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Assessing the suitability of flours from five pearl millet (*Pennisetum americanum*) varieties for bread production

[1*]Tortoe, C., [1]Akonor, P. T., [1]Hagan, L., [2]Kanton, R. A. L., [2]Asungre, P. A. and [2]Ansoba, E. Y.

[1]*CSIR-Food Research Institute, P. O. Box M20, Accra, Ghana*
[2]*CSIR-Savanna Agricultural Research Institute, P. O. Box 46, Manga-Bawku, Ghana*

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Abstract

Flour of five new varieties of improved certified pearl millet (*Pennisetum glaucum*) were evaluated for their physicochemical, functional properties and performance in bread products. The formulated breads were evaluated by 50 untrained panellists. The flours had colour values of L*(60.0 to 70.4), a* (+0.3 to +1.1) and b*(+4.3 to +10.5), low mean water solubility (3.8 ± 0.1) and swelling properties (4.5 ± 0.1) but high water binding capacity (121.4 ± 2.1). SAR002 (*Naaad Kohblug*) had the highest protein (11.1%), fibre (1.3%), ash (1.2%) and lower fat (3.6%). SAR001 (*Kaanati*) had the highest fat (4.3%) and ash (1.5%) but the lowest protein (7.9%). The bread showed no interactive effect ($p > 0.05$) between variety and replacement level with millet flour. Rather, a significant difference ($p < 0.05$) was observed for the two factors. Increasing proportions of millet flour in the composite flour resulted in a decrease in attribute and acceptability scores of bread. A mean score of 6.4 (slightly like) was obtained for attribute rating and acceptability of bread to 20% proportion of millet flour. Bread produced from SAR001 was the most accepted.

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an important staple cereal in the diets of Africans and Asians. It is a multipurpose crop grown for both food and non-food uses such as feed, fodder and fuel (Malik *et al.*, 2002; Anu Seshgal and Kwatra, 2006; Basavaraj *et al.*, 2010). The crop is adapted to environments characterised by low rainfall, marginal soil fertility and high temperatures. In Ghana, it is widely cultivated in the semi-arid agro-ecology of the three Northern regions, where it provides reliable harvest although its cultivation requires minimal material inputs. In 2012, nearly 180,000 MT of millet was produced in Ghana from about 170,000 hectares of cropped land (MoFA, 2013).

Millet is grown mainly as a staple for human consumption and serves as important source of nourishment for households. It is also used in the production of beverages. Millet contains significant amounts of protein, fibre and minerals such as iron and zinc, as compared to key cereals such as rice or maize. Millet also contains vitamins and essential amino acids, as well as antioxidants with various health benefits. They are slowly digestible and known to have low glycaemic index (Shobana *et al.*, 2009; Singh *et al.*, 2010; Singh *et al.*, 2012). Regardless of its rich nutritional components, the crop also contains significant amounts of tannins and phytates, which reduce the bioavailability of micronutrients (Gull *et al.*, 2016).

Utilization of millet is largely domestic even though it holds several prospects as a food crop. Its nutritional and chemical properties make it suitable as a raw material for large-scale processing of food products. For example, it has low glycaemic index, antioxidant activity and suitable for people with celiac disease. Millet might be further explored for its health-enhancing properties and its use as food ingredients (Gulia *et al.*, 2007; Basavaraj *et al.*, 2010). However, the low utilisation of millets is due to the few available food forms and unavailability of millet processing technologies (Shobana and Malleshi, 2007). In recent years, several advances have been made to expand the range uses of several local cereal crops including millet. Millet has been used in extruded *fura* (Filli *et al.*, 2011), couscous (Bora, 2013), and its flour has been used to replace considerable proportions of wheat flour in snacks and bakery products (Singh *et al.*, 2012), noodles and pasta (Ma *et al.*, 2014; Gull *et al.*, 2015).

*Corresponding author.
Email: ctortoe@yahoo.co.uk

In order to expand the utilisation of millet, new varieties of millet have been developed to complement the existing varieties on the local and international markets. The present work was therefore designed to assess the functional properties and nutritional compositions of five newly developed and improved varieties of millets, and assess their flour performance in bread production. Results obtained in the present work would provide valuable information on these new varieties, which will aid in utilising them in specific foods or industrial applications.

Materials and methods

Millet varieties

Five newly developed and improved (certified) varieties of millet namely *Kaanati* (SAR001), *Naad-Kohblug* (SAR002), *Akad-Kom* (SAR003), *Afribeh-Naara* (SAR004) and *Waapp-Naara* (SAR005) with seed colour of ivory, deep grey, grey, yellow, grey, respectively, were obtained from the CSIR-Savanna Agricultural Research Institute, Experimental Station at Manga-Bawku in the Upper East region of Ghana. The millet varieties were improved through modern plant breeding systems. The millets were washed, dried at 50°C for 6 h (Apex dryer, Apex Construction Limited, London), milled separately into flour in a hammer mill (Full circle-pulveriser, Jacobson Machine Works, Inc.) to pass through a 250 µm sieve at extraction rate of 80%, air-tight packaged in polypropylene sachets and stored for further analysis.

Colour of flours

The colour was determined using a Minolta Chroma meter (CR-310 Minolta, Japan). The device was calibrated with a reference white porcelain tile (L_0 = 97.63, a_0 = 0.31 and b_0 = 4.63) prior to determinations. The colour of the flours was described in L* a* b* notation, where L* was a measure of lightness, a* defined the components on the red-green axis, and b* defined the components on the yellow-blue axis. All determinations were done in triplicates.

Chemical composition

The flours were analysed in triplicates for moisture, ash, fat, protein and fibre contents using approved procedures of the AOAC International (AOAC, 2000). Carbohydrate was estimated by difference.

pH and Total Titratable Acidity

The pH and total titratable acidity (TTA) of the flours were determined in triplicates using the approved methods of the Association of Official Analytical Chemists (AOAC, 2000).

Functional properties of flour

Using 2.5% aqueous flour dispersions in centrifuge tubes, the tubes were capped and heated at 85°C for 30 min in a water bath with shaker (Grant OLS200, UK). The tubes were then cooled to room temperature and centrifuged for 15 min at 2,200 rpm (Remi Research, R23, India). Precipitated paste was separated from the supernatant and weighed (W_p). The supernatant was evaporated in a hot air oven at 105°C (Gallenkamp Hotbox, UK), and the residue weighed (W_r). Determinations were done in triplicates and the Swelling Power (SP) and Solubility index (SI) were calculated as follows:

$$SP = \frac{wt\ of\ precipitated\ paste\ (Wp)}{wt\ of\ sample\ (Wo)} - wt\ of\ residue\ in\ supernatant\ (Wr)$$

$$SI = \frac{wt\ of\ residue\ in\ supernatant\ (Wr)}{wt\ of\ sample\ (Wo)}\ x\ 100$$

Where W_o was the weight of sample.

Bread baking procedure

The bread formula consisted of wheat-millet composite flour (300 g), margarine (50 g) sugar (20 g), a pinch of salt and baking instant yeast (Saf Instant® Yeast, USA). The millet in the wheat-millet composite flour was substituted at three levels of 10, 20 and 30% for all the five millet varieties. All the ingredients were mixed thoroughly for 3 min at low speed before kneaded into soft dough. The kneaded dough was allowed to rise for 30 min before panning and proofing at room temperature for 120 min. The loaves were baked at 175°C for 20 min, and allowed to cool at room temperature for 1 h before the sensory evaluation.

Sensory evaluation of bread

A total of 50 untrained panellists, who regularly patronise bread and had previous experience in sensory evaluation, were employed. The panellists were non-smokers with no reported cases of food allergies. They evaluated the samples based on common attributes such as appearance, aroma, taste, texture and overall acceptability using a 9-point Hedonic scale, where 1 represented ‘‘extremely dislike’’ and 9 represented ‘‘extremely like’’ (Rampersad *et al.*, 2003; Stone and Sidel, 2004; Hooda and Jood, 2005; Lawless and Heymann, 2010). An atmosphere of complete quietness and privacy was provided for each panellist. The evaluation was conducted in a sensory facility conforming to ISO 8589. Samples were presented to panellists following a randomised design matrix (XLSTAT ver 2012, Statsoft, France). Each panellist was provided with four slices of cucumber to refresh their palate and rinse with still water before tasting subsequent samples.

Statistical analysis

The data obtained were compared using Analysis of Variance (SPSS 17.0.1), assuming a probability level of $p < 0.05$. Significantly different means were separated by Duncan's Multiple Range Test. The results were reported as mean ± standard error. Regression analysis (SPSS 17.0.1) was conducted to determine the influence of the sensory attributes on acceptability of the millet-wheat composite bread.

Results and discussion

Physicochemical and functional properties of millet flours

The millet genotypes ranged from greyish to straw-coloured and these perceived colours have been ascribed to pericarp colour thickness, endosperm and aleurone pigmentation (McDonough and Rooney, 1989). The colour of the millet flours indicated whiteness index ranged from 59.77 to 70.48 (Table 1). This shows that the flours were not white but had a tone characteristic of the millet grains as described by Taylor and Anyango (2011). Flours from all the varieties differed significantly ($p < 0.05$) from each other in lightness, with SAR001 being the lightest and SAR002, the darkest. The a* and b* values varied from 0.13 – 1.07 and 4.30 – 10.45, respectively. Significant differences ($p < 0.05$) were observed as well. Among the flours, SAR002 showed the highest intensity of redness and SAR004 was the least. Interestingly, SAR004 and SAR001 were the most yellow among all the flours, with a* value of more than +10. Varietal differences observed in flour colours were likely the result from variations in the amounts of C-glycosylflavones and other phenolics which are responsible for colour pigmentation in millet (Akingbala, 1991).

Table 1. Colour of millet flour

Variety	L*	a*	b*
SAR001	70.48 ± 0.08^{e}	$+0.32 \pm 0.01^{b}$	$+10.33 \pm 0.04^{d}$
SAR002	59.77 ± 0.14^{a}	$+1.07 \pm 0.01^{d}$	$+5.49 \pm 0.21^{b}$
SAR003	60.83 ± 0.14^{b}	$+0.75 \pm 0.02^{c}$	$+4.30 \pm 0.05^{a}$
SAR004	67.48 ± 0.23^{d}	$+0.13 \pm 0.02^{a}$	$+10.45 \pm 0.09^{d}$
SAR005	61.84 ± 0.13^{c}	$+0.75 \pm 0.02^{c}$	$+8.18 \pm 0.02^{c}$

Means bearing different superscripts are significantly different ($p < 0.05$)

The flours showed a seemingly restricted swelling power (SP) with a mean of 4.5 g/g and low water solubility index (SI) of 3.8 (Figure 1). A descending order of the SI and SP of the flours was SAR004 > SAR003 > SAR005 > SAR002 > SAR001, and SAR002 > SAR005 > SAR003 > SAR004 > SAR001, respectively (Figure 1). In both parameters, SAR001 was the lowest. Flours from all the varieties were observed to be largely similar ($p > 0.05$) in their swelling and solubility behaviour. The SP and SI for these varieties were lower compared to that observed for starches from different millet varieties by Bhupender *et al.* (2013). Generally, SP and SI are greatly influenced by amylose and amylopectin content as well as their chain length distribution and therefore similarities among the flours' SI and SP seem to suggest a resemblance in amylose and amylopectin properties among the five millet varieties. The amylose and amylopectin are responsible for the properties of starch pastes, gels and starchy food systems (Lindeboom *et al.*, 2004). SP is indicative of intermolecular association between starch polymers associated with eating quality, while SI describes the extent of dissolution of carbohydrates and other water-soluble components present in the flours. The SP is influenced by the amylose that acts as both a diluent and an inhibitor of swelling and is responsible for retrogradation in starches (Tester and Morrision, 1990). The amylopectin is responsible for the gelatinisation behaviour of starches. Interestingly, there are short and long chains of amylopectin and starches with higher amounts of long chains results in gels with higher viscosity and stability as compared to their short chain counterparts (Jane and Chen, 1992; Noda *et al.*, 1998; Jane *et al.*, 1999; Stevenson *et al.*, 2007; Tattiyakul *et al.*, 2007).

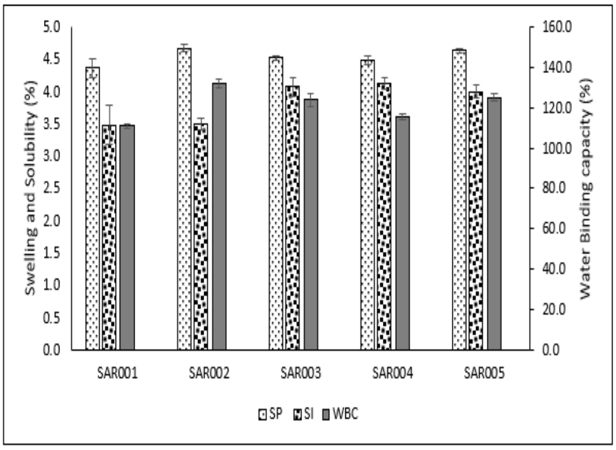

Figure 1. Functional characteristics of millet flour.

Water-binding capacity (WBC) of the flours, which is a reflection of protein-moisture interaction, ranged between 111 and 132% for SAR001 and SAR002. A descending order of the WBC of

Table 2. Chemical properties of millet flour.

Variety	pH	aw	Moisture
SAR001	6.33 ± 0.14^{a}	0.567 ± 0.007^{a}	9.25 ± 0.03^{a}
SAR002	6.93 ± 0.01^{b}	0.589 ± 0.001^{b}	9.18 ± 0.03^{a}
SAR003	6.31 ± 0.20^{a}	0.590 ± 0.003^{b}	9.94 ± 0.05^{b}
SAR004	6.80 ± 0.13^{b}	0.595 ± 0.004^{b}	10.01 ± 0.23^{b}
SAR005	6.19 ± 0.02^{a}	0.589 ± 0.005^{b}	10.42 ± 0.05^{c}

Means within the same column with different superscripts are significantly different ($p < 0.05$)

the flours was SAR002 > SAR003 > SAR005 > SAR004 > SAR001 (Figure 1). The WBC is largely influenced by protein content and the differences in protein levels of these varieties might account for the significant differences ($p < 0.05$). In studies by Das *et al.* (2010) and Hoover and Sosulski (1986), the authors attributed the high WBC to loosely associated amylose and amylopectin, and the association of hydroxyl groups to form hydrogen and covalent bonds between starch chains, which also lowers the WBC. Varieties with high amounts of proteins are likely to possess a lot of water-binding sites, which in turn increases their WBC as reported by Wotton and Bamunuarachchi, (1978). WBC was higher than that obtained for starches from different millet varieties (Bhupender *et al.*, 2013).

Millet flour prepared from the five varieties were fairly neutral (Table 2), with their pH ranging between 6.2 and 6.9 for SAR005 and SAR002, respectively. Flours made from the different millet varieties were significantly different ($p < 0.05$) in their pH. Further statistical analysis (DMRT) however, established similarity among some varieties, resulting in two categories; one group having pH < 6.5 (SAR001, SAR003 and SAR005), and the other, > 6.5 (SAR002 and SAR004). The pH of these flours was comparable to the range (6.4 - 6.8) reported by Bhupender *et al.* (2013) for millets and also similar to the pH of wheat flour (6.4) reported by Eriksson *et al.* (2013). The pH of flours from the millet varieties suggests the flours are feasible for utilisation in bakery applications.

Moisture and water activity are important parameters that greatly influence the keeping properties and quality of flours. High moisture and water activity enhance physical and biochemical reactions and also support the growth of microorganisms which result in product spoilage and the subsequent loss of quality. Moisture and water activity of the flours significantly differed among the varieties (Table 2). Regardless of these differences, moisture (9.7 - 10.6%) and water activity (0.57 - 0.60 a_w) of the flours were low and appropriate to extend the shelf-life of the flours (CAC, 1985). The moisture content observed was similar to 10%, 9.62% and 12.0% for pearl millet flour, corn starch and pearl millet starch, respectively (Wankhede *et al.*, 1990, Mepba *et al.*, 2009; Suma and Urooj, 2015). These ranges are considered to be within the acceptable range and beneficial in terms of shelf-life and keeping quality of the flours and starches (Wankhede *et al.*, 1990, Mepba *et al.*, 2009; Suma and Urooj, 2015). According to Aguilera *et al.* (1995), high amounts of moisture in flour might result in caking of the flour, which is caused by aggregation of particles into lumps that lowers the quality and functionality of the flour.

Nutritional composition of millet flour

The protein content varied from 7.9 to 11.1 g/100 g for SAR001 and SAR002, respectively and was significantly different ($p < 0.05$) from one variety to another (Table 3). DMRT showed no similarities between the protein levels among all the millet varieties. The protein content of these varieties were lower than 12.5-13.6% (Ali *et al.*, 2003), and compared well with 7.7-12.1 g/100 g (Saleh *et al.*, 2013) for different millet varieties but were higher than 7.3 and 8% for pearl and finger millets (Gull *et al.*, 2016). Protein content in excess of 7% makes these varieties a potential for use in fighting protein-energy malnutrition, especially, among children in areas where the crop is grown.

Table 3. Proximate composition of millet flour.

Variety	Protein	Fibre	Ash	Fat	Carbohydrate	Energy
SAR001	7.90 ± 0.07^{a}	1.37 ± 0.00^{c}	1.46 ± 0.02^{a}	4.32 ± 0.15^{b}	75.71 ± 0.28^{c}	373.3 ± 0.6^{a}
SAR002	11.10 ± 0.14^{e}	1.33 ± 0.00^{c}	1.23 ± 0.01^{a}	3.56 ± 0.32^{a}	73.59 ± 0.42^{b}	370.9 ± 1.8^{a}
SAR003	9.35 ± 0.21^{c}	1.26 ± 0.02^{b}	0.91 ± 0.05^{a}	3.68 ± 0.23^{ab}	74.87 ± 0.42^{bc}	370.0 ± 1.2^{a}
SAR004	8.76 ± 0.06^{b}	1.27 ± 0.01^{b}	1.32 ± 0.43^{a}	4.11 ± 0.12^{ab}	74.54 ± 0.83^{bc}	370.2 ± 2.1^{a}
SAR005	9.79 ± 0.12^{d}	1.20 ± 0.01^{a}	0.92 ± 0.02^{a}	4.03 ± 0.02^{ab}	73.65 ± 0.11^{b}	370.1 ± 0.3^{a}

Means within the same column with different superscripts are significantly different ($p < 0.05$)

The variation in crude fibre among the millet varieties was relatively narrow although significant ($p < 0.05$). This component was highest in SAR001 (1.4%) and lowest in SAR005 (1.2%). Dietary fibre is important part of plant, which is not digestible by the stomach but plays an indispensable role in lowering blood cholesterol and sugar levels. The protein and the fibre assist in water absorbing of the flours (Kinsella *et al.*, 1976; Suma and Urooj, 2015). The ash content of millet flour was in a descending order of SAR003 < SAR005 < SAR002 < SAR004 < SAR001. Despite this, the trend all five varieties was much similar ($p > 0.05$) in their ash content. The ash levels were higher than pearl millet (0.7%), but lower than finger millet (2.2%) reported by Gull *et al.* (2016). Nutritionally, millets have been identified as a good source of calcium, iron and other minerals (Shobana *et al.*, 2009, Singh *et al.*, 2010; Singh *et al.*, 2012). Lipids provides a very good source of energy and aids in transporting fat soluble vitamins, insulates internal tissues and contributes to important cell processes. The millet contained significant proportions of fat, ranging from 3.56 g/100 g (SAR002) to 4.32 g/100 g (SAR001). The fat content of the millets differed significantly ($p < 0.05$) from one variety to another. The level recorded in the present work was higher than a mean of 0.2% reported by Bhupender *et al.* (2013). Interestingly, the millet flours had more than 70% total carbohydrate. SAR001 was the highest (75.71%) and SAR002 was the lowest (73.59%). The amount of carbohydrates in these millet varieties was comparable to amounts reported for other cereal grains commonly consumed in Ghana such as maize (73.0%), sorghum (73.0%) and slightly higher than wheat (71.0%). Variations observed in carbohydrate content of these varieties were significant ($p < 0.05$). The mean amount of energy provided by the millets was 370.0 kcal/100 g, making them a rich source of energy. This is comparable with other staple cereals such as rice (345.0 kcal/100 g), maize (125.0 kcal/100 g) and sorghum (329.0 kcal/100 g) (Kinsella *et al.*, 1976; Wankhede *et al.*, 1990; Dykes and Rooney, 2006; Mepba *et al.*, 2009; Suma and Urooj, 2015).

Sensory evaluation

Sensory evaluation of breads made from millet-wheat composite flours revealed that, irrespective of variety, rating of the various flours was affected by the proportion of the millet used (Table 4, Figure 2). Factorial ANOVA showed no significant interactive effect ($p > 0.05$) between variety and level of substitution. However, there was significant main effect of variety and level of substitution on the various attributes. The main effect of substitution level suggested that, increasing the amount of millet in the composite flour resulted in lower attribute and acceptability scores. For example, the score for appearance of bread made from SAR001 reduced by 1.2, and the acceptability of SAR005 reduced by 2.1 when the proportion of millet was increased 3-fold (Table 4). Nevertheless, a mean score of 6.4 (slightly like) was obtained for acceptability of bread with 20% millet flour substitution. Generally, SAR001 scored higher for all the attributes, apart from texture, in which SAR005 was rated higher at 10% millet flour substitution. Additionally, bread made from SAR001 were the most acceptable, whereas SAR002 and SAR003 recorded the lowest acceptability scores.

Table 4. Sensory attributes of millet-wheat composite flour bread.

Variety	Level (%)	Appearance	Aroma	Taste	Texture	Acceptability
SAR001	10	7.2 ± 0.2^{f}	7.3 ± 0.1^{h}	7.4 ± 0.1^{h}	7.0 ± 0.2^{fgh}	7.3 ± 0.2^{g}
	20	7.0 ± 0.2^{f}	6.7 ± 0.2^{efg}	6.8 ± 0.3^{fgh}	6.6 ± 0.2^{fgh}	6.8 ± 0.2^{efg}
	30	6.0 ± 0.2^{cde}	6.0 ± 0.3^{bcd}	5.6 ± 0.3^{cde}	6.2 ± 0.3^{def}	6.2 ± 0.3^{def}
	10	6.3 ± 0.3^{def}	6.6 ± 0.3^{defg}	6.6 ± 0.3^{efgh}	6.4 ± 0.2^{efg}	6.3 ± 0.3^{def}
SAR002	20	5.5 ± 0.3^{bcd}	5.7 ± 0.4^{bcd}	5.7 ± 0.3^{cde}	6.1 ± 0.2^{def}	5.8 ± 0.3^{cde}
	30	4.6 ± 0.4^{a}	5.2 ± 0.4^{ab}	4.7 ± 0.4^{ab}	4.4 ± 0.4^{ab}	4.6 ± 0.3^{ab}
	10	6.7 ± 0.2^{ef}	6.5 ± 0.3^{defg}	6.4 ± 0.2^{efg}	6.7 ± 0.2^{fgh}	6.7 ± 0.2^{efg}
SAR003	20	6.2 ± 0.3^{def}	6.2 ± 0.3^{cde}	5.7 ± 0.3^{cde}	5.8 ± 0.3^{cde}	5.9 ± 0.3^{cde}
	30	4.8 ± 0.4^{ab}	4.6 ± 0.4^{a}	4.3 ± 0.3^{a}	4.2 ± 0.4^{a}	4.1 ± 0.4^{a}
	10	7.0 ± 0.2^{f}	7.3 ± 0.2^{h}	7.0 ± 0.2^{gh}	7.0 ± 0.2^{gh}	7.1 ± 0.2^{fg}
SAR004	20	5.4 ± 0.3^{abc}	5.6 ± 0.3^{abc}	6.0 ± 0.3^{def}	5.6 ± 0.3^{cd}	5.8 ± 0.3^{cd}
	30	5.1 ± 0.4^{abc}	5.3 ± 0.3^{ab}	5.1 ± 0.4^{bcd}	4.6 ± 0.4^{ab}	5.2 ± 0.3^{bc}
	10	7.1 ± 0.3^{f}	7.2 ± 0.2^{fg}	6.9 ± 0.4^{fgh}	7.2 ± 0.3^{h}	7.1 ± 0.3^{fg}
SAR005	20	5.8 ± 0.3^{cde}	6.1 ± 0.3^{cde}	6.5 ± 0.2^{efg}	6.1 ± 0.2^{def}	6.4 ± 0.3^{def}
	30	4.8 ± 0.4^{ab}	4.7 ± 0.4^{a}	4.9 ± 0.4^{abc}	5.1 ± 0.4^{bc}	5.0 ± 0.4^{bc}

Means within the same column with different superscripts are significantly different ($p < 0.05$)

(A)

(B)

Figure 2. (A) Millet flour, and (B) millet bread.

Texture and taste were the most influential predictors of the bread acceptability. This observation is in agreement with the assertion by Kihlberg (2004) that taste and texture are the most important quality indicators of bread which influence acceptance. Even though appearance and aroma are essential attributes and might affect the acceptability of food products, they did not significantly (p < 0.001) influence panellists' preference for bread made from millet-wheat composite flour. The performance of the different millet varieties in the final product, in respect of the key sensory attributes was quite promising. Mean scores of 5.97 (appearance), 6.06 (aroma), 5.92 (taste) and 5.87 (texture) which were interpreted as "slightly like" were obtained.

Conclusion

Chemical analysis on the millets indicated that these newly developed varieties have significant levels of protein, fibre, ash, and fat, and might contribute more than 350 kcal of energy per 100 g, thus has the potential to fight malnutrition. The nutritional composition of these varieties could be relied on as a food source to satisfy the nutrient needs of millions of consumers especially those within communities where they are produced. These varieties might also serve as a good source of raw material for industrial and domestic food applications. Although all five varieties yielded good potential in the production of bakery products, bread made from SAR001 (*Kaanati*) were rated higher for its attributes and overall acceptability, especially at 10% substitution of millet flour in composite flour with wheat flour.

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Conflict of interest

The authors hereby state that there is no conflict of interest regarding this publication.

References

Aguilera, J. M., Del Valle, J. M. and Karel, M. 1995. Caking phenomenon in amorphous food powders. Trends in Food Science and Technology 6: 149-155.

Akingbala, J. O. 1991. Effect of processing on flavonoids in millet (*Pennisetum americanum*) flour. Cereal Chemistry 68: 180-183.

Ali, M. A. M., El Tinay, A. H. and Abdalla, A. H. 2003. Effect of fermentation on the in-vitro protein digestibility of pearl millet. Food Chemistry 80: 51-54.

Anu Sehgal, S. and Kwatra, A. 2006. Nutritional evaluation of pearl millet based sponge cake. Journal of Food Science and Technology 43(3): 312-313.

AOAC. 2000. Official Methods of Analysis of AOAC, 17th ed. Gaithersburg, MD: AOAC Press.

Basavaraj, G., Parthasarathy Rao, P., Bhagavatula, S. and Ahmed, W. 2010. Availability and utilization of pearl millet in India. Journal of SAT Agricultural Research 8: 1-6.

Bhupender, S. K., Rajneesh, B. and Baljeet, S. Y. 2013. Physicochemical, functional, thermal and pasting properties of starches isolated from pearl millet varieties. International Food Research Journal 20: 1555-1561.

Bora, P. 2013. Nutritional properties of different millet types and their selected products. Guelph, Canada: University of Guelph, MSc Thesis.

CAC. 1985. Codex Standard for wheat flour: CODEX STAN 152-1985. Rome, Italy: Codex Alimentarius Commission.

Das, A. B., Singh, G., Singh, S. and Riar, C. S. 2010. Effect of acetylation and dual modification on physico-chemical, rheological and morphological characteristics of sweet potato starch. Carbohydrate Polymers 80: 725-732.

Dykes, L. and Rooney, L. W. 2006. Sorghum and millet phenols and antioxidants. Journal of Cereal Science 44: 236-251.

Eriksson, E. 2013. Flour from three local varieties of cassava (*Manihot esculenta Crantz*): Physico-chemical properties, bread-making quality and sensory evaluation. Sweden: Swedish University of Agricultural Sciences, thesis.

Filli, K. B., Nkama, I., Jideani, V. A. and Abubakar, U. M. 2011. Application of response surface methodology for the study of composition of extruded millet-cowpea mixtures for the manufacture of *fura*: a Nigerian food. African Journal of Food Science 5: 884-896.

Gulia, S. K., Wilson, J. P., Carter, J. and Singh, B. P. 2007. Progress in grain pearl millet research and market development. Issues in New Crops and New Uses, 2007: 197-203.

Gull, A., Prasad, K. and Kumar, P. 2015. Optimization and functionality of millet supplemented pasta. Food Science and Technology, Campinas 35: 626-632.

Gull, A., Prasad, K. and Kumar, P. 2016. Evaluation of functional, anti-nutritional, pasting and microstructural properties of millet flours. Journal of Food Measurement and Characterization 10(1): 96-102.

Hooda, S. and Jood, S. 2005. Organoleptic and nutritional evaluation of wheat biscuits supplemented with untreated and treated fenugreek flour. Food Chemistry 3: 427-435.

Hoover, R. and Sosulski, F. 1986. Effect of cross linking on functional properties of legume starches. Starch/Starke 38: 149-155.

Jane, J. Y. and Chen, J. F. 1992. Effect of amylose molecular size and amylopectin branch chain length on paste properties of starch. Cereal Chemistry 69: 60-65.

Jane, Y., Chen, Y. Y., Lee, L. F., Mcpherson, A. E., Wong, K. S., Radosavljevic, M. and Kasemsuwan, T. 1999. Effects of amylopectin branch chain length and amylose content on the gelatinization and pasting properties of starch. Cereal Chemistry 76: 629-637.

Kihlberg, I. 2004. Sensory quality and consumer perception of wheat bread. Towards sustainable production and consumption. Effect of farming systems, year, technology, information and values. Uppsala, Sweden: Acta Universitatis Uppsaliensis, Doctoral thesis.

Kinsella, L. E. 1976. Functional properties of protein in foods: A survey. Journal of Food Science and Nutrition 7: 219-280.

Lawless, H. T. and Heymann, H. 2010. Sensory evaluation of food principles and practices, 2nd ed. New York: Springer Science and Business Media, LLC.

Lindeboom, N., Chang, P. R. and Tyler, R. T. 2004. Analytical, biochemical and physico-chemical aspects of starch granule size, with emphasis on small granule starches: A Review. Starch/Starke 56: 89-99.

Ma, D. Y., Zhang, J., Lou, X. Y., Wang, X. N., Wang, C. Y. and Guo, T. C. 2014. Color, cooking properties and texture of yellow alkaline noodles enriched with millet and corn flour. International Food Research Journal 21: 1187-1192.

Malik, M., Singh, U. and Dahiya, S. 2002. Nutrient composition of pearl millet as influenced by genotypes and cooking methods. Journal Food Science and Technology 39 (5): 463-468.

McDonough, C. M. and Rooney, L. W. 1989. Structural characteristics of *Pennisetum americanum* (Pearl Millet) using scanning electron and fluorescence microscopy. Food Microstructure 8: 137-149.

Mepba, H. D., Eboh, L., Eko, C. B. and Ukpabi, U. J. 2009. Composition and pasting properties of starch from two cocoyam cultivars. Journal of Food Quality 32: 522-537.

MOFA, 2013. Agriculture in Ghana, Facts and Figures, 2012. Statistical Research and Information Directorate (SRID), Accra, Ghana: Ministry of Food and Agriculture.

Noda, T., Takahata, Y., Sato, T., Suda, I., Morishita, T., Ishiguro, K. and Yamakawa, O. 1998. Relationships between chain length distribution of amylopectin and gelatinization properties within the same botanical origin for sweet potato and buckwheat. Carbohydrate Polymers 37: 153-158.

Rampersad, R., Badrie, N. and Comissiong, E. 2003. Physiochemical and sensory characteristics of flavored snacks from extruded cassava/pigeon pea flour. Journal of Food Science 68: 363-367.

Saleh, A. S., Zhang, Q., Chen, J. and Shen, Q. 2013. Millet grains: nutritional quality, processing, and potential health benefits. Comprehensive Reviews of Food Science and Food Safety 12(1): 281-295.

Shobana, S. and Malleshi, N. G. 2007. Preparation and functional properties of decorticated finger millet (*Eleusine coracana*). Journal of Food Engineering 79: 529-538.

Shobana, S., Sreerama, Y. and Malleshi, N. 2009. Composition and enzyme inhibitory properties of finger millet (*Eleusine coracana* L.) seed coat phenolics: Mode of inhibition of α-glucosidase and pancreatic amylase. Food Chemistry 115: 1268-1273.

Singh, K. P., Mishra, A. and Mishra, H. N. 2012. Fuzzy analysis of sensory attributes of bread prepared from millet-based composite flours. LTW-Food Science and Technology 48: 276-282.

Singh, K. P., Mishra, H. N. and Saha, S. 2010. Moisture-dependent properties of barnyard millet grains and kernel. Journal Food Engineering 96: 598-606.

Stevenson, D. G., Jane, Jay-Lin. and Inglett, G. E. 2007. Structures and physicochemical properties of starch from immature seeds of soybean varieties (*Glycine max* (L.) Merr.) exhibiting normal, low-linolenic or low-saturated fatty acid oil profiles at maturity. Carbohydrate Polymers 70: 149-159.

Stone, H. and Sidel J. L. 2004. Sensory evaluation practices, 3rd ed., Food Science and Technology International Series. USA: Elsevier.

Suma, P. and Urooj, A. 2015. Isolation and characterization of starch from pearl millet (*Pennisetum typhoidium*) flours. International Journal of Food Properties 18 (12): 2675-2687.

Tattiyakul, J., Pradipasena, P. and Asavasaksakul, S., 2007. Taro *Colocasia esculenta* (L.) Schott, amylopectin structure and its effect on starch functional properties. Starch/Starke 59: 342-347.

Taylor, J. R. N. and Anyango, J. O. 2011. Sorghum flour and flour products: production, nutritional quality and fortification. In: Preedy, V. R, Watson, R. R. and Patel, V. B., eds. Flours and breads and their fortification in health and disease prevention, 1st ed., p. 127. New York: Academic Press.

Tester, R. F. and Morrison, W. R. 1990. Swelling and gelatinization of cereal starches I. Effect of amylopectin, amylose and lipids. Cereal Chemistry 67: 551-557.

Wankhede, D. B., Rathi, S. S., Gunjal, B. B., Patil, H. B., Waide, S. G., Rodge, A. B. and Sawate, A.R. 1990. Studies on isolation and characterization of starch from pearl millet (Pennisetum americanum (L) Leeke) grains. Carbohydrate Polymers 13: 17-28.

Wotton, M. and Bamunuarachchi, A. 1978. Water binding capacity of commercial produced native and modified starches. Starch/Starke 33: 159-161.