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Nutritional, Rheological and Organoleptic Properties of Whole Meal Flour Prepared from Stem Rust Resistant Wheat Varieties Released in Kenya

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Abstract Wheat is an important cereal crop in most diets thus its nutritional content is crucial in addressing microelement deficiencies. This study focused on Zn, Fe, phytic acid and resistant starch content and their effect on rheological and organoleptic properties for whole meal flour from Kenyan wheat varieties. Zn and Fe levels ranged from111 to 305 ppm and 26 to 91 ppm, whereas phytic acid and resistant starch levels ranged from 2.66 to 5.05 ppm and 0.37 to 6.03%. Variety and site significantly ($p<0.05$) influenced iron and resistant starch content, whereas variety and variety × site influenced zinc and phytic acid. Protein and gluten levels ranged between 11.96 to 14.53% and 7.81% to 19.60% respectively. All the varieties recorded high water absorption levels ranging from 72.2% to 80.8%, while DDT ranged from 4.00 to 9.83 minutes. P and L values ranged between 21 to 79 and 16 to 51 mm, external loaf characteristics ranged between 2.2 to 4.3 and 2.13 to 3.70 for taste and aroma. Zinc and protein positively correlated (r=0.69, $p<0.05$), stability and P (r=0.69 $p<0.05$) and DDT and stability (0.71 $p<0.05$). Phytic acid and crust colour (r=0.66 $p<0.05$), zinc and shape (r=0.78 $p<0.05$), zinc and acceptability (r=0.77 $p<0.05$), DDT and shape (r=0.74 $p<0.05$), aroma and shape (r=0.67 $p<0.05$) were positively correlated. The results obtained indicate varieties tested contained considerable levels of zinc, iron, resistant starch, low levels of phytic acid and they had no adverse effect on rheological and organoleptic parameters of whole meal flour.

Keywords: *zinc and iron content, dough development time, rheological, organoleptic, protein, whole meal flour*

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1. Introduction

Bread is described as a fermented confectionary product produced mainly from wheat flour, by a series of rheological processes involving mixing, kneading, proofing, shaping and baking [1,4]. The physicochemical and rheological properties of flour differ significantly among wheat varieties and these variations determine wheat end use [39]. Therefore wheat suitable for one particular use may have certain properties that are totally unsatisfactory for other uses [3]. These variations in functional properties of wheat cultivars are attributed largely to their gluten quality and content [34]. However for commercial production of bread, sensory evaluation is mostly relied upon as a measure of consumer preference of the end product formed and its ranking when compared to others [10]. Hedonic testing is often used to determine consumers' attitude towards a particular food by determining the degree of acceptance of a new product or the need to improve existing food products.

Apart from sensorial preference, in the recent past there has been a push for consumption of nutritious and healthy foods. Nutrition deficiency especially micronutrients is one among the most serious global challenges. This has led to advocacy not only to improve food security but also access to staple nutritious food in developed and developing countries [31]. Wheat (*Triticum aestivum* L.) is considered to be the most important staple crop worldwide. It also contains fair amounts of micronutrients zinc and iron, and substantial amount of resistant starch and nutrient fibre. High quantities of resistant starch and nutrient fibre enhance absorption of mineral nutrient elements as they increase the time and provide large surface area for their absorption [9]. Wheat therefore offers a platform to address the problem of micronutrient bioavailability and deficiency simultaneously.

White flour is mostly preferred by bakers and consumers since it is easier to process and handle during dough processing and kneading and consumers prefer the finished product due to their smooth and appealing textures. However the 'goodness' of wheat is lost during processing for white flour, because important nutrients including dietary fibres are lost due to removed bran and germ [11]. Therefore to address nutritional deficiency using wheat there is need to shift from producing products using refined to whole meal flour. In addition to varietal differences, utilization of whole meal wheat flour in production of baked wheat products is challenging, and hence evaluation of the effects of nutritional quality on rheological and organoleptic properties is inevitable. This study was therefore carried out to determine the influence of the levels of zinc, iron, phytic acid and resistant starch in whole meal flour and whether there existed any correlation with either the rheological and or organoleptic properties of dough.

2. Materials and Methods

2.1. Materials

Seeds for 9 newly released bread wheat varieties namely Robin, Eagle 10, Kenya Tai, Kenya Sunbird, Kenya Wren, Kenya Korongo, Kenya Hawk 12, Kenya Kingbird and Njoro II were obtained from the Kenya Agricultural and Livestock Research Organization, Food Crops Research Centre located at Njoro. The nine varieties were planted in three study sites located in traditionally wheat growing regions in Kenya namely; Eldoret, Mau-Narok and Naivasha. The variety Njoro BWII was used as a control due to its superior milling and baking properties in particular, high protein and gluten levels.

Prior to planting, seeds were coated with copper oxychloride ($Cu_2(OH)_3Cl$) a broad spectrum fungicide that controls both fungal and bacterial diseases. The varieties were planted in a completely randomized block design (RCBD) with plots measuring 6 by 1.5 metres. The land was fertilized with di-Ammonium phosphate (DAP) fertilizer at the rate of 50 Kg/ ha before planting. The varieties were then allocated randomly on the plots within the three blocks to give rise to three replicates plots for each variety, using a random number table. No irrigation was undertaken during planting and growing of the wheat crops.

At maturity dry wheat heads were harvested in each of the study sites and the grains threshed. The grain was further dried to reduce the moisture levels to about 12-13% which was confirmed using the NIR spectrophotometer grain analyzer machine. For each variety 400g of dry wheat grain were separately milled to give whole meal wheat flour whose extraction rate for all samples was above 75%.

2.2. Zinc and Iron Analysis

A grain sample of 10 g from each variety was separately milled using a chromium ball mill (Retsch mill model, MM 400) whose milling compartment was coated with Teflon. The compartment was cleaned with water after milling each variety to prevent sample cross contamination. A sample of 0.3 g of the whole meal flour for each variety was separately digested using selenium-sulphuric acid mixture. This was followed by determination of zinc and iron concentrations using the Atomic Absorption Spectrophotometer (Shimadzu Model AA-6300, Tokyo-Japan) at 213.86 and 248.33 nm, respectively.

2.3. Phytic Acid and Resistant Starch Analysis

Determination of phytic acid was done by digesting 1 g of whole meal flour samples with 0.4M hydrochloric acid using a protocol adopted from a study conducted on rice mutants with low phytate [33]. A sample of 100 mg of flour was used to analyze for resistant starch using the megazyme resistant starch assay procedure (11/02 AOAC Method 2002.02, AACC Method 32-40).

2.4. Determination of Whole Meal Flour Proximate Composition

Whole meal flour proximate composition was determined using the near infrared spectrophotometer. About 5 g of flour was packed in a flour cuvette and placed in the Foss Infratec grain analyzer model 1241 measuring cell for analysis of flour protein and gluten levels following AACCI method 39-11.01 (Approved Methods of the American Association of Cereal Chemists International, 11^{th} edition, 2000).

2.5. Evaluation of the Rheological Properties of Whole Meal Flour

Rheological characteristics of whole meal dough for different varieties were evaluated by use of a farinograph and an alveograph following the AACC Method 54-21 and Method 54-30A, respectively (Approved Methods of the American Association of Cereal Chemists, 10^{th} edition, 2000). Whole meal bread was prepared using the straight dough method- long fermentation according to AACCI method 10-09.01 (Approved Methods of the American Association of Cereal Chemists International, 11^{th} edition, 2000). The ingredients used were; 100 g wheat flour, 3 g shortening, 3 g milk powder, 0.03 g malt, 4 g sugar, 2 g salt, 2 g yeast, water according to the farinograph results. The correct amount of water for each flour was added to each sample and mixed thoroughly. The resulting dough was then placed in a bread bowl and incubated in the fermentation unit for 105 minutes. After first rising, dough underwent first punching to reduce air bubbles and fermented for another 50 minutes. The dough underwent second punching and was placed in bread pan and placed again in the fermentation unit for 25 minutes. After the dough rose while in the bread pan it was baked at 400^0 Fahrenheit for 25 minutes. After baking, the loaves were analysed for their volume using the rapeseed displacement method following AACCI method 10-05.01 (Approved Methods of the American Association of Cereal Chemists International, 11^{th} edition, 2000).

2.6. Sensory Evaluation

Analysis was done following a procedure by [18] but was modified to use a 5 point hedonic scale where 1=very bad, 2=bad, 3=moderate, 4=good and 5=very good. In this study, 30 trained panelists consisting both male and female participated in the sensory analysis. They were taken through the terms and methodologies in the score sheets prior to the actual analysis. The analysis was conducted in a clean and well-lit food and nutrition laboratory. Each panelist was provided with a three digit coded loaf to prevent re-evaluation of the same product and a score sheet for recording their results. For shape and crust colour, the evaluators were given one unsliced whole meal bread while for evaluation of taste and aroma, they were served with a 2 x 3 x 5 cm slice of bread in a clean plate. The evaluators were each provided with a glass of clean drinking water, to rinse off the taste of the previous sample before proceeding to the next.

2.7. Data Analysis

The data generated for all parameters analysed was subjected to ANOVA using SAS software, and the means separated by LSD ($p<0.05$). The relationship between nutritional, rheological and organoleptic properties was evaluated by carrying out correlation analysis.

3. Results

3.1. Fe, Zn, Phytic Acid, Resistant Starch, Protein and Gluten Content

Analysis of variance revealed that iron and zinc content in whole meal flour prepared from the 9 bread wheat was significantly ($p<0.05$) influenced by variety, cropping site and interaction (variety × site).

However there were no clear generalized trends observed due to the effects of site or variety. Nonetheless irrespective of variety and site, iron and zinc content in whole meal flour prepared from the 9 bread wheat ranged between 111 to 305 ppm and 26 to 91 ppm, respectively. The highest iron content over all sites was obtained in flour prepared using K.Korongo and K.Hawk 12 varieties grown in Eldoret site. Flour prepared using Njoro BWII generally recoded the lowest iron content at 111.11 and 138.89 ppm for crop grown in Naivasha and Eldoret sites, respectively. Flour prepared using K.Wren and K.Korongo varieties for crop grown in Mau- Narok iron content was 2 folds lower than Njoro BWII which contained concentrations of 222.22 ppm (Table 1). Although there were no clear trends observed, analysis of the means using LSD test revealed that Iron content for flour prepared using Robin, K.Sunbird and K.Kingbird varieties were not significant ($p<0.05$) across the three sites. Iron content in Eagle 10 and K.Tai for crop grown in Naivasha was significantly ($p<0.05$) different from those grown in Eldoret and Mau-Narok. Whereas iron content in K.Wren, K.Korongo and K.Hawk for crop grown in Eldoret was different from those grown in Naivasha and Mau-Narok (Table 1).

Highest zinc concentration of 91.50 and 88.23 ppm were recorded in Njoro BWII flour prepared using crop grown in Naivasha and Eldoret, respectively. Zinc levels recorded in varieties K.Wren and K.Korongo were 35.95 and 26.14 ppm, respectively representing 2.45 and 2.38 folds lower than Njoro BWII variety grown in Eldoret and Mau-Narok sites. K.Kingbird and K.Korongo crop grown in Naivasha recorded the lowest zinc levels at 32.68 ppm, which was 2.8 folds lower than zinc content in the control variety Njoro BWII (Table 1). Analysis of means revealed that zinc content in flour prepared from crop grown in Eldoret and Mau-Narok did not differ significantly ($p<0.05$) except for Eagle 10 and Njoro BWII, whereas for K.Kingbird flour, zinc content was significantly ($p<0.05$) different across all the three study sites (Table 1).

Table 1. Iron and Zinc concentrations for selected Kenyan wheat varieties grown in Eldoret Mau-Narok and Naivasha

Site / Variety	Iron			Zinc		
	Eldoret	Mau-Narok	Naivasha	Eldoret	Mau-Narok	Naivasha
Robin	194.4^{bc}	138.9^{ab}	194.4^{bc}	65.36^{fg}	62.09^{ef}	84.97^{hi}
Eagle 10	194.4^{bc}	222.2^{c}	138.9^{ab}	52.29^{de}	75.16^{gh}	71.89^{fg}
K.Tai	194.4^{bc}	194.4^{bc}	111.1^{a}	42.48^{bcd}	35.95^{abc}	65.36^{fg}
K.Sunbird	194.4^{bc}	222.2^{c}	194.4^{bc}	26.14^{a}	75.16^{gh}	45.75^{cd}
K.Wren	222.2^{c}	111.1^{a}	138.9^{ab}	35.95^{abc}	26.14^{a}	42.48^{bcd}
K.Korongo	305.6^{d}	111.1^{a}	138.9^{ab}	45.75^{cd}	45.75^{cd}	32.68^{ab}
K.Hawk12	305.6^{d}	138.9^{ab}	138.9^{ab}	42.48^{bcd}	42.48^{bcd}	65.36^{fg}
K.Kingbird	194.4^{bc}	222.2^{c}	194.4^{bc}	68.63^{fg}	68.63^{fg}	32.68^{ab}
Njoro BWII	138.9^{ab}	222.2^{c}	111.1^{a}	88.23^{i}	62.09^{ef}	91.50^{i}

Means in each parameter followed by same letter are not significantly ($p<0.05$) different as revealed by Fisher LSD ($p<0.05$) test. All values are in ppm.

Resistant starch (RS) and phytic acid (PA) content in the whole meal flours prepared ranged between 0.37 to 6.00 g/100g and 2.66 to 5.05 ppm, respectively (Table 2) and the concentration of RS and PA were significantly ($p<0.05$) influenced by variety and interaction. The highest concentration of RS for crop grown in Eldoret was obtained in varieties K.Hawk 12, K.Tai and K.Wren, at 6.0, 5.9 and 4.7 g/100g, respectively, which were significantly ($p<0.05$) higher when compared to the control Njoro BWII variety which had RS concentration of 2.0g/100g. However for Naivasha and Mau-Narok sites, significantly ($p<0.05$) higher concentration of RS was obtained on Njoro BWII when compared with the 8 varieties (Table 2). Analysis of the means indicated that RS content in K.Tai and K.Kingbird flour were significantly ($p<0.05$) different across the three sites unlike for Njoro BWII.

Furthermore RS content in Robin and Eagle 10 flour for crop grown in Naivasha were significantly ($p<0.05$) lower than for crop grown in Eldoret and Mau-Narok. On the other hand flour prepared from K.Sunbird, K.Wren, K.Korongo and K.Hawk12 for crop grown in Eldoret contained significantly ($p<0.05$) higher RS when compared with flour from crop grown in Naivasha and Mau-Narok (Table 2).

Generally highest phytic acid content was observed in wheat crop grown in Naivasha, while those grown in Mau-Narok had lowest content, except Njoro BWII, Robin, Eagle10, K.wren and K.Tai varieties which had the lowest PA irrespective of the site (Table 2). In Eldoret site highest phytic acid content was obtained in K.Sunbird, K.Kingbird and Njoro BWII flours. A general trend was observed where highest PA content was obtained in flour prepared using Njoro BWII variety across all study sites and lowest PA values were obtained with K.Wren, Eagle10 and Robin flours (Table 2). Comparison of the means revealed no significant ($p<0.05$) difference in flour PA content for most of the varieties across the three sites except for K.Hawk 12 and K.Kingbird whose flour PA content for each site was significantly different (Table 2). PA content for flour prepared using K.Tai and K.Sunbird varieties were significantly ($p<0.05$) high and low for crop grown in Naivasha and Mau-Narok, respectively (Table 2).

Table 2. Resistant starch, phytic acid, protein and gluten levels in whole meal flour prepared using crop from 9 Kenyan bread wheat varieties grown in 3 wheat growing zones in Kenya

	Resistant Starch (g/100g)			Phytic Acid (ppm)			Protein (%)			Gluten (%)		
Site / Variety	Eldoret	Mau-Narok	Naivasha	Eldoret	Mau-Narok	Naivasha	Eldoret	Mau-Narok	Naivasha	Eldoret	Mau-Narok	Naivasha
Robin	1.17^{efgh}	1.47^{h}	0.37^{a}	2.71^{ab}	2.66^{a}	2.66^{a}	14.03^{k}	13.90^{k}	13.57^{i}	19.47^{i}	19.60^{i}	20.83^{k}
Eagle 10	1.42^{gh}	1.16^{efgh}	0.45^{ab}	2.66^{a}	2.66^{a}	2.71^{ab}	13.73^{j}	10.37^{a}	13.97^{k}	18.87^{h}	11.27^{c}	20.43^{j}
K.Tai	5.90^{m}	2.65^{jk}	1.30^{fgh}	3.04^{abc}	2.71^{ab}	5.05^{f}	13.43^{hi}	11.80^{d}	13.37^{h}	8.97^{b}	14.97^{e}	21.57^{l}
K.Sunbird	1.47^{h}	0.48^{abc}	0.37^{a}	4.79^{ef}	3.48^{cd}	4.62^{ef}	13.47^{hi}	10.83^{b}	14.27^{l}	15.53^{f}	14.73^{e}	23.07^{n}
K.Wren	4.66^{l}	0.83^{bcde}	0.98^{defg}	2.66^{a}	2.71^{ab}	2.66^{a}	13.37^{h}	10.87^{b}	13.73^{j}	13.70^{d}	11.20^{c}	20.30^{j}
K.Korongo	2.27^{ij}	0.78^{abcde}	0.68^{abcd}	3.04^{abc}	3.26^{bcd}	2.71^{ab}	12.87^{g}	11.43^{c}	14.53^{m}	22.23^{m}	7.80^{a}	23.40^{n}
K.Hawk12	6.03^{m}	0.91^{bcdef}	0.68^{abcd}	3.70^{d}	2.83^{ab}	5.05^{f}	12.13^{e}	10.27^{a}	13.47^{hi}	15.03^{e}	11.50^{c}	19.53^{i}
K.Kingbird	2.35^{ij}	2.98^{k}	0.92^{cdef}	4.35^{e}	2.83^{ab}	5.00^{f}	12.50^{f}	11.47^{c}	14.20^{l}	21.03^{k}	17.70^{g}	24.23^{o}
Njoro BWII	2.01^{i}	2.04^{i}	2.01^{i}	4.79^{ef}	5.05^{f}	5.05^{f}	14.03^{k}	14.03^{k}	14.03^{k}	19.47^{i}	19.47^{i}	19.47^{i}

Means in each parameter followed by same letter are not significantly ($p<0.05$) different as revealed by Fisher LSD ($p<0.05$) test.

Protein and gluten composition for whole meal flour was significantly influenced ($p<0.05$) by variety and interaction. Furthermore highest protein and gluten levels were recorded in flours of crop grown in Naivasha, particular K.Sunbird and K.Kingbird, while lower levels were obtained in crop grown in Mau-Narok except for the varieties Robin and Njoro BWII (Table 2). Flour prepared using Eldoret crop recorded mixed results with some varieties having high protein levels but low gluten levels as opposed to crop grown in Mau-Narok and Naivasha sites, whose flour protein and gluten were highly correlated (Table 2). Overall, the control Njoro BWII and Robin varieties recorded high protein and gluten levels while lower protein and gluten levels were recorded in flour prepared using K.Hawk12 variety. Protein and gluten content for each flour prepared per variety across the three sites were significantly ($p<0.05$) different except for Njoro BWII and Robin (Table 2).

3.2. Rheological Characteristics

Flour prepared from wheat crop grown in Naivasha generally recorded high WA values compared with Eldoret and Mau-Narok site. Nonetheless WA score of 69.33 to 80.8 % were obtained across all sites and interestingly, K.Tai recorded the highest and lowest WA scores (Table 3). The WA scores for Robin, K.Wren and K.Hawk 12 for flour prepared using crop grown in Mau-Narok and Eldoret site were not significantly ($p<0.05$) different, a similar trend was obtained with K.Korongo flour prepared using crop grown in Eldoret and Naivasha. However WA score for Njoro BWII across the three sites were not significantly different (Table 3). The DDT scores varied across the 3 study sites irrespective of variety grown although Robin, Njoro BWII and K.Korongo values obtained across the three sites were not significantly ($p<0.05$) different, unlike for K.Tai and K.Kingbird.

Exceptionally high DDT scores were recorded on K.Tai and K.Sunbird for wheat crop grown in Eldoret, while low DDT was recorded in K.Hawk12 for flour obtained from crop grown in Mau-Narok (Table 3). On the other hand analysis of dough stability revealed that K.Hawk12 and Njoro BWII scores were not significantly ($p<0.05$) different across the three sites, while for K.Tai, K.Sunbird and K.Korongo, and Eagle 10 and Robin only scores for flour from crop grown in Naivasha and Mau-Narok, respectively were significantly ($p<0.05$) different. The varieties K.Sunbird and Eagle 10 recorded remarkably higher DDT values for crop grown in Eldoret and Mau-Narok (Table 3).

Table 3. Rheological characteristics of whole meal flour prepared from 9 Kenyan bread wheat varieties grown in 3 study sites.

	Water absorption (WA) (%)			Dough development time (DDT) (min)			Dough stability (min)			Resistance to elasticity (P) (mm)			Resistance to extensibility (L) (mm)		
Site / variety	Eldoret	Mau-Narok	Naivasha	Eldoret	Mau-Narok	Naivasha	Eldoret	Mau-Narok	Naivasha	Eldoret	Mau-Narok	Naivasha	Eldoret	Mau-Narok	Naivasha
Robin	77.83^{kl}	77.87^{kl}	79.03^{m}	6.50^{cdef}	6.50^{cdef}	6.00^{bcd}	9.33^{fg}	12.83^{ij}	10.00^{g}	45.33^{h}	40.00^{efg}	42.33^{gh}	29.67^{h}	18.67^{ab}	39.67k
Eagle 10	80.73^{n}	77.77^{k}	78.67^{lm}	9.33^{gh}	7.00^{ef}	6.83^{def}	6.83^{bc}	16.17^{k}	5.83^{b}	42.00^{fg}	79.33^{m}	39.00^{ef}	24.67^{ef}	30.00^{h}	16.00^{a}
K.Tai	77.83^{kl}	80.80^{n}	69.33^{a}	13.50^{j}	8.83^{g}	11.50^{i}	13.67^{ij}	14.00^{j}	15.50^{k}	37.00^{e}	55.33^{j}	66.67^{k}	43.33^{l}	51.00^{m}	22.67^{de}
K.Sunbird	71.23^{b}	73.43^{ef}	74.87^{ghi}	11.83^{i}	6.17^{bcde}	6.67^{cdef}	19.17^{l}	12.50^{hl}	8.00^{cd}	41.00^{fg}	66.67^{k}	49.00^{i}	30.00^{h}	42.33^{kl}	22.00^{cde}
K.Wren	71.87^{bc}	72.23^{cd}	77.93^{kl}	7.33^{f}	5.33^{b}	5.83^{bc}	8.67^{def}	11.50^{h}	4.33^{a}	23.33^{a}	23.67^{ab}	27.67^{e}	31.33^{hi}	26.67^{fg}	21.00^{bcd}
K.Korongo	75.13^{i}	74.03^{fg}	75.00^{hi}	6.67^{cdef}	5.83^{bc}	6.00^{bcd}	8.50^{de}	9.33^{efg}	6.50^{b}	21.67^{a}	26.67^{bc}	48.67^{i}	19.67^{bc}	20.33^{bcd}	21.33^{bcd}
K.Hawk12	72.33^{cd}	73.10^{de}	77.67^{jk}	6.83^{def}	4.00^{a}	6.50^{cdef}	8.50^{de}	8.00^{cd}	8.33^{de}	29.33^{c}	57.67^{j}	51.33^{i}	43.00^{l}	22.00^{cde}	21.33^{bcd}
K.Kingbird	78.53^{klm}	74.20^{fgh}	76.83^{j}	5.83^{i}	9.00^{gh}	6.83^{def}	5.83^{b}	9.17^{defg}	8.83^{defg}	51.00^{i}	70.67^{l}	41.67^{fg}	28.67^{gh}	34.33j	33.00^{ij}
Njoro BWII	75.07^{hi}	75.07^{hi}	75.07^{hi}	9.17^{h}	9.83^{h}	9.83^{h}	9.17^{defg}	9.17^{defg}	9.17^{defg}	50.33^{i}	32.67^{d}	50.33^{i}	28.50^{gh}	29.00^{gh}	28.50^{gh}

Means for each parameter followed by same letters are not significantly different at as revealed by LSD ($p<0.05$) test.

ANOVA results for resistance to extension (L) and resistance to elasticity (P) revealed that they were significantly ($p<0.05$) influenced by variety and interaction. The whole meal flour prepared from K.Tai, K.Hawk12 and K.Sunbird varieties grown in Eldoret and Mau-Narok sites, recorded highest L values unlike K.Korongo and Robin that recorded lower values. P values for varieties Eagle 10 was exceptionally high for the crop grown in Mau-Narok and low for K.Wren and K.Korongo for flour prepared using wheat crop grown in

Eldoret (Table 3). Water absorption (WA), mixing tolerance index (MTI), dough development time (DDT) and stability were significantly (*p<0.05*) influenced by cropping site, variety and interaction.

3.3. Organoleptic Characteristics

Hedonic scores for shape and crust colour, ranged between 2.2 to 4.3 and 2.80 to 4.10, respectively across the 3 study sites (Figure 1a & Figure 1b) and were significantly (*p<0.05*) influenced by variety, site and interaction. Loaves from wheat crop grown in Eldoret scored highest for shape except K.Wren variety, while those from Mau-Narok recorded lowest scores except Njoro BWII. Bread baked from wheat grown in Naivasha recorded moderate scores with the highest score obtained on K.Tai and K.Korongo recorded the lowest score at 2.40 (Figure 1a). Varietal comparison across the study sites showed that Njoro BWII over all varieties, had higher scores while K.Wren and K.Korongo posted lower scores. Wheat crop grown in Eldoret generally had the most preferred loaf shapes while Mau-Narok had the least preferred (Figure 1a).

Analysis of bread crust colour revealed that all the varieties recorded desirable crust colour regardless of site in which wheat crop was grown. However exceptional higher values were recorded for K.Hawk12 and K.Kingbird for crop grown in Mau-Narok while the lowest score was recorded in K.Wren for crop grown in Eldoret (Figure 1b). Regardless of site, the Njoro BWII variety scored highly for crust colour compared to the other varieties. Overall crusts of bread baked using whole meal flour from varieties grown in Naivasha and Mau-Narok scored higher values compared to those grown in Eldoret (Figure 1b).

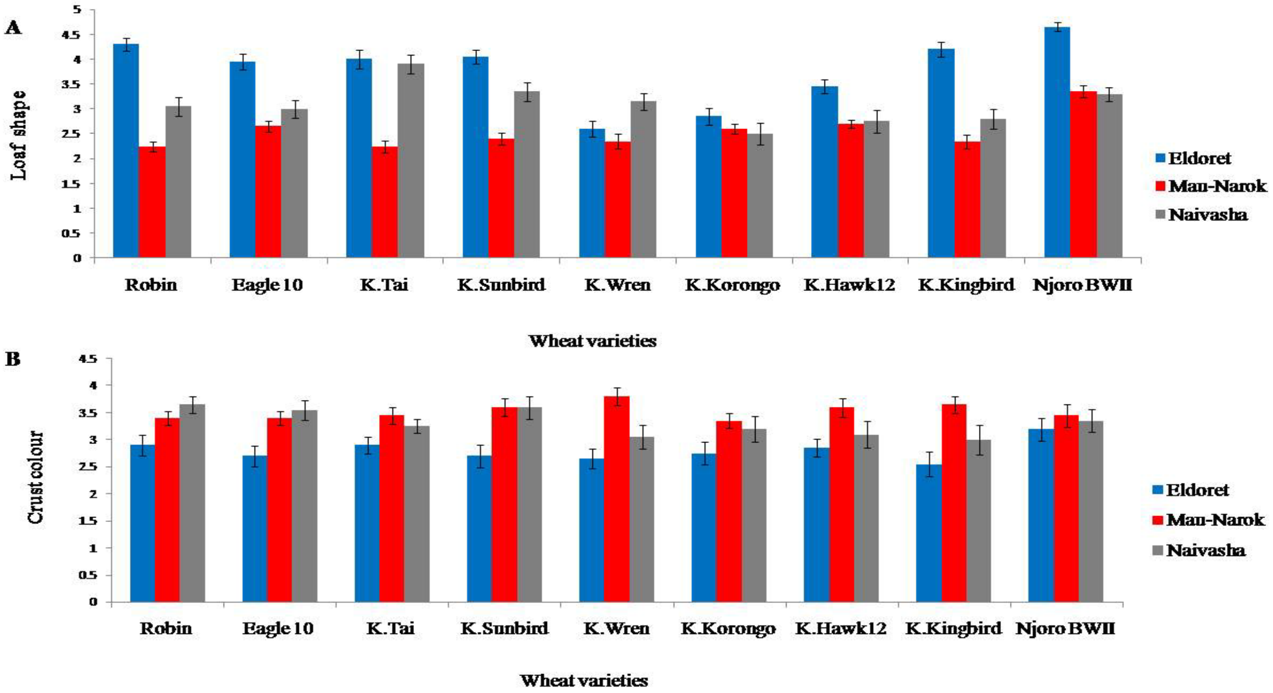

Figure 1. Visual evaluation of bread characteristic of bread prepared using whole meal flour prepared from 9 Kenyan bread wheat varieties. A-Loaf shape, B- Crust colour

Regardless of growing site, scores for aroma and taste ranged between 2.55 to 3.80 and 2.15 to 3.05, respectively (Figure 2a & Figure 2b) and scores for aroma were significantly (*p<0.05*) influenced by site. Comparison of aroma scores across the 3 sites indicated that bread baked from varieties grown in Mau-Narok and Naivasha scored higher values compared with the same varieties when grown in Eldoret (Figure 2a).

Scores for taste across the three sites were generally low and there were no clear trends observed across sites or varieties, although lower scores were generally obtained on Robin, Eagle, K.Tai and Sunbird for crop grown in Mau-Narok. On the other hand lower values were scored for K.Korongo, K.Hawk12, K.Kingbird and NjoroBWII for crop grown in Naivasha. (Figure 2b). Bread baked from flour prepared using Njoro BWII when in grown in Eldoret and, K.Kingbird and K.Korongo when grown in Mau-Narok recorded the highest aroma scores (Figure 2b). Noticeably, Eagle 10 and K.Tai recorded very low scores for bread baked from crop grown in Mau-Narok, while in K.Wren scored the lowest for crop grown in Naivasha (Figure 2b).

For general bread acceptability, the scores ranged between 2.55 to 3.5 and analysis of variance revealed that the scores were significantly (*p<0.05*) influenced by interaction of site and wheat variety. Acceptability scores for bread prepared with flour from wheat crop grown in Eldoret was highest when compared with the other two study sites. Generally Njoro BWII recorded highest acceptability scores when it was grown in Eldoret and lowest when grown in Mau-Narok.

3.4. Correlation analysis between nutritional, rheological and organoleptic properties

Correlation analysis between the nutrients revealed a positive correlation (r=0.69) between zinc levels and protein content in the whole meal flour prepared from the 9 varieties grown in the three study sites. On the other hand correlation analysis between nutritional, rheological and organoleptic properties showed positive correlation between phytic acid and crust colour, stability and resistance to elasticity, and also between dough development time and resistance to elasticity (Table 4). Significant correlation between zinc levels and bread, zinc level and general acceptability. Analysis of rheological and organoleptic properties also revealed a positive correlation between dough development time and shape and aroma with shape (Table 4).

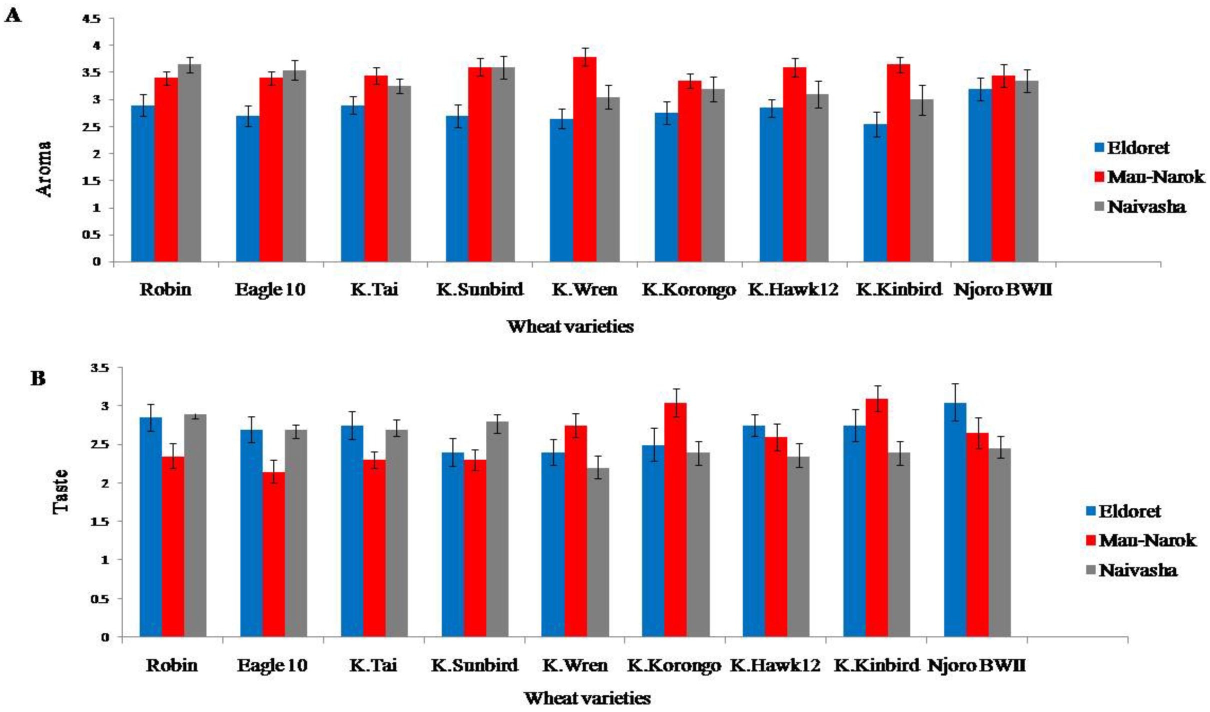

Figure 2. Sensory evaluation of breads prepared using whole meal flour prepared from 9 Kenyan bread wheat varieties A-Aroma scores, B- Taste scores

Table 4. Correlation analysis between the nutritional, rheological and organoleptic properties of whole meal flour from Kenyan bread wheat varieties

	Nutritional quality						Rheological characteristics					Organoleptic characteristics				
	PA	Zn	Fe	RS	Protein	Gluten	WA	STA	DDT	P	L	Aroma	Shape	Taste	CRC	ACCE
PA	1.00	0.3 0.9	0.15 0.70	0.24 0.53	0.18 0.65	0.30 0.43	-0.45 0.22	0.13 0.74	0.55 0.12	0.42 0.26	0.43 0.25	0.24 0.54	0.65 0.06	0.35 0.35	0.66 0.05*	-0.02 0.97
Zn		1.00	-0.13 0.73	0.23 0.55	0.69 0.04*	0.61 0.08	0.56 0.11	0.02 0.96	0.30 0.44	0.04 0.92	0.44 0.24	0.61 0.09	0.78 0.01**	0.58 0.10	0.40 0.28	0.77 0.02*
Fe			1.00	-0.36 0.16	-0.49 0.18	0.27 0.47	-0.03 0.94	-0.03 0.94	-0.17 0.66	-0.02 0.97	0.51 0.16	-0.32 0.40	-0.20 0.61	0.07 0.85	0.09 0.81	-0.01 0.98
RS				1.00	-0.28 0.46	-0.43 0.25	-0.20 0.61	0.07 0.86	0.43 0.24	0.58 0.10	0.04 0.92	-0.31 0.42	0.11 0.78	0.03 0.94	0.59 0.09	-0.38 0.32
Protein					1.00	0.60 0.09	0.27 0.49	0.18 0.65	0.29 0.45	0.03 0.94	-0.06 0.87	0.63 0.07	0.58 0.10	0.53 0.14	0.07 0.85	0.31 0.42
Gluten						1.00	0.31 0.41	-0.19 0.62	0.14 0.72	-0.04 0.92	0.25 0.51	0.16 0.77	0.34 0.37	0.82 0.01	0.28 0.47	0.19 0.62
WA							1.00	0.005 0.99	0.09 0.81	-0.06 0.88	0.37 0.33	0.07 0.85	0.21 0.59	0.32 0.41	0.002 0.99	0.52 0.15
STA								1.00	0.56 0.12	0.69 0.04*	0.47 0.20	0.49 0.18	0.47 0.21	-0.23 0.55	0.04 0.91	-0.09 0.82
DDT									1.00	0.71 0.03*	0.61 0.08	0.14 0.71	0.74 0.02*	0.25 0.51	0.47 0.21	-0.21 0.58
P										1.00	0.55 0.12	0.18 0.65	0.52 0.15	0.09 0.81	0.60 0.09	-0.29 0.45
L											1.00	0.15 0.70	0.62 0.07	0.22 0.57	0.50 0.17	0.25 0.51
Aroma												1.00	0.67 0.05*	-0.05 0.90	0.03 0.94	0.59 0.09
Shape													1.00	0.35 0.35	0.54 0.13	0.41 0.27
Taste														1.00	0.62 0.08	0.17 0.66
CRC															1.00	0.13 0.74
ACCE																1.00

Levels of significance are *P<0.05, **P<0.01, ***P<0.001. R values without * are not significantly correlated. PA-Phytic acid Zn-Zinc, Fe-Iron, RS-Resistant starch, WA- water absorption, STA-stability, DDT- dough development time, P- resistance to elasticity, L- resistance to extensibility, CRC-crust colour and ACCE- Acceptability.

4. Discussion

4.1. Site and Genotypic Impact on nutritional Composition of Whole Meal Wheat Flour

Micronutrient concentrations especially zinc and iron are relatively low in kernels of most cereals crops. Furthermore variation in the kernel concentration of micronutrient is influenced by genotype. In studies conducted using wild relatives and landraces of wheat it has been established that considerable variations exist in grain zinc and iron concentration [14,15,16]. These variations have led to setting of targets for zinc and iron biofortification in wheat grain to 40 and 60 ppm, respectively [30]. Therefore concentrations of iron in the whole meal flour of 9 Kenyan wheat bread varieties used in our study were all above the set targeted level, with the lowest concentrations being almost 2 fold more than the set target of 60 ppm, while the highest was five folds more. For zinc, the levels recorded in all test varieties across the 3 sites suggest that that all varieties tested were zinc sufficient with regard to classification done by [8] who set 10 ppm as the deficient range.

Protein and gluten levels were highly influenced by the genotype, site and interaction between genotype × site. Gluten is highly correlated with protein levels where high protein levels usually indicate high gluten levels and thus factors affecting protein levels have a direct influence on gluten levels [42]. In a study conducted by [37] wheat varieties grown in dry areas had high protein levels, this trend was also observed for varieties grown in Naivasha, an area that generally experiences higher temperatures and low rainfall compared to Eldoret and Mau-Narok. Furthermore in a study conducted by [29], the effects of interaction between genotype × environments on protein levels were significant though in most cases much lower compared to the effects of genotype or environment. In our study, results obtained indicate that genotypes with high protein levels maintained the same across the 3 study sites and those with low levels maintained the same. Nonetheless the effect of environmental on protein and gluten levels was evident in Naivasha and Mau-Narok sites where the highest and lowest protein levels were obtained irrespective of the genotype. On the other hand the influence of genotype on grain protein levels was also observed with control variety Njoro BWII and Robin recording higher levels, while K.Hawk12 recording lower levels, irrespective of site. The proximate composition of wheat grains especially protein and gluten may have been be affected by yield of the genotype. Reference [19], in their report, indicated that yield of wheat grown in dry areas is usually low hence their composition is usually concentrated in the few grains available leading to higher protein levels. From the results obtained in our study, very high yielding varieties such as K.Hawk12 and K.Korongo, flour prepared from their kernels tended to have lower protein levels, whereas low yielding varieties like K.Kingbird had higher protein levels, these differences may be associated to dilution effect of nitrogen. Nitrogen is a major constituent of amino acids and thus influences the levels of proteins. Therefore high uptake of nitrogen by low yielding varieties ensures that it is channeled to protein synthesis in the few grains available leading to high protein concentration while in high yielding varieties, it will be distributed evenly leading to reduced protein content per grain [40].

RS, soluble glucose and starch content in cereals vary depending mostly on site and genotype however for RS, environmental variation is difficult to predict and control compared to genetic variation [7]. Genetic variation is due to allelic variation in the starch biosynthetic genes as is the case in commercial maize varieties, which exhibit little variation in resistant starch levels, [32,36]. This is in line with variations observed in the study genotypes where some recorded up to 5 fold more RS than others when grown in the same cropping site. Wheat varieties contain the same synthetic genes for RS but some genotypes are able to over express them more than in the other varieties leading to enhanced RS levels.

Phytic acid content in flours ranges from 3.77, 2.96 and 8.50 ppm for hand-made refined flours, factory refined flours and for the whole grain flours, respectively [12]. Results obtained in this study for phytic acid in whole meal flour were all below 6 ppm irrespective of site or variety and were below previously reported values above. The results also indicated that site and varietal factors had significant influence on phytic acid content in wheat grains, but site appears to be a predominant factor in influencing the phytic acid content. Similar results have been observed on studies done on barley and rice which concluded environmental effect as the main contributor to phytic acid content in the grains [13,24]. Also associated with phytic acid in seed, is phosphorus concentration in the soil. Seeds from locations high in soil phosphorous have enhanced levels of phosphorous which influences seed phytate content [21]. While each cropping site was treated with the same amount of fertilizer (DAP), soils conditions in Naivasha especially pH may have favoured phosphate uptake by the varieties as compared to the other sites. Mobility of phosphorous is enhanced at pH range of 6.0 to 7.0 since at this range, the inorganic phosphate (Pi) is free compared to lower ranges observed in Eldoret and Mau-Narok which provides an environment for binding of inorganic phosphorous to metal ions making it unavailable for plant uptake [35].

4.2. Rheological Properties of Whole Meal Flour

Whole meal flours are known to absorb high amounts of water for them to be hydrated to the desired level for baking and it usually increases with the amount of whole meal flour added [20]. Water absorption for whole meal flour of the 9 Kenyan bread wheat varieties was enhanced regardless of site with highest level being 80% while the lowest was at 69%. The high WA level observed in whole meal flour was as a result of bran containing high levels of pentosans which require more water to be hydrated [38].

On the other hand high DDT scores was recorded in varieties with high protein and quality gluten while low levels were recorded in varieties with low protein. Whole meal dough with low protein and gluten cannot withstand prolonged dough making process as opposed to those with high protein and gluten levels.

The presence of bran in whole meal flours, usually increase the level of proteins which require more mixing time for water molecules to hydrate the flour components to the desired and the required consistency level [38]. Our results also show that dough stability for varieties grown in Mau-Narok had higher scores and lowest for varieties grown in Naivasha. Dough with more stability is highly preferred since it is able to withstand vigorous mechanical processes in the baking process without weakening and end up with good quality products. Presence of bran interferes with the continuity of the gluten matrix responsible for dough stability making it weaker [37].

MTI is a measure of the rate of dough weakening or softening and together with the other farinograph parameters is used in predicting the quality of end product to expect. Flours with MTI's values of ≤30 BU are preferred as they indicate flours that don't weaken easily. High levels of MTIs are associated with flours that weaken easily as was the case with whole meal flour from Naivasha while low levels are associated with flours that are strong as was the case for flour prepared using Mau-Narok crop.

The length and height of the alveogram gives the measure of resistance elasticity and resistance to extension and is an indicator of gluten quality. Gluten which is composed of glutenins and gliadins is a non-functional/storage protein in wheat and is highly responsible for dough formation, extensibility and elasticity [6]. Upon correct mixing, high quality gluten assumes the properties of an elastic material that is capable of stretching under pressure. This was observed in K.Tai, K.Hawk12 and K.Kingbird varieties which recorded the highest P value across the 3 sites indicating they were more elastic compared to K.wren and K.Korongo varieties which recorded lower values irrespective of site. Elastic dough leads to well raised and shaped breads which are springy, spongy and of high quality. The major gluten component responsible for elasticity is the glutenin component which is part of the seed storage protein and is water insoluble [6]. However like any elastic material, the glutenin matrix also has its elastic limit which when exceeded, leads to dough rupture.

L values for all the varieties grown in the 3 sites, were lower although Eldoret recorded the lowest values, while Mau-Narok recorded highest values. In whole meal flour, bran and germ particles integrate into the dough matrix disrupting the continuity of the gluten protein network especially the gliadin component which results in weaker and less firm dough [23,26]. Reference [22] in their study on temperature effect on gluten protein they discovered that gliadin molecules reduce the stiffness and increase the extensibility of the gluten phase resulting in higher values of L. However in study reported herein, due to presence of differently sized bran and germ particles which interrupted the protein matrix, low L values were observed for all the varieties grown in the three sites.

4.3. External Loaf Characteristics

Loaf prepared using flour obtained from crop grown in Eldoret had the highest shape scores compared to varieties grown in Mau-Narok and Naivasha. Loaf shape is highly dependent on the integrity of gluten especially the ability to withstand pressure from CO_2 produced and the high temperatures during the baking process. Presence of bran and germ particles interferes with the continuity of the dough creating many weak points that easily give in when exposed to extreme conditions resulting to flat breads as observed in loaves baked from wheat crop grown in Naivasha and Mau-Narok.

Crust colour of bread is usually as a result of browning reaction and caramelization reactions which when controlled give rise to an attractive brown colour. Popular breads usually have attractive brown colour on their crust and are usually associated with the browning reaction and caramelization reactions products [2]. The browning reaction is a chemical reaction between an amino acid and a reducing sugar, while caramelization is a complex group of reactions that take place when sugars are subjected to high temperatures in the absence of amino acids [41]. Crust browning occurs when the baking temperature is greater than 110°C [28]. At high temperatures, water is quickly removed from the dough surface and the high levels of proteins in whole meal flour offers optimum conditions for Maillard reaction. The end products of Maillard reactions are melanoidins which are responsible for browning of the crust [27]. In our study moderate scores for crust colour at levels above 3 were obtained on all varieties irrespective of site, suggesting that browning reaction occurred to all the varieties at an almost similar magnitude.

4.4. Flavour Characteristics and Acceptability

The melanoidins formed impact aroma to baked breads and other products. Scores for all the varieties in the three sites were above 3, an indicator that the product aroma was appealing irrespective of site where wheat crop was grown. For whole meal bread the scores were within the commonly acceptable range since no additives to improve aroma were included.

Analysis of taste showed that all varieties scored lower values irrespective of site of growth. This may have been due to the compounds formed during the prolonged baking time in the oven. When overexposed to high temperatures, the melanoidins formed impacts a bitter taste which might have resulted in the taste parameter having lower scores. The bitter undesired taste experienced could also have resulted from the formation of bitter compounds such as acrylamide formed in prolonged maillard reactions [2,17].

Bread acceptability levels for most varieties were highly influenced by the shape and taste of the varieties. For varieties that had bread with irregular shapes and scored low on taste, their score on general acceptability greatly reduced. This is because for baked products, the shape and taste of the product greatly influence the desire and preference of the consumer.

4.5. Correlation Analysis

Correlation analysis between nutrition quality of wheat and the organoleptic properties showed significant effect between phytic acid and crust colour and also with crumb colour. This might have been due to high levels of bran in the whole meal flour which improves the crust colour [25]. The bran components contains high protein levels which undergo caramelization and browning reaction to improve bread colour. The results obtained herein are similar to [25]. In their research bread colour improved and darkened with increase of bran particles in their flour samples. Aroma and shape are highly dependent on protein levels of the flour used. More protein in the flour provides free amino groups that react with water molecules leading to the formation of aromatic compounds [5], while in relation to shape, the protein resists escape of CO_2 leading to the loaf structure hence the correlation.

5. Conclusions

The results of this study show that the varieties tested contained considerable levels of iron, zinc and resistant starch and low levels of the undesirable phytic acid. This is encouraging as the varieties can help in addressing micronutrient deficiency especially of the study microelements. Generally, the correlation analysis showed that the nutritional content had no adverse effect on rheological and organoleptic parameters of whole meal flour. This information is useful to breeders as they can now breed for wheat varieties with high levels of desired parameters without fear of whether the rheological and organoleptic properties will be affected by the increased levels. The information generated herein will go a long way in helping the fight against micronutrient deficiency while at the same time the varietal nutritional information will help baker produce high quality bread that is healthier, beneficial and also acceptable by consumers.

As a recommendation, further research on the different levels or amounts of zinc, iron, phytic acid and resistant starch that would affect the rheological and organoleptic properties of whole meal flour should be investigated.

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Statement of Competing Interests

The authors have no competing interests.

References

[1] Abdelghafor R.F., Mustapha A.I., Ibrahim A.M.H. and Krishnan P.G. (2011). Quality of bread from composite flour of sorghum and hard white winter wheat. *Advanced Journal of Food Science and Technology*, 3(1):9-15.

[2] Ahrne L., Andersson C.G., Floberg P., Rosen J. and Lingnert H. (2007). Effect of crust temperature and water content on acrylamide formation during baking of white bread: steam and falling temperature baking. *Journal of Food Science Technology*, 40: 1708-1715.

[3] Anjum F.M., Ahmad I., Butt M.S., Arshad M.U. and Pasha I. (2008). Improvement in end use quality of spring wheat varieties grown in different eras. *Journal of Food Chemistry*, 106(2): 482-486.

[4] Banu I., Georgeta S., Violeta S.I. and Luliana A. (2012). Effect of the addition of wheat bran stream on dough rheology and bread quality. *Journal of Food Technology*, 36(1):39-42.

[5] Bekedam E.K, Schols H.A., Boekel M.A.J.S., and Smith G. (2006). High molecular weight melanoidins from coffee brew. *Journal of Agricultural and Food Chemistry*, 54:7658-7663.

[6] Belderok B., Mesdag J., Donner D.A. (2000). Bread making quality of wheat: A century of breeding in Europe. Kluwer Academic Publisher: Dordrecht, the Netherlands, pp. 30-31.

[7] Birt D.F., Terri B., Suzanne H., Jay-Lin J., James H., Li L., John M., Samuel M., Gregory J.P., Matthew R., Kevin S., Paul S. and Elizabeth M. (2013). Resistant Starch: Promise for Improving Human Health. *Journal of Advances in Nutrition*, 4: 587-601.

[8] Bhupinder, S., Senthil, K.A.N., Singh B.K. and Usha K. 2005. Improving zinc efficiency of cereals under zinc deficiency. *Journal of Current Science* 88(1):36-44.

[9] Coudray C, Demigne C, Rayssiguier Y (2003). Effects of dietary fibers on magnesium absorption in animals and humans. Journal of Nutrition, 133:1-4.

[10] Crina M., Laura S., Simona M., Stancuta S. and Sevastita M. (2012). Sensory evaluation of bakery products and its role in determining of the consumer preferences. *Journal of Agroalimentary Processes and Technologies*, 18(4):304-306.

[11] Dewettinck K., Van Bockstaele F., Kuhne B., Van de Walle D., Courtens T.M. and Gellynck X. (2008). Nutritional value of bread: influence of processing, food interaction and consumer perception. *Journal of Cereal Science*, 48:243-257.

[12] Febles C.I., Arias, A., Hardisson A., Rodrıguez-Alvare, C. and Sierra A. (2002). Phytic acid level in wheat flours. *Journal of Cereal Science*, 36:19-23.

[13] Fei D., Junmei W., Saihua Z., Zhenzhen X. and Guoping Z. (2007). Genotypic and environmental variation in phytic acid content and its relation to protein content and malt quality in barley. *Journal of Food Chemistry*, 105:606-611.

[14] Genc, Y., Humphries, J.M., Lyons, G.H. and Graham, R.D. 2005. Exploiting genotypic variation in plant nutrient accumulation to alleviate micronutrient deficiency in populations. *Journal of Trace Elements and Medical Biology* 18:319-324.

[15] Gomez-Becerra, H.F., Erdem, H., Yazici A., Tutus, Y., Torun, B., Ozturk, L. and Cakmak, I. 2010a. Grain concentrations of protein and mineral nutrients in a large collection of spelt wheat grown under different environments. *Journal of Cereal Science* 52: 342-349.

[16] Gomez-Becerra, H, F., Yazici, A., Ozturk, L., Budak, H., Peleg, Z., Morgounov, A., Fahima, T., Saranga, Y. and Cakmak, I. 2010b. Genetic variation and environmental stability of grain mineral nutrient concentrations in *Triticum dicoccoides* under five environments. *Euphytica* 171: 39-52.

[17] Gokmen V., Acar O.C., Koksel H. and Acar J. (2007). Effects of dough formula and baking conditions on acrylamide and hydroxymethylfurfural formation in cookies. *Journal of Food Chemistry*, 104:1136-1142.

[18] Iwe, M.O. (2002). Handbook of sensory methods. Projoint Communication Services Limited, Enugu, Nigeria, pp.70-72.

[19] Jones, C. and Olson R.K. (2012). Practices to increase wheat grain protein. Montana State University Extension. EBO206. Http:// landresources.montana.edu/soil fertility/ PDF by format/ publication.

[20] Kalnina S., Rakcejeva T., Kunkulberga D. and Galoburda R. (2015). Rheological properties of whole wheat and whole triticale flour blends for pasta production. *Journal of Agronomy Research* 13(4):948-955.

[21] Kim J.C., Mulla B.P., Selle P.H and Pluske J.R. (2002). Levels of total phosphorus and phytate in three varieties of Western Australian wheat in response to growing region and growing season. *Australian Journal of Agricultural Research*, 53: 1361-1366.

[22] Koehler P., Kieffer R. and Wieser H. (2010). Effect of hydrostatic pressure and temperature on the chemical and functional properties of wheat gluten III: Studies on gluten films. *Journal of Cereal Scence*, 51: 140-145.

[23] Kunkulberga D., Klava D., Ruza A., Zirvite I. and Riekstina A. (2007). Development of whole grain products. In: Proceedings of 4 International congresses "Flour-Bread'07". *6th Croatian congress of cereal technologists, Croatia*, p. 300-305.

[24] Liu Z. H., Cheng F. M. and Zhang G.P. (2005b). Grain phytic acid content in japonica rice as affected by cultivar and environment

and its relation to protein content. *Journal of Food Chemistry*, 89:49-52.

[25] Majzoobi M., Farahnaky A., Nematolahi Z., Mohammadi H., and Taghipour A.M.J. (2013). Effect of different levels and particle sizes of wheat bran on the quality of flat bread. *Journal of Agriculture Science and Technology*, 15:115-123.

[26] Manthey F.A. and Schorno A.L. (2002) Physical and cooking quality of spaghetti made from whole wheat durum. *Journal* of *Cereal Chemistry,* 79:504-510.

[27] Michalska A., Amigo-Benavent M., Zielinski H. and Castillo M.D. (2008). Effect of bread making on formation of Maillard reaction products contributing to the overall antioxidant activity of rye bread. *Journal of Cereal Science*, 48:123-132.

[28] Mondal A. and Datta A.K. (2008). Bread baking. A review. *Journal of Food Engineering*, 86:465-474.

[29] Mladenov N., Przulj N., Hristov N., Djuric V and Milovanovic M. (2001). Cultivar by environment interactions for wheat quality traits in semi-arid conditions. *Journal of Cereal Chemistry*, *78*(3): 363-367.

[30] Ortiz-Monasterio, J.I., Palacios-Rojas, E., Meng, E., Pixley, K., Trethowan, R. and Pena, R.J. 2007. Enhancing the mineral and vitamin content of wheat and maize through plant breeding. *Journal of Cereal Science* 46:293-307.

[31] Philip J.W. and Martin R.B. (2009). Biofortification of crops with seven mineral elements often lacking in human diets iron, zinc, copper, calcium, magnesium, selenium and iodine. *Journal of New Phytologist*, 182: 49-84.

[32] Pollak L.M., Scott M.P. and Duvick S.A. (2011). Resistant starch and starch thermal characteristics in exotic corn lines grown in temperate and tropical environments. *Journal of Cereal Chemists*, 88:435-440.

[33] Raboy V., Paola F.G., Kevin A.Y., Sierra D.S., Suewiya G.P., Andrew T.B., Pushpalatha P.N. M., William F.S., and David S.E. (2000). Origin and seed phenotype of maize low phytic acid 1-1 and low phytic acid 2-1. *Journal of Plant Physiology*, 124: 355-368.

[34] Rao V.K., Mulvaney S.J. and Dexter J.E. (2000). Rheological characterisation of long and short mixing flours based on stress-relaxation. *Journal of Cereal Science,* 31(2):159-171.

[35] Rastija M., Jurica Jovic., Dario Iljkic., Vlado Kovacevic and Domagoj R. (2014). Response of winter wheat to ameliorative phosphorus fertilization. *49th Croatian and 9th International Symposium on Agriculture*, Dubrovnik Croatia, 412-415.

[36] Rohlfing K.A., Pollak L.M. and White P.J. (2010). Exotic corn lines with increased resistant starch and impact on starch thermal characteristics. *Journal of Cereal Chemists*, 87:190-193

[37] Saleem N., Ahmad M., Wani S.A.., Vashnavi R. and Dar Z.A. (2015). Genotype environment interaction and stability analysis in Wheat (*Triticum aestivum L.*) for protein and gluten contents. *Journal of Scientific Research and Essays*, 10(7):260-265.

[38] Sanz-Penella J.M., Collas C. and Haros M. (2008). Effect of wheat bran and enzyme addition on dough functional performance and phytic acid levels in bread. *Journal of Cereal Science*, 48:715-721.

[39] Stathopoulos C.E., Tsiami A.A., David S.J. and Dobraszczyk B.J. (2008). Effect of heat on rheology, surface hydrophobicity and molecular weight distribution of glutens extracted from flours with different bread-making quality. *Journal of Cereal Science*, 47(2):134-143.

[40] Triboi E., Martre P., Girousse C., Ravel C. and Triboi-Blondel A.M. (2006). Unraveling environmental and genetic relationships between grain yield and nitrogen concentration for wheat. *European Journal of Agronomy*, 25 (2): 108-118.

[41] Tsai P.J., Yu T.Y., Chen S.H., Liu C.C. and Sun Y.F. (2009). Interactive role of colour and antioxidant capacity in caramels. *Journal of Food Research International*, 42:380-386.

[42] Zhao C.X., He M.R., Wang Z.L., Wang Y.F. and Lin Q. (2009): Effects of different water availability at post anthesis stage on grain nutrition and quality in strong-gluten winter wheat. *Comptes Rendus Biologies*, 332: 759-764.