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The functional properties of four cassava varieties as affected by fermentation time

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Abstract

Freshly harvested cassava varieties (NR 8082, TMS 419, TMS 4(2) and TMS 30572) were each divided into 5 portions, peeled, washed, soaked and fermented for different times (0, 24, 48, 72, 96 hours) in water. The water was regularly changed at 6-hour intervals. Both the fermented and unfermented (fermented for zero hours) tubers were mashed, bagged, de-watered (with a hydraulic press), oven-dried, milled, sieved and packaged. The zero-fermented or unfermented cassava flour represented high-quality cassava flour (HQCF). The flours obtained (HQCF and fermented odourless cassava flours) from the four cassava varieties were used to study the effect of fermentation time on quality characteristics of odourless flours from four cassava varieties comparatively. Most of the measured quality characteristics of cassava flour were affected by varietal differences. The results showed that fermentation, irrespective of cassava variety, influenced progressive increases in foaming capacity (3.76 - 4.19%), water absorption capacity (1.27-1.53g/g), oil absorption capacity (2.99~3.23g/g), emulsion capacity (40.65-46.68%), The longer the period of fermentation, the higher the level of increases for the above-stated quality parameters. However, beyond 48 hours of fermentation, the quality parameters started decreasing with an increase in fermentation time. And there were decreases in bulk density (0.74-0.72g/cm^3), swelling index (1.18-1.07%), gelation temperature (71.33-68.67°C), viscosity (0.182-0.176Pa.s), wettability (11.59-7.49s), and photometric colour index (7.71-5.84) as time of fermentation increased from 0-96 hours. Therefore, cassava tubers should be fermented for 48 hours to obtain cassava flours with good functional properties.

Key words: Cassava varieties, fermentation, functional properties.

Introduction

Root vegetables are foods rich in minerals (such as calcium, potassium and iron) and vitamins (such as vitamins A, B and C), and they are actively recommended to the elderly to prevent cardiovascular disease, osteoporosis, dementia, and other conditions. Cassava (*Manihot esculenta*) is an annual tuberous root crop that is the third largest source of carbohydrates, providing a basic diet for over half a billion people in the tropics and serving as a source of income for small-scale farmers and raw material for industrial products (Howeler *et al.*, 2013). This root vegetable is rich in minerals and vitamins and is actively recommended to the elderly to prevent various lifestyle diseases (Kim *et al.*, 2022). However, the major limitation to cassava product acceptance is the presence of toxic cyanogenic glucosides, which release cyanide and can be fatal to humans. While hydrogen cyanide (HCN) can be removed through grinding, chopping, cooking in water, drying, and dehydration (Krishnakumar *et al.*, 2021), fermentation is the most effective method for detoxifying cyanide and improving the functional properties of cassava flour.

Cassava originated in South America and has become an important crop for food security in many developing nations due to its capacity to withstand harsh weather conditions and flourish in poor soils. Cassava is the second most productive root and tuber crop after yam (FAO, 2007), and it is the third most calorie-dense food after maize and rice (Sis, 2013). It is regarded as a food security crop with significant potential for industrial applications (Amoa-Awua *et al.*, 2005). Cassava's flexibility is reflected in its many applications. The tuber can be made into garri, tapioca, and flour for human use, whereas the leaves are cooked and consumed, particularly in Sierra Leone and Liberia.

Pigs, goats, horses, and cattle can all be fed sweet cassava tubers, either raw or boiled. Furthermore, cassava is a vital ingredient in many food items due to its unique properties, including clarity and appearance, low flavor, and excellent viscosity, making it a popular choice in the food sector. Traditional cassava processing procedures include peeling, washing, soaking, and fermenting the tubers. These methods have been modified by regularly replacing the soaked water with fresh water or immersing the cassava tubers in flowing streams or rivers. This improved technology produces odourless fermented cassava flour with no off-color or sour taste. Fermentation, a crucial stage in cassava processing, not only improves the sensory properties of cassava flour but also increases its safety by lowering cyanogenic glycosides.

Despite cassava's widespread use, there is a need to systematically analyze the functional properties of odourless cassava flours, both fermented and unfermented, derived from different cassava species and impacted by varying fermentation times. Functional properties such as foaming capacity, water absorption capacity, oil absorption capacity, emulsion capacity, bulk density, swelling index, gelation temperature, viscosity, wettability, and photometric colour index are important in determining cassava flour's suitability for various industrial applications.

This study aimed to assess the functional qualities of flours derived from four cassava varieties (NR 8082, TMS 419, TMS 4(2), and TMS 30572) fermented at different times. The goal was to determine the optimum fermentation time required to produce cassava flour with good functional characteristics for various applications.

Materials and methods

Source of materials: Roots of four varieties of cassava: sweet cassava (TMS 4(2) and TMS 30572) and bitter cassava (NR 8082 and TMS 419), most commonly available improved cassava varieties developed by the International Institute of Tropical Agriculture (IITA) Ibadan and National Root Crops Research Institute (NRCRI) Umudike, Abia State Nigeria, were used. The 12-month-old tubers were harvested manually from the National Root Crops Research Institute (NRCR) Umudike, Abia State, Nigeria.

Unfermented high-quality cassava flour (HQCF) preparation: Healthy cassava roots (12 months old) with no bruises and cracks were harvested and processed within 24 hours using Dziedzoave *et al.* (2006) method. The indigestible outer layers of the roots were peeled with a sharp stainless-steel knife, washed with potable water and a sponge to scrub off impurities, and mashed with a field marshal (7.5 HP diesel engine). The mash was bagged in clean sacks, labeled, tied and dewatered on a hydraulic press at the garri processing unit of the NRCRI Umudike. Off-colour and odour from fermentation was avoided by keeping the dewatering time short (< 1 hour). The cake was manually disintegrated to reduce the particle size, then oven-dried on foiled oven racks at 60°C for 24 hours with an electric hot air thermo-regulated oven (Gallenkamp, Bs Model Ov-160). The dried samples were pulverized in a disc attrition mill and sieved to obtain fine flour with uniform particle size; packed in air tight plastic containers to avoid moisture uptake and individually labeled.

Fermented cassava flour preparation: The method described by Oyewole and Odunfa (1989) was adopted. A portion of the four cassava varieties that had already been prepared was separately soaked in water in 20-litre plastic containers for the fermentation process under ambient conditions (30$\pm$2°C), which favours the growth of lactic acid bacteria (Westby, 2001). The fermentation periods varied: 24 hours, 48 hours, 72 hours, and 96 hours, with the water being changed every 6 hours throughout the period. The fermented roots were rewashed with portable water, mashed, bagged and dewatered, and dried, milled, sieved and packed as described earlier.

Determination of the functional properties

Bulk density: Onwuka's (2005) method was used to determine bulk density.

The bulk density (g/mL) = Weight of sample (g)/volume of sample (mL)

Wettability: The test material to be damped and the time required for the sample to become completely wet were recorded (Onwuka, 2005).

Water absorption capacity (WAC): The method described by Onwuka (2005) was used. The volume difference was recorded as the volume of water absorbed or retained by one gram of sample = (V_1-V_2) mL/g. Where V1 = initial volume of water before centrifugation and V_2 = final volume of water after centrifugation.

Oil absorption capacity (OAC): The method described by Onwuka (2005) was used. The volume of free oil was read directly from the graduated centrifuge tube and recorded as the volume of oil absorbed or retained per gram sample.

OAC = (V_1-V_2) mL/g, V_1 = initial volume of oil before centrifugation V_2 = final volume of oil after centrifugation.

Foaming capacity: The method described by Onwuka (2005) was adopted. The foam capacity was expressed as percentage increase in volume.

$$\text{The foam capacity} = \frac{\text{Volume after whipping - Volume before whipping}}{\text{Volume before whipping}} \times 100$$

Emulsification capacity (EC): The method described by Onwuka (2005) was adopted. Emulsion capacity is expressed as the amount of oil emulsified and held per gram of sample.

Emulsion capacity (%) = X/Y×100

Where; X = height of emulsified layer; Y = height of whole solution in the centrifuge tube.

Swelling Index: The swelling index was calculated using Onwuka's method (2005).

$$SI(\%) = \frac{W2-W1}{W1} \times 100$$

Where; W_1 = weight of sample before swelling, W_2 = weight of sample after swelling

Gelation temperature: This was determined using Onwuka's method (2005), which is the temperature at which a 3% sample suspension started forming gel under laboratory conditions. The temperature at the point was recorded as the Gelation temperature.

Viscosity: The Oswald viscometer method (Onwuka, 2005) was used. The experiment was replicated three times and average values were recorded in Pa.s.

Data analysis: Data were analyzed according to the procedures of Steel and Torrie (1980). Flour samples obtained from 4 cassava varieties (2 bitter and 2 sweet cultivars) were arranged in a completely randomized design (CRD) with 3 replications and errors reported as standard deviation from the mean. Data collected were subjected to analysis of variance (ANOVA) and the least significant differences were calculated using the statistical package for social sciences (SPSS) version 16.00 software. Mean separation was done by the Fisher's least significant difference (LSD). A significant difference was accepted at (P < 0.05) level.

Results and discussion

Foaming capacity: The foaming capacities of the fermented odourless cassava flours were observed to increase with significant differences (P<0.05), as fermentation time was increased (Tables 1 and 2). The values were higher compared to those of unfermented cassava flours (HQCF). The foaming capacity of the flours produced from NR 8082 and TMS 419 cassava varieties increased from 3.76% to 4.75% and from 3.52% to 4.98%, respectively; similarly, for the flours from TMS 4(2) and TMS 30572, foaming capacity increased from 3.11% to 4.28% and from 3.92% to 4.91% respectively, after 72 hours of fermentation. Among the four varieties of cassava flours used, NR 8082 fermented cassava flours recorded the lowest percentage increase in foaming capacity. Foam is produced by trapping gas pockets in a liquid or solid, forming bubbles. The foaming capacity of the starch samples can be rated as low since they do not contain a considerably high amount of protein compared to legumes. Flour with high foaming stability may find application in baked and confectionery products such as cakes and cookies (EI-Adawy and Taha, 2001). The fermented odourles cassava flours' high foaming capacity makes them better for the production of baked and confectionery products than the unfermented cassava flours (HQCF).

Bulk density: There was no significant difference (*P*>0.05) in the bulk density of unfermented (HQCF) and fermented odourless cassava flours throughout fermentation. The bulk densities of the flours from zero hour to 48 hours of fermentation were statistically equal for all cassava varieties (0.71 to 0.79g/cm^3). The values, however, decreased slightly from 72 hours of fermentation for all four flours (Tables 1 and 2). Comparatively, flours produced from NR 8082 and TMS 30572 cassava varieties had similar bulk densities, while those produced from TMS 4(2) had the least. This study's results were very similar to the bulk density (0.75g/cm^3) for unfermented cassava flour reported by Sanni *et al.* (2004). The decrease in bulk density after 48 hours of fermentation could be due to the degradation of polysaccharides, which might occupy more space than monosaccharides and could have contributed to lower bulk density. The low bulk density recorded by the fermented odourless cassava flours after 48 hours of fermentation may be due to the starch particles becoming looser during the fermentation period (Plaami, 1997). Bulk density is influence by the structure of starch polymers and the loose structure of starch polymers, resulting in low bulk density (Oyeyinka *et al.*, 2020). Okpala *et al.* (2013) reported that high bulk is very important to flour producers because high bulk density is an indication that the flour is heavy. Hence it will occupy less space and would require less packaging materials per unit weight, resulting in lower packaging cost.

High bulk density is desirable for greater ease of dispersibility of food powder and reduction of paste thickness (Udensi and Eke, 2002). The low bulk density of the fermented flours could be an advantage in formulating baby foods where high nutrient density to low bulk is desired.

Swelling index: No significant difference (P>0.05) in the swelling indices of fermented and unfermented cassava flours from all four varieties. In flours produced from NR 8082 and TMS 419 cassava varieties, the swelling index decreased slightly from 1.18% to 1.07% and from 1.10% to 1.08%, respectively; in flours from TMS 4(2) and TMS 30572 cassava varieties, it decreased from 1.15% to 1.10% and from 1.15% to 1.09% respectively (Tables 1 and 2).

After 96 hours of fermentation, the swelling index of flours from NR 8082 variety reduced by 9.3% compared to the rest. The swelling index in flours produced from TMS 4(2) and TMS 419 cassava varieties was reduced after 96 hours of fermentation by 4.3% and 1.8%, respectively. The swelling index is an indication of the water absorption index of the granules (Oyeyinka *et al.*, 2020); it reflects the extent of associative force within the granules; therefore, the higher the swelling index, the lower the associative force (Sanni *et al.,* 2005). The significant reduction in swelling index with fermentation duration suggested that microorganisms could break macromolecule structures during fermentation (Achinewhu *et al.,* 1998). The swelling index measures the degree of exposure of the internal structure of starch present in food to the action of water. The slight decrease in the swelling index of the fermented odourless cassava flours suggested a saturation effect following increasing exposure of the sample to the action of water. High swelling capacity is a criterion for a good quality product with better digestibility. Therefore, the fermentation process for cassava flour production is not recommended when targeting an increased swelling index.

Table 1. Effect of fermentation time on functional properties of unfermented cassava flour (HQCF) and Fermented odourless cassava flour

Samples	Foaming capacity (%)	Bulk density (g/cm^3)	Swelling Index (%)	Gelation temperature (°C)	Water absorption capacity (g/g)
NR 8082					
HQCF	3.76±0.6^C	0.74±0.11	1.18±0.02	71.33±0.10	1.27±0.10^C
24h	3.99±0.10^{bc}	0.74±0.11	1.08±0.01	71.00±1.00	1.33±0.03^{bc}
48h	4.75±0.10^a	0.74±0.10	1.08±0.01	70.17±3.00	1.37±0.07^{bc}
72h	4.75±0.09^a	0.72±0.11	1.05±0.02	70.83±1.00	1.47±0.07^{ab}
96h	4.19±0.04^b	0.72±0.11	1.07±0.02	68.67±0.02	1.53±0.03^a
LSD	0.225099	-	-	-	0.170159
TMS419					
HQCF	3.52±0.10^d	0.79±0.09	1.1010.02	71.17±0.01^a	1.50±0.05^b
24h	3.93±0.10°	0.7910.10	1.08+0.02	70.50+0.05^b	1.57±0.20^b
48h	4.96±0.10^a	0.79±0.10	1.08±0.03	70.33±0.03^C	1.60±0.0.06^b
72h	4.98t0.10^a	0.76±0.00	1.08±0.00	69.33±0.03^d	1.77i0.10^{ab}
96h	4.68±0.10^b	0.74±0.10	1.08±0.02	68.33±0.10^e	1.97±0.03^a
LSD	0.269045	.	-	0.147362	0.282177

Table 2. Effect of fermentation time on the functional properties of unfermented cassava flour (HQCF) and fermented cassava flour

Samples	Foaming capacity (%)	Bulk density (g/cm^3)	Swelling Index (%)	Gelation temperature (°C)	Water absorption capacity (g/g)
TMS 4(2)					
HQCF	3.11±0.0^C	0.73±0.02	1.15±0.15	72.50±1.99	1.37±0.02
24h	3.67±0.2^b	0.72±0.02	1.10±0.10	71.83±1.00	1.43±0.02
48h	4.23±0.0^a	0.72±0.02	1 .07±0.02	71.50±0.99	1.47±0.01
72h	4.28±0.1^a	0.71±0.01	1 .08±0.01	71.77±0.98	1.63±0.01
96h	4.18±0.0^a	0.71±0.01	1.10±0.10	69.83±0.03	1.89±0.01
LSD	0.27	-	-	•	
TMS 30572					
HQCF	3.42±0.1^e	0.74±0.01	1.15±0.00	71.83±1.00^a	1.23±0.03^d
24h	3.92±0.0^d	0.74±0.02	1.10±0.10	71.17±1.01^a	1.27±0.02^{cd}
48h	4.9l±0.01^a	0.74±0.04	1.07±0.07	70.83±1.00^a	1.33±0.03^C
72h	4.56±0.0^C	0.73±0.03	1.10±0.02	70.33±0.03^{ab}	1.47±0.02^b
96h	4.75±0.0^b	0.72±0.01	1.09±0.00	68.33±0.97^b	1.77±0.02^a
LSD	0.15	-	-	2.395	0.08

Values are means of triplicate analysis ± standard deviation. Means with different superscript letters along the columns, are significantly different (*P* < 0.05). HQCF stands for high-quality cassava flour; 24-96h is the fermentation period.

Gelation temperature: The gelation temperatures of the fermented odourless cassava flours from NR 8082 and TMS 4(2) had no significant differences (P>0.05), while those of the fermented flours from TMS 30572 and TMS 419 cassava varieties had significant differences (P<0.05). The gelation temperatures of the unfermented cassava flours (HQCF) were higher than those of fermented odourless cassava flour. Increased fermentation time decreased the gelation temperature of the fermented flour. In flours from NR 8082 and TMS 419 cassava varieties, gelation temperatures decreased from 71.33°C to 69.67°C and from 71.17°C to 68.33°C respectively (Table 1). In flours produced from TMS 4(2) and TMS 30572, cassava varieties gelation temperatures decreased from 72.50°C to 69.83°C and from 71.83°C to 68.33°C respectively (Table 2). The observed values were comparable to 73.4 °C to 74.80 °C reported for maize flour (Bolade, 2009). The observed low gelation temperature of the fermented flours may probably be due to enzyme activity stimulated by the fermentation process, which breaks down the matrix embedding the starch granules, thus allowing the granules to swell freely and gelatinize faster. Longer fermentation time significantly decreases gelation temperature due to starch decomposition during the fermentation process. The decrease in gelation temperature is also in line with the decreasing levels of starch due to microbial activities that degraded starch into simpler compounds. The higher temperature of gelatinization reflects greater internal granule stability. The lower gelation temperature of the fermented flour implies that the flour will gelatinize faster at a reduced temperature (Baah, 2009).

Water absorption capacity (WAC): The water absorption capacity of all flour samples increased significantly (P<0.05) with an increase in fermentation time, and it was affected by cassava variety. The fermented odourless cassava flours' water absorption capacity was higher than that of the unfermented cassava flour (HQCF). The mean water absorption capacity values for flours from NR 8082 and TMS 419 increased from 1.27g/g to 1.53g/g and from 1.50g/g to 1.97g/g, respectively (Table 1). Significant differences existed in the water absorption capacity of some flour samples produced from TMS 4(2) and TMS 30572 cassava varieties (Table 2). The effect of fermentation on the water absorption capacity of the flours was more pronounced in the cassava flour samples from TMS 30572 cassava variety, with an increase of 43.95%. The lowest increase in water absorption capacity was observed in flours produced from NR 8082 cassava variety, which increased by 20.5%. The values obtained in this study compared well with the values recorded by Achinewhu and Owuamanam (2001). Water absorption capacity measures the extent of water retention in flour and is reported to affect the ability of flour to form a paste (Olu *et al.,* 2012).

The increase in water absorption capacity of the fermented odourless flours could be attributed to the presence of high hydrophilic constituents, which increased with an increase in the fermentation time (Badifu and Akubor, 2001). During fermentation, proteolytic activity takes place, which causes an increase in the number of non-polar groups (Etudaiye *et al.,* 2009). The observed increase in water absorption capacity also suggested that the initial structure of the starch granules may have been exposed to a greater extent during fermentation due to the increased activities of microorganisms (Tanya *et al.*, 2006). Water absorption capacity is important in developing ready-to-eat foods; a high absorption capacity may assure product cohesiveness (Houson and Ayenor, 2002). In bread making, it is usually preferable to have flour that can absorb a large quantity of water. Measurement of absorption is done to determine the quantity of water the dough can absorb, which in turn indicates dough yield and shelf life. The comparative increment in water absorption capacity in fermented-odourless cassava flours over the unfermented cassava flours (HQCF) showed that fermented odourless cassava flours with high water absorption capacity are likely to produce better baked products. Better water retention suggests better performance in texture and/or comminuted meat and baked products.

Oil absorption capacity (OAC): The increased fermentation period increases the oil absorption capacity of cassava flour just like water absorption capacity. Significant differences (P< 0.05) existed in the oil absorption capacities of unfermented cassava flours (HQCF) produced from NR 8082, TMS 4 (2) and TMS 30572 and their fermented odourless cassava flours fermented for 72 and 24 hours, respectively. The fermented flours' oil absorption capacity increased with the fermentation time for all cassava varieties used. The flours produced from NR 8082 and TMS 419 cassava varieties had oil absorption capacities, which increased from 2.99g/g to 3.20g/g and from 2.96g/g to 3.41g/g, respectively (Tables 3). Flours produced from TMS 4(2) and TMS 30572 cassava varieties had oil absorption capacity values, increasing from 2.75g/g to 2.96g/g and 2.90g/g to 3.08g/g, respectively (Table 4). The percentage increases in the oil absorption capacities of the fermented odourless cassava flours were as follows: NR 8082 (8.0%); TMS 419 (15.2%); TMS 4(2)(7.6%) and TMS 30572 (6.2%). Oil absorption capacity is the ability of the flour protein to bind fat by capillary attraction physically. It is of great importance since fat acts as flavour retainer, gives a soft texture to food and improves the mouthfeel in addition to being energy source. Therefore, fermented odourless cassava flour is preferable to unfermented cassava flour (HQCF) for products that require higher oil absorption flour.

Emulsion capacity: The fermented odourless cassava flours showed a significant increase in emulsion capacity compared to the unfermented cassava flour (HQCF) in all samples (P < 0.05), except for the flours made from the TMS 30572 cassava variety, where no significant difference (P > 0.05) was observed in the increase of emulsion capacity in the fermented flours.The emulsion capacity of the flours increased with an increase in fermentation time in all the varieties of cassava used. The flours produced from NR 8082 and TMS 419 cassava varieties had emulsion capacity, increasing from 40.65% to 46.68% and from 39.03% to 47.23%, respectively. Flours produced from TMS 4(2) and TMS 30572 cassava varieties had emulsion capacity, increasing from 40.06% to 43.24% and from 40.10% to 42.97%, respectively. The effect of fermentation on the emulsion capacity of cassava flours was more pronounced in flours produced from bitter cassava varieties (NR 8082 and TMS 419). These flours recorded a greater percentage of emulsion capacity.

Emulsion capacity indicates the maximum amount of oil that can disperse in water and held together by protein in the flour. Meanwhile, emulsion stability indicates the ability of an emulsion with a certain composition to remain unchanged (Enujiugha *et al.*, 2003). The increase in emulsion capacity of the fermented flours was because of the increase in protein content in the fermented odourless cassava flours (Adebowale *et al.*, 2005). The capacity of protein to enhance the formation and stabilization of emulsion is important for many applications in food products like cake, coffee, etc. The samples' high emulsion capacity indicates that the flour can act as an excellent emulsifier in various foods.

Table 3. Effect of fermentation time on functional properties of unfermented cassava flour (HQCF) and fermented odourless cassava flour

Samples	Oil absorption capacity(g/g)	Emulsion capacity (%)	Viscosity (Pa.s)	Wettability (s)
NR 8082				
HQCF	2.99±0.10^{b}	40.6510.20^{d}	0.182+0.00	11.59±1.0^{a}
24h	3.08±0.01$^{at>}$	41.8411.00^	0.181±0.00	11.11±1.0^{a}
48h	3.11±0.01^{ab}	42.43±0.20^{c}	0.179±0.00	10.23±0.3^{ab}
72h	3.2010.10^{a}	44.06±0.00^{b}	0.178±0.00	8.10±0.10^{bc}
96h	3.23±0.10^{a}	46.68±0.02^{a}	0.17610.00	7.49±0.10
LSD	0.21	1.25	-	-
TMS419				
HQCF	2.96±0.051	39.03+1 .03^{c}	0.181 ±0.00	11.7210.20’
24h	3.11 ±0.01	38.8511. 10^{c}	0.179±0.00	10.51±0.01^{b}
48h	3.2010.20	41.07±2.02^{c}	0.178±0.00	9.75±0.04^{c}
72h	3.3510.05	44.73±0.00^{b}	0.176±0.00	8.17±0.02^{d}
96h	3.4110.40	47.23±2.00^{a}	0.17510.01	7.52±0.02^{c}
LSD	-	2.41	-	0.24

Values are means of triplicate analysis ± standard deviation. Means with different superscript letters along the columns, are significantly different (P < 0.05).

Table 4. Effect of fermentation time on the functional properties of unfermented cassava flour (HQCF) and fermented cassava flour

Samples	Oil absorption capacity (g/g)	Emulsion capacity (%)	Viscosity (Pa.s)	Wettability (s)
TMS 4(2)				
HQCF	2.75±0.05^{d}	40.06±1.00^{d}	0.186±0.00	10.49±0.01
24h	2.74±0.04^{b}	40.44±1.01^{b}	0.183±0.00	9.71±0.01
48h	2.80±0.02^{b}	41.54±1.00^{b}	0.181 ±0.00	8.14±0.02
72h	2.90±0.02^{a}	41.89±0.10^{b}	0.1+ ±0.00	7.08±0.03
96h	2.96±0.03^{a}	43.24±0.10^{a}	0.179±0.00	6.19±0.01
LSD	0.08	2.12	-	-
TMS 30572				
HQCF	2.90±0.05^{C}	40.10±1.00	0.184±0.00	11.74±0.02^{3}
24h	2.99±0.01^{b}	40.69±1.00	0.183±0.02	11.29±0.00^{b}
48h	3.02±0.02^{ab}	42.54±2.02	0.182±0.02	10.29±0.01
72h	2.99±0.00^{b}	42.97±1.98	0.178±0.00	8.45±0.05^{d}
96h	3.08±0.01^{a}	42.73±2.00	0.177±0.00	7.95±0.02^{e}
LSD	0.08	-	-	0.08

Values are means of triplicate analysis ± standard deviation. Means with different superscript letters along the columns, are significantly different (P< 0.05).

HQCF stands for high-quality cassava flour, and the fermentation period ranges from 24 to 96 hours. As a result, fermented odourless cassava flours may be more suitable for food formulations such as pastries, frozen desserts, cake batters, mayonnaise, and salad dressings compared to high-quality cassava flour.

Viscosity: The decrease in viscosity of the fermented odourless cassava flours over the unfermented cassava flours in all the cassava varieties used had no significant difference (P>0.05). An increase in fermentation time was observed to decrease the viscosity of the fermented flours irrespective of the variety. Flours from the bitter cultivars (NR 8082 and TMS 419) recorded the least viscosity from 0.182Pa.s to 0.176Pa.s and from 0.181Pa.s to 0.175Pa.s, respectively. Flours produced from the sweet cassava varieties (TMS 4(2) and TMS 30572) had their viscosity also reduced from 0.186Pa.s to 0.179Pa.s and from 0.184Pa.s to 0.177Pa.s, respectively. Comparatively, the viscosities of flours produced from the sweet cultivars were affected more by an increase in fermentation time with an equal percentage reduction of 3.8% for the set of flours produced from TMS 30572 and TMS 4(2), respectively. Flours produced from NR 8082 and TMS 419 recorded 3.29 and 3.3% percentage reductions. An extended fermentation period was found to decrease flour viscosity. The lower viscosity observed in the fermented flour was because of the hydrolysis of starch by microbial enzymes. Similar results were found in previous studies in which starch hydrolysis was proposed as a main factor for the decrease in viscosity (Vatanasuchart *et al.,* 2015). Viscosity was related to molecular weight, granular composition, pH and electrolytes of the solution (Aurand *et al.*, 2005). High viscosity indicates good-quality starch and low viscosity indicates that the starch has undergone some degree of degradation (Bolade, 2009). The decrease in viscosity was attributed to the enzymic breakdown of higher molecular weight polysaccharides and polypeptides to lower molecular weight dextrins and peptides during fermentation. Flour with higher amylose content gives a higher final viscosity. Ariahu *et al.* (1999) reported the viscosity-reducing effect of fermentation. The amount of aeration is dependent on the viscosity of the batter. A low-viscosity batter will fall short of holding the air cells in the structure, resulting in a low-volume cake. If the batter is thick, it would be difficult for the air bubbles to escape, resulting in high volume of cake (Sahi and Alava, 2003). Viscosity is the most commonly used parameter to determine a starch-based sample quality. It gives an idea of the ability of a material to gel after cooking. The variations in viscosity among the varieties of cassava used may be due to varietal differences and the age of the plant (Kenneth, 2013).

Wettability: The fermented odourless cassava flours had a significantly lower wettability than unfermented cassava flours (HQCF) in all cassava varieties. The wettability of flours made from the NR 8082 and TMS 419 cassava varieties decreased from 11.59 sec to 7.49 sec and 11.72 sec to 7.52 sec, respectively. Wettability decreased in flours made from the TMS 4(2) and TMS 30572 cassava varieties as fermentation time increased from 10.49 sec to 6.19 sec and 11.74 sec to 7.95 sec, respectively. The results revealed that as the fermentation periods increased, the time of wettability of the flours decreased. Fermented odourless cassava flours had the shortest wettability time, as opposed to unfermented cassava flours (HQCF). Wettability is a measure of how easily water can be dispersed and displaced by any sample, and fermented odourless cassava flours with the lowest wettability perform better in texture and in comminuted meat and cakes. Fermentation was found to reduce Mucuna flour wetting time (Udensi and Okonkwo, 2006). The benefits of using the fermentation process to produce odourless cassava flours far outweigh those of not fermenting cassava to produce high-quality cassava flour (zero-time fermented cassava flour-HQCF).

The fermentation periods yielded good quality odourless cassava flours in terms of functional capacities because they had higher values of water absorption capacity, oil absorption capacity, foaming capacity and emulsion capacity. However, despite the cassava variety, the best fermentation time to obtain odourless cassava flours with the best functional properties was 48 hours. Generally, fermented odourless cassava flours had better flour qualities and could produce cookies, biscuits, cakes, comminuted meat products, infant formulas and bread production.

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