Advance Journal of Food Science and Technology 5(11): 1407-1412, 2013
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: September 24, 2012 Accepted: November 08, 2012 Published: November 05, 2013

Effects of Sorghum Flour Addition on Chemical and Rheological Properties of Hard White Winter Wheat

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Abstract: This study was carried out to investigate the chemical and rheological properties of different blends prepared using hard white winter wheat (HWWW; *Triticum aestivum* Desf.) and whole or decorticated sorghum (*Sorghum bicolor*). Whole and decorticated sorghum were used to replace 5, 10, 15 and 20% of wheat flour. Wheat samples had higher protein, moisture and calcium values and lower fat, ash, carbohydrates, iron and phosphorous values compared to whole and decorticated sorghum flours. Decortication of sorghum grains decreased moisture, ash, fat, crude protein, iron and phosphorous content, but increased carbohydrate content. Farinogram properties such as dough water absorption, development time and stability and Farinograph quality number decreased as the amount of substituted sorghum increased; whereas mixing tolerance index increased. Moreover, at fixed gluten levels, as sorghum flour increased in the blend, wet gluten, dry gluten and gluten index decreased. Increasing sorghum in the blend also decreased energy, resistance to extension and extensibility of the dough, but contributed to an increase in the ratio of resistance to extensibility. Furthermore, as fermentation time increased, energy, resistance to extension and the ratio number of energy to extension increased, whereas extensibility decreased.

Keywords: Flour mix and rheology, nutrients, proximate analysis, sorghum (Sorghum bicolor), wheat (*Triticum aestivum* Desf.), white wheat

INTRODUCTION

Wheat (*Triticum aestivum* Desf.) is currently one of the most important nourishing cereal crops worldwide (Lobell *et al*., 2008) and in Sudan ranks second after sorghum in terms of consumption. With a sharp increase in urbanization and ways of life during the past 50-60 years, Sudan's annual wheat consumption has surpassed 1 million tons (FAO, 2001). The same trend is seen in other areas of Africa and Asia where sorghum used to dominate as the sole bulk grain crop. Wheat flour made from both hard and soft wheat has been the major ingredient of leavened bread for many decades because of its functional proteins. In spite of an increase in bread consumption in those aforementioned areas, predominantly Sudan, much of the wheat is imported as wheat with high gluten functionality is not suitable for cultivation in the tropical area for climatic reasons (Edema *et al*., 2005). Not only is Sudan's local production of wheat insufficient, but the Sudanese mills spend much foreign currency to import wheat flour for bread and other baked products. Food shortages and crises are not uncommon as a result. This situation has necessitated the need for blending wheat with locally grown sorghum to meet the local demand for bread.

Sorghum is consumed in Sudan in fermented forms, mainly as Kisra (local thin bread), aceda (thick porridge) and nasha (thin porridge), but several studies have shown the possibility of incorporating it, both as whole and decorticated grain, in wheat flour at various levels to produce bread when wheat is in short supply (Abdel-Kader, 2000). Decortication is a process whereby the pericarp and portions of the germ are removed, resulting in starch-rich product that has very low fiber and reduced protein (Taha, 2000). On the other hand, dehulling of sorghum grain improves iron availability as the removed hull is rich in phytate, a compound that binds iron, magnesium and zinc and renders them biologically unavailable.

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Table 1: Chemical composition (%) of wheat, whole and decorticated sorghum flours

Type of flour	Moisture	Ash	Crude fat	Crude protein	Carbohydrate	Ca	Fe	P
Whole sorghum flour	8.16[a]	1.76[a]	2.87[a]	10.85[a]	76.4	0.016	0.013	0.281
Decorticated sorghum flour	7.89[b]	1.32[b]	2.03[b]	10.62[a]	78.1	0.017	0.0078	0.216
Extracted wheat flour	11.44	0.52	1.05	15.06	71.9	0.024	0.0023	0.105

Mean values having different superscript letter (s) in each column differ significantly ($p \leq 0.05$)

The objective of this study, therefore, was to evaluate the effects of addition of whole and decorticated sorghum flour on the chemical and rheological properties of hard white winter wheat.

MATERIALS AND METHODS

Materials: Commercial sorghum grain of the local cultivar 'Tabat' was used in this study. Experimental wheat flour of Hard White Winter Wheat (HWWW) cultivar 'Alice' (Ibrahim *et al*., 2008) was obtained from South Dakota State University at Brookings, SD, USA.

Methods*:*

Preparation of sorghum and wheat grains for analysis: Grain of HWWW was milled using an experimental mill in Manhattan, Kansas, USA to 72% extraction rate flour. Sorghum grain was cleaned and freed from foreign materials. Grain was decorticated at the Food Research Center in Khartoum, Sudan using an experimental mill (Schule, F. H. SCHULE GMBH. MASCHINENFABRIK, Hamburg, Germany 1976). Part of the grain was milled to whole sorghum flour and the rest was milled at 70% extraction rate.

Whole sorghum, decorticated sorghum (70%) and HWWW (72%) flours were kept in a freezer for subsequent chemical analyses and rheological evaluation.

Preparation of composite flour blends: Wheat flour which was used for bread making was blended following substitution with 0, 5, 10, 15 and 20% whole sorghum flour. The same was repeated with decorticated sorghum flour. A blender was used to mix the flours at an amount of 1 kg flour for about one hour per cycle using a Twin shell dry blender (The Patterson Kelly Co. Inc. East Stroudsburg, Pennsylvania-patents no 2, 514, 126). The composite flours were stored in an airtight container and stored in a freezer until required.

Chemical and rheological analyses: Moisture, ash, fat content, calcium, iron and phosphorus of wheat and sorghum grains and composite flours were determined according to the AOAC International (2000) procedure. Wet gluten content was determined according to the AACC (2000) method and farinograph tests were carried out according to the AACC (2000) method. Official methods of AACC (2000) were also used to determine the extensiographic characteristics of the flours.

Statistical analysis: The analysis of variance (ANOVA) was performed to examine the significance of sorghum fortification on proximate composition of wheat flour. Fischer protected Least Significant Difference (LSD) test was used in means separation using a 0.05 level of significance (Gomez and Gomez, 1984). All analyses were performed in triplicate (n = 3).

RESULTS AND DISCUSSION

Chemical composition of wheat and sorghum flours: The results of moisture, ash, crude protein, fat, carbohydrates and some minerals contents of wheat and sorghum flours are illustrated in Table 1. As shown in this table the moisture content of wheat flour was 11.44%, higher than the 9.9% that Carson and Sun (2000) worked with. Moreover, Abdalla (2003) reported moisture content of Australian wheat flour (72-75% extraction) and Indian wheat flour (82% extraction) at 13.45 and 10.67%, respectively.

The ash content of extracted wheat flour, as shown in Table 1, was 0.52%. This result agreed with the previous findings of 0.31-0.62% reported by Pareds-Lopez *et al*. (1978) and higher than the 0.45% reported by Egan *et al*. (1981). However, it was lower than the 0.6% reported by Coskuner and Karababa (2005). The ash content of the aforementioned Australian wheat flour was 0.52% as reported by Abdalla (2003). On the other hand, Idowu (1996) reported a larger ash content of wheat flour of 1.3%.

Our results showed that the fat content of wheat flour (72% extraction) was 1.05% (Table 1). This value is similar to that obtained by Abdel-Kader (2000), who reported that the fat content of soft wheat flour (82% extraction) milled from white Australian wheat was 1.25% and lower than the finding of Idowu (1996) who reported fat content of 1.6%.

The protein content of HWWW flour from the 2009 crop year, as shown in Table 1, was 15.06%. This result falls within the range of 8.5-16.1% reported by Chung *et al*. (2001). However, it is higher than the 12.3% obtained by Pomeranz *et al*. (1977) and 10.97 and 10.3% obtained by Abdalla (2003) of Australian and Indian wheat flour.

Table 1 shows that the total carbohydrate content of wheat flour (71.93%) is lower than that reported by Abdalla (2003) on Australian and Indian wheat at 73.33 and 75.39%, respectively.

As shown in Table 1, calcium, iron and phosphorus content of wheat flour were 0.024, 0.0023 and 0.105%,

Table 2: Farinograph readings of dough made from a blend of wheat flour and either whole or decorticated sorghum flour

Farinograph Parameters	Control	Whole sorghum flour %				Decorticated sorghum flour %			
		5	10	15	20	5	10	15	20
Water absorption (14% moisture)	63	62.4	61.9	61.0	60.0	62.4	61.7	61.1	59.9
Development time (min)	10.1	8.4	7.4	7.8	7.8	8.8	8.5	8.1	7.2
Stability (min)	17.8	16.2	14.6	13.9	13.3	17.1	16.0	14.5	13.2
Mixing tolerance index MTI (FU)	11	17	21	23	25	20	23	26	28
Farinograph quality number (mm)	197	150	126	134	127	158	143	137	127

respectively. Taha (2000) studied the minerals content of two Sudanese wheat cultivars (Condor 72%, Debeira 72%). Calcium, iron and phosphorus contents of variety Condor were 0.51%, 102 ug/mg and 0.2%. Debeira had calcium, iron and phosphorous content of 0.54%, 82 ug/mg and 0.14%, respectively.

Proximate composition of whole and decorticated sorghum flours: As shown in Table 1, the moisture content of the whole and decorticated sorghum flours were 8.16 and 7.89%, respectively. These results were within the range of 5.7 to 10% reported by Yousif and Magboul (1972) for Sudanese sorghum cultivars, but higher than 6.3% as found by Elshewaya (2003). However, these values were below the range of 8.89 to 9.88% reported by Arbab (1995). Elsayed (1999), who studied two Sudanese sorghum cultivars, found moisture content of 7.37 and 8.00% for Tabat and 'Feterita', respectively.

The ash content of whole and decorticated sorghum flours, as shown in Table 1, were 1.76 and 1.32%, respectively. The results were in agreement with Purseglove (1972) who reported ash content of 1.5-2%. These values were also found to be within the ranges of 1.1-2.7% reported by Shephered *et al*. (1970) and 1.3-1.9% reported by Yousif and Magboul (1972). However, it is higher than that reported by Elshewaya (2003) who reported ash content of the sorghum cultivar Tabat as 1.43%. Elsayed (1999) reported 1.5 and 1.8% ash contents of Tabat and Feterita, respectively.

The fat content of whole and decorticated sorghum flours were 2.87 and 2.03%, respectively (Table 1). These values were within the range of 2.5-5.1 and 2.5-3.5%, respectively as reported by Shephered *et al*. (1970) and El-Tinay *et al*. (1979). Fat content value of whole sorghum was lower than 3.25% reported by Elshewaya (2003) as well as Elsayed (1999) who found fat content of the two Sudanese sorghum cultivars, Tabat and Feterita, to be 3.37 and 4.68%, respectively.

The crude protein of whole and decorticated sorghum flours, as shown in Table 1, was 10.85 and 10.62% respectively. These values were within the range of 8.8-11.6% which was reported by El-Tinay *et al*. (1979). Protein content of whole sorghum cultivar Tabat was higher than that of 8.74% reported by Elshewaya (2003). Elsayed (1999) found that the protein content of Tabat and Feterita were 6.64 and 12.71%, respectively. However, Abdalla (2003) reported that the flour protein content of Sudanese sorghum variety Fakimustahi was 15.47%.

Table 1 shows the total carbohydrates content of whole and decorticated sorghum flours as 76.36 and 78.14%, respectively. Similar results (78.96%) were obtained by Elshewaya (2003) and Elsayed (1999) who reported 78.78 and 71.33% total carbohydrates of Tabat and Feterita, respectively. However, these results were higher than the 71.0 to 73.4% reported by Eggum *et al*. (1983). Abdalla (2003) found the total carbohydrates of Sudanese sorghum cultivar Fakimustahi to be 72.68%.

As shown in Table 1, calcium, iron and phosphorous content in the whole and decorticated sorghum flours were 0.016, 0.017, 0.013 0.0078, 0.281, 0.216%, respectively. The FAO (1995) reported that iron content in sorghum was 4.2 (mg/100 g) on dry basis. Taha (2000) studied the minerals content of three Sudanese sorghum cultivars, Dabar, Fakimustahi and Tetron, (100% extraction rate). He found that the amount of calcium was 0.62, 0.52 and 0.60%; phosphorous was 0.16, 0.12 and 0.12% and iron was 80, 65 and 72 µg/mg, respectively.

Rheological properties of the dough prepared from composite flour of wheat and whole/decorticated sorghum flours: Farinograph readings of dough made from a composite of wheat flour and either whole or decorticated sorghum flour are presented in Table 2. For both treatments, as the substitution level of sorghum flour increased, the water absorption values and dough development time of the blends decreased. Similar results were obtained by Carson and Sun (2000), who reported that, at fixed gluten levels, as sorghum flour increased, water absorption decreased slightly. Moreover, the results indicated that substitution with sorghum flour resulted in lower dough stability time. The decrease is more evident in the blends containing 20% whole and decorticated sorghum flours and 80% HWWW. The results also showed that when the percentage of sorghum flours increased in the dough, the farinograph quality number values of blended flours decreased for both sorghum flour types. The results also showed that, as the substitution level of

Table 3: Gluten quantity and quality of composite flours of wheat blended with either whole or decorticated sorghum flours

Quality Characteristics	Control	Whole sorghum flour %				Decorticated sorghum flour %			
		5	10	15	20	5	10	15	20
Dry gluten (%)	13.7	13.3	12.6	12.2	12.2	13.0	12.9	12.3	12.2
Wet gluten (%)	36.7	36.5	35.0	34.6	34.4	35.4	35.2	34.5	34.3
Gluten index%	96.6	96.5	96.0	92.9	87.5	96.8	96.5	91.2	92.4

Table 4a: Extensiogram readings of dough made from wheat flour with different levels of whole sorghum flours

Quality Characteristics	Control			Whole sorghum flour %											
				5			10			15			20		
	45min	90min	135min	45 min	90min	135min	45min	90min	135min	45min	90min	135min	45min	90min	135min
Energy (cm2)	88	129	141	82	105	108	71	100	100	64	84	94	62	88	84
Resistance to Extension (BU)	326	491	568	314	494	547	254	372	364	297	402	420	311	459	493
Extensibility (mm)	149	144	144	146	127	127	151	149	147	129	127	134	123	122	115
Maximum resistance (BU)	457	729	793	435	670	694	356	529	532	376	499	535	371	552	559
Ratio Number (R/E)	2.2	3.4	4	2.2	3.9	4.3	1.7	2.5	2.5	2.3	3.2	3.1	2.5	3.8	4.3

Table 4b: Extensiogram readings of dough made from wheat flour with different levels of decorticated sorghum flours

Quality Characteristics	Control			Decorticated sorghum flour %											
				5			10			15			20		
	45min	90min	135min	45min	90min	135min	45min	90min	135min	45min	90min	135min	45min	90min	135min
Energy (cm2)	88	129	141	81	145	131	81	108	130	69	94	105	66	85	91
Resistance to extension (BU)	326	491	568	359	622	697	338	503	595	292	459	503	338	495	529
Extensibility (mm)	149	144	144	136	143	117	141	129	137	137	127	130	122	115	113
Maximum resistance (BU)	457	729	793	445	810	980	431	656	751	371	569	615	409	572	630
Ratio number (R/E)	2.2	3.4	4	2.6	4.3	5.9	2.4	3.9	4.4	2.1	3.6	3.9	2.8	4.3	4.7

sorghum flours increased, MTI increased. The highest MTI was observed in the sample of 80% HWWW: 20% whole or decorticated sorghum flours. This result is in agreement with work reported by Abdalla (2003), who stated that the degree of softening increased with increasing the amount of sorghum flour.

Generally, increasing substitution with non-wheat cereal flour will have increasingly deleterious effects on rheological quality. Coskuner and Karababa (2005) reported that although stronger dough is preferred for loaf-raised bread, generally medium strength dough is preferred for flat bread-making. If the dough is too strong it will not react properly during the sheeting or flattening processes involved in the baking of flat bread.

Gluten content and gluten index: Table 3 shows the effect of substitution of wheat flour with whole and decorticated sorghum flour on gluten. It was noticed that dry gluten decreased in increasing the amount of whole and decorticated sorghum flours. The dry gluten content of wheat flour was 13.7%. This result agrees with work reported by Kulkarni *et al*. (1987) who found that the dry gluten of hard red winter and hard red spring wheat ranged from 9.4-15.1 and 11.7-15.3%, respectively. The values are higher than those reported by Huebner and Rothfus (1968) who concluded that dry gluten from different cultivars of hard wheat ranged between 9 and 11%.

The decrease in dry gluten in composite flour may be due to decrease in gluten content of the composite flour caused by the increase of sorghum content. This finding is in harmony with that obtained by Taha (2000), who reported that the dry gluten content of wheat flour (control) is higher than a composite flour of wheat and sorghum. Also, wet gluten decreased as the amount of whole and decorticated sorghum flours increased. However, the decrease was more obvious beyond 10% sorghum flour substitution. This is due to the absence of gluten in sorghum flour. The wet gluten content of wheat flour was 36.7%. This finding is similar to that obtained by Mohamed (2000) who reported that wet gluten of white flour from Sudanese cultivars (season 1997/98) was in the range of 32.6 to 38.77%. Furthermore, the gluten index decreased as the percentage of sorghum flours increased. The lowest gluten index 87.5% was obtained from 20% whole sorghum: 80% wheat flour as compared with 96.6% for the control.

Extensiogram readings: Table 4a and b summarize the data obtained from the extensiogram. The results showed that, in general, increasing the substitution of sorghum flours reduced the energy, the resistance to extension, extensibility and maximum resistance of the dough to extension; while the ratio of resistance to extensibility increased. The decrease in energy meant that less work would be needed to stretch and break the dough as sorghum flour increased.

Similar findings were reported by Carson and Sun (2000) that at fixed gluten amounts, with increasing sorghum flour substitution percentage, dough strength and extensibility decreased significantly. The results also indicate that, generally, as time increased, the energy, resistance to extension, maximum resistance and ratio of resistance to extension increased, while the extensibility decreased. This result agreed with that reported by Abdalla (2003), who found that the resistance to extension ratio number and energy increased with increasing the time from 45 to 135 min, while extensibility decreased. Moreover, Hamaker (2001) reported that addition of sorghum to wheat flour produces marked negative effects on rheological properties of dough. The decrease in energy, resistance and extensibility of dough as affected by increasing the percentage of sorghum may be due to the reduction of gluten as the percentage of sorghum increased.

CONCLUSION

Wheat flour had higher protein, moisture and calcium values and lower fat, ash, carbohydrates, iron and phosphorous values compared to whole and decorticated sorghum flours.

The decortication of sorghum grain decreased moisture, ash, fat, crude protein, iron and phosphorous content. However, carbohydrate content increased. Water absorption, dough development time, stability time and farinograph quality number of the dough decreased with increasing level of sorghum flour in both whole and decorticated blends, while the mixing tolerance index of the dough increased. Moreover, the high quantity and strong quality of gluten in composite flour samples decreased as the amount of sorghum flour substitution increased. In addition, increasing the substitution of sorghum flours reduced the energy, the resistance to extension, extensibility and maximum resistance of the dough to extension while the ratio number of resistance to extensibility increased. It was also noted that the fermentation time of the extensiogram increased, the energy, resistance to extension, maximum resistance and the resistance to extensibility ratio number of the dough increased, while the extensibility decreased.

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