere (dust) over a period of time [13] and [2]. According to [38], the following factors work against traditional fermented foods: Inadequate raw material grading and cleaning contributing to the presence of foreign matter (such as insects, stones) in the final product, crude handling and processing techniques employed, lack of durability (shelf life), lack of homogeneity and unattractive presentation. [39] reported that most indigenous fermentation processes occur in environments that fail to observe good manufacturing practice (GMP) or code of hygiene.

4. CONCLUSION

The bulk density and physico chemical properties of *lafun* flour from dried chips compared favourably with those from fresh cassava tubers. *Lafun* processed from chips exhibited similar gelling abilities and water absorption capacities as *lafun* from fresh tubers. Water absorption capacity increased with temperature. The pasting temperatures were not significantly different in all the samples, pasting properties of fresh *lafun* were higher than for samples from dried chips. The experimental samples were preferred to the commercial sample on sensory analysis. Chips soaked in water and dried at 50℃ gave the best results.in terms of color, aroma, taste and overall acceptability. The study concludes that *lafun* flour with good functional and sensory characteristics could be processed from chips, dried preferably at 50℃ and soaked in water at an initial temperature of 60℃.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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