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Effect of Germination Period on the Physicochemical, Functional and Sensory Properties of Finger Millet Flour and Porridge

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ABSTRACT--- ***The effect of germination period on the physicochemical, functional and sensory properties of finger millet flour and porridge was studied. Finger millet grains were germinated naturally at 0, 24, 48 and 72 h, oven dried at 60°C for 10 h and milled into four independent flour samples and porridge was also prepared from four flour samples. The result revealed significant (p<0.05) reduction in pH of finger millet flours from pH 6.24 to 5.72 while TTA increased significantly from 0.50 to 1.34% lactic acid equivalent with progressive in germination process from un-germinated to germination after 72 h. The viscosity of finger millet porridge decreased from 4777 of un-germinated finger millet flour to 420 cP of germinated finger millet after 72 h. There was an increase in Hunter L*, a* and b* colour values of finger millet flour samples with an increase in germination period although a* value did not show any significant (p<0.05) increase. In terms of the functional properties, there was significant (p<0.05) increase of the oil and water absorption capacity including the solubility of the germinated finger millet flour samples. Least gelation concentration significantly increased at 72 h of germination. However, germination period significantly reduced the bulk density and swelling power of the finger millet flour samples. Porridge prepared from germinated and un-germinated finger millet flours for 24 and 48 h were well accepted. Germination had positive effects on some physicochemical, functional and sensory properties of FM flour and porridge.***

Keywords---- Finger millet, germination, porridge, functional properties, sensory evaluation

1. INTRODUCTION

Finger millet is one of the well-known and important cereal grains globally and serves as a staple food to many people in developing countries in Africa and Asia [1]. Finger millet (FM) grains are small-seeded caryopses (diameter is about 1.2–1.8 mm), most of them have spherical shape with coloured seed coat which is light brown or brick red as well as the thin membrane with pericarp that is not firmly connected and covers the whole seed which normally separates during harvesting or basic abrasion [2,3]. Various types of products are produced from FM grains and flours. Around 75% of FM production is normally used to produce different traditional products like "mudde", "dosa", "idly" and "paddu.

Germination is a traditional processing method that is used to enhance the nutritional and functional properties of cereal grains including their digestibility [4,5]. Various studies have exhibited that the chemical and nutritional profile of cereal grains such as wheat, barley, rice, rye and oats are improved after germination [6]. However, germination is not widely practiced in developing countries especially in cereal based gruels and porridges but is used mainly for local brewing [7]. Developing nutrient dense cereal gruels and porridge from locally grown raw materials using suitable small to medium scale production technologies such as germination has been recommended as a viable and suitable approach in addressing Protein Energy Malnutrition problem [8,9]. Therefore, the aim of this study was to determine the effect of germination period on the physicochemical, functional and sensory properties of finger millet flour and porridge.

2. MATERIALS AND METHODS

Sample collection

Finger millet grains were purchased from a street vendor in Thohoyandou, Limpopo province, South Africa. The samples were transported to the Department of Food Science and Technology at the University of Venda and stored at room temperature (25˚C) until they germinated and then milled into flour. Analytical grade reagents were bought from Lasec laboratory, Centurion, South Africa.

Experimental design

One factor which was considered was the germination of finger millet grains at different rates. The experiment was set up as a completely randomised design. The factor levels were: 24, 48, and 72 h to germinate. Un-germinated finger millet grain was used as a control. Each experiment was done in triplicate.

Germination of finger millet
Finger millet grains were visually sorted, cold tap water was used to clean and wash them. The millets were then soaked in a 5 L bucket containing cold water for 10 h at room temperature of 27 ± 2˚C. Water was drained from finger millet grains following soaking and they were split by weight into four equal portions. Finger millet grains were spread individually on clean jute bags covered with a damp cotton cloth and then left for 0, 24, 48, and 72 h to germinate. Finger millet grains were sprinkled with water at 4 h break to stimulate the germination process.

Production of germinated finger millet flour
An oven dryer was used to dry germinated finger millet grains at 60˚C for 10 h and then grinded using a hammer mill into flour. A 300 mm sieve was used to sieve germinated flour samples, air tight polyethylene bags were used to package finger millet flour samples. The samples were put in a plastic container with lid and they were kept in a freezer at -10˚C until analysed.

Determination of physicochemical properties of finger millet flour and porridge pH
About 10 g of each sample of germinated finger millet flours and control (ungerminated flour) was mixed with 100 mL of distilled water in order to measure the pH values of control and germinated finger millet flour samples. The mixture was left at room temperature for 30 min. The pH meter was then used to measure the pH values of the supernatant [10].

Total titratable acidity
About 10 g of each sample of germinated finger millet flours and control was dissolved in 100 mL of distilled water and 10 mL aliquots was titrated with 0.1 N NaOH to phenolphthalein end point [10].

Colour
Colour of germinated flours and control samples was measured using a Hunterlab LabScan XE Spectrophotometer CIELAB and colour coordinate values L* (Lightness/darkness), a* (redness/green) and b* (yellowness/blue) were recorded.

Viscosity
Different samples of milled (5 g into 100 mL distilled water) germinated FM flours to different times were boiled/cooked for 20 min to gelatinise the starch. They were then cooled to 20°C. Brookfield viscometer (Model RV, Brookfield Engineering, Inc., USA) using spindle number Q3 rotating at 100 rpm was used to measure the viscosity of the slurry and the centipoise (cP) were used to measure the viscosity of the cold paste [11].

Functional properties
The bulk density, oil and water absorption capacity was determined using the method of Adebowale *et al*. [12] while the solubility and swelling power of the finger millet flour samples were measured using the method of Moorthy *et al*. [13].

Preparation of porridge
Porridges were prepared from each flour sample. Twenty grams of flour was mixed with 100 mL of cold tap water (20% w/v) in a clean white plastic cup to form a slurry. This was cooked by placing the cups in boiling water and stirred continuously for 10 min [14].

Sensory evaluation of porridge
The cooked porridges were evaluated for colour, aroma, mouthfeel, taste and overall acceptability by 50 panellists made up of students and staff of the University of Venda using a nine-point Hedonic scale (where 1 = dislike extremely and 9 = liked extremely). The panellists used voluntarily participated in the consumer acceptability test.

Ethical clearance
Ethical clearance was sought from the University Research Ethics Committee due to the sensory evaluation which was conducted. Panellists were asked to read and sign the consent form before they participated in the study.

Statistical analysis
The experimental data generated were subjected to analysis of variance (ANOVA) procedure of SPSS version 23 (SPSS, IBM, Chicago USA) at 5% significant level and means were separated using the Duncan multiple range test.

3. RESULTS AND DISCUSSION

Physicochemical properties of fermented finger millet flours
The effect of germination period on the pH of finger millet flour samples is shown in Figure 1. Germination significantly ($p<0.05$) decreased the pH from pH 6.24 of un-germinated millet flour to pH 6.19, 5.93 and 5, 72 of germinated FM flours for 24, 48 72 h respectively. Similar results were reported by Ocheme & Chimna [14] of a decrease in pH from

6.53 of soaked, un-germinated millet flour. The decrease in pH of flours may be as a result of production of organic acids during germination. Studies have shown that germination induces the synthesis of hydrolytic enzymes, such as starch degrading enzymes and proteases with the release of sugars and amino acids. These sugars are utilized by microorganisms (Lactic acid bacteria and yeast) [15]. The fall in pH which was observed throughout the period of germination is similar to the spontaneous germination and fermentation of millet [16,17].

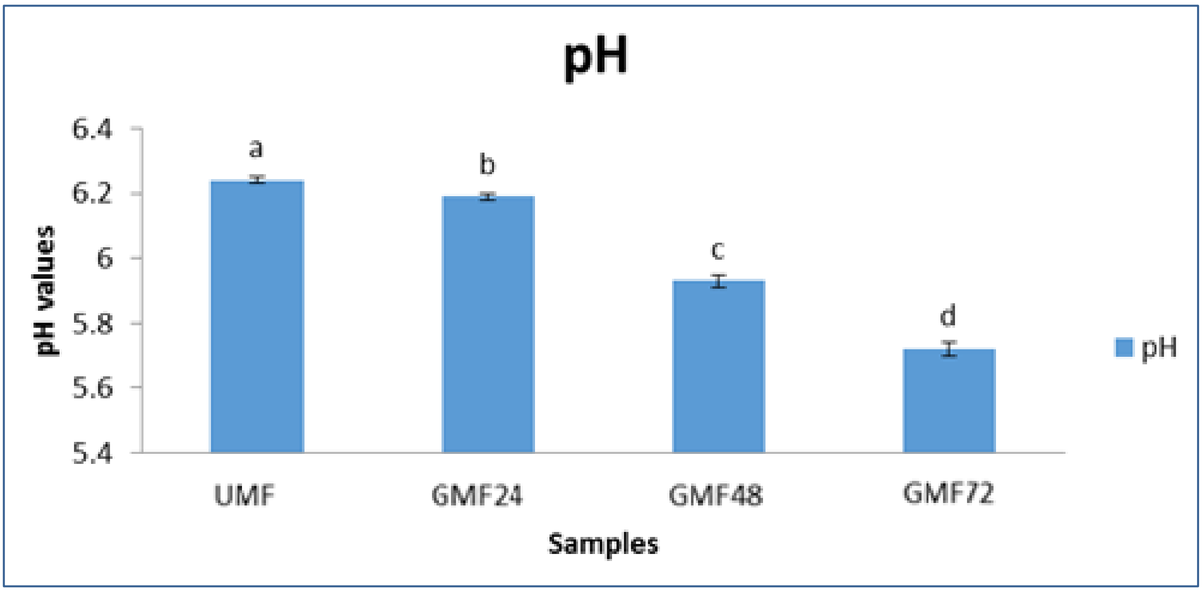

Figure 1: Effect of germination on the pH of finger millet flour

(Where UMF=un-germinated millet flour and GMF=Germinated millet flour for 24, 48 and 72 h respectively).

Effect of germination on the total titratable acidity (TTA) of FM flours is shown on Figure 2. Germination resulted in an increase in TTA of FM flours from 0.5, 0.64, and 0.74 to 1.34% lactic acid equivalent of control and germinated FM for 24, 48 and 72 h respectively. The early increase in TTA could be due to acid production by the beneficial microorganisms such as lactic acid bacteria breaking down sugars to produce, among other secondary fermentation products, lactic acid [18,19]. The increase in acidity which accompany germination might be an indication of the way in which some of the complex organic molecules such as phytin, protein and lipids could be hydrolysed to fatty acids, acid phosphates and amino acids and therefore improving the digestibility of germinated FM flours and porridges [20,21]. An increase in TTA is an indication of free fatty acid product in the flour as a result of soaking and germination [22].

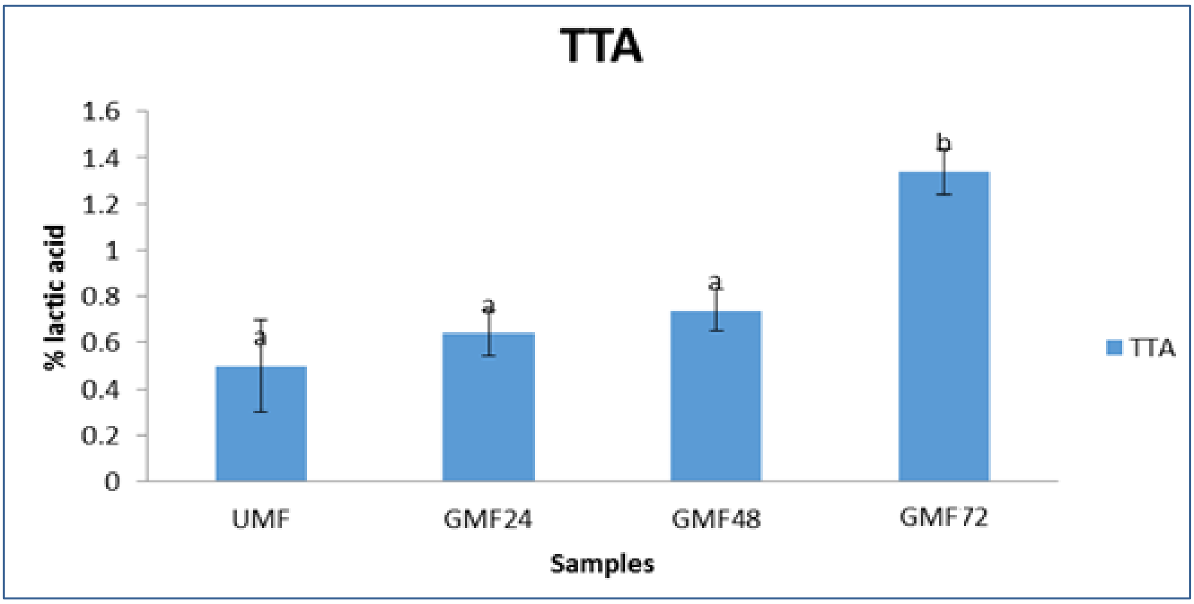

Figure 2: Effect of germination on the total titratable acidity of finger millet flour.

(Where UMF=un-germinated millet flour and GMF=Germinated millet flour for 24, 48 and 72 h respectively).

The effect of germination period on the colour of finger millet flour samples and porridges is shown in Table 1. Germination increased the lightness (L) value from Hunter L 70.10 of un-germinated finger millet flour to Hunter L 72.83 of germination after 72 h. However, there was no significant difference (P<0.05) on the control (un-germinated) and germinated finger millet flours after 24 and 48 h, respectively. Moreover, there was no significant difference (p<0.05) observed on the redness (a*) value of the finger millet flours. The increase in germination period significantly (p<0.05) increased the yellowness (b*) value of the finger millet flours. After cooking of the porridge, the L, value showed a decrease. The lower L value meant that the finger millet grains lost their brightness during cooking because the L value measures the colour on the light to dark axis. Mandge *et al*. [23] observed similar results on how cooking affect the lightness and the cooked porridge lost brightness. The darkness that was observed in this study could be as a result of browning reaction that occurred during the oven drying of finger millet grains. Increase in germination period however, shows an increase in the L value. The L values of all finger millet flours did not show any significant difference at p<0.05. There was a significant decrease in the redness (a*) of porridge. However, yellowness (b*) significantly increased (p<0.05). The change in the yellowness of the porridges was largely influenced by the effects of Maillard reaction and other reactions that caused pigment destruction. All these dissimilarities could be the result of the shear forces produced during cooking of the porridges which increased the rate of the chemical reactions between reducing sugars and amino acids that occur during cooking [24] .

Table 1. Colour analysis of germinated finger millet flour and porridge

Sample	Flour			Porridge		
	L*	a*	b*	L*	a*	b*
UFM	70.10±0.44[a]	3.63±0.15[a]	7.60±0.20[a]	31,47±0.15[a]	7.33±0.21[ab]	7.33±0.21[a]
GFM24	70.77±0.67[a]	3.63±0.25[a]	8.03±0.67[a]	31.80±0.35[a]	7.80±0.20[b]	7.60±0.26[ab]
GFM48	71.13±0.25[a]	3.83±0.15[a]	8.93±0.58[b]	31.87±0.90[a]	7.23±0.32[a]	7.93±0.25[ab]
GFM72	72.83±1.18[b]	3.87±0.23[a]	9.47±0.15[b]	34.29±0.64[a]	3.63±0.35[c]	8.20±0.26[b]

Values are mean± Standard deviation of triplicates determination. Means in the same column followed by the same subscript are significantly different (p<0.05), UFM=Un-germinated finger millet flour, GFM= Germinated finger millet flour for 24, 48 and 72 h respectively.

The effect of germination on the viscosity of finger millet flours is shown in Figure 3. The viscosity of the flours showed a significant (p<0.05) decrease from 4777 of un-germinated FM flour to 2533, 577, 420 cP of germinated finger millet flours for 24, 48 and 72 h, respectively. Determining the viscosity of germinated paste or flours is important since it is one of the physicochemical characteristics that shows the extent of malt content in hydrolytic enzymes. This result indicates that porridge from germinated FM flours could be produced at a solid concentration which is higher, 15% (w/v), without surpassing the upper viscosity limit (3000 cP). The decrease of viscosity of FM flours observed throughout germination was caused by the degradation of starch into shorter chain polysaccharides by the action of amylase developed during the germination process [25,26]. The decrease in flour's viscosity induced by germination is desirable for preparation of weaning foods. Low viscosity can make infants consume more food easily because of the solid that is added to the weaning food blend. Low viscosity of the germinated finger millet flours will no doubt help in increasing the nutrient density of the porridges and gruels, which is advantageous to the young ones [25]. The decrease of viscosity is a consequence of alpha amylases action during germination. A noticeable increase in alpha amylase and other amylases during fermentation and germination of cereal grains was reported by Evans *et al*. [27]. Amylase enzymes tend to break down starch granules during the cooking process thus reducing viscosity without dilution with water while simultaneously enhancing the energy and nutrient density [26]. The result of this study is in line with reports by Ikujenlola [28] and Adetuyi *et al*. [29] that germination or sprouting has viscosity reducing effect on cereals and legumes.

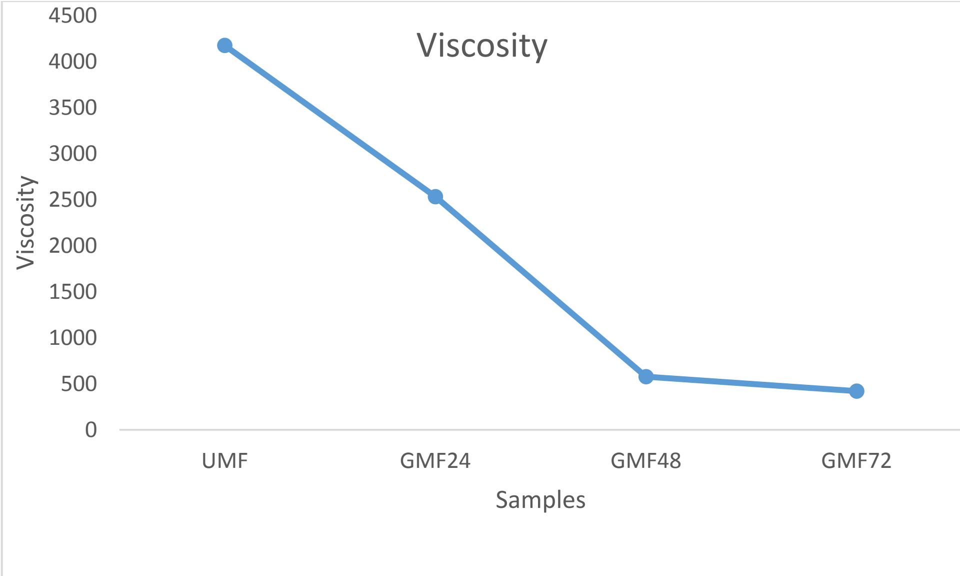

Figure 3: Effect of germination on the viscosity of finger millet porridge
(Where UMF=un-germinated millet flour and GMF=Germinated millet flour for 24, 48 and 72 h respectively).

Functional properties of germinated finger millet flours

Table 2 represents the functional properties of germinated finger millet flour samples. The results of water absorption capacity of the finger millet flours show a significant difference ($p<0.05$) in germination at 24 h as compared to germination at 48 h and 72 h, but not significantly different to the control (un-germinated flour). This means that water absorption capacity increased with increasing germination period of 48 and 72 h, respectively and this might be due to major chemical constituents which are proteins and carbohydrates in the flour samples because they have hydrophilic parts that are polar [30]. Similar observations of increase in water holding capacity of different germinated flours were reported [20,31]. The increased water absorption capacity observed in this study could be due to the production of compounds such as soluble sugars that have good water holding capacity [20]. The high values recorded at 48 and 72 h indicate the suitability of germinated FM flour samples and their isolate to be included into food formulations containing water especially those that involve handling of the dough [32]. Lower water absorption capacity is advantageous for preparing soft porridge. The solubility of the flour samples ranged from 1.87 to 8.32%. The solubility index of the flour samples significantly ($p<0.05$) increased with increase in germination time. The highest value (8.32%) was obtained at 72 h of germination. The increase in solubility index in this study could be as a result of the increased amylases activity and similar increase in the levels of soluble sugars [33]. High solubility of the germinated FM flour samples indicates that the flour will be suitable for infants [34].

Table 2. Some functional properties of finger millet flour germinated at different period of time.

Variety	WAC(ml)	SOLB(%)	SP(g/g)	BD(g/cm^3)	LGC (%)	OAI(ml)
CTR	1.33±0.12^{ab}	1.87±0.01^{a}	4.83±0.53^{b}	0.78±0.01^{b}	8.67±1.15^{b}	1.63±0.06^{b}
G24	1.20±0.00^{a}	2.79±0.05^{a}	3.79±0.16^{ab}	0.82±0.02^{c}	5.33±1.15^{a}	1.67±0.06^{b}
G48	1.57±0.15^{b}	6.30±0.98^{b}	4.36±0.97^{b}	0.75±0.01^{a}	4.67±1.15^{a}	1.77±0.06^{a}
G72	1.53±0.23^{b}	8.32±0.42^{c}	3.17±0.05^{a}	0.75±0.01^{a}	8.00±0.00^{b}	1.78±0.06^{a}

Mean scores in the same column with different superscripts are significantly different ($p<0.05$). CTR=control, G24=germination at 24 h, G48=germination at 48 h, G72=germination at 72 h, WAC= water absorption capacity, SOLB= solubility, SP=swelling power, BD=bulk density, LGC=least gelation concentration, OAI=oil absorption index.

Swelling power significantly ($p<0.05$) decreased as germination progressed, with the value of un-germinated (control) FM flour at 4.83 g/g compared to the least value obtained as 3.17 g/g on 72 h of germination. There was a decrease in the swelling power of the germinated FM flour samples because amylases disrupted hydrogen atoms existing in FM and proteases were hydrolysed into sugars and amino acids, respectively [20,35]. Similar observations of decrease in swelling power capacity of germinated and sprouted flours were reported by Adadeji *et al*. [20]. Low swelling capacity is good for handling of the food in the gut, especially in infants. The bulk density ranged from 0.75 to 0.82 g/cm^3 and a significant

($p<0.05$) decrease of the flour samples at 48 and 72 h germination time was observed. The reduction of bulk density at 48 and 72 h germination could be due to the fact that germination tends to soften the grains thereby making milling easier with smaller particles sizes than un-germinated grains [21]. Moreover, the observed decrease in bulk density may also be due to complex compounds such as starch and proteins being broken down by modification that take place during germination [4]. Reduced bulk density promotes easy digestibility of food products, especially children with digestive system that is immature [36]. Reduced values of bulk density in this study leads to the flour samples packaged in less quantity with a constant volume which saves costs for packaging. The least gelation concentration ranged from 4.67% to 8.67% although there was significant ($p<0.05$) decrease of the finger millet flour samples at 24 and 48 h germination time. The gelation concentration of the finger millet flour which germinated at 24 and 48 h was significantly lower ($p<0.05$) than the un-germinated finger millet flour. The increase in the least gelation concentration of the germinated FM flour at 72 h may be due to the altered carbohydrate composition of the FM grains [14]. The values of oil absorption capacity of the FM flour samples ranged from 1.63 to 1.78 g/m. The oil absorption capacity of the FM flour samples showed a significant ($p<0.05$) increase with increase in germination time. The result corresponds with the work of Imtiaz *et al*. [5] who reported an increase in oil absorption capacity of germinated wheat and mungbean seed flour. Deepali *et al*. [37] stated that the increase in oil absorption capacity during germination might be due to solubilisation and disconnection of proteins which lead to vulnerability of non-polar constituents that are within the protein molecule. The result shows that FM flour may be used as thickeners in some liquid and semi liquid food preparations to replace some oil seeds and legumes [32].

Sensory evaluation properties of germinated finger millet porridges

The effect of germination on the consumer acceptability of finger millet porridge is shown in Table 3. The colour of porridge from un-germinated, germinated finger millet for 24 and 48 h were preferred to those from germinated finger millet flour for 72 h. There was no significant difference ($p<0.05$) observed in the colour of porridge made from control and germinated finger millet for 24 and 48 h. The results obtained in this study were similar with findings by Kikafunda *et al*. [38] who found that most panellists preferred porridge which was lighter in colour, while the least preferred porridge was the one germinated for 72 h which had the dark brown colour. Similar results of preferred porridge made from germinated finger millet for 48 h as compared to the un-germinated millet flour were observed by Ocheme & Chinma [14] without significant difference ($p<0.05$) using germination of pearl millet. The change in the colour of porridges produced from germinated finger millet flour was caused by the development of brown pigments which occurred during oven drying after germination when there was reaction of starch with proteins through a Maillard reaction [25]. Results on the aroma of finger millet porridges showed no significant difference ($p<0.05$) in un-germinated finger millet and germinated FM for 24 and 48 h although the control (un-germinated) finger millet porridge had highest score of 6.30. However, germinated finger millet porridge for 72 h showed significant difference ($p<0.05$) when compared with the rest of the samples. The results revealed that no significant difference ($p<0.05$) was observed in the mouthfeel of all samples from un-germinated finger millet to germinated finger millet for 24, 48 and 72 h, respectively and they were all accepted. However, the scores of mouthfeel showed rather lower scores as compared to all other attributes. The taste of the finger millet porridge samples showed a significant ($p<0.05$) difference with increase as germination period increased. Un-germinated finger millet porridge scored significantly higher value (6.18) than germinated FM porridges. The taste of germinated finger millet porridge for 72 h was rather not acceptable and it was the least scored by panellists. This may be due to off flavour that occurred as a result of germination for 72 h. The result is similar to those obtained by Almeida-Dominguez *et al*. [33] who found that gruels produced from germinated sorghum flour had bitter taste, slightly brown colour and strong malt flavour than gruels produced from un-germinated sorghum flour.

Table 3. Consumer acceptability of germinated finger millet porridge

Sample	Colour	Aroma	Mouthfeel	Taste	Overall acceptability
UFM	7.10^{a}	6.30^{a}	5.92^{a}	6.18^{a}	6.28^{a}
GFM24	6.50^{a}	6.12^{a}	5.32^{a}	5.40^{ab}	5.74^{a}
GFM48	6.48^{a}	5.92^{a}	5.24^{a}	5.08^{b}	5.70^{a}
GFM72	4.82^{b}	5.18^{b}	5.10^{a}	4.46^{c}	5.00^{b}

Values are mean± Standard deviation of triplicates determination. Means in the same column followed by the same subscript are significantly different ($P<0.05$), UFM=Un-germinated finger millet flour, GFM= Germinated finger millet flour for 24, 48 and 72 h respectively.

Porridge prepared from un-germinated finger millet flour, germinated finger millet flour for 24, 48 and 72 h were well accepted although porridge prepared from germinated finger millet flour for 72 h showed significant ($p<0.05$) difference compared to the rest of the samples. This indicates that porridge prepared from un-germinated and germinated finger millet flour for 24 and 48 h compared favourably. Ocheme & Chinma [14] observed similar overall acceptability of porridge prepared from un-germinated and germinated pearl millet flour.

4. CONCLUSION

This study demonstrated that germination showed positive effects on some physicochemical, functional and sensory properties of finger millet flour and porridge. Germination caused a decrease in pH as well as the viscosity. However, the TTA and lightness (L) value of finger millet flour were significantly increased with germination time. There was significant increase of the oil and water absorption capacity including the solubility of the germinated finger millet flour samples. However, germination period significantly reduced the swelling power and bulk density of the finger millet flour samples. The reduction in both two functional properties demonstrate the possibility of germinated finger millet flours to be used as ingredients in different foods such as baby food, sauces and cakes. Moreover, the decrease in bulk density is advantageous since it results in small amounts of the germinated finger millet flour samples packaged in a constant volume. Porridge samples prepared from germinated finger millet flour were well accepted.

5. CONFLICT OF INTEREST

None declared

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