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Different Moisture Contents of Tempered Hulled and hull-less Barley Grains Prior to Milling
1. Effect on Extraction Rate, Color and Characteristics of Flours

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Abstract

The purpose of this work was to study the effect of different moisture contents (12, 14, 16 and 18%) of conditioned hulled and hull-less barley grains prior to milling on extraction rate, color and characteristics of flours. Flour extraction rate was decreased as the tempering moisture of grains prior to milling increased. In all conditioning treatments, the flour yield was lower in hulled than in hull-less variety. The flour color was significantly improved (become white) as the conditioning moisture of hull-less barley grains before milling increased, while the hulled barley showed slight improving. The chemical composition of flours including protein, fat, crude fiber, ash, pentosan, β-glucan, bond and total phenolic compound and phytic acid contents showed decreasing, whereas starch, reducing sugar and free phenolics contents were raised as the conditioning moisture of grains prior to milling in both varieties increased. A slight raise in solubility of protein and starch with substantially increasing in the solubility of pentosan and β-glucan was observed in all flours from both barley varieties as the tempering moisture of grains before milling increased. The solubility of β-glucan was higher in flours from hulled than that corresponding flours from hull-less variety and this reflected the higher values of relative viscosity of flour water extract from the former than the latter. The Rapid Visco Analyser (RVA) measurements for the flours obtained from hull and hull-less barley indicated that the values for pasting temperature, time to gelatinization, time to peak, peak viscosity, trough viscosity and final viscosity were decreased as the moisture content of barley grains prior to milling increased.

Keywords: *hulled, hull-less, barley, tempering, milling, flour, extraction rate, color, pentosan, β-glucan, phenolics, phytic acid, viscosity, RVA*

Introduction

Barley (*Hordeum vulgare* L.) is a resilient plant, tolerant of a range of conditions, which may have been cultivated since *15000 B.C.* (Fast and Caldwell, 2000). Barley is grown as a commercial crop in some hundred countries world-wide and is one of the most important cereal crops in the world. Barley assumes the fourth position in total cereal production in the world after wheat, rice and maize, each of which covers nearly 30% of the world's total cereal production (Reddy *et al*., 2014). Barley is usually classified as spring and winter types, two-rowed or six-rowed and hulled or hull-less. Hull-less barley requires minimal milling process, owing to the absence of hulls, and remain most of the germ and endosperm which is occasionally lost in the process of pearling or dehulling **(**Gangopadhyay *et al*., 2015**).**

The use of roller-mills ends up in darker flour with a higher ash content caused by an increased brittleness of the hull and consequently a deteriorated separation of bran and shorts (Klamczynski and Czuchajowska, 1999). Tempering barley before milling process can increase particle size and reduce the proportion of fines particles less than 1.0-mm (Hironaka *et al*., 1992). On the other hand, Quinde *et al*., (2004) reported that, although, barley had a variety of potential food uses, the dark gray color of the final products negatively affected consumer acceptability, and they mentioned that discoloration potential of barley in food products was dependent on the class and genotype of barley. In addition, Izydorczyk *et al*., (2003) studied the effect of increasing the moisture content of tempered Canadian hull-less barley before milling from 12.5 to 14.5%; and found strongly improving in flour brightness with a moderate loss of flour yield on a whole un-pearled barley basis; and when the moisture content increased to 16.5%, flour yield decreased without improvement in brightness.

In recent times barley has been mainly used as animal feed or has been processed into beer malt, while only a minor amount (2%) of total world production of barley has been used in human food production (Baik and Ullrich, 2008). The reasons that make barley unpopular as human food are: (i) presence of a husk that is difficult to remove, (ii) most of the barley is used up by the malting and brewing industry, (iii) barley lacks the gluten proteins therefore cannot be used in leavened bakery products and (iv) strong taste and gummy mouth feel of whole barley kernels (Sharma and Gujral., 2010). Barley should be used as a human food because it has one of the highest levels (up to 6%) of β-glucan, a water-soluble polysaccharide, nutritionally classified as soluble dietary fiber (Dandey and Bobraszczyk, 2001). Recently, barley flour and whole grain products have been formulated in food research laboratories to increase the diversity of barley food products available and to improve the utilization potential of these healthful grains (Badr *et al*., 2000). Scientific evidence shows that adding barley to one's diet can provide health benefits of serum cholesterol lowering (Coles *et al*., 2007), barley β-glucan controls blood glucose better and lowers glycemic index as well as improve the insulin response (Östman *et al*., 2007) . In previous investigations of Swanson and Penfield (1988) and Dhingra and Jood (2004) indicated that wheat bread with barley flour added at 15-20% was acceptable in overall flavor, appearance and texture, but an increase portion of barley flour caused a decrease in loaf volume and, dull brown color and hard crumb texture.

Egypt is one of the largest wheat importing countries, because the yearly local production of wheat covered only about 52-55% of total requirements for bread making and other bakery products (Othmann and Barghash, 2015). Egypt faces great problem in increasing of population rate and consequently increasing of imported wheat, therefore, we trying to decrease the amount of imported wheat using the mixing of other cereals such as barley flour with wheat flour for bread production. The objective of the present work was therefore to study the effect of different moisture contents of tempered hulled and hull-less barley grains prior to milling on extraction rate, color and characteristics of flour.

2-Materials and Methods

2.1.Materials: Grain samples of hulled barley cultivars *Giza 123* and hull-less barley cultivars *Giza 130* were purchased from Agricultural Research Center of Giza.

2.2. Methods:

2.2.1. Milling: 50 kg of each hull and hull-less barley grains sample were cleaned thoroughly, and the foreign seeds and materials were removed by hand picking followed by sieving. The barley grains were then conditioned by wetting the grains using different amounts of tap water. The tempering process was completed by mixing and storing the moist grains for 15-24 hours to obtain different moisture contents of tempered grains at 12, 14, 16, and 18%o prior to milling. Milling was run in a local stone mill. The straight flours thus obtained was sieved through suitable sieves (350, 300 and 250 µm) to flour and other milling fractions. The obtained flour samples were cooled immediately and stored in air tight plastic containers at 4 ºC until analysis.

2.2.2. Analytical Methods

2.2.2.1. determination of barley flour color*:* The color of barley flour samples was carried out according to the method described by Bao *et al.* (2005) using a Hunter Colorimeter fitted with optical sensor (Momcolor Inc.) on the basis of CIE L*, a*, b* color space. *L** is a measure of the brightness from black (0) to white (100). Parameter *a** describes red-green color with positive *a** values indicating redness and negative *a** values indicating greenness. Parameter *b** describes yellow-blue color with positive *b** values indicating yellowness and negative *b** values indicating blueness. The total color difference (Δ*E*) was calculated from the Hunter *L*, *a* and *b* values according to Equation: $\Delta E = (L^2+a^2+b^2)^{0.5}$. The Chroma value indicates color intensity or saturation and it is equal $(a^2+b^2)^{0.5}$. Hue angle was calculated as H^o and is equal $tan^{-1} (b^*/a^*)$.

2.2.2.2. Determination of chemical composition:

Moisture, protein, starch, reducing sugars, crude fat, crude fibers and ash contents were determined according to the methods described in the AOAC (1995**).** Total pentosan content was determined by a colorimetric phloroglucinol method (Douglas, 1981) using xylose as a standard. The total β-glucan was quantified according to the method reported by McCleary and Glennie (1985) using a 'β-glucan assay kits (Megazyme International Ireland Ltd., Wicklow, Ireland). For determination of free, bound and total phenolic compounds, the method descript by Abdel-Gawad (1982) was used for liberation and extraction of total phenolic compounds from the samples via alkali hydrolysis followed by extraction the phenolics at pH 3.5 using diethyl acetate, dehydration with anhydrous sodium sulfate, removing diethyl acetate and finally the residue was dissolved in methanol. Free phenolic compounds were extracted from the samples by methanol only without alkali hydrolysis. Phenolic compounds were determined by Folin-Ciocalteu method spectrophotometrically (Singleton and Rossi, 1965), and as standard gallic acid were used. The results were expressed as milligrams of gallic acid equivalents (GAE) per100 gram of flour sample on dry weight basis. Bound phenolic compounds were calculated by subtract free phenolics from total phenolics. The phytic acid was determined in terms of its phosphorous content, using the method described by Kent-Jones and Amos (1957). The phytic acid (IP6) was calculated from phytate phosphorus from the weight ratio of phosphorus atoms per molecule of IP6 (1:3.52) according to Abdel-Gawad 2016. The water-soluble protein, starch, pentosan and β-glucan were determined in water soluble extract of barley flours by mixing 10g flour with 100 ml of distilled water; stirred for 15 min at room temperature (22ºC±1), then centrifuged for 10 min at 2500 rpm. The obtained supernatant was filtered through filter paper Whitman No.1 in a measuring flask 100 ml and finally dilute with distilled water to the mark. Aliquots of extract were used for determination of protein (Lowry *et al.*, 1951), starch (AOAC, 1995), pentosan (Douglas, 1981) and β-glucan (McCleary and Glennie, 1985).

***2.2.2.3* Relative viscosity of water soluble extract:** The water-soluble fraction was obtained without endogenous enzyme inactivation, using a simple water extraction (flour to distilled water 1:10), with constant starring (150 rpm), at three different temperatures 25, 35 and 45°C in water bath. The extracts were centrifuged for 10 minutes at 5,000 rpm. Following the centrifugation, an aliquot of 5 ml supernatant was removed for the relative viscosity assay by Micro-UBBELOHDE viscometer according to method of Richter *et al*. (1968). All results were expressed as values relative to that of water.

2.2.2.4 Rapid Visco Analyser: The pasting behaviors of barley flours were evaluated using Rapid Visco-Analyzer (Perten instruments, a Perkin Elmer company) and conducted following the manufacture's instruction and as described by Higley *et al*. (2003).

2.2.2.5 Statistical analysis: Analysis of variance and significant differences among means were tested by one-way ANOVA using SPSS software (version 16.0 for Windows, SPSS Inc., Chicago, IL). Analysis of Variance (ANOVA) was completed using Duncan’s multiple comparison for mean difference testing.

3. Results and Discussions

3.1 Extraction rate of flour:

It is common knowledge that conditioning moisture has a profound effect on wheat milling product yield and product refinement (Dexter and Martin 2002). Therefore, the effect of different moisture contents of tempered barley grains prior to milling on yield of flour and other milling fractions of hulled and hull-less barley were examined. Figure 1 showed the yield of milling fractions of hulled and hull-less barley grains, which milled at different moisture levels (12%, 14%, 16% and 18%). After milling of barley grains using a local stone mill and sieving of whole flour, hulled barley grains produce four milling fractions: flour, fine bran, coarse bran and hulls whereas, the hull-less barley grains produce the same first three milled products, but without hulls fraction. The most of hulls of hull-less barley grains are removed during washing and tempering treatment of grains. The flour yield of both barley cultivars ranged from 41.83 to 83.10 %, and the highest flour extraction rate (83.10%) was observed for hull-less barley grains at conditioning moisture of 12%. In previous studies, Izydorczyk *et al*. (2003) reported that the extraction rate for roller milled barley cultivars ranging from 51.1% to 63.1% and Bhatty (1999) found the average of flour extraction rate ranged from 43% to 60% for different barley cultivars. It could be seen from Figure 1, that the increase of moisture content of barley grains from 12 to 18% prior to milling decreased the flour yield from 58.52 to 41.83% in hulled barley and from 83.10 to 68.32% in hull-less barley. Generally, the Figure 1 indicated a negative correlation between moisture content of barley grains prior to milling and flour yield. This confirm the fact that when the conditioning moisture increases the husk and outer layers of grains become more moist so that preventing the formation of fine particles during milling. Some previous investigations indicated that the increase in moisture content of tempered hull-less barley from 9 to 16% caused decreasing in flour yield (Bhatty, 1997) and change in particle size distribution as well as lowering of flour yield (Al-Suaidy, 1971).

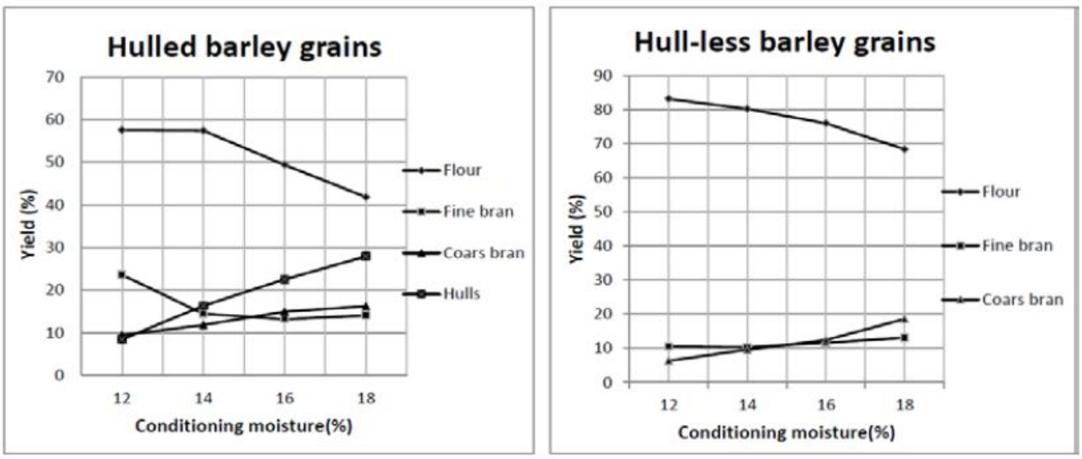

Fig.1: yield of milling fractions of hulled and hull-less barley grains.

3.2 Flour color:

The color of flour is a matter of the greatest importance in the milling industry because it affects the color of the crumb of finished baked product. The color of barley flour was evaluated by CIE Lab color scale (*L*, a* and b**). The *L** value indicates the lightness, 0-100, representing (0) dark to (100) light. The statistical analysis in Table 1 indicated that the *L** value of flour was significantly affected by barley cultivars. The flour from hull-less barley had higher *L** values (white) than that corresponding flour from hulled barley as a consequence of the hull and pericarp particles present in the flour of the latter variety. Barley flour color varies not only with different cultivars but also within the same cultivars grown in different seasons and in different growth locations (Bhatty, 1993). The color of different flours from each cultivars (Table 1) was dependent on the moisture content of grains prior to milling. The low moisture content of conditioning (12%) resulted in low *L** value (dark color) for flour from both cultivars. The statistical analysis of the data in Table 1 indicated significant higher *L** values for flours from hull-less barley milled at 14% , 16% and 18% moisture prior to milling than that of corresponding flours from hulled barley milled at the same tempering moisture content. The *L** values which indicated the brightness of color were increased as the conditioning moisture of hull-less barley increased and the flour of this variety which milled at high moisture (18%) showed significantly the highest L*value. The results of Table 1 showed improving in color brightness of flours from hulled variety milled at 14 and 16% moisture content before milling but no significant differences among themselves. The results of our study are agreement of that reported by Izydorczyk *et al*., 2003; they found that increasing conditioning moisture from 12.5 to 14.5% strongly improved flour brightness with only a moderate loss of flour yield and as the moisture content was increased to 16.5%, flour yield declined without a compensating improvement in brightness. The a* value which gives the degree of the red-green color, with a higher positive a* value indicating more redness. In this study, the changes in redness or a* values of flours were high significant as affected by barley cultivars and ranged from 0.14 to 0.4, with variable changes between tempering levels. On the other hand, there was a trend to increase in a* values of flours milled from hulled barley grains and decrease in these values for the flours of hull-less barley with increasing the conditioning moisture levels. Actually, flour color in barley is influenced by anthocyanin pigments (purple, blue, or dark) (Bhatty, 1993). The b* value indicates the degree of yellow-blue color, with higher positive b* value indicating more yellow. The b* value of flour was affected significantly with barley cultivars. The b* value ranged from 5.68 to 9.73. The highest b* value was observed for flour from 18% conditioning treatment of hull-less barley grains and the lowest for flour from 12% conditioning treatment of hulled barley. Sharma and

Gujral (2010) studied the color properties of eight commonly grown Indian hulled barley cultivars and reported similar results for L*, b* and a* color values. Although particle size differences influenced results, the differences in the CIELAB color space parameters were related to flour ash contents and flour yellow pigment contents. L^* was correlated with flour ash content (Oliver *et al*., 1993). The total color difference (ΔE) of flours was significantly affected by barley cultivars. There was an increase in ΔE value with increment of moisture content of tempered barley grains. The highest (ΔE) value was observed for 18% conditioning moisture while 12% conditioning treatment had the lowest value in both barley cultivars. The statistical analysis in Table 1 indicated that the chroma values were significantly affected with barley cultivars. The term Hue is defined as an attribute of visual perception according to which an area appears to be similar to one of the colors red, yellow, green, and blue, or to a combination of adjacent pairs of colors considered in a closed ring (C.I.E, 1987). There was a relationship between the values of a * and b * and the range of hue angles were 0-90° (Choudhury, 2014).

Table 1: Effect of moisture content of tempered barley grains prior to milling on the color of flour.

Samples	Moisture content of barley grains prior to milling (%)	*L**	*a**	*b**	ΔE	*Chroma*	*Hue*
Flours from *Giza* 123 (hulled barley)	12	73.44f	0.14d	5.68h	13.38h	5.68h	88.58a
	14	77.53c	0.18cd	6.09g	13.86g	6.09g	88.31c
	16	77.76c	0.16bcd	6.38f	14.01f	6.38f	88.56a
	18	77.00d	0.40a	7.22d	14.36e	7.23d	86.83g
Flours from *Giza* 130 (hull-less barley)	12	76.48e	0.38b	7.61c	14.53d	7.62c	87.14e
	14	87.96b	0.36bc	7.75b	15.36b	7.76b	87.34d
	16	88.06b	0.37b	7.18e	15.09c	7.19e	87.05f
	18	89.47a	0.26bcd	9.73a	16.54a	9.73a	88.47b

Each value is the mean of triplicate determinations. Different letters means significant differences at ($p < 0.05$), whereas values with the same letter means no significant differences.

3.3 Chemical composition:

The changes in gross chemical composition of flours obtained from tempered barley grains with different moisture contents prior to milling are shown in Table 2. The moisture contents of flours obtained from hulled and hull-less barley were increased significantly with increasing the moisture contents of tempered grains. The moisture content of a flour after milling are ordinarily dependent on the moisture content of tempered grains and the degree of heating produced during milling (Srinivasan and Smith, 2012). Protein, crude fat, pentosan, β-glucan, crude fiber and ash contents of flours from both cultivars were decreased significantly with increment the moisture content of grains prior to milling. The decrease of these components is related to lowering the flour extraction rate because most of them are localized in outer layers of grains than in endosperm. In addition, the increasing of moisture contents of tempered grains prevented the formation of fine particles of grain outer layers during milling and therefore pass not through the sieves during flour production (Kent-Jones and Amos, 1967). The increase of moisture content of barley grains from 12 to 18% prior to milling decreased the total β-glucan content from 3.84 to 2.37% in hulled barley flour and from 4.20 to 3.37% in hull-less barley flour. This confirms the fact that when the conditioning moisture increases, the husk and outer layers of grains become moist, so that decreasing the flour contamination with fine particles which containing higher amount of β-glucan. In this concept Bhatty (1993) showed that amount of total beta glucan content of flour, bran and shorts of hull-less barley was 4.3, 6.3 and 8.4%; respectively on free moisture basis. Besides, Zheng *et al*., (2011) reported that the flour of six hull-less barley cultivars had the lowest concentration of β-glucan, which was derived from the endosperm cell walls.

Starch, reducing sugars and free phenolics of flours of both cultivars were increased with increment of conditioning moisture content. The increasing of starch is related to low flour extraction rate because the starch localized mainly in endosperm cells, whereas the increase in reducing sugars and free phenolics is as result of enzymes activation at high moisture content during conditioning process. Kleinwächter *et al*. (2014) reported variable activities of the enzymes α-amylase, β-amylase and β-glucanase in the different steeped barley. The increase in free phenolics and decrease in bound and total phenolic content in both barley cultivars (Table 2) may be attributed to the bound phenolics becoming free by the action of enhanced hydrolytic enzyme activity (Mailard *et al*. 1996). The phenolic compounds are mainly concentrated in cell walls of the grain outer layer mostly esterified to the arabinose side groups of arabinoxylans (Mailared and Berest, 1995). The phytate phosphorus and phytic acid content varied significantly among barley cultivars. The hulled barley flours contain higher phytate than hull-less barley flour because the hulls and pericarp in hull variety contain higher phytate than the endosperm. The phytate content decreased in all tested flours as the tempered moisture of grains prior milling increased which may be due to the lowering of flour extraction rate and/or to enhancing activity of enzyme phytase during conditioning process.

Table 2: Effect of different moisture contents of tempered barley grains on the changes of chemical composition of obtained flours.

Samples	Moisture content of barley grains prior to milling (%)	Moisture (%)	Chemical composition of barley flours (on dry weight basis)												
			protein* (%)	fat* (%)	starch* (%)	Pentosan (%)	β-Glucan (%)	Reducing sugars* (%)	Crude fiber* (%)	Ash* (%)	phenolic compounds (mg GAE/100g flour)			phytic acid phosphorus (mg/100g flour)	phytic acid (mg/100g flour)
											Free	Bound	Total		
Flours from *Giza123* (hulled barley)	12	10.55h	11.03c	2.37b	70.16h	4.16a	3.84b	0.600f	2.49a	1.76a	66.10h	162.77a	228.87c	158.45a	562.17a
	14	11.73f	10.95d	1.97d	70.46g	4.12b	3.63d	0.637e	2.42b	1.74b	87.38g	125.75d	213.13e	158.09b	560.92b
	16	12.10d	10.39e	1.87e	71.20f	3.81c	3.62e	0.705d	1.85e	1.69c	103.73f	74.56e	178.29g	94.59f	335.63f
	18	12.49c	9.81f	1.67g	72.06e	2.62d	2.37h	0.770c	1.84e	1.67d	107.41e	59.73g	167.14h	93.60g	332.08g
Flours from *Giza130* (hull-less barley)	12	11.37g	11.67a	2.41a	77.08d	2.58e	4.20a	0.744cd	2.20d	1.41e	112.21d	137.18b	249.39a	147.55c	523.53c
	14	11.98e	11.29b	2.06c	77.92c	2.54f	3.78c	0.744cd	2.28c	1.34f	116.76c	128.63c	245.39b	124.09d	440.30d
	16	12.96b	11.03c	1.89e	78.87b	2.42g	3.56f	1.04b	1.86e	1.32g	151.74b	70.13f	221.87d	114.28e	405.46e
	18	13.04a	10.89d	1.72f	79.39a	2.09h	3.37g	1.11a	1.65f	1.29h	175.38a	34.31h	209.69f	78.10h	277.12h

**Calculated on dry weight basis.*
Each value is the mean of triplicate determinations. Different letters means significant differences at ($p < 0.05$), whereas values with the same letter means no significant differences.

3.4 Solubility of flour components:

The values of protein solubility in distilled water of different barley flours ranged from 9.94 to 13.05% (Table 3). There was small increase in protein solibility of flours with increasing the conditioning moisture before milling. Soluble starch content of barley flours increased significantly in both barley varieties by increase of conditioning moisture of the grains before milling but the increment was higher in hulled barley flour than that in hull-less barley flour. The increase in soluble starch content may be due to the degradation of starch by amylases, which activated during tempering of barley grains, into low molecular weight fragments (Hug-Iten *et al*., 2003). The soluble starch extracted at room temperature (22ºC±1) from flours of two barley cultivars and determined as a percentage of total flour starch ranged from 0.25 to 3.25% (Table 3). These results are similar to that reported for wheat (0.9-1.67%) by Kulp and Lorenz (1981) and for three barley cultivars (0.9-2.1%) by Šubarić *et al*., (2011). In addition, it could be seen from Table 3 that the content of soluble pentosans in barley flours ranged from 0.16 to 0.46%; and there was an increase in water-soluble pentosan contents with increasing the moisture content of tempered grains. This increase may be due to increase the activity of xylanases by increment of conditioning moisture. The soluble pentosan as a percentage of total flour pentosan was increased from 5.77% to 17.56% in hulled barley flours and from 6.14% to 8.67% in hull-less barley flours as moisture tempering increase from 12% to 18%; respectively. Andersson *et al*., (2003) reported that the arabinoxylan contents in straight-run white flours of four hull-less barley samples (conditioned to 14.3% moisture) were 1.2–1.5%, of which ≈17% was water-extractable. The solubility of pentosan in hull-less barley flours were lower than hulled barley flours (Table 3). It is known that the husk of barley contains high contents of pentosan than the endosperm. On contrary Holtekjølen *et al*., (2006) found that hull-less varieties having a significantly higher content of soluble arabinoxylan than the hulled samples.

Table 3: Effect of moisture content of tempered barley grains prior to milling on the solubility of flour components (on dry weight basis).

Samples	Moisture content of barley grains prior to milling (%)	Soluble protein (g/100g flour)	Soluble protein as % of total flour protein	Soluble starch (g/100g flour)	Soluble starch as % of total flour starch	Soluble pentosan (g/100g flour)	Soluble pentosan as % of total flour pentosan	Soluble β-glucan (g/100g flour)	Soluble β-glucan as % of total flour β-glucan
Flours from *Giza123* (hulled barley)	12	1.23b	11.15e	1.46d	2.08d	0.24d	5.77g	1.53c	39.84e
	14	1.22b	11.14e	1.98c	2.81c	0.30c	7.28d	1.67b	46.00c
	16	1.26a	12.13b	2.05b	2.88b	0.31b	8.14c	1.71b	47.24b
	18	1.28a	13.05a	2.34a	3.25a	0.46a	17.56a	1.94a	81.85a
Flours from *Giza130* (hull-lessbarley)	12	1.16c	9.94g	0.19h	0.25h	0.16g	6.20f	0.67f	15.95h
	14	1.18c	10.49f	0.25g	0.32g	0.16g	6.29f	1.36e	35.97g
	16	1.26a	11.42d	0.31f	0.39f	0.17f	7.02e	1.40de	39.33f
	18	1.26a	11.57c	0.38e	0.48e	0.18e	8.61b	1.44d	42.73d

Different letters mean significant differences at ($p < 0.05$), whereas values with the same letter mean no significant differences.

The soluble β-glucan content exhibited significantly increasing in flours of both barley varieties as the moisture content of tempering grains before milling increased (Table 3). Such increase may be due to hydration and solubilization of more beta-glucan molecules from the cell wall matrix when the moisture content of tempered grains enhanced. In this study, the soluble β-glucan in barley flours ranged from 1.53 to 1.94% in hulled barley and 0.67 to 1.44% in hull-less barley. Likewise Anker-Nilssen *et al*. (2008) reported that the water-soluble β-glucan contents for eight different cultivars and five different growth temperatures ranged from 0.6% to 3.3% (on dry weight). The flours from hulled barley showed significantly higher β-glucan solubility (soluble β-glucan as a percent of total flour β-glucan) than that of flours from hull-less barley. It increased from 39.84% to 81.85% and from 15.95% to 42.73% in flours of hulled and hull-less barley verities when the tempered moisture of grains raised from 12% to 18%; respectively. Izydorczyk *et al*., (2000) showed that extractability of soluble β-glucan ranged between 20.6% and 52.5%. Benito-Román *et al*., (2011) reported that the solubility represents the maximum amount of β-glucan that can be dissolved in water to form a homogenous solution under controlled conditions of temperature, pressure and molecular weight of the polymer. Generally, the highest solubility values were achieved with the lowest molecular weight of β-glucans. The higher solubility of β-glucan and pentosan of hulled barley flours than that observed for hull-less barley flours (Table 3) is the reason for the higher relative viscosity of flour water extracts of the former than that of the latter (Fig.2). The relative viscosity of flour water extract determined at different temperatures (25, 35 and 45ºC) indicated variations in decreasing of viscosity as the temperature assay increased. The relative viscosity values were increasingly as the conditioning moisture of grains prior milling raised (Fig.2). Soluble fibers such as mixed-linked β-glucans in barley (Coles *et al*., 2007) and arabinoxylans in rye (Wang *et al*., 2016) or wheat (Skendi and Biliaderis 2016) interfere with the absorption of nutrients, particularly fats, due to the increased viscosity of the intestinal contents. Correspondingly, these fibers lower blood cholesterol (Östman *et al*., 2007). The reduced fat absorption and blood cholesterol content is probably partly caused by binding or trapping of bile salts in the gut due to high viscosity (Moundras *et al*., 1997), and/or a reduced emulsification and lipolysis of the fat (Pasquier *et al*., 1996). In addition, it has been shown that diets with a high viscosity may increase the microbial activity in the digestive tract (Choct *et al*., 1996). An increased microbial activity may deconjugate bile salts and alter gut health.

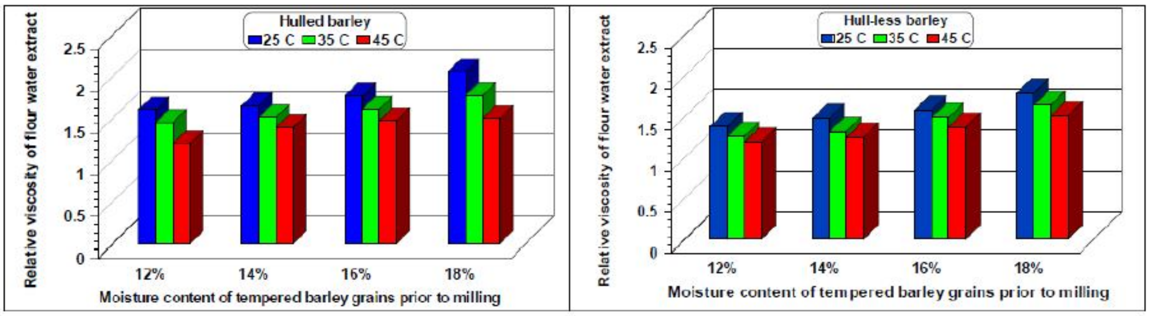

Fig.2: Relative viscosity at different temperatures of flour water extract from hulled and hull-less barley grains tempered at different moisture content prior to milling.

3.5 Starch characteristics:

Table (4) illustrated the Rapid Visco Analyser (RVA) measurements for the barley flours obtained from grains milled at different conditioning moisture. The values of barley flours for pasting temperature, time to gelatinization, time to peak, peak viscosity, trough viscosity and final viscosity were decreased as the moisture content of barley grains prior milling was increased. The pasting temperature of flours from hulled and hull-less barley ranged from 75.0 to 84.75°C. Sharma and Gujral (2010) reported that pasting temperature for eight commonly grown Indian hulled barley cultivars ranged from 81.13 to 85.50°C and Eriksson (2012) studied different barley varieties and he found that pasting temperature ranged from 65°C to 93°C. The decrease of time to gelatinization (Table 4) may be due to binding the phosphorus released from degradation of phytic acid as phosphate monoesters with amylose. Ormerod *et al*. (2002) reported that the higher amylase and divalent cation of starch are consistent with a more raped swelling and gelatinization. Higley *et al*. (2003) found a negative correlation between the time to gelatinization and the high contents of amylase, phosphorus, calcium and magnesium of starch. Besides, Copeland *et al*., (2009) showed that the peak time and peak viscosity can be associated with the water absorption capacity. The decrease which happened in peak viscosity after conditioning treatment of both barley cultivars grains to high moisture content may be due to the increase of alpha amylase activity, Preedy *et al*. (2011) reported that high peak viscosity reflect weak alpha-amylase activity. Tang and Copeland (2007) reported that the content and rate of amylose leaching, resulting in a higher pasting temperature and lower peak viscosity. Trough viscosity is measured at the minimum point following peak viscosity. Breakdown viscosity is the difference between peak and trough viscosity. In this work, the hull-less barley flours tended to have lower trough viscosity than the hulled flours. Similar results were reported by (Gray *et al.*, 2010).

In terms of setback parameter, cooling causes the re-association of starch molecules which results in gel structure formation and an increase in final viscosity due to retrogradation. The difference between the final viscosity and the trough viscosity is the setback viscosity. A low setback value is indicative of low retrogradation. Table (4) illustrated that there was a trend to decrease in the total setback with the increase in conditioning moisture. Moreover, the conditioning treatment 18% of hull-less barley had the lowest setback (570cP) and final viscosities (802cP). This could suggest that breads containing barley flours obtained from moist grains to 18% moisture before milling would not stale rapidly than breads containing barley flours obtained from dry milling. Likewise, Gray *et al.*, (2010) reported that hull-less cultivar had significantly lower setback and final viscosities than the other cultivars they studied.

Table 4: Effect of the moisture content of tempered barley grains on the starch characteristics of obtained flour (on base of 14% moisture)

Samples	moisture content of barley grains prior to milling (%)	Rapid Visco Analyser (RVA) characteristics							
		Pasting temperature (°C)	Time to gelatinization (min)	Time to Peak (min)	Peak viscosity (Pa. s)	Breakdown (Peak-Trough) (Pa. s)	Trough Viscosity (Pa. s)	Total setback (Pa. s)	Final viscosity (Pa. s)
Flours from *Giza123* (Hulled barley)	12	84.75	3. 9	6.53	3.299	1.378	1.921	1.415	3.336
	14	83.9	3. 8	6.33	2.745	1.205	1.540	1.303	2.843
	16	83.2	3.75	6.27	1.984	0.993	0.991	0.998	1.989
	18	81.45	3.65	5.93	1.969	1.161	0.808	1.094	1.902
Flours from *Giza130* (Hull-less barley)	12	84	3.9	6.33	2.818	1.119	1.699	1.257	2.956
	14	81.4	3.55	5.93	2.073	1.195	0.878	1.090	1.968
	16	75.0	3.3	5.93	2.048	1.250	0.798	1.198	1.996
	18	75.0	3.15	5.07	1.235	1.003	0.232	0.570	0.802

4. Conclusion

The hulled and hull-less barley grains were conditioned at different moisture content prior milling. The increasing of tempering moisture prior milling decreased the flour extraction rate and improved flour color (become white) with increment the solubility of pentosan and β-glucan.

5. Reference

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محتوى رطوبة مختلفة لتكييف حبوب الشعير المغطى والعاري قبل عملية الطحن
١ – التأثير على معدل الاستخلاص واللون وخصائص الدقيق

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الملخص

أجرى هذا البحث لدراسة تأثير اختلاف المحتوى الرطوبي (18,16,14,12%) لحبوب الشعير المغطى والعاري قبل عملية الطحن على معدل الاستخلاص وكذلك لون وخصائص الدقيق الناتج.

ولقد استبان من نتائج الدراسة انه مع زيادة نسبة رطوبة التكييف في حبوب الشعير قبل عملية الطحن، حدث انخفاض في معدل استخلاص الدقيق بشكل ملحوظ. هذا ولقد كانت نسبة الدقيق الناتج من الشعير العاري اعلى من مثيلتها في الشعير المغطي.

ولقد أظهرت نتائج الدراسة أيضاً لون الدقيق الناتج من صنف الشعير العاري (جيزة 130) قد تحسن بشكل ملحوظ (أصبح أبيض) مع زيادة نسبة الرطوبة في الحبوب قبل عملية الطحن ، بينما تحسن لون الشعير المغطى (جيزة 123) بشكل أقل.

هذا ولقد تمت دراسة التركيب الكيميائي للدقيق الناتج من صنفي الشعير المغطى والعاري، واظهرت النتائج أن البروتين والدهون والألياف الخام والرماد والبنتوزان والبيتاجلوكان وكذلك المواد الفينولية الكلية والمرتبطة ، بالإضافة إلى حامض الفيتيك قد انخفضت مع زيادة نسبة الرطوبة في حبوب الشعير قبل عملية الطحن.

بينما سجلت نتائج تقدير النشا والسكريات المختزلة وكذلك المواد الفينولية الحرة ارتفاعاً ملحوظاً، مع زيادة نسبة الترطيب في حبوب الشعير قبل عملية الطحن.

ولقد وجد زيادة في نسبة كل من البروتين الذائب والنشا الذائب بكميات طفيفة في عينات الدقيق الناتج من صنفي الشعير محل الدراسة مع زيادة نسبة الرطوبة في الحبوب قبل الطحن، بينما سجلت نسبة كل من البنتوزان والبيتاجلوكان الذائب في الماء ارتفاعاً ملحوظاً. ولقد انعكست النسب المرتفعة للبيتاجلوكان والبنتوزان الذائب في الماء في عينات الدقيق الناتج من الشعير المغطى على ارتفاع قيم اللزوجة النسبية في المستخلص المائي لدقيق الشعير المغطى عن مثيلتها في الشعير العاري.

وعند استخدام جهاز Rapid Visco Analyser (RVA) لتقييم عينات الدقيق محل الدراسة، تم الحصول على عدد من المقاييس المختلفة مثل: درجة حرارة بداية الجلتنة، وقت الجلتنة، الوقت اللازم للوصول للزوجة القصوى، اللزوجة القصوى، اللزوجة الدنيا وكذلك اللزوجة النهائية ؛ ولقد سجلت جميع المقاييس السابقة انخفاض ملحوظ مع زيادة نسبة الرطوبة في حبوب الشعير قبل عملية الطحن.