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RHEOLOGICAL PROPERTIES IN RELATION TO BREAD MAKING QUALITY OF ETHIOPIAN IMPROVED BREAD WHEAT (Triticum Astivum L) CULTIVARS GROWN AT KULUMSA, ARSI, ETHIOPIA

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ABSTRACT

With the emergence and increase of food processing industries utilizing bread wheat as a raw material, information on rheological quality characteristics to match end use quality is very essential. In line with this, the current study was initiated with objectives to characterize the rheological properties in relation to bread making quality of Ethiopian improved bread wheat varieties. The grain of 23 bread wheat cultivars was collected from Kulumsa Agricultural Research Center (KARC) from harvest of 2012. Collected samples were analyzed for farinographic, fermentometric and Alveographic quality characters. Significant variations in all parameters considered were observed among the cultivars except CO2 retention coefficient (RC). Most of the wheat genotypes fall from good to best dough stability time (DST) while 30% of them scored DST below the minimum requirement (<4 min) for leavened bread production. Deformation energy (W) also varied from the highest (W=324.79 x 10-4J) for Pavon 76 (the standard) to the lowest (77.85 x 10-4J) Dinkinesh. Amount of CO2 gas produced and retained by all the dough of bread wheat cultivars were high while TV obtained by Gassay and Katar are greater. Considering most rheological quality characters, bread wheat cultivars Simba, Pavon 76, sofumar, Kakaba, Sirbo and Kbg-01 can be considered as having superior bread making quality. Cultivars Dinkinesh, Mellenium, Mada Walabu, Alidoro, Tay and Digalu are bread wheat cultivars suitable for making soft wheat products.

Keywords: Rheology, Water absorption: Retention Coefficient, Configuration ratio

Introduction

Wheat is unique in its property that wheat flour alone has the ability to form dough that exhibits the rheological properties required for the production of leavened bread. Dough is usually leavened by bread yeast, which ferment dough sugar and produces mainly carbon dioxide and alcohol (Bratovanova, 1996). Eventhogh, bread-making quality of wheat flour is determined by the quantity and quality of its proteins, the dough makeup process is the key step in producing

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quality dough and, thereby, quality crumb texture and structure. This process consists of a series of steps including weighing, mixing, fermentation, dividing, molding, and panning.

During dough mixing, wheat flour is hydrated and the gluten proteins are transformed into a continuous, cohesive viscoelastic gluten protein network. The variation in mixing time as a function of protein quality is very dependent on the cultivar and protein level. In this context, gluten-cross linking enzymes such as Transglutaminase can actively contribute to confer the functional properties of dough and is able to improve the functionality of flour proteins through the formation of large insoluble polymers (Caballero *et al*, 2005).

Most bread-making processes require strong extensible dough to provide best bread quality. In contrast, weaker but extensible dough is required for most types of biscuits and cookies (Walker & Hazelton, 1996). That means fitness of wheat flour for making intended end product depends largely on the particular dough rheological properties such as stability, extensibility, development time, water absorption, fermentation properties and others. Rheological properties of wheat flour which is measured while mixing and developing into dough can be made by farinograph, farmantograph, alviograph and other dough rheological measuring instruments. The farinograph measures the energy required to mix dough as it progresses through water absorption, dough development and dough breakdown. Water absorption in wheat flour which increases linearly with protein content, although the slope of the regression curve is determined by the genotype and is regarded as a function of protein content, damaged starch, pentosans and gluten strength.

The flour with higher water absorption gives more favorable end products because it improves the texture and grain of the bread (Simon, 1987). Rheological properties in wheat flour are particularly sensitive to the amount of water; the effect is more visible with a decrease in the amount of water (Eliasson & Larsson, 1993) which in turn depends on protein quality and quantity. The low protein wheat, (less than 12%) require long mixing time and certain reducing agents to shorten the mixing time (Hoseney, 1986) even though direct correlation between flour protein and mixing strength does not always exist. Kunerth and D, Appolonia (1985) evaluated over 240 hard red spring wheat and reported little or no relationship between wheat protein content and farinograph peak mixing time, dough stability and mixing tolerance index.

Alveographic parameters like dough elasticity (P), extensibility (L) and dough deformation energy (W) obtained from an alveograph also describe the viscoelastic properties of dough (Atwell, 2001). The alveograph tenacity (AlvP) measures dough tenacity as related to the maximum pressure required for the deformation of the dough, while the alveograph extensibility

(AlvL) indicates the extensibility of the curve and AlvP/L is the configuration ratio of the curve. The swelling index (AlvG) is the square root of the essential volume of air required to rupture the bubble and is primarily a measure of dough extensibility. The AlvW value is regarded as the measure of flour strength (Faridi & Rasper, 1987). Extensive research done on hard wheat and soft wheat (Rasper *et al.*, 1986) has shown that processing behaviour of wheat flour can be determined by the alveograph and suitability for specific end-use can be evaluated. Variation in AlvL and AlvW is more influenced by the environment than AlvP, due to the influence of protein content on AlvL and AlvW (Ames *et al.*, 2003).

On the other hand, fermentation is an important step in the bread making process, where the expansion of air bubbles previously incorporated during mixing provides the characteristic aerated structure of bread, which is central to its appeal (Dobraszczyk et al., 2000). The rising ability on fermentation of wheat dough can be accessed through ferment metric parameters. These includes, the maximum dough development height (Hm), total time elapsed to reach maximum dough development height (T1), maximum height at the end of the test (h), the total volume of CO_2 generated during fermentation process (Vt), retention coefficient (Cr and the time when gas starts to escape from the dough (Tx). On the other hand, H'm: maximum height of gaseous release curve, (T1’) time spent to reach H'm can be assessed through dough development and gaseous release curves. Few studies have been made on the changing rheological properties during fermentation and baking.

Although these quality tests are clearly important in bread making, most grain, flour and dough quality tests are based only on physic-chemical characteristics of Ethiopian bread wheat. Even physico chemical quality reports are available for few released wheat cultivars (Senayit, 2007) in relation to bread making quality. However, the quality parameters evaluated vary from cultivar to cultivar and releasing institutions. So the objective of the study is to classify Ethiopian improved bread wheat varieties on the bases of some rheological quality characters in relation to bread making quality.

MATERIALS AND METHODS

Description of Bread Wheat Grain Source Area

The grain of 23 bread wheat varieties namely (Aldoro, Bolo, Danda, Digelu, Dinkinesh, Dodota, Enseno-1, Galil, Gassay, Hawi, Kakaba, Katar, Kbg-01, Kubsa, Madda walabu, Milennium, Simba, Sirbo, Sofumer, Sula, Tay and Tossa) including the control (Pavon-76) was collected from Kulumsa Agricultural Research Center (KARC) from field activity carried out during the

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2011/12 main cropping season. Kulumsa Agricultural Research Center is located in Arsi Zone of Oromia Regional State of Ethiopia and lies at an altitude of 2200 masl., 8°10'N latitude, 39°10'E longitude, representing a medium altitude and moderate rainfall (830 mm/annum). Sample preparation and milling was carried out using (UDY laboratory mill, model 3010 Udy corporation, USA) after conditioning at 16% moisture content and kept for 48 hrs at room temperature and made to pass through 500μm standard laboratory sieve.

Rhological Quality Parameters

The flour of the test genotypes was analyzed for the following quality characters using standard protocols. Alveographic parameters were determined according to AACC, (2000) Method 54-30A using ChOpin Alveograph (ChOpin SA model MA82, France) by mixing 250 g flour with 2.5% NaCl. Chopin alveograph parameters; dough elasticity (P = Pav X 1.1 mm), extensibility (L, mm) and deformation energy of the dough (W= 6.54 × S) was computed to evaluate the gluten strength.

Farinograph test was done by a constant dough weight method as described in AACC (2000) Method 54-21 at 30±0.2°C using a 300g mixing bowel at a mixing speed of 63 rpm. using Farinograph (Brabender-E® OHG, Duisburg, type 827504 Germany). From the resulting curve farinogram indices were measured by the farinogram software (Brabender® Farinogram version: 2.3.6, 1996-2005, Microsoft Corporation). These includes:- Water absorption (WAB), Dough development time (DDT) (min), Stability Time (DST) (min), Mixing tolerance index (MTI) (FU), Time to break down (BDT) (min), Farinograph quality number (FQN) was computed.

Rheofermentometer values was done by taking 250 g flour, 7 g instant dry (Saf) bakery yeast, 5 g salt (NaCl = analytical grade) and distilled water using CHOPIN F3 Rheofermentometer (CHOPIN, France) by following the instrument instruction manual (CHOPIN, 2001). At the end of fermentation, the maximum dough development height (Hm), the total volume of CO_2 (Vt), retention coefficient (Cr), maximum gaseous release curve height (H'm), the time at which dough attains the maximum height (T1) and the time when gas starts to escape from the dough (Tx) was determined from the resulting dough development and gaseous release curves.

Statistical Analysis

Statistical Analysis System (SAS) was used for the analysis of variance (ANOVA) using General Linear Model (GLM) procedure (SAS Institute, 2001) SAS version 9.1. The significance differences between mean values (mean separation) was expressed by Least Significant

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Difference tests (LSD) method at P<0.05 and P<0.01. Pearson correlation was used to see the association among measurable and measured characters

RESULTS AND DISCUSSION

Farinograph provides information on the amount of water required for dough to reach a definite consistency and on general profile of the mixing behavior of the dough. Farinograph water absorption (WAB), dough development time (DDT), dough stability time (DST), mixing tolerance index (MTI) and dough time to break (TTB) (dough weakening time) presented in (Table 1.) have shown significant variation (P<0.05) among bread wheat genotypes. Farinograph WAB corrected to 500 FU at 14% moisture content had ranged from the smallest 54.53% (Bolo) 65.30% (Simba). Most (52.2%) of the bread wheat cultivars under this test showed significantly (P<0.05) higher (>60%) WAB (corrected for 500 FU) which match with experiments done by Ermias, 2005, Lin 2003 and Naeem *et al.* 2009 which vary from 54.47% to 68 % for experiments done in different countries on different wheat lines.

The flour from strong wheat cultivars possessed the ability to absorb and retain larger amounts of water (Pyler, 1988) and that having low WAB produces dough low in moisture which on baking may produce dry and stiff breads of poor quality. Stronger wheat flours have the ability to absorb and retain more water as compared to weak flours. Higher water absorption is required for good bread characteristics, which remain soft for a longer time (Simon, 1987). According to report of USDA, (2007), good bread wheat for better bread making should have WAB value above 60BU for white winter wheat and above 62BU for red winter wheat. In this study, more than 52% of the test cultivars had WAB values above 60% which make them suitable for bread making.

Dough development time which is the measures of relative gluten strength of flour or semolina Zounis and Quail, 1997 and Narasimha, (2008), varied from 1.87 (Alidoro) to 10.77 min for Sofumer. Bread wheat varieties, Sofumer, Hawi, Dodota, Kgb-01 and Katar got higher DDT (10.77, 9, 9.67, 9.50, 8.97 and 8.13min) respectively while wheat verities; Tay, Millennium, Bolo and Alidoro have got shorter DDT (3.57, 3.67, 2.73 and 1.87min) respectively. This result is in the same range with experiments done by Rafiq (2009) on three Canadian bread wheat varieties. In general, higher DDT reflects strong flour while lower value is an indication of weak gluten. From the current study, correlation table

Table 1. The Farinograph values of the 23 bread wheat cultivars

Varity	*WA (%)*	*DT(min)*	*ST(min)*	*TI(FU)*	*TB(min)*
Aidoro	55.33 ± 0.06^{l}	1.87 ± 0.15^{o}	5.87 ± 0.15^{ef}	19.67 ± 0.58^{m}	8 ± 0.26^{g}
Bolo	54.53 ± 0.12^{m}	2.73 ± 0.45^{n}	7.50 ± 0.20^{d}	27.00 ± 1.00^{m}	11.67 ± 0.12^{d}
Danda'a	60.33 ± 0.21^{g}	6.10 ± 0.10^{fgh}	3.83 ± 0.31^{h}	87.33 ± 2.08^{ef}	7.10 ± 0.10^{i}
Digalu	54.73 ± 0.06^{m}	5.47 ± 0.25^{ijk}	6.37 ± 0.31^{e}	38.67 ± 3.06^{k}	9.17 ± 0.31^{f}
Dinkinesh	64.00 ± 0.00^{b}	4.47 ± 0.06^{l}	2.43 ± 0.60^{ij}	103.67 ± 2.08^{d}	4.97 ± 0.06^{k}
Dodota	56.50 ± 0.10^{k}	9.50 ± 0.20^{bc}	13.93 ± 0.76^{a}	20.33 ± 1.15^{l}	18.67 ± 1.22^{a}
Enseno	61.60 ± 0.10^{e}	6.47 ± 0.55^{fg}	2.80 ± 0.20^{i}	78.67 ± 1.53^{g}	7.90 ± 0.20^{hg}
Galil	62.63 ± 0.06^{c}	5.43 ± 0.12^{jk}	1.93 ± 0.12^{jk}	134.67 ± 4.04^{c}	6.13 ± 0.12^{j}
Gassay	61.97 ± 0.12^{d}	6.67 ± 0.15^{f}	5.83 ± 0.25^{ef}	87.67 ± 3.06^{ef}	8.07 ± 0.21^{g}
Hawi	60.17 ± 0.29^{g}	9.67 ± 0.42^{b}	9.93 ± 0.23^{b}	43.33 ± 2.52^{j}	12.63 ± 0.25^{c}
Kakaba	60.90 ± 0.10^{f}	6.60 ± 0.26^{fg}	7.50 ± 0.53^{d}	46.33 ± 3.06^{ij}	9.33 ± 0.25^{f}
Katar	60.30 ± 0.10^{g}	8.13 ± 0.78^{d}	5.33 ± 0.15^{fg}	50.33 ± 3.06^{i}	10.90 ± 0.26^{e}
Kbg-01	59.63 ± 0.15^{h}	8.97 ± 0.21^{c}	10.17 ± 0.42^{b}	38.67 ± 2.52^{k}	12.30 ± 0.20^{c}
Kubsa	59.10 ± 0.10^{j}	5.13 ± 0.12^{k}	2.53 ± 0.12^{i}	86.67 ± 1.53^{f}	6.27 ± 0.06^{j}
M.Walabu	61.10 ± 0.10^{f}	6.03 ± 0.76^{ghi}	5.07 ± 0.40^{g}	57.67 ± 2.52^{h}	8.43 ± 0.06^{g}
Millinium	62.13 ± 0.06^{d}	3.67 ± 0.15^{m}	1.77 ± 0.06^{k}	146.00 ± 1.00^{b}	4.53 ± 0.12^{k}
Pavan	62.80 ± 0.10^{c}	6.57 ± 0.15^{fg}	4.93 ± 0.83^{g}	78.67 ± 1.53^{g}	8.20 ± 0.10^{g}
Simba	65.30 ± 0.17^{a}	4.53 ± 0.15^{l}	1.60 ± 0.10^{k}	178.33 ± 3.06^{a}	5 ± 0.10^{k}
Sirbo	59.40 ± 0.00^{i}	7.63 ± 0.21^{de}	8.43 ± 0.21^{c}	45.00 ± 2.00^{j}	10.77 ± 0.15^{e}
Sofumer	59.80 ± 0.10^{h}	10.77 ± 0.25^{a}	14.17 ± 0.15^{a}	27.33 ± 2.08^{l}	16.60 ± 0.46^{b}
Sula	59.30 ± 0.17^{ij}	7.53 ± 0.58^{e}	8.37 ± 0.29^{c}	46.67 ± 3.51^{ij}	10.40 ± 0.30^{e}
Tay	59.30 ± 0.10^{ij}	3.57 ± 0.23^{m}	2.60 ± 0.00^{i}	105.33 ± 0.58^{d}	4.80 ± 0.17^{k}
Tossa	61.53 ± 0.31^{e}	5.87 ± 0.06^{hij}	5.37 ± 0.23^{fg}	91.33 ± 3.51^{e}	7.40 ± 0.10^{hi}
G. Total	***60.10±2.73***	***6.23±2.24***	6.01±3.56	***71.28±41.61***	***9.10±3.57***
LSD(0.05)	0.2256	0.5659	0.59	3.9769	0.5331
CV	*0.23*	*5.52*	5.93	*3.39*	*3.57*

Values with the different letters within a column are significantly different ($p < 0.05$), WAB = water absorption (%), DDT = dough development time (min), DST = dough stability time (min), DBT = dough break down time (min), FQN = farinograph quality number, cv = coefficient of variation, LSD= least significance deference, values are mean ± standard deviation.

According to report of USDA (2007), bread wheat for better bread making should have farinograph DDT between four and eight minutes for red winter wheat. In this study, 82.6% of

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the test cultivars had DDT, which falls between 4 and 8 minutes. From this, it is clear that most of the test cultivars were suitable for bread making.

The maximum DST in minutes was recorded for wheat variety Sofumar (14.17min) followed by Dodota (13.93min) while the lowest DST was for Simba (1.60mn) followed by Millennium (1.77min) and Galil (1.93min). Most of the verities (43.48%) have dough stability time between 5 and 10 min, 13.04% above 10 and 30.43% blow 5min. Dough stability indicates the time when the dough maintains maximum consistency and is a good indicator of dough strength. Good quality dough has stability of 4–12 min while satisfactory DST is about 6 min (Kulhomäki and Salovaara, 1985). For the industrial dough mixing too short or too long mixing time is not desirable. Flours having short mixing time are problematic in baking technology that involves long fermentation, as they are less tolerant to over-mixing and over fermentation (Koppel and Ingver, 2010).

The dough stability time obtained in this study were in close consistent with study done by Rafiq (2009) which fall between 2.62 and 11.40 min for 16 bread wheat cultivars grown under Pakistan condition. According to Koppel and Ingver (2010) DST varies from 1.3 to 9.6 min where 82.6% of the cultivars fall in the current study. Most of the wheat cultivars from the current study fall from good to best DST ranges eventhough 30% of them scored DST below the minimum requirement (<4 min) for leavened bread production. Cultivars Galil, Millennium and Simba were bread wheat verities with the lowest dough stability time.

Dough mixing tolerance index varied from the highest 178.33 (Simba) to 19.67 (Alidoro). Dough mixing tolerance index of Simba was significantly ($P<0.05$) different from the rest (i.e appeared weak). Dobraszczyk (2004) stated that, degree of softening (MTI) for strong flour is 70 (FU). But, for weak flour, degree of softening is 135 FU. Yamamoto *et al*. (1996) also reported that for soft wheat, MTI of 90-190 FU. Generally, the higher the mixing tolerance index value, weaker is the flour (Naeem *et al*., 2009). The Farinogram (MTI) data reordered for flour of 17 bread wheat cultivars in the current study was less than 90, which make them to be class of strong and medium strong wheat flour and the rest or 6 of them resembles that of soft wheat character

The TB ranged from 4.53min (Millennium) to 18.67min (Dodota). Dodota (18.67 min) variety scored the highest and significantly different ($P<0.05$) TB value from the rest of the cultivars followed by Sofumer (16.60 min), Hawi (12.63 min) and Kgb-01 (12.30 min) from the top. On the other hand the smallest results were recorded for bread wheat cultivars Tay (4.80 min), Millennium (4.53 min), Dinkinesh (4.97 min) and Simba (5.01 min) which were not statistically different ($P>0.05$) form each other.

Alveographic parameters

The Chopin alveograph parameters indicated (table 2) a wide range of dough strength among the bread wheat cultivars. Analysis of variance showed significant differences ($P < 0.05$) among bread wheat cultivars for Chopin alveograph elasticity (P), dough extensibility (L), deformation energy (W) and configuration ratio (P/L). The flour gluten quality measured with Chopin alveograph (Table 2) appeared to vary from low 67.17 (Kbg-01) to high 122.99 mm (Hawi) as far as dough elasticity was concerned. The elasticity value for variety Hawi was significantly higher and followed by Katar, Dodota, Pavon 76 and Millennium. Significantly the highest L value on the other hand was recorded for bread wheat variety Kakaba (98.00 mm) followed by Sirbo (63.28 mm) and Pavon 76 (62.68mm). Cultivars Alidoro, Tay and Dinkinesh having L values 25.33, 26.33 and 27 mm respectively, had shown significant and low extensibility values. ChOpin alveograph deformation energy (W) also varied from the highest (W=324.79 x 10^{-4}J) for Pavon 76 followed by (W=298.14 x 10^{-4}J) for Kakaba and (W=242.57 x 10^{-4}J) for Sula to the lowest (77.85 x 10^{-4}J) Dinkinesh. Elasticity to extensibility ratio (P/L) showed high significant difference ($P<0.001$) among bread wheat varieties. The highest P/L value was recorded for Hawi (4.35 mm) followed by Tay (3.66 mm) and the lowest for Kakaba (1.02 mm) and Kbg-01 (1.51mm).

According to Maghirang, (2006), alveographic elasticity (P) varied from 73 to 145 mm for Hard red winter wheat (HRW) and from 66 to 159 mm for Hard red spring (HRS). Alveographic tenacity (L) also varied from 38 to 134 mm for HRW and 66 to 191 HRS. Work (W) value ranges were 109–793 x10^{-4}J for HRS wheat flour and 208–573 x10^{-4} J for HRW wheat flour. Configuration ratio (P/L) ranges from 0.36 to 2.21 for HRS wheat and 0.48–3.94 for HRW wheat who have done his experiment on 100 HRW and 98 HRS bread wheat genotypes. Hruškova and Famĕra, (2003), also indicated that alveograph energy varied from 161.10^{-4}J) to 271.10-4 J), elasticity from 58-99 mm, extensibility from 71-109 mm, and configuration ratio (P/L) from 0.6 to 1.12. The results from the current study were in close consistency with the earlier findings.

Dubois *et al*. (2008), reported that strong flours are characterized by high W and low to medium L values. Particularly, the suitability of certain wheat/flour for intended purpose on the basis of alveogram values differ between different countries and is influenced by the availability of raw material of certain quality. A standard wheat quality have alveograph elasticity (P) values for range 60-80 mm, very good wheat quality 80-100 mm, whilst extra strong wheats are characterized by P value higher than 100 mm. Moreover, the L of 100 mm is generally considered as good, although some applications require higher values (e.g. biscuit production). Wheat suitable for bread production should exhibit P/L value lower than 0.80. Concerning the interpretation of W value good quality wheat and improving wheat are characterized by W value in the range 220-300 and higher than 300, respectively (Bordes *et al.,* 2008).

Bread wheat flour having W value more than 300 is strong, greater than 220 is superior bread flour, more than 160 is bread flour and more than 115 is biscuit flour (ChOpin 2000). However, in case of P/L ratio, wheat flour having more than 0.6 can be appropriate for bread making. According to Faridi *et al.,* (1987) one of the basic factors for wheat classification is the alveograph W parameter. In Europe, flour with W value between 130 and 160 can be classified as useful for bread production, 160 to 250 as an improver of baking properties and above 250 as flour with strong gluten. Accordingly, bread wheat cultivars Dinkinesh, Alidoro and Tay are the one with the lowest W value and classified as biscuit flour varieties. Pavon 76 and Kakaba can be used as improver flours and the rest cultivars fall under best to standard bread flours. Based on P/L values, all the bread wheat values got configuration ratio (p/L) around normal to strong dough range. Bread wheat varieties, Digalu, Gassay, Kbg-01, Pavon 76, Sirbo and Tossa are those with optimal P/L values. On the bases alveographic elasticity (P) and extensibility, almost all bread wheat cultivars under current test fall under good to strong bread wheat flour.

Table 2. Alveographic quality parameters of the 23 bread wheat varieties

Variety	P(mm)	L(mm)	W(x 10^{-4}J)	P/L
Alidoro	91.37±0.39^{hij}	27.00±2.60^{j}	116.71±19.57^{m}	3.40±0.31^{bc}
Bolo	101.17±8.82^{cde}	45.00±3.00^{d}	181.68±13.35^{ghi}	2.25±0.06^{i}
Danda'a	118.15±1.91^{ab}	40.67±1.53^{d}	196.05±2.84^{efg}	2.91±0.11^{def}
Digalu	84.59±0.85^{kl}	51.17±3.88^{c}	161.12±9.23^{jk}	1.66±0.12^{jk}
Dinkinesh	78.76±1.00^{l}	26.33±2.08^{j}	77.85±0.13^{n}	3.00±0.25^{efg}
Dodota	115.31±5.19^{b}	40.67±3.79^{d}	208.86±10.36^{def}	2.85±0.30^{fg}
Enseno	106.11±8.75^{cd}	39.83±2.25^{ef}	210.27±11.18^{de}	2.66±0.07^{gh}
Galil	88.55±1.94^{ijk}	32.67±3.51^{hi}	136.32±7.47l^{m}	2.73±0.24^{fgh}
Gassay	100.76±2.14^{def}	53.83±1.53c	220.01±14.84^{d}	1.87±0.08^{j}
Hawi	122.99±3.34^{a}	28.33±1.53^{ij}	184.44±10.92^{ghi}	4.35±0.14^{a}
Kakaba	99.65±3.47^{ef}	98.00±4.58^{a}	298.14±35.64^{b}	1.02±0.07^{l}
Katar	115.30±1.57^{b}	35.83±1.26^{fgh}	197.51±6.83^{efg}	3.22±0.12^{cd}
Kbg-01	67.17±2.11^{m}	44.50±3.77^{d}	148.55±15.90^{kl}	1.51±0.09^{k}
Kubsa	90.63±3.40^{hij}	39.67±1.94^{ef}	135.22±10.26^{lm}	2.29±0.20^{i}
M.Walabu	94.95±5.48^{fgh}	37.67±4.16^{efg}	173.96±16.65^{hij}	2.53±0.14^{hi}
Millennium	106.47±3.83^{cd}	33.67±4.51^{gh}	189.61±5.45^{fgh}	3.19±0.33^{cde}

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Pavon 76	106.74±1.72^{c}	62.68±1.06^{b}	324.79±6.25^{a}	1.70±0.01^{jk}
Simba	95.43±0.34^{e-h}	38.00±3.77^{efg}	160.58±0.16^{jk}	2.53±0.25^{hi}
Sirbo	99.34±1.37^{ef}	63.28±0.64^{b}	227.07±0.81^{cd}	1.57±0.01^{k}
Sofumar	95.55±0.74^{e-h}	36.00±0.00^{fgh}	166.07±2.19^{ijk}	2.65±0.02^{gh}
Sula	97.78±3.39^{efg}	39.00±0.00^{ef}	242.57±3.00^{c}	2.51±0.09^{hi}
Tay	92.56±1.30^{ghi}	25.33±1.26^{j}	119.48±1.67^{m}	3.66±0.22^{b}
Tossa	85.90±1.61^{jk}	50.12±1.92^{c}	194.67±3.85^{efg}	1.72±0.10^{jk}
Mean	**98.05±13.21**	**43.01±15.77**	**185.72±55.86**	**2.51±0.79**
LSD (P<0.05)	**5.96**	**4.51**	**19.79**	**0.29**
CV	**3.70**	**6.38**	**6.48**	**6.93**

Values with different letter within a column are significantly different ($p < 0.05$), P = dough resistance to deformation; L = extensibility, P/L= configuration ratio, W = Deformation work, LSD= least significance difference, CV= coefficient of variation.

Rheofermentometric parameters

The rheofermentometer gives two curves, namely dough development curve (DDC) which shows maximum height of the dough during development, time to maximum height and height of the curve at the end of the test. The second curve is the gaseous release curve (GRC) gives total volume of gas produced due to yeast fermentation activity, produced gas retention volume, time to maximum volume, lost gas volume, and retention coefficient.

Dough Development Curve Results

The maximum height (Hm) of dough development curve, which predicts the rising ability of dough of different wheat varieties, were given in table 3 have shown high significant differences ($P<0.01$) in Hm among the cultivars tested. The dough development height varied from 27.07mm (Alidoro) to 13.17mm (Hawi). The wheat cultivars Alidoro and Kakaba were ranked at top regarding Hm eventhough they were statistically at par. The wheat cultivars Mada Walabu, Hawi, Enseno and Dodota were ranked at the bottom and were significantly different among each other for the Hm value.

Maximum height of dough development curves of dough for wheat cultivars under this test is in close relation with the results obtained by Habtu, (2010) which varied from 19.60 to 26.47mm for five Ethiopian bread wheat varieties. The dough development curve for the cultivars indicated that Hm were below the height of other typical curves, which have been carried out

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with the ChOpin protocol (ChOpin, 2000). According to this protocol, a flour to be considered as good baking quality should possess development height (Hm) >40 mm and also good tolerance during fermentation. The lower in Hm of fermenting dough from the current study was most probably due to the nature of the genotypes and the higher extraction rate as it was sifted through (< 710µm) diameter sieve.

The height of dough at the end of the test (h) had varied from 26.57 mm (Kakaba) to 13.83 mm (Hawi) (Table 3)**.** The result showed that there was significant difference ($P<0.05$) among the test varieties on behalf of (h). The maximum values regarding dough height at the end of the test was obtained for the cultivars Alidoro and Kakaba which were significantly different ($P<0.05$) from the rest of the varieties. The lowest mean values of dough height at the end of the dough fermentation process was obtained for wheat cultivars pavon 76, Enseno, Dodota, Hawi and Mada Walabu which were not-significantly different ($P>0.05$) among each other but significantly different from the rest varieties. Weakening coefficient (WC= (Hm-h)/Hm) of the dough which shows the proportion of decrease in volume for the fermenting dough varied from the lowest 0.17% (Danda'a) to 3.17% (Dodota). As described by Kanemaru, (2005) lower WC indicated better bread volume as volume loss during fermentation is lower and hence Dodota appeared poor in this regard while Danda'a appeared best performer.

Time required for the dough to reach the maximum height (T1); was seen in Table 7. The results revealed that there was high significant differences ($P<0.01$) regarding T1 due to bread wheat genotypes. Time to maximum height varies from the smallest 60.00 min (Alidoro) to the highest 179.67 min (Danda'a). Bread wheat cultivars Danda'a, Galil, Gassay, Hawi, Katar, Kbg-01, Kubsa, Mada Walabu, Millennium, Pavon 76, Sofumar, Sula and Tossa have taken longer time to reach Hm but significantly not different regarding T1. These bread wheat cultivars also got longer T1 and smaller weakening coefficient (WC) or Hm-h/Hm and having no T2, which make them cultivars with better baking performance. On the other hand dough made from bread wheat cultivars Alidoro and Bolo have taken shorter fermentation and significantly different ($P<0.05$) T1. In the current test, there is no wheat variety with T2 (time at which the dough tolerates fermentation)

Table 3. F3 Rheofermentometric dough development curve parameters

Var	*Hm*	*h*	*Hm-h/Hm*	T_1	*Tx*
Aldoro	27.07±0.55[a]	26.50±0.56[a]	2.10±0.44[a-e]	60.00±5.57[h]	-
Bolo	20.57±3.70[cde]	19.93±3.60[c-f]	3.07±0.29[abc]	124.33±9.02[g]	-
Danda'a	18.53±0.15[def]	18.50±0.10[d-g]	0.17±0.29[h]	179.67±0.58[a]	-
Digalu	16.30±1.35[fgh]	16.07±1.40[g-j]	1.43±0.49[d-h]	167.67±11.06[bcd]	-
Dinkinesh	15.77±1.37[f-i]	15.27±1.37[hij]	3.17±0.31[ab]	148.00±2.65[e]	-
Dodota	14.33±3.46[hi]	13.83±3.46[ij]	3.47±1.22[a]	138.00±2.65[ef]	29.33±2.52[bc]
Enseno	13.33±3.27[hi]	13.27±3.31[ij]	0.57±0.51[gh]	173.67±6.03[e-d]	30.33±4.51[bc]
Galil	21.60±1.06[bcd]	21.47±1.08[bcd]	0.60±0.26[gh]	173.00±4.58[a-d]	18.33±3.06[d]
Gassay	16.17±1.27[f-i]	15.83±1.26[g-j]	2.03±0.35[b-f]	169.00±6.56[a-d]	-
Hawi	13.17±1.33[i]	13.10±1.28[ij]	0.47±0.40[gh]	177.67±2.52[ab]	-
Kakaba	26.90±2.52[a]	26.57±2.47[a]	1.27±0.12[d-h]	167.67±9.29[bcd]	36.33±6.51[b]
Katar	17.53±0.55[efg]	17.23±0.70[f-i]	1.35±0.39[d-h]	175.67±4.04[abc]	-
Kbg-01	19.40±2.69[cde]	19.27±2.58[c-f]	0.63±0.55[gh]	178.33±1.53[ab]	-
Kubsa	19.43±1.16[cde]	19.27±1.11[c-f]	0.83±0.29[e-h]	175.00±2.00[a-d]	84.67±8.50[a]
M.Walabu	13.37±1.10[hi]	13.20±1.21[ij]	1.28±1.16[d-h]	177.67±2.52[ab]	-
Milinium	17.67±1.98[efg]	17.30±2.36[f-i]	2.23±2.54[a-d]	171.00±9.00[a-d]	-
Pavan-76	20.47±0.45[cde]	20.40±0.50[cde]	0.33±0.29[h]	178.00±2.00[ab]	-
Simba	23.77±1.60[b]	23.60±1.65[ab]	0.70±0.26[fgh]	127.00±10.15[fg]	-
Sirbo	20.53±0.40[cde]	20.17±0.51[c-f]	1.77±1.70[c-g]	164.00±16.52[d]	-
Sofumar	18.23±0.57[ef]	18.00±0.70[e-h]	1.30±1.15[d-h]	179.33±1.15[a]	-
Sula	16.20±1.06[f-i]	16.13±1.17[g-j]	0.43±0.75[gh]	179.00±1.00[a]	-
Tay	22.43±0.42[bc]	22.27±0.38[bc]	0.77±0.23[e-h]	166.33±10.69[cd]	25.67±6.11[cd]
Tossa	14.60±3.21[ghi]	14.53±3.15[ij]	0.43±0.38[gh]	178.67±1.53[ab]	-
G.Total	***18.58±4.22***	***18.33±4.18***	***1.32±1.17***	***162.12±27.82***	***37.44±22.92***
CV	***10.04***	***10.24***	***63.72***	***4.17***	***14.95***
LSD	***3.067***	***3.09***	***1.38***	***11.11***	***9.96***

Same letter within a column are not significantly different ($p < 0.05$) by LSD, Hm (mm) = height maximum dough development, h (mm) = height of the dough development at the end of the test and Hm-h/Hm (%) =lowering of the development percentage after 3 hours compared to T1, T1 (mn) = time of maximum rise expressed in hours and minutes

Gaseous Release Curve Results

All parameters from gaseous release curve were influenced significantly ($P<0.05$) due to genotype. The results indicated that H'm ranged from the smallest 83.93mm (Tossa) to the largest 156.33mm (Dinkinesh). Bread wheat varieties, Dinkinesh, Bolo, Alidoro, Gassay and

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Dodota got the highest H'm values while lower H'm values were recorded for bread wheat cultivars Tossa, Sofumar and Sula. Time to maximum height (T'1) values also varied from smallest 32min (Smba) to the largest 168min (Kakaba). The total volume of CO_2 produced, retained and retention coefficient was significantly varied ($P<0.05$) due to test genotypes (table 4). It was also seen that the values ranged from the smallest 2051.67ml (Tay) to the largest values 3293.33ml (Gassay) for TV and from 66.33ml (Bolo) to 28.33 ml (Dinkinesh) regarding amount of CO_2 lost during fermentation. Amount of gas retained during fermentation on the other hand varied from 3262.33ml (Gassay) to 2011 ml (Tay). The amount of CO_2 lost from fermenting dough have a direct and significant relation with % PSI ($P<0.01$) and significant ($P<0.05$) and indirect association with kernel vitreousiness. Retention coefficient (%RC showed no significant difference ($P>0.05$) among all the cultivars tested except Millinium and the rest of the cultivars tested and all values are very close to 100%. Retention coefficient is very close to 100 for flour extracted from healthy grain. This coefficient drops to 50/60 % for flour that comes from the end of grinding, beating, or conversion or for flours extracted from damaged or poorly preserved grain (ChoPin, 2000).

Table 4. F3 Rheofermentomentric gaseous release curve parameters for the wheat varieties under the current test

Var	*H'm*	*T'1*	*TV*	*L*	*RV*	*RC*
Aldoro	$150.57±4.51^{ab}$	$62.33±8.02^{d-g}$	$2565.00±12.12^{b-h}$	$32.67±2.08^{c-f}$	$2532.00±10.82^{b-g}$	$98.73±0.12^{a}$
Bolo	$154.87±2.70^{a}$	$48.00±10.15^{g-j}$	$2258.67±85.01^{f-i}$	$66.33±5.51^{a}$	$2192.00±87.40^{e-i}$	$97.07±0.32^{a}$
Danda'a	$137.90±19.37^{bc}$	$45.33±6.51^{ijk}$	$2755.67±409.59^{bcd}$	$30.33±2.08^{ef}$	$2724.67±410.57^{bcd}$	$98.87±0.25^{a}$
Digalu	$116.83±4.24^{de}$	$45.33±4.62^{ijk}$	$2061.33±317.46^{i}$	$32.33±3.06^{c-f}$	$2029.00±314.62^{hi}$	$98.40±0.10^{a}$
Dinkinesh	$156.33±5.08^{a}$	$67.00±2.00^{de}$	$2743.33±183.50^{b-e}$	$28.33±2.08^{f}$	$2715.00±185.50^{bcd}$	$98.93±0.15^{a}$
Dodota	$141.57±6.01^{abc}$	$53.00±12.12^{e-i}$	$2609.33±54.12^{b-g}$	$38.67±1.53^{b}$	$2571.00±55.24^{b-f}$	$98.53±0.06^{a}$

Enseno	99.00±7.07^{fg}	60.00±9.54^{d-h}	2342.00±205.83^{c-i}	35.67±4.73^{bcd}	2306.33±202.43^{d-i}	98.50±0.10^{a}
Galil	110.00±1.84^{ef}	158.33±7.64^{ab}	2512.67±115.53^{b-i}	32.67±3.21^{c-f}	2480.00±118.20^{b-h}	98.70±0.20^{a}
Gassay	147.40±15.19^{ab}	54.67±3.51^{e-i}	3293.33±149.32^{a}	31.00±1.00^{def}	3262.33±148.60^{a}	99.08±0.03^{a}
Hawi	110.90±5.68^{ef}	47.00±4.58^{hij}	2546.33±97.04^{b-h}	31.33±2.89^{def}	2515.33±100.11^{b-g}	98.77±0.21^{a}
Kakaba	104.93±7.95^{ef}	168.33±7.09^{a}	2383.67±243.41^{c-i}	32.00±2.00^{c-f}	2351.67±241.50^{c-i}	98.67±0.06^{a}
Katar	135.57±5.76^{bc}	52.00±10.82^{f-i}	2918.67±115.24^{ab}	30.00±2.00^{ef}	2888.67±113.30^{ab}	98.96±0.05^{a}
Kbg-01	95.80±8.78^{fg}	45.67±6.51^{h-k}	2187.00±94.82^{ghi}	29.00±0.00^{ef}	2158.00±94.82^{f-i}	98.67±0.06^{a}
Kubsa	99.13±18.21^{fg}	54.00±2.65^{e-i}	2288.00±570.23^{e-i}	36.67±6.43^{bc}	2251.00±577.19^{e-i}	98.30±0.87^{a}
M.Walabu	131.17±10.98^{cd}	100.00±5.00^{c}	2661.00±303.50^{b-f}	30.00±0.00^{ef}	2631.00±303.50^{b-e}	98.87±0.15^{a}
Milinium	107.97±10.36^{ef}	54.67±10.60^{e-i}	2270.00±114.56^{f-i}	40.33±2.52^{b}	2229.67±112.17^{e-i}	92.90±9.27^{b}
Pavan-76	116.50±4.37^{de}	71.00±10.15^{d}	2804.00±31.75^{bc}	33.33±0.58^{cde}	2771.00±32.70^{bc}	98.83±0.06^{a}
Simba	136.50±6.51^{bc}	32.00±11.36^{k}	2444.67±669.26^{c-i}	33.33±1.53^{cde}	2411.33±670.71^{c-i}	98.53±0.55^{a}
Sirbo	129.03±2.44^{cd}	43.67±15.14^{ijk}	2465.33±351.02^{b-i}	30.67±0.58^{ef}	2434.67±350.44^{b-i}	98.70±0.17^{a}
Sofumar	85.77±12.66^{g}	144.33±12.66^{c}	2139.67±251.12hi	33.33±1.53^{cde}	2106.33±252.54^{ghi}	98.40±0.26^{a}
Sula	88.63±8.32^{g}	62.67±11.06^{def}	2174.00±121.50^{ghi}	29.33±0.58^{ef}	2143.67±121.01^{f-i}	98.63±0.06^{a}
Tay	97.33±2.69^{fg}	36.67±7.37^{jk}	2051.67±96.72^{i}	40.33±7.09^{b}	2011.33±100.48^{i}	98.00±0.44^{a}
Tossa	83.93±12.43^{g}	44.67±6.03^{ijk}	2301.33±499.46^{d-i}	32.00±1.00^{c-f}	2269.00±499.95^{d-i}	98.53±0.38^{a}
GTotal	119.03±23.99	67.42±38.26	2468.55±377.08	34.33±8.03	2434.13±379.29	98.33±2.02^{a}
CV	7.82	12.95	11.40	8.80	11.59	1.99
LSD	15.29	14.35	462.41	4.96	463.59	3.21

Values followed by different letters with in a column indicate significant difference ($P < 0.05$). Note: CV = coefficient of variance, H'm= the maximum rise of gaseous release curve T'1 = time of maximum rise of gaseous, TV = Total Volume of Gas (CO_2) formed, RV = Retention Volume, RC = Retention Coefficient, Values = mean±Std, LSD= least significance difference.

Summary, Conclusions and Recommendations

Grain yield and disease resistance are the most important selection criteria in Ethiopian wheat breading program. On the other hand, there is a great demand for bread wheat cultivars with the required qualities and the past research works are limited in this aspect as information on rheological quality parameters are necessary to assess the suitability of wheat cultivars for

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different industrial products. The emergence of food industries utilizing wheat and its primary products are increasing and need to select for high and characterized grain and flour quality factors to match end use.

Bread wheat varieties Simba and Dinkinesh having higher WAB value also have higher MTI, Sofumar Dodota and Kbg-01 with longer DDT also have longer DST are cultivars which are best in leavened bread making. Dough fermentation quality assessed also indicated high significance difference due to genotypes. The maximum height of dough development curve (Hm) was observed for Alidoro which also taken shorter time to reach Hm and Kakaba which also the highest curve height at end of the test (h). The high T1 value, which takes around three hours in most varieties, indicates that the true Hm may not reach untill the end of test. On the other hand, Tx was recorded only for Dodota, Inseno, Galil, Kakaba and Kubsa. Dinkinesh, Bolo, Gassay, Alidoro and Dodota are bread wheat genotypes with superior H'm values. Sula, Sofumar and Tossa are the one with the lowest H'm. Amount of CO_2 gas produced and retained by all the dough of bread wheat cultivars were high while TV obtained by Gassay and Katar are greater. Amount of CO_2 produced and retained are 100% associated.

Based on results of rheological quality parameters evaluated, it is difficult to get wheat variety, which fulfills all the criteria required for bread making. Considering most rheological quality characters, bread wheat cultivars Simba, Pavon 76, sofumar, Kakaba, Sirbo and Kbg-01 can be considered as having superior bread making quality. Cultivars Dinkinesh, Mellenium, Mada Walabu, Alidoro, Tay and Digalu are bread wheat cultivars suitable for making soft wheat products.

Information obtained in this work is useful for millers and bakers for the selection of suitable variety for their intended uses. On the other hand research institutes should co-work with different wheat processing industries and local users so that the feedback will be utilized in breeding programs to incorporate important quality controlling genes into a high yielding and disease resistant commercial varieties. Finally, in Ethiopia, there should be wheat class breading and genetic improvement program which work on molecular level to identify genes responsible for certain quality attribute and wheat class breading as hard bread wheat and soft liens.

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References

AACC, 2000. Approved Methods of the American Association Cereal Chemists. *American Association of Cereal Chemists.* Inc., St. Paul, Minnesota.

Amsal Tarekegn, D.G. Tanner, Taye Tessema and Chanyalew Mandefro, 2000. Agronomic and economic evaluation of the on-farm N and P response of bread wheat grown on two contrasting soil types in central Ethiopia. *In:* The Eleventh Regional Wheat Workshop for Eastern, Central, and Southern Africa. CIMMYT, Addis Ababa, Ethiopia and the Environment. Cambridge University Press, UK.

Bonet, A., C.M. Rosell, P.A. Caballero, M. Gomez, I. Pérez-Munuera and I. Hernando, 2006. Glucose oxidase effect on dough rheology and bread quality: a study from macroscopic to molecular level. *Food Chemistry*. p.43.

Bordes, J., G. Branlard, F.X. Oury, G. Charmet and F. Balfourier, 2008. Agronomic characteristics, grain quality and flour rheology of 372 bread wheats in a worldwide core collection. *Journal of Cereal Science.* (48)3:569-579.

Caballero, P.A., A. Bonet, C.M. Rosell and M. Gomez, 2005. Effect of microbial transglutaminase on the rheological and thermal properties of insect damaged wheat flour. *Journal of Cereal Science*. 42(1):93-100.

CHOPIN, 2001. Laboratory mill CDI manual for experimental milling of hard and soft wheat. CHOPIN group Tripette and Renuad, France. 45p.

Bratovanova, P., 1996. Relationship between yeasts and lactic acid bacteria during fermentation of dough. Khranitelna promishlenost. 45:7-11.

Dobraszczyk, D.J., 2004. Dough rheology. *In*: Wrigley, C., H. Corke and C.E. Walker. *Encyclopedia of Grain Science*. pp 400-415. Elsevier Accadamic, Press Oxford, UK.

Dubois, M., A. Dubat and B. Launay, 2008. The AlveoConsistograph Handbook (2nd edition), AACC International, ISBN 978-1-891127-56-4, St. Paul, Minnesota, USA.

Ermias Estifanos, Geremew Bultosa, Habtemu Zeleke and H. Sigh, 2007. Agronomic performance and bread making quality of adivanced bread wheat (*Triticum astivum* L.) lines in east Oromia Ethiopia. *East African Jouoronal of Science.* 1(1):25-34.

Faridi, H. and J.M. Faubion, 1995. Wheat usage in North America. *In*: Faridi H. & J.M. Faubion, eds. Wheat end uses around the world, St Paul, MN, USA, *American Association of Cereal Chemists.* p. 1-41.

Farid, H. and V.F. Rasper, 1987. The Alveography Handbook. AACC. St. paul. MN. USA

Faridi, H.A., 1980. Technical and nutritional aspects of Iranian breads. Baker's Digest. pp. 18-22.

Hoseney, R.C., 1994b. Soft wheat products. In: Principles of Cereal Science and Technology, 2nd ed. St. Paul, MN: AACC, Inc. Pp. 275-306.

Hruskova, M, I. Svec and O. Jirsa, 2006. Correlation between milling and baking parameters of wheat varieties. *Journal of Food Engineering.* 77: 439-444.

Hruskova, M., and O. Famera, 2003. Prediction of wheat and flour Zeleny sedimentation value using NIR technique. *Czech Journal of Food Science.* 21:91-96.

Hruškova M. And O. Faměra, 2003. Evaluation of wheat flour characteristics by the alveo-consistograph. *Polish Journal of Food and Nutrition Sciences.* 12:53 (2) 25-28.

Maghirang, E.B., G.L. Lookhart, S.R. Bean, R.O. Pierce, F. Xie, M.S. Caley, J.D. Wilson, B.W. Seabourn, M.S. Ram, S.H. Park, O.K. Chung and F.E. Dowell, 2006. Comparison of Quality Characteristics and Breadmaking Functionality of Hard Red Winter and Hard Red Spring Wheat. *Cereal Chemistry*. 83(5):520–528.

Naeem, M.S., K. Naseem, N. Siddiqui, M. Amjad, T. Hameed and S. Khalil, 2009. Quality evaluation of different wheat cultivarsfor the production of unleavened flat bread (chapatti). *Pakistan Journal of Nutrition.* 8(11): 1773-1778.

Narasimha, B.R., 2008. A study of the rheological properties and gluten protein components associated with enhanced baking quality in durum wheat (*triticum turgidum* L. Var. *Durum*). Pp1-129.

Peterson, C.J., R.A. Graybosch, D.R. Shelton and P.S. Baenziger, 1998. Baking quality of hard red winter wheat: Response of genotypes to environment in the Great Plains. *Euphytica.* 100:157-162.

Rafiq, M.K., 2009. Electrophoretic and immunochemical characterization of pakistani wheats in relation to chapatti and bread making quality. Pp 1-225.Faisalabad Pakistan.

Rasper, V.F. and C.E. Walker, 2000. Quality evaluation of cereals and cereal products. In: *Handbook Cereal Science and Technology*, *Second Edition*. K. Kulp and J.G. Ponte, Jr. (eds). Newyork.

Senayit Wondimu, 2007. Evaluation of Some Bread Wheat (*Triticum aestivum* L.) Genotypes for quality traits, yield and yield components and association among characters. M.Sc. Thesis. pp.100-101.

Simon, S.J., 1987. More wheat with superior baking quality. *Cereal Foods World*. 32 :323-331.

Solomon Gelalcha, Desalegn Debelo, Bedada Girma, T.S., Payne, Zewde Alemayehu and Balcha Yale, 2000. Milling and baking quality of Ethiopian bread wheat cultivars. *In*: CIMMYT. 2000.

ISSN: 2456-8643

The eleventh regional wheat workshop for Eastern, Central and Southern Africa, A.A. Ethiopia. CIMMYT.

U.S. Wheat Inspection Associate, 2007. Wheat and Flour Testing Methods*: A Guide to Understanding Wheat and Flour Quality: Version 2* is taken, with permission, from *Overview of U.S. Wheat Inspection Associates*.

Walker, C.E. and J.L. Hazelton, 1996. Dough rheological tests. *Cereal Foods World*. 41(1): 23-28.

Zounis, S. and KJ. Quail, 1997. Predicting test bakery requirements from laboratory mixing tests. *Journal of cereal Science*. 25: 185-196.