

# Effect of Processing method on Pasting, Morphological and Sensory Properties of Akamu- a Nigerian Fermented Maize Product

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**Abstract** Akamu is a lactic acid bacteria fermented cereal-based food that complements infant diets in most African countries. The effect of fermentation with *Lactobacillus* (*L.*) *plantarum* starter culture and gamma-irradiation on the pasting and morphological properties of Akamu was investigated. The sensory property of porridges from the *L. plantarum* fermentation and artificially acidified maize slurries was also investigated. The irradiated ground maize (IGM) and its *L. plantarum* strain fermented samples had significantly ( $p < 0.05$ ) the lowest peak (128.70 – 135.33 RVU) and final viscosities (68.50 -108.33 RVU). Un-irradiated ground maize (GM) and the traditionally fermented samples had significantly ( $p < 0.05$ ) the highest pasting properties (1920.50 – 2641.00 and 3378.80 – 3819.00 RVU for peak and final viscosities respectively). Scanning electron microscopy revealed the granular structure of starch: fermented samples had etches, while irradiated granules were rough and different from its un-irradiated counterpart. Porridges of the un-irradiated ground maize and the traditionally fermented sample had thick and solid linkages against the weak and viscous nature of irradiated samples. The sensory attributes (flavour, sourness, and overall acceptability) of the porridges from *L. plantarum* fermented sample was significantly ( $p > 0.05$ ) the most acceptable to the assessors. This study revealed that irradiation lowered the pasting properties of the maize slurries and caused changes in the morphological properties of both the uncooked slurries and their porridges. The sensory attributes of Porridge from the *L. plantarum* fermented maize slurry were most acceptable to the assessors.

**Keywords:** Akamu, fermentation, gamma irradiation, maize slurries and porridges, pasting properties, morphological and sensory properties

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## 1. Introduction

Fermentation is used widely in the processing of cereals for the preparation of a wide variety of dishes in Africa and some other developing countries. In the human diet fermentation has helped in the enhancement of nutritive and sensory properties [1,2], decrease of anti-nutritional factors; phytate and polyphenols for nutrient availability [3,4], extension of shelf life [5], inhibition of growth of enteropathogens [6], improvement of digestibility and conferment of health benefits [7,8].

Major African fermented cereal-based foods are derived mainly from maize, sorghum, millet, rice, or wheat. Texture-wise the products could be in the form of doughs, porridges, beverages or stiff gels. Depending on locality, various names may be given to the same product or to products that are basically similar but had slight variations in their production processes [9]. In Kenya, Ghana, South Africa, Sudan, and Uganda some cereal-based porridges are known as *Ikii*, *Akasa* and *Koko*, *Mawe* and *Ting*, *Aceda*, and *Obusera*, respectively [10-16]. In Nigeria,

Akamu is a traditional lactic acid fermented cereal-based meal, made basically from maize (*Zea mize*), and other cereals; sorghum or millet [17].

The traditional process of Akamu production involved steeping of the grain in excess water for 2 - 3 days, washing, wet milling and wet sieving. The extracted solids are allowed to sediment overnight, during which fermentation by various microorganisms associated with the raw material and utensils take place. The resultant product (Akamu) varies in colour from white to yellow or dark brown depending on the variety of the cereal used. Addition of an equal part of boiling water to the fermented slurry with vigorous stirring yields a nearly gelatinized lump-less porridge. The porridge is often eaten with beans cake (*akara*) or beans pudding (*moi-moi*) and it constitutes an integral part of adult main meals or food for convalescents in many African countries [18]. The porridge when diluted to thinness of 8 - 10% total solid plays an important role in the nutrition of infants and young children as a complementary food [17,19]. The fermented slurry when cooked with water produces a stiff gel called *akidi* that serves as convenient food for travelers [18].

Starch is the major polysaccharide in cereals that plays important role in food viscosity [20]. It is a semi crystalline granule composed of two main glucan: amylose and amylopectin [20]. The normal maize starch consists of 75% branched amylopectin and 25% of linear amylose and this varies significantly depending on the maize variety [21]. When heated in excess water, starch granules imbibe water and swell to several times its initial size, ruptures and simultaneously releases amylose into the medium, which causes increase in viscosity. According to Tester and Morrison [22], the amylopectin component of starch is mainly responsible for starch swelling while amylose restrict swelling maintaining the integrity of the starch granule.

Modification of starch structure may occur during food processing which may have influence on the pasting properties of the food. Yuan *et al.* [23] reported that the decrease in the final viscosity and setback of fermented corn starch with increase in fermentation time. Decrease in gelatinization temperature and peak viscosity of fermented rice starch was reported by Lu *et al.* [24]. The rice starch granules had slight superficial corrosion under the scanning electron microscope [24]. Fermentation may change the amorphous region as well as the chemical composition of starch granule and hence affect the physical properties of the flour and the rheological properties of the resultant food [23,24]. Steeping or soaking and wet milling of grains have also been reported to influence the physical and chemical properties of starch [25]. According to Chiang and Yeh [26], increased moisture content after soaking of rice grains resulted in loosening of the kernel structure yielding small particle size flour with little starch damage. The resultant starch from flour of small particle sizes had increased peak viscosity. During traditional *Akamu* (spontaneously fermented maize starch slurry) production, the grains are steeped in water for efficient wet milling and starch yield. Thereafter, the starch slurry (*Akamu*) is fermented. The fermented slurry is prepared with boiling water to obtain gelatinized porridge for consumption.

Various microbial metabolites (lactic, acetic, oleic and linoleic acids, esters, higher alcohols and aldehydes, ethyl acetate and diacetyl and 5-hydroxymethylfurfural) are produced during microbial fermentation of cereal and have been implicated in the enhancement of the shelf-life and sensory characteristics of such products [27,28]. Fermented cereal foods are known and appreciated for certain specific eating qualities, the sensory attributes (appearance, colour, flavour, texture, sweetness or sourness) are therefore crucial in their acceptability. Fermentation of *Gowe* a sorghum-based gruel with selected starter of *L. fermentum* alone or in combination with *Kluyveromyces marxianus* was found to have sensory characteristics (colour, taste and aroma) that were acceptable to consumer as the traditional spontaneous product [29]. Stronger and acceptable *ogi* aroma was observed in fermentation with starter cultures of *L. brevis* and *Saccharomyces cerevisiae* [17].

The process of *Akamu* production was modified by skipping the soaking, wet milling and wet sieving stages. The modified production method utilized irradiated and un-irradiated flour from dry milled maize grains. The maize slurry was prepared by the addition of water

inoculated with pure starter cultures of *L. plantarum* strains for the fermentation. The aim was to investigate the effect of gamma irradiation and *L. plantarum* fermentation on the pasting property and starch structure of *Akamu*. The consumer sensory acceptability of *Akamu* fermented with pure culture of *L. plantarum* and artificially acidified porridge was also investigated.

## 2. Materials and Methods

### 2.1. Maize Flour and *Akamu* Sample

Organic maize flour (L1530) was obtained from Health Food Shop, Rickard Lanes', Plymouth, UK. About 50±0.01 g of the flour was weighed into cellophane bags, sealed and irradiated with <sup>60</sup>Co at 25.88±0.79 kGy (Becton Dickinson and Company, Plymouth, UK). The traditionally prepared *Akamu* sample was obtained from Rivers State, Nigeria-

### 2.2. Starter Cultures and Their Preparation

The *L. plantarum* strain coded NGL5 was previously identified from the traditional *Akamu* sample using PCR and sequencing analysis [30]. A probiotic counterpart: *L. plantarum* (LpTx) was used in the fermentation of samples for sensory analysis to ascertain consumer acceptability whether should be *Akamu* used as a vehicle for the relay of probiotics. The probiotic counterpart was identified from a probiotic food supplement obtained from Health Food Shop, Rickard Lanes', Plymouth UK-

### 2.3. Starter Culture Preparation

The *L. plantarum* strains were cultivated by streaking on de Man, Rogosa and Sharpe (MRS) agar incubated at 37°C for 24 h. Thereafter, distinct colonies were grown in MRS broth at 37°C overnight. Cells were harvested by centrifugation (Hettich Zentrifugen Rotina 46 S, Tuttlingen, Germany) at 4000 *x g* for 10 min, washed twice in phosphate buffered saline (PBS) (pH 7.3±0.2) and re-suspended in PBS such that 1 mL of inoculum produced 10<sup>9</sup> CFU mL<sup>-1</sup>.

### 2.4. Fermentation of the Ground Whole Maize Slurries

The ground whole maize slurries for fermentation were prepared by adding 100 mL of sterile distilled water containing 1 mL of the microbial inoculant into 50±0.01 g of the maize flour in a 500 mL conical flask. The inoculated slurries were distributed in 50 mL quantity into sterile transparent 250 mL plastic containers with screw caps (Fisher Scientific, Loughborough, UK) and incubated at 30°C. After 0, 24, and 72 h, samples were withdrawn and preserved at -80°C until needed for analysis. Un-inoculated ground maize and its irradiated counterpart were as well analysed.

### 2.5. Pasting Properties

The traditional *akamu* and the *L. plantarum* fermented ground whole maize slurries were freeze dried in Edwards

Modulyo bench top freeze dryer (Mecha Tech Systems Ltd, Thornbury, Bristol, UK) and ground to flour using an 80 mm unglazed laboratory mortar and pestle (Sigma Aldrich, Gillingham Dorset, UK). The resultant flour from the freeze dried samples and the unfermented flour of the irradiated and un-irradiated ground maize samples were sieved using 500  $\mu\text{m}$  sieve size in a motorized sieve shaker (Retsch AS 200 basic, Haan, Germany) at amplitude of 80 mm for 5 to 10 s.

Thereafter, the pasting properties (pasting temperature, peak time, peak final viscosity, breakdown, holding strength and setback) of 2.93 g of the samples suspended in 25 mL of distilled water in the RVA aluminium canister were determined using a Rapid Visco Analyser (RVA-4 series, Newport Scientific, Warriewood, Australia) following a standard method (profile 1) described in the instructional manual. The profile involved an idle temperature of 50°C, initial paddle rotation for 10 s at 960 rpm and then at 160 rpm for the rest of the test period. Samples were heated to 95°C at a rate of 12°C min<sup>-1</sup>, held at 95°C for 3.7 min and then cooled at the same rate to 50°C. The RVA pasting curves were automatically plotted and pasting parameters: pasting temperature, peak time, peak final viscosity, breakdown, holding strength and setback were determined using Thermocline for windows version 2.2 software (Newport Scientific, Warriewood, Australia). The viscosity was expressed in Rapid Visco Units (RVU).

## 2.6. Microscopic Examination of the Cooked and Uncooked Samples

The morphology of the samples was obtained by using scanning electron microscope (SEM). The cooked *akamu* and ground whole maize samples were flash frozen in liquid nitrogen and freeze dried overnight in EMITECH K750 bench top freeze dryer (Orgeval, France). Fragments of the freeze dried samples and the dry uncooked samples were mounted on circular aluminium stubs with double-sided sticky tape, coated with gold to a nominal thickness of 10 nm were cooked on EMITECH K550. Thereafter, the prepared samples were examined and photographed in a scanning electron microscope (JEOL 5600LV SEM, JEOL Ltd., Herts, England) at an accelerating voltage of 15 kV.

## 2.7. Sensory Analysis

### 2.7.1. Porridge Preparation

Sensory evaluation was carried out on porridges prepared from maize slurry fermented by pure starter culture of *L. plantarum* (NGL5) and its probiotic counterpart (LpTx). Unfermented and artificially acidified unfermented maize slurries served as controls. Acidification was achieved using food grade monohydrate citric acid (Fisher Scientific, UK) to a concentration of 82 mmol L<sup>-1</sup> that corresponded to the average concentration of acid in the fermented samples (titratable acidity of 1.729%). The frozen slurries were allowed to completely thaw at 25°C for 3 h. To 250 mL of the sample slurry was added equal volume of boiling water and then microwaved for 2 min with vigorous stirring after each minute to obtain a lump free porridge. The porridges were distributed in 15

mL samples into labelled transparent plastic mini pots with lids and maintained at 45°C.

### 2.7.2. Recruitment of Panelists and Hedonic Test

In line with the Plymouth University policy, the sensory evaluation protocol received the approval of the Human Ethical Committee of the Faculty of Science and Technology. Thirty panellists were recruited from within the University of Plymouth staff, postgraduate and undergraduate students via e-mail invitation and verbal communications. The appearance, colour, aroma, sourness (acidity), flavour, texture (smoothness) and overall acceptability of the samples were evaluated in sensory evaluation booths where porridge samples were presented in random order with a ballot sheet for each sample. The scores were based on a 9-point hedonic scale, with the degree of likeness of the product attribute expressed as follows: 1- dislike extremely, 2 - dislike very much, 3 - dislike moderately, 4 - dislike slightly, 5 - neither like nor dislike, 6 - like slightly, 7 - like moderately, 8 - like very much and 9 - like extremely.

## 2.8. Statistical Analysis

Statistical analysis was carried out using Minitab (Release 16.0) Statistical Software English (Minitab Ltd. Coventry, UK). Statistical differences and relationship among variables were evaluated by analysis of variance (ANOVA) under general linear model and Tukey pairwise comparisons at 95% confidence level. The non-parametric Friedman test and 2-sample t-test were employed in determining the statistical differences among the product sensory attributes.

## 3. Results and Discussion

### 3.1. Pasting Properties

Figure 1 presented the RVA pasting curve showing the peak viscosity, holding strength and final viscosity of the samples (*Akamu*, *L. plantarum* fermentation - AL5 and ground maize - GM). The pasting parameters are shown in Table 1. The irradiated ground maize (IGM) and its *L. plantarum* fermented samples had an undetected pasting temperature with very low peak and final viscosities. The traditional sample had significantly ( $p < 0.05$ ) the highest pasting properties. The traditional *akamu* sample and the un-irradiated ground maize had pasting temperatures (~77°C) similar to that of a typical maize starch [21,31]. Pasting temperature is an indication of the minimum temperature required to cook the sample. This explained why the addition of boiling water to traditional *akamu* slurry yielded a cooked gelatinized gruel for consumption. The undetectable pasting temperature of the irradiated ground maize and its *L. plantarum* fermented samples implied the sample's inability to form a paste at the range of the experimental temperature.

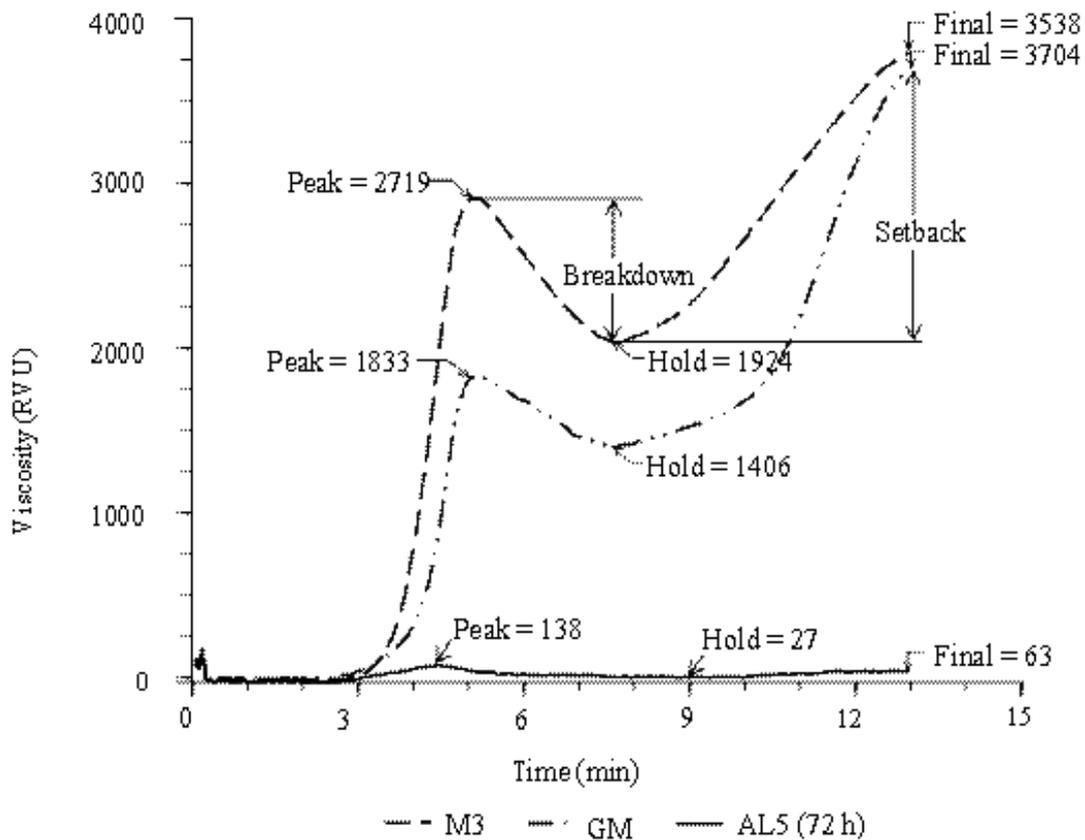
Peak viscosity occurs at the equilibrium point between swelling and the leaching out of amylose component of the starch [32] hence it reflects the water-binding capacity of the starch granules and the flimsiness of swollen granules. The starch structure of the traditional *akamu* and

the un-irradiated ground maize may have allowed greater water absorption and granule extension causing increased polymer leaching and subsequent increase in viscosity. The significantly ( $p < 0.05$ ) least peak viscosities ( $\leq 139.5$  RVU) of the irradiated sample and its fermented counterpart could be attributed to structural changes in the starch granules by gamma irradiation. Similar low peak viscosity had been reported for corn starch irradiated at 30 - 40 kGy [33]. The cleavage of the glycosidic bonds of starch molecules by gamma irradiation lowers starch water absorption and swelling capability which results in low peak viscosity [33,34].

Although, fermentation had been implicated in lowered peak viscosity of corn starch [23], the significant variation in viscosity of the samples was more of that of the effect

of irradiation than starch hydrolysis by fermentation as evidenced in the spontaneously fermented traditional *Akamu* having much higher peak viscosity than the *L. plantarum* fermented irradiated samples.

With the increasing viscosity, the mechanical agitation from the paddle will generate shear force greater than that of the granules in starch/water system, thereby causing the swollen granules to loss integrity and rupture followed by decrease in viscosity [35]. This breakdown was observed in all the samples in this study. The breakdown of the irradiated and the *L. plantarum* fermented irradiated samples in relation to their peak viscosities was higher than the un-irradiated ground maize and the traditional *Akamu*. This was in agreement with the study by Rombo *et al.* [36] that irradiated samples are more sensitive to shear.



**Figure 1.** Rapid Visco Analyser (RVA) pasting curve showing the peak viscosity, holding strength and final viscosity of the traditional *Akamu* sample (M3), unfermented and un-irradiated ground maize (GM) and the 72 h *L. plantarum* strain fermented irradiated ground maize slurry AL5

**Table 1.** The pasting properties of traditional *Akamu* sample, irradiated ground maize slurry fermented by *L. plantarum* strain (NGL7) and unfermented, irradiated and un-irradiated ground maize

Samples	*Time (h)	Viscosity (RVU)					Peak Time (Min)	Pasting Temp (°C)
		Peak viscosity	Holding strength	Breakdown	Final viscosity	Setback		
AL5	0	128.70±22.00 <sup>c</sup>	33.67±10.97 <sup>c</sup>	95.00±12.29 <sup>c</sup>	72.67±14.36 <sup>c</sup>	39.00±6.08 <sup>c</sup>	4.53±0.07 <sup>b</sup>	
	72	139.50±2.12 <sup>c</sup>	33.50±9.19 <sup>c</sup>	106.00±7.07 <sup>c</sup>	68.50±7.78 <sup>c</sup>	35.00±1.41 <sup>c</sup>	4.63±0.05 <sup>b</sup>	
GM		1920.50±123.70 <sup>b</sup>	1415.00±12.70 <sup>b</sup>	505.50±111.00 <sup>b</sup>	3819.00±162.00 <sup>a</sup>	2404.00±149.00 <sup>a</sup>	5.10±0.05 <sup>a</sup>	76.67±3.43
IGM		135.33±9.71 <sup>c</sup>	58.67±10.26 <sup>c</sup>	76.67±0.58 <sup>c</sup>	108.33±10.21 <sup>c</sup>	49.67±1.53 <sup>c</sup>	4.47±0.00 <sup>b</sup>	
M3		2641.00±54.30 <sup>a</sup>	1880.50±49.60 <sup>a</sup>	760.50±33.90 <sup>a</sup>	3378.80±110.60 <sup>b</sup>	1498.30±83.00 <sup>b</sup>	5.32±0.13 <sup>a</sup>	76.86±0.80

Values with the same superscript do not differ significantly ( $p \leq 0.05$ ). N=3±SD

\*Fermentation time

AL5 – Maize slurry fermented by the *L. plantarum* isolated from traditional *Akamu* sample

GM - Un-irradiated and unfermented ground maize

IGM - Irradiated unfermented ground maize

M3 - Traditional *Akamu* sample.

On cooling, the setback and the final viscosity of the un-irradiated ground maize increased significantly ( $p < 0.05$ ) greater than its peak viscosity. The setback of the un-irradiated sample could be attributed to greater association of amylose fractions as setback is related to the degree of polymerization of the amylose fraction leached during swelling [37]. The degree of polymerisation of amylose may be lowered by the hydrolytic effect of fermentation, which may account for variations in the setback and final viscosity of the traditional *Akamu* and the unfermented ground maize. Although, increases in short chain of amylopectin during fermentation had been reported in the amorphous region which could associate like the amylose to improve the paste viscosity [23], increased viscosity during cooling however was only observed in the traditional *Akamu* sample and not the fermented irradiated ground maize slurries. A similar characteristic was reported for native and irradiated corn starch and the decrease in viscosity of the irradiated sample was attributed to the formation of low molecular weight molecules from the degradation of amylopectin by the gamma irradiation [33]. Since the final viscosity also marks the ability of the material to form gel after cooking and cooling, the traditional *Akamu* sample and the un-irradiated ground maize were more stable than the irradiated samples.

The low viscosity of the *L. plantarum* strain fermented irradiated ground maize slurry however, would be desirable for infant complementary food for a nutrient-dense product without dilutions with excess water. *Akamu* with low viscosity may not be appreciated by some adults and could be considered as spoiled or containing low dry matter content. The dry matter contents of the samples (2.93 g weight) were the same and this further emphasizes the likely changes that may have taken place in the irradiated samples as compared to the un-irradiated samples. For adult who would prefer thicker gruel, such high viscosity can be achieved by the addition of more of the ground maize which would imply increase in nutrient composition.

### 3.2. Morphology of Cooked and Uncooked *Akamu* and Ground Whole Maize Samples

The morphologies of the samples from the scanning electron microscope (SEM) are shown in Figure 2. The un-irradiated and unfermented ground whole maize (GM) had polygonal granules that were surrounded by thin film (Figure 2a) while the surfaces of the irradiated ground whole maize (IGM) granules were rough with many protuberant areas (Figure 2b). The granules of the *Akamu* sample (M3) had etches and attached on the granules were the bacterial rods of the fermenting microorganisms (Figure 2c). The structure of the porridges revealed weak and porous linkages for the irradiated ground maize (IGM) (Figure 2d). Thick and solid linkages were observed in the un-irradiated ground maize (GM) samples (Figure 2e) while the *Akamu* sample appeared more elastic (Figure 2f).

The granular structure of the uncooked *Akamu* and the un-irradiated samples were similar to that of a typical corn starch [33,38]. The thin film surrounding the granules of the unfermented dry ground maize samples suggest

matrixes of protein and fat around the granules while etches on the granules from the fermented *Akamu* sample confirmed the hydrolysis of starch granules during fermentation [24,38,39]. Similar grooves associated with corn starch granules were suggested to be highly amorphous and easily gelatinised [31]. This further explained the significantly ( $p < 0.05$ ) higher peak viscosity of the *Akamu* sample. As shown in Figure 2b, the surface of the granules of the irradiated sample was different from its un-irradiated counterpart indicating the possible effect of the gamma-irradiation on the starch granules. Microscopic examination of the extent of granule deformation and disruption in the samples further explains the pasting behaviour of the samples. The cleavage of the glycosidic bonds of starch molecules by irradiation was evidenced in the viscous nature of the cooked sample. The weak linkages of the cooked irradiated sample were unable to entrap the absorbed water during swelling. The gamma irradiation hydrolysed molecules were unable to recrystallize upon cooling confirming the study that excessive hydrolysis of starch by gamma irradiation could degrade starch molecules to very small molecules making recrystallization impossible [33]. Thus, the irradiated sample had very low peak and final viscosity and was unable to form gel within the experimental temperature range (50-90°C). This also explained the similar pasting behaviour of the fermented irradiated samples. Conversely, the thick and solid linkages of the un-irradiated ground maize and the traditional *Akamu* samples permitted re-association of leached starch components within the entombment as to enhance the pasting viscosity.

### 3.3. Sensory Evaluation

The mean of the sensory attributes for the different treatments are shown in Figure 3 while the mode and frequency of occurrence of the ratings are listed in Table 2.

**Table 2. The mode and its frequency of occurrence for the sensory rating of the *L. plantarum* strains fermentation and the artificially acidified and unfermented ground maize porridges**

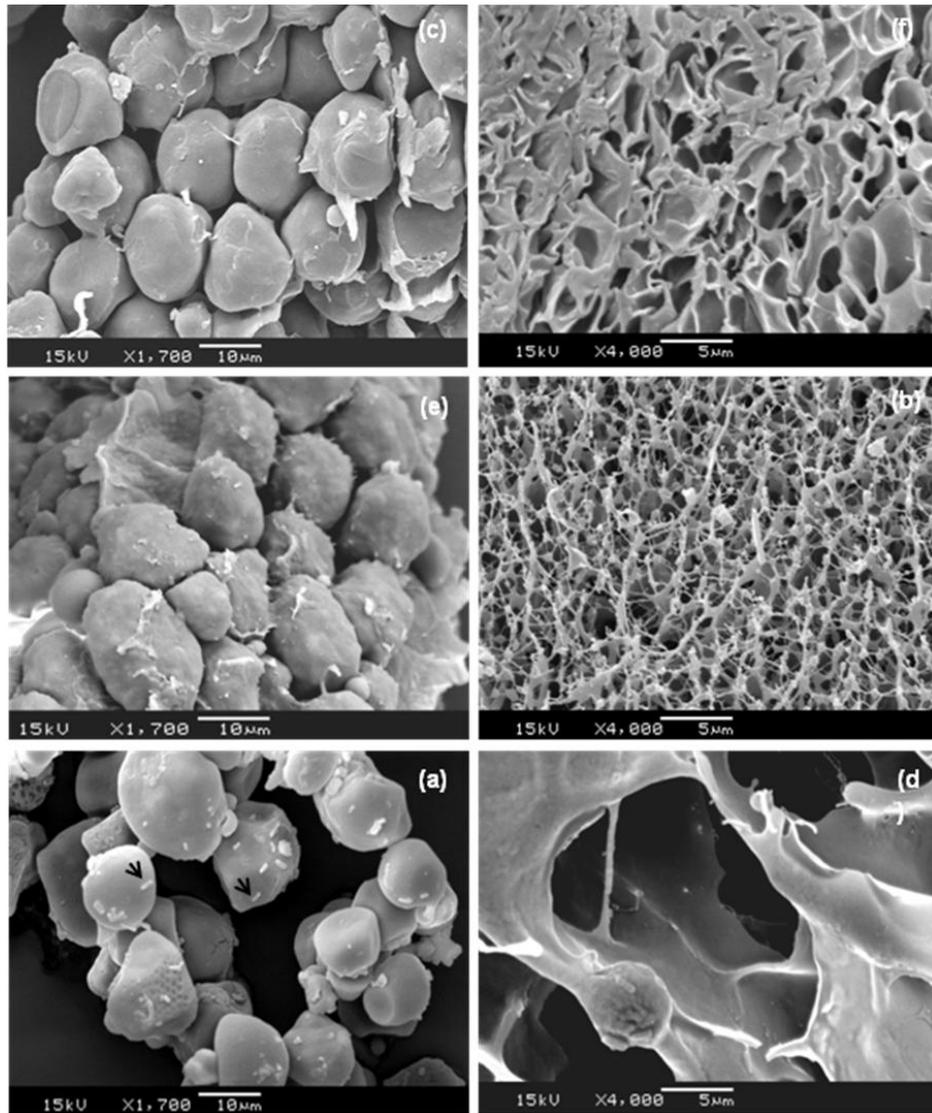
Sensory attributes	Parameters	Treatments			
		ACD	PLpTx	PL5	UUA
Aroma	Mode	6,7	7	7	6
	Frequency	7	9	8	11
Appearance	Mode	7	7	7	7
	Frequency	12	10	13	9
Colour	Mode	7	7	7	7
	Frequency	11	14	12	10
Flavour	Mode	3,4,5,6	5	5	5
	Frequency	5	9	8	9
Sourness	Mode	4	7	5	7
	Frequency	8	6	7	9
Texture	Mode	7	7	7	7
	Frequency	10	9	11	10
Overall Acceptance	Mode	3	7	7	5,7
	Frequency	7	10	10	7

ACD-Artificially acidified porridges

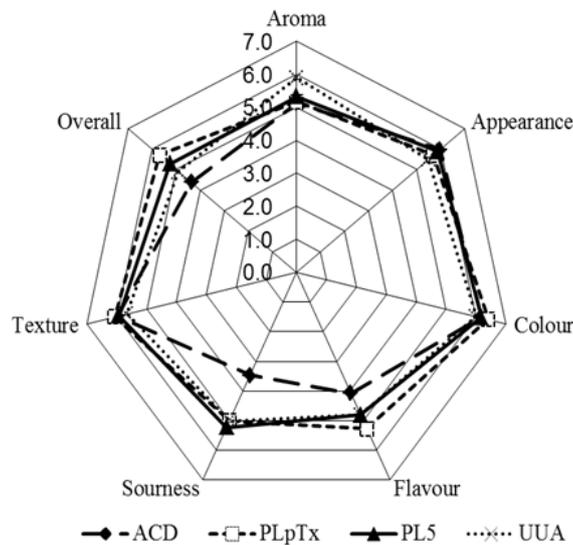
UUA-Unfermented un-acidified porridges

PL5 - Porridges from the fermentation by the *Lb. plantarum* strain isolated from *Akamu*

PLpTx- Porridges from the fermentation by the Commercial probiotic *L. plantarum* strain.



**Figure 2.** Scanning Electron microscopy (SEM) showing the structure of starch granules in the samples before cooking (a - c) and after cooking (d - e) (a and d - uncooked and cooked un-irradiated and unfermented ground maize (GM), respectively; b and e - uncooked and cooked irradiated ground maize (IGM), respectively; c and f - uncooked and cooked traditional fermented *akamu* (M3), respectively; The arrow indicates the fermenting microorganism (short rods))



**Figure 3.** Sensory attributes: aroma, appearance, colour, flavour, sourness, texture and overall acceptability rating of *L. plantarum* strain fermented maize porridges. (ACD - Artificially acidified porridge, UUA - Unfermented un-acidified porridge, PL5 - Porridge of ground maize slurries fermented by *L. plantarum* strains isolated from traditional *Akamu* sample, PLpTx - Porridge of ground maize slurry fermented by commercial probiotic *L. plantarum* strain (LpTx))

The samples did not differ significantly ( $p>0.05$ ) in their rating for appearance, colour, texture and aroma. The mean rating for the flavour ( $4.07\pm 1.96$ ), sourness ( $3.47\pm 1.96$ ) and overall acceptability ( $4.37\pm 1.94$ ) of the acidified sample was significantly ( $p>0.05$ ) the least. Although the mean for the *L. plantarum* fermented samples for aroma, appearance, texture and overall acceptability were 'neither like nor dislike', the frequently occurred rating was 'like moderating'. The frequently occurred rating for the flavour of both *L. plantarum* strain fermented samples was 'neither like nor dislike', while the sourness of the endogenous *akamu* differed significantly ( $p>0.05$ ) from the sample fermented by the probiotic strain. The assessors had moderate likeness for the sourness of the traditionally fermented *akamu* and the *L. plantarum* fermented sample. The acidified sample was reported to be tart: too strong and leaving a bitter taste while the *L. plantarum* fermented samples were characterised by flavours that evoked honey and apples. This suggested the likely influence of microbial metabolites on the flavour of the *L. plantarum* fermented product that was not achieved by the artificial acidification. The *L. plantarum* fermented samples on the overall was moderately accepted while the acidified and the unfermented samples were disliked. Porridges from traditionally fermented maize slurries are usually consumed with the addition of sugar, salt and/or milk depending on affordability. The addition of any of these would therefore enhance the acceptability of the *L. plantarum* strain fermented samples.

#### 4. Conclusion

This study revealed that irradiation lowered the pasting properties of the maize slurries and caused changes in the morphological properties of both the uncooked slurries and their porridges. The traditionally fermented sample had higher pasting properties than the irradiated and starter culture fermented ground whole maize slurries, although low viscosity would be desirable for infant feeding. Microscopic examination of the extent of granule deformation and disruption in the samples revealed some changes in the starch structure due to irradiation and fermentation. This also provided further explanation to the pasting behaviour of the irradiated and un-irradiated samples. The sensory attributes (flavour, sourness, and overall acceptability) of the porridges from *L. plantarum* strain fermented samples were significantly ( $p>0.05$ ) the most acceptable to the assessors. The acceptability of the probiotic fermented sample also reveals that maize porridges can serve as a vehicle to rally probiotics for their physiological benefits.

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#### References

- [1] Osundahunsi, O.F. and O.C. Aworh, (2003). Nutritional evaluation, with emphasis on the protein quality of maize-based complementary foods enriched with soya bean and cowpea Tempe. *International Journal of Food Science and Technology*, 38: 809-813.
- [2] Odunfa, S.A., et al., (2001). Evaluation of lysine and methionine production in some Lactobacilli and yeasts from Ogi. *International Journal of Food Microbiology*, 63(1-2): 159-163.
- [3] Hellström, A.M., et al., (2003). Biodiversity and phytase capacity of yeasts isolated from Tanzanian Togwa. *International Journal of Food Microbiology*, 136(3): 352-358.
- [4] Towo, E., E. Matuschek, and U. Svanberg, (2006). Fermentation and enzyme treatment of tannin sorghum gruels: effects on phenolic compounds, phytate and in vitro accessible iron. *Food Chemistry*, 94(3): 369-376.
- [5] Teniola, O.D. and S.A. Odunfa, (2002). Microbial assessment and quality evaluation of Ogi during spoilage. *World Journal of Microbiology and Biotechnology*, 18(8): 731-737.
- [6] Lawal, A.K., O.B. Oyedoyin, and O.O. Olatunji, (2009). Fate of pathogenic bacteria during fermentation of cereal porridge ("Ogi")-a weaning food formula. *Nigerian Food Journal*, 27(1): 19-26.
- [7] Elyas, S.H.A., et al., (2002). Effect of natural fermentation on nutritive value and in vitro protein digestibility of pearl millet. *Food Chemistry*, 78(1): 75-79.
- [8] Lei, V., H. Friis, and K.F. Michaelsen (2006). Spontaneously fermented millet product as a natural probiotic treatment for diarrhoea in young children: An intervention study in Northern Ghana. *International Journal of Food Microbiology*. 110(3): 246-253.
- [9] Jespersen, L. (2003). Occurrence and taxonomic characteristics of strains of *Saccharomyces cerevisiae* predominant in African indigenous fermented foods and beverages. *FEMS Yeast Research*, 3: 191-200.
- [10] Kalui, C.M., et al., (2009). Functional characteristics of *Lactobacillus plantarum* and *Lactobacillus rhamnosus* from Ikii, a Kenyan traditional fermented maize porridge. *African Journal of Biotechnology*, 8(18): 4363-4373.
- [11] Lei, V. and M. Jakobsen, *Microbiological characterization and probiotic potential of Koko and Koko sour water, African spontaneously fermented millet porridge and drink*. Journal of Applied Microbiology, 2004. 96: p. 384-397.
- [12] Hounhouigan, D.J., et al., (1999). Use of starter cultures of Lactobacilli and yeast in the fermentation of Mawe, an African Maize product. *Tropical Science*, 39: 220-226.
- [13] Yousif, N.M.K., et al., (2010). Diversity of lactic acid bacteria from Hussuwa, a traditional African fermented sorghum food. *Food Microbiology*, 27: 757-768.
- [14] Yousif, N.M.K., et al., (2005). Molecular characterization, technological properties and safety aspects of enterococci from 'Hussuwa', an African fermented sorghum product. *Journal of Applied Microbiology*, 98(1): p. 216-228.
- [15] Mukisa, I.M., et al., (2012). The dominant microbial community associated with fermentation of Obushera (sorghum and millet beverages) determined by culture-dependent and culture-independent methods. *International Journal of Food Microbiology*, 160(1): 1-10.
- [16] Muyanja, C.M.B.K., et al., (2003). Isolation, characterisation and identification of lactic acid bacteria from Bushera: A Ugandan traditional fermented beverage. *International Journal of Food Microbiology*, 80(3): 201-210.
- [17] Teniola, O.D. and S.A. Odunfa, (2001). The effects of processing methods on the levels of lysine, methionine and the general acceptability of Ogi processed using starter cultures. *International Journal of Food Microbiology*, 63(1-2): 1-9.
- [18] Umoh, V. and M.J. Fields, (1981). Fermentation of corn for Nigerian Agidi. *Journal of Food Science*, 46: 903-905.
- [19] Osungbaro, T.O., (1990). Effect of fermentation period on amylose content and textural characteristics of "Ogi" (a fermented maize porridge). *Journal of Fermentation and Bioengineering*, 70(1): 22-25.
- [20] Frazier, R.A., (2009). *Food Chemistry*, in *Food Science and Technology*, G. Campbell-Platt, Editor. Wiley-Blackwell: Oxford, UK.

- [21] Sandhu, K.S., N. Singh, and M. Kaur, (2004). Characteristics of the different corn types and their grain fractions: physicochemical, thermal, morphological, and rheological properties of starches. *Journal of Food Engineering*, 64(1): 119-127.
- [22] Tester, R.F. and W.R. Morrison, (1990). Swelling and gelatinization of cereal starches. I. Effects of amylopectin, amylose, and lipids. *Cereal Chemistry*, 67(6): 551-557.
- [23] Yuan, M.-L., et al., (2008). Effect of spontaneous fermentation on the physical properties of corn starch and rheological characteristics of corn starch noodle. *Journal of Food Engineering*, 85(1): 12-17.
- [24] Lu, Z.-H., et al., (2005). The effects of natural fermentation on the physical properties of rice flour and the rheological characteristics of rice noodles. *International Journal of Food Science & Technology*, 40(9): 985-992.
- [25] Zheng, G.H., F.W. Sosulski, and R.T. Tyler, (1998). Wet-milling, composition and functional properties of starch and protein isolated from buckwheat groats. *Food Research International*, 30(7): 493-502.
- [26] Chiang, P.-I. and A.-I. Yeh, (2002). Effect of Soaking on Wet-milling of Rice. *Journal of Cereal Science*, 35(1): 85-94.
- [27] Charalampopoulos, D., et al., (2002b). Application of cereals and cereal components in functional foods: a review. *International Journal of Food Microbiology*, 79(1-2): 131-141.
- [28] Salmeron, I., et al., (2009). Volatile compounds produced by the probiotic strain *Lactobacillus plantarum* NCIMB 8826 in cereal-based substrates. *Food Chemistry*, 117(2): 265-271.
- [29] Vieira-Dalodé, G., et al., (2008). Use of starter cultures of lactic acid bacteria and yeasts as inoculum enrichment for the production of Gowé, a sour beverage from Benin. *African Journal of Microbiology Research*, 2: 179-186.
- [30] Obinna-Echem, P.C., V. Kuri, and J. Beal, (2014). Evaluation of the microbial community, acidity and proximate composition of Akamu, a fermented maize food. *Journal of the Science of Food and Agriculture*, 94(2): 331-340.
- [31] Kuakpetoon, D. and Y.-J. Wang, (2007). Internal structure and physicochemical properties of corn starches as revealed by chemical surface gelatinization. *Carbohydrate Research*, 342(15): 2253-2263.
- [32] M, K. and S.K. S, (2013). *Starch: Its Functional, In Vitro Digestibility, Modification and Application*, in *Biotechnology: Prospect and Application*, S.R. K, et al., Editors. Springer Science and Business Media: London. p. 42.
- [33] Lee, Y.-J., et al., (2006). Physicochemical Properties of Gamma-Irradiated Corn Starch. *Journal of Food Science and Nutrition*, 11: 146-154.
- [34] Chung, H.J. and Q. Liu, (2009). Effect of Gamma Irradiation on Molecular Structure and Physicochemical Properties of Corn Starch. *Journal of Food Science*, 74(5): C353-C361.
- [35] Alamri, M.S., A.A. Mohamed, and S. Hussain, (2013). Effects of alkaline-soluble okra gum on rheological and thermal properties of systems with wheat or corn starch. *Food Hydrocolloids*, 30(2): 541-551.
- [36] Rombo, G.O., J.R.N. Taylor, and A. Minnaar, (2001). Effect of irradiation, with and without cooking of maize and kidney bean flours, on porridge viscosity and in vitro starch digestibility. *Journal of the Science of Food and Agriculture*, 81(5): 497-502.
- [37] Chung, H.-J., H.-Y. Jeong, and S.-T. Lim, (2003). Effects of acid hydrolysis and defatting on crystallinity and pasting properties of freeze-thawed high amylose corn starch. *Carbohydrate Polymers*, 54(4): 449-455.
- [38] Naguleswaran, S., et al., (2013). The susceptibility of large and small granules of waxy, normal and high-amylose genotypes of barley and corn starches toward amylolysis at sub-gelatinization temperatures. *Food Research International*, 51(2): 771-782.
- [39] Koo, S.H., K.Y. Lee, and H.G. Lee, (2010). Effect of cross-linking on the physicochemical and physiological properties of corn starch. *Food Hydrocolloids*, 24(6-7): 619-625.