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The Effects of Two-Step Tempering Treatment on the Rheological Characteristics of Flour in Bread Wheat (*Triticum aestivum* L.)

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ABSTRACT
In flour milling, tempering is the last process applied to the wheat before grinding and it has a unique and vital role in wheat processing technology. In wheat milling, tempering is conventionally done in one step. In this study, two bread wheat (*Triticum aestivum* L.) varieties (Adana-99 and Russian) with different hardness degree were subjected two-step tempering process in addition to single-step (classical) tempering process. The potential of two-step tempering treatment a) to improve the wheat and flour qualities and b) on the rheological characteristics of wheat flour was the explored. Each wheat variety was subjected to four different tempering treatments. These were; a. no tempering (control), b. single-step tempering for 24 h, c. single-step tempering for 48 h and d. two-step tempering for 48 h. The tempering treatment resulted in a significant improvement in the rheological properties. This positive effect was more evident in the extensograph measurements compared to farinograph measurements. Two-step tempering treatment significantly increased the resistance, ratio and energy values of the dough. This showed that two-step tempering significantly increased strength, force, resistance, and the ability to retain gas properties of dough, which are the most important quality criteria for bread dough. Tempering treatment for 48 h among single step tempering treatments resulted in improved flour quality. The findings conclude that, water when added to the wheat in the tempering process in two-steps results in an improved flour quality in terms of rheological properties.

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İki Aşamalı Tavlama Uygulamasının Ekmeklik Buğdayda (*Triticum aestivum* L.) Unun Reolojik Özelliklerine Etkileri

ÖZET
Un değirmenciliğinde tavlama, öğütmeden önce buğdaya uygulanan son işlemdir ve buğday işleme teknolojisinde benzersiz ve hayati bir role sahiptir. Buğday öğütmede tavlama geleneksel olarak tek aşamada yapılır. Bu çalışmada, farklı sertlik derecelerine sahip iki ekmeklik buğday (*Triticum aestivum* L.) çeşidi (Adana-99 ve Rus), tek aşamalı (klasik) tavlama işlemine ek olarak iki aşamalı tavlama işlemine tabi tutulmuştur. İki aşamalı tavlamanın a) buğday ve un kalitesini iyileştirme ve b) buğday ununun reolojik özelliklerini ıslah etme potansiyeli araştırılmıştır. Her bir buğday çeşidi, dört farklı tavlama işlemine tabi tutulmuştur. Bunlar; a. tavsız (kontrol), b. 24 saat süreyle tek aşamalı tavlı, c. 48 saat süreyle tek aşamalı tavlı ve d. 48 saat süreyle iki aşamalı tavlı. Tavlama işlemi, reolojik özelliklerde önemli iyileşme sağlamıştır. Bu olumlu etki, ekstensograf ölçümlerinde, farinograf ölçümlerine kıyasla daha belirgindir. İki aşamalı tavlama işlemi hamurun direnç, oran ve enerji değerlerini önemli ölçüde artırmıştır. Bu, iki aşamalı tavlamanın ekmek hamuru için en önemli kalite kriterleri olan mukavemet, kuvvet, direnç ve gaz tutma yeteneği özelliklerini önemli ölçüde artırdığını göstermiştir. Tek aşamalı tavlanmış örnekler arasında 48 saat tavlama un

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kalitesini geliştirmiştir. Bulgular, tavlama prosesinde suyun buğdaya iki aşamada eklenmesinin reolojik özellikler açısından un kalitesini geliştirdiğini ortaya koymuştur.

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INTRODUCTION

Wheat is consumed by processed to semi-finished cereal products like flour, semolina, starch, bulgur, and/or to final products like bread, pasta, noodle, cakes, biscuits, crackers, wafers, cookies. Among these products, wheat flour has a particular importance as it constitutes the basic structure of many bakery products both in terms of quality and quantity (Dizlek and Ozer, 2016). As in the factors that determine the quality of all other intermediate and finished products, the quality of wheat flour is also; it depends on the quality of the wheat(s) used in its production and the processing steps applied in the production of the wheat flour.

The processes involved in the processing of wheat into flour and semolina in milling can be grouped under three major groups: 1) Preparation processes (buying and storing of wheat, cleaning, and separating it from foreign substances, blending, washing, and tempering), 2) Milling operation and 3) Flour storage and blending operations. All these process steps affect milling products' qualitative and quantitative properties to be obtained (Delcour and Hoseney, 2010). Additionally, the labor and the rigor shown in the preparation processes help obtain high-quality flour and semolina. Also, there is overall reduction in energy consumption of the milling factory and these results in roller-sieve systems to be used efficiently and an increased lifespan. Therefore, as shown tempering has a special and important place in cereal industry.

In flour milling, tempering, which is the last process applied to the wheat in the preparation stage for grinding before feeding to the rolls to break the wheat and reduce the size to produce the desired material; it is the process of adding cold or hot water to the wheat and resting the it for a while to absorb this water. As it can be understood from the definition, in the tempering process; first the moisture content of the wheat mass is determined and then the appropriate amount of water (target moisture in soft wheat 15-16.5%, in hard wheat 16-18%) is added. After this process, wheat is left to rest in the silos to equilibrate the moisture content and allow evenly distribution, which will result in optimum properties for grinding. The tempering process's main objectives can be specified as follows: To provide easier crushing of wheat, to reduce the energy consumption of the factory, to obtain more flour from a unit amount of wheat, to obtain flour with low ash content (Keskinoğlu et al., 2001; Yoo et al., 2009). Tempering time, tempering water temperature and different tempering methods (warm, hot, steamy, microwave, ultrasound etc.) have been emphasized in the studies (Butcher and Stenvert, 1973; Stenvert and Kingswood, 1976; Moss, 1977; Finney and Bolte, 1985; Ibanoglu, 2001; Keskinoğlu et al., 2002; Sünter, 2003; Kweon et al., 2009; Warechowska et al., 2016).

The rheological properties are significant in grain and milling technology and give an essential idea about bread-making (Diraman et al., 2013; Dizlek and Ozer, 2017a). The rheological properties of the dough prepared from wheat flour can be evaluated by various methods such as farinograph, extensograph, mixograph and alveograph (Diósi et al., 2015; Aslan and Gul, 2016; Gul et al., 2017; Dizlek and Ozer, 2017a). The farinograph test is the essential in terms of being a basic analysis that reveals the rheological properties and bread qualities of flour during kneading (Basar et al., 2016). The most critical rheological properties of dough are often described as resistance (elasticity), strength and extensibility (EX) are determined by Extensograph (Dizlek and Ozer, 2017a).

The amount of water to be supplied to the wheat mass during tempering is usually given at one (single) step. However, in this study, two bread wheat (*Triticum aestivum* L.) varieties with different hardness degree were subjected to a two-step tempering process in addition to single-step (classical) tempering process. The potential of this treatment to improve the wheat and flour rheological and bread properties was then investigated.

MATERIAL and METHODS

Material

Wheat: In the study, two different bread wheat (*Triticum aestivum* L.) varieties namely a low-protein, soft 'Russian' variety imported from Russia and a domestic, medium hard 'Adana-99' wheat variety were used. Both wheat samples were 2017 crop season. The Adana-99 variety was supplied from İslamoğlu Trade in Osmaniye (Turkey) and the Russian variety was supplied from Sunar Özlem Flour Factory (Osmaniye, Turkey). Approximately 100 kg of each wheat variety was supplied. The samples taken from the wheat masses in accordance with the sampling method were stored in 50 kg jute bags and stored in cold storage (+4 °C) until they were analyzed and ready for milling.

Flour: After applying different tempering processes to the two wheat varieties, the wheat varieties were milled according to method (Kurt and Dizlek, 2020) described in method section to obtain subsequent flours.

Water: Potable water supplied within the campus of University of Osmaniye Korkut Ata (Osmaniye, Turkey) was used in tempering of the wheat.

Laboratory Type Mill: Wheat samples were milled into flour by using; the first three pieces of breaking, the last two reducing rolls, 'Chopin' brand 'CD1' model tempered wheat grinding mill (Chopin Technologies, Paris, France).

Methods

Formation of Experimental Wheat Groups

With the tempering, the target moisture content of the Adana-99 wheat used in the study was 17% and the Russian wheat was 16.5%. The amount of tempering water for given a wheat masses was calculated according to American Association of Cereal Chemists International (AACCI) Method 26-95.01 (AACCI, 2010). Wheat samples were tempered by cold tap water. Within the scope of this research, the experimental materials and the pattern were formed by applying the following different tempering treatments in each of the two bread wheat varieties whose qualities are different (Table 1):

a) no tempering (= control)
b) single-step tempering for 24 h (The amount of water calculated according to the target moisture is given to the wheat at one time and tempered for 24 h)
c) single-step tempering for 48 h (The amount of water calculated according to the target moisture was given to the wheat in one time and tempered for 48 h)
d) two-step tempering for 48 h (Adana-99 and Russian wheat were initially treated with 15% and 15.5% moisture content, respectively, with the first tempering water and resting for 24 h. At the end of the 24 h period, second tempering water added to Adana-99 and Russian wheat to a target moisture of 17% and 16.5%, respectively (In summary, the wheat samples were tempered two times and the final moisture content of the wheat was adjusted to the percentage in b) and c)).

Taking into account commercial conditions, in the study, also the flour obtained from wheat, (tempered according to item d)), was rested in cool and dry room conditions for 30 days. The rheological properties of this sample were also studied.

Table 1. Experimental design of the research.
Çizelge 1. Araştırmanın deneysel tasarımı.

Tempering Time (*Tavlama Süresi*) (h) (*saat*)	Tempering Number (*Tavlama Sayısı*)	Wheat Variety (*Buğday Çeşidi*)	
		Adana-99	Russian Rus
0 (non-tempered=control) (*tavsız=kontrol*)	0	x	x
24	1	x	x
48	1	x	x
48	2	x	x
48[a]	2[a]	x	x

[a] Wheat flour that has been tempered two-step for 48 h and kept in room conditions for 30 days.

Grinding Process

Optimally tempered wheat samples were separately milled into flour using a laboratory mill. Cleaned and tempered wheat was first broken by the crushing system, then semolina, coarse bran and some crushed flour were separated from crushed wheat. The semolina obtained as the main product was reduced to the flour by milling in the reduction system and divided into refined fine bran by-products. The separated refined fine bran was passed through the reduction system for a second time to obtain whole flour. These flour samples were used for rheological analyses. Adana-99 and Russian wheat samples were milled at 52.3% and 61.3% "wheat flour" extraction rates, respectively.

Analysis of Wheat Samples

The physical and chemical properties of two different wheat samples used in the study are given in detail in the previous study (Kurt and Dizlek, 2020). Some of the technological properties of flour samples were determined according to AACCI Methods therefore Adana-99 and Russian wheat samples had average 28.5% and 21.6% wet gluten content; 9.2% and 6.7% dry gluten content; 38 and 32 mL sedimentation value; 31 and 20 mL delayed sedimentation value; 337 and 356 s falling number value, respectively.

Measurements of Rheological Characteristics of Wheat Flour Groups

Wheat flour samples were objected to farinograph and extensograph tests with the purpose of determining important rheological parameters of wheat flours for cereal industry. AACCI Approved Method 54-21.02 (AACCI, 2010) was followed to determine farinograph properties (water absorption [WA], dough development time [DDT], stability time [ST], softening degree [SD], and farinograph quality number [FQN]). The mixing bowl for 300 g flour was used. AACCI Approved Method 54-10.01 (AACCI, 2010) was used to determine extensograph features. For this purpose; resistance to extension (R_5), maximum resistance to extension (R_{max}), EX, ratio (R_{max} EX^{-1}) and energy values in 45th', 90th', and 135th' were determined. An average of the 3 values was used in the discussion of the results. Rheological properties were determined two days after flour milling. Briefly, tempered flour from each treatment group was compared with the flour of non-tempered group (control).

Statistical Analysis

All experiments were carried out in two replicates. Means and standard deviations were determined using Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, WA). Variance of analysis (ANOVA) was used to obtain conclusion on measured characteristics of wheat and flour samples. Duncan's multiple comparison test was used to determine difference among treatment means at (P<0.05). Statistical analysis was performed using the statistical package program developed by the SAS statistical institute (The SAS System for Windows v6.12).

RESULTS and DISCUSSION

Effects of Different Tempering Treatments on Farinograph Properties of Flour

The farinograph test has been a standard tool of the cereal chemists for many years, giving information related to WA and kneading properties of wheat flours (D'Appolonia and Kunerth, 1984; AACCI, 2010; Aydoğan et al., 2012; 2015). The farinograph test is performed to evaluate the behavior of dough against mixing at a specified constant speed with specified water addition (Diósi et al., 2015). Farinograph DDT is an essential indicator of protein quality of flour and strong flour has been reported to have a higher DDT than weaker ones (Karababa and Ozan, 1998). It is reported that the ST is a parameter indicating the flour strength, tolerance of flour to kneading and that strong flours have high ST (Basar et al., 2016).

Farinogram values of flour obtained from Adana-99 and Russian wheat samples with different tempering treatments are summarized in Table 2. In both wheat samples, it was determined that tempering process reduced WA of flour (P<0.05). The results showed, among the single-step tempered samples, wheat flour sample which was tempered for 48 h had higher WA than the 24 h tempered wheat; whereas among the 48 h tempered wheat samples, single-step tempered sample had higher WA than two-step tempered sample; among two-step tempered samples, the sample whose flour was rested for 30 days had higher WA. The easier separation of the flour from the bran by tempering treatment, and therefore the easier release of the pure endosperm layer by milling reduced the transition of compounds with high water holding ability such as cellulose and pentosane in the bran layer to flour, and this situation led to a decrease in WA capacity. Also Sünter (2003) reported that, increasing the tempering time from 12 h to 24, 36 and 48 h resulted in a decrease in the farinograph WA values of the flour samples. It was determined that there was no significant difference (P>0.05) between two different tempering treatments (single and two-step) in terms of DDT.

Table 2. Effect of tempering treatment on farinograph properties of two wheat varieties[1].
Çizelge 2. Tavlama işleminin iki buğday çeşidinin farinograf özelliklerine etkisi[1].

Wheat Variety (*Buğday Çeşidi*)	Tempering Treatment (*Tavlama Muamelesi*)	Water Absorption (*Su Absorpsiyonu*) (%)	Dough Development Time (*Hamur Gelişme Süresi*) (min) (*d*)	Stability Time (*Stabilite Süresi*) (min) (*d*)	Softening Degree (*Yumuşama Derecesi*) (B.U.)[2]	Farinograph Quality Number (*Farinograf Kalite Sayısı*)
Adana-99	non-tempered (control)	60.6^{a}±0.3	2.4^{a}±0.1	8.4^{d}±0.2	66^{a}±7	92±8
	single-step tempered for 24 h	58.2^{c}±0.2	2.2^{a}±0.0	11.4^{c}±0.3	41^{b}±3	41^{b}±2
	single-step tempered for 48 h	58.9^{b}±0.1	2.3^{a}±0.0	12.6^{b}±0.1	34^{c}±2	51^{a}±3
	two-step tempered for 24 h	58.1^{c}±0.2	2.2^{a}±0.1	12.9^{a}±0.1	31^{c}±3	43^{b}±2
	two-step tempered for 48 h (rested for 30 days)	59.1^{b}±0.3	2.4^{a}±0.1	13.1^{a}±0.2	30^{c}±4	42^{b}±1
Russian	non-tempered (control)	57.6^{a}±0.3	1.7^{a}±0.1	2.7±0.2	68^{b}±7	36^{a}±3
	single-step tempered for 24 h	54.8^{c}±0.2	1.7^{a}±0.0	2.8±0.2	81^{ab}±7	31^{a}±3
	single-step tempered for 48 h	56.2^{b}±0.2	1.7^{a}±0.2	2.3±0.3	94^{a}±9	27^{a}±3
	two-step tempered for 24 h	55.2^{c}±0.2	1.7^{a}±0.0	2.7±0.3	80^{ab}±6	31^{a}±2
	two-step tempered for 48 h (rested for 30 days)	58.3^{a}±0.4	1.7^{a}±0.1	2.8±0.2	60^{c}±2	32^{a}±2

[1] Mean values in the table for the same column and same variety (Adana-99 or Russian) shown with the different superscript letter are significantly different (P<0.05). [2] Brabender Unit.

WA is the amount of water required by a given weight of flour to yield dough of given consistency. Farinograph WA is mainly influenced by the properties of flour main components, starch and gluten. It correlated also with dough ST. High WA is desirable. High WA combined with low SD indicates good quality flour, whereas a high WA combined with a high SD indicates poor quality flour. Farinograph ST is correlated with flour strength. Long ST are generally more suited for variety bread production and often require longer kneading times (Aydoğan et al., 2015).

There was no statistically significant difference (P>0.05) between the samples of Russian wheat variety in terms of ST, I contrast there was a considerable difference between the ST of samples in Adana-99 wheat variety. Accordingly, the tempering process increased the ST of samples in Adana-99 variety (P<0.05). This increase was highest in two-step tempered samples. It was determined that the 48 h tempered samples had a higher ST than the 24 h tempered samples. ST (in full) of tempered samples was higher than the control sample, thus the ST, which is an important farinogram parameter as it shows flour strength and the processing tolerance of the dough (Dizlek and Ozer, 2017a), additionally, it illustrate how tempering process is important. It was found that the different tempering treatments in the experiment caused a meaningful variation among the flour samples of the Adana-99 variety. It was therefore determined that the two-step tempering process significantly improved (P<0.05) the most critical farinogram quality parameter (Table 2). However, the same conclusion was not observed with Russian wheat variety. It was also observed that, the ST of the two wheat samples was different due to the diverse characteristics of the wheat varieties. According to this, the ST of the flours belonging to the Adana-99 variety was 3-5 times higher than that of the Russian variety. In accordance with the ST, SD of Adana-99 variety decreased with tempering treatment. The reduction was higher in the 48 h tempered samples. Clearly from the results 48 h tempered samples with a SD halved, relative to the control sample, however, a two-step tempering has a beneficial effect in improving the flour quality. In the Adana-99 variety, although there is a significant difference between the control sample and tempered samples in terms of SD, there is limited difference between the tempered samples. A contradictory result in SD was witnessed in the Russian variety treated wheat samples. A sample with the best SD was the tempered twice for 48 h and the flour was rested for 30 days. A low FQN, has been associated with weak flour, in contrast a high value is associated with strong flour. It is not advisable to evaluate FQN for untampered wheat (D'Appolonia and Kunerth, 1984). Therefore, the FQN of all samples, including the non-tempered samples, were determined during the farinograph measurements, but the control sample was not taken into consideration when comparing the treatments. Values of FQN showed that the Adana-99 variety has superior properties compared to the Russian variety. It has been determined that there is no significant difference between the tempered treatments in terms of FQN (Table 2).

Codina (2010) provides the following information using the Brabender farinograph device for the determination of flour quality. Flours with WA capacity of more than 65% are of very high quality, flours of 60-65% are of high quality, flours of 55-60% are acceptable quality, and flours of less than 55% are unacceptable (inadequate) quality. Flours with DDT of more than 3 min are very high quality, flours with 2-3 min are high quality, flours with 1.5-2 min are acceptable quality, and flours with less than 1.5 min are unacceptable quality. Flours with a ST of more than 8 min are of very high quality, flours with 5-8 min is high quality, flours with 3-5 min are acceptable quality, and flours with less than 3 min are unacceptable quality. Flours with a dough SD of less than 60 B.U. are of very high quality, flours with 60-80 B.U. are high quality, flours with 80-100 B.U. are acceptable quality, and flours with more than 100 B.U. are unacceptable quality. Flours with FQN of more than 65 are very high quality, flours with 50-65 are high quality, flours with 40-50 are acceptable quality, and flours with less than 40 are unacceptable quality. According to the data stated by Codina (2010), Adana-99 sample had acceptable quality in terms of WA and FQN; The Russian sample had acceptable quality in terms of WA, DDT, and SD; it was determined that the Adana-99 had very high quality in terms of ST and SD, whereas Russian variety had low quality in terms of ST and FQN (Table 2). On the other hand, it was reported that (Canadian Grain Commission, 2009) DDT value was lower than 2 min in weak flour, 2-3 min in medium strong flour, 3-5 min in strong flour, and 5-12 min in very strong flour. The ST value was lower than 4 min in weak flour, 4-7 min in medium strong flour, 7-14 min in strong flour, and higher than 14 min in very strong flour. According to these data, Adana-99 wheat flour groups was evaluated as (medium) strong, while the Russian wheat flour groups was evaluated as weak (Table 2).

In the study, while the application of different tempering treatments on the Adana-99 wheat variety resulted in a significant (P<0.05) and meaningful modification on the ST and SD of flour samples, it is not possible to mention the same effect on Russian variety. Similarly, Warechowska and co-workers (2016) reported that, in the Astoria and Cytra wheat used in their research, the increase in the amount of moisture (from 12% to 18%) added to the wheat by tempering caused an average of 4 min increase in the

ST and an average of 35 B.U. decrease in the SD of the flour. These values had a statistically significant effect on these criteria, but the effect was insignificant in the Radunia wheat variety. These findings indicate that tempering treatments do not have the same effect on all wheat varieties, so it is useful and necessary to determine the appropriate tempering conditions for each wheat variety. It was observed that when the tempering treatment was applied, gluten quality (ST) of the Adana-99 wheat flour samples sharply increased and the WA capacities of both flour samples reduced according to Table 2 (P<0.05).

Effects of Different Tempering Treatments on Extensograph Properties of Dough

Extensograph, draws a unique graph about the dough's resistance against extension and it's EX (D'Appolonia and Kunerth, 1984). The extensograph records a force-time curve for a piece of dough stretched until it breaks. Attributes of force-time curves (extensograms), are used to assess the dough general quality characteristics. In the evaluation of extensogram; R_5, R_{max}, EX, energy, and ratio are the common measurements (AACCI, 2010). The greater the dough ratio and energy values, the greater the fermentation tolerance, gas holding ability, and suitability for processing. Holistically, the extensograph test gives unique clues concerning bread-making, since, determination of the test takes longer period approximately (135 min) as in regular bread-making (Dizlek and Ozer, 2017 a; b).

The data on extensograph measurements is presented in Table 3. Tempering of wheat samples resulted in a significant increase in the dough resistance values (P<0.05). This can be seen by examining the values of R_5 and R_{max}. The data on the Adana-99 variety clearly shows that the best treatment is a two-step tempering process. The two-step tempering treatment increased the dough resistance value one of the dough quality indicator, it is one of the critical. It was determined that samples having the best resistance value after two-step tempering treatments were single-step tempering for 48 h, followed by single-step tempering for 24 h. However, it was also observed that even in single-step tempered samples for 24 h dough resistance was significantly higher than what was experienced in non-tempered control sample. However, the positive effect of the tempering process on the dough resistance of the Adana-99 variety was more noticeable than the Russian variety. The dough resistance of the 48-h two-step tempered wheat was 75% higher in R_{max} value and 82% higher in R_5 value than the control sample.

Table 3. Effect of tempering treatment on extensograph properties[1] of wheat flours[2].
Çizelge 3. *Tavlama işleminin buğday unlarının[2] ekstensograf özelliklerine[1] etkisi.*

Wheat Variety (*Buğday Çeşidi*)	Tempering Treatment (*Tavlama Muamelesi*)	R_5 (Resistance to Extension) (*Uzamaya karşı direnç*) (B.U.)[3]	R_{max} (Dough Resistance) (*Hamur Direnci*) (B.U.)[3]	Extensibility (EX) (*Uzayabilme Yeteneği*) (mm)	Ratio (R_{max} EX^{-1}) (*Oran*) (B.U. mm^{-1})	Energy (*Enerji*) (cm^2)
Adana-99	non-tempered (control)	$295^d±12$	$419^d±18$	$174^a±3$	$2.41^d±0.11$	$99^d±2$
	single-step tempered for 24 h	$343^c±12$	$497^c±17$	$161^b±3$	$3.07^c±0.10$	$105^c±1$
	single-step tempered for 48 h	$398^b±19$	$573^b±26$	$165^b±2$	$3.47^b±0.15$	$123^b±2$
	two-step tempered for 24 h	$537^a±27$	$735^a±26$	$150^c±2$	$4.88^a±0.18$	$139^a±3$
	two-step tempered for 48 h (rested for 30 days)	$494^a±29$	$678^a±27$	$151^c±1$	$4.47^a±0.19$	$133^a±4$
Russian	non-tempered (control)	$331^c±8$	$385^c±10$	$127^a±3$	$3.02^d±0.07$	$67^c±2$
	single-step tempered for 24 h	$370^b±10$	$438^b±11$	$130^a±2$	$3.36^c±0.08$	$76^b±1$
	single-step tempered for 48 h	$428^a±13$	$492^a±18$	$117^b±3$	$4.21^a±0.11$	$76^b±2$
	two-step tempered for 24 h	$374^b±9$	$455^{ab}±16$	$131^a±3$	$3.46^c±0.06$	$79^{ab}±3$
	two-step tempered for 48 h (rested for 30 days)	$399^a±14$	$489^a±18$	$132^a±3$	$3.70^b±0.09$	$85^a±3$

[1] The average values of 45^{th}', 90^{th}', and 135^{th}' measurements were given.
[2] Mean values in the table for the same column and same variety (Adana-99 or Russian) shown with the different superscript letter are significantly different (P<0.05).
[3] Brabender Unit.

In contrast to resistance values in the Adana-99 variety, tempering treatment caused a decrease in the EX of the doughs. Accordingly, the doughs belonging to the two times tempered applications with the highest resistance value had the lowest EX value, with respect to the control the EX of these dough decreased by about 14%. On the other hand, it was found that there was a limited variation in terms of the EX values of the doughs in the Russian variety, and just that according to the control sample 1 cm (about 9%) decrease was observed in the dough's EX of the wheat sample which was single-step tempered for 48 h. Expectedly, dough resistance increased but there was a reduction in EX values with the tempering treatment. The ratio values of the dough samples increased significantly (P<0.05) compared to the control sample. The increment is more than twice as much as the control sample for the Adana-99 variety two-step tempered sample for 48 h. The positive effect of tempering treatment was also observed in the Russian variety in terms of ratio values. However, it was determined that the best series in the Russian variety in terms of ratio value emerged after a 48-h single-step tempering treatment. It has been determined that two-step tempered treatments had the highest value in terms of energy value, which is an important indicator of the dough gas holding ability. In the Adana-99 variety, the energy value of the two-step tempered sample for 48 h (without flour resting) was 40% higher than that of the control sample. Depending on the variety properties, the energy value of the dough of Adana-99 non-tempered control sample is approximately 50% higher than the Russian sample of the same feature. In both varieties, the energy values of the dough samples increased parallel with an increase in the number (from 1 to 2) and time (from 24 h to 48 h) of tempering. On this increment, the effect of the number of tempering was found to be more dominant than the tempering time. A similar effect can be mentioned in terms of other extensogram criteria. By examining the findings of the extensograph data together (Table 3); there are very significant differences between the different treatments discussed in the experiment, these differences are more obvious in Adana-99 variety. There is a limited difference between the treatments in the farinographic measurements (Table 2), however it was determined that the difference in the characteristics of the dough, which is an extremely important indicator about the bread quality of the flour, and in this sense, the dough, which is rested for 90, 135 min as in bread making, is observed more clearly in the extensograph measurements. The data of the extensograph measurements showed a high correlation with the ST and SD values of Adana-99 variety, as mentioned above, the top (superior) flour and dough characteristics of two-step tempered treatments, which constitute the basic sheet leg of the study, have been demonstrated. Clearly it can be seen by examining the resistance values (Table 3), particularly in two-step tempering, generally tempering, significantly increased the strength, force and resistance of the dough. Resistance criterion is the most important quality criterion taken into consideration in extensograph measurements (AACCI, 2010). It was observed that the Russian variety having lower bread-making quality than the Adana-99 also improved its bread-making quality through the tempering treatments (dough strength, resistance, gas holding, and fermentation ability increased).

Generally, analytical findings from samples tempered for 48 h are better than samples tempered for 24 h. This situation is thought to result from the use of cold tempering method in the tempering of wheat samples in the study. Özkaya and Özkaya (2005) reported that homogeneous distribution of water in grain during cold tempering requires a relatively long period of time, which may be up to 72 h. The findings obtained from our study are consistent with the findings and/or conclusions of previous researchers. Accordingly, Tekeli (1964) and Diraman (2010) stated that, by the steam-tempering of the sunn pest-damaged wheat, negative conditions in dough processing such as sticky, runny, splay, soft dough characteristics, difficult to shape dough, poor hand, and machine processing ability of dough can be eliminated. Similarly, Posner and Hibbs (1997) reported that, tempering in the temperature range of 36-43 °C prevents the negative properties of dough such as runny and splay. Warechowska and co-workers (2016) declared that the dough belonging to the tempered treated wheat had a more stable structure during kneading.

CONCLUSIONS

In this study, the effects of two-step tempering treatment, on the rheological characteristics and hence bread properties of two different bread wheat were investigated. There was no significant difference between the tempering treatments in the Russian variety in terms of farinograph values, however with an increase in the number and time of tempering in Adana-99 variety, the ST of flour samples increased, SD and WA ability reduced. Moreover, there was a significant difference in extensographic measurements. The findings from extensograph defines the dough testing properties while flour testing properties are defined by farinograph parameters, therefore, both parameters providing more meaningful information in describing bread quality. Extensographic data showed that it is more useful to apply the tempering process to wheat at two-step rather than single-step. In these measurements, the best series compared to other treatments appeared in the 48-h two-step tempered samples. Subsequently, it was concluded that tempering time would be more appropriate for 48 h compared to 24 h. As a result, the tempering treatment resulted in a significant improvement in the rheological properties of flour. This positive effect was more evident in the extensograph measurements compared to farinograph measurements. Two-step tempering treatment significantly increased the resistance, ratio and energy values of the dough. This showed that two-step tempering treatment significantly increased ($P<0.05$) strength, force, resistance, and the ability to retain gas properties of dough, which are the most important bread dough quality parameters. Tempering treatment for 48 h among single-step tempering treatments resulted in a more improved flour quality. As a result; the findings include clues that, the fact that water is added to the wheat in the tempering process in two-steps improved the flour quality in terms of rheological properties. However, it is clear that further studies are required on this subject.

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Author's Contributions

All authors contributed to the study conception and design. Mustafa Kurt has provided research materials, milled the wheat groups and performed the laboratory work. Halef Dizlek performed the statistical analysis, interpreted the results and drafted the manuscript. The first draft of the manuscript was written by Halef Dizlek. Tempering process of wheat samples and writing - original draft preparation of the manuscript were written by Mustafa Kurt and Halef Dizlek; Writing - review and editing were performed by Halef Dizlek. All authors commented on previous versions of the manuscript. Also all authors read and approved the final manuscript. Halef Dizlek is the Master of Science supervisor of Mustafa Kurt.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

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