Physical Properties and Consumer Perceptions of Pearl Millet Sourdough Fresh Bread

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Abstract
Bread is a common staple food in developing countries and also in many other regions of the world. Pearl millet sourdough was utilized in combination with whole-wheat flour for bread preparation. Loaf and sensorial characteristics of control bread made using wheat flour were compared with bread prepared using Pearl millet sourdough and wheat flour. Seven different formulations of the millet sour dough (90%, 80%, 70%, 60%, 50%, 40%) and 100% wheat flour were evaluated. Bread prepared with millet flour presented good loaf characteristics and sensory attributes. Consumer preference test was conducted using 50 consumers assessing the attributes of appearance, colour (crust), color (crumb), aroma, taste, sponginess, after taste and overall acceptability with a nine-point hedonic scale. The measured loaf characteristics for millet sourdough bread were colour, volume, weight and specific volume. Control sample had the highest overall acceptability score of 7.9, followed by 50% sample recording a score of 6.7 (liked moderately). The least overall acceptability score of 3.6 was recorded by 80% millet sourdough bread. Analysis of variance showed that the specific volume of the bread samples was significantly different at 95% confidence interval. However, the volume of the samples with 60% and 70% millet sourdough were not significantly different from each other. Millet sourdough could be a suitable ingredient for bread formulations, maintaining their nutritional value and sensorial quality in addition to being a gluten-free product.

Keywords: Pearl millet, Pearl millet sourdough bread, loaf characteristics, gluten free, acceptability

Propriétés Physiques et Perceptions des Consommateurs à L'égard du Pain Frais au Levain de Millet Perlé

Résumé
Le pain est un aliment de base commun dans les pays en développement et dans de nombreuses autres régions du monde. Le levain de millet perlé a été utilisé en combinaison avec la farine de blé entier pour la préparation du pain. Les caractéristiques du pain de contrôle à base de farine de blé ont été comparées à celles du pain préparé à base de levain de mil perlé et de farine de blé. Sept formulations différentes de la pâte sûre de millet (90%, 80%, 70%, 60%, 50%, 40%) et de la

farine de blé 100% ont été évaluées. Le pain préparé avec de la farine de mil présentait de bonnes caractéristiques de pain et des attributs sensoriels. Le test de préférence des consommateurs a été effectué à l'aide de 50 consommateurs évaluant les attributs de l'apparence, de la couleur (croûte), de la couleur (chapelure), de l'arôme, du goût, de l'éponge, du goût et de l'acceptabilité globale à l'aide d'une échelle hédonique à neuf points. Les caractéristiques mesurées du pain au levain de mil étaient la couleur, le volume, le poids et le volume spécifique. L'échantillon témoin affichait la cote globale d'acceptabilité la plus élevée, soit 7,9, suivi de 50 % avec une cote de 6,7 (moyenne). Le score d'acceptabilité le moins élevé, soit 3,6, a été enregistré par 80 % de pain au levain de mil. L'analyse de la variance a montré que le volume spécifique des échantillons de pain était significativement différent à un intervalle de confiance de 95 %. Toutefois, le volume des échantillons contenant 60 % et 70 % de levain de mil n'était pas significativement différent l'un de l'autre. Le levain de mil pourrait être un ingrédient approprié pour les formulations de pain, en maintenant sa valeur nutritionnelle et sa qualité sensorielle en plus d'être un produit sans gluten.

Mots-clés : Millet perlé, Pain au levain de millet perlé, caractéristiques du pain, sans gluten, acceptabilité

Introduction

The major millet species in the world is pearl millet (*Pennisetum glaucum* (L.), followed by foxtail, proso and finger millet (Shahidi and Chandrasekara, 2013). Pearl millet is a food that supplies a major proportion of calories and protein to large segments of populations in the semi-arid tropical regions of Africa and Asia (O'Kennedy *et al*., 2006). Millet is a gluten-free and low-cost cereal (approximately 40% lower than the price of corn), which is resistant to drought and nutrient-poor soils (Gomes *et al*., 2008). The global millet production was estimated at 27.8 million tons. More than 50% of the millet production is currently finding its way into alternative uses as opposed to its consumption only as a staple (Food and Agriculture Organization, 2015). Countries in Africa and Asia produced 56% and 41% of the total world production, respectively (Shahidi and Chandrasekara, 2013).

Bread is an important staple food in both developed and developing countries. It is so important in human diet that increases in its price have triggered off angry protests in some countries where up to 50% of their total calories are supplied by bread alone (Pomeranz and Clifton, 1996; Akobundu, 2006). Worldwide, bread consumption is one of the largest consumed food product, with over 9 billion kg of bread being produced annually (Georgsson, 2015; Hebeda and Zobel, 1996). This demand has been driven by consumers seeking convenient fresh products that provide a source of nutritional value (Georgsson, 2015; Hebeda and Zobel, 1996). Consequently, freshness is a key component in consumer acceptability and choice of bread. However, the freshness perception is not easily described, particularly as it is likely to vary from one bread type to another.

Bread is relatively expensive in West

Africa. The reason being that the major raw material in bread making, wheat, is imported. Wheat is a temperate cereal crop, which may not grow in the tropics due to climatic reasons. With the increase in the bread consumption in Ghana, efforts have now been made to promote the use of composite flours in which flours from root crops and cereals which are locally grown crops were partially substituted into wheat flour for bread making (Tortoe *et al*., 2014). This composite flour programme would thereby minimize the demand for imported wheat; produce protein- enriched bread (Giami *et al*., 2004; Olaoye *et al*., 2006); conserve foreign reserves (Eddy *et al*., 2007) and widen the utilization of indigenous crops in food formulation (Ade-Omowaye *et al*.,2008).

Reports have been published on the successful composite bread technology (though such bread still require at least 70% wheat flour to be able to rise), using some indigenous crops like soybeans, plantain, cocoyam, sweet potato, breadfruit, breadnut (Oluwole *et al*., 2005; Onuh and Egwujeh, 2005; Olaoye *et al*. 2006; Eddy *et al*., 2007; Ade-Omowaye *et al*., 2008; Malomo, 2010; Malomo *et al*., 2011). Some authors have studied its viability in bakery products such as breads, biscuits and pasta (Rathi *et al*., 2004; Saha *et al*., 2011; Schoenlechner *et al*., 2013), aiming to replace whole-wheat flour with millet flour. Due to its low cost, desirable nutritional characteristics, and health benefits (such as antioxidant activity and low glycemic index), and the antimicrobial and antioxidant activity of its polyphenols (Chethan and Malleshi, 2007) there is increased interest in using millet as a raw material in bread production. Additionally, millet does not contain gluten and is known for its low carbohydrate concentration and low glycemic index (Singh *et al*., 2010; Suma and Urooj, 2014). The acceptability of the foods developed with millet flour, such as biscuit dough and bread, is reported to be very good (Saha *et al*., 2011; Schoenlechner *et al*., 2013).

Fermentation is known to improve the nutritional value of raw materials and by using fermented foods in the diet; the nutritional status of the individual can be improved (Motarjemi and Nout, 1996). Other studies on nutritional changes in fermented millet have found improvement of the *in vitro* protein digestibility (Antony and Chandra, 1998; Ali *et al*., 2003) and a significant reduction in total polyphenols and phytic acid content (Obizoba and Atii, 1994; Sharma and Kapoor, 1996; Antony and Chandra, 1998; Elyas *et al*., 2002; Tou et *al*., 2006). There is increase in total free amino acids and minerals (Antony and Chandra, 1998), and a reduction in trypsin inhibitor activity (Antony and Chandra, 1998) when fermenting millet.

Sourdough fermentation is a type of solid state fermentation used in preparation of some food products. The process is a useful tool for adding value to locally available agriculture produce as well as foster cultural and geographical distinctiveness. Sourdough fermentation impacts unique characteristics on ground cereals or starchy raw materials; this includes making them available in different forms, improving the nutritional properties of cereal, food preservation through lactic acid, reduction of toxins, enhancing a range of flavors, odor and textures of food (De Vuyst and Neysens, 2005; Chavan and Chavan 2011; Karrar, 2016). Sourdoughs are used worldwide for a huge variety of products: leavened bread, fermented gruels, alcoholic and/or acid fermented drinks, vinegar and fermented rice (Hammes *et al*., 2005; Achi and Ukwuru, 2015 and Adinsi *et al*., 2014). Today, sourdough is used in the industry of breads, cakes, and flakes (Thiele *et al*., 2002; Chavan and Chavan 2011). Use of sourdough in breads has acquired popularity as a means to improve the quality, flavor and shelf life of breads. French breads, Italian, Panetone and soda crackers are also examples of wheat products that rely on the process of souring. Conventional bread dough fermentation increases elasticity and viscosity, whereas the addition of sourdough to final bread dough results in decreased elasticity and yields softer dough (Chavan and Chavan 2011).

The objective of this study was to develop millet sour dough bread using different proportions of millet sourdough and wheat flour, and to assess consumer acceptability of the millet sourdough composite bread.

Materials and methods

Materials

Pearl millet samples were obtained from CSIR-Savanna Agricultural Research Institute, Manga in the Upper East region of Ghana.

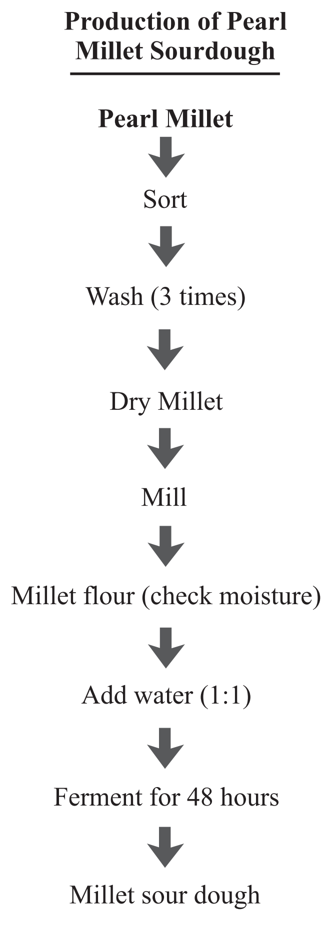

Figure 1: Protocol for production of pearl millet sourdough

Table 1: Common ingredients weights for millet sour dough bread preparation

Ingredients	Weight (g)
1. Water	180
2. sugar	20
3. Salt	10
4. Margarine	20
5. Nutmeg	0.1
6. Vanilla essence	2.5 mL

Table 2: Proportions for formulating of composite Pearl millet sourdough bread

Bread Percentage (%)	Millet sourdough (g)	Wheat flour (g)
Control	-	600
40	240	360
50	300	300
60	360	240
70	420	7180
80	480	120
90	540	60

Methods

Different formulations of Pearl millet sourdough bread were prepared per the method shown in (Table 2) and figure 2 based on earlier work (Tortoe *et al.,* 2014). The formulations used were as follows: 90% millet sourdough, 80% millet sourdough, 70% millet sourdough, 60% millet sourdough, 50% millet sourdough, 40% millet sourdough and 100% wheat flour.

Methods for Preparation of Millet Sourdough Bread

Weigh ingredients

↓

Sieve wheat flour

↓

Add millet sour dough to wheat flour (Depending on proportions)

↓

Mix thoroughly to form a dough

↓

Knead dough for 15min until smooth

↓

Cut into desirable sizes and mold into well-greased baking pans

↓

Cover with clean cloth and allow it to proof (3 - 4h)

↓

Bake in a moderately hot oven set at 160°C for 35 - 45min

↓

Remove, allow to cool and package in Polypropylene bag

↓

Millet sourdough composite bread

NB: The more sourdough used the lesser water used

Figure 2: Preparation of millet sourdough bread

Evaluation of the Baking Qualities of Composite Millet Sourdough Bread Samples

Loaf volume

Loaf volume was determined by using Rape seed displacement method (AACC, 2000, Standard 10-05). This was done by loading millet grains into an empty box with calibrated mark until it reached the marked level and unloaded back. The bread sample was put into the box and the measured millet was loaded back again. The remaining millet grains left outside the box was measured using measuring cylinder and recorded as loaf volume in cm^3.

Specific volume

The specific volume (volume to mass ratio) (cm^3/g) was thereafter calculated.

Colour measurements

The colour of the bread crust and crumb (inside and outside) were measured using a Minolta Chromameter CR310-Japan colorimeter model D25-PC2 (Hunter of employees of the National Institute of Aglaboratories, Reston, VA) after calibration using a white tile (L=97.51, a=5.45, b=-3.50) according to AACC Method 14-22.01, 2000). Colour was expressed in terms of lightness (L) and colour difference. ΔE was calculated as $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$,

(ΔL is change in L value (standard L- recorded L),

Δa is change in a value standard a- recorded a, Δb is change in b value (standard b- recorded b), where lightness (L) = (+), green (a) = (-); yellow (b) = (+), blue (b) =(-) colour value.

Analyses was conducted three times per sample and the mean calculated.

Consumer Acceptability of Composite Pearl Millet Sour Dough Bread

For consumer acceptability studies, Pearl millet sourdough bread were prepared using six different formulations of the millet sour dough with wheat flour (90%, 80%, 70%, 60%, 50%, 40%), control sample was prepared using 100% wheat flour. Fifty (50) consumers were used in the study and they were selected according to criteria of familiarity with the product. The consumer tests were carried out in the Sensory Science Laboratory of the CSIR-Food Research Institute. The samples were evaluated on a nine-point hedonic scale (1- dislike extremely, 5- neither like nor dislike and 9- like extremely) as suggested by Tomlins *et al*., (2005), Meilgaard *et al*., (1988), based on the attributes of appearance, colour (crust), colour (crumb), aroma, taste, sponginess, after taste and overall acceptability. All the six composite bread samples and the 100% wheat bread were presented randomly on white plates labelled with three random digit codes. In the study, samples were served to consumers in two days, four samples and three samples respectively. Consumers were offered mineral water and cucumber to rinse their mouths between samples.

Data Analysis

Analysis of variance (ANOVA, alpha = 0.05) and Duncan Multiple range test were performed to determine significant differences between means of treatments for the consumer acceptance tests (Minitab 14, Minitab Inc, Brandon Court, United Kingdom.

Results and Discussions

The colour of the different bread formulations is presented in Tables 3 and 4. Lightness value L* indicates how dark/light of a sample (varying from 0-black to 100-white), a* is a measure of greenness/redness, b* is the grade of blueness/ yellowness. Values for the crumb (inside) was whiter than the crust (outside). It varied from 56.62 to 64.25 (Table 3). The L value for the crust (exterior) ranged from 52.77 to 57.59 (Table 4). Generally, a and b

Table 3: Instrumental colour of bread crumb of composite millet sourdough bread and control (100% wheat bread)

Sample	L	a	b
40%	63.96±0.54[a]	1.65±0.05[c]	12.81±9.98[a]
50%	62.33±0.38[a]	1.94±0.09[b]	18.67±0.22[a]
60%	63.72±1.48[a]	1.90±0.12[b]	18.52±0.40[a]
70%	59.38±0.73[b]	1.88±0.03[b]	17.32±0.12[a]
80%	56.62±0.81[c]	2.17±0.04[a]	17.27±0.05[a]
90%	57.43±0.31[bc]	1.95±0.04[b]	16.29±0.14[a]
Control	64.25±1.29[a]	1.47±0.04[d]	19.50±0.25[a]

Means across a column with different letters are significantly different at P≤0.05
Mean of three determinations±standard deviation, Control - 100% wheat flour, 40%-40% millet sourdough substitution + 60% wheat flour, 50%-50% millet sourdough substitution + 50% wheat flour, 60%-60% millet sourdough substitution + 40% wheat flour, 70%-70% millet sourdough substitution + 30% wheat flour, 80%-80% millet sourdough substitution + 20% wheat flour, 40%-90% millet sourdough substitution + 10% wheat flour

Table 4: Instrumental colour of bread crust from composite millet sourdough bread and control (100% wheat bread)

Sample	L	a	b
40%	56.84±1.77[ab]	10.32±0.30[b]	19.97±0.99[d]
50%	57.59±1.51[a]	8.31±0.33[c]	27.91±0.64[a]
60%	53.98±0.57[abc]	9.66±0.58[b]	28.12±0.20[a]
70%	56.01±2.66[abc]	4.81±0.29[d]	24.46±0.43[b]
80%	55.52±1.27[abc]	3.73±0.07[e]	21.96±0.12[c]
90%	52.77±0.45[c]	2.85±0.06[f]	17.48±0.13[e]
Control	53.41±0.53[bc]	11.68±0.22[a]	27.38±0.31[a]

Means across a column with different letters are significantly different at P≤0.05
Mean of three determinations±standard deviation, Control - 100% wheat flour, 40%-40% millet sourdough substitution + 60% wheat flour, 50%-50% millet sourdough substitution + 50% wheat flour, 60%-60% millet sourdough substitution + 40% wheat flour, 70%-70% millet sourdough substitution + 30% wheat flour, 80%-80% millet sourdough substitution + 20% wheat flour, 40%-90% millet sourdough substitution + 10% wheat flour

values for crust (outside) was higher than the crumb (inside) (Tables 3 and 4)..
The results for loaf weight (g) are presented in Figure 3, it was found that loaf weight (g) of bread samples 90%, 40% and control were 271.6, 332.2 and 456.3g respectively.

These results revealed that loaf weight of bread samples decreased with increasing levels of millet sourdough. Contrary results were obtained by (Mongi *et al.*, 2011), according to them, the loaf weight of bread samples was increased with increasing level of non-wheat flour (cocoyam flour). The reason could be attributed to the fact that their flour was from a root crop but sour cereal dough was used in our study, the starch properties vary for roots and cereals.

Loaf volumes of the samples were calculated

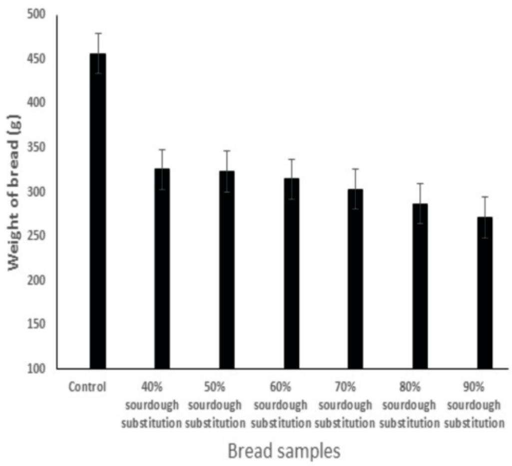

Figure 3: Weight of bread prepared with different formulations of millet sourdough and wheat flour.

and presented in Table 5. It was revealed that millet composite bread 90% and 80% samples were found to have lowest loaf volume readings (114 and 206 respectively) and thus have low specific volumes 0.42 and 0.72 respectively (Table 5). Control and 40% bread samples produced using high proportions of wheat flour gave highest loaf volumes and thus higher specific loaf volumes compared to other samples (1200 and 811) and (2.63 and 2.49) respectively. It was observed experimentally that as the percentage of millet sourdough increased in the bread, the loaf volume and specific loaf volume decreased. This might be due to large particle size and damaged starch percent of millet sourdough. Decrease in loaf volume with increasing levels of millet sourdough may be ascribed to reduced carbon dioxide (CO_2) retention in millet sourdough bread sample as explained by (Rao and Hemamalini, 2011). It is also obvious that substitution of wheat flour by other flour reduces the gluten fraction which is the source of elasticity in dough. This elasticity helps in retaining carbon dioxide produced during fermentation. Reduced gluten fraction in 90%, 80%, 70%, 60% bread samples caused a compact, compressed, less aerated texture and decreased rise in loaf size.

These results are in agreement with (Gomez *et al*., 2003) and (Yusnita and Wong, 2011), who indicated that, addition of dietary fiber rich substances in baking products reduce loaf volume.

Similar trend of results was obtained for specific volume of loaf in the current research (Table 5). Specific volume of millet sourdough bread (cm3/g) ranged from 0.42 to 2.63, 2.61cm3/g for 90%, 40% and control bread respectively. Specific volume of bread with 90% and 80% formulation was significantly lower ($p<0.05$) than that of 40% and control (Table 5). It is apparent that bread samples with reduced volume will also have reduced specific volume. Present results are in-line with the findings of (Constandache 2005), (Islam *et al*, 2007), who reported decrease in loaf volume and specific volume with the increased substitution of wheat flour with other flour.

Analysis of variance (Table 5) showed that the specific volume of the bread samples were significantly different at $p<0.05$). However, the volume of the samples with 60% and 70% millet sourdough were not significantly different from each other. Control sample which had 100% wheat flour had the highest specific volume (Table 5). The complex interaction between wheat flour and yeast produces carbon which causes the bread to rise and increase in volume during the

Table 5: Volume and specific volume of millet sourdough bread

Sample	Volume	Specific Volume
Control	1200.0±11.1[a]	2.63±0.02[a]
40%	811.0±18.5[b]	2.49±0.08[b]
50%	649.7±8.1[c]	2.01±0.03[c]
60%	404.0±8.7[d]	1.28±0.03[d]
70%	393.3±7.6[d]	1.30±0.02[d]
80%	206.7±6.5[e]	0.72±0.02[e]
90%	114.3±4.0[f]	0.42±0.02[f]

Note: Means across a column with different letters are significantly different at P≤0.05
Control- 100% wheat flour,40%-40% millet sourdough substitution + 60% wheat flour, 50%-50% millet sourdough substitution + 50% wheat flour, 60%-60% millet sourdough substitution + 40% wheat flour, 70%-70% millet sourdough substitution + 30% wheat flour, 80%-80% millet sourdough substitution + 20% wheat flour, 40%-90% millet sourdough substitution + 10% wheat flour

Table 6: Mean scores of appearance, colour (crust and crumb), aroma, taste, after-taste, sponginess, and overall acceptability for six composite millet sour dough and 100% wheat flour bread samples

Millet sourdough samples	Appearance	Color (crust)	Color (crumb)	Aroma	Taste	After taste	Sponginess	Overall acceptability
Control	7.8±1.02[a]	7.7±0.80[a]	7.1±1.32[a]	7.6±1.17[a]	7.7±1.05[a]	7.7±1.06[a]	7.2±1.18[a]	7.9±1.06[a]
40%	7.2±1.21[abc]	7.0±1.25[abc]	6.8±1.26[a]	6.8±1.24[bc]	6.2±1.58[b]	5.7±1.61[b]	6.5±1.39[ab]	6.4±1.51[bc]
50%	7.3±0.87[ab]	7.2±1.00[ab]	6.8±1.10[a]	6.8±1.00[ab]	6.3±1.34[b]	5.8±1.47[b]	6.5±1.41[ab]	6.7±1.48[b]
60%	6.4±1.47[c]	6.3±1.49[cd]	6.7±1.22[a]	6.0±1.70[c]	4.9±1.78[cd]	4.7±1.87[c]	6.2±1.54[b]	5.5±1.59[c]
70%	6.6±1.14[bc]	6.4±1.35[bc]	6.5±1.21[a]	6.3±1.46[bc]	5.5±1.52[bc]	5.0±1.48[bc]	5.8±1.39[b]	5.7±1.58[c]
80%	5.0±1.90[d]	5.0±1.95[e]	5.1±1.93[b]	4.9±1.97[d]	3.5±1.95[e]	3.5±1.98[d]	4.0±1.79[c]	3.6±1.93[d]
90%	5.5±2.08[d]	5.5±2.11[de]	5.0±1.98[b]	5.0±1.66[d]	3.9±1.84[de]	3.5±1.49[d]	4.4±1.92[c]	4.3±2.01[d]

Means within columns with different letters are significantly different at $p < 0.05$. Control- 100% wheat flour, 40%-40% millet sourdough substitution+ 60% wheat flour, 50%-50% millet sourdough substitution + 50% wheat flour, 60%-60% millet sourdough substitution + 40% wheat flour, 70%-70% millet sourdough substitution + 30% wheat flour, 80%-80% millet sourdough substitution + 20% wheat flour, 40%-90% millet sourdough substitution + 10% wheat flour,

proofing stage. Bread formulated using 40% millet sourdough and 60% wheat flour bread had reduced specific volume compared to the 100% wheat flour bread. This might be due to the less amount of gluten available in the formulation since millet sourdough does not contain gluten. The same trend was observed in the rest of the formulations. The higher the percentage of millet sourdough in the bread, the lesser the specific volume. The only exception was with the 60% and 70% formulations which had similar volume.

The results of the sensory evaluation of the sourdough bread are presented in Table 6. Generally, the sourdough bread samples were significantly different for all the parameters evaluated. As expected, the control sample performed better in all the parameters evaluated, having a score range of 7.1 to 7.9 followed by sample 50% recording a score range of 5.8 to 7.3. Sample 80% was the least preferred among all samples evaluated.

The appearance of the sourdough bread samples revealed that all the samples were significantly different except for 80% and 90% bread samples. This implies that the appearance of 80% and 90% sourdough bread samples was similar but different from the other samples. The appearance of samples 80% and 90% sourdough bread was the least preferred by the consumers. The appearance of the control sample was liked most (7.8, liked very much) followed by sample 50% (7.3, liked moderately).

The colour (crust) of the samples underwent a similar trend with the control sample being preferred the most (7.7) followed by 50% (7.2), whilst 80% was the least preferred (5.0). Concerning the colour of the crumb, the control sample scored the highest (7.1) followed by 50% (6.8) and 40% (6.8). Sample 90% scored the least (5.0). The aroma of the control sample was most preferred (7.6, liked very much), followed by 50% (6.8) and 40% (6.8). The after taste and sponginess attributes followed a similar trend. Regarding taste, control sample is the most preferred followed by sample 50%. Sample 80% taste was the least preferred (3.5, disliked slightly).

The control sample recorded the highest overall acceptability score of 7.9 (liked very much), followed by 50% sample recording a score of 6.7 (liked moderately). Sample 80% recorded the least overall acceptability score of 3.6 (disliked slightly).

Conclusions

Control sample was highly preferred with an overall acceptability score of 7.9 whereas 50% sample recorded a score of 6.7. Sample 80% had the lowest overall acceptability score of 3.6. Millet sourdough bread prepared using 90% and 80% from the substitution of whole wheat flour with millet sourdough were found to have less improved loaf characteristics than that of control bread sample which was prepared using wheat flour only.

The 50% millet sourdough bread should be promoted since it was preferred. This healthy type of bread will reduce the money spent on importation of wheat flour for bread production in Ghana. It is also obvious that substitution of wheat flour by other flour reduces the gluten fraction which will go a long way to reduce the risk of celiac diseases in consumers.

The production of bread using composite 50% wheat flour and 50% millet sourdough is feasible and accepted by consumers. This type of bread is healthy because the gluten levels is minimized and the use of millet sourdough in bread making will help reduce the foreign exchange used in the importation of wheat flour in Ghana.

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