YYÜ TAR BİL DERG
(YYU J AGR SCI)
2017, 27(1): 77-81

Geliş Tarihi (Received): 14.12.2016
Kabul Tarihi (Accepted): 28.02.2017

Araştırma Makalesi/*Research Article (Original Paper)*

Effect of Some Operating Parameters on Wheat Size Reduction Process During the First Break Rollers

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Abstract: In this study, the effects of roll speed and roll gap on wheat size reduction process were studied; the physical properties of wheat kernels were also determined for the initial moisture content. Selected roll speed levels were 500 and 525 rpm, while roll gap levels at the nip point were 0.6, 0.7, and 0.8 mm. Size reduction experiments were carried out for Soft White Winter (SWW) wheat. The geometric mean diameter, thickness dimension, thousand kernel mass, bulk density, and NIR hardness index of wheat kernels at the 13.07% d.b. of moisture content were 3.88 mm, 2.81 mm, 43.03 g, 816.20 kg m^{-3}, and 40, respectively. Protein content of wheat kernels was also determined as 9.0% d.b. On the other hand particle size distribution was not generally affected by roll speed statistically, while it was statistically affected by roll gap ($p<0.01$).

Keywords: First break rolls, Physical properties, Size reduction process, Wheat

İlk Kırma Valsleri Sürecinde Bazı İşletme Parametrelerinin Buğday Boyut Küçültme İşlemi Üzerindeki Etkileri

Özet: Bu çalışmada, vals hızının ve vals aralığının buğday boyut küçültme işlemi üzerindeki etkileri çalışılmış; ayrıca buğdayın mevcut nem içeriği için bazı fiziksel özellikleri belirlenmiştir. Deneyler için, vals hızları sırasıyla 500 ve 525 dev dak^{-1} ve vals aralıkları 0.6, 0.7 ve 0.8 mm olarak seçilmiştir. Çalışmada materyal olarak Yumuşak Beyaz Kışlık buğday kullanılmıştır. Mevcut nem içeriğinde, buğday çeşidinin geometrik ortalama çap, kalınlık boyutu, bin tane ağırlığı, hacim ağırlığı ve NIR sertlik indeksi değerleri sırasıyla 3.88 mm, 2.81 mm, 43.03 g, 816.20 kg m^{-3}, and 40 olarak saptanmıştır. Söz konusu bu buğday çeşidinin protein içeriği %9.0 k.b. olarak belirlenmiştir. Öte yandan partikül boyut dağılımı, genelde, vals hızından istatistiksel olarak etkilenmezken, vals aralığından istatisksel olarak etkilenmiştir.

Anahtar kelimeler: Buğday boyut küçültme işlemi, Buğday, İlk kırma valsleri

Introduction

Wheat is the leading cereal produced in the world, with a production of 713 million tones (FAO 2013). Structure of the wheat kernel consists of three major parts namely bran (14-16%), endosperm (81-84%), and germ (2.5-4%) (Campbell 2007). Endosperm and germ are covered with the bran which protects them against mechanical damages both before harvesting and after harvesting. In order to use wheat in food industry such as bread, cakes, cookies, and pasta, the endosperm should be separated as much as possible from the germ and the bran physically and converted into flour.

The process of converting wheat into flour at roll mills is defined as a gradual reduction process. Gradual reduction process consists of two main systems namely break and reduction, which are interconnected. There are four or five roll pairs in the break system. Aim of the first break rolls which are used at the first stage of break system is to open wheat kernels and to get a granulation distribution of maximum large middlings with a minimum of flour and fine fraction (Posner and Hibs 2011). The first break rolls are grooved to accomplish functions cited above. These grooves are slight slant along the rolls. The direction of the slant in one roll is opposite to that in the paired roll so that at the clearance the edges of the grooves to perform a scissors-like action (Matz 1991). The first break rolls that are also formed by a pair of rolls rotating toward each other at different speeds allow opening up the wheat kernels with minimum bran breakage and the first break flour (Kalkan et. al. 2014).

During the first break rolls, wheat kernels are broken into a wide range of particle sizes. The particle size distribution of product obtained from the first break rolls is of critical importance (Campbell 2007). Likewise, it affects the operating parameters of second break rolls such as roll speed, roll gap, and roll differential. Particle size distribution obtained from the first break rolls varies up to 2000 µm (Fang and Campbell 2003). The particles that are smaller than 150 µm take place in the first break flour. Quality of the first break flour is important since it affects the quality of end product that is final flour.

There are several reported studies in the literature on wheat milling process. Scanlon and Dexter (1986) investigated the effects of roll speed and roll differential on kernel size reduction. They reported that increasing roll speed gave greater breakage.

The objective of this study was to determine the effects of operating parameters on wheat size reduction process during the first break rolls for cv. Palandöken-97 variety.

Materials and Methods

Sample preparation and determination of some physical properties

Wheat cultivar of Palandöken-97 (SWW) was used in the experiments. Cv. Palandöken-97 was obtained from the Farm of Agriculture Faculty, Ataturk University in Erzurum (eastern part of Turkey). The bulk of wheat was free from damaged and diseased kernels, dirt, stones, and foreign pieces. The initial moisture content of the wheat kernels was determined by drying samples in a hot air oven set at 105 ºC for 24 h (Suthar and Das 1996) and was found to be 13.07% d.b.

In order to determine the dimensions of the kernel, 100 individual untempered kernels were randomly selected and their three principal linear dimensions namely length (L), width (W) and thickness (T) were measured by a digital vernier reading to an accuracy of 0.01 mm. Geometric mean diameter (D_g) was calculated using the formula below (Mohsenin 1986):

$$D_g = (LWT)^{1/3} \tag{1}$$

One hundred kernels were weighed to determine thousand kernel mass in an electronic balance reading to 0.001 g and multiplied by 10 to give the mass of thousand kernels. Bulk density was measured using a mass per hectoliter tester, calibrated in kg cm^{-3} (Deshpande 1993). Wheat kernels were tested for protein content and hardness index by using NIR technique (Inframatic, model 8600, Perten Instruments AB).

Tempering process was made by spraying on the sample in the plastic drum with dimensions of 45 cm in diameter and 135 cm in length. The wheat bulk in the drum was gently mixed rocking by hand on a floor for 30 minutes. Afterwards the sample was kept at 20 ºC at laboratory for 10 h. Tempering moisture for size reduction process was 16.5% d.b.

First break roll unit

For size reduction process, the first break roll unit that was designed and it was equipped to adjust roll gap, roll speed, roll differential, and wheat feed rate (Figure 1). Each of the first break rolls is independently driven by its own variable three-phase electric motor (3 kW; 2900 rpm) with V-belts and an intermediate shaft. These electric motors are set to desirable speeds by a variable frequency AC motor speed controllers (Schneider ATV71HU30N4-3kW-480V). Roll gap and wheat feed rate are set through adjustment mechanisms on the mill. Aspects of design properties of the first break rolls are given in Table 1.

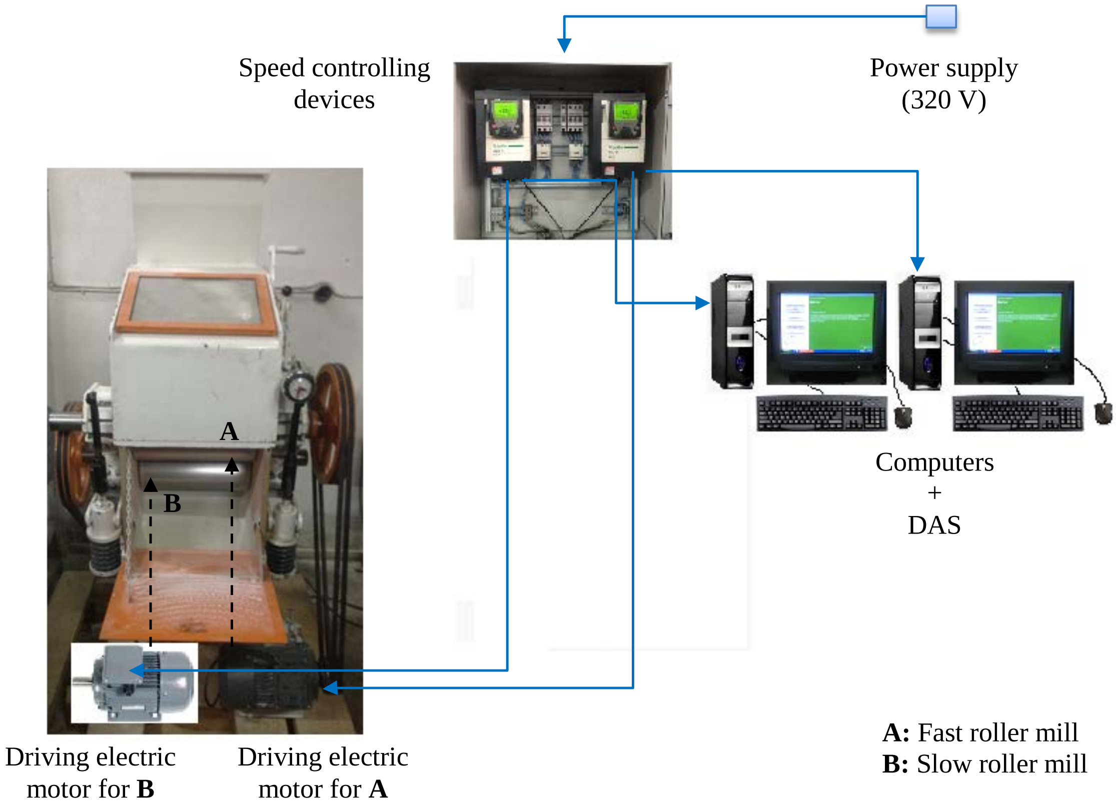

Figure 1. First break roll unit

Table 1. Aspects of design properties of the first break rollers

Aspects of design properties	Values
Corrugation depth, mm	0.981
Corrugation number per cm	3.9
Groove angle, °	30/60
Roll length, mm	400
Roll diameter, mm	250
Corrugation angle, %	6
Land, mm	0.15

Operating parameters in the size reduction process

Fast rotating first break roll was set at a speed of 500 and 525 rpm and speed of slow rotating first break roll was changed to obtain differential speed of 2.5:1. Size reduction process was carried out at three roll gaps of 0.6, 0.7, and 0.8 mm. For each size reduction process, 1300 g of sample was used. Roll disposition was set dull to dull. Experiments were replicated twice.

Evaluation material reduced in size

The material reduced in size for each experiment was collected and sieved with adjustable frequency and shaking time of 10 minutes and separated into five fractions using wire mesh sieves of size 1180, 530, 250, and 150 µm, along with a bottom collection pan. After the process was completed, a balance accurate to 0.01 g was used to weigh the material remaining on each sieve and in the fine collectors. Five fractions obtained were coarse fraction (over 1180 µm), sizing (through 1180 µm and over 530 µm), large middlings (through 530 µm and over 250 µm), fine fraction (through 250 µm and over 150 µm), and the first break flour (through 150 µm).

Experimental design and statistical analysis

The study was carried out according to a completely randomized factorial arrangement of two fast rotating the first break roll speeds by three roll gaps by two replications using one type of cultivar. The data obtained from the study were analyzed by using SPSS statistical software (version 20). In addition, Duncan's test was used to distinguish differences between the combinations of the mill setting variables.

Results and Discussion

Physical properties of wheat kernel

As seen from the Table 2, physical properties of wheat kernels called as Palandöken-97 at the initial moisture content (13.07% d.b.) were 3.88 mm, 2.81 mm, 43.03 g, 816.20 kg m^{-3}, and 40, which they were geometric mean diameter, thickness dimension, thousand kernel mass, bulk density, and NIR hardness index, respectively. In addition 9.0% d.b. was the protein content of cv. Palandöken-97. Fundamental physical properties mentioned above were supported by existent literature (Kalkan and Kara 2011).

Table 2. Physical properties of untempered wheat

Physical properties	Value
Moisture content, % d.b.	13.07
Protein content, % d.b.	9.0
NIR hardness index	40
Bulk density, kg m^{-3}	816.20
Thousand kernel mass, g	43.03
Geometric mean diameter, mm	3.88
The third longest dimension (Thickness), mm	2.81

Wheat size reduction process

The effects of roll speed and roll gap on wheat size reduction process are presented in Table 3. As the results were evaluated regardless of roll gap, increasing the fast rotating first break roll speed from 500 to 525 rpm had the following effects: amounts of coarse and fine fraction decreased slightly, amounts of sizing and large middlings increased slightly, and amount of the first break flour decreased significantly ($p<0.05$) (Table 3). Hsieh et al. (1980) reported that wheat kernels are scraped more severely at a higher roll speed. Information cited by others are in line with the results observed in our study. Likewise, amount of coarse fraction was lower at the roll speed of 525 rpm. On the other hand, as roll gap varied from 0.6 mm to 0.8 mm, amount of coarse fraction decreased and amounts of sizing, large middlings, fine fraction and the first break flour increased (Table 3) ($p<0.01$). Because wheat kernels could not find suitable area in size reduction zone, the amount of coarse fraction was the highest at roll gap of 0.6 mm. Conversely, amounts of sizing, large middlings, fine fraction and the first break flour were the lowest at roll gap of 0.6 mm.

Conclusion

The initial moisture content of cv. Palandöken-97 was determined 13.07% d.b. The geometric mean diameter, thickness dimension, thousand kernel mass, bulk density, and NIR hardness index of cv. Palandöken-97 at the 13.07% d.b. of moisture content were 3.88 mm, 2.81 mm, 43.03 g, 816.20 kg m-3, and 40, respectively. Protein content of wheat kernels investigated was also found as 9.0% d.b. Particle size distribution obtained depending on the operating parameters of the first break rolls presented differences. The amounts of coarse fraction, fine fraction, and first break flour were higher at roll speed of 500 rpm than 525 rpm of roll speed. Whereas amounts of sizing and large middlings were lower at roll speed of 500 rpm compared to the 525 rpm of roll speed.

Table 3. The effects of operating parameters on particle size distribution, %

Particle size distribution	Fast rotating roll speed, rpm	Roll gap, mm			Average
		0.6	**0.7**	**0.8**	
Coarse fraction	500	86.52*a[¥]	82.72b	82.08c	83.77
	525	87.36a	85.58b	75.89c	82.94
	Average	86.94	84.15	78.99	83.36
Sizing	500	6.26a	8.47b	8.60b	7.78
	525	6.25a	7.18b	12.86c	8.76
	Average	6.26	7.83	10.73	8.27
Large middlings	500	3.98a	4.93b	5.06b	4.66
	525	3.74a	4.22b	6.99c	4.98
	Average	3.86	4.58	6.01	4.82
Fine fraction	500	1.37a	1.55b	1.71c	1.54
	525	1.06a	1.30b	1.90c	1.42
	Average	1.22	1.43	1.81	1.48
First break flour	500	1.89a	2.34b	2.55b	2.26
	525	1.59a	1.73a	2.37b	1.90
	Average	1.74	2.04	2.46	2.08

[¥]Values followed by the same letter in the same row are not significantly different by Duncan's multiple range test.

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