The Rheological Properties and Influence of Milling Conditions on Solvent Retention Capacity of Australian and Russian Wheat Flour

Abo-Dief, M.F.[1], Taiseer, M. Abo-Bakr [2], Youssef, M.M.[2] & Ayat, M. Moustafa[2]

(1) Arabian Milling & Food Industries Co., Borg Al-Arab, Alexandria, Egypt.

(2) Food Science and Technology Dept., Fac. of Agric. University of Alexandria, El-Shatby, 21545, Alexandria, Egypt.

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ABSTRACT

The present work aimed to study the rheological properties of two types of wheat flour (Australian and Russian). Furthermore, the influence of time tempering and milling systems (hard and normal) on the values of solvent retention capacity (SRC) and gluten performance index (GPI) of the two types of wheat flour were investigated which applied on a full industrial scale. The results of Alveograph parameters indicated that Australian wheat flour exhibited higher values of all parameters except elasticity/ extensibilityratio than their counterparts for Russian wheat flour. Meanwhile, there were differences between the two types in the Mixolab simulator properties.

Also, the results revealed that flour obtained from the tempered Australian wheat for different times of tempering exhibited significantly ($P \leq 0.05$) higher solvent retention values than their counterparts for Russian wheat. The results indicated that the values of lactic acid solvent retention capacity (LA-SRC) and ethanol solvent retention capacity (ET-SRC), were higher for flour obtained by normal milling. Meanwhile, the results of sodium carbonate (SC-SRC), sucrose (SU-SRC) and water (WA-SRC) values were higher when hard milling was used than normal milling for the two types of wheat flour. The present study showed an increase in the gluten performance index values after increasing the roller gap for the two wheat types.

Keywords: Rheological properties, solvent retention capacities, LA-SRC, ET-SRC, SC-SRC and WA-SRC.

INTRODUCTION

The quality of wheat is closely related to the quality of its milled products particularly flour and is usually judged by its suitability for particular end use. Botanically, three wheat species, *Triticum aestivum* L., *T. compactum*, and *T. durum* are of commercial importance. These species differ considerably in their characteristics, and their differences are reflected in the uses of the milled products. Australian prime hard wheat is a class wheat among five different classes currently available in Australia. While USSR standards grade 3 (white spring) wheat is class wheat among five different classes are currently available in Russian and used mainly for bread making (Khan& Shewry, 2009, Posner, 2009).

Wheat hardness or texture is the common characteristic used by millers to classify wheat in terms of hard and soft. The microscopic examination showed that hard wheat has a uniform endosperm structure with starch granules firmly impeded in the surrounded protein matrix. In contrast, soft wheat kernels have a much disordered structure with a protein matrix in many cases being pulled away from the starch granules (Mabille *et al*., 2001, Fang &Campbell, 2002 , Turnbull *et al.*, 2003, Dziki &Laskowiski, 2005, Posner, 2009).

The rheological properties during mixing, kneading and extension of dough were different in the technological phase of milling in which they were extracted. Alveograph parameters such as dough elasticity (P) and deformation energy (W) have been known as important functional flour specifications that can provide information about the functionality of the flour (Pojic *et al*., 2014). The high extraction rate caused a negative effect on the rheological properties of dough such as, alveograph parameters (P, L, G, P/L ratio) (Aprodu *et al*., 2010, Ulmer, 2011, Finnie & Atwell, 2016, Moradi *et al.,* 2016 , Brütsch *et al*., 2017).

The solvent retention capacity (SRC) is a physicochemical test carried out on hard and soft wheat flours to determine their properties during mixing such as baking quality , hydration performance and end use . The ability of flour to keep a set of five solvents produces the profile quality of the flour for predicting bakery performance (Slade &Levine 1994, Roccia *et al*., 2006 , Xiao *et al*., 2006). The water absorption, damaged starch, retention profile of gluten proteinsand pentosans were determined by the SRC test using four different solvents: lactic acid (LA) (5% w/w) in water is related to glutenin characteristics, sodium carbonate (5% w/w) in water is related to the contents of damaged starch, Sucrose (50% w/w) in water is correlated to pentosans characteristics, and water SRC is affected by all of those flour constituents (Haynes, 2009, Guzmán *et al.,* 2015).

The SRC gives bakery, mill scientists and laboratory technicians the potentiality to:

1- describe the ability of the flour to absorb water during the mixing process and to release that water during the baking process. 2- determine the level of damaged starch in the flour. 3- establish a profile quality of the flour for predicting functionality and specification conformance. 4- evaluate the different mill stream flour for their use and applications in the targeted end product. Also, the values of SRC highly correlate with rheological dough properties such as extensograph, alveograph and farinograph (Duyvejonck *et al*., 2011, Hruskova *et al*., 2012, Lndgren &Simsek 2016, Labuschagne *et al*., 2021).

The dilute lactic acid solution (5% w/w) LA-SRC was used to measure gluten quality and functionality. Flour swelling in lactic acid is related to gluten formation and protein quality. It affects the properties of glutenins during the fermentation process for baked products. The LA- SRC values decreased due to reducing of tempered wheat moisture and increasing flour extraction rates. The "LA-SRC" values varied from 51% to 177% according to the type of wheat flour (Kweon *et al*., 2009, Kweon *et al*., 2011, Hruskova *et al*.,2012).)

Dilute aqueous 5% of sodium carbonate solution "SC-SRC" is the solvent for damaged starch (Donelson & Gaines, 1998). It represents a measure of wheat pentosan content and its functionality. Higher SC-SRC values resulted in a higher amount of damaged starch that will be produced when moisture in the grain decreases, making the kernel harder. The SC-SRC values varied from 51 to 126% according to the type of wheat flour (, Khan & Shewry, 2009, Kweon *et al*., 2009, Kweon *et al*., 2011, Barak *et al*., 2014).

Sucrose-SRC values decreased due to reducing of tempered wheat moisture and increasing flour extraction rates and increased significantly with decreases in particle size (Kweon *et al*., 2011, Barak *et al*., 2014). In baking, xylanase can activate both soluble and insoluble pentosans in flour, resulting in improving the dough properties, stability, handling , better crumb structure and higher loaf volume will be obtained (Slade &Levine, 1994, Kweon *et al*., 2011 , Ali *et al*., 2014). Pentosans connect indirectly to ash content and directly to the alveograph specifications. Higher SC-SRC values are an indication of a higher amount of damaged starch (Rahil *et al*., 2015, Chavoushi, *et al*.,2022). The SU-SRC values for different wheat types ranged from 51 to 126% (Kweon *et al*., 2011).

The water W- SRC solvent can mist and swell the flour contents" gluten, damaged starch, and pentosans. Generally, soft wheat products need flours with low water absorption. In contrast, hard wheat products require flours with high water absorption. Water-SRC is affected by all water absorption components in flour (Slade &Levine, 1994, Kweon *et al*., 2011, Barak *et al*., 2014).

In general, the SRC values were correlated with loaf volume , whereas the LA- SRC values were the highest correlation ,followed by SU-SRC and least by distilled waterSRC. Also, the absorptions determined by the solvents are highly correlated with each other, this is more clear for W-SRC, SC-SRC, and SU-SRC. (Xiao *et al.,* 2006, Carver, 2009, Labuschagne *et al*., 2021).

The gluten performance index (GPI), is a new valuable SRC parameter, determinate asGPI = lactic acid / (sodium carbonate + sucrose) SRC value. In general when the GPI value increased by about one- third of the flour yield the flour extraction increased (Gaines 2000, Kweon *et al*., 2011). Triticale flours containing a higher amount of anti-parallel β-sheets and tyrosine resulted in higher lactic acid-SRC and (GPI), (Chavoushi, *et al*., 2022).

The present work aimed to study the rheological properties of two types of wheat flour (Australian and Russian). Furthermore, the influence of time tempering and milling systems (hard and normal) on the solvent retention capacity (SRC) values and gluten performance index (GPI) of the two types of wheat flour were investigated.

MATERIALS AND METHODS

Materials:

Two different types of wheat (*Triticum aestivum* L.) available in Egypt were used: Australian wheat (prime hard wheat, particle size index, 15.8%, specific weight, 80.6 kg/hl, protein, 15.5%, ash, 1.97% falling number, 532s, wet gluten, 33.8%) and Russian wheat (Gosudarstvennyy Standart grade 3, particle size index, 18.3%, specific weight, 78.9 kg/hL, protein, 12.8%, ash, 1.64%, falling number, 385 s, wet gluten, 26.2%). Wheat samples were obtained from the Arabian Milling and Food Industries Company, Alexandria, Egypt.

Milling process

The present study was applied on a full industrial scale. The experimental designs and the quantity of the milled wheat flour are given in Figure (1).

The Australian and Russian wheat samples (30 tons per type) were cleaned and tempered to 16 and 15.5% moisture, respectively by adding water. The amount of water required was calculated from the following formula:

Weight of added water =

[(100−original moisture% ÷ 100−desired moisture %) −1] × (weight of sample).

The tempering was carried out in two stages: The first stage lasted 32 hr, and the second stage lasted 4 hr. The milling process was carried out as normal milling and controlled using an automatic programmable logic controller (PLC) system supplied by Bühler (Switzerland) at Arabian Milling and Food Industries Company, Alexandria, Egypt. The roller flour mill had five break rolls and eleven reduction rolls beside one reduction roller (C10) with 1100 flutes in *circumference*, and the capacity of the mill is 300 tons/day.

Two transactions for wheat grinding were conducted, and the roll spacing was set mechanically using a feeler gauge. The normal milling system was used with break rollers of 0.4(B1) , 0.2 (B2), 0.1(B3) and 0.05 mm(B4 and B5). The reduction rollers measured, 0.08 mm for C1A, C2A, C1B,C2B and C3, and 0.06 mm for C4:C9.

Scanning Electron Microscope (SEM)

Scanning Electron Microscope" SEM "examination was used to identify the properties of the outer layers of the two wheat grain types. A sample was adhered on a SEM mount using double-sided conductive adhesive tapes and sputter coated with a 100–200 A ˚ thick layer of gold (JEOL JFC-1600 Fine Coater, Tokyo, Japan). The mounted sample was then placed on the SEM stage and images were digitally captured at 10 kV with 1500 magnification.

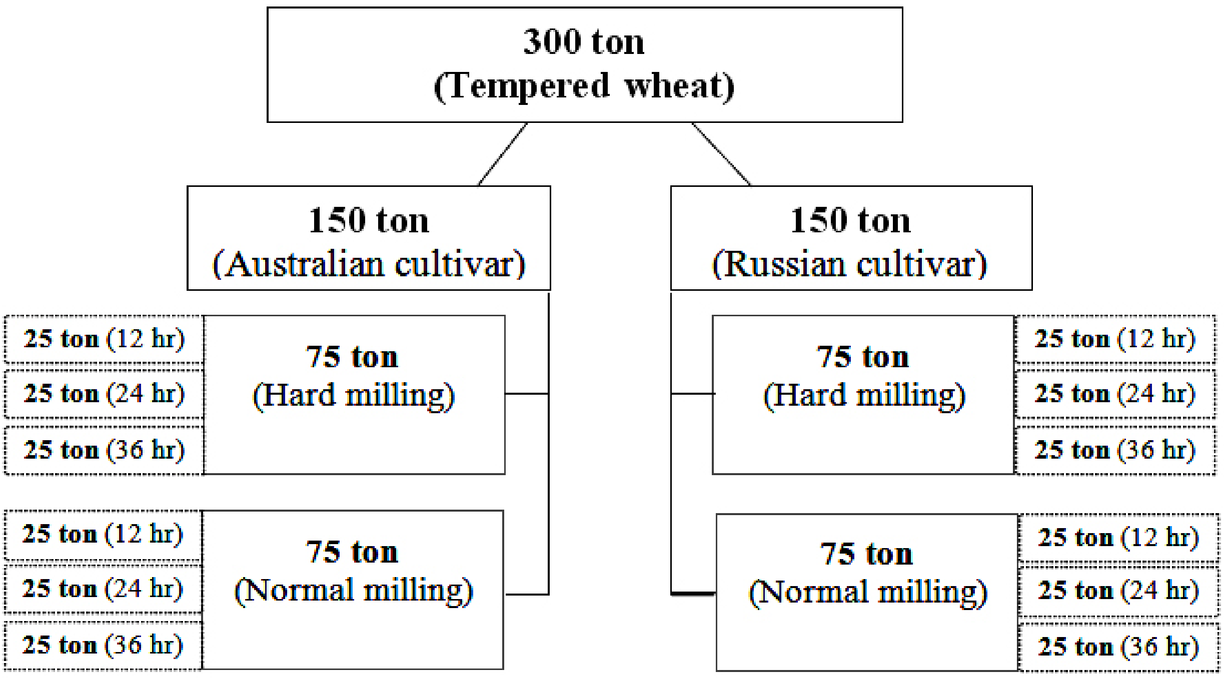

Fig. 1: Experimental design and wheat milled quantity

Solvent retention capacity and gluten performance index

Solvent retention capacity (SRC) is the weight of solvent held by flour after centrifugation. It is expressed as percent of flour weight (14% moisture basis).The solvent retention capacity tests were conducted according to the AACCI 2000 method 56-11.02. Five solvents are independently used to produce four SRC values: water (WA-SRC), 50% sucrose (SU-SRC),5% sodium carbonate (SC-SRC), 55% ethanol (ET –SRC) and 5% lactic acid (LA-SRC). The SRC value for each solvent was calculated as follows:

$$\% SRC = \left(\frac{gel\ wt}{flour\ wt} - 1\right) * \left(\frac{86}{100 - \%\ flour\ moisture}\right) * 100$$

The gluten performance index (GPI) was determined from the SRC data (Kweon *et al.*2011) and calculated according to the following formula:

$$\text{GPI} = \left(\frac{Lactic\ acid\ SRC}{Sodium\ carbobnateSRC + Sucrose\ SRC}\right)$$

Rheological methods (Alveograph and Mixolab Simulator)

The rheological properties of flour were determined by a Chopin alveograph according to AACCI 2000 (method 54-30.02) and Mixolab simulator (Chopin, Tripette and Renaud) according to the AACCI 2000 (method 54-60.01) and the ICC 2006 (method 173).

RESULTS AND DISCUSSION

Properties of the outer layer of the seed coat

To understand the milling behavior of wheat, it is necessary to know the morphology and histology of the single wheat grain, the structure of the entire kernel is important in determining the movement of moisture during drying and conditioning (Khan & Shewry, 2009).

The scanning electron micrograph of the outer grain layer for the two wheat types is shown in Figure (2). It can be noted that there are differences in the visual appearance of the outer layers of wheat grain (pericar*p* and aleuron layer) between the two wheat types. The cross section of Russian wheat kernels shows that the pericar*p* is more compact and has the largest size of the aleurone layer than the Australian wheat kernels.

The seed coat enclosed the endosperm and germ, fruit coat (pericarp) surrounds the seed and adheres closely to the seed coat to form a kernel or grain (caryopsis). The properties of the hull or bran layer are very important in determining the movement of moisture during drying and conditioning. Figure (2) shows that the hull of the Russian wheat type was more compact and thick than that of Australian wheat kernels. The aleurone layer cells under the outer layer were thicker for the Russian wheat kernel than that of Australian wheat kernel. These cells are approximately square and embedded in protein matrix which is the first layer of endosperm joined by the aleurone layer. The starch granules in this layer are covered with a protein matrix. The ratio of seed coat increases with a decrease in grain size, the larger the kernel, the lower rates of seed coat.

Rheological characteristics of Australian and Russian wheat flour

Alveograph parameters

The results of alveograph shown in Figure (3) indicate that Australian wheat flour exhibited higher values of all alveograph parameters ex-

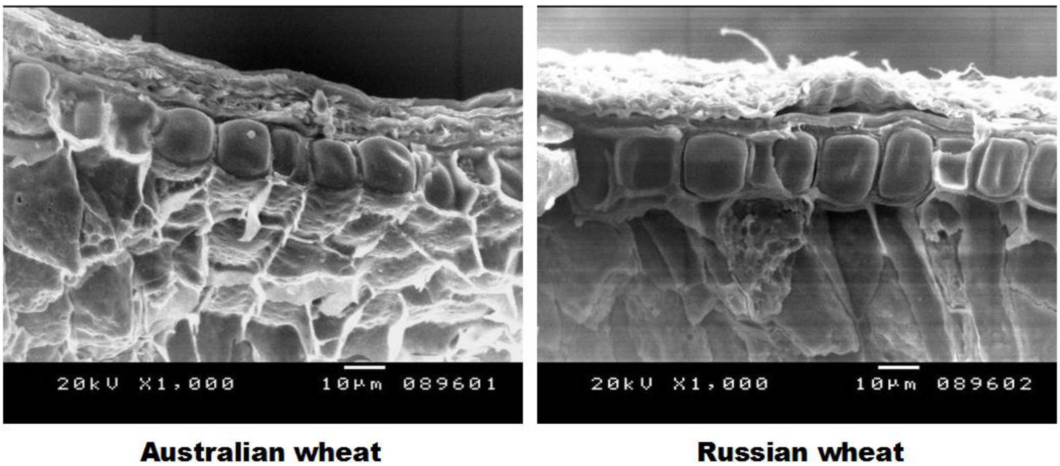

Fig. 2: Scanning electron micrograph of outer grain layers for Australian and Russian wheat flour

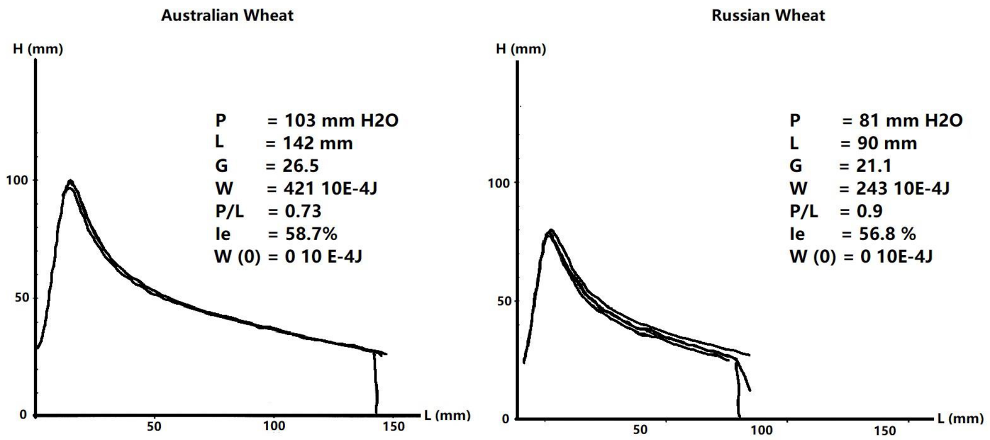

Fig 3: Alveograph rheological characteristics of Australian and Russian wheat flour

cept elasticity/ extensibility than those of Russian wheat flour. The former parameters were elasticity (103mm), extensibility (142 mm), swelling index (26.5),elasticity index (58.7), deformation energy (421 J) and elasticity/ extensibility (0.73). Meanwhile, they were 81mm, 90 mm, 21.1, 56.8, 243 J and 0.9, respectively for Russian wheat. These results indicate that Australian wheat flour had much better properties than the other type. Generally, dough mixing tests of whole wheat flour is a predicted indicator to the rheological properties of the obtained flour from the milling process.

Mixolab simulator parameters

Figure (4) represents the mixolab simulator properties of wheat flour of the two wheat types. The results show that there are differences between the two types of wheat in mixolab properties .Australian wheat recorded high water absorption (61.1%), dough stability time (15.5 min),dough development time (5.5 min) and low weakening Farinograph unit (21 FU). The stability value is an indication of the flour strength, stronger dough was obtained with higher values (Moradi *et al*., 2016, Brütsch *et al*., 2017) Meanwhile, Russian wheat, exhibited57.2%, 8 min, 2.5min and 42 FU for these parameters, respectively.

The farinographic parameters such as water absorption and dough development time increased when the flour extraction rate increased (Aprodu *et al*., 2010, Mueen-ud-Din *et al*., 2010). Moreover,

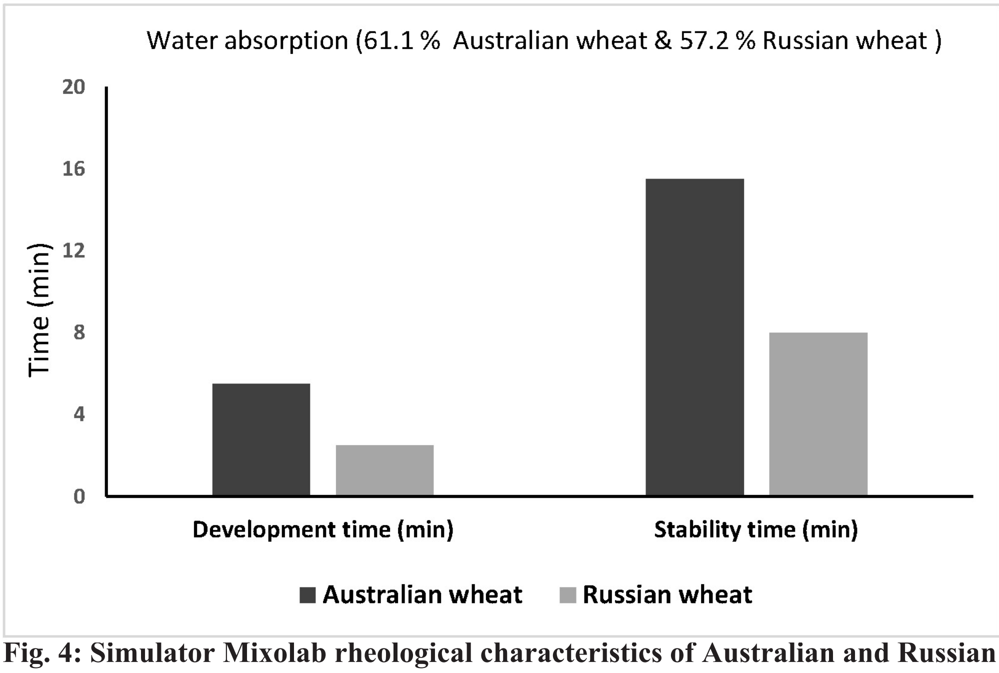

Fig. 4: Simulator Mixolab rheological characteristics of Australian and Russian wheat flour

the elongation of development time was an indication to the effect of the interaction between fibers and gluten that prevents the moistening of the proteins. So, the aggregation and disaggregation of the high molecular weight proteins in wheat were affected (Moradi *et al*., 2016).

Effect of tempering time and milling system on solvent retention capacity(SRC) of the wheat flour

The following experiments were undertaken to study the effect of tempering time and milling system (hard and normal) on the SRC values and gluten performance index (GPI) of the flour obtained from the two wheat types.

In general, the results given in Table (1) reveal that flour obtained from the tempered Australian wheat at different times exhibited significantly ($P \leq 0.05$) higher solvent retention values than flour obtained from Russian wheat.

Lactic acid (LA-SRC)

The results of lactic acid solvent retention capacity (LA-SRC), which is associated with gluten protein characteristics indicated that the Australian wheat exhibited significantly ($P \leq 0.05$) higher LA –SRC values by hard milling than the Russian wheat tempered for different times. The highest LA-SRC (143.7%) for the Australian wheat was obtained after tempering for 12 hr. On the other hand, extending the tempering period to 24 hr resulted in significantly ($P \leq 0.05$) lower LA-SRC (132.8%). Meanwhile, the highest LA-SRC (96.97%) for the Russian wheat was achieved after tempering for 24 hr, while the lowest value (84.96%) was found after 12 hr of tempering. No significant ($P \leq 0.05$) differences were found between the values after tempering for 24 hr and 36 hr. These results may be due to the differences in the kernel sizes and wet gluten proportion between the two types of wheat because the flour lactic acid SRC was correlated to the wet gluten and protein contents (Hruskova *et al*., 2012).

The results given in Table (1) indicate that the produced flour from the Australian wheat by normal milling at different tempering times exhibited significantly ($P \leq 0.05$) higher solvent retention values than those of the Russian wheat. The Australian wheat exhibited significantly ($P \leq 0.05$) higher LA -SRC values (137.2 to 148.3 %) than those of Russian wheat (85.92-99.87 %) at different tempering times. The normal milling exhibited the highest LA-SRC for the Australian wheat after tempering for 12 hr while the lowest value was recorded at 24 hr of tempering. This reveals that prolonging the tempering period of the Australian wheat to 24 hr resulted

Table 1: Effect of wheat type and milling conditions on the solvent retention capacity of the wheat flour[a]

Cultivars	Milling system	TT (hr)	Lactic acid (%)	Ethanol (%)	Sodium carbonate (%)	Sucrose (%)	Water (%)	GPI
Australian	Hard	12	143.7[bc]	80.44[f]	98.40[a]	130.2[a]	85.75[a]	0.63[d]
		24	132.8[e]	79.67[g]	93.53[c]	123.1[c]	80.24[c]	0.61[e]
		36	142.9[c]	79.86[g]	94.79[b]	125.2[b]	83.08[b]	0.65[c]
	Normal	12	148.3[a]	90.83[c]	92.42[d]	114.1[e]	77.95[de]	0.72[a]
		24	137.2[d]	105.8[a]	87.53[g]	115.1[d]	73.99[f]	0.68[b]
		36	145.3[b]	96.37[b]	90.62[e]	111.4[f]	77.56[de]	0.72[a]
Russian	Hard	12	84.96[i]	71.68[k]	90.62[e]	110.7[f]	78.36[d]	0.42[k]
		24	96.79[g]	77.54[h]	87.97[g]	104.2[h]	76.48[e]	0.50[g]
		36	95.00[g]	75.04[j]	89.27[f]	107.6[g]	73.91[f]	0.47[i]
	Normal	12	85.92[i]	76.95[i]	83.88[h]	99.66[j]	71.67[g]	0.47[j]
		24	99.87[f]	85.9[d]	83.67[h]	102.5[i]	69.94[h]	0.54[f]
		36	90.53[h]	83.65[e]	81.86[i]	104.4[h]	71.28[gh]	0.49[h]
L.S.D value			2.21	0.56	0.82	0.87	1.69	0.01

[a] Expressed on 14 % moisture basis

Values followed by the same letters in the same column are not significantly different ($P \leq 0.05$).

TT, tempering time(hr) , GPI, gluten performance index.

in significantly ($P \leq 0.05$) lower value of LA-SRC (137.2%). Meanwhile, for the Russian wheat the highest LA-SRC SRC (99.87 %) was obtained after tempering for 24 hr, while the lowest value was figured out at 12 hr of tempering.

The data indicated that normal milling resulted in significantly ($P \leq 0.05$) higher LA-SRC values than those of hard milling for the two wheat types at the different tempering times applied here. Alveograph results can be related to flour corresponding SRC values. Moreover glutenin proteins mainly contribute in elastic properties (Wrigley *et al*., 2006, Kweon *et al*., 2011). From these results, it can be concluded that the values of the LA-SRC differ according to the wheat type and the tempering time. Kweon *et al* (2011) reported that LA-SRC values varied from 51 to 177% according to the type of wheat flour.

Ethanol (ET-SRC)

The results of the ethanol solvent retention capacity (ET-SRC), which is associated with gliadins characteristic indicate that the Australian wheat exhibited by hard milling significantly ($P \leq 0.05$) higher ET-SRC values (80.44%) and (79.9%) after tempering for 12 and 24 hr, respectively (Table1). No significant differeance was noted between the value after tempering for 24 and 36 hrs. Meanwhile, for the Russian wheat, the values can be arranged in descending order based on tempering time as follow: tempering for 24 hr then, 36 hr followed by 12 hr.

The data given in Table (1) indicate that the flour obtained by normal milling of both wheat types resulted in the highest ET-SRC values (105.8% and 85.9%) after tempering for 24 hr for the Australian and the Russian wheat, respectively. Meanwhile, the corresponding lowest values (90.38 and 76.95%) were obtained after tempering for 12 hr.

The present study revealed that the normal milling resulted in significantly ($P \leq 0.05$) higher ET-SRC values than those obtained by hard milling for both wheat types at different tempering times. Alveograph results can be correlated to flour corresponding SRC values .Gliadins play an important role in dough extensibility (Wrigley *et al*., 2006, Kweon *et al*., 2011). Accordingly the ET– SRC values was depended on wheat types.

Sodium carbonate (SC-SRC)

Generally, the results of sodium carbonate (SC-SRC) which is associated with the level of damaged starch indicate that the flour of Australian wheat exhibited significantly ($P \leq 0.05$) higher SC-SRC by hard milling at all tempering times than the their counterparts for Russian wheat (Table 1).

The flour of the Australian wheat exhibited SC-SRC values ranged between 93.53 and 98.40%, whereas, the flour of the Russian wheat exhibited SC-SRC ranging between 87.97 and 90.62 %. For both types of wheat, the highest value was achieved after 12 hr of tempering time, while the lowest value was after 24 hr of tempering. On the other hand, extending the tempering time to 36 hr, resulted in an increased the values to 94.79% and 89.27 % for the Australian and the Russian wheat, respectively. This result can be explained by the different levels of damaged starch of the two types. This may be due to the diversity of weight kernels for both types and the difference in grain hardness among the two wheat types. Test weight and the grain hardness improvable are correlated with the SC-SRC (Hruskova *et al.*, 2012 , Barak *et al.,* 2014).

The SC-SRC values obtained by normal milling varied from 87.53 to 92.42 % for the Australian wheat flour, while the Russian wheat flour explored different SC-SRC values ranging from 81.86 to 83.88%. The significantly ($P \leq 0.05$) highest SC-SRC values (92.42 and 83.88%) were obtained after tempering for 12 hr for the Australian and the Russian wheat, respectively. Accordingly, extending the tempering period caused a decrease in the values of SC-SRC.

The present study revealed that the normal milling resulted in significantly ($P \leq 0.05$) lower SC-SRC values than those obtained from the hard milling for the two types of wheat at different tempering times. This can be attributed to the lower levels of damaged starch obtained after normal milling comparable to hard milling. The level of damaged starch during the milling process varies with the severity of grinding. In other words more damaged starch was obtained after increasing the compressive stress by rollers (Scanlon *et al*., 1988, Ali *et al*., 2015).

The damaged starch content in flour may be due to the tempering conditions and the SC-SRC is related to the levels of damaged starch. Higher SC- SRC values are indicating for a higher amount of damaged starch (Khan & Shewry 2009, Ali *et al*., 2014).

Sucrose (SU-SRC)

The data given in Table (1) indicate that the flour obtained from the Australian wheat exhibited significantly ($P \leq 0.05$) higher SU-SRC values by hard milling than those of the Russian wheat at different tempering times. This is due to the difference in the protein content for both types (15.45 % for Australian wheat and 12.76 % for Russian wheat). Xiao *et al*., (2006) observed negative correlations between protein content of hard winter wheat and 50% sucrose SRC tests.

It was noted that the Australian wheat flour exhibited significant ($P \leq 0.05$) SU-SRC values ranging between 125.2 and 130.2 % after hard milling being higher than those of the Russian wheat flour (in a range from 104.2 to 110.7%) for different tempering times. The results indicate that significantly ($P \leq 0.05$) higher values of SU-SRC (130.2 %and 110.7 %) were obtained after tempering for a short period (12 hr) for the Australian and the Russian wheat, respectively. Meanwhile, the lowest SU-SRC values (123.1) for the Australian and(104.2 %) for the Russian wheat were obtained after tempering for 24 hr. Higher SC-SRC values are an indication for higher amount of damaged starch (Rahil *et al*., 2015).

The results in Table (1) indicate that the significantly ($P \leq 0.05$) highest SC-SRC values (115 and 107.55%) were obtained by normal milling after tempering for 24 hr for the Australian wheat flour. On the other hand, the flour obtained from the Russian wheat exhibited the highest SU- SRC values (104.4 and 99.10%) after 36 and 12 hr of tempering, respectively. Consequently, extending the tempering time caused an increase in SU-SRC values for both wheat types.

The present study indicated that the normal milling showed significantly ($P \leq 0.05$) lower SU-SRC values than hard milling for both wheat types at different tempering times. This can be attributed to the lower levels of protein content obtained after normal milling comparable to the hard milling. In accordance, Xiao *et al*., (2006) observed negative correlations between the protein content of hard winter wheat and 50% sucrose SRC tests. So, the milling system affects the values of SU-SRC of the flour of both wheat types, investigated in the present study.

Water (WA-SRC)

The results of WA-SRC show that Australian wheat flour exhibited significantly ($P \leq 0.05$) higher WA-SRC with the hard milling than Russian wheat flour at the different tempering times (Table1). The Australian wheat exhibited significantly ($P \leq 0.05$) higher WA-SRC values ranging between 80.24 and 85.75% than those of the Russian wheat which ranged between 73.91 and 78.36 %. The highest values of WA-SRC were obtained after tempering the two types of wheat for 12 hr and the lowest one was found after tempering for 24 hr for the Australian wheat and 36 hr for the Russian wheat. This result may be due to the higher protein content, wet gluten proportion, gluten index and level of damaged starch for the Australian wheat than the Russian wheat. The water absorption of wheat flour is affected by many factors, such as starch properties (damaged starch) and gluten quality (Kweon *et al.,* 2011 , Ahmed *et al*., 2015).The WA-SRC is influenced by all water absorption components in flour (Barak *et al*., 2014).

It is well known that water is used as the reference solvent since it can hydrate and swell gluten, damaged starch and arabinoxylans of flour. The water solvent is specifically correlated to the water holding capacity of flour, which is important for the processing and end product quality of baked goods (Kweon *et al*., 2011).

The significantly ($P \leq 0.05$) higher WA-SRC values (77.95 and 71.67%) were found by normal milling for the Australian and the Russian wheat, respectively after 12 hr of tempering. No significant differences were observed in WA-SRC values for the Australian wheat at different tempering times (Table1). In contrast, the Russian wheat gave different values of WA-SRC at different tempering times. Extending the tempering time of the Russian wheat to 36 hr resulted in significantly ($P \leq 0.05$) the lowest SC-SRC (65.46%).So, the tempering times affect the SC-SRC values of both wheat types.

The normal milling showed significantly ($P \leq 0.05$) lower WA-SRC than the hard milling for both wheat types at different tempering times. This can be attributed to the lower level of protein content and damaged starch as a result of increasing the roller gap. Starch properties (damaged starch) and gluten quality, affect the water absorption of wheat flour.

Generally, the absorptions determined by the solvents are highly associated with each other, and this is observed for W-SRC, SC-SRC, and Su-SRC. Obviously, there is an overla*p* in wheat components regarding absorption in each solvent (Carver, 2009, Ahmed *et al*., 2015).

Gluten performance index

The gluten performance index value represents the overall work of gluten in an environment of the modulating networks of flour polymers (Kweon *et al*., 2011).

The results of the gluten performance index given in Table (1) show that the flour obtained from the Australian wheat exhibited a significantly ($P \leq 0.05$) higher gluten performance index values with hard milling than those of the Russian wheat for the different tempering times. The significantly ($P \leq 0.05$) highest gluten performance index values ranging between 0.61 and 0.65 % were found for the Australian wheat. Meanwhile, the Russian wheat showed values ranged between 0.42 and 0.5% at different tempering times. The highest value was obtained after tempering for 36 hr for the Australian wheat and after 24 hr for the Russian wheat. On the other hand, the lowest values were obtained after tempering for 12 hr for both wheat types. This is due to the difference in wet gluten and damaged starch contents between the two types of wheat.

It is worth to mention that pentosans from the aleuron layer exhibited negative effects on gluten quality. Gluten is formed by interactions of the protein, glutenin and gliadin, which also associates with lipids and pentosans during dough formation, pieces of bran may damage the gluten network (Faridi, 1990).

The results in Table (1) indicate that tempering times had different effects on the gluten performance index for both wheat types by using the normal milling system as compared to the hard one. The results show significantly ($P \leq 0.05$) higher gluten performance index values by normal milling for the Australian than the Russian wheat at different tempering times. The significantly ($P \leq 0.05$) highest gluten performance index value (0.72) of flour obtained from the Australian wheat was found after tempering for 12 hr. It is worth to mention that extending tempering period to 24 hr gave a lower gluten performance index (0.68). In contrast for the Russian wheat, the significantly ($P \leq 0.05$) highest gluten performance index (0.54) was obtained after extending the tempering period to 24 hr.

Generally, the gluten performance index improved by using the normal milling system. The present study showed an increase in the gluten performance index values after increasing the roller ga*p* for both wheat types. This is due to the lower flour extraction rate and the protein content obtained by normal milling. It is well known that bran pieces obtained by hard milling may damage the gluten network. Also, the GPI value increased by about one- third of all flour yield when flour extraction increased (Faridi, 1990, Gaines, 2000, Kweon *et al*., 2011).

CONCLUSIONS

The present study was applied on a full industrial scale. Such a study is scarce in the literatures. Moreover, no many studies have used Russian wheat as a source in this respect.

The results indicate that Australian wheat had much better rheological properties than Russian wheat. Furthermore, the results reveal that flour obtained from the tempered Australian wheat for different times of tempering exhibited significantly ($P \leq 0.05$) higher solvent retention values than their counterparts for Russian wheat. Also, the milling systems affect the SRC of the types of wheat.

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الملخص العربى

الخواص الريولوجية وتأثير ظروف الطحن المختلفة على القدرة للاحتفاظ بالسوائل (المذيبات) لدقيق القمح الأسترالي والروسي

محمد فتحي أبو ضيف[١]، تيسير محمود أبوبكر[٢]، محمد محمود يوسف[٢]، آيات محمد مصطفى[٢]

١- الشركة العربية للمطاحن والصناعات الغذائية، برج العرب، الإسكندرية، مصر.

٢- كلية الزراعة، جامعة الإسكندرية، الشاطبي، الإسكندرية، ٢١٥٤٥، مصر.

الهدف من البحث هو دراسة الخواص الريولوجية لصنفين من دقيق القمح (الأسترالي – الروسي). وايضا دراسة تأثير ظروف الطحن المختلفة (درجة حرارة وزمن التكييف – الطحن العادى والقاسي) على قدرة الدقيق على الاحتفاظ بالسوائل (المذيبات) وذللك على نطاق صناعى. أوضحت النتائج أن دقيق القمح الأسترالي أعطى قيماً أعلى لكل الخواص الريولوجية المقاسة بجهاز الألفيوجراف فيما عدا النسبة بين المرونة والمطاطية مقارنة بدقيق القمح الروسي. بينما القيم المقاسة بجهاز الميكسولاب وتشمل امتصاص الماء وزمن ثبات العجين وزمن وصول العجين كانت أعلى للقمح الأسترالي بالمقارنة للقمح الروسي. وبالتالي فإن الخواص الريولوجية للقمح الأسترالي هي الأفضل.

تبين من النتائج ان الدقيق الناتج من طحن القمح الأسترالى بعد التكييف لأزمنة مختلفة أعطى قيمًا للقدرة على الأحتفاظ بالسوائل أعلى من القمح الروسى . وكانت النتائج مرتفعة عند أستخدام حمض اللاكتيك والايثانول كمذيبات عند أستخدام الطحن العادى (Normal) . بينما باستخدام كل من كربونات الصوديوم ومحلول السكروز والماء كمذيبات كانت القيم أعلى عند استخدام الطحن القاسى (Hard) بالنسبة لصنفى القمح. كما اوضحت النتائج أن قيم معامل الجلوتين تزداد بزيادة المسافة بين الطواحين (الطحن العادى) لكلا صنفى القمح.