The Effect of Reduction Rolls During the Milling Process on the Physicochemical Properties of Flour and Rheological Characteristics of Dough and Barbari Bread

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Abstract
Reduction rolls play an important role in the process of flour production and increasing the quality of flour used in baking industry is considered as the most important factor to improve the qualitative and nutritional qualities of bread. So the aim of this study was to evaluate the effect of removing C1A, C1B, C2, C3 and C5 reduction rolls on the physicochemical properties of the flour and rheological properties of dough and the selection of the most effective rolls in milling process in a completely randomized design ($P \leq 0.05$). The results showed that two samples of flour that Also the sample, which C3 reduction rolls was removed, had the lowest gluten content (25%), gluten index (70), and zeleny sedimentation volume (17 mL). And the water absorption, development time, stability, and valorimeter number of the dough had the greatest reduction in this sample. Therefore, according to the results, it was found that by removing the C3 reduction roll in milling process, the physicochemical properties of the flour and the rheological properties of dough were strongly weakened. In the next step, the Barbari bread was produced by the flour obtained from this sample and control and its characteristics were examined. The results showed that the hardness of the sample by removing C3 reduction roll was higher (more than 35%) than the control sample during 2 and 72 h after baking. Also, the control had the highest score of overall acceptance in sensory evaluation. According to the results of this study, removing the C3 reduction roll, had the most effect on the quality of flour, dough and final product than the other roll in milling process.

Introduction
One of the most important cases in producing good quality bread is using good quality flour. The milling process is of particular significance in obtaining flour with the desired characteristics. In the milling process, the most significant purpose is to separate the shell (bran) and germ from the central part of the wheat (endosperm) and to reach the highest value of flour extraction with the lowest amount of bran and germ, since these compounds

increase flour ash. Ever since the process of milling the grain has been recognized by humans, simplification and making the milling process efficient using existing facilities and solutions, has always been the focus. New concepts and ideas will only succeed if the quality of the finished product is not affected and the reduction in capital required for operating and maintenance costs is reached (Baltensperger, 1993). The common technical knowledge in the milling process is that after each milling step, the compounds must be screened and the smaller material must be removed before re-milling (Owens, 2001).

Over years, the main equipment used in the milling process has been designed to increase efficiency, yet the flour production technology has not changed significantly since the introduction of the roll mill (Walz), purifier and sieve (Baltensperger, 2001). In order for the wheat to become conditioned flour, it is passed through two series of rolls (1-crushing or grooving roll and 2- reduction or softening roll). In the first series rolls (crushing or grooving) made of stainless steel, the wheat shell is opened and the endosperm is separated from the shell in successive and gradual stages (Ahmadi Nodoushan, 2017; Fistes, 2015).

The first series is often made up of 4 (or more) crushing rolls, which are serially interconnected and each feeds its own feed from the previous one. Each machine has two rolls that rotate in parallel with each other at opposite directions and different speeds and the wheat is shed and crushed between them (Ahmadi Nodoushan, 2017; Ali Akbarnia & Azarbad, 2010). After each crushing to separate the endosperm, bud, shell, and the shell to which the endosperm is still attached, the mixture is passed through a sieve system to separate the above compounds. The sieves are usually positioned horizontally, so that the larger sieve are higher the smaller ones are placed lower. The sieves have a circular motion and are parallel to the floor. Each device

may be composed of 12 sieves. Ultimately, after crushing rolls and sieves, the shattered particles enter the second series of rolls, i.e. the section of the reduction rolls. The number of rolls in this section may be 12 or more. In this section, as in the previous section, each device consists of two rolls (which rotate in parallel and in opposite directions at different speeds) and feeds from the previous machine (Ahmadi Nodoushan, 2017; Fišteš & Vukmirović, 2009; Gilbert, 2002).

Ultimately, the endosperm particles are converted into flour and the last shell and germ particles are removed. The rolls in this section are divided into two types of flat and rough, which is the criterion for the division between the rolls. If the distance between the two rolls is low, the soft roll is produced and the name of the roll is soft. If the distance between the two rolls is large, the coarser roll is called the rough roll device. The order of entry of the endosperm particles is such that the particles first enter the rough roll and then the soft roll. In this section, like the crushing roll part, sieves are used to separate the particles by size. Finally, the final output of the sieves is flour with uniform particles (Ahmadi Nodoushan, 2017; Posner, 2000). The roll mill compared to older mills has advantages like lower power consumption, precise adjustment of roll pressure, uniform feeding throughout the rolls, less energy wastage, longer life, easier roll replacement, occupying less space, targeting the crushing operation, and being healthy (Ali Akbarnia & Azarbad, 2010).

This machine is of the main and most significant machines in the production line of flour mills. The significance of rolling mills is undeniable, especially when producing industrial flours, which sometimes have a flour content of up to 85% below 125 μm. It is clear that the task of softening the flour can only be reached by rolls with the proper design and construction characteristics. In line with this, Fistes (2015) stated that under the same conditions in terms of the distance

between the rolls and the sifting process, in the 8 roll milling process, increasing the extraction efficiency followed by decreasing the distance between the rolls and increasing the size of the soft flour particles and then energy consumption is reduced without reducing flour quality. Moreover, Opáth (2014) examined the technical parameters of rolling mill flour extraction. The purpose of the study was to examine the power consumption of roll mill during flour grinding. The results indicated that the milling process has 15 stages and the hourly efficiency of the roll mill in the first stage is 3006.72 kg/h. The highest crushing effect was seen in the first milling stage, so that the particle size after the first milling stage was 12% of the initial grain size.

Scanlon, Dexter, & Biliaderis (1988) examined the relationship between particle size and the physical properties of hard red spring wheat flour produced by a reduction roll and stated that starch damage increased with increase in heterogeneity and decreasing distance between rolls. These researchers screened the flour produced by two sieves with 53 and 91 μm aperture sizes and observed that particles smaller than 53 μm had greater starch damage than coarse particles. He stated that starch damage is most likely due to the more fragmentation of flour particles than the change in their stress state. The shear stress applied to the bond between the starch and the protein causes the state to change and break the flour particles.

Hence, given the points stated regarding reduction rolls in flour production process, as well as increasing the quality of flour used in the baking industry is considered as the most important factor in improving the quality and nutritional properties of bread. In the present study, the effect of reduction rolls during grinding process on physicochemical properties of flour and rheological properties of Barbari dough and bread were examined.

Nowadays, turning to a shorter production line to reduce energy consumption and costs is one of the weaknesses of flour mills in the country that in the short line of the product should be removed as soon as possible from the flour mesh and roll pressure to accelerate this issue. Moreover, the flour meshes are selected in larger size and by increasing the volume of the inlet load to the roll and the overpressure, the rolls are heated by friction that the roll heating has adverse effects on gluten and pressure and starch damage highly increases. It is worth noting that damage to starch in a good range that maximizes water uptake is desirable, but excessive damage to the crop. Here, reduction rolls have the greatest effects on the quality of flour produced. Thus, the purpose of the study was to evaluate the quality of flour produced and to compare flour production in a long line mill and a short line mill (the shortness and length of a mill line are the number of rolls in a mill). There are significant disagreements between the line makers and the product designers. Furthermore, given the variety of wheat inputs to the factories, it was impossible to import a variety of wheat into two factories because the wheat was distributed in quota by government agents and could be intercepted and seized. Thus, only one roll was removed from the circuit for 2 h each to produce a shorter production line and the flour produced was evaluated.

Materials and methods
Materials
The study was done at the Iranian flour factory (Tehran, Iran) and a traditional bread unit in Tehran was used for the second stage of the present study (Barbari bread preparation). The incoming wheat was thoroughly mixed with the plant and ready to be conditioned and subsequently milled to produce quality flour.

Other chemicals required for chemical tests were the Merck brand (Germany). Materials used in the production of Barbari bread such as yeast (*Saccharomyces cerevisiae*) were prepared from Razavi Yeast Factory (Mashhad, Iran) and stored in

a refrigerator (4 °C).

Wheat conditioning
The time needed for wheat sleep is at least 20 h during the warm seasons of the year (the time the present study was conducted) and moisture was added to the wheat and then entered storage. The temperature of incoming dry wheat was 26 °C. The moisture content was added to the samples at a ratio of two-thirds at first conditioning (wheat temperature about 29 °C) and one-third at second conditioning (wheat temperature about 32 °C).

Sampling from the input wheat to production line
Given the variety of wheat cultivation, which is more than a hundred native and modified varieties cultivated in the country, in the field of flour production in factories we do not encounter a specific wheat type and we tried our best to mix it. Then, it was cleaned using a laboratory winnowing machine (a/s Rationel Kornservice, Denmark) and during this phase dust, straw, stone, other herbaceous seeds and broken wheat seeds were separated. Wheat samples were milled to full flour using a laboratory hammer mill (Laboratory Mill 3100, Germany).

Evaluation of physicochemical properties of incoming wheat flour
Measuring moisture was done according to Iranian National Standard No. 2705 (Iranian National Standardization Organization [ISIRI], 2011a), method for measuring the moisture content of cereals and its products and measuring the amount of ash, wet gluten and felling number edited by the AACC (2000), 08-01, 38-11 and 81-B56, respectively.

Sampling by removing reduction rolls
The first stage of the present study was done at the Iran flour factory. In this industrial unit, wheat flour was produced with 15 rolls (MIAG, Germany) including 7 rolls are crushers and 8 rolls are reduction. It has to be noted that the reduction rolls are

shown on the German and Turkish production line with the letter C and on the American production line with the letter M. Thus, according to the studies conducted and the purpose of this study that was to examine the effect of reduction rolls on the quality of flour produced, at each stage one of C1A, C1B, C2, C3 and C5 rolls are taken out from the production circuit and the wheat enters the sieve without going through the removed roll and goes through the other milling steps. Indeed, the roll numbers or alphabetical order is the coarse-grained display of the particles that slide forward, so that C2 roll load goes from C1A, C1B, B2 and B1 and the C2 load goes to C3 and C4. Moreover, C1A roll load comes from B1 and load goes to C2. C1B roll load comes from B2 and its load goes to C2 and C4. C3 roll load comes from C2 and the load goes to C4 and C5 and finally C5 reduction roll load comes from C3 and C4 and the load goes to C6 and B4F. Sampling was done at the end of the line to examine the physicochemical properties of wheat flour and rheological properties of the dough. It has to be noted that as the distance between the rolls is not measurable and in the grinding process the rolls are adjusted based on the load output and the output load shattering rather than measuring the distance to change the type of wheat to always constant distance. This is because our testing and sampling took at least 2 h to maintain constant distance between the rolls at all sampling steps.

Evaluation of physicochemical properties of wheat flour
Moisture content was measured according to Iranian National Standard No. 2705 (Iranian National Standardization Organization [ISIRI], 2011a), and ash content, gluten index and Zeleny sedimentation volume were measured using AACC (2000) 08-01, 38-12A, and 54-11, respectively.

Wet gluten content was measured according to AACC (2000) 11-38. A two-step wash of gluten (Perten, Sweden) was used to measure the gluten in whole flour

samples containing bran particles. Thus, in the first step of washing, the starch is washed and a gluten structure is formed, and in the second step, the bran particles easily pass through a 700 μm sieve.

The damaged starch content in the flour particles was measured according to the Amperometric principle and in accordance with Iranian National Standard No. 16933 (Iranian National Standardization Organization [ISIRI], 2013). This machine (Chopin, France) reports the damaged starch in less than 10 min with a UCD unit with a numerical range from 12 to 28.

Flour particle aggregation was measured using a sieve shaker (BADI, Iran) with a rotational speed of 200 rpm and sieves with 125, 180 and 475 μm apertures according to Iranian National Standard No. 103 (Iranian National Standardization Organization [ISIRI], 2011b). In doing so, the sieve was first weighed and placed in the upstream of the vibrating device from 125 to 475 μm in size, respectively.

Evaluation of rheological properties of the dough

Farinography test was done according to AACC Standard No. 21-54 (AACC, 2000) by Farinograph machine (Yucebas machine, Turkey). Farinograph measures and records dough resistance to mixing. This experiment was used to evaluate flour water absorption and specify the strength and other properties of dough during mixing.

The effect of reduction roll on the quality of Barbari bread

At the end of the first step, the most significant reduction roll, with the most effect on the physicochemical properties of the flour and the rheological properties of the dough, was identified and the flour sample was prepared in the absence of this roll, with the control sample with all rolls active in its production steps to bake Barbari bread. to prepare Barbari bread dough, two wheat flour samples, selected after reviewing the results of the above tests, were used with water (according to

Farinograph test water absorption rate), 2% yeast and 1% NaCl (Shekholeslami & Karimi, 2012).

Evaluation of qualitative and sensory characteristics of Barbari bread

Texture firmness evaluation of Barbari bread samples was done using a TTS (QTS, UK) during 2 and 72 h after baking. The maximum force needed to perform a penetration test by a cylindrical end probe (2 cm in diameter at 2.3 cm in height) at a speed of 30 mm/min from the center of the bread was calculated as an index of firmness (Pourfarzad *et al*., 2011).

Moreover, the sensory characteristics of Barbari bread produced in terms of taste (nasty taste, salty and alkaline taste, raw or sour taste or natural aroma of bread), texture (doughiness or unusual softness, bread firmness, crunchiness and fragility, chewing capability, dryness and hardness of bread, pellets and paste in the mouth and adhesion to teeth) and general acceptance (overall acceptability of the sample) were evaluated by 10 panellist. The coefficient of evaluation of traits ranged from very bad (1) to very good (5) (Stone & Sidel, 2004).

Statistical analysis

The results were evaluated using SPSS18. A completely randomized design with 6 treatments was used in doing so. The samples were prepared in three replications and the means were compared by Duncan test at the significance level (P<0.05). Finally, Microsoft Excel 2013 was used to plot the graphs and the most important roll with the most effect on the flour quality and rheological properties of the dough was introduced. Additionally, the texture and sensory properties of two samples of Barbari bread made from control flour and flour with the most important reduction roll removed from the circuit were compared using T-test.

Results and discussion

Physicochemical properties of whole wheat flour

The physicochemical properties of whole wheat flour used in the study are described in Table (1).

Table 1. Physicochemical properties of whole wheat flour

Physicochemical properties	Value
Moisture (%)	8.48±0.36
Wet gluten (%)	21.3±0.08
Ash (%)	1.22±0.02
Falling number (s)	385.00±15.00

Evaluation of the physicochemical properties of flour

Ash

The results of removing C1A, C1B, C2, C3 and C5 reduction rolls and control samples (without roll removal) on the ash content of the flours produced are shown in Fig. (1). As the results show, with the removal of C1A and C5 rolls, the highest and lowest ashes were observed in the flour samples, respectively. Ash value is one of the main characteristics of flour, according to which the flour is classified into different types. Wheat bran has the highest value of ash so if the ash content in the flour increases, it indicates an increase in the amount of bran in the flour. According to the Iranian National Standard No. 103 (Iranian National Standardization Organization [ISIRI], 2011b), the permissible range for ash for Barbari flour is 0.70 to 0.85, with the amount of ash in all samples being within the permissible range. It seems that as at the beginning of the mill the flour particles are obtained from the farthest point from the bran (wheat brains), they have at least minerals. Thus, by adding flour, this portion is reduced to the final flour of the finished product ash and if the primary rolls (especially C1A) are removed, the sample ash may increase.
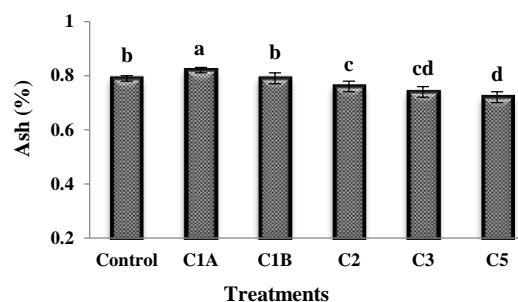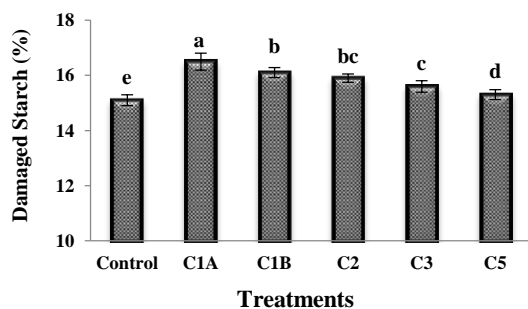

Fig. 1. The effect of removing C1A, C1B, C2, C3 and C5 reduction rolls and control on the ash content of the flour samples
Similar letters were not statistically significant at ($P<0.05$).

Damaged starch

The results of the effect of removal of C1A, C1B, C2, C3 and C5 reduction rolls and control (without roll removal) on damaged starch in flour samples are seen in Fig. (2). As the results show, with the removal of C1A roll, the highest damaged starch was observed in the flour produced in the control sample. Starch shapes the main component of all cereal grains and their products. In evaluating the quality of wheat flour, the physical conditions and the mechanical damage to the starch granules is very important during the mechanical grinding operations. The semi-crystalline structure of starch granules can be damaged by the mechanical operation of the grinding process. Limited damage to starch granules has a positive effect on wheat flour quality. However, over-damaged starch will have a significant negative impact on product quality (Kent & Evers, 1994). Limited starch damage makes it easier to release internal granule components like amylose and better penetration of water and enzymes into the granule, which in turn affects the dough properties and product properties of such flours (Peighambardoust, 2017). The degree of physical damage to the starch largely depends on the conditions of the grinding process. From the beginning to the end of the mill path, the damaged starch increases with the progress of mechanical operations. Using mechanical forces and pressures (reducing the gap

between crushing rolls, using sharp groove rolls and increasing the number of crushing rolls) significantly increases the damaged starch during the crushing process of wheat grains (Cochet, 2012; Peighambardoust, 2017). During the grinding process, when the flour is softened by the reduction rolls, the particle size becomes smaller at each step, resulting in a smaller gap between the rolls. Thus, it seems that when C1A roll is removed, particles larger than normal suddenly (i.e., when C1A worked and the particles were slightly softened) enter C1B roll. Thus, at this stage, as these particles bear a lot of pressure, the starch damage increases with the removal of other rolls. It is normal in the control sample because no roll is removed and the particles enter the next roll at the appropriate size at each step, thus experiencing proper and predictable pressure and the damaged starch is minimized.

Fig. 2. The effect of removing C1A, C1B, C2, C3 and C5 reduction rolls and the control sample on the damaged starch in the flour samples
Similar letters were not statistically significant at (*P*<0.05)

Wet gluten and gluten index

The results of the effect of reduction roll removal on wet gluten and gluten index in flour samples are shown in Table (2). As the results show, after the control sample, the highest wet gluten and gluten index were in the samples that had C1A and C5 rolls removed. However, the sample with the lowest C3 roll was removed when it was produced. According to Iranian National Standard No. 103 (Iranian National Standardization Organization

[ISIRI], 2011b), the minimum gluten content for Barbari flour is 27%, which is lower than the standard reference in flour samples produced by the removal of C2 and C3 rolls. Wheat protein contents and quality are known as indices with determinant effects on the physicochemical properties of wheat flour dough and consequently on its functional properties and baking potential (MacRitchie, 1980). As these prominent properties of the protein are primarily related to gluten-forming proteins, measuring protein in wheat or wheat flour is usually related to the determination of wet and dry gluten (Peighambardoust, 2017). This production unit seems to have the highest value of soft endosperm (this portion of the endosperm contains the highest amount of gluten protein) as the input to C2 and C3 rolls. Thus, when the rolls are removed because the flour particles enter the subsequent rolls and the ability to extract flour with appropriate gluten is reduced, wet gluten in the final flour will reduce. Concerning the control sample, as no roll was removed; the endosperm was gradually separated from the bran at each step, resulting in higher wet gluten and final flour content compared to the other samples.

Table 2. The effect of removing C1A, C1B, C2, C3 and C5 reduction rolls and control on wet gluten and gluten index in flour samples

Treatment	Wet gluten (%)	Gluten Index (-)
Control	28.30±0.69[a]	90.00±2.20[a]
C1A	27.50±0.51[a]	83.00±1.90[c]
C1B	26.50±0.53[a]	79.00±1.70[d]
C2	26.03±0.38[cd]	75.00±2.00[e]
C3	25.00±0.22[d]	70.00±1.80[f]
C5	27.50±0.61[b]	86.00±1.90[b]

Similar letters were not statistically significant at (*P*<0.05).

Zeleny sedimentation volume

The results of the effect of reduction roll removal on Zeleny sedimentation volume in the flour samples are given in Fig. (3). As the results show, after the control sample, the highest volume of Zeleny sedimentation was produced in the flours after the removal of C1A and C5 rolls.

However, in the sample with C3 roll removed during production had the lowest Zeleny sedimentation volume. In the past, wheat was used to determine the quality of total protein, but since not all wheat proteins are suitable for baking quality and only gluten proteins are bakery properties, the method for measuring total protein content is another. Outdated and quality determination of wheat and flour bakeries is done using specialized tests such as the Gluten Index and the Zeleny sedimentation Test (Peighambardoust, 2017). As clarified in the measurement for wet gluten, the amount of sediment deposited by Zeleny sedimentation likely decreased when C2 and C3 rolls were removed. It should be noted that according to the results of Shahedi, Kabir, & Bahrami (2005), who determined the flour quality and rheological properties of dough for production of Taftoon bread using Iranian wheat, it was stated that Zeleny number showed the highest correlation with bread quality and accounted for 68.8% of the variation in bread quality. Moreover, Baniasadi, Azizi, & Sahari (2005) showed that the Zeleny number has a 95% positive effect on bakery quality.
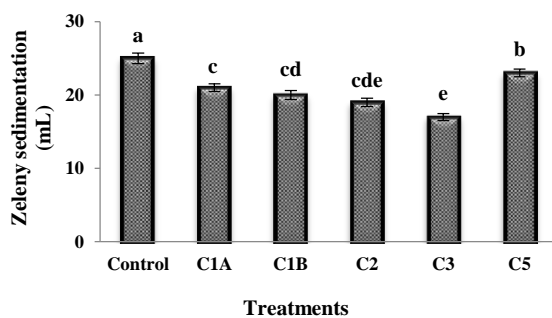
Fig. 3. Effect of removal of C1A, C1B, C2, C3 and C5 reduction rolls and control sample on the Zeleny sedimentation in the flour samples
Similar letters were not statistically significant at (*P*<0.05).

Flour particle aggregation
The results of the effect of reduction roll removal on particle aggregation of flour samples are shown in Table (3). As the results show, the control sample and the samples in which C1A and C1B rolls were

removed had the highest particle size smaller than 125 μm. However, roll removal had no significant effect on particle size greater than 475 μm. Similar results were seen for particle aggregates with sizes greater than 125 μm and more than 180 μm, such that with the removal of C5 roll, more aggregates with sizes greater than 125 and 180 μm were obtained.

Concerning grain particle size, one has to note that uniformity of flour particles and maximum particle size of less than 125 μm are desirable. At least 50% of flour particles must be less than 125 μm in size, according to Iranian National Standard No. 103 (Iranian National Standardization Organization [ISIRI], 2011b). As the distance between the rolls is reduced to the end rolls (such as the C5 roll) and subsequently the flour particle size becomes smaller, it is natural that when these rolls are removed, the probability is greater flour particle size increases.

Moreover, it has to be noted that in the short line, the product should be removed as soon as possible from the flour mesh, which will increase the pressure of the rolls to accelerate this issue, and this increase in pressure will cause the rolls to warm up. As a result of the friction that the rollr bearings have a gluten-free effect, the high pressure disrupts the starch damage process, which is too much damage to the starch. On the other hand, increase in the size of the mesh as a result of coarse-grained crop production reduces water absorption due to the large size of the particles because, as mentioned, the best grain size is 125 μm. As only the endosperm breaks into smaller particles by this size and passes through the mesh, but the bran becomes elastic due to the absorption of moisture (in conditioned operations) and rarely crosses the roll, it reaches below 125 μm.

One can state that with the removal of C5 roll the particle size is smaller than 125 μm less than the other samples and as a result the particle size of more than 125 μm increases with the removal of C5 roll.

Table 3. The effect of removal of C1A, C1B, C2, C3 and C5 reduction rolls and control on particle size in flour samples

Treatment	Particle graining *			
	On a 475 μm sieve	On a 180 μm sieve	On a 125 μm sieve	Under a 125 μm sieve
Control	0.10 ± 0.01^{ns}	0.70 ± 0.05^{c}	21.20 ± 0.80^{d}	78.20 ± 1.20^{a}
C1A	0.20 ± 0.01^{ns}	0.70 ± 0.04^{c}	21.10 ± 0.70^{d}	78.10 ± 1.00^{a}
C1B	0.10 ± 0.02^{ns}	0.70 ± 0.05^{c}	21.20 ± 0.80^{d}	78.30 ± 1.20^{a}
C2	0.10 ± 0.01^{ns}	0.90 ± 0.03^{bc}	23.70 ± 0.50^{c}	75.30 ± 1.10^{b}
C3	0.20 ± 0.02^{ns}	1.00 ± 0.04^{b}	24.50 ± 0.40^{b}	74.30 ± 1.30^{c}
C5	0.10 ± 0.01^{ns}	1.20 ± 0.05^{a}	25.80 ± 0.50^{a}	72.90 ± 1.20^{d}

* Mean numbers are three replication.
Similar letters in each column were not statistically significant at ($P<0.05$).
ns: No significant difference was seen at ($P<0.05$) level.

Moisture

The results of the effect of removing the reduction rolls on the moisture contents of the flour samples are shown in Fig. (4). As the results show, by removal of C1A and C5 rolls, the highest and lowest moisture contents were observed in the flour samples, respectively. Moisture is one of the most important factors in preventing microbial, chemical and enzymatic spoilage during storage of a food material (Fatemi, 2004; Jafari, Poormohammadi, & Asadpou, 2011). Wheat grain behavior in both the storage and the grinding stages depends largely on their moisture contents. Wheat with inadequate moisture will not be technologically appropriate at the milling stage. Wheat and flour moisture levels correlate with the economic benefits of milling units. Wheat flour is sold by weight, and any change in its moisture contents can have a benefit or disadvantage to the production unit, and unfortunately can be a source of profit for a limited number of flour producers. Thus, it is important to control the moisture contents and accuracy of its test methods from a technological, maintenance and economic point of view (Ali Akbarnia & Azarbad, 2010; Peighambardoust, 2017).

According to the Iranian National Standard No. 103 (Iranian National Standardization Organization [ISIRI], 2011b), the maximum moisture content of Barbari flour is 14.2%. According to the results, the sample in which the C1A roll was removed has moisture contents of 14.5% which is higher than the standard

limit. Various factors are involved in determining flour moisture like particle size, ash or bran content, damaged starch, and gluten flour content. The sample that produced C1A roll seems to have been removed because it had more ash (or in other words bran) and damaged starch as well as a particle size of less than 125 μm. Hence, it is more capable of absorbing and retaining moisture. In the case where C5 roll was removed, the conditions are quite the opposite of the one in which the C1A roll was removed and so it is normal to have the lowest moisture content.
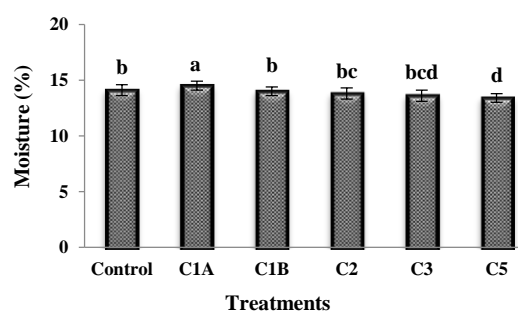
Fig. 4. The effect of removal of C1A, C1B, C2, C3 and C5 reduction rolls and control on the moisture contents of the flour samples
Similar letters were not statistically significant at ($P<0.05$).

Evaluation of rheological properties
Water absorption
The results of the effect of reduction roll removal on farinograph properties are presented in Table (4). As the results show, the highest water uptake was observed in the control and sample with C1A roll removal, whereas the lowest water uptake was observed in the sample with C2 roll

removal and with C3 roll removal. Overall, strong flours with high gluten contents and quality, high extraction flours, soft flours (fine particle size), flours with damaged starch percentage and high pentosan content and mature flours (aged) have high water absorption percentages (Peighambardoust, 2017). As the sample had the highest value of these parameters by removing C1A roll in the damaged starch measurement section, gluten content, particle size less than 125 μm and ash content, it was expected that this sample would have higher water absorption. In the case of the control sample, it was expected that the amount of gluten, ash, and particle size below 125 μm would increase as in the case of C1A roll removal. It is natural that the lower the samples tested, the lower the effective parameters in increasing flour water uptake, so the amount of flour absorbed will decrease. Concerning the effect of ash content, Moradi, Ghiassi Tarzi, Seyyedain Ardebili, & Azizinejad (2010) stated that higher ash contents show higher value of bran that increase water absorption. Concerning the effect of gluten on water absorption of flour, Moradi et al. (2010) and Mohtarami, Esmaiili, Alizadeh Khaledabad, & Seyedain Ardabili (2014) stated that strong flour has more water absorption than weak flour and this phenomenon is because of high protein quality of flour that can retain and absorb more moisture.

Table 4. The effect of reduction roll removal on dough farinograph properties

Treatment	Farinographic characteristics of dough					
	Water absorption (%) *	Dough development time (min)	Dough stability time (min)	Degree of dough softening (Brabender Unit)		Valorimetric value (-)
				10 min	20 min	
Control	56.50±1.20[a]	3.31±0.07[a]	7.14±0.07[a]	65.30±2.50[e]	96.10±3.40[d]	67.00±1.07[a]
C1A	56.00±1.40[a]	3.00±0.05[b]	6.78±0.05[b]	74.10±1.50[d]	108.20±2.50[c]	63.30±0.05[b]
C1B	56.30±1.30[a]	2.30±0.08[c]	6.20±0.08[c]	85.30±2.20[b]	114.50±2.80[bc]	59.10±0.08[c]
C2	53.00±1.00[c]	1.80±0.06[d]	5.53±0.06[d]	94.20± 1.80[b]	121.70±2.80[b]	57.60±0.12[cd]
C3	53.00±1.10[c]	1.24±0.07[e]	4.10±0.07[e]	102.70±3.00[a]	134.30±2.20[a]	54.00±0.90[d]
C5	54.80±1.40[b]	3.08±0.09[b]	6.82±0.09[b]	74.60±2.10[d]	108.80±1.90[c]	63.20±1.33[b]

* Mean numbers have three replication.

Similar letters in each column were not statistically significant at ($P<0.05$).

Dough development and stability time

The results indicate that the control sample showed the highest dough development time and dough stability time, whereas the lowest value of these parameters was observed in the sample with C3 roll removal. Indeed, the time it takes (in minutes) from the start of mixing to reaching the first curve to the maximum peak is called the development time or optimal mixing time. During the development of the dough, one can state that the hydration of the flour is complete and the dough's gluten network is fully formed due to the mechanical forces involved in the mixing process and encapsulates the starch granules (Peighambardoust, 2006). Concerning the significance of gluten in this test, it is normal for the control sample to have more development time because of the gluten contents and gluten index than other samples (William, El-Haramein, Nakkoul, & Rihawi, 1986). Moreover, the sample has less development time by C3 roll removal as it has the lowest gluten value.

On the other hand, the time (minutes) that the upper point of the Farinogram curve reaches 500 line (time of arrival) until the upper point of the curve crosses the 500 line (exit time) is termed the dough resistance or durability. Dough stability is used more than other Farinogram indices to compare the strengths or weaknesses of different flours. However, as long as Farinogram curve remains on line 500, the gluten network acquires and maintains its viscoelastic properties and has good

performance properties (formability, mechanical strength tolerance and gas retention) (Peighambardoust, Van Brenk, Van der Goot, Hamer, & Boom, 2007). Given the significance and quality of gluten in this test, it is normal for the control sample to have a longer retention time than other samples (William *et al.*, 1986) because of the gluten content and gluten index. Moreover, the specimen with lower C3 roll removal has less stability time because it has the lowest gluten contents.

Dough softening degree

As the results indicate in the sample with C3 roll removal, the highest dough softening was observed at 10 and 20 min after the test, whereas the lowest was observed at the control sample at 10 and 20 min after the start of the test. Regarding this, Akbari Rad, Najafian, Esmailzadeh Moghadam, & Khodarahmi (2010) claimed that increasing the degree of softening indicates that with increase in gluten content, the dough strength increased and became looser. The later the dough loosens, the longer the dough evolves and the longer it stays. Considering the significance and quality of gluten in this test, it is normal for the control sample to have a lower degree of softening at 10 and 20 min after onset because of gluten content and gluten content than the other samples. Furthermore, the sample with C3 roll removal has a higher degree of softening of the dough at 10 and 20 min after the start of the test as it has the lowest gluten content.

Valorimetric value

The results showed the highest valorimetric value was in the control sample, whereas the lowest valorimetric value was observed in the sample with C3 roll removal. A value called the valorimeter is obtained using a special Farinograph ruler on a chart recorded by mechanical Farinographs to show the strength of the flour as a single number.

Given the importance and quality of gluten in this test, it is normal for the control sample to have a higher valorimetric value than other samples because of the gluten content and gluten index. Moreover, the sample with C3 roll removal has lower valorimetric value because it has lower gluten content.

Quantitative and qualitative evaluation of Barbari bread

According to the results of the previous tests, it was found that the flour sample prepared by removing the C3 reduction roll had the highest contrast with the control sample (without roll removal). By eliminating this roll, the physical and chemical properties of the flour and the rheological properties of the resulting dough are greatly weakened. Hence, as the texture and sensory evaluation are key parameters for baking products, especially traditional breads, Barbari bread samples obtained from the removal of C3 reduction roll and bread made with control flour (where no roll was removed) were compared.

Texture firmness

Comparing the firmness of the sample and control texture with removal of the C3 roll is presented in Table (5). As stated in the previous step, removing C3 roll drastically reduces the quality of flour, whereas the control sample where all rolls are in orbit has a higher overall quality. Hence, by comparing the firmness of Barbari bread with control flour and Barbari bread with C3 reduction roll removal at 2 and 72 h after baking, there was a significant difference at 5% level. It was seen that Barbari bread made from control flour had less firmness at both intervals. Previous studies clearly showed that flour prepared by removing C3 roll had higher starch content, coarse particle size and weaker mechanical rheological properties (Farinography) than control flour. Thus, given the significance of starch in the staling process, it is natural that the greater

the damage to this compound, the more amylopectin retrograde (starch back) occurs, the faster the staling will occur. Moreover, as the particle size of the flour in the sample is larger with the removal of C3 roll and thus with the ability to absorb less moisture, and according to the results of the Faringography section (water absorption part), expect the reduction of water absorption power in the sample by roll removal C3 is not far-fetched.

Table 5. Textural and sensory characteristics of Barbari bread prepared from control sample flour (without roll removal) and flour with C3 roll removal

Textural and sensory characteristics	Flour sample	
	Control (without roll removal)*	C3 sample with roll removal
Firmness (2 h after baking)	25.09±0.15[b]	33.82±1.08[a]
Firmness (72 h after baking)	42.21±1.26[b]	58.67±1.43[a]
Taste	4.18±0.12[a]	3.87±0.16[b]
Texture	4.56±0.08[a]	3.42±0.12[b]
Overall acceptance	4.63±0.16[a]	3.80±0.21[b]

* Mean numbers are three replications.
Similar letters in each row were not statistically significant at (P<0.05).

Sensory properties
Tasting judges showed significant differences at 5% level when examining texture, taste and overall acceptance parameters between Barbari bread made from control flour and from C3 softener roll removal. Barbari bread produced from control flour had the highest scores in all three parameters (Table 5).

In sensory test to score a product texture, doughiness or abnormal softness, firmness, brittleness and excessive fragility cause the fracture points. Regarding the texture characteristics of the sensory evaluators, the control sample was smoother and uniform, which was expected with respect to the previous section (bread texture evaluation). When it comes to examining the taste of the product, it is critical to understand that taste is a combination of the two senses of smell and taste. Hence, the taste depends on two main components, volatile combinations (aroma) and non-volatile, which are sensed by the taste buds on the tongue. Various factors in the nutrient may affect the release of volatile components plus taste. Most scholars argue that understanding the taste intensity and release of flavoring agents depends on the texture of the finished product (Baines & Morris, 1987). Boland, Buhr, Giannouli, & Van Ruth (2004) justify the cause of this event by various interactions between flavorings and texture structure. Thus, according to the studies and the results obtained from the textural evaluation, the control sample with a softer texture was predicted to have a better taste.

Conclusions
One of the weaknesses clear in mill factories in Iran is turning to the short line by eliminating a number of rolls to reduce energy consumption and costs. However, in a long line as there is more opportunity for production operations, the roll pressure is proportional to the input product and the output can be proportional to the sieve with arbitrary aggregation and conventional damaged starch and compensate for some of the weakness of incoming wheat. Some of the rolls have more effect on the quality, and the results of this study showed that the sample that had been removed in the grinding process of the C3 softener roll had the lowest gluten content, gluten index, Zeleny sudimentation volume, important qualitative in the baking process, was enjoyed. The rheological properties evaluation showed that by removing C3 roll, the water absorption, development time, stability time and valorimetric value of the dough reduced the most. Thus, the flour removed in the milling process, C3 roll, is most in contrast to the control sample. Additionally, the firmness of the sample of Barbari bread prepared from the control sample at both 2 and 72 h after baking was lower than that of C3 roll removal. Moreover, in the sensory

evaluation section, the control sample received a greater overall acceptance score. Thus, given the results of this study, it was found that by removing C3 reduction roll the physicochemical properties of flour, rheological properties of the dough and baking properties of the bread significantly weakened and this roll was superior to other soft rolls with the greatest effect on the quality of flour, dough and finished product. Indeed, as the layered endosperm is converted into flour in the rolls, one can state that the best endosperm layer is separated by C3 reduction roll and this type of roll failure and being faulty has great effects on the quality of flour and finished product.

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تأثیر غلتک‌های نرم‌کننده طی فرایند آسیابانی بر خصوصیات فیزیکوشیمیایی آرد و ویژگی‌های رئولوژیکی خمیر و نان بربری

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چکیده

غلتک‌های نرم‌کننده در فرایند تولید آرد نقش مهمی دارند و ازآنجایی‌که افزایش کیفیت آرد مورداستفاده در صنایع پخت به‌عنوان مهم‌ترین فاکتور در بهبود خصوصیات کیفی و تغذیه‌ای نان بشمار می‌آید، هدف از انجام این پژوهش ارزیابی تأثیر حذف غلتک‌های نرم‌کنندهٔ C1A، C1B، C2، C3 و C5 بر ویژگی‌های فیزیکوشیمیایی آرد و خصوصیات رئولوژیکی خمیر و انتخاب مؤثرترین غلتک در فرایند آسیابانی در یک طرح کاملاً تصادفی بود ($P \leq 0/05$). نتایج نشان داد که دو نمونهٔ آرد که در فرایند آسیابانی آنها غلتک‌های C5 و C3 حذف شده بودند، از میزان رطوبت، خاکستر، اندازهٔ ذرات کوچک‌تر از ۱۲۵ میکرون و نشاستهٔ آسیب‌دیدهٔ کمتری برخوردار می‌باشند. همچنین نمونه‌ای که در فرایند آسیابانی آن غلتک C3 حذف شده بود از کمترین میزان گلوتن (۲۵ درصد)، اندیس گلوتن (۷۰)، حجم رسوب زلنی (۱۷ میلی‌متر) برخوردار بود. همچنین با حذف غلتک C3 جذب آب آرد، زمان توسعه، زمان پایداری و ارزش والوریمتری بیشترین کاهش را نسبت به نمونهٔ شاهد نشان داد. بنابراین مشخص شد آردی که در فرایند آسیابانی آن، غلتک C3 حذف شده است، ویژگی‌های فیزیکوشیمیایی آرد و خمیر به شدت تضعیف گردید. در ادامه این پژوهش با آرد حاصل از این نمونه و نمونهٔ شاهد نان بربری تولید شد و نتایج نشان داد که میزان سفتی بافت نمونه با حذف غلتک C3 نسبت به نمونهٔ شاهد در هر دو بازهٔ زمانی (۲ و ۷۲ ساعت پس از پخت) بیش از ۳۵ درصد افزایش یافت. همچنین در بخش ارزیابی حسی، نمونهٔ شاهد امتیاز پذیرش‌کلی بیشتری را به خود اختصاص داد. بنابراین باتوجه‌به نتایج این تحقیق مشخص شد که حذف غلتک C3 نسبت به سایر غلتک‌های نرم‌کننده بیشترین تأثیر را بر کیفیت آرد، خمیر و محصول نهایی دارد.

واژه‌های کلیدی: خصوصیات رئولوژیکی، غلتک نرم‌کننده، فرایند آسیابانی، گندم، نان بربری