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Optimization of Indigenous Food (Gari) Fermentation with Respect to Time and Texture

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Abstract

Indigenous fermented foods are brought about mainly by the action of microorganisms which in turn results in desirable biochemical changes, thereby leading to optimization and modification of the fermented product. An example of indigenous fermented food in Nigeria is cassava, (*Manihot esculenta* Crantz). However, cassava roots are fermented in various parts of Africa for a number of reasons which includes removal of substantial quantity of Cyanide, optimization of the texture into a more desirable product and to provide a desirable sour taste. Cassava is also fermented in order to improve the texture, nutritional value, taste, aroma, as well as enhancing the shelf-life of the desired product. The aims of this research work are to optimize cassava, an indigenous food fermentation with respect to texture and to ferment cassava at different time duration (24, 48 and 72 hours) for the production of gari paste, to carry out TPA (hardness, cohesiveness, adhesiveness, springiness) in order to determine if these fermentation times will have effect on these textural parameters. Gari paste, a product of cassava fermentation at different duration of fermentation (24, 48 and 72) hours were individually subjected to TPA using Brookfield CT3 texture analyzer with a compression speed of 10mm/S, percentage compression of 75%, trigger load of 6.8g, and 2 cycles. The textural parameters being analyzed were hardness, cohesiveness, adhesiveness and springiness. Fermentation of cassava at 24, 48 and 72 hours of fermentation did not have direct effect on TPA cohesiveness of gari paste as the values obtained were generally low as cohesiveness is linked with the internal bond of a material implying that the higher the deformation of a product, the higher the deformation of the internal structures and hence, low levels of cohesiveness. TPA adhesiveness of gari paste at 24, 48 and 72 hours of fermentation on the other hand had inconsistent values and were not linked to fermentation rather, on the age of the cassava as well as the processing method while TPA springiness of gari paste fermented at 24 hours were low 0.86 and 0.87 respectively for the first and second cycle. The values increased at 48 hours of fermentation. These values were 11.87 and 12.31 respectively. At 72 hours of fermentation, the springiness obtained for the first cycle fell within the same range as that of 48 hours (11.83), while it decreased to 0.9 for the second cycle. The decrease was caused by the test protocol, shape of the sample and volume fraction resulting from decreased granule swelling power, and low amylose leaching, a product of high granule internal stability. Fermentation showed significant effect on TPA hardness of gari paste at the various fermentation times, mostly at 72 hours of fermentation due to decrease in starch content. It was observed that the higher the fermentation time, the higher the moisture loss which in turn increased the hardness of the gari paste, reduced the springiness, reduced the cohesiveness and reduced the adhesiveness. The statistical analysis for the determination of P-values showed no significant difference between fermentation times and the test parameters.

Keywords: *Indigenous Food, Gari, Fermentation, Statistical Analysis, Time, Texture, Hardness, Cohesiveness*

1. Introduction

Fermentation remains one of the oldest methods of food preservation deeply rooted in traditional cultures, which is speculated to have been developed through the years by women with the sole intention of preserving food for longer period, time of scarcity, imparting desirable flavour and aroma into foods and for the reduction of toxicity [34]. There are some foods, indigenous to Africa which could be cultivated, fermented and produced for domestic as well as commercial purposes. These foods include those obtained from cereals; Ogi, Burukutu, Pito, kwunu, otika. Those derived from fruit fermentation; Agadagidi, Cacao wine, Eketeke, Ugba, those fermented from tubers; Abacha, Elubo, Fufu, Gari, Loiloi, Kokobele and those obtained from tree sap; Ogogoro, palm wine [12]. However, Blandio et al. (2013) discuss that right from the time of civilization, there has been a close link between the activities of man and the role of microorganisms in fermentation although little attention was paid to the role played by microorganisms in food fermentation. Cassava is classified as a tuber which could be fermented for the production of gari, fufu, abacha, cassava chips. However, fermentation of cassava into gari which is the subject area of this research work involves microbiological and biochemical changes of starch metabolism by lactic acid bacteria thereby giving rise to organic acid and a significant reduction in pH [22]. Fermented foods could lead to food poisoning if not fermented properly or if the production environment is not hygienic enough [9]. An example is cassava tubers which contains hydrogen cyanide which could lead to problems associated with some tissues and organs of the body if not fermented properly [37]. According to Oyewole and Isah [30], ataxic neuropathy and thyroid disease is becoming high in Africa as a result of inability to ferment cassava tubers properly which contains hydrogen cyanide. Obilie et al. [20] noted that the reason for fermenting cassava roots before the production of gari includes removal of hydrogen cyanide, optimizing the texture, nutritional value, imparting a desirable sour taste and aroma, and extending the shelf life of the product. Gari is an indigenous cassava product which is fermented in order to optimize the texture of the product. According to Ogugbue et al. [23] gari is a granular, starchy essential fermented based food in Africa with high amount of energy, obtained from cassava (*Manihot esculenta* Crantz). Processing of cassava involves peeling of fresh cassava tubers, washing, grating, dewatering, fermentation and frying the grated cassava mash into gari [30]. Gari can be consumed dry, socked in water along with fish, milk, sugar, salt, or stirred with hot water and consumed with soup. Texture is an important characteristic that can be used in most food industries to ascertain quality and acceptability of food (Opera and Chen 2013). Therefore, having sound knowledge on the textural properties of foods is essential in ensuring product's acceptability, measurement, control, and optimization of food product.

1.2. Overview of Cassava

Cassava (*Manihot esculenta* Crantz) is an important root crop in the tropics which makes up for a greater part of the diet of the population [6]. According to Jensen et al. [14], cassava is a durable crop which yields high increase even when grown in minor and unfavourable conditions, its major components are water (60g $100g^{-1}$), Carbohydrate (38g $100g^{-1}$) and limited protein, fat and fibre content of 1.4, 0.28 and 1.8g $100g^{-1}$ respectively. Cassava is routinely fermented in West Africa by adopting several methods before being consumed. Oyewole and Ogundele [29] noted that the several methods which cassava can be fermented before consumption are classified into two groups, which are submerged fermentation and solid state fermentation. Submerged fermentation process is achieved by the roots being soaked in water in the case of fufu production while solid state fermentation does not require the roots being soaked in water as in the case of gari production. According to Obilie et al. [20], cassava roots are fermented in various parts of Africa for several reasons which include obtaining a desired sour product, getting rid of substantial quantity of cyanide and for the modification of the texture of the products. Cassava contains cyanide which could be present in two forms; Linamarin and Lotaustralin. This cyanogenic glucoside in cassava could pose some health problems to the body if proper fermentation does not occur to reduce this anti-nutritional substance [8]. This finding is in line with the research conducted by Nyirenda et al. [19] where the authors reported that linamarin and lotaustralin compounds are incorporated in cassava which releases a toxic chemical substance, hydrogen cyanide when being processed or chewed. He also mentioned that the breakdown of cyanogenic glucosides; linamarin and lotaustralin to hydrogen cyanide comprises of cyanogenic intermediates in the form of cyanohydrins (α-hydroxynitriles). Furthermore, Simeona and Fishbein (2004) discuss the toxic effects of insufficiently processed cassava to include acute poisoning, chronic dietary consumption, problems associated with the central nervous system and cardiovascular system. This findings correlates with the research carried out by Orjiekwe et al. [27], where the authors investigated the health disorders associated with poorly processed products as a result of sub-lethal amount of cyanogens to include aggravation of goiter, cretinism, cardiovascular diseases like encelopathy and neutropathy which could lead to death or severe damage to the heart, brain and degeneration of the optic nerves. Therefore, there is need for proper processing and fermentation of cassava in order to minimize toxicity of the product.

1.3. Overview of Gari, an Indigenous Food Fermented from Cassava

Gari is creamy-white gritty flour with a sour taste and a desirable flavour produced from the fermentation of fresh cassava tubers. According to Olopade et al. [25], gari is the most regularly consumed food in Nigeria and about 70% of the whole cassava production in Nigeria is used in the production of gari. He further mentioned that gari makes up a greater part of the diet in West African Sub region. Studies carried out by Jekayinfa and Olajide [15] reveal that gari is classified solely on the texture, the length of fermentation, indigenous place of production and the colour, based on the addition or no addition of palm oil. Furthermore, gari when soaked in water has a high swelling capacity and has the ability to absorb approximately four times of its volume in water. Ogugbue et al. [24] reported that Gari is highly rich in starch and fibre content, and consist of some important vitamins like vitamin A that is required for good health. Additionally, what makes gari very filling when consumed is the high fibre content which also constitutes significant reduction in constipation and bowel disease. However, there are various ways that gari can be consumed; the various ways as reported by Egwim et al. [7] includes, soaking it in water directly without further cooking and consuming it by complementing with sugar, smoked fish, roasted groundnuts, coconut, cooked cowpea, milk or stirring the processed gari in hot water to form a stiff paste known as 'Eba'. The paste (Eba) is usually consumed by making small balls from it and eating by dipping it in soup either by swallowing or chewing [4, 11].

1.4. Fermentation of Cassava into Gari

Ray and Sivakumar [32] discussed that gari production is a laborious procedure of which the production method tend to be different depending on the region. However gari production involves peeling of fresh cassava tubers, washing of the peeled tubers, grating and packing the grated mash into woven bags and tying the bag firmly. Dewatering is then allowed to take place by placing heavy objects on top of the bag to enable the juice drain out while allowing the mash to undergo solid state fermentation for 3-4days [10]. Studies done by some researchers have shown that fermentation of the grated tubers plays important role in preserving the desired gari product, help in imparting flavour to the gari as well as help in a significant reduction of cyanide and overall functional and textural properties of the product [23]. Similarly, Owuamanam et al. [28] in their research observed that fermentation enhances taste of gari while also softening the fermented mash and as a result, enhances the release of hydrogen cyanide present in cassava tubers. After the process of dewatering, the wet cake is sieved into small pieces called grits, it is then roasted or fried in a hot pan to form a dry granular product called gari [13]. Ahaotu et al. [2] in their research reported that *Alcaligens faecalis, Lactobacillus plantarum, Geotrichum candidum and Leuconostoc cremoris* are mostly the predominant

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microorganisms found during cassava fermentation for the production of gari.

2. Materials

a. Aluminium foil
b. Bowl
c. Brookfield CT3 texture analyser machine
d. Cassava
e. Dari
f. Frying pan
g. MRS agar plate
h. MRS BROTH
i. Sieve
j. Wooden spatula

2.1. Method

One (1) kg out of the 6kg grated cassava mash which was subjected to fermentation was taken out after 24 hours of fermentation. The mash was sieved and transferred to a frying pan. The hob was turned on and the mash was fried for 5 minutes at a temperature of 150°C by continuously stirring it at 1 minute interval. After the frying process, a fine and colourless granule known as gari was obtained. It was allowed to cool and a paste was made from it by pouring a hot water in a bowl and using a wooden spatula to stir it until a semi-solid paste was obtained. It was wrapped in an aluminium foil and taken to the lab for texture profile analysis. Gari paste made after 24 hours of fermentation was placed on the flat surface of the platform of Brookfield CT3 texture analyser machine. The position of the instrument base was determined by clearing the base and allowing the plunger to come in contact with the base table of the Brookfield texture analyser machine. The length of the sample was measured with instrument trigger load of 6.8g. This was achieved by placing the gari paste at 24 hours of fermentation on the platform of the Brookfield texture analyser and allowing the plunger to compress the sample. The same procedure was repeated for cassava fermented for 48 hours and 72 hours.

2.2 Test Parameters

a. Trigger load of 6.8g
b. Number of cycles = 2
c. Percentage compression of 75% for the first and second cycles without delay.
d. Test speed of 10mm/Sec.
e. Brookfield CT3 instrumental texture analyser was used to analyse different textural properties of the gari paste at 24, 48 and 72 hours of fermentation respectively.

3. Results

3.1. Growth of *Lactobacillus plantarum* On MRS Agar

Colonies of *Lactobacillus plantarum* were observed spreading across all the plates. The plates showed good growth with large cream-whitish colonies. Examples of the MRS agar plate showing the growth of *Lactobacillus plantarum* is shown in Figure 1.

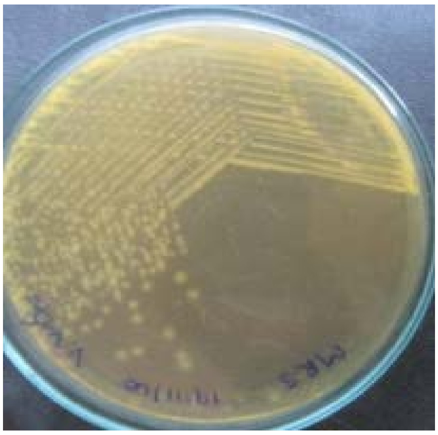

Figure 1: Growth of Lactobacillus plantarum on MRS agar

3.2. Growth of *Lactobacillus Plantarum* in MRS Broth

Turbid growth was observed after incubating the MRS broth containing *Lactobacillus plantarum.*

Figure 2: MRS broth containing Lactobacillus plantarum.

3.3. Texture Profile Analysis (TPA) Hardness of Gari Paste at 24, 48 and 72 Hours of Fermentation

TPA hardness was carried out on gari paste at 24, 48, and 72 hours of fermentation as shown in Table 1. From the result, it was observed that the hardness of gari paste at 24 hours of fermentation for the first cycle was 1105.0 while it increased to 1206.5 for the second cycle. There was a slight decrease in the hardness values obtained at 48 hours of fermentation. The hardness values obtained at 48 hours of fermentation for the gari paste was 1077 and 991 respectively for the first and second cycle. For the hardness of gari paste at 72 hours of fermentation, the values obtained for the first and second cycle respectively decreased further to 918 and 991, although the second cycle was slightly higher than the first as shown in Table 1;

Table 1: TPA of Gari at 24, 48 and 72 Hours of Fermentation Showing the Values obtained with respect to Hardness

TPA Parameter	24 Hours	48 Hours	72 Hours
Hardness	1105.0	1077	918
	1206.5	991	991

3.4. Texture Profile Analysis (TPA) Cohesiveness of Gari At 24, 48 and 72 Hours of Fermentation

The TPA cohesiveness carried out on gari paste at 24, 48 and 72 hours of fermentation is summarized in Table 2. These values were low, although some were found to be slightly higher than others. From the result, the cohesiveness of gari fermented at 24 hours for the first cycle was 0.26 while it slightly increased to 0.33 for the second cycle. For the cohesiveness of gari paste at 48 hours of fermentation, the value obtained for the first cycle was 0.42 while the value slightly decreased to 0.39 for the second cycle. At 72 hours of fermentation, the cohesiveness value for the first cycle was seen to be 0.17 while it was 0.39 for the second cycle.

Table 2: TPA Cohesiveness of Gari At 24, 48 And 72 Hours of Fermentation Showing the Respective Values Obtained for the First and Second Cycle.

TPA Parameter	24 Hours	48 Hours	72 Hours
Cohesiveness	0.26	0.42	0.17
	0.33	0.39	0.39

3.5. Texture Profile Analysis (TPA) Adhesiveness of Gari at 24, 48 And 72 Hours of Fermentation

TPA adhesiveness of gari paste at 24, 48 and 72 hours of fermentation is summarized in Table 3. The adhesiveness of gari paste at 24 hours of fermentation was 9.72 for the first cycle and then increased to 12.72 for the second cycle. For adhesiveness at 48 hours of fermentation, the value obtained for the first cycle was 17.41 while for the second cycle, the value decreased to 10.93. At 72 hours of fermentation, the value obtained for the first cycle was 13.50 while for the second cycle, the value obtained was the same as that of the second cycle of adhesiveness at 48 hours of fermentation (10.93).

Table 3: TPA Adhesiveness Of Gari At 24, 48 and 72 Hours of Fermentation Showing the Respective Values obtained for both the First and Second Cycles

TPA Parameter	24 Hours	48 Hours	72 Hours
Adhesiveness	9.72	17.41	13.50
	12.42	10.93	10.93

3.6. Texture Profile Analysis (TPA) Springiness of Gari at 24, 48 And 72 Hours of Fermentation

The TPA analysis springiness of gari paste fermented at 24 hours followed a similar trend, 0.86 and 0.87 for the first and second cycle respectively. For 48 hours of fermentation, springiness for the first cycle was 11.87 while that of the second cycle was 12.37. At 72 hours of fermentation, the springiness for the first cycle was 11.83 while there was an observable decrease in the value obtained for the second cycle of springiness of gari at 72 hours of fermentation, 0.9. Table 4 summarizes the result obtained as follows;

Table 4: TPA Springiness of Gari at 24, 48 and 72 Hours of Fermentation showing the Respective Values for the First and Second Cycles

TPA Parameter	24 Hours	48 Hours	72 Hours
Springiness	0.86	11.78	11.83
	0.87	12.31	0.9

3.7. Statistical Analysis for Determination of Probability of Difference (p-value) between the Fermentation times and the Test Parameters

Statistical analysis (ANOVA: Single factor) was done to determine the significant differences between the various test parameters; hardness, cohesiveness, adhesiveness and springiness at 24, 48 and 72 hours of fermentation. The P-value used for the statistical analysis was based on ($P<0.05$). The P-value obtained when the hardness of gari fermented at 24, 48 and 72 hours were analysed statistically was 0.102, for the comparison of the cohesiveness of gari fermented at 24, 48 and 72 hours, the P-value was 0.456, the P-value obtained for the comparison of adhesiveness of gari fermented at 24, 48 and 72 hours was 0.373 while for the springiness of gari fermented at 24, 48 and 72 hours, the P value was 0.183. From the result, it was observed that there were no significant differences between the various test parameters and gari fermented at 24, 48 and 72 hours as the P-values obtained were all greater than 0.05 ($P> 0.05$). The summary of this result is shown in Table 5. Statistical analysis (ANOVA: single factor, carried out for the statistical analysis is summarized in appendix 1, 2, 3 and 4.

Table 5: Summary of the P-values obtained between the various test conditions at 24, 48 and 72 hours of fermentation

TPA Parameters at 24, 48 and 72 Hours of Fermentation	P-Values
Hardness	0.102
Cohesiveness	0.456
Adhesiveness	0.373
Springiness	0.183

4. Discussion

In this study, TPA parameters (hardness, cohesiveness, adhesiveness, springiness) were applied to ascertain the changes on the textural properties of cassava paste and to determine the effects of the varying fermentation time on the textural properties of cassava paste. TPA methodology has been used to measure the textural attributes of food which gives a good relationship with organoleptic properties [4, 5]. Sensory evaluation was not included for this study.

4.1. Growth of *Lactobacillus Plantarum* in Mrs Agar and Mrs Broth (Oxoid)

Pure strains of *Lactobacillus plantarum* were successfully isolated from starter culture of *Lactobacillus plantarum* obtained from Microbiology Laboratory, Coventry

University. Starter culture of *Lactobacillus plantarum* was chosen for this study because research done by various authors have revealed that lactic acid bacteria is the most predominant microorganisms incriminated in food fermentation, of which *Lactobacillus plantarum* has been studied extensively and it has been observed that it is one of the lactic acid bacteria incriminated in cassava fermentation. Ahaotu et al. [2] in their research had *Lactobacillus plantarum* as one of the isolated microorganisms in the fermentation of undewatered cassava pulp.

MRS agar was used as the agar of choice for the growth of *Lactobacillus plantarum* due to some literatures which revealed that MRS agar is a favourable growth medium for lactic acid bacteria. This observation was in conformity to the study conducted by Bujance et al. (2006) who mentioned that MRS agar is the most frequently used agar that favour the growth of *Lactobacilli*, as well as non-*Lactobacilli* based on their successful isolation, identification and enumeration of *Lactobacillus plantarum* on MRS agar. However, the colour and type of colonies produced by *Lactobacillus plantarum* on MRS agar in this study was in contrary with the study of Bujance et al. (2006). In their study, *Lactobacillus plantarum* produced yellow colonies with yellow hallow due to the addition of sorbitol to their MRS agar, while in the present study, *Lactobacillus plantarum* was seen to produce large cream white colonies on MRS agar plate. This observation was possibly due to acid production by lactic acid bacteria [31].

Lactobacillus plantarum showed turbid growth on MRS broth, this suggests that the bacteria thrived well in the broth. The centrifuging and washing of *Lactobacillus plantarum* grown in MRS broth twice with PBS was similar to the research carried out by Bujalance et al. [3] which during the isolation of *Lactobacillus plantarum* centrifuged and washed the bacteria twice with PBS. Putri et al. [31] in an attempt to analyse the survival and long term preservation of bacteria in water and in PBS compared the growth and survivability of gram positive bacteria *Lactobacillus monocytogens, Staphylococcus aureus* and a gram negative bacteria, *Escherichia coli* in water and PBS. It was observed that the gram negative bacteria thrived well in water than in PBS while the gram positive bacteria survived longer in PBS and declined in growth in water. Linking this study with the present study, *Lactobacillus plantarum* is a gram positive bacteria, and this suggests that it can survive for a longer period of time in PBS than in water.

4.2. Texture Profile Analysis (TPA) Hardness of Gari Paste at 24, 48 And 72 Hours of Fermentation

According to Bourne [5], hardness is the maximum force required to compress a sample. Rodriguez-Sandoval et al [33] described Hardness as a parameter used in quantifying how stiff a material is, by applying different methodologies. Despite the fact that hardness values of gari paste at 24, 48 and 72 hours of fermentation were observed to be generally high as presented in Table 1 and there was still a trend of the values decreasing slightly further with increase in the fermentation time. From the result in Table 1, hardness of gari paste at 24 hours of fermentation for the first and second cycle was 1105.0 and 1206.5 respectively. These values were however high, although the hardness value for the second cycle tend to be higher than the first cycle. Although literatures have not been found with similar values of hardness, the difference in the experimental data in the present study with the data from existing studies could be attributed to the fact that TPA was carried out on gari paste, a product of cassava fermentation in the current study, while TPA was carried out on different product in previous studies. For example, Rosenthal [35] carried out TPA on gelled system, and detected hardness value of 0.154, TPA on noodles and obtained a hardness value of 0.447 while Oduro-Yeboah et al. [21] obtained the hardness values of 1.72, 1.35, 0.55, 2.00 (in replicates) for cassava plantain flour fufu, and 1.65 for pounded fufu. Several other researchers carried out TPA on cassava dough of which hardness was one of the parameters being analysed. Numfor [18] in an attempt to analyse the physicochemical changes in cassava starch and flour associated with fermentation and its effect on textural properties obtained hardness values of 2.25, 2.03 and 2.13 for native cassava, cassava fermented naturally and cassava fermented with cultures respectively. In this study, the reason why hardness values of gari paste at 24 hours of fermentation were high could have been as a result of high amount of starch content present in cassava. As discussed in the literature, starch is a major characteristic used in measuring the texture of root crops. Numfor et al. [17] reported that hardness is a measure of various components of intermolecular forces of starch molecules and swollen granules in the paste. This implies that cassava is rich in starch, and as fermentation begins at 24 hours, the high amount of starch present in cassava still remains high and does not get degraded immediately due to the short fermentation time, thereby leading to stiffness or hardness of the gari paste, but as fermentation time increases, the starch content decreases thereby slightly reducing the hardness of the gari paste to a considerable amount. This observation was in line with the research conducted by Afoakwa et al. [1], where the authors pointed out that starch content tends to decrease as fermentation time increases. To further ascertain this point, they carried out a research in an attempt to analyse the souring and starch behaviour during co-fermentation of cassava and soybean into gari. Their result revealed that the starch content decreased with increasing fermentation time; the starch content at 24 hours and 48 hours were 62.32 (24 hours) versus 60.46 (48 hours), 60.81 (24 hours) versus 58.43 versus (48 hours), 59.04 (24 hours) versus 54.30 (48 hours) and 55.21 (24 hours) versus 52.56 (48 hours), having an overall effect on the hardness of the gari paste. As fermentation proceeded up to 48 hours, the hardness values of gari paste were observed to reduce slightly, compared to the hardness values obtained at 24 hours of fermentation. The hardness values of gari paste for the first and second cycle at 48 hours of fermentation were 1077 and 991 respectively, implying that the starch content began to decrease as the fermentation time began to increase, as well as the gari paste not being as hard as 24 hour gari paste. Similarly, at 72 hours of fermentation, the values obtained for the gari paste were 918 and 991 respectively for the first and second cycle, meaning that these values were lower than the hardness values obtained at 24 and 48 hours of fermentation, even though the hardness value for the second cycle at 72 hours of fermentation was the same as that of the second cycle at 48 hours of fermentation. Afoakwa et al. [1] also added that the conversion of starch molecules into sugar by microorganisms during fermentation process could also be responsible for the decreased starch content with increasing fermentation time. Trong, Walter and Hamann (1997) detected high correlations of hardness between instrumental hardness and sensory hardness and described it as factors which describes the disintegration of food in the mouth, suggesting that the key factor in hardness is how strongly the tissues are held together. Rodriguez-Sandoval et al. [33] noted that high values in the hardness of gari paste could have resulted from increased association with volume fraction of free starch, which produces an elastic network in an uninterrupted phase within the system. They also added that the interactions that existed between the granules which acted as filler in the matrix as well as an elastic framework could as well account for increase in hardness. However, in the study of TPA in gelled system, Rosenthal [35] noted that when the speed of compression is increased, it leads to a corresponding increase in hardness. These findings contradicted with the present study, as the speed of compression used was 10mm/seconds and were constant for all the test parameters. The hardness values in this study were observed to be higher than some and vice versa at different fermentation times. From the researcher's point of view, effect of fermentation on hardness could have probably been seen to decrease further if fermentation was extended to 96 and 120 hours of fermentation.

4.3. Texture Profile Analysis (TPA) Cohesiveness of Gari Paste at 24, 48 And 72 Hours of Fermentation

Rodriguez-Sandoval et al. [33] defined cohesiveness as the direct work required to overcome the internal bonds of a material. As shown in Table 2, TPA cohesiveness carried out on gari paste at 24, 48 and 72 hours of fermentation showed low values of cohesiveness with respect to these fermentation times. At 24, 48 and 72 hours of fermentation for the first and second cycle, the cohesiveness values obtained for the gari paste were 0.26 and 0.33 (24 hours), 0.42 and 0.39 (48 hours), 0.17 and 0.39 (72 hours) of fermentation as shown in Table 2. Many authors have obtained low values of cohesiveness while carrying out TPA on various products These low levels of cohesiveness were in line with the study of Numfor [18], where cohesiveness of 0.68, 0.75 and 0.79 were obtained for native flour of cassava, cassava fermented naturally and cassava fermented with culture respectively, although with slight differences in values with the cohesiveness obtained in the present study. Also, Rosenthal [35] obtained a low cohesiveness of 0.167 in the study of TPA in a gelled system. Singh et al. [38] also obtained low cohesiveness values of 0.094, 0.29 and 0.55 in triplicates in a study on the instrumental texture analysis (TPA) of Dates fruits. Furthermore, Oduro-Yeboah et al. [21] in their research on instrumental and sensory texture profile characteristics of fufu to plantain flour obtained low cohesiveness value 0.167. These observations suggests that since by definition, cohesiveness has to do with the direct function of the work required to suppress the internal bonds of a material, it therefore implies that the more deformed a structure is, the more deformed the internal structure would be, thereby resulting in low levels of cohesiveness [35]. This consideration was further supported by Numfor [18] who discussed that cohesiveness is linked with intermolecular forces within a food chain, and a decrease in the values of cohesiveness could be attributed to such forces. However, it is worth mentioning that the inability of the starch granules to produce adequate amount of amylose could have contributed to the low levels of cohesiveness [18]. Similarly, Numfor et al. [16] reported a decrease in the cohesiveness of fermented cassava paste and they attributed these decrease in cohesiveness to reduced volume fraction, resulting from decreased lower granule swelling power and low amylose leaching, a product of high granule internal stability. Linking these observations to the present study with respect to several literatures on cohesiveness and the values obtained, it was clearly seen that the values of cohesiveness were generally low, irrespective of the kind of the product subjected to analysis, as well as the nature of the analysis done. Hence, fermentation, as well as fermentation time may not have contributed to a larger extent to the cohesiveness of gari paste or any food product as many authors worked on different products, and as the values did not follow a particular trend of fermentation with increase in fermentation, rather, cohesiveness is linked with the internal bonds of a material and it would be expected that the higher the deformation of a product, the higher the deformation of the internal structures.

4.4. Texture Profile Analysis (TPA) Adhesiveness of Gari Paste at 24, 48 And 72 Hours of Fermentation

In the TPA of adhesiveness of gari paste at 24, 48 and 72 hours of fermentation, there were discrepancies in the results obtained, as the values were inconsistent. From Table 3, at 24 hours of fermentation, the values of adhesiveness obtained for both the first and second cycle of gari paste were 9.72 and 12.42, at 48 hours of fermentation, the adhesiveness values of the gari paste for the first and second cycles were 17.41 and 10.93 while at 72 hours of fermentation, the values for adhesiveness were 13.50 and 10.93 for the gari paste for both cycles respectively as shown in Table 3. These discrepancies in adhesiveness cannot be explained as individual entity neither can they be attributed to effects of fermentation as well as the various fermentation time, rather, conclusions could be drawn based on general observations. Though adhesiveness values of gari paste would have been expected to be decreasing as fermentation time increases, the shape of the sample subjected to instrumental test, could have effect some changes to the test protocol [35]. Numfor et al. [17] obtained inconsistent values on the adhesiveness of native cassava flour, cassava fermented naturally and those fermented with culture. Although these values were not revealed in their research, they attributed the inconsistencies to the cassava paste spreading over the contact surface of the texture analyser machine. According to Singh et al. [38], adhesiveness can be defined as the work required to overcome the attractive force between a product and the contact surface. Also, Rodriguez- Sandoval et al. [33] defined adhesiveness as the negative force area. However, the possible explanations behind these discrepancies could have resulted from the chemical constituents, physicochemical characteristics, morphology and molecular characteristics of the starch present in the cassava roots, structural components of the cassava tubers subjected to fermentation like cell solid component, tugour pressure that makes up the cell, mechanical ability of the cell walls to deformation and the cohesiveness supplied by the binding material of the middle lamella [36]. Oduro-Yeboah et al. [21] reported that adhesiveness at moderate level is a common characteristics of paste-like foods of which they obtained moderate adhesiveness values of 0.30, 0.36, 0.59, 0.34 in (replicates) for fufu from cassava plantain-flour while they obtained an adhesiveness value of 1.2 for pounded fufu though in their research, fermentation was not part of the scope of the work. In this present study, the researcher's possible opinion to these discrepancies is that though the adhesiveness values would have been expected to follow a trend of slight decrease as fermentation time increases due to the fact that fermentation improves the texture of foods as reviewed in the literature, these discrepancies in adhesiveness with the different fermentation times could be attributed to the different varieties of the cassava tubers used for this study as they were bought randomly from the market for the purpose of this study. These varieties in the cassava, possibly, the processing method as well as the age of the cassava when it was harvested and how long it was kept in the shop before purchase could have also contributed to these inconsistent values as well as having an effect on the adhesiveness of the gari paste, thereby giving rise to inconsistent values in the adhesiveness of the gari paste. Ogunnaike et al. [22] in the study of the effects of submerged and anaerobic fermentations of cassava flour (Lafun) affirmed that some of the factors and limitations and that brings about changes in the overall texture and quality of Lafun flour, contrary to the anticipated quality and texture could be the processing method, environmental factor, the variety of cassava used, the age of the cassava and the fermentation process.

4.5. Texture Profile Analysis (TPA) Springiness of Gari Paste at 24, 48 And 72 Hours of Fermentation

The TPA springiness result for gari paste at 24, 48 and 72 hours of fermentation is shown in Table 4, and the values obtained at 24 hours of fermentation for the springiness of gari paste were 0.86 and 0.87 respectively for the first and second cycles. These values were low and correlated with the research of Oduro-Yeboah et al. [21], where the authors obtained similar springiness values ranging between 0.85-0.90 while carrying out TPA on fufu from cassava plantain-flour though without fermentation. Springiness was defined by Opara [26] as a sample's ability to return back to its original state after the force of deformation is removed from it. Numfor et al. [17] attributed decrease in springiness to volume fraction resulting from decreased granule swelling power, and low amylose leaching, a product of high granule internal stability. At 48 hours of fermentation, one would have anticipated a further decrease in in the springiness of the gari paste, since fermentation is supposed to improve the texture of the gari paste at 48 hours of fermentation but rather, the values were in contrary to what was anticipated. The values obtained for the springiness of gari paste at 48 hours of fermentation for the first and second cycle were 11.87 and 12.31 respectively. At 72 hours of fermentation, the springiness of gari paste for the first and second cycle was 11.83 and 0.9 respectively. From the result at 48 and 72 hours of fermentation, it was keenly observed that the values of the springiness of the gari paste at 48 and 72 hours of fermentation fell within the same range, implying that there was no effect of fermentation on the springiness at these fermentation times. However, the value of the second cycle at 72 hours of fermentation began to decrease. This suggests that if fermentation time had proceeded to 96 and 120 hours, probably, there would have been visible variations, as well as effects of fermentation on the springiness of the gari pastes. Nonetheless, there are some factors which could have impeded the values of the springiness of gari paste not to follow a trend of decrease with respect to these fermentation times, these factors includes; texture of the gari paste, owing to chemical composition, the physicochemical characteristics, morphology, molecular structure of the starch present in the cassava tubers, quantity, as well as the quality of other root components, macro components of the cassava roots, physicochemical and structural components of the tuber tissues, for example, solid component of the cell, turgour pressure of the cell, the ability of the cell wall to withstand mechanical deformation, cohesiveness supplied by the cementing material of the middle lamella, as well as the rate of hydration of the gari paste [36]. However, from the researcher's point of view, the protocol in performing this experiment in terms of cassava fermentation for the production of gari paste, the test protocol, the shape of the product which might result in a slight change in the test protocol might be a contributing factor towards the results being in contrary to what was anticipated.

4.6. Statistical Analysis for Determination of Probability of Difference (P-Value) Between the Fermentation Times and the Test Parameters

From the results shown in Table 5, one way analysis of variance, single factor revealed that the P value obtained when hardness was measured over the fermentation times (24, 48 and 72 hours) was 0.102 ($P>0.05$). The P value obtained when cohesiveness was measured over these fermentation times was 0.456 ($P>0.05$), for the adhesiveness measured over these fermentation times, the P value was 0.373 ($P>0.05$), while for the springiness measured over these fermentation times, the P value obtained was 0.183 ($P>0.05$). These observations imply that there was no significant difference between the various parameters measured over these fermentation times (24, 48 and 72 hours). However, this statistical confidence may not be relied upon or justified as enough replicates of the sample were not used, and therefore cannot really be verified as statistical analysis works well with a wider interval of samples. Notwithstanding the insignificant statistical differences, this does not imply that the products are identical as the key factor responsible for these insignificant differences in P values was as a result of the tests not replicated. Although proximate analysis, evaluation of sensory parameters and effects of fermentation on hydrogen cyanide were not the aims and objectives of this research work, Irtwange and Achimba [11] in their research on the effect of duration of fermentation on the quality of gari, showed that hydrogen cyanide decreased as the duration of cassava fermentation increased. The result of the analysis of variance also showed a high significant effect of the duration of cassava fermentation on hydrogen cyanide at ($P\leq 0.01$) as the hydrogen cyanide was able to be degraded to a significant level with increase in the duration of fermentation. The result of the proximate analysis also showed that there was a significant effect of the duration of fermentation on the swelling index of gari at ($P\leq 0.01$), implying that as fermentation lasted for up to 3 days, microorganisms releases organic acid and amylase which degrades starch, thereby resulting in increased swelling ability. From the result of the sensory evaluation they obtained, it was observed that the duration of cassava fermentation had an effect on the colour, aroma and sourness of the gari. Cassava fermented between 3-5 days produced gari with the most desirable aroma, colour and sourness. Linking their results to this present study, no significant differences between the various fermentation times and the different test parameters suggests that the products may be different at different fermentation times with respect to aroma, colour, sourness, swelling capacity and effect of hydrogen cyanide though these analysis were not carried out, but from a texture point of view based on this study, these parameters make very little difference over the three fermentation times. With regards to reports on TPA parameters, Rosenthal [35] argued that researchers make reference to their results as if the results are unconditional and directly similar to other results. However, the data obtained in this research suggests that comparing and contrasting TPA results would only be well founded if similar test protocols, as well as test geometry, speed of compression, percentage compression, are all the same. This argument is well grounded as some of the literatures reviewed in this research carried out TPA with different probes and plungers, different test speeds, different trigger load, different percentage of compressions as well as different test geometries compared to the present study, which would not likely produce the same result. For example, Oduro-Yeboah et al. [21] carried out TPA on fufu made with cassava and plantain flour using TA-XT2i, Stable Micro Systems texture analyser and adopted a speed of 1.0mm S^{-1} with percentage compression of 30% and a trigger load of 0.05N. The result obtained for their analysis is not expected to be identical to the result obtained in this research as the test protocols are not the same. Similarly, the Brookfield CT3 texture analyser operating instructions/manual documents that some of the empirical factors as well as test conditions that will have effect on the results generated on the Brookfield CT3 texture analyser includes size of the sample, age of the sample, temperature of the sample, base and edge effects of the machine, the type of probe used/sample container, fat, protein, starch content, in the case of fatty, protein and starchy foods, surface characteristics of the sample, pH of the sample, temperature of the sample, uniformity of the product.

5. Conclusion

Instrumental texture profile analyses of gari paste were carried out on gari paste at 24, 48 and 72 hours of fermentation. The major texture parameters considered were hardness, cohesiveness, adhesiveness and springiness. The hardness values obtained for the gari paste were found to be high although fermentation caused slight changes with increase in fermentation time. The values at 48 hours were found not to be as high as values obtained at 24 hours, while the values obtained at 72 hours were further decreased compared to 24 and 48 hours values obtained for the hardness of the gari paste. These slight changes were attributed to degradation of starch as fermentation increased. TPA cohesiveness of gari paste at 24, 48 and 72 hours of fermentation showed low values, although these decrease did not follow a particular trend. Low levels of cohesiveness were attributed to reduction in intermolecular forces within a food chain. The adhesiveness of gari paste at 24, 48 and 72 hours of fermentation showed inconsistent results. These inconsistent values were attributed to factors like the shape of the sample, the sample fouling the contact surface of the machine, the structural and physicochemical properties of the cassava tubers. The springiness of the gari paste at 24, 48 and 72 hours of fermentation were observed to be low at 24 hours, but had almost the same values at 48 and 72 hours of fermentation. The effect of fermentation on springiness would have been seen if fermentation proceeded up to 96 and 120 hours. The one way ANOVA results could not really be verified as enough replicates of the samples were not used. Although the samples may be different in terms of aroma, colour, sourness, effect of hydrogen cyanide, with these fermentation times, these were not part of the aims and objectives of this research work. The various fermentation times showed very little effect and difference over these textural parameters. However, it can be concluded that the duration of fermentation used in this study has little or no effect on the textural parameters being analysed, as the test protocols, as well as test geometry, speed of compression, percentage compression, size and age of sample, kind of probe, starch content, varietal differences could have effect on the final results obtained.

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