SciencePG
Science Publishing Group

Environment and Genotype Effect on Quality Baking Traits of Advanced Stem Rust Wheat (*Triticum aestivum* L.) Lines Grown in Kenya

Samuel Ngure Kariithi[1, 2, *], Stephen Abwao Indieka[2], Manfred Miheso Masheti[3]

[1]Food Chemistry and Quality Department, Kenya Agricultural and Livestock Research Organization, Njoro, Kenya

[2]Biochemistry and Molecular Biology Department, Egerton University, Egerton, Kenya

[3]Community Development Department, Baraka Agriculture College, Molo, Kenya

Email address:
sammy_re@yahoo.com (S. N. Kariithi)
[*]Corresponding author

To cite this article:
Samuel Ngure Kariithi, Stephen Abwao Indieka, Manfred Miheso Masheti. Environment and Genotype Effect on Quality Baking Traits of Advanced Stem Rust Wheat (*Triticum aestivum* L.) Lines Grown in Kenya. *International Journal of Food Science and Biotechnology*. Vol. 6, No. 4, 2021, pp. 85-95. doi: 10.11648/j.ijfsb.20210604.11

Abstract: Physicochemical and rheological properties of wheat flour defines its end use and are influenced by variety and environmental factors. New varieties need to be evaluated under different environments to determine the environment and variety best suited desired quality characteristics. This study was designed to evaluate the baking quality performance of 17 advanced stem rust wheat lines and 3 varieties under different environments. Completely Randomized Block Design experiments were set up in five zones in Kenya; Njoro, Narok, Naivasha, Eldoret and Timau where the 17 advanced lines and 3 varieties were grown and different baking quality parameters evaluated. The baking quality parameters were analysed following the approved and AACCI methods as described in the materials and methods section. Protein results ranged from 7.90 to 14.67%, gluten12.30 to 32.20%, and zeleny 10.07 to 56.33% respectively. Dough development time ranged from 1.50 to 7.33 minutes, dough stability0.92 to 15.67 minutes, water absorption60.67 to 70.07% and mixing toleranceindex8.33 to 96.67 B.U. Hectolitre weight ranged from 59.19 to 80.14 Kg/Hl, flour extraction 59.19 to 82.50%, starch47.17 to 75.27, ash0.50 to 1.26% and moisture11.67 to 16.10%. Timau a cooler environment in comparison to the other regions recorded lower protein levels compared to Narok a hotter environment which recorded high protein, gluten and zeleny levels regardless of line/genotype evaluated, confirming the influence of environment on baking quality parameters. K. Ibis and R1290 recorded high protein levels except in Timau which points to the stability of genotypic qualities across the environments. Timau proved to be the best site for soft wheat and Njoro for hard wheat due to the high quality characteristics observed in the lines/genotypes.

Keywords: Protein Content, Tolerance, Stability, Water Absorption

1. Introduction

Wheat is an important food crop and continues to play a crucial role in combating hunger and improving global food security [23]. In Kenya, wheat ranks as the second most important cereal crop after maize and contributes significantly in food security, poverty reduction and employment creation [12]. Demand for wheat and its products in Kenya continue to increase due to population growth and urbanization. To meet the raising demands and ensure grain production especially under challenges of climate change, new cultivars must be developed and evaluated for their high yield and quality. Thus, the main objective of many wheat breeding programmes has been to produce well-adapted and high-yielding varieties with finest end-use quality [8, 9].

In Kenya most wheat research has mainly focused on improving yields and resistance to diseases especially stem rust, while research into the end use characteristics has lagged behind. The most important factors considered when

evaluating end-use quality are physiochemical and rheological properties of wheat flour: which have a greater bearing on the end use and quality of wheat products [22]. These properties of flour vary significantly among varieties and have far reaching effects on the end use [24]. The quality of the end product depends upon the quality of wheat grain and wheat suitable for one particular use may have certain properties that are totally unsatisfactory for other uses [2]. These variations, especially in functional properties are attributed largely to their gluten quality and quantity [19]. This study focused on the evaluation of proximate composition and rheological properties of 17 advanced Stem Rust Resistant lines and3Kenyan bread wheat cultivars grown in five study sites regarded as Kenyan wheat belts.

2. Materials and Methods

2.1. Plant Materials Used in the Cropping Sites (Eldoret, Naivasha, Narok, Njoro and Timau)

17 advanced Stem Rust Resistant wheat lines and 3 varieties namely, Robin, K.Ibis, Njoro BWII and were all obtained from the Kenya Agricultural and Livestock Research Organization, Food Crops Research Centre located at Njoro. The 17 lines were selected based on their superior agronomical traits such as resistant to stem rust fungal infection, high yields, resistance to waterlogging and sprouting among other farmer desired traits. These lines were at an advanced release stage but their quality parameters needed to be evaluation before they could be released. The three wheat varieties were used as the quality control samples due to their superior baking properties especially the protein, gluten and zeleny qualities. The quality profiles for the three varieties used as controls in this study are: Njoro BWII (13-14.5% protein content, 19-22% gluten content and 35-45% zeleny content); Robin (13-14.5% protein content, 19-21% gluten content and 32-38% zeleny content) and K.Ibis (11.5-12.5% protein content, 25-30% gluten content and 40-50% zeleny content). The 17 wheat lines and the 3 control genotypes were grown in zones with differing agro-climatic conditions; Eldoret, Naivasha, Narok, Njoro and Timau as shown (Table 1) and analysed for physiochemical and rheological properties.

Table 1. Geographical location and edaphic features of Eldoret, Naivasha, Narok, Njoro and Timau experimental sites.

Site	Altitude (m)	Longitude	Latitude	Soil pH	Temperature (°C)	Precipitation (mm)
Eldoret	2073	35°17'E	0°31'N	5.4-6.0	16.8	1103
Naivasha	1884	36°26'E	0°43'S	6.2-7.4	18.5	677
Narok	1898	35°51'E	1°41'S	5.4-8.2	18.1	771
Njoro	1800	35°35'E	0°23'S	5.8-6.8	17.5	1080
Timau	2410	37°14'E	0°50'N	4.0-6.5	15.2	1162

2.2. Experimental Design in Eldoret, Naivasha, Narok, Njoro and Timau

The wheat varieties and lines were planted in a Completely Randomized Block Design. The well prepared and levelled land was divided into three blocks, each consisting of 20 equal plots whose dimensions were 6 m in length and 1 m in width. The soil in each plot was treated with Di-Ammonium Phosphate (DAP) fertilizer at the rate of 50 Kg/ha before planting. After wheat seedlings had germinated the weeds in the experimental plots were controlled by spraying with 'Twigamethalin' herbicide for control of broadleaf weeds and grasses on wheat farms.

2.3. Harvesting and Sample Preparation

The wheat crop was grown for four months and harvested when the wheat head had completely filled and dried. The harvested lines/cultivars were then threshed and winnowed to remove physical debris and foreign matter. It was then dried in open air to reduce the moisture to 14.0% which is safe for storage. Moisture was determined using an Infratec grain analyzer following [1] method number 39.00.01.

2.4. Hectolitre Weight and Flour Extraction

The bushel weight/ hectoliter weight was determined using [1] method number 55-10.01. Flour extraction was determined using [1] method number 26-10.02. Then one kilogram of the harvested kernels were cleaned and milled using a Buhler miller (Number 220177, Uzwil, Switzerland) to yield white flour. The recovered flour in grams was calculated as a percentage weight of the starting wheat grain before milling.

2.5. Evaluation of Rheological Properties and Chemical Composition

The proximate flour composition was determined using the Foss Infratec Grain Analyzer (Model 1241 Denmark) following the outlined procedures in [1] method number 39-00.01. Approximately, 5g of flour was packed in a flour cuvette and placed in the Infratec Grain analyzer measuring cell for analysis of flour protein, gluten levels, moisture, starch, zeleny and ash content. The water absorption of flour was determined based on the procedure adapted from method [1].

2.6. Data Analysis

Data collected in triplicates per variety/line was subjected to Analysis of variance (ANOVA) for comparison and differences determination and correlation analysis to associations among the varieties at $p<0.05$ level of significance. Means differences were then separated by Fisher's least significant difference (LSD) test. ANOVA and

LSD were conducted using SAS software Version 9.1.3 (SAS Institute, Inc., 2004). Multivariate analysis was done using R software version 3.4.4. Biplot analysis was carried out using packages 'factoextra' and 'FactoMineR' packages while 'gplots' in R-software was used to generate a heatmap.

3. Results and Discussions

3.1. Protein, Gluten and Zeleny Content of Lines and Genotypes in the 5 Study Environments

Protein and gluten composition for wheat flour was significantly ($p<0.05$) influenced by variety, site and interaction between variety × cropping site. Protein levels ranged from 7.90 to 14.67% across the five study sites. In Eldoret, highest levels were recorded in R1286 at 14.67% while the lowest was recorded in Njoro BWII at 11.47%, in Naivasha highest and lowest protein levels were recorded in R1301 and Njoro II at 13.70 and 11.60%. In both Narok and Njoro, highest protein levels were recorded in K.Ibis at 13.97% while lowest levels were recorded in R1306 and R1305 at 10.67 and 11.47%. In Timau, highest and lowest protein levels were recorded in R1308 and Robin at 11.33 and 7.90% respectively. Gluten levels were highest for R1298 and R1308 at 27.37% while lowest levels were recorded in R1287 at 19.20% for cultivars grown in Eldoret. For crop grown in Njoro and Narok, highest gluten levels were recorded in K. Ibis and R1301 at 32.13 and 32.20%.

Timau recorded the lowest gluten levels regardless of the line/ cultivar with exceptionally low levels recorded in R1303 and R1304 at 17.47 and 17.20% (Table 2).

Agro climatic characteristics influence protein and gluten content in wheat; wheat grown in agro climatic regions with relatively warm temperatures contain high protein and gluten levels of up to 15% compared to varieties grown in cooler temperatures [21]. This pattern was observed in our study where irrespective of genotype, wheat grown in Narok and Naivasha sites, areas which experience relatively warmer temperatures had higher protein and gluten compared with those grown in Timau site. Timau is much cooler compared to the other 4 sites (Table 1). Gluten which is made up of glutenins and gliadins is a major storage protein found in wheat. Environmental conditions especially warmer temperatures and water stress shortens the grain filling period which increases the concentration of gluten and the ratio of gliadins/ glutenin in the kernel [7].

Zeleny/sedimentation value is related to the swelling of glutenins, which are intimately associated with the bread making quality of flours. Zeleny content ranged from 10.07 to 56.33% across the five study sites. Highest zeleny content were recorded for genotypes grown in Naivasha and Njoro while the lowest levels were recorded in Timau site. R1302 line and Robin recorded lowest levels at 12.43 and 10.07, when grown in Timau, while Njoro II and K.Ibis recorded the highest levels at 51.57 and 56.33%, when grown in Njoro site.

Table 2. Protein, gluten and zeleny content analysis for wheat varieties grown in Eldoret, Naivasha, Narok, Njoro and Timau cropping sites.

Variety	Protein				
(Size)	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	12.83efg	12.43gh	12.30bcdefg	13.33b	8.87d
R1286	14.67a	12.63fg	12.47bcde	12.73fg	9.57c
R1287	12.47h	12.90de	12.97b	13.07cde	9.90b
R1288	13.03de	11.63k	12.27bcdefg	13.03de	9.57c
R1290	13.27c	13.47ab	12.03defgh	13.33b	8.30ij
R1291	13.03de	13.37b	11.90efgh	13.37b	10.00b
R1294	11.50k	12.93de	12.23cdefg	13.17bcd	8.17jk
R1298	12.43h	13.07cd	12.60bcde	13.27bc	8.83de
R1301	12.37hi	13.70a	12.63bcd	12.67hg	8.93d
R1302	11.57k	13.37b	11.50h	11.57j	8.40hi
R1303	12.00j	12.10ij	11.63gh	12.60hg	8.67f
R1304	12.17ij	12.70ef	12.53bcde	12.50h	8.50gh
R1305	13.53b	13.10cd	12.30bcdefg	11.47j	8.13k
R1306	12.77fg	13.27bc	10.67i	12.90ef	9.43c
R1308	12.73g	13.07cd	11.33hi	13.27bc	11.33a
R1309	12.80fg	11.93j	12.37bcdef	12.03i	8.93d
R1312	12.97def	12.33hi	12.30bcdefg	13.03de	9.50c
KIBIS	13.10cd	13.23bc	13.97a	13.97a	8.63fg
ROBIN	11.60k	12.30hi	11.73fgh	12.47h	7.90l
NJOROII	11.47k	11.60k	12.90bc	13.33b	8.70ef

Variety	Gluten				
(Size)	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	23.60bcd	25.47efghi	26.67efgh	28.60cdef	18.53efgh
R1286	26.23abc	26.77bcde	27.80abcdef	27.93defgh	22.40bcd
R1287	19.20e	12.30a	29.23abcde	28.37cdef	21.77bcde
R1288	25.17abcd	25.53efghi	28.13abcdef	28.93bcde	23.00bc
R1290	24.23abcd	28.20a	26.77defgh	29.67bc	19.40defgh
R1291	26.57ab	24.50i	27.63bcdefg	30.23b	24.70ab
R1294	21.87de	25.27fghi	26.33efgh	29.60bc	18.97efgh

| Size | Gluten | | | | |
Variety	Eldoret	Naivasha	Narok	Njoro	Timau
R1298	27.37a	26.53bcdef	31.23abcd	28.30cdefg	21.17cdef
R1301	23.07cd	25.10ghi	32.20a	28.17cdefg	18.23fgh
R1302	23.20bcd	26.00defgh	24.00fgh	26.57hij	19.07efgh
R1303	23.73bcd	25.33fghi	31.73ab	27.57efghi	17.47gh
R1304	23.77bcd	26.40cdefg	27.33bcdefgh	27.40fghi	17.20h
R1305	27.37a	27.20abcd	26.87cdefgh	25.13j	18.73efgh
R1306	23.70bcd	27.83ab	23.33gh	28.77bcdef	20.97cdef
R1308	23.97abcd	27.50abc	23.03h	29.33bcd	26.90a
R1309	23.87bcd	25.20fghi	28.17abcdef	26.33ij	20.37cdefgh
R1312	24.47abcd	25.53efghi	26.90cdefgh	27.80efghi	22.87bc
KIBIS	22.87cd	27.47abc	31.30abc	32.13a	19.53defgh
ROBIN	25.43abc	24.83hi	31.47ab	26.80ghi	18.17fgh
NJOROII	25.83abc	25.43efghi	26.83cdefgh	27.77efghi	20.67cdefg

| Size | Zeleny | | | | |
Variety	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	35.03ef	35.70jk	33.80e	48.87de	21.93cde
R1286	43.03a	36.67j	45.00a	43.33gh	22.13cd
R1287	38.07d	44.57ef	31.63g	43.57gh	22.80c
R1288	35.17e	31.63l	45.17a	48.27e	21.40de
R1290	38.30c	45.63de	33.13e	49.03cde	14.07j
R1291	35.10e	47.37bc	35.20d	50.73bcd	25.10b
R1294	31.33i	41.80h	35.87d	48.90de	14.33ij
R1298	33.97g	39.37i	44.97a	48.57e	15.40h
R1301	34.00fg	50.93a	33.37e	45.60f	16.97g
R1302	30.17jk	45.17def	31.83fg	38.03i	12.43k
R1303	29.87k	39.13i	31.87fg	41.73h	14.70hij
R1304	31.07ij	43.90fg	39.93c	39.70i	14.53hij
R1305	39.37b	43.77fg	27.90h	35.30j	13.03k
R1306	33.90g	46.40cd	18.13i	35.13j	19.20f
R1308	33.90g	42.37gh	33.03ef	50.87bc	31.97a
R1309	38.70bc	36.73j	13.10j	43.13h	17.00g
R1312	33.93g	39.70i	42.63b	50.50bcd	21.17e
KIBIS	36.77d	48.13b	31.03g	56.33a	15.37h
ROBIN	30.37ijk	34.47k	39.23c	45.03fg	10.07l
NJOROII	32.70h	35.47jk	44.50a	51.57b	15.07hi

Means followed by the same letter in the same column are not significantly different at P<0.05 Level of significance. Means were separated using Fishers LSD

Wheat flour with a 30% and above are considered as having good quality for making pan breads. All the cultivars/lines grown in Eldoret had good baking quality except for R1303 which had 29.87% zeleny value while for cultivars grown in Naivasha they all surpassed the zeleny threshold for baking as they recorded values greater than 30.00%. In Narok cropping sites, all cultivars/lines recorded excellent zeleny values except for R1305, R1306 and R1309. All cultivars grown in Njoro recorded values greater than 30% which was excellent for baking while in Timau, no cultivar met the 30% zeleny threshold baking quality except for R1308 which recorded values of 31.97% (Table 2). The results obtained from this study show that zeleny levels in wheat flours is highly influenced by environment factors as was observed in studies done [18, 16]. In their studies, high temperatures increased the concentration of Zeleny while in cooler environments, low zeleny levels were reported.

3.2. Dough Stability, Dough Development Time and Mixing Tolerance Index

Dough stability, dough development time and mixing tolerance index (MTI) were significantly ($p<0.05$) influenced by variety, site and interaction of variety × cropping site (ANOVA). In Eldoret dough stability ranged from 1.92 to 10.33 minutes. In Naivasha and Narok, highest levels were recorded in R1305 and K.Ibis at 15.67 minutes while lowest stability levels were recorded in Njoro BWII and R1303 at 2.75 and 2.08 minutes. In Njoro, highest dough stability levels were recorded in Robin at 9.17 minutes while the lowest levels were recorded at R1298 and R1305 at 3.33 minutes. Timau cropping site recorded overall lower stability times except for R1291 and R1308 which recorded dough stability of 10.33 and 10.00 minutes. Dough development time ranged from 1.50 to 7.33 minutes across the five study sites. In Eldoret and Naivasha highest dough development time levels were recorded in R1305 and R1290 at 5.33 and 5.67 minutes while lowest levels were recorded in R1294 at 2.17% and R1288 and R1312 at 2.33 minutes. Flour from K. Ibis, R1298 and R1290 grown in Narok recorded the highest dough development times at 7.33, 6.83 and 6.67 minutes, while flour prepared from K. Ibis and R1304 grown in Timau recorded the lowest levels at 1.50 and 1.75 minutes (Table 3). Long mixing times while an indicator of hard wheat could translate to higher running costs for the manufacturers and long production times which. in the end could lead to less products and low profits. A flour with

moderate mixing times is preferred

Dough stability is an indicator for flour strength and reflects the quantity and quality of dough protein [15], hence factors affecting protein levels strongly influences dough stability. The influence of environment and the genotype* environment interaction was observed in the high dough development time and dough stability for the different environments especially in Njoro BWII, R1285 and R1287 (Table 3). Flours with very low dough stability and dough development time values, change from a solid like to liquid like structure quickly indicating weak gluten, thus undesirable for baking pan bread [14].

Flours with mixing tolerance index (MTI) values of ≤30 BU are preferred as they indicate relative strong flours [11]. High level of MTI as obtained in flour from wheat grown in Timau site, indicates weak flours associated with low protein, gluten and zeleny levels in wheat grain. On the other hand, low levels as is the case for flour prepared from wheat crop grown in Narok site, is associated with strong flour [11]. Wheat grown in environments with high temperatures accumulate high levels and high quality proteins that impact strength to the dough thus reducing dough weakening while in cooler environments the quality of the protein might be low which may lead to high MTI values an indicator of relative weak flours.

Table 3. *Stability, dough development time and mixing tolerance index analysis for wheat varieties grown in Eldoret, Naivasha, Narok, Njoro and Timau cropping sites.*

Site Variety	Stability Eldoret	Naivasha	Narok	Njoro	Timau
R1285	6.92ef	6.67e	8.83ef	6.00e	0.92l
R1286	6.33f	6.00ef	11.83c	4.17gh	3.33e
R1287	4.00gh	11.00b	7.67gh	3.92hi	6.42b
R1288	6.33f	8.92c	10.00d	3.75hi	2.00ghijk
R1290	6.83f	8.25cd	9.00e	5.83e	3.42e
R1291	4.25g	8.83c	9.83d	5.17f	10.33a
R1294	1.92k	8.33cd	6.75i	3.50i	2.50fg
R1298	2.00jk	4.83g	13.25b	3.33i	2.33fgh
R1301	4.08g	5.17fg	8.25fgh	4.67fg	1.50jkl
R1302	2.58j	9.17c	8.58ef	4.17gh	2.25fghi
R1303	2.33jk	6.42e	2.08k	4.75fg	4.50d
R1304	3.42hi	11.58b	7.67gh	6.00e	2.67f
R1305	8.92c	15.67a	7.58h	3.33i	1.75hijk
R1306	7.70de	7.75d	7.67gh	7.00d	3.76e
R1308	8.00d	3.25h	4.33j	7.17cd	10.00a
R1309	10.33a	4.92g	8.33efg	4.67fg	1.67ijk
R1312	7.75d	7.67d	8.33efg	8.50b	5.75c
KIBIS	9.58b	3.25h	15.67a	8.83ab	2.42fg
ROBIN	3.33i	3.33h	11.50c	9.17a	2.08fghij
NJOROBWII	7.75d	2.75h	11.33c	7.67c	1.42kl

Site Variety	Dough development time Eldoret	Naivasha	Narok	Njoro	Timau
R1285	3.42cde	3.33efgh	3.33fg	2.67efg	2.17cdef
R1286	3.83bc	2.83ghi	4.33de	2.00g	2.08cdef
R1287	3.00efg	3.67defg	3.67ef	2.17g	3.92a
R1288	2.33hi	2.33i	5.33c	2.67efg	2.33bcde
R1290	3.17def	5.67a	6.67ab	3.00def	1.92def
R1291	3.58cd	5.17ab	3.83ef	4.17b	2.42bcde
R1294	2.17i	4.00def	3.67ef	3.00def	2.50bcd
R1298	2.33hi	3.17fghi	6.83a	3.00def	2.00cdef
R1301	3.50cde	4.50bcd	5.08cd	3.33cde	3.00b
R1302	2.50ghi	4.17cde	3.67ef	2.67efg	1.83def
R1303	2.67fghi	3.50efgh	2.00i	2.17g	2.67bc
R1304	2.25i	3.67defg	3.00fgh	3.67bcd	1.75ef
R1305	5.33a	2.83ghi	3.50ef	2.33fg	2.00cdef
R1306	2.67fghi	3.67defg	2.17hi	3.83bc	2.25cde
R1308	2.83fgh	5.00abc	2.50ghi	4.17b	3.83a
R1309	2.50ghi	2.67hi	5.08cd	2.33fg	2.17cdef
R1312	4.33b	2.33i	4.33de	3.00def	2.25cde
KIBIS	3.17def	2.67hi	7.33a	3.33cde	1.50f
ROBIN	2.33hi	3.17fghi	5.83bc	5.00a	2.25cde
NJOROBWII	3.67cd	4.50bcd	4.25de	3.67bcd	2.00cdef

Site Variety	Mixing tolerance index				
	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	21.67j	36.67ghi	23.33fg	46.67fg	66.67d
R1286	36.67gh	63.33cd	36.67e	76.67bc	56.67ef
R1287	53.33f	23.33jkl	45.00bcd	73.33bcd	48.33fg
R1288	31.67hi	43.33fgh	40.00ed	70.00cd	66.67d
R1290	41.67g	46.67efg	36.67e	76.67bc	85.00b
R1291	58.33def	50.00ef	26.67f	73.33bcd	45.00g
R1294	75.00ab	26.67ijk	41.67cde	76.67bc	55.00f
R1298	83.33a	56.67de	26.67f	83.33b	85.00b
R1301	75.00ab	83.33a	41.67cde	96.67a	65.67de
R1302	56.67ef	23.33jkl	43.33cde	43.33gh	65.00de
R1303	63.33cde	16.67klm	51.67b	63.33de	45.00g
R1304	70.00bc	13.33lm	26.67f	56.67ef	65.00de
R1305	33.33gh	8.33m	48.33bc	63.33de	70.00d
R1306	15.00j	23.33jkl	38.33de	43.33gh	50.00fg
R1308	33.33gh	76.67ab	76.67a	56.67ef	45.00g
R1309	33.33gh	63.33cd	43.33cde	36.67gh	96.67a
R1312	36.67gh	33.33hij	41.67cde	13.33j	35.00h
KIBIS	36.67gh	70.00bc	23.33fg	23.33ij	71.67cd
ROBIN	66.67bcd	56.67de	16.67g	66.67j	80.00bc
NJOROBWII	23.33ij	43.33fgh	8.33h	33.33hi	55.00f

Means followed by the same letter in the same column are not significantly different at P<0.05 Level of significance. Means were separated using Fishers LSD.

3.3. Analysis of Hectolitre Weight, Flour Extraction and Starch Content

Hectolitre weight ranged from 59.19 to 80.14 Kg/hl, flour extraction 59.19 to 82.50% and starch 60.67 to 70.07% across the five study sites (Table 4). Highest hectolitre weight was recorded in R1302 grown in Naivasha while the lowest was recorded in R1286 grown in Eldoret. Eldoret site recorded averagely lower levels compared to the other four sites. The highest flour extraction levels were recorded in R1286 grown in Naivasha at 82.50% while the lowest was recorded in R1286 line grown in Eldoret at 59.19%. Overall Timau site recorded the highest starch content values while Njoro recorded the lowest (Table 4).

Hectolitre weight remains among the most essential and widely used grading system for cereals [5]. High hectolitre weight is preferred by both farmers and traders and is highly influenced by environment, variety, their interaction and management practices [6]. In our study the effect of variety and environment were evident, while G*E interaction was highly manifested especially in Eldoret where low levels were recorded for most of the varieties while the same varieties recorded higher levels when grown in Timau. These observations are in line with a study conducted [13], who concluded that hectolitre weight is determined mainly by genotype, environment and their interaction though the influence of genotype is of less importance. Varieties with high flour extraction are more desirable as this translates to higher incomes for millers. The effects of environment and G*E effect on flour extraction was clearly evident for wheat grown in Timau and Narok sites, which recorded slightly higher and lower levels compared to the other sites. This is in agreement with observation [17] who showed that varieties with high hectolitre weight also record high flour extraction rates but in most cases have low protein content. Wheat growing regions that experience high temperatures especially during grain filling, record low levels of starch content while areas with low temperatures record high starch levels. High temperatures decrease the activities of starch biosynthetic enzymes leading to accumulation of low starch content [25]. This was evident in Timau site which is much cooler at 15.2°C compared to the other sites which recorded the highest starch levels compared to those grown in Naivasha and Narok.

Table 4. Hectolitre and flour extraction analysis for wheat varieties grown in Eldoret, Naivasha, Narok, Njoro and Timau cropping sites.

Site Variety	Hectolitre				
	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	69.83efg	72.21o	77.42ab	71.00h	76.72bc
R1286	59.19j	77.87de	74.60fgh	73.17c	75.77gh
R1287	72.30a	76.61ij	74.77efg	73.27c	75.53hi
R1288	69.60fg	74.23n	73.55i	72.30fg	76.63bcd
R1290	69.30g	75.49m	77.77a	71.35h	75.48hi
R1291	69.88defg	77.89de	74.33h	72.05g	74.00k
R1294	71.50b	76.90hi	77.02b	71.17h	75.29i
R1298	62.64i	77.09gh	75.31c	70.47i	75.12ij
R1301	67.50h	77.87de	75.38c	74.33b	76.00efg
R1302	67.17h	80.14a	74.60fgh	72.78de	74.85j
R1303	67.53h	77.40fg	74.81def	74.48b	77.33a
R1304	71.00bc	78.23cd	75.20cd	73.11cd	76.81ab

Variety	Hectolitre				
Site	Eldoret	Naivasha	Narok	Njoro	Timau
R1305	70.52cd	77.26fgh	75.10cde	69.77j	76.20ef
R1306	70.33de	76.00kl	75.40c	72.61ef	75.11ij
R1308	69.50fg	78.41c	74.37gh	70.31i	74.25k
R1309	71.27b	77.61ef	73.30i	75.42a	74.07k
R1312	71.30b	78.42c	72.00k	74.29b	75.83fgh
KIBIS	69.30g	75.64lm	74.33h	70.39i	76.21def
ROBIN	70.50cd	76.30jk	72.83j	71.26h	75.87fgh
NJOROII	70.10def	79.30b	75.17cde	73.41c	76.33cde

Variety	Flour extraction				
Site	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	78.97cd	76.67c	72.20c	68.47ef	72.73a
R1286	78.10cde	82.50a	71.30d	70.50cde	70.50cde
R1287	76.90fg	65.73i	69.90e	74.30b	66.33i
R1288	75.20h	75.30d	72.67c	70.93cd	67.63hi
R1290	75.03h	70.27g	71.00d	69.27def	70.73bcd
R1291	76.07gh	76.67c	73.53b	68.33f	67.50hi
R1294	77.87def	72.53f	69.07f	69.17def	67.97gh
R1298	75.77gh	72.00f	69.20f	73.53b	69.17efg
R1301	75.53h	70.00g	67.10gh	70.13cdef	63.87j
R1302	79.20bc	79.00b	67.20gh	70.73cd	67.60hi
R1303	76.77fg	77.20c	70.00e	71.43c	72.20ab
R1304	75.30h	75.30d	67.60g	69.83cdef	67.67hi
R1305	80.30ab	73.67e	63.07j	66.00g	68.67fgh
R1306	79.07c	70.30g	61.10l	69.27def	71.77abc
R1308	78.43cde	68.53h	74.17a	70.03cdef	70.20de
R1309	77.30ef	75.33d	63.00j	69.27def	66.37i
R1312	79.07c	69.23gh	66.77h	71.20cd	69.97def
KIBIS	77.80def	73.07ef	63.23j	71.17cd	64.83j
ROBIN	80.50a	73.10ef	65.40i	79.13a	71.10bcd
NJOROII	70.30i	72.20f	62.20k	69.40cdef	70.40cde

Variety	Starch				
Site	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	65.27f	64.73jk	66.27e	63.27jk	67.97ef
R1286	62.73g	64.87ijk	63.43j	64.40ef	66.83h
R1287	66.47cd	65.47def	65.43gh	66.13a	67.33g
R1288	65.73e	66.63b	64.57i	64.27fg	67.17gh
R1290	65.06f	64.20l	65.80f	63.73hij	69.80a
R1291	65.67e	65.53de	65.73f	63.37ijk	66.03i
R1294	68.23a	65.20fgh	66.23e	63.80ghi	69.70ab
R1298	65.03f	65.47def	65.43gh	64.83de	68.93cd
R1301	66.50cd	64.93hij	66.13e	64.47ef	67.60fg
R1302	68.37a	65.67d	67.13c	65.83ab	70.00a
R1303	66.63cd	66.37bc	68.03b	65.67ab	68.63d
R1304	66.50cd	65.27efg	65.27h	64.90cde	67.93ef
R1305	65.67e	64.83jk	67.07c	65.47b	69.63ab
R1306	66.30d	64.63k	70.07a	65.40bc	67.60fg
R1308	66.70c	65.13ghi	66.73d	64.10fgh	66.33i
R1309	66.70c	67.53a	67.17c	65.80ab	68.77d
R1312	65.23f	66.53bc	65.53fgh	63.03k	67.30g
KIBIS	65.40ef	65.17gh	69.93a	60.67m	69.30bc
ROBIN	67.77b	67.53a	65.57fg	65.33bcd	69.30bc
NJOROII	65.27f	66.27c	66.30e	61.90l	68.07e

Means followed by the same letter in the same column are not significantly different at P<0.05 Level of significance. Means were separated using Fishers LSD.

3.4. Flour Water Absorption, Ash and Moisture Content

The flour water absorption, ash and moisture content were significantly (*p<0.05*) influenced by variety, site and interaction of variety × cropping site. Flour water absorption levels ranged from 47.17 to 75.27%, ash 0.50 to 1.26% and moisture content 11.67 to 16.10%. The lowest water absorption level was recorded in R1298 at 47.17% while the highest levels were recorded in R1290 and R1286 at 73.47 and 75.27% all grown in Eldoret site. Highest ash content was recorded for wheat grown in Eldoret while the lowest were recorded for those grown in Timau site. R1286 recorded the highest values at 1.26% for crop grown in Eldoret while R1290, R1294 and K.Ibis recorded the lowest levels at 0.50%

for crop grown in Timau (Table 5). Highest moisture level was recorded in R1285 for crop grown in Naivasha while the lowest levels was recorded in R1291 for crop grown in Njoro (Table 5).

Wheat flour containing high protein levels absorb high levels of water to ensure the flour is hydrated to the required consistency [10]. Except for Timau cropping site, all our results were in agreement with those of [4, 11] which showed that water absorption increases with increase in protein content. Ash determination is of great value to the miller

because it is a relatively accurate index of the separation of endosperm from pericarp and germ in any particular flour [20]. High rainfall after wheat physiological maturity negatively influences wheat quality due to increased severity of disease and enzyme activity [3]. From the moisture results obtained for all the varieties and lines across the five cropping sites, it is evident that their quality had not been affected by moisture since it was within the desired ranged when harvesting.

Table 5. Flour water absorption, ash and moisture content for wheat varieties grown in Eldoret, Naivasha, Narok, Njoro and Timau cropping sites.

Variety	Flour water absorption				
Site	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	68.20e	56.83l	63.50def	65.17c	66.30fgh
R1286	75.27a	64.83hi	63.77cde	67.97a	69.53c
R1287	69.80cde	66.93ef	62.63efg	64.87cd	67.30de
R1288	71.97bc	62.43k	60.73ij	67.40ab	65.97gh
R1290	73.47ab	66.47efg	64.50bcd	67.63ab	57.60m
R1291	71.17bcd	65.53gh	60.73ij	66.57b	64.53j
R1294	61.67gh	72.33b	59.83jkl	65.30c	59.07l
R1298	47.17j	69.70c	63.87cde	61.33h	64.40j
R1301	65.17f	73.63a	66.57a	63.97de	70.47b
R1302	63.77fg	73.33ab	62.37efgh	61.33h	66.93ef
R1303	61.23gh	64.07ij	57.67m	62.77fg	73.03a
R1304	63.60fg	66.63efg	61.30ghij	63.23efg	65.00ij
R1305	62.10gh	67.57de	65.53ab	63.33ef	66.37fgh
R1306	62.67fg	68.37d	60.13jk	64.00de	65.93gh
R1308	63.73fg	67.13ef	65.17abc	66.57b	67.00ef
R1309	63.67fg	66.00fgh	58.43lm	66.60b	66.57efg
R1312	68.47de	66.13fg	60.87hij	63.17efg	67.93d
KIBIS	60.23h	64.17ij	62.37efgh	62.20gh	63.20k
ROBIN	55.83i	66.07fg	59.07klm	63.33ef	65.60hi
NJOROII	64.93f	63.27jk	62.00fghi	67.03ab	62.83k

Variety	Ash				
Site	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	1.17abcd	1.07a	0.67cde	0.83a	0.60bc
R1286	1.26a	0.97bc	0.70bcd	0.77abc	0.63b
R1287	1.13abcde	0.80f	0.63de	0.80ab	0.63b
R1288	1.10bcde	0.87def	0.67cde	0.73bc	0.60bc
R1290	1.13abcde	0.90cde	0.70bcd	0.73bc	0.50d
R1291	1.03def	0.97bc	0.77ab	0.70cd	0.60bc
R1294	0.93fg	1.00ab	0.67cde	0.77abc	0.50d
R1298	1.23ab	0.93bcd	0.67cde	0.80ab	0.60bc
R1301	1.13abcde	1.07a	0.67cde	0.73bc	0.70a
R1302	1.00efd	0.87def	0.67cde	0.63d	0.60bc
R1303	1.10bcde	0.80f	0.67cde	0.70cd	0.70a
R1304	1.07cdef	0.80f	0.70bcd	0.70cd	0.60bc
R1305	1.03def	0.83ef	0.70bcd	0.70cd	0.60bc
R1306	1.13abcde	0.90cde	0.73abc	0.70cd	0.60bc
R1308	1.13abcde	0.90cde	0.80a	0.70cd	0.60bc
R1309	1.03def	0.80f	0.60e	0.70cd	0.60bc
R1312	1.07cdef	0.80f	0.60e	0.70cd	0.60bc
KIBIS	1.20abc	0.83ef	0.60e	0.77abc	0.50d
ROBIN	0.87g	0.90cde	0.60e	0.77abc	0.60bc
NJOROII	0.67h	0.60g	0.73abc	0.73bc	0.57c

Variety	Moisture				
Site	Eldoret	Naivasha	Narok	Njoro	Timau
R1285	13.17cdef	16.10a	13.03abc	11.83ef	13.37b
R1286	13.20cdef	13.17c	12.93abc	11.80ef	13.17cd
R1287	13.23bcde	12.77ef	13.07ab	12.23bc	13.23bc
R1288	13.17cdef	12.13l	12.70e	12.07cd	13.17cd
R1290	13.13def	12.20kl	12.83de	12.17bc	13.13cd

Variety	Site Moisture Eldoret	Naivasha	Narok	Njoro	Timau
R1291	13.10ef	12.20kl	12.97bcd	11.67f	13.23bc
R1294	13.27bcde	12.87ed	13.13a	12.07cd	13.17cd
R1298	13.10ef	12.50ghij	13.13a	12.13cd	12.90e
R1301	13.03fg	12.67fg	12.27f	12.23bc	13.0\d
R1302	12.90g	11.93m	12.90cd	12.17bc	12.77e
R1303	13.03fg	12.53ghi	13.13a	12.47a	13.33b
R1304	13.30bcd	12.43ij	12.87d	12.07cd	13.33b
R1305	13.20cdef	12.33jk	13.07ab	12.17bc	13.27bc
R1306	13.20cdef	12.73ef	13.03abc	11.93de	13.27bc
R1308	13.33bc	12.50ghij	13.17a	12.17bc	13.37b
R1309	13.53a	12.63fgh	13.13a	11.93de	13.57a
R1312	13.40ab	12.97d	12.87d	12.23bc	13.37b
KIBIS	13.33bc	12.43ij	13.13a	12.37ab	13.17cd
ROBIN	13.17cdef	13.73b	12.93bcd	12.17bc	13.13cd
NJOROII	13.23bcde	12.47hij	13.07ab	12.37ab	13.17cd

Means followed by the same letter in the same column are not significantly different at P<0.05 Level of significance. Means were separated using Fishers LSD

3.5. Biplot and Cluster Analysis for Proximate and Rheological Parameters

Cluster analysis for proximate and rheological parameters was done to analyse variance in the multiple variables among varieties and across the cropping sites. The first component was the cause of the most available variance while the second component justifies less variance. Multivariate comparison was done by comparing the Eigen values of PC1 and PC2 of principal component analysis (PCA) for both the genotypes and the quality traits across the five sites. The PC1 and PC2 accounted for 56.6% of the total variability (PC1=36.8% and PC2=19.8%). In the biplot, vectors of dough stability, dough development time, water absorption, zeleny, protein and gluten content were positively correlated (Figure 1A).
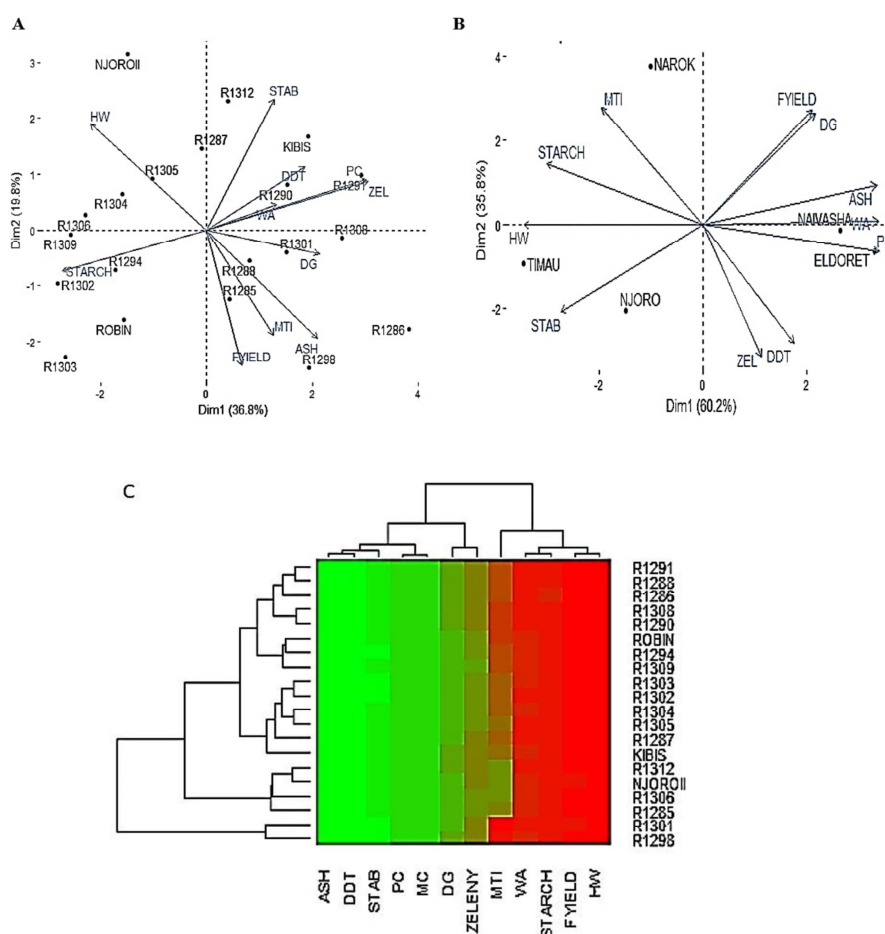

Figure 1. *A-PCA biplot analysis for genotypes and quality traits: B-PCA biplot analysis for site and quality traits and C-Heatmap and bi-dimensional clustering of quality traits and genotypes.*

This was in agreement with a study [18] which demonstrated that traits showing acute angles were positively correlated, whereas those which formed obtuse or straight angles are negatively correlated, and those with right angle have no correlation. In the upper right square comprising R1312, K.Ibis, R1290 and R1291 recorded the highest values for dough stability, dough development, water absorption, protein and zeleny content. R1312 and R1291 outscored the other two for the traits in that group. R1285, R1286, R1288, R1298, R1301and R1308 scored highest values for gluten, ash, mixing tolerance index and flour yield with R1286 recorded the highest values for the traits followed by R1298 and R1308. In the upper left square, Njoro BWII, R1287, R1304, R1305 and R1306 recorded overall highest levels for hectolitre weight with Njoro BWII outscoring all the others. In the lower left square, varieties/lines Robin, R1294, R1302, R1303 and R1309 highest values for starch with R1303 scoring the highest followed by Robin (Figure 1A).

Site and traits interaction showed high variation accounting for 96% (PC1=60.2% and PC2=35.8%) (Biplot). The high dough stability observed in Timau and Njoro cropping site could be attributed to almost similar weather conditions experienced in both the cropping sites. Narok cropping site recorded the highest levels for mixing tolerance index and starch while hectolitre weight recorded almost same levels as when the varieties were grown in Njoro cropping site. Eldoret and Naivasha cropping sites recorded the highest values for protein, gluten, zeleny, dough development time, water absorption, flour yield and ash content. Eldoret emerged as the best site followed by Naivasha, Narok, Njoro and finally Timau (Figure 1B).

Cultivars/ wheat line classification based on variety, quality traits a heat map was generated in combination with bi-dimensional hierarchical clustering using PCA Eigen values (Figure 1C). Horizontal clustering grouped the varieties into two sub clusters and four distinct clades indicating close similarity among the analysed varieties. The first sub cluster comprised of two lines R1298 and R1301 while the second sub cluster comprised of all the remaining lines. A closer look on the physiochemical and rheological properties revealed the two lines had almost similar properties which could be an indicator that they did not segregate during cross breeding. The second sub-cluster had two clades in which all the other lines and varieties clustered. The first clade was composed of R1285, R1306, R1312 and Njoro BWII cultivars/lines which recorded high levels of protein, gluten and zeleny values across the five study sites. The second clade also consisted of two released varieties K.Ibis and Robin which have been classified as hard red grains an indicator that the second cluster was composed of hard wheat varieties/ cultivars with superior bread baking properties.

The 20 study cultivars grouped into 2 clusters and 3 sub clusters indicating a closer but distinct relationship for the variables analysed. All the varieties/cultivars showed high stability for water absorption, flour yield, starch and hectolitre weight characterised by the solid red colour which clearly brings out the effect of genotypes on these parameters. Ash, dough development time, dough stability, moisture and protein content were also stable for all the varieties/ lines characterised by the solid green colour (Figure 1C).

4. Conclusions

Environments conditions play a major role in determining the quality of wheat and this influences the end use of wheat. As clearly observed from our data, when wheat lines and varieties were grown in regions/environments characterised by much lower temperatures and high rainfall throughout the year such as Timau, they recorded lower protein levels and enhanced starch levels compared to the same varieties when grown in areas with much warmer temperatures and slightly lower rainfall such as Narok. This trend was also observed for gluten content and zeleny content as shown by our data. Previous studies have shown that G*E interaction impacts heavily on the quality of wheat varieties, this was also clearly observed from results for protein, gluten and zeleny content across the five study sites. These results offer an insight of not only the varieties/lines with highest qualities but also the regions in which respective end use qualities can be maximized. Wheat grown in Timau would be best suited for making soft wheat products due to the low protein and gluten quantities while wheat grown in Njoro would be best suited for hard wheat products due to the high protein and gluten qualities

5. Recommendations

Baking quality screening of new lines/cultivars in wheat breeding programmes in different agroclimatic regions should be an important aspect integrated in the selection of individual lines/cultivars best suited for certain regions.

Acknowledgements

References

[1] Shiferaw B, Smale M, Braun H. J, Duveiller E, Reynolds M and Muricho G. Crops that feed the world. Past successes and future challenges to the role played by wheat in global food security. Journal of Food Security. 2013; 5: 291–317.

[2] Kamwaga J, Macharia G., Boyd L., Chiurugwi, T., Midgley, I., Canales C., Marcheselli M., Maina I. Kenya wheat production handbook, Morven Kester E. A Ltd. Nairobi 2016.

[3] Li Y, Wu Y, Hernandez-Espinoza N, Pena R. J. The influence of drought and heat stress on the expression of end-use quality parameters of common wheat, J. Cereal Sci. 2013; 57: 73-78. https://doi.org/10.1016/j.jcs.2012.09.014.

[4] Lopes M. S, Reynolds M. P, Jalal-Kamali M. R, Moussa M., Feltaous Y, Tahir I. S. A. et al. The yield correlations of selectable physiological traits in a population of advanced spring wheat lines grown in warm and drought environments, Field Crop Res. 2012; 128: 129-136. https//doi: 10.1016/j.fcr.2011.12.017.

[5] Schmiele M, Jaekel L. Z, Patricio S. M. C, Steel C. J, Chang Y. K. Rheological properties of wheat flour and quality characteristics of pan bread as modified by partial additions of wheat bran or whole grain wheat flour, Int. J. Food Sci. Technol. 2012; 47 (10): 2141–2150. https://doi.org/10.1111/j.1365-2621.2012.03081.x.

[6] Stathopoulos C. E, Tsiami A. A, David S. J, Dobraszczyk B. J. Effect of heat on rheology, surface hydrophobicity and molecular weight distribution of glutens extracted from flours with different bread-making quality, J. Cereal Sci. 2008; 47 (2): 134-43.https//10.1016/j.jcs.2007.03.002.

[7] Anjum F. M, Ahmad I, Butt M. S, Arshad M. U, Pasha, I. Improvement in end use quality of spring wheat varieties grown in different eras, Food Chem. 2008; 106 (2): 482-486. https://doi.org/10.1016/j.foodchem.2007.06.011.

[8] Rao V. K, Mulvaney S. J, Dexter J. E. Rheological characterisation of long and short mixing flours based on stress-relaxation, J. Cereal Sci. 2000; 31 (2): 159-171. https://doi.org/10.1006/jcrs.1999.0295.

[9] AACC. Approved methods of the American association of cereal chemists, 10th edn American Association of Cereal Chemists, St. Paul, MN, USA 2000.

[10] Saleem N, Ahmad M, Wani SA, Vashnavi R, Dar Z. A. Genotype environment interaction and stability analysis in Wheat (*Triticum aestivum* L.) for protein and gluten contents. Sci. Res. Essays. 2015; 10 (7): 260-265. https://doi.org/10.5897/SRE2015.6180.

[11] Johansson E and Prieto-Linde M. Influence of nitrogen application rate and timing on grain protein composition and gluten strength in Swedish wheat cultivars, J. Soil Sci. Plant Nut. 2004; 167: 345–350. https//:doi: 10.1002/jpln.200320332.

[12] Mutwali N. A, Abdelmoniem I, Yasir S. A, Isam A. M. Effect of environment and genotypes on the physicochemical quality of the grains of newly developed wheat inbred lines, J. Food Sci. 2016; 4 (4): 508-520. https://doi.org/10.1002/fsn3.313.

[13] Maria S, Tadeusz A, Zofia B, Zygmunt K, Hideyuki K, Malgorzata M, Boguslawa L, Wiktor O, Bolesław S, Karolina K. Effect of genotype, environment and their interaction on quality parameters of wheat breeding lines of diverse grain hardness, Plant Prod ci. 2012; 15 (3): 192-203. https://doi.org/10.1626/pps.15.192.

[14] Kucerova J. The effect of sites and years on the technological quality of winter wheat grain, Plant Soil Environ. 2005; 51 (3): 101-109.

[15] Khatkar B. S. Effect of mixing time on dynamic rheological properties of wheat flour dough, J. Food Sci. Technol. 2004; 41: 320-322.

[16] Kariithi S. N, Abwao S. I, Ndung'u J. N, Njau P. Nutritional, rheological and organoleptic properties of whole meal flour prepared from stem rust resistant wheat varieties released in Kenya, WJAR. 2016; 4 (6): 173-182. https//doi: 10.12691.

[17] White E and Watson S. An investigation of the relationship between hullability and morphological features in grains of four oat varieties, Ann. Appl. Biol. 2010; 156 (2): 281-295. https://doi.org/10.1111/j.1744-7348.2009.00386.x.

[18] Girma F, Haile D, Reta D, Mengistu B, Seyfudin M, Firehiwot G. Grain hardness, hectolitre weight, nitrogen and phosphorus concentrations of Durum wheat (Triticum turgidum L. var. Durum) as influenced by nitrogen and phosphorus fertilisation, World Appl. Sci. J. 2012; 20 (10): 1322-1327. https// doi: 10.5829/idosi.wasj.2012.20.10.622.

[19] Kaya Y and Akcura M. Effects of genotype and environment on grain yield and quality traits in bread wheat (T. aestivum L.), J. Food Sci. Technol.2014; 34 (2): 386-393. https// doi: 10.1590/fst.2014.0041.

[20] Mohan D and Gupta R. K. Relevance of physiological efficiency in wheat grain quality and the prospects of improvement, Physiol Mol Biol Plants. 2015; 21 (4): 591-596. https//.doi: 10.1007/s12298-015-0329-8.

[21] Yan S. H, Yin Y. P, Li W. Y, Liang T. B, Li Y, Wu Y. H, Wang P, Geng Q. H, Dai Z. M, Wang Z. L. Effect of high temperature during grain filling on starch accumulation, starch granule distribution, and activities of related enzymes in wheat grains, AAS. 2008; 34: 1092-1096. DOI: 10.3724/SP.J.1006.2008.01092.

[22] Kalnina S, Rakcejeva T, Kunkulberga D, Galoburda R. Rheological properties of whole wheat and whole triticale flour blends for pasta production, Agron. Res. 2015; 13 (4): 948-955.

[23] Constantinescu G, Dabija A, Buculei A, Rebenciuc I. Evaluation of cereal cultivar impact on bread quality, J. Agroaliment. Processes Technol. 2011; 17 (4): 473-476.

[24] Sakhare S. D and Inamdar A. A. The cumulative ash curve: a best tool to evaluate complete mill performance, J Food Sci Techno. 2011; 51 (4): 795-799. https//doi: 10.1007/s13197-011-0549-z.

[25] Bhatia V. S, Yadav S, Jumrani K, Guruprasa K. N. Field deterioration of Soybean seed: Role of oxidative stress and antioxidant defense mechanism, Plant Biol. 2010; 32 (2): 179-190.