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EFFECT OF PRE-MILLING TREATMENTS ON WHEAT FLOUR QUALITY

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The present investigation was carried out to determine the physical, chemical and morphological characteristics of wheat grains and their effect on flour quality. The effect of pretreatments on flour extraction rate and its quality was also determined. Three pre-milling treatments *viz.* conditioning, yeast treatment and acid treatment were applied to four wheat (*Triticum aestivum)* cultivars C-306, Raj-3765, PBW-343 and KW-11 and compared with tempering. Pre-milling treatments increased the flour extraction rate more than that of tempering. The flour extraction rate was the highest for acid treated grains and the lowest for conditioned grains, whereas the flour quality of acid treated grains was poor. Therefore, yeast treatment was selected giving a slightly lower extraction rate and good flour quality than acid treatment. It was also observed that wheat cultivars with better physicochemical and morphological properties showed good flour quality in comparison to wheat cultivars with inferior physicochemical and morphological properties.

Keywords: wheat, pre-milling treatments, conditioning, tempering

Introduction

Wheat (*Triticum aestivum*) is an ancient known food crop; cultivated since the beginning of human civilization, it ranks first among world cereal crops (Ahmed et al., 2010). Worldwide consumption of wheat is estimated to be 732 million metric tons for the year 2017 (International Grain Council, 2017). Wheat is the staple food for over 4-5 billion people in as many as 43 countries in the world. It is the most popular cereal grain for baked goods. The visco-elasticity of wheat dough and its rheological properties make wheat superior to other cereal grains.

Bread wheat quality is very important for making a wide range of end-use products. It can be characterized by milling and food-making qualities. Milling quality is predominantly influenced by the grain shape, size, grain hardness (GH), test weight (TW), thousand-kernel weight (TKW), and flour color. On the other hand, food-making quality is determined by several physical and chemical parameters such as: flour protein content (FPC), ash content, sedimentation value

(SV) and dough rheological properties (mixograph parameters) (Kunert et al., 2007), which are traditional measures of the bread-baking potential of wheat (Hruskova and Famera, 2003).

The whole cereal grain is not edible for human being. To convert the cereal grain into edible form, milling is necessary. The aim of wheat milling is to isolate the endosperm without contamination by the outer parts of the grain and the germ. A specific characteristic of wheat for milling is the presence of a crease in the kernel. The crease presents the greatest difficulty for separation of starchy endosperm from other grain parts (Evers and Millar, 2002). Kweon et al. (2009) studied the effect of conditioning parameters on the milling performance and flour functionality for soft red winter (SRW) wheat grain. Flour yield was more reduced in all samples conditioned at 15% moisture than for samples conditioned to 12% moisture. Whereas the flour quality of the 15% conditioned sample was better than the 12% conditioned samples due to less bran contamination. Several researchers also used solid state fermentation for loosen the bran and increase bioavailability (Chawla et al. 2017 and Sadh et al. 2017).

The moisture content of wheat grain after harvesting is 11 to 12%. Milling efficiency is increased by increasing moisture content up to17% for hard wheat and 15.5 to 16.5% for soft wheat varieties. Tempering (T) and conditioning increase the moisture of wheat grain (Kulp and Ponte, 2000). Some treatments used to improve the properties of flour made from such wheat grain include yeast treatment (Y) (Siegel, 1987) and acid treatment (A) (Lamsal et al., 2008).

The objective of the present study was to check the morphology and physico-chemical properties of selected wheat cultivars and their influence on milling and flour quality. Four wheat cultivars were milled after three different pre-milling treatments and compared with tempering treatment for wheat flour quality.

Materials and Methods

Materials

Four wheat cultivars *viz*. C-306, Raj 3765, PBW-343 and KW-11 were procured from the wheat breading farm, Haryana Agriculture University, Hisar (India). Wheat grains were stored in airtight plastic containers with parad tablets (Himalaya, India) enclosed in cloth for the protection of wheat grains. All solvents and reagents employed in this study were of analytical grade and were purchased from Rankem (New Delhi, India). Baking yeast was procured from AbMauri India (P) Ltd. (Uttar Pradesh, India). Vinegar and sugar were purchased from the local market, Hisar, India.

Morphological Characteristics

Wheat cultivars were cleaned and the morphological characteristics of grain were studied. Color and shape were evaluated by simple inspection of color and length and breadth of grain, respectively. Phenol test was used for the detection of purity of a cultivar. For this, 50g of wheat cultivars were dipped into 10% phenol solution for 1h and then washed with water and the color of the grains was observed. Seeds with different color were adulterated with low quality grains. The incidence of yellow berry (%) was determined using the method as described by Anon (1989). The grain appearance score was determined using the method as described by AOAC (2010).

Physical Parameters of Grains

Test weight, hectoliter weight, thousand-kernel weight and length/breadth ratio were determined using the methods as described by Kaushik *et al.* (2013). Hectoliter weight (hl) was determined using hectoliter weight apparatus (Inframatic 9500, Perton, Klerksdorp, Zimbabwe). Length, breadth and crease depth were measured using digital vernier caliper.

Pre-milling treatment

Tempering (T)

The wheat grains were tempered to increase moisture content using the method as described by Kulp and Ponte (2000). The moisture content of wheat cultivars was determined using a digital moisture meter (R. L. Wason & Company, India). The moisture content of wheat grains was increased to 16% by adding the calculated amount of water (40°C) to the wheat grains, which were then intensively mixed in a continuous mixer in order to disperse water uniformly. The tempered wheat cultivars were given a certain rest period in the bins to allow the water to distribute optimally within the different parts of the grains and to reduce the hydration differences among them.

Conditioning (C)

The wheat grains were conditioned using the method as described by Kulp and Ponte (2000). Wheat grains were steeped in hot water (60˚C) for 4h. Water was removed and grains were dried under sunlight. Then moisture content was adjusted by tempering the grains to 16%.

Yeast Treatment (Y)

The wheat grains were yeast treated using the method as described by Siegel (1987). The amount of 1kg wheat grains were steeped in 1l of water having yeast (57g/l), sugar (28.5g/l) and vinegar (10ml/l) at 35±1˚C for 2h. After 2h the water was drained and grains were then washed two times with tap water and the third time with distilled water and dried under sunlight. Wheat grains were then tempered and moisture content was maintained to 16%

Acid Treatment (A)

The wheat grains were acid treated using the method as described by Lamsal et al. (2008). Wheat grains were soaked in 2% (w/w) dilute sulfuric acid for 1h at 45-55˚C. Wheat grains were then rinsed three times with tap water to remove residual acid and dried at room temperature. The dried wheat grains were tempered and the moisture level was maintained to 16%.

Milling

The above pretreated wheat cultivars were milled using roller-mill (Chopin Laboratory CD-1 mill, France) and the flour obtained was stored in airtight plastic containers under ambient conditions for further analysis. In order to ensure the purity of the roller-milled flour samples from each lot, mechanical and manual cleaning of the roller-mill including air blasting was applied between the milling of each of the wheat samples (Sharma et al. 2017).

SDS-Sedimentation Volume

Sodium Dodecyl Sulfate (SDS Solution) sedimentation volume of flour samples was estimated according to the method described by Axford (1978). The flour (5g) was suspended first in 50 ml water and afterwards 50 ml of SDS –Lactic acid reagent (solution contained 0.9% lactic acid and 2% SDS) were added. The mixture was allowed to settle for 40 minutes before reading the sedimentation value in ml.

Falling Number Test

The falling number was determined by approved methods described by AACC (2010) and the results were expressed in time as seconds.

Dough Tensile Strength and Percent Elongation at Break

Dough Tensile strength and % elongation at break of different dough samples were determined using a Texture Analyzer TA.XT2i (Stable Micro System, Surrey, UK), operated according to the ASTM Standard Method. Three specimens of each film were measured (40 mm width) and cut using a cutter. The peak loads and extension at break were recorded for testing film specimens. The tensile strength and % elongation at break were calculated according to the ASTM method. Each test piece was placed centrally on the sample platform of Kieffer with the extension hook previously positioned beneath.
Percent elongation at Break was determined by the following equation:

$$\%\text{ elongation } = \frac{\text{distance sample stretched}}{\text{original length of sample}} \cdot 100$$

Proximate Analysis

All wheat grains were powdered using a Falling number mill (Model 3100, Sweden), passed through a 100 mesh sieve and stored in airtight containers in a refrigerator till further chemical analysis. Whole wheat grain powder and wheat flour samples were analysed for moisture, ash, protein and fat contents using AOAC (2010).

Statistical Analysis

Data are presented as mean ± Standard error mean (SEM) (n=3), linear regression analysis and 95 % confidence intervals were calculated using Microsoft Excel 2007 (Microsoft Corp., Redmond, WA). Data were subjected to a single way analysis of variance (ANOVA) (Sachdeva et al., 2015).

Results and Discussion

Morphological Characteristics

The wheat cultivars were assessed for their morphological characteristics *viz.* grain color, shape, phenol test, yellow berry incidence and grain appearance score (Table

1). Amber color was observed for all four wheat cultivars. The shape of grains was observed as cylindrical, oval, oblong and ovate for KW-11, PBW-343, C-306 and Raj-3765 cultivars, respectively. In the phenol test, all four wheat cultivars showed purity as the color of all seeds was similar. The yellow berry incidence in grains of four wheat cultivars ranged between 2.82 to 8.71. All wheat cultivars exhibited desirable incidence of yellow berry of less than 10%. The grain appearance scores of wheat cultivars ranged from 5.25 to 6.84, which revealed that these wheat cultivars were accepted for trade.

Table 1. Morphological characteristics of four wheat grains

Characteristics	**Color**	**Shape**	**Crease**	**Phenol test**	**Yellow berry Incidence (%)**	**Grain appearance Score**
KW-11	Amber	Cylindrical	Medium	Dark brown	3.66±0.03	5.25±0.08
PBW-343	Amber	Oval	Medium	Dark brown	8.34±0.06	6.40±0.10
C-306	Amber	Oblong	Medium	Light-brown	8.71±0.07	6.84±0.11
Raj-3765	Amber	Ovate	Medium	Light-brown	2.82±0.05	6.37±0.07

Data are presented as mean ± SEM (n=3).

Physical Parameters

Physical parameters of four wheat cultivars were determined and data are presented in Table 2. Hectoliter weight is the rough index of kernels density and regularity of size. The hectoliter weight of four wheat cultivars was ranged between 78.09 and 84.27 kg/hl for KW-11 and C-306 wheat cultivars, respectively. The hectoliter weight of C-306 was significantly higher ($P<0.05$) than other three wheat cultivars. According to the Canadian system, all the four wheat cultivars qualify as grade 1 (Hectoliter weight more than 78.0 kg/hl) for trade market (Anon 1989).

Thousand kernel weight was the lowest for KW-11 (42.59g) followed by 43.25g (Raj-3765), 43.27g (PBW-343) and C-306 (44.81g) (Table 2). Significant difference ($P>0.05$) was observed in the thousand kernel weights of KW-11, Raj-3765, PBW-343 and C-306 wheat varieties. It was inferred from the above results that C-306 wheat cultivar had larger size and density than other wheat cultivars. Similar result regarding thousand kernel weight was reported by Supekar (2005).

The kernels with a low L/B ratio have an oval shape and kernels having a higher L/B ratio have a cylindrical shape. The L/B ratio was 2.01mm (PBW-343), followed by 2.07mm (KW-11), 2.14mm (RAJ-3765) and 2.22mm (C-306) (Table 2). The L/B ratio of PBW-343 and KW-11 was significantly lower ($P<0.05$) than C-306, whereas RAJ-3765 had non-significant difference ($P>0.05$). Similar test weight, thousand kernel weight and L/B ratio were reported by Kaushik et al. (2013) and Kumar et al. (2013).

The crease depth of four wheat cultivars was low with 1.64mm (C-306), 1.72mm (Raj-3765), 1.77mm (PBW-343) and 1.85mm (KW-11) (table 2). KW-11 showed significantly higher crease depth than other three wheat cultivars.

Table 2. Physical characteristics of wheat kernels

Wheat variety	Hectoliter wt. kg/hl	1000 Kernel wt. (g)	L/B ratio	Crease depth (mm)
KW-11	78.09 ± 0.35^{a}	42.59 ± 0.21^{a}	2.07 ± 0.03^{a}	1.85 ± 0.02^{b}
PBW-343	79.53 ± 0.59^{a}	43.27 ± 0.69^{a}	2.01 ± 0.05^{a}	1.77 ± 0.04^{ab}
C-306	84.27 ± 0.61^{c}	44.81 ± 0.45^{b}	2.22 ± 0.02^{b}	1.64 ± 0.06^{a}
RAJ-3765	82.6 ± 0.23^{b}	43.25 ± 0.29^{a}	2.14 ± 0.07^{ab}	1.72 ± 0.02^{a}

Data are presented as mean ± SEM (n=3).
a-b Means with same superscript in column do not vary significantly (p<0.05) from each other.

Extraction Rate

The extraction rate of four wheat cultivars by four different methods (tempering, conditioning, yeast and acid treatment) was determined and the obtained results are given in Table 3. Extraction rate was ranged from 61.21% to 71.62% for KW-11 (T) and C-306 (A), respectively. Extraction rate was the least in tempering treatment for all wheat cultivars, whereas acid treatment showed a higher extraction rate. Conditioning treated wheat grains had a significantly higher (P<0.05) extraction rate in comparison to tempering treated wheat grains.

Table 3. Extraction rate of wheat flour after pre-milling treatments

Treatment used	Wheat varieties extraction rate (%)			
	KW-11	**PBW-343**	**C-306**	**Raj-3765**
Tempering	61.21 ± 0.41^{a}	65.35 ± 0.60^{a}	67.21 ± 0.49^{a}	64.00 ± 0.81^{a}
Conditioning	65.92 ± 0.72^{b}	66.22 ± 0.40^{b}	69.71 ± 0.14^{b}	66.11 ± 0.40^{b}
Yeast treatment	67.70 ± 0.47^{c}	70.63 ± 0.14^{c}	71.00 ± 0.49^{c}	68.92 ± 0.35^{c}
Acid treatment	68.25 ± 0.46^{c}	70.75 ± 0.23^{c}	71.62 ± 0.32^{c}	69.33 ± 0.22^{c}

Data are presented as mean ± SEM (n=3).
a-b Means with same superscript in column do not vary significantly (p<0.05) from each other.

Wheat grains treated with yeast and acid had no significant difference (P>0.05) in extraction rate in all four wheat cultivars and both had significantly higher extraction rate in comparison to conditioning and tempering treatments. Out of four wheat cultivars, C-306 had a higher extraction rate in all pre- treated wheat grains. It was also inferred that grains with inferior physical characteristics showed lower extraction rate of flour. Similar extraction rate was reported by Kumar et al. (2013).

Proximate Analysis of Wheat Cultivars

The proximate analysis of four wheat cultivars was also conducted and data are given in Table 4. Moisture content of RAJ-3765 was significantly lower than other three wheat cultivars. There was no significant difference in the moisture content of KW-11, PBW-343 and C-306. The moisture content of wheat cultivars ranged from 11.53 to 12.46% for RAJ-3765 and C-306, respectively and these values are in close agreement with the values reported by Supekar et al. (2005).

The ash content of all four wheat cultivars was significantly different from each other. The ash content of KW-11 was the highest followed by PBW-343, RAJ-3765 and C-306 cultivars. The ash content of wheat cultivars ranged from 1.543 to 1.710% for C-306 and KW-11, respectively.

The lipid content was the lowest for KW-11 and was significantly lower than PBW-343, C-306 and RAJ-3765 cultivars. The lipid content ranged from 3.28 to 3.75% for KW-11 and RAJ-3765, respectively.

The protein content ranged from 10.96 to 13.63% for KW-11 and C-306, respectively. The protein content of KW-11 was significantly lower than other wheat cultivars. The protein content of PBW-343 was significantly lower than C-306, whereas RAJ-3765 had no significant difference compared to PBW-343 and C-306.

Table 4. Physico-chemical analysis of four wheat cultivars

Wheat cultivars	Composition (%)			
	Moisture	**Ash**	**Lipids**	**Protein**
KW-11	12.17±0.021^{b}	1.710±0.003^{d}	3.28±0.09^{a}	10.96±0.17^{a}
PBW-343	12.03±0.064^{b}	1.629±0.003^{c}	3.65±0.12^{b}	12.98±0.09^{b}
C-306	12.46±0.17^{b}	1.543±0.004^{a}	3.68±0.06^{b}	13.63±0.13^{c}
RAJ-3765	11.53±0.21^{a}	1.575±0.008^{b}	3.75±0.08^{b}	13.23±0.11^{bc}

Data are presented as mean ± SEM (n=3).
a-b Means with same superscript in column do not vary significantly ($p<0.05$) from each other.

Proximate Analysis of Wheat Flour

The compositional analysis of wheat flour was also carried out and data are presented in Table 5.

Moisture Content

The moisture content of wheat cultivars ranged between 12.33 to 14.21% for KW-11 (C) and PBW-343 (A), respectively. The moisture content of flour obtained after tempering and conditioning of wheat grains was lower than the one obtained from yeast and acid treatment. Flour moisture content increased in comparison to whole grain moisture content.

Ash Content

The ash content indicates the quality of wheat flour: if ash is more, it is considered that flour is of low quality and there is contamination of bran or soil. The ash content of flour obtained after pre-milling treatments ranged from 0.326 to 0.474% for C-306 (Y) and KW-11 (A), respectively. The ash content of flour obtained after acid treatment was significantly higher than the ash content of flour obtained after yeast treatment. There was no significant difference between tempered, conditioned flour samples and yeast treated flour samples. The ash content of pure endosperm ranges between 0.30 to 0.35% (de Man 1999). The ash content of flour obtained after acid treatment was higher than the normal range of ash content, indicating contamination of bran into flour samples. Tempering, conditioning and yeast treated flour samples were characterized by ash contents comparable to the ash content of the endosperm, indicating that, in the case of these treatments, flour contamination with bran was low. Flour ash content decreased in comparison to whole grain. It was due to the removal of high ash content bran in flour in comparison to whole grain.

Table 5. Physico-chemical analysis of wheat flour

Wheat flour samples	Composition (%)			
	Moisture	Ash	Lipids	Protein
KW-11 (T)	12.51±0.26^{ab}	0.377±0.011^{ab}	1.61±0.05^{ab}	11.67±0.01^{a}
(C)	12.33±0.25^{a}	0.356±0.009^{a}	1.57±0.04^{ab}	11.71±0.02^{a}
(Y)	12.52±0.26^{ab}	0.346±0.008^{a}	1.50±0.02^{ab}	11.77±0.03^{a}
(A)	12.65±0.28^{a}	0.474±0.011^{b}	1.33±0.06^{a}	11.53±0.00^{a}
PBW-343 (T)	12.71.0.24^{ab}	0.371±0.012^{ab}	1.74±0.04^{b}	13.78±0.03^{b}
(C)	13.20±0.33^{ab}	0.353±0.014^{ab}	1.69±0.05^{b}	13.85±0.02^{b}
(Y)	13.29±0.28^{b}	0.349±0.007^{a}	1.57±0.02^{ab}	13.94±0.08^{b}
(A)	14.21±0.35^{b}	0.461±0.016^{b}	1.45±0.04^{ab}	13.59±0.09^{b}
C-306 (T)	12.91±0.25^{ab}	0.341±0.011^{a}	1.66±0.07^{b}	14.54±0.06^{b}
(C)	13.32±0.29^{b}	0.335±0.010^{a}	1.63±0.06^{b}	14.66±0.06^{b}
(Y)	13.87±0.28^{b}	0.326±0.009^{a}	1.53±0.04^{ab}	14.65±0.02^{b}
(A)	13.99±0.31^{b}	0.428±0.015^{b}	1.51±0.04^{ab}	14.29±0.07^{b}
Raj-3765 (T)	13.14±0.27^{ab}	0.352±0.009^{ab}	1.75±0.05^{b}	13.89±0.04^{b}
(C)	13.41±0.34^{b}	0.345±0.013^{a}	1.72±0.05^{b}	13.94±0.09^{b}
(Y)	13.58±0.36^{b}	0.334±0.017^{a}	1.59±0.04^{a}	13.99±0.06^{b}
(A)	13.95±0.29^{b}	0.449±0.023^{b}	1.47±0.05^{a}	13.56±0.07^{b}

Data are presented as mean ± SEM (n=3).
a-b Means with same superscript in column do not vary significantly ($p<0.05$) from each other.

Lipids Content

The lipid content is very low in wheat (1-3%). It ranged from 1.33 to 1.75 % for KW-11 (A) and RAJ-3765 (T), respectively and agreed with the values obtained by Prabhasankar and Rao (2008). The lipid content of flour obtained after tempering and conditioning was slightly higher than the lipid content of flour obtained after acid and yeast treatment. This indicates that different milling procedures affect the lipid content of flour. Flour lipid content decreased in comparison to whole grains, as wheat lipids are present mainly in the bran and germ part of the wheat grain.

Protein Content

The protein content of wheat cultivars treated with different pre-milling treatments is presented in Table 5, where it can be observed that the treatments had non-significant effect on the protein content of flours of wheat cultivars after different pre-milling treatments. The protein content of KW-11 wheat cultivar was significantly lower than the other three wheat cultivars used in this study. If we compare the protein content of flours with grain protein content, a slight increase in protein content was observed. The protein content ranged from 11.67 to 14.66% for KW-11 (A) and C-306 (C), respectively. Similar results were reported by Supekar

(2005) and Ram (2001). KW-11 appeared suitable for cakes and cookies and the other three wheat cultivars are suitable for bread making.

Quality evaluation of Wheat Flour

The quality of the flour was studied using SDS sedimentation volume, falling number and texture analyser and data are presented in Table 6.

SDS (Sedimentation Volume)

The SDS sedimentation volume of wheat flour indicates the wheat flour quality. The SDS sedimentation volume of wheat flours is based on the fact that the gluten protein absorbs water and swells considerably when treated with lactic acid. SDS sedimentation volume ranged from 32.02 to 48.50 for KW-11 (A) and C-306 (Y) flours, respectively (Table 6) and our SDS values are in agreement with the values obtained by Supekar et al. (2005) and Kaushik et al. (2016). The SDS volume of flours obtained after yeast treatment showed higher SDS volume in comparison to flours obtained after other three treatments in all wheat cultivars. The SDS value of flours treated with acid had lowest SDS value in comparison to flours obtained after other treatments in all wheat cultivars. It can be inferred from the above results that pre milling treatments showed an effect on the wheat flour quality. The data on the SDS volume of wheat flours of these wheat cultivars indicated that only KW-11 was suitable for biscuit making, the rest of the wheat cultivars were suitable for bread making.

Falling Number

Falling number indicates the quality of flour and of the grains from which flour was obtained. The lower the falling number will be, the lower the amylase activity and vice-versa. Different products need different level of α-amylase for best quality product. Falling number instrument analyzes viscosity by measuring the resistance of flour and water paste to a falling plunger. The falling number of flour samples ranged from 317 to 483.01 for PBW-343 (A) and C-306 (Y), respectively. Significant difference was observed between flours for the falling number obtained after acid treatment than other treatments in all wheat cultivars. The bread formed from more amylase flour lost its texture. If the amylase activity is low, the bread becomes hard and grainy in texture. Similar falling numbers were reported by Kumar et al. (2013).

Tensile Strength

Tensile strength indicates the flour quality, elasticity and gluten protein strength. The percentage elongation indicates the elastic properties of wheat gluten. Good quality flour gives more tensile strength. The tensile strength of dough ranged from 14.55 to 47.80 for KW-11 (A) and C-306 (Y), respectively. A significant difference was observed between the tensile strength of wheat dough samples. The tensile strength of flours obtained from acid treated grains had significantly lower tensile strength than the one of flours obtained from other treatments. It is due to the difference in the composition of flour, strength of gluten and quality of gluten protein. Higher tensile strength flour showed better quality for bread manufacturing and vice-versa. Tensile strength indicates the quality and quantity of gluten protein.

The percentage elongation of dough ranged from 5.79 to 20.52 for KW-11 (A) and C-306 (Y), respectively. A significant difference was observed in the % elongation of wheat dough samples prepared from flours obtained after acid treatment compared to other treatments.

Table 6. Quality of wheat flour obtained after different pre-milling treatments

Flour Samples	SDS value	Falling number	Tensile strength	% elongation
KW-11 (T)	32.66±0.47^{a}	407.88±3.78^{bc}	19.82±1.08^{ab}	6.53±0.37^{a}
(C)	35.07±0.28^{ab}	424.05±4.41^{bc}	22.14±1.40^{ab}	6.97±0.26^{a}
(Y)	36.56±0.35^{ab}	447.12±12.15^{bc}	23.79±0.78^{ab}	8.14±0.60^{a}
(A)	32.02±0.43^{a}	351.16±3.45^{ab}	14.55±0.96^{a}	5.79±0.34^{a}
PBW-343 (T)	36.30±0.69^{ab}	366.24±10.59^{ab}	26.56±1.85^{ab}	14.82±1.06^{b}
(C)	37.53±0.24^{b}	382.18±6.25^{ab}	28.26±1.72^{ab}	15.65±1.44^{b}
(Y)	38.51±0.16^{b}	392.46±5.89^{b}	29.78±1.41^{ab}	17.69±0.99^{b}
(A)	34.93±0.32^{ab}	317.43±7.72^{a}	16.34±0.86^{ab}	10.60±0.37^{a}
C-306 (T)	46.39±0.35^{c}	411.99±4.77^{bc}	42.85±2.4^{b}	16.68±1.01^{b}
(C)	47.02±0.42^{c}	471.19±4.10^{bc}	45.94±3.23^{b}	20.29±1.23^{c}
(Y)	48.50±0.40^{c}	483.01±8.09^{c}	47.80±2.81^{b}	20.52±0.72^{c}
(A)	45.25±0.32^{c}	396.06±5.25^{bc}	27.92±1.66^{ab}	15.1±1.04^{b}
Raj-3765 (T)	33.35±0.28^{ab}	397.98±10.94^{bc}	24.73±1.78^{ab}	13.59±0.68^{b}
(C)	35.57±0.14^{ab}	405.04±2.62^{bc}	32.29±2.37^{b}	15.33±1.05^{b}
(Y)	36.32±0.26^{ab}	458.20±13.27^{bc}	32.97±1.56^{b}	15.76±1.15^{b}
(A)	33.51±0.47^{ab}	378.22±24.89^{ab}	18.21±1.63^{ab}	11.84±1.01^{b}
C.D.	4.71	73.99	16.21	7.58

Data are presented as mean ± SEM (n=10).
a-b Means with same superscript in column do not vary significantly ($p<0.05$) from each other.

Conclusions

Wheat morphological characteristics and physical properties indicated wheat grain quality and also correlate with extraction rate and wheat flour quality. Test weight and hectoliter weight showed positive correlation between each other. The flour extraction rate increased with pre-milling treatments in comparison to tempering. Acid treated grains had a higher extraction rate but its flour quality was poor. The SDS-sedimentation value of flour obtained from acid treated grains was low as compared to other treatments. The tensile strength and % elongation of acid treated wheat flour were minimal in each wheat cultivar. Pretreatment affects the extraction rate and out of four milling treatments, the flour obtained from yeast treated grains gave the best flour quality.

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