

Quality of Bread from Composite Flour of Sorghum and Hard White Winter Wheat

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Abstract: This study was carried out to investigate the baking properties of whole, decorticated sorghum- (*Sorghum bicolor*) - wheat (*Triticum aestivum* Desf.) composite flours as well as to determine the physical characteristics and organoleptic quality of pan and balady breads made from those flours. Whole and decorticated sorghum flours were used to replace 0, 5, 10, 15, and 20% by weight of bread wheat flour. Sensory evaluation results showed that up to 20% wheat replacement with whole or decorticated sorghum flour produced acceptable pan and balady breads. Decreases, however, were noted in all sensory properties except odor.

Key words: Bread, flour mix, sorghum (*Sorghum bicolor*), white wheat (*Triticum aestivum* Desf.)

INTRODUCTION

Bread is an important staple food in both developed and developing countries. Wheat (*Triticum aestivum* Desf.) flour of both hard and soft wheat classes has been the major ingredient of leavened bread for many years because of its functional proteins. In Sudan, the consumption of wheat bread is increasing in both rural and urban areas as a consequence of changing taste, convenience and consumer subsidies. However, bread can only be made from imported high gluten wheat which is not suitable for cultivation in the tropical areas for climatic reasons (Edema *et al.*, 2005).

Several developing countries have encouraged the initiation of programs to evaluate the feasibility of alternative locally available flours as a substitute for wheat flour. Many efforts have been carried out to promote the use of composite flours, in which a portion of wheat flour is replaced by locally grown crops, to be used in bread, thereby decreasing the cost associated with imported wheat (Olaoye *et al.*, 2006). Most of the research conducted on the use of composite flour for bread making purposes (Adeyemi and Idowu, 1990; Dhingra and Jood, 2004; Hsu *et al.*, 2004; Khalil *et al.*, 2000; McWatter *et al.*, 2004) was devoted to studying the effects of different flour substitutions on bread making quality. Acceptability studies conducted at the Food Research Centre in Khartoum, Sudan, indicated that breads made with composite flour of 70% wheat and

30% sorghum were acceptable (FAO, 1995). Consumer acceptance trials in Nigeria indicated that breads made with 30% sorghum flour were comparable to 100% wheat bread (Aluko and Olugbemi, 1989; Olatunji *et al.*, 1989). Bread with 30% sorghum and 70% wheat was also prepared in Senegal (FAO, 1995). Carson and Sun (2000) investigated the rheological properties and bread baking potential of sorghum-based composite flour containing variable amount of vital wheat gluten. They observed a decrease in water absorption, dough strength and extensibility, and increase in mixing time as the sorghum flour proportion was increased in the samples at fixed gluten protein levels.

Sorghum is the staple food crop in Sudan where it is consumed in fermented forms, mainly as Kisra (local thin bread), aceda (thick porridge) and nasha (thin porridge). Several studies have indicated the possibility of incorporating sorghum both as whole and decorticated grain in wheat flour at various levels to produce bread when wheat is in short supply.

The objective of this study was to evaluate the physical and baking properties of whole and decorticated sorghum-wheat composite flours as well as to determine the organoleptic acceptability of the resulting breads.

MATERIALS AND METHODS

The study was conducted in several locations in 2007. Product development efforts and sensory analysis

were done in the food research labs of South Dakota State University under the supervision of Dr. Padmanaban Krishnan. Texture Profile Analysis of finished food products was carried out in the Food and Biomaterials labs in the Ag Biosystems Engineering Department at South Dakota State University, Brookings SD, USA as well as the labs of Food Research Center, Shambat, Khartoum North, Sudan.

Materials: Commercial sorghum flour of the local cultivar 'Tabat' and experimental wheat flour of hard white winter wheat (HWW) cultivar 'Alice' (Ibrahim *et al.*, 2008) were blended in different ratios in this study. Other ingredients used were yeast (instant dry yeast was obtained from the local market), tap water at 37.8° to 43.3°C, sugar (Sucrose, finely granulated, white, commercial grade), salt (NaCl, finely granulated commercial grade), and shortening (partially hydrogenated vegetable oil, Crisco). All chemicals used for analysis were of analytical grade.

Methods:

Preparation of composite flour blends: Wheat flour was blended with 0, 5, 10, 15, and 20% whole sorghum flour. The same was repeated with decorticated sorghum flour. A Cross-Flow blender (The Patterson Kelly Co. Inc., Stroudsburg, PA) was operated for 1 h to produce homogenous 1 kg blends. The composite flours were stored in air tight containers in a freezer until needed.

Pan bread: The standard formula used for pan bread was: 300 g flour, 4.5 g yeast, 4.5 g salt, 9 g shortening, 9 g sugar, and variable water. All dry ingredients were weighed and placed in a mixer (Cuisinart Food preparation center) for 5 sec. Then a suspension of the yeast in water was added. The mixture was further run at high speed for 92 sec. Water was added to the mixture as indicated by the farinogram results. The dough temperature was 28.9° - 32.2°C following mixing. Dough was transferred and scaled into three portions, rounded into balls by hand then placed in lightly greased fermentation bowls and placed in the fermentation cabinet (National Company, Lincoln, NE) at 30°C and 85% relative humidity for 20 min. The fermented dough were then passed through a sheeter (National Manufacturing Co, Lincoln, NE) using 7.6 cm roll width and 0.5 cm roll gap, molded by hand, placed in lightly greased pans (14.3 cm × 8.1 cm × 4.9 cm), and finally returned to the fermentation cabinet for a final proof for 50 min. When the height of dough had risen to about 1 - 2 cm above the pans, the pans were placed in a convection oven (Despatchoven Co. - JENN. AIR convection oven) at 212.8°C for 18 min. The oven was preheated to 212.8°C and conditioned with 1L beaker full of water placed on the same shelf throughout baking. Loaves were weighed after cooling and the volume was recorded. Then, bread

was left to cool for a further 25 min and sliced (1 cm width) using an electric knife. Some slices were kept at room temperature in sealed plastic bags for sensory evaluation and measurement of physical characteristics.

Balady bread: The following formula was used for making balady bread: 250 g flour, 1.5 g yeast, 0.5 g salt, 80 ppm ascorbic acid, and variable water.

Ingredients were weighed and made into dough in a Mono-Universal laboratory dough mixer for 5 min at medium speed. The dough was placed in a fermentation cabinet at 28°C and 85% relative humidity for 1 h. After removal from the fermentation cabinet, the dough was divided into three pieces of 140-148 g each and formed into balls by hand. The dough balls were allowed to rest for 30 min under the same conditions, then dusted with flour and shaped into circular flat forms by hand. The flattened dough pieces were returned to the fermentation cabinet and proofed for 45 min, then baked in a commercial oven (Real Forni- VERONA) at 250°C for 8-10 min. The bread was left to cool for 7 min, then kept closed in polyethylene bags at room temperature (25°C) for sensory evaluation and physical characteristics measurement.

Bread evaluation:

Physical evaluation:

Specific volume of pan bread: The specific volume of bread was calculated according to the AACC method 10-05.01 (AACC, 2000) by dividing volume (cc) by weight (g). Loaf volume was measured by rapeseed displacement immediately after removal from the oven and weighing. Loaves were placed in a container of known volume into which rapeseeds were run until the container was full. The volume of seeds displaced by the loaf was considered as the loaf volume.

Loaf Specific Volume (LSV), was calculated according to the following:

$$L.S.V = \text{Loaf volume (cc)} / \text{Loaf weight (g)} = \text{cc /g}$$

Crumb color of pan bread: A Minolta Spectrophotometer (Model 508d, Japan) was used to determine bread color. The spectrophotometer was attached to the bread crumb and measurements were taken. Three readings were taken and average *L*, *a*, and *b* values were recorded.

Bread color results were reported in terms of 3-dimensional color values based on the following rating scale:

L-value	Whiteness	100 white 0 black
a-value	Positive values Negative values	(+) red color (-) green color
b-value	Positive values Negative values	(+) yellow color (-) blue color

Texture Profile Analysis (TPA) for pan bread: Bread texture (hardness, springiness, cohesiveness, chewiness, gumminess and resilience) was determined Using Texture Profiles Analysis (TPA).

Breads were sliced transversely using an electric knife to obtain uniform slices of 2 cm thickness. Bread slices taken from the center of each loaf were used to evaluate the crumb texture. By using a cork corer, a sample of 2 cm height was taken. The TPA was performed using a Sintech universal testing machine (TA.HD plus). The computer was set for Test works software and an appropriate test was selected for the TPA analysis. Samples were placed in between the two load cell (908 kg) plates of the machine, and the load cell was slowly brought to a lower level, so that it touched the sample. Parameters like length, diameter, speed, the percent compression, and number of cycles (two) were inputted before starting compression of the sample. Then, the load cell started slowly moving downwards, compressing the sample with a 5 sec. wait between first and second compression cycles. The TPA was performed on 9 loaves per blend.

Texture profile analysis and calculation: The parameters are listed below together with a brief definition of each:

Hardness: the force required to compress the material by a given amount. It is defined as the peak force during the first compression cycle (First bite). It is expressed in lb or N.

Cohesiveness: the strength of the internal bonds in the sample. It is defined as the ratio of the positive force area during the second compression to that during the first compression. It is calculated by Area 2/ Area 1.

Springiness: the elastic recovery that occurs when the compressive force is removed. It is defined as the height that food recovers during the time that elapses between the end of the first bite and the start of the second bite. It is calculated by Length 2 / Length 1 (mm/mm).

Gumminess: the energy required to break down a semi-solid food ready for swallowing. It is defined as the product of hardness and cohesiveness.

Chewiness: the energy required to chew a solid food into a state for swallowing. It is defined as the product of gumminess and springiness.

Resilience: It is how well a product “fights to regain its original position”. It is calculated by Area 5 / Area 4 (Nmm/Nmm).

Determination of circumference of Balady bread: Circumferences of 9 samples were measured in cm from triplicate baking of Balady bread using a measuring tape. The determinations were carried out after loaves were allowed to cool for 1 h.

Sensory evaluation: Semi trained panelists were given a hedonic scale questionnaire to evaluate the bread using a 9 points scale (1- extremely dislike, 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 - extremely like). Pan bread was evaluated for general appearance, crumb grain, odor, softness, taste, mouth feel and overall acceptability. Balady bread was evaluated based on general appearance, softness, aroma, taste, crumb color, mouth feel and overall acceptability measures.

During sensory evaluation, panelists were instructed to drink water or rinse their mouths to clear the palate after each evaluation. Sensory evaluation was done on the same day that the breads were prepared.

Statistical analysis: The analysis of variance (ANOVA) was performed to examine the significance level of all parameters measured. Least Significant Difference (LSD) test was used for means comparison. All analyses were performed in triplicate (n = 3). The level of significance for the F-test and means comparison was $p \leq 0.001$ (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Physical properties of pan and flat (Balady) breads:
Specific volume of pan bread: The effect of sorghum flours on specific volume of wheat pan bread is presented in Table 1. Bread specific volume decreased significantly with increasing sorghum substitution level. The volumes of bread made from composite flours, were lower than those made from pure hard white winter wheat (HWW). The highest bread specific volume was 5.93 (cc/g) obtained with 100% HWW flour (control), while flour containing 20% whole or decorticated sorghum flour resulted in the lowest bread specific volume of 5.04 and 5.27 (cc/g), respectively. This finding is in agreement with that reported by Aluko and Olugbemi's (1989), who found lower volumes associated with composite as opposed to 100% wheat. This can be attributed to lower levels of gluten network in the dough and consequently less ability of the dough to rise; due to the weaker cell-wall structure. However, the specific volumes of the 5, 10, and 15% levels of substitution were not significantly different from each other. This is in agreement with Morad *et al.* (1984) who concluded that the substitution of hard wheat flour with up to 20% sorghum flour

Table 1: Effect of whole and decorticated sorghum flours addition on specific volume of pan bread

	Control	Whole sorghum flour (%)				Decorticated sorghum flour (%)			
		5	10	15	20	5	10	15	20
Loaf weight(g)	154	154	152	152	153	154	153	153	154
Loaf volume (cc)	913	866	836	832	772	873	871	851	811
Loaf specific volume (cc/gm)	5.93 ^a	5.61 ^b	5.55 ^{bc}	5.47 ^{bc}	5.04 ^d	5.66 ^{ab}	5.61 ^b	5.48 ^{bc}	5.27 ^{cd}

Mean values with different superscript letter(s) within each row differ significantly ($p \leq 0.001$)

Table 2: Effect of adding whole or decorticated sorghum flours on wheat flour bread crumb color

	Control	Whole sorghum flour (%)				Decorticated sorghum flour (%)			
		5	10	15	20	5	10	15	20
L-value	72.54 ^a	71.58 ^{ab}	69.18 ^{bc}	68.69 ^c	65.29 ^d	72.07 ^a	70.11 ^{abc}	68.73 ^c	68.42 ^c
a-value	-0.75 ^a	-0.67 ^a	-0.47 ^b	-0.23 ^c	-0.13 ^c	-0.69 ^a	-0.48 ^b	-0.45 ^b	-0.43 ^b
b-value	9.51 ^a	10.40 ^{abc}	11.45 ^{cde}	12.53 ^{ef}	12.67 ^f	10.26 ^{ab}	10.99 ^{bcd}	11.16 ^{bcd}	11.68 ^{def}

Mean values with different superscript letter(s) within each row differ significantly ($p \leq 0.001$)

significantly decreased the loaf volume of pan bread, and Perten *et al.* (1980) who reported that the addition of sorghum to wheat flour negatively influence the volume of bread. Nevertheless, acceptable bread as made with 70:30% wheat: sorghum blends in other studies (Taha, 2000).

Abdel-Aal *et al.* (1993) reported that loaf and specific volumes of pan breads prepared from composite flours were 25-60% lower than those obtained from pure wheat flour but that flat breads tolerated protein supplements extremely well. On the other hand, Badi *et al.* (1976) reported that adding 10% millet-sorghum flour to the standard baking formula slightly increased loaf volume and improved crumb grain. However, adding sorghum flour (5-20%) to the standard formula decreased loaf volume although acceptable breads were produced.

Crumb color of pan bread: The color values *L* (light-dark), *a* (red-green), and *b* (yellow-blue) of the crumb of pan bread samples of blended flour are provided in Table 2. The results indicate that, as the percent of sorghum flours replacement increased, *L*-values shifted significantly from white to gray, *a* values shifted from green to red, and *b*-values shifted from blue to yellow. Overall, the *L*-values of the bread crumb samples substituted with sorghum flours decreased from 72.54 to 65.29, indicating a significant increase ($p < 0.001$) in grayish color. The highest *a*-value was that of bread made with 20% whole sorghum flour (-0.13); whereas, the lowest value was observed in bread made from 100% wheat flour (-0.75) as indicated by a higher intensities of green color. On the other hand, the lowest *b*-value was associated with bread made from the 100% wheat flour (9.51), whereas the highest value (12.67) was associated with bread made with 20% whole sorghum flour.

The effects of whole sorghum flour substitution on the color of the bread crumb were more obvious than that of decorticated sorghum flour substitution, where bread samples made with 100% wheat gave lower *L*-values and higher *a* and *b*-values when compared to the samples

made with added decorticated sorghum flour. In contrast, Torres *et al.* (1993) reported that the addition of decorticated sorghum flour did not significantly ($p < 0.05$) affect the color of flour for tortillas. However, tortillas containing sorghum flour had undesirable black specks that affected their appearance. Also, Morad *et al.* (1984) studied the effect of sorghum variety on baking properties of U.S. conventional bread, Balady bread and cookies. He found that the color values of pocket bread made from whole wheat flour was similar to those made from brown and yellow sorghum at 30% and white sorghum up to 40% substitution. Bread crumb color, especially of samples made with brown sorghums could compete with whole wheat bread. The results from this study indicate that sorghum seed-coat darkened crumb color. This may be due to the fact that the fibers and pigments reduced the green component in crumb color and shifted the color somewhat towards the gray- red, whereas sorghum coat imparted a yellowish tint on the crumb.

Texture characteristics of pan bread: Pan bread texture was determined as hardness, cohesiveness, springiness, gumminess, chewiness, and resilience using a TPA Texture Analyzer.

As shown in Table 3, it is evident that all TPA parameters of the experimental breads, except springiness and chewiness, were significantly different ($p \leq 0.001$). The results showed that, as the amount of sorghum flours increased, the hardness of bread crumb increased. With up to 5% whole and decorticated sorghum flours, no significant difference ($p \leq 0.001$) was observed in hardness. The replacement of wheat flour with sorghum flours decreased cohesiveness, and resilience in bread samples; however, it increased gumminess. The results of springiness (which indicates the percentage recovery of bread), and resilience (which express the ability or speed of material to return to its original shape after a stress) indicated that when the substitution level of sorghum flours increased, the bread required more time to recover its shape. Gumminess and chewiness are secondary

Table 3: Effect of adding whole or decorticated sorghum flours on wheat flour pan bread texture

Texture characteristics	Whole sorghum flour (%)					Decorticated sorghum flour (%)			
	Control	5	10	15	20	5	10	15	20
Hardness (N)	11.48 ^a	12.22 ^a	16.70 ^b	19.65 ^{bc}	21.15 ^c	12.22 ^a	17.24 ^{bc}	20.05 ^{bc}	20.56 ^{bc}
Cohesiveness	0.71 ^a	0.69 ^a	0.70 ^a	0.63 ^{bc}	0.61 ^c	0.70 ^a	0.64 ^b	0.63 ^{bc}	0.54 ^d
Gumminess (N)	8.19 ^a	8.48 ^a	11.65 ^{bc}	12.42 ^{bc}	12.90 ^{bc}	8.55 ^a	11.05 ^b	12.63 ^b	11.10 ^b
Springiness	0.90 ^a	0.75 ^a	0.82 ^a	0.87 ^a	0.81 ^a	0.90 ^a	0.85 ^a	0.84 ^a	0.77 ^a
Chewiness (N)	7.41 ^a	6.35 ^a	9.61 ^a	10.80 ^a	10.45 ^a	7.70 ^a	9.37 ^a	10.61 ^a	8.55 ^a
Resilience	0.37 ^a	0.33 ^{ab}	0.32 ^b	0.26 ^{cd}	0.24 ^{de}	0.31 ^b	0.29 ^{bc}	0.29 ^{bc}	0.21 ^e

Mean values with different superscript letter(s) within each row differ significantly ($p \leq 0.001$)

Table 4: Circumference (cm) of balady bread

Control	Whole sorghum flour (%)				Decorticated sorghum flour (%)			
	5	10	15	20	5	10	15	20
36.97 ^a	35.43 ^{bc}	34.60 ^{cd}	34.60 ^{cd}	34.47 ^d	36.2 ^{ab}	35.67 ^b	34.50 ^d	34.70 ^{cd}

Mean values with different superscript letter(s) within the row differ significantly ($p \leq 0.001$)

Table 5: Sensory evaluation of pan bread from composite flour of wheat flour with whole or decorticated sorghum flours.

Sensory attributes	Whole sorghum flour (%)					Decorticated sorghum flour (%)			
	Control	5	10	15	20	5	10	15	20
General appearance	8.44 ^a	8.11 ^a	7.11 ^{bcd}	6.51 ^{de}	5.11 ^f	7.78 ^{ab}	7.57 ^{abc}	6.78 ^{cd}	5.57 ^{ef}
Crumb grain	8.22 ^a	7.99 ^{ab}	7.13 ^c	6.33 ^d	6.20 ^d	7.49 ^{bc}	7.78 ^{abc}	7.12 ^c	5.70 ^d
Mouth feel	8.22 ^a	7.59 ^{ab}	7.11 ^{abc}	6.00 ^{cd}	4.89 ^d	7.72 ^{ab}	7.33 ^{ab}	6.89 ^{bc}	4.89 ^d
Odor	7.75 ^a	6.94 ^a	6.25 ^a	6.63 ^a	5.59 ^a	6.88 ^a	7.13 ^a	6.63 ^a	6.45 ^a
Taste	8.44 ^a	7.22 ^b	6.74 ^b	6.44 ^{bc}	5.22 ^d	7.22 ^b	7.00 ^b	6.58 ^{bc}	5.44 ^{cd}
Softness	8.67 ^a	7.67 ^b	7.56 ^b	6.92 ^b	5.44 ^c	7.79 ^{ab}	6.94 ^b	7.68 ^b	5.65 ^c
Overall acceptability	8.29	7.59	6.98	6.47	5.41	7.48	7.29	6.95	5.62

Mean values with different superscript letter(s) within each row differ significantly ($p \leq 0.001$)

parameters. Chewiness is the most indicative characteristic of bread. It is calculated by multiplying gumminess, and springiness, whereas the determination of gumminess is calculated by multiplying hardness and cohesiveness. The results showed that gumminess increased with an increased amount of sorghum flours in the blends. Furthermore, results revealed that gumminess and chewiness values are highly dependent on hardness rather than on cohesiveness or springiness values.

It was reported that since wheat flours contain gluten protein which by suitable development gives the bread its unique and much desired texture; the inclusion of sorghum flours dilutes wheat gluten, and consequently weakens its strength. The presence of starch in baking affects crumb characteristics (Taha, 2000).

Circumference of Balady bread: The substitution effects of sorghum flour on Balady bread quality are shown in Table 4. A slight yet significant decrease in bread circumference has occurred with the inclusion of any amount of sorghum flour.

Sensory evaluation of breads:

Pan bread: The sensory properties of pan breads made from blends of wheat and whole /decorticated sorghum flours as well as the 100% wheat bread are presented in Table 5. All sensory scores of general appearance, crumb grain, taste, softness, mouth feel, and over all acceptability were significantly different among blend

samples, except odor. All breads were rated as acceptable by the panel except for mouth feel attribute of the samples with 20% whole and decorticated sorghum flour. The preference, however, has decreased as the substitution of sorghum level increased. Generally, individual sensory scores of pan bread made with whole sorghum flour were slightly lower than those of blends of decorticated sorghum flour. This result may be explained by the characteristics of the grain coat in the flour. Overall, the results have shown that the level of preference declined with decreasing the level of wheat flour in the bread.

In contrast to the above results, Anglani (1998), Carson *et al.* (2000) and Hugo *et al.* (2000, 2003a) reported that addition of 20 to 50% sorghum flour to wheat flour produced excellent bread. Moreover, Summer and Nielson (1976a) produced acceptable Nigerian bread using an 80/20 wheat/sorghum composite flour blend; whereas, Perten (1977) reported satisfactory production of French- type bread from composites of 85% wheat flour (87% extraction) and 15% sorghum flour. Composite bread produced from composite flours at the ratios 90/10, 80/20 and 70/30 wheat/sorghum were found to yield acceptable bread quality (Taha, 2000).

Balady bread: With respect to the organoleptic evaluation of the bread produced, results of the overall quality associated with the ratio of the sorghum flour are shown in Table 6. The general appearance of Balady bread was significantly different ($p \leq 0.001$) with

Table 6: Sensory evaluation of balady bread supplemented with whole/ decorticated sorghum flours.

Sensory attributes	Control	Whole sorghum flour (%)				Decorticated sorghum flour (%)			
		5	10	15	20	5	10	15	20
General appearance	8.33 ^a	7.00 ^b	6.96 ^b	5.83 ^c	5.83 ^c	7.33 ^b	7.33 ^b	7.44 ^b	7.56 ^{ab}
Crumb color	8.56 ^a	7.44 ^{bcd}	6.89 ^{de}	6.22 ^{ef}	5.89 ^f	8.02 ^{ab}	7.78 ^{abc}	7.11 ^{cd}	6.78 ^{de}
Softness	8.28 ^a	6.56 ^{cd}	6.60 ^{cd}	6.11 ^{de}	5.44 ^e	7.67 ^{ab}	7.33 ^{bc}	7.32 ^{bc}	6.78 ^{bcd}
Aroma	7.93 ^a	7.87 ^a	6.56 ^{bc}	6.56 ^{bc}	6.33 ^c	7.22 ^{ab}	7.85 ^a	7.22 ^{ab}	7.67 ^a
Taste	8.29 ^a	7.15 ^{bc}	6.46 ^{cd}	5.88 ^{de}	5.66 ^e	7.33 ^b	7.10 ^{bc}	6.90 ^{bc}	6.87 ^{bc}
Mouth feel	8.00 ^a	8.12 ^a	6.67 ^{cd}	6.44 ^{cd}	6.11 ^d	7.74 ^{ab}	7.00 ^{bcd}	7.33 ^{abc}	6.78 ^{cd}
General acceptability	8.23	7.36	6.69	6.17	5.88	7.55	7.40	7.22	7.07

Mean values with different superscript letter(s) within each row differ significantly ($p \leq 0.001$)

increasing levels of sorghum flours (whole/ decorticated). The crumb color of the breads made with 5 and 10% substituted decorticated sorghum flour was similar to the control (100% wheat flour); whereas at higher levels of substitution, samples were significantly darker ($p \leq 0.001$). These results are in agreement with those reported by Summer and Nielsen (1976b), who concluded that incorporation of 20% sorghum flour in bread formulation darkened the internal and external loaf color.

Taste scores decreased significantly as the level of sorghum flour increased. A slight bitter taste at a 10% or greater added level of whole sorghum flour may be due to the phenolic compounds and tannins found in the seed-coat. When the proportion of sorghum flours increased in breads, the softness and mouth feel of bread scores decreased significantly. These results were more apparent in the samples with whole sorghum rather than decorticated sorghum flour levels. Generally, it was observed that both the typical bread and that made with up to 20% sorghum flours substitution did not vary significantly ($p \leq 0.001$) in aroma characteristic. However, there was a variation in general acceptability among sorghum flours substitution levels in our study. Bread made with 100% wheat flour had a higher acceptability score compared to all sorghum flours substitutions.

In this study, overall bread quality at the different levels of whole and decorticated sorghum flours substitution levels was found to be acceptable. However, acceptability increased as the level of sorghum flour, decorticated or whole, decreased. These results are in agreement with the work of Kyomugisha (2002).

CONCLUSION

Higher levels of substitution of wheat flour with whole or decorticated-sorghum flours resulted in lower circumferences of Balady and a decrease in specific volume of pan bread. Whole sorghum flour blends gave lower loaf scores as compared to decorticated sorghum flour blends. There were significant differences in the *L*, *a*, and *b*-values, among the different levels of substitution. However, crumb color was directly related to sorghum extraction rate and the level of substitution.

Increasing the level of sorghum flours decreased cohesiveness, springiness and resilience, and increased hardness, gumminess and chewiness of pan bread made with whole or decorticated sorghum-wheat composite flour.

Acceptable pan and Balady bread could be made by substitute with up to 20% whole or decorticated sorghum flours. However, sensory evaluation results also indicated an increased preference for bread that had lower levels of whole or decorticated sorghum flour.

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