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RESEARCH ARTICLE

CHARACTERIZATION AND IMPROVEMENT OF FLOURS OF THREE SUDANESE WHEAT CULTIVARS FOR LOAF BREAD MAKING

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Abstract

The aim of this study was to characterize and improve the flour of three Sudanese wheat cultivars for loaf bread making. Three local wheat cultivars; Debaira, Wadi Elneel, and Elneelain, and Canadian wheat (as control) were treated with three improvers: Alpgida (A), Samabeel (S), and Zena (Z). The results showed significant difference in the quality tests among the flours and breads made from the three local cultivars and Canadian wheat flours. Addition of improvers to the three local cultivars and Canadian wheat flours significantly ($P \leq 0.05$) affected the quality tests with the exception of sedimentation value. For the local cultivars, addition of improvers increased alpha-amylase activity, Pelshenke test value, degree of softening, resistance, extensibility, specific loaf volume and decreased water absorption. On the other hand, addition of improvers to the Canadian cultivars increased alpha-amylase activity, Pelshenke test value, resistance, specific loaf volume and decreased water absorption, degree of softening and extensibility. Sensory evaluation of loaf showed that loaf bread made from the Canadian wheat flour with Z improver gained the highest score of general acceptability (8.5). Generally, Debaira cultivar showed better bread making quality as compared with the other two local cultivars.

Keywords: Bread-making, Debaira, Elneelain, Sudanese wheat, Wadi Elneel.

Introduction

With an annual production of about 620 million tonnes, bread wheat (*Triticum aestivum L.*) is one of the world's most important crops (Bordes *et al.*, 2008). Wheat is unique among cereals, because it contains gluten which has the characteristic of being elastic when mixed with water and retains the gas developed during dough fermentation. The quality of wheat flour for bread-making is generally evaluated by the amount of protein and quality of gluten (Khatkar *et al.*, 1995). The wheat flour containing large amount of protein and high quality of gluten is used for normal bread, whereas that of lower amount of protein is mostly used for confectionary or cakes (Caballero *et al.*, 2007).

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Wheat produced in different parts of the world differ greatly in their intrinsic protein qualities and quantities, the quantity is influenced mainly by environmental factors, but the quality of protein is mainly a heritable characteristic (Bordes *et al.*, 2008). Baking quality is determined by the physical properties of dough, its oxidative properties, the flour water absorption, bread volume, and the color of the bread crumb and crust. The baking properties of a dough sample depend on the flour's ability to form dough that, after mixing and during fermentation, has appropriate physical properties. The strength thus contributed to the dough is an important part of the bread making quality of the flour (Menkovska *et al.*, 2002). For several thousand years, bread has been one of the major constituents of the human diet, making the baking of yeast-leavened and sourdough breads one of the oldest biotechnological processes. In wheat bread making, flour, water, salt, yeast and/or other micro-organisms are mixed into visco-elastic dough, which is fermented and baked (Goesaert et al., 2005). Wheat flour is the major ingredient and consists mainly of starch (cca. 70–75%), water (cca. 14%) and proteins (cca. 10–12%). In addition, non-starch polysaccharides (cca. 2–3%), in particular arabinoxylans (AX), and lipids (cca. 2%) are important minor flour constituents relevant for bread production and quality (Goesaert *et al.*, 2005). During all steps of bread making, complex chemical, biochemical and physical transformations occur, which affect and are affected by the various flour constituents. In addition, many substances are nowadays used to influence the structural and physicochemical characteristics of the flour constituents in order to optimize their functionality in bread making (Goesaert *et al.*, 2005). In Sudan, wheat is a strategic field crop, since it constitutes the main staple food for most of the urban and rural population. Wheat cultivation in Sudan expanded recently and occupying the largest area in Sudanese irrigated schemes, and it is the second most important cereal crop after sorghum in the country (Ishag, 1994). The consumption of wheat bread in Sudan 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). Since Sudanese wheat are generally of poor bread making quality, which is attributed to the low protein and gluten quantity and quality, in addition to low alpha amylase activity.

Hence improvement of flour quality is very essential for production of good quality bread. Therefore, the aim of the present study was to investigate the effect of different improvers on the rheological and bread making properties of three local Sudanese wheat cultivars compared with Canadian wheat.

Materials and Methods

Materials

Three Sudanese wheat cultivars (Elneelian, Debaira, and Wadi Elneel) and one Canadian wheat cultivar were obtained from Hudieba Research Station and Wheata flour mill (Khartoum, Sudan), respectively. The samples were cleaned and the physical characters such as, 1000 kernel weight, hectoliter weight was determined. Then wheat grains were milled in Quadrumat Junior Mill (Brabender, GmbH & Co. KG, Duisburg, Germany) to white flour (72% extraction rate), and prepared for chemical analysis and bread making.

Three types of bread improvers: Z Zena (Zena, Khartoum North), A Alpgida (Healthcare) and S Samabeel (Samabeel Int. Ltd. Co., Khartoum, Sudan) were obtained from the local market (Khartoum, Sudan) and used according to the manufactures recommendation. All chemicals and reagents were of analytical grade.

Proximate composition analysis

The determination of moisture, fiber, fat, protein and ash were carried out according to AOAC (1995) methods.

Determination of gluten quantity and quality

Gluten quantity and quality of wheat flours with and without improvers were carried out according to the revised standard ICC method No. 155 and

158 (Perten, 1995) by using Glutomatic 2200 system (Perten Instruments AB, Huddinge, Sweden). Ten grams of the sample was mixed into dough with 5 ml distilled water in a test chamber with bottom sieve. The dough was then washed with 2% solution of sodium chloride. The gluten ball obtained was centrifuged at maximum speed by centrifuge (Type 2015) and quickly weighed. The percentage of wet gluten remaining on the sieve after centrifugation is defined as the gluten index. The total wet gluten was dried in heater (Glutork, 2020) to give the dry gluten. The weight of gluten was multiplied by ten to give the percentage of wet or dry gluten.

Falling number

Alpha – amylase activity of wheat flours with and without improvers was determined according to Perten (1996). Appropriate flour sample weight, was weighed and transferred into falling number tube and 25 mL distilled water was added, the stopper was fitted into the top of the viscometer, and shaked well until a homogenous suspension was formed. The viscometer tube was placed in the boiling water bath, and locked into position. The test automatically starts. The sample was stirred for 60 seconds, and then the viscometer stirrer was stopped in up position, released and sinked under its own weight through the uniform gelatinized suspension. The time in seconds for the stirrer to fall through the suspension was recorded as the falling number (seconds), the required flour sample weight (RFW) was obtained from the correction tables of sample weight to 14% moisture basis (Perten, 1996), corresponding to 7g at 14% moisture, no change is made in the quantity of the water used (25 mL).

Calculations:

$$\text{Required Flour Weight (g)} = 7 \times \frac{100 - 14}{100 - \text{Actual moisture content}}$$

Sedimentation value

Sedimentation value of wheat flours with and without improvers was carried out according to the official standard methods (AACC, 2000). About 3.2 g of fine flour samples were placed in 100 mL glass stoppered graduated cylinder, simultaneously timing started when 50 mL distilled water containing bromophenol blue was added. Then the flour and water were thoroughly mixed by moving stoppered cylinder horizontally length wise, alternately right and left, through space of 7 In 12 times in each direction in 5 seconds, then flour was completely swept into suspension during mixing. At the end of first 2 min period, the contents were mixed for 30 seconds, in this manner the cylinder was completely inverted then righted up, as if it were pivoted at center, this action was performed smoothly 18 times in the 30 seconds then was let to stand 1.5 min. After that 25 mL of isopropyl alcohol lactic acid were added, mixed immediately by inverting cylinder four times as the latest step then was left to stand 1.75 min., mixed again for 15 sec, then the cylinder was immediately placed in upright position and let to stand for 5min.The factor to obtain sedimentation value was brought from table on 14% moisture basis, (AACC, 2000).

Pelshenke test

Pelshenke test was carried on wheat flours with and without improvers according to AACC method (2000). Approximately 4g of each sample were blended and weighed using quadruplicate one pair on each of two different days, the sample of two different days were put into 150 mL low form beaker. Then, 2.25 mL of yeast suspension were mixed with meal via stirring rod. The resulting mass was then transferred to palm of hand, kneaded, round meal ball, replaced in a beaker and covered with 80 mL water (30 °C). The time of immersion was noticed and the beaker was transferred to a constant temperature cabinet, the time was noted when ball started to disintegrate as time in min. The yeast suspension was made up daily (in the two days) by suspending 10 g fresh compressed yeast in 100 mL water.

Farinograph

Brabender farinograph method was carried on wheat flours with and without improvers according to AACC method (2000). Titration curve was used for the assessment of the water absorption for each flour sample. A sample of 300 gram (14% moisture) was weighed and transferred into a cleaned mixer. The farinograph was switched on 63 rpm for 1 min, then the distilled water was added from especial burette (the correct water absorption can be calculated from the deviation, 20 units deviation correspond to 0.5% water, if the consistency, is higher than 500 F. U. more water is needed and vice – versa). When the consistency is constant, the instrument was switched off and the water drawn from the burette indicates water absorption of the flour in percentage. The measuring mixer was thoroughly cleaned. A sample of 300 g was weighed, and then introduced into the mixer; the farinograph was switched on such as before. The water quantity, which is determined by the titration curve, was fed at once. When an appreciable drop on the curve was noticed, the instrument was run further 12 min before shutting off.

Extensograph

Extensograph method was used according to ICC method (2001). The extensograph and farinograph were set and operated at 30°C. The dough for extensograph was prepared as for the farinograph, but the amount of water used for mixing was 2% less due to the addition of 2% salt and the dough was mixed for 5 min only. Two pieces of dough (150 g each) were weighed, molded on the balling unit, rolled with dough roller into cylindrical test pieces, fixed in the dough holder, and stored in the rest cabinet for 45 min. The dough piece was placed on the balance arm of extensograph and stretched by stretching hook until it broke. During the period of stretching the behavior of the dough was recorded on a curve via extensograph. This test was performed at 45, 90, and 135 min intervals.

Preparation of loaf bread

The procedure described by Badi *et al.* (1978) was modified for this type of bread. Bread improvers A, S, and Z were added at 0.025, 0.05, and 0.06 g, respectively according to manufacture recommendation. Dry ingredients (flour 250 g, dry yeast 2.5 g, salt 1.5 g and sugar 3 g) were mixed for 1 min using Mono – Universal laboratory dough mixer. Water was added (based on the farinograph optimum absorption) and mixed for 3 min at medium speed. After mixing the dough was allowed to rest for 10 min at room temperature (38 °C), scaled to three portions of 120 g each, molded into round balls and allowed to rest for another 10 min. Then molded again, put in pans and transferred into the fermentation cabinet for 45 min. The fermented doughs were then baked in Simon Rotary baking oven at 250°C for 15-20 min.

Physical characteristics of loaf bread

The loaves were left to cool for 1 h at room temperature (38 °C). The weight of the loaf bread was taken in grams. The loaf volume was determined by the seed displacement method according to Pyler (1973). Briefly, the loaf was placed in a container of known volume into which small seeds (millet seeds) were run until the container is full. The volume of seeds displaced by the loaf was considered as the loaf volume. The specific volume of the loaf was calculated according to the AACC method (2000) by dividing volume (CC) by weight (g).

Sensory evaluation of loaf bread

The loaves were sliced with an electric knife and prepared for sensory evaluation at the same day. The sensory evaluation of bread samples (aroma, taste, crumb texture, crumb color, crumb cell uniformity, general acceptability) was carried out by 10 panelists semi trained. The surrounding conditions were kept the same all through the panel test.

Statistical analysis

The analysis of variance (ANOVA) was performed to examine the significant effect in all parameters measured (Snedecor and Cochran, 1989). Duncan Multiple Range Test was used to separate the means (Duncan, 1955).

Results and Discussion

Chemical composition

The results on the chemical composition of the three local commercial wheat cultivars (season 2003/2004) and Canadian wheat is shown in Table 1. The moisture content of the wheat flour (72% extraction rate) of the three local wheat cultivars ranged from 11.50 to 12.07% compared to 10.4%

of Canadian wheat. Analysis of variance showed significant differences ($P \leq 0.05$) among the three Sudanese cultivars in their moisture content. Debaira showed the highest value, while Elneelain gained the lowest value. The results obtained here were higher than values obtained by Ahmed (1995) who reported that, the moisture content of Sudanese wheat cultivars ranged from 6.33 to 8.6%.

Table 1. *Chemical composition of the flours of the three local wheat cultivars (harvested season 2003/2004) and Canadian wheat flour (72% extraction rate)*

Cultivar	Moisture (%)	Protein (%)	Ash (%)	Fat (%)	Fibre (%)
Canadian	10.40^{c}	14.36^{a}	0.35^{c}	1.01^{c}	1.12^{a}
Debaira	12.07^{a}	13.57^{b}	0.55^{a}	1.22^{a}	1.08^{a}
Wadi Elneel	11.50^{b}	11.97^{c}	0.41^{b}	1.13^{b}	1.15^{a}
Elneelain	12.00^{a}	10.77^{d}	0.50^{a}	1.04^{c}	1.06^{a}

Mean values having different superscript letter in each column differ significantly at ($P \leq 0.05$) using Duncan's Multiple Range Test (DMRT)

However, Mohamed (2000) found that moisture content of four Sudanese wheat cultivars Debaira, Elneelain, Condor and Sasaraib range between 7.5 and 7.95%. Elagib (2002) reported that moisture content of three Sudanese wheat cultivars Debaira, Elneelain, and WadiElneel ranged between 6.23 and 7.49%. The differences in moisture content in these studies may be due to the variation in genotypes and environmental conditions. Moisture content is greatly affected by relative humidity at harvest and during storage. It is well known that moisture content is one of the most important factors affecting the quality of wheat (Anon, 1987). Since it has direct economic impact, higher moisture content of Sudanese wheat cultivars compared to that of Canadian wheat might be preferable in milling industry as well as bread making. Ash content of the flours of the local wheat cultivars ranged from 0.55 to 0.41%. However, ash content of local cultivars is higher than that of Canadian wheat flour (Table 1). The ash content of Debaira, Wadi Elneel and Elneelain was similar to those reported by Ahmed (1995) who stated that ash content of white flours of different Sudanese cultivars ranged between 0.31 and 0.47%. Moreover, Mohamed (2000) found that ash content of white flours of four Sudanese cultivars Debaira, Elneelain, Condor and Sasaraib ranged from 0.38 to 0.50%. Furthermore, the ash contents in white flour of Pakistani spring wheats cultivars were ranged from 0.41 to 0.55% (Khan *et al.*, 2009). Statistical analysis of the results showed significant difference ($P \leq 0.05$) among wheat flours (72% extraction rate) in the ash content of the three local cultivars. Ash content has been considered an important indicator of flour quality. It gives some indication of the miller's skill and the degree of refinement in processing and it is directly related to the amount of bran in the wheat, and hence has a rough inverse relationship to flour yield (Zeleny, 1971). The differences observed in the ash content in the present study among wheat varieties may be ascribed to differences in wheat genotypes and environmental conditions. Protein contents of the flours of three local wheat cultivars ranged from 10.77 to 13.57%. The results of the present study are in consistent with the results reported by Anjum *et al.* (2005) and Khan *et al.* (2009) who reported variation in protein content among Pakistani wheat varieties from 9.68 to 13.45 % and from 10.23 to 11.60 %, respectively. The results are also supported by the studies of Mohamed (2000) who reported, that protein content of white flour of different Sudanese cultivars ranged between 11.79 and 13.85, but, it showed high variation from that reported by Elagib (2002) who found that the protein content of whole flour of different Sudanese cultivars ranged between 9.37 and 11.17%. This may be due to variations in the growing conditions, genotypes and growing conditions. It is well known that the protein content of wheat is highly influenced by the environmental conditions, grain yield and available nitrogen as well as the variety genotype (George 1973; Khan *et al.*, 2009). Analysis of variance showed significant differences ($P \leq 0.05$) among the flours of the three local cultivars in their protein content. Interestingly, the protein content of the flour (72% extraction rate) of Debaira cultivar (13.57%) is close to that of Canadian wheat flour (14.36%) of the same extraction rate. This result indicated that the Debaira cultivar could effectively be used for bread making. The reason could be that high protein content causes good baking performance and high water absorption (Bloksma, 1972; Meredith, 1966). It is well known that the quality of wheat flour for bread making is generally evaluated by the amount of protein and quality of gluten. The wheat flour containing large amount of protein and high quality of gluten is used for normal bread, whereas that of lower amount of protein is mostly used for confectionary or cakes (Miyazaki *et al.,* 2004). Fat contents of the flours of the local cultivars ranged from 1.04 to 1.22%. These values agreed with the results reported by Ahmed (1995) who found that fat content of white flour of the Sudanese wheat cultivars ranges between 0.85 and 1.73%. It was also similar to those of Mohamed (2000) who reported that fat contents of white flour of Sudanese wheat cultivars Debaira, Elneelain, Condor and Sasaraib, were found to be in the range of 1.33 to 1.43%. Fat content of the flours of local wheat cultivars is significantly higher than that of Canadian wheat flour. Analysis of variance showed significant differences ($P \leq 0.05$) among the flours of the local cultivars and Canadian wheat in the fat content. Fiber contents of the flours of the local cultivars ranged from 1.06 to 1.15. These results are higher than those reported by Egan *et al.* (1981) who found that the fiber percentage in the wheat flour (72% extraction rate) ranges between 0.1 and 0.3%. Our results are also higher than those reported by Ahmed (1995) and Mohamed (2000) who found that the fiber contents for local Sudanese wheat flours were in the range of 0.30 to 0.48% and 0.40 to 0.48%, respectively. Higher fiber content is preferable from nutritional standpoint because adequate fiber intake has been related to a lower incidence of cancer of the colon and some types of heart diseases and to better control diabetes (Anon, 1987). Statistical analysis of results showed insignificant differences ($P \geq 0.05$) among the flours of the local cultivars as well as Canadian wheat in the fiber content. Generally, local wheat cultivars showed superior results of moisture, ash and fat compared to that of Canadian wheat. Among the Sudanese local varieties, Debaira cultivars is superior to others varieties because it showed the highest values of moisture, protein, ash and fat contents.

Gluten quantity and quality

Gluten values (wet, dry and gluten index) of the three Sudanese cultivars and Canadian wheat flours with and without improvers were shown in Table 2. Wet gluten contents ranged from 40.0 to 24.6%. Similarly, it has recently been reported that the wet gluten content of Pakistani spring wheat cultivars are ranged between 38.83 and 28.47% (Khan *et al.,* 2009). Moreover, Mutwali (2011) reported that the wet gluten value of 20 Sudanese cultivars is ranged between 46.94% and 28.63%.The Canadian wheat flour with A improver gave the highest value, whereas the lowest value was observed in Elneelain with A improver. The wet gluten of Debaira cultivar (37.60%) without improver is higher ($P \leq 0.05$) than those of other local cultivars, Elneelain (31.05%) and Wadi Elneel (28.05%), and was close to that of Canadian wheat flour (39.10%) without improver. Furthermore, addition of improvers showed similar enhancement of the wet gluten content of Debaira and Canadian wheat flours. This result demonstrated that the local cultivar Debaira could efficiently be used for bread making as Canadian wheat is the major wheat flour used in baking industry in Sudan. Dry gluten values of wheat flours with and without improvers were ranged from 14.0 to 7.97%. These results are in a good agreement with range 10.49 to 13.60% of Pakistani spring wheat (Khan *et al.,* 2009). Similar results were also obtained by Mutwali (2011) who reported that the dry gluten content of Sudanese wheat cultivars grown in three different regions are ranged between 8.96 and 16.76 %. The Canadian wheat without improvers gained the highest values, while Elneelain with A improver gained the lowest value. Within the local varieties the highest dry gluten content was observed in Debaira wheat flour, whereas, the lowest dry gluten content was recorded for Elneelain cultivar. It is worth to note that, addition of improvers has insignificant effect of the dry gluten values of all wheat cultivars. The Gluten Index (GI) is a method of analyzing wheat protein that provides simultaneous determination of gluten quality and quantity (AACC, 2000). Gluten index values of Sudanese and Canadian wheat cultivars and were found to be in the range of 93.34 to 64.53%.

Table 2. *Gluten quantity and quality, falling number, pelshenke test and sedimentation value of the three Sudanese wheat cultivars and Canadian wheat flours with and without improvers*

Cultivar	Improver	Gluten quantity and quality			Falling No. (sec.)	Pelshenke test (min.)	Sedimentation value (cm^3)
		wet gluten %	Dry gluten %	Gluten index %			
Canadian	Control	39.10^{ab}	14.00^{a}	93.34^{a}	602.7^{c}	92.10^{c}	37.40^{a}
	Z	39.75^{ab}	13.65^{b}	87.93^{bc}	546.7^{e}	97.00^{b}	37.40^{a}
	A	40.00^{a}	13.90^{ab}	84.13^{cdef}	525.0^{f}	98.17^{b}	37.40^{a}
	S	39.60^{ab}	13.70^{b}	91.17^{ab}	467.3^{i}	103.4^{a}	37.40^{a}
Debaira	Control	37.60^{c}	12.75^{c}	86.71^{cd}	676.0^{a}	49.23^{h}	32.30^{b}
	Z	39.10^{ab}	12.80^{c}	82.65^{ef}	647.3^{b}	57.13^{f}	32.30^{b}
	A	38.85^{b}	12.65^{c}	83.14^{def}	517.0^{fg}	65.33^{e}	32.30^{b}
	S	39.05^{ab}	12.75^{c}	86.42^{cde}	466.7^{i}	69.23^{d}	32.30^{b}
Wadi Elneel	Control	31.05^{d}	10.20^{e}	81.80^{f}	595.0^{c}	40.63^{i}	27.90^{c}
	Z	31.00^{d}	10.30^{e}	82.27^{f}	583.0^{d}	49.93^{h}	27.90^{c}
	A	30.80^{d}	10.35^{e}	81.99^{f}	513.7^{g}	52.97^{g}	27.90^{c}
	S	31.35^{d}	11.35^{d}	83.26^{def}	412.0^{j}	56.23^{f}	27.90^{c}
Elneelain	Control	28.05^{e}	8.90^{f}	64.53^{i}	486.3^{h}	28.83^{l}	19.60^{d}
	Z	26.70^{f}	8.60^{g}	71.51^{h}	485.3^{h}	29.50^{l}	19.60^{d}
	A	24.60^{g}	7.97^{h}	70.95^{h}	405.3^{j}	31.50^{k}	19.60^{d}
	S	28.50^{e}	8.39^{g}	78.05^{g}	396.3^{k}	34.57^{j}	19.60^{d}

Mean values having different superscript letter in each column differ significantly at ($P \leq 0.05$) using Duncan's Multiple Range Test (DMRT)

These results agreed with those of Mutwali (2011) who reported a range of 36.4 to 92.8% for gluten index of 20 Sudanese wheat cultivars from three different locations. Canadian wheat flour without improvers gained the highest value, whereas the lowest value was gained by Elneelain without improvers. Among the Sudanese wheat cultivars, Debaira cultivar without improver showed highest gluten index (86.71%) followed by Wadi Elneel (81.80%) and then Elneelain (64.53%). Although, addition of improvers reduced the gluten index of Canadian and Debaira wheat flours, it is however on the other hand, increased the gluten index of Wadi Elneel and Elneelain cultivars. Throughout all improvers, the improver S gave the best results of gluten index all cultivars compared to other improvers. It is worth to note that the gluten index of Sudanese local varieties is within the optimal range (55-100) for bread making. According to Curic *et al.* (2001) gluten index in the range of 75-90% provides the optimal bread making quality for Central European cultivars. Whereas, in Israel, grains with gluten index lower than 40 are restricted to animal feed, hence their price is lower than for bread making grains. In addition, there are penalties for the 40–55 gluten index class, while the 55–100 gluten idex class is considered suitable for bread making (Har Gil *et al*., 2011) Generally, analysis of variance showed significant differences ($P \leq 0.05$) among the four cultivars with and without improvers in their wet, dry and gluten index values. Debaira gained the higher values of Sudanese cultivars followed by Wadi Elneel and then Elneelain; this is due to the difference in their protein content and quality. From the gluten quality results, it could be assumed that the wheat variety Debaira possessing higher wet and dry gluten content may have better potential for bread making and should be used to explicit its potential in the development of new varieties by the wheat scientists.

Falling number (seconds)

The falling number of the three Sudanese cultivars and Canadian wheat flours with and without improvers was shown in Table 2. Alpha – amylase activity of the cultivars with and without improvers is found to be in the range of 676 to 396 seconds. Previously, many reports indicate that the falling number is varied between different genotypes that cultivated in different environment. From them, Kaldy and Rubenthaler (1987) found that the falling number of soft white, winter and spring wheats, ranged between 380 and 450 seconds, and between 111 and 479 seconds, respectively. While, Lukow and Mcvett (1991) observed that falling number of hard red spring wheat cultivars ranges between 302 and 332 seconds. Ahmed (1995) showed that the falling number values of some Sudanese wheat cultivars ranged between 396 and 486 seconds. However, Mohamed (2000) found that the falling number values of four Sudanese wheat cultivars Debaira, Elneelain, Condor and Sasaraib ranged between 425 and 675 seconds. Extremely higher falling numbers in the range of 508.0 to 974.7 sec were reported by Mutwali (2011) for 20 Sudanese wheat cultivars. This higher falling number may be attributed to dry harvest season which consequently affect the activity of alpha-amylase. Debaira without improvers gained the highest value (low alpha-amylase activity), whereas Elneelain with S improver gained the lowest value (high alpha – amylase activity). Statistical analysis revealed highly significant differences ($P \leq 0.05$) among the four cultivars with and without improvers, in their falling number values. From these results it could be observed that the values of falling number of the four cultivars without improvers, were relatively high (low alpha – amylase activity), and this may be attributed to dry harvest time. It was also observed that the addition of improvers increase the alpha-amylase activity, perhaps these improvers contain alpha – amylase enzyme. Generally, Debaira cultivar showed the highest values of falling number (low alpha – amylase activity) among the four cultivars. S improver gave the best result (high alpha – amylase activity) compared with the other two improvers. Perten (1996) mentioned that falling number values below 150 seconds (high amylase activity, sprout damaged wheat) is likely to produce sticky bread crumb. While, 200 to 300 seconds (optimal amylase activity), produces bread with good crumb, and above 300 seconds (low amylase activity, sound wheat), the bread crumb is likely to be dry and the loaf volume is reduced.

Sedimentation value (cm^3)

Wheat sedimentation test is a combined measure of gluten quality and quantity. Sedimentation values of the three Sudanese cultivars and Canadian wheat flour with and without improvers were shown in Table 2. Sedimentation values of the four cultivars with and without improvers ranged from 37.4 to 19.6 cm^3. Similarly, Mutwali (2011) reported a range of 19.0 to 40.3 mL for the sedimentation value of 20 Sudanese wheat cultivars grown at three different locations. While, Mohamed (2000) showed that, the sedimentation value of Sudanese wheat cultivars Debaira, Elneelian, Sasaraib, and Condor ranged between 21 and 24 cm^3. These results showed variation from those reported by Elagib (2002) who found that sedimentation values for the same local cultivars ranged from 13.67 to 19.07 cm^3, this may be due to the variation in the growing seasons and/or conditions. Canadian wheat without improvers gave the highest value, while Elneelain without improvers gave the lowest value. The present result indicated that the sedimentation values among the four cultivars were not affected by the addition of improvers. Generally, Debaira revealed the highest values of sedimentation compared with Wadi Elneel and Elneelain cultivars. Again this result indicates that Debaira cultivar is suitable for bread making as it showed high sedimentation values that close to the sedimentation value of Canadian wheat flour.

Pelshenke test

The Pelshenke test of the three Sudanese cultivars and Canadian wheat flours with and without improvers was shown in Table 2. The values of Pelshenke test of the four cultivars with and without improvers ranged from 28.8 to 103.4 minutes. Slightly similar observation was reported by Khan *et al.* (2009) who found the Pelshenke value of Pakistani spring wheat ranged from 51.04

to 150.12 minutes. The Canadian wheat with S improver gained the highest value, whereas, Elneelain without improvers gained the lowest value. Analysis of variance showed significant difference ($P \leq 0.05$) among the four cultivars with and without improvers in their pelshenke test values. From these results it could be observed that the values of Pelshenke test of the four cultivars indicated the positive effect of adding improvers. S improver gave the best result compared with the other two improvers. Debaira gained the highest value among the Sudanese cultivars studied. Pelshenke values give an estimate of the strength of the wheat and combined gas retention capacity of the wheat protein complex. Williams et al. (1986) reported that wheat with Pelshenke values of 150-200 minutes is most suitable for bread making.

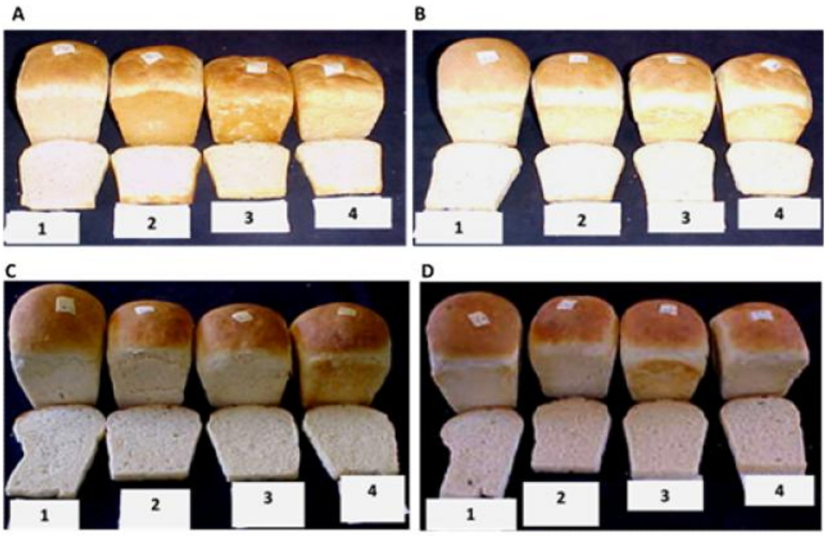

Fig. 1. *Loaf bread prepared from the flours of Canadian (1), Debaira (2), Wadi Elneel (3), and Elneelain (4) wheat cultivars. (A) Without improver, (B) with Z improver, (C) with S improver, and (D) with A improver*

Table 3. *Effect of bread improvers on farinogram readings of the three Sudanese wheat cultivars and Canadian wheat flours*

Cultivar	Improver	Water absorption corrected to14%	Dough Stability (min)	Dough development time (min)	Degree of softening (ICC), FU
Canadian	Control	61.3	17.1	7.8	38
	Z	60.5	17.8	2.5	23
	A	60.0	14.4	3.7	35
	S	59.7	14.8	3.0	34
Debiara	Control	66.0	2.7	4.5	95
	Z	65.1	4.0	4.8	120
	A	63.5	4.1	3.8	128
	S	62.7	4.4	3.2	126
Wadi Elneel	Control	64.4	3.2	4.0	85
	Z	63.4	4.3	4.3	106
	A	62.5	3.6	2.0	147
	S	62.1	2.8	1.7	160
Elneelain	Control	63.9	2.6	3.0	106
	Z	63.3	2.2	1.7	155
	A	62.7	1.1	1.5	205
	S	61.6	1.2	1.7	192

Each value is the mean of triplicate samples.

Farinogram results

The farinogram results of the flours of the three Sudanese cultivars and Canadian wheat with and without improvers are shown in Table 3. Water absorption values of the cultivars with and without improvers ranged from 66.0 to 59.7%. These results were similar to the range 57 to 62% obtained by Mutwali (2011) for Sudanese wheat cultivars grown in three different locations. The highest value was observed in Debaira without improvers, while the Canadian wheat with S improver gained the lowest value. From the results it is clear that addition of improver to the cultivars exhibited decrease in water absorption compared with the same cultivars without improvers, comparing the Canadian to Sudanese wheat flours (control) the water absorption for Canadian wheat flour is lower than Sudanese wheat flours, this may be due to the difference in milling system between Sudanese and Canadian wheat flours. Generally high farinograph water absorption of flour is considered an indication of good baking performance. The reason could be that high protein content causes good baking performance and high water absorption (Bloksma, 1972). Thus Sudanese wheat cultivars could possibly be used for bread making because the showed higher water absorption compared to Canadian wheat cultivar. Dough development time was found to be in the range of 7.8 to 1.5 min (Table 3). Similarly, Mutwali (2011) reported that the dough development time for Sudanese wheat cultivar is found in the range of 1.68 to 5.16 min. The Canadian wheat without improvers gave the highest value, while Elneelain with A improver gained the lowest value. From the present results it is clear that the dough development time was decreased in the flour without improvers with low protein content, these results were in general agreement with the findings of Anaka and Tipples (1979) who reported that, dough development time decreases in the flour with low protein content. Faubion and Hoseney (1990) reported that, the full bread making potential of the dough is attained only at the optimum point of dough development. The dough stability values ranged from 17.8 to 1.1 min. Among the Sudanese cultivars the dough stability was ranged between 4.4 and 1.1 minutes.

Table 4. *Effect of bread improvers on Extensogram readings of the three Sudanese wheat cultivars and Canadian wheat flours*

Cultivar	Improver	Energy (cm)^2			Resistance (cm)			Extensibility (mm)			R/E		
		45 min	90 min	135 min	45 min	90 min	135 min	45 min	90 min	135 min	45 min	90 min	135 min
Canadian	Control	153	139	151	252	277	290	235	207	209	2.1	2.5	2.7
	Z	176	187	186	390	666	813	189	145	138	4.0	7.0	7.4
	A	181	181	165	366	547	594	199	164	146	3.6	5.3	6.4
	S	207	177	185	401	600	664	202	148	152	4.0	6.7	6.6
Debiara	Control	68	73	72	191	191	188	183	194	191	1.4	1.4	1.4
	Z	115	113	129	290	342	426	187	162	154	2.5	3.3	4.2
	A	103	107	122	257	294	314	183	170	180	2.3	2.9	3.0
	S	145	167	162	306	413	444	198	181	170	2.9	4.1	4.5
Wadi Elneel	Control	48	49	51	208	210	227	137	139	137	1.7	1.7	1.9
	Z	64	76	74	279	395	506	131	119	102	2.7	4.0	5.6
	A	66	72	74	258	308	350	140	132	124	2.4	3.2	3.8
	S	69	79	75	256	325	396	146	136	118	2.5	3.3	4.2
Elneelain	Control	27	31	32	140	152	162	120	129	126	1.2	1.2	1.4
	Z	43	39	36	246	363	410	110	81	71	2.5	4.6	5.8
	A	44	47	39	200	329	330	128	102	91	2.0	3.6	3.8
	S	47	41	42	230	326	378	123	93	88	2.3	3.8	4.5

Each value is the mean of triplicate samples.

Recently, it is reported that the dough stability of Sudanese wheat cultivars are ranged between 6.2 and 2.0 minutes (Mutwali, 2011). Compared to Canadian wheat the Sudanese wheat showed considerably lower dough stability. The highest value was observed in the Canadian wheat with Z improver, whereas the lowest value was observed in Elneelain with A improver.

The degree of softening values was found to be in the range of 205 to 23 FU. Consistent with these results, the degree of softening of Sudanese wheat cultivars is recently reported to be in the range of 301 FU to 62.5 FU (Mutwali, 2011). Elneelain with A improver gave the highest degree, whereas the Canadian wheat with Z improver gave the lowest degree. The degree of softening of Canadian wheat cultivar is lower than that of Sudanese wheat cultivars. This indicated that the Sudanese wheat cultivars are of hard type wheat.

Extensogram results

The extensogram results of the flours of the three Sudanese cultivars and Canadian wheat with and without improvers are showed in Table 4. Flour cultivars with improvers exhibited an increase in the energy and resistance at 45 min, 90 min, 135 min, compared to the cultivars without improvers. The energy of the Canadian wheat flour is quite higher than that of Sudanese wheat.

However, among the Sudanese wheat flours the Debaira cultivar showed the highest energy compared to the other cultivars. From the present results, using S improver with the four cultivars flours showed higher values of energy at 45 min, 90min, 135 min compared with cultivars without improvers and with the other two improvers. The results also showed that as the fermentation time increased the resistance values of the four cultivars with and without improvers increased. Generally, the addition of improvers to the four cultivars flours showed decrease in extensibility at 45 min, 90 min, 135 min compared with cultivars without improvers. While the addition of improvers to the same cultivars flours revealed an increase in resistance/ extensibility ratio compared to the cultivars without improvers. Perhaps these improvers contain oxidizing agents causing more s – s groups in the dough resulting in high resistance to extension. Kieffer (2003) has published results from comparative investigations of dough rheology and dough yield and he concluded that only resistance is positively related to baked volume.

Table 5. *Physical characteristics of loaf breads made from the three Sudanese wheat cultivars and Canadian wheat flours with and without improvers*

Cultivar	Improver	Loaf Weight (g)	Loaf Volume (cm^3)	Loaf Specific volume (cm^3/g)
Canadian	Control	111.4	383.3	3.443^c
	Z	111.3	416.7	3.743^b
	A	111.7	423.3	3.787^b
	S	111.2	456.7	4.113^a
Debiara	Control	105.3	336.7	3.067^g
	Z	111.5	343.3	3.080^g
	A	112.0	343.3	3.207^{ef}
	S	111.3	373.3	3.357^d
Wadi Elneel	Control	105.8	280.0	2.647^h
	Z	108.7	328.3	3.020^g
	A	111.8	341.7	3.063^g
	S	111.1	361.7	3.257^e
Elneelain	Control	106.0	271.7	2.563^i
	Z	107.7	328.3	3.047^g
	A	110.5	336.7	3.057^g
	S	110.2	348.3	3.163^f

Mean values having different superscript letter in each column differ significantly at (P≤0.05) using Duncan's Multiple Range Test (DMRT)

Physical characteristics of loaf bread

Bread specific volume of the three Sudanese cultivars and Canadian wheat flours with and without improvers was shown in Table 5. Specific volume (cm^3/g) values of the flours breads with and without improvers ranged from 4.113 to 2.563 cm^3/g. The Canadian wheat with S improver gave the highest value, whereas Elneelain loaf volume and pelshenke test value indicates that the increase of pelshenke test value (min) correlates positively with the bread volume. Generally Debaira gained the higher values of specific volume compared with the other two Sudanese cultivars. S improver gave the best result followed by A and then Z improver. From the present results, it is clear that the specific volume of the loaf bread was affected by the addition of improvers and by wheat quality, as indicated by the amount of protein content, gluten quantity and quality, Sedimentation value and pelshenke test value. These results are supported by results of Elagib (2002).

Sensory evaluation of loaf bread

The scores of aroma of loaf bread made from three Sudanese cultivars, and Canadian wheat flour with and without improvers are showed in Table 6. The aroma of bread scores ranged from 8.1 to 4.2. The aroma score of breads made from the Canadian wheat without improvers gave a higher value, with no significant difference ($P \geq 0.05$) compared with bread made from the same cultivar with the three improvers. While the bread made from Elneelain without improvers gained lower value. The present results showed that Debaira cultivar gained higher scores of aroma among the local cultivars. Treatment with A improver gave the best result of aroma among the three improvers.

Table 6. *Sensory evaluation of loaf bread made from the three Sudanese cultivars and Canadian wheat flours with and without improvers*

Cultivar	Improver	Aroma	Taste	Crumb texture	Crumb color	Uniformity	General acceptability
Canadian	Control	8.1^{a}	7.4^{abc}	8.3^{a}	7.8^{ab}	8.2^{a}	8.4^{a}
	Z	7.9^{ab}	7.8^{ab}	7.8^{abc}	8.1^{a}	8.1^{ab}	8.5^{a}
	A	8.1^{a}	8.2^{a}	8.3^{a}	7.2^{abc}	7.2^{bcd}	8.2^{ab}
	S	7.3^{abc}	7.9^{a}	8.1^{ab}	8.1^{a}	8.1^{ab}	8.4^{a}
Debaira	Control	7.0^{cd}	7.4^{abc}	7.2^{cd}	7.4^{abc}	7.4^{abcd}	7.2^{cd}
	Z	7.0^{cd}	7.0^{bcd}	7.1^{cd}	7.4^{abc}	7.7^{abc}	7.8^{abc}
	A	7.1^{cd}	7.8^{ab}	7.4^{bc}	7.7^{ab}	7.2^{bcde}	7.5^{bcd}
	S	6.8^{cd}	7.5^{abc}	7.2^{cd}	7.5^{abc}	7.5^{abcd}	7.7^{abc}
Wadi Elneel	Control	5.3^{fg}	5.2^{gh}	5.3^{fgh}	5.4^{ef}	4.8^{g}	5.5^{efg}
	Z	5.3^{fg}	6.0^{fg}	5.9^{efg}	5.8^{de}	7.0^{cde}	6.0^{e}
	A	6.9^{cd}	6.9^{cde}	7.2^{cd}	6.7^{cd}	7.0^{cde}	6.9^{d}
	S	6.2^{de}	6.2^{def}	6.0^{ef}	6.7^{cd}	6.7^{def}	6.1^{e}
Elneelain	Control	4.2^{h}	4.2^{i}	4.7^{h}	4.6^{f}	4.4^{g}	4.3^{g}
	Z	4.5^{gh}	4.6^{hi}	5.1^{gh}	5.4^{ef}	7.0^{cde}	5.1^{f}
	A	5.9^{ef}	6.1^{ef}	6.4^{de}	6.9^{bc}	6.3^{ef}	5.9^{e}
	S	5.3^{fg}	5.8^{fg}	5.6^{efg}	5.9^{de}	5.9^{f}	5.1^{f}

Mean values having different superscript letter in each column differ significantly at ($P \leq 0.05$) using Duncan's Multiple Range Test (DMRT)

The taste scores of the bread are found to be in the range of 8.2 to 4.2. The taste score of the bread made from the Canadian wheat with A improver gave the highest value, with no significant difference ($P \geq 0.05$) compared with the breads made from the same cultivar with the other two improvers and without improvers, and with breads made from Debaira cultivar with A and S improver and without improvers. Whereas the bread made from Elneelain without improvers gained the lowest value. Generally, the Canadian wheat gained higher scores of bread taste with low variation with Debaira followed by Wadi Elneel and then Elneelain cultivar. Treatment with A improver gave the best results of bread taste followed by S and then Z improver. The scores of bread crumb texture ranged from 8.3 to 4.7. A higher crumb texture was gained by bread made from the Canadian wheat without improvers, forming insignificant differences ($P \geq 0.05$) with breads made from the same cultivar with the three improvers. Whereas the bread made from Elneelain without improvers gained lower value. Generally, Debaira cultivar gained higher scores of crumb texture among Sudanese cultivars. Treatment with A improver gave the best results of crumb texture among the three improvers. The scores of bread crumb color are found to be in the range of 8.1 to 4.6. The score of bread crumb color made from the Canadian wheat with S and Z improvers gained the highest value, showing insignificant differences ($P \geq 0.05$) with breads made from the same cultivar with A and without improvers, and with breads made from Debaira cultivar with and without improvers. While the bread made from Elneelain without improvers gave the lowest value. From the results Debaira cultivar gave the highest scores of crumb color compared with the other two local cultivars. Treatment with A improver gained the best results of crumb color compared with the other improvers.

The bread crumb cell uniformity scores ranged from 8.2 to 4.4. The uniformity score of bread made from the Canadian wheat without improvers gained a higher value, showing insignificant difference ($P \geq 0.05$) compared with breads made from the same cultivar and from Debaira cultivar without and with Z and S improvers. While the bread made from Elneelain without improvers gained a lower value, with no significant difference compared with breads made from Wadi Elneel without improvers. Generally, Debaira cultivar gained higher scores of crumb cell uniformity among the local cultivars.

Treatment with S improver gave the best result of crumb cell uniformity compared with the other two improvers. The scores of bread general acceptability are found to be in the range of 8.5 to 4.3. The general acceptability of bread made from the Canadian wheat with Z improver gave a higher value, with no significant different ($P \geq 0.05$) compared with breads made from the same cultivar with the other two improvers and without improver, and with breads made from Debaira cultivar with Z and S improvers. Whereas the bread made from Elneelain without improver gave a lower value. Generally, Debaira cultivar gained higher scores of general acceptability among the local cultivars; this may be due to its good bread making qualities, followed by Wadi Elneel and then Elneelain.

Conclusions

From this work it could be concluded that, the addition of improvers showed positive effect on rheological properties of the investigated cultivars. Debaira cultivar gave the best flour quality for bread-making compared with the other local cultivars. This study revealed the ability of producing good loaf bread from Sudanese cultivars. The most convenient improver for loaf bread is improver A. Further studies shall specifically focus on the breeding of high yielding with high quality and diseases resistant varieties of local wheat cultivars. Investigations are also needed to produce suitable improvers to increase the bread making quality for the local wheat cultivars.

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