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Some Physical and Nutritional Properties of Hulled Wheat

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Abstract: To design a machine for handling, cleaning, conveying, storing and milling, the physical properties of material must be known. For this purpose, einkorn and emmer wheat physical properties were investigated in this study. For einkorn spikelets, length, width, thickness, equivalent diameter, sphericity, surface area, volume, aspect ratio, bulk density, true density, porosity thousand spikelet weight, angle of repose, terminal velocity were found to be 10.88 mm, 3.33 mm, 2.15 mm, 4.34 mm, 0.39 %, 52.22 mm^2, 23.47 mm^3, 0.31, 410.64 kg/m^3, 1034.00 kg/m^3, 60.28 %, 37.78 g, 22.01°, 4.81 m/s, respectively. For emmer spikelets, corresponding values are 12.36 mm, 4.97 mm, 2.72 mm, 5.67 mm, 0.45 %, 83.91 mm^2, 51.85 mm^3, 0.40, 476.79 kg/m^3, 1003.35 kg/m^3, 52.48 %, 78.82 g, 23.02°, 5.30 m/s, respectively. For einkorn kernels, corresponding values are 6.77 mm, 2.87 mm, 1.88 mm, 3.37 mm, 0.49 %, 29.86 mm^2, 11.66 mm^3, 0.43, 793.02 kg/m^3, 1239.25 kg/m^3, 36.00 %, 30.82 g, 22.31°, 5.61 m/s and for emmer kernels, 7.61 mm, 2.64 mm, 2.31 mm, 3.59 mm, 0.47 %, 35.28 mm^2, 14.65 mm^3, 0.35, 725.00 kg/m^3, 1248.33 kg/m^3, 41.92 %, 37.08 g, 24.02°, 5.96 m/s, respectively. Also the differences of hulled wheat were examined as in comparison with common wheat. It was determined that hulled wheat kernels are smaller but denser than common wheat.

Key Words: Hulled wheat, einkorn, emmer, physical properties

Kavuzlu Buğdayların Bazı Fiziksel ve Besinsel Özellikleri

Özet: Taşıma, temizleme, depolama ve öğütme makinalarının tasarımı için malzemenin fiziksel özelliklerinin bilinmesi gerekir. Bu amaçla, bu çalışmada siyez ve gerniğin fiziksel özellikleri araştırılmıştır. Siyezin kavuzlu hali için uzunluk, genişlik, kalınlık, eşdeğer çap, küresellik, yüzey alanı, şekil oranı, hacim, yığın yoğunluğu, gerçek yoğunluk, gözeneklilik, bin dane ağırlığı, yığılma açısı ve kritik hız sırasıyla 10.88 mm, 3.33 mm, 2.15 mm, 4.34 mm, % 0.39, 52.22 mm^2, 23.47 mm^3, 0.31, 410.64 kg/m^3, 1034.00 kg/m^3, % 60.28, 37.78 g, 22.01°, 4.81 m/s olarak tespit edilmiştir. Gernik için aynı değerler, 12.36 mm, 4.97 mm, 2.72 mm, 5.67 mm, % 0.45, 83.91 mm^2, 51.85 mm^3, 0.40, 476.79 kg/m^3, 1003.35 kg/m^3, % 52.48, 78.82 g, 23.02°, 5.30 m/s bulunmuştur. İlgili değerler sırasıyla, siyezin özü için 6.77 mm, 2.87 mm, 1.88 mm, 3.37 mm, % 0.49, 29.86 mm^2, 11.66 mm^3, 0.43, 793.02 kg/m^3, 1239.25 kg/m^3, % 36.00, 30.82 g, 22.31°, 5.61 m/s, gerniğin danesi için ise 7.61 mm, 2.64 mm, 2.31 mm, 3.59 mm, % 0.47, 35.28 mm^2, 14.65 mm^3, 0.35, 725.00 kg/m^3, 1248.33 kg/m^3, % 41.92, 37.08 g, 24.02°, 5.96 m/s olarak saptanmıştır. Ayrıca kavuzsuz buğdaylara göre farklılıklar irdelenmiştir. Kavuzlu buğday danelerinin kavuzsuz buğdaylara göre daha küçük fakat daha yoğun olduğu tespit edilmiştir.

Anahtar Kelimeler: Kavuzlu buğday, siyez, gernik, fiziksel özellikler

Introduction

Hulled wheat species (einkorn, emmer and spelt) are among the most ancient cereal crops of the Mediterranean region. Einkorn (*Triticum monococcum*) is genetically the most basic wheat type with a diploid chromosome number (2n=14) and contains two sets of a single genome. Emmer (Triticum dicoccum), another ancient wheat, is tetraploid (2n=28) and combines two distinct genomes, whereas spelt wheat (*Triticum spelta*) and common wheat (triticum aestivum) are hexaploid (2n=42) and contain 2 sets of three different genomes (Kimber and Sears 1983). Einkorn and emmer were instrumental in the rise and spread of agriculture and a significant food source for several thousand years, before it was replaced by the more productive polyploid wheat during the Eneolithic period (Nesbitt and Samuel 1996). Hulled wheat is a typical example of an underutilized plant species. These species have a considerable importance in terms of food security and local cultural value, but are relatively unknown and undervalued in commercial production. Most underutilized species, often neglected by researchers and policy makers, are in danger of disappearing due to different reasons, from agronomic and genetic, to economic and cultural factors (Padulosi et al. 2002).

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According to Karagöz (1996) in Turkiye, hulled wheat were cultivated from 1948 to 1968 over 100 000 ha of land, and after this period there was a sharp decrease in their cultivation in 1993. The total acreage was reduced to 12 900 ha (1240 kg ha^{-1} yield) which corresponds to about 9% of the area cultivated in 1953.

Hulled wheat is currently interest for use in specialty bakery products. In some practices of alternative medicine, ancient wheat have been proposed for inclusion in the diet of patients being treated for health problems such as colitis ulcerous, high blood cholesterol, rheumatoid arthritis, depression and cancer (Strehlow et al. 1994). Einkorn attracts attention due to its high levels of protein, carotenoids, phosphorus and antioxidant (Brandolini et al. 2007).

Several studies conclude that einkorn is a promising candidate for the development of new or special foods such as bakery products, baby food or products with high content of dietary fibre, carotenoids and tocols (Borghi et al. 1996, Løje et al. 2003). Einkorn flour is often considered to have poor dough and baking properties (D’Egidio and Vallega 1994, Abdel-Aal et al. 1997). Its dough is weak, sticky, difficult to handle and has a low mixing tolerance. Emmer flour can substitute wheat flour in most bakery products: breads, pasta, savory and sweet biscuits, cakes, and waffles. Modern cooks are rediscovering the full flavors of whole grain emmer pasta and bread, as well as adding emmer grains to dishes such as soups (Giuliani et al. 2007)

Information regarding the physical properties of hulled wheat is very important in the design of equipment for harvesting, transporting, cleaning, separating, packing, storing and processing it into different foods. Principal dimensions are useful in selecting sieve separators. Bulk density, true density, and porosity can be useful in sizing grain hoppers and storage facilities. Thousand grain weight of grain is used for calculating the head yield. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through the chute. Flow ability of grain is usually measured using the angle of repose. The terminal velocity is useful in grain transportation by air. Since the systems currently used have been designed without taking these criteria into consideration, the resulting designs lead to inadequate applications. These cases result in a reduction in work efficiency and an increase in product losses. Therefore, determination and consideration of these properties play an important role in designing proper equipments.

Many studies have been carried out on the physical properties of grains and seeds, such as wheat (Tabatabaeefar 2003, Dziki and Laskowski 2005, Demirbaş and Dursun 2007), rice (Varnamkhasti et al. 2007), green wheat (Al-Mahasneh and Rababah, 2007), sunflower seeds (Gupta and Das 1997) but no study concerning physical properties of einkorn and emmer have been carried out. The methods that are currently in use for hulled wheat production have two major disadvantages: firstly, they are slow and cannot be suited for large scale production, and secondly they cannot be guaranteed to provide a consistent good quality product. Hulled wheat production provides an economic advantage for local farmers, since it is commonly sold at a price that is two times as high as wheat. Giuliani et al. (2007) suggest an active public awareness campaign targeted at producers, consumers, and policy makers in order to ensure the promotion of this product in Türkiye and they noticed that the research activities should be implemented to improve the quality of processing and of the final product. Therefore, the objective of this study was to explore some of the physical properties that use to design equipment of hulled wheat and nutrient content.

Materials and Methods

Materials

Einkorn and emmer spikelets were used in this study (Figure 1.). Samples were randomly selected Kastamonu, Türkiye (1100 m a.s.l.). Hulled wheat’s spikelets and kernels were investigated separately in this study. The spikelets were cleaned manually and stones, straw and dirt were removed. Moisture content was determined by oven method at 105 °C ± 3 °C during 24 h (Gupta and Das 1997). The average moisture contents of samples were found to be 9.99% and 9.98% w.b. for einkorn and emmer, respectively.

a **b**

Figure 1. Emmer (a) and Einkorn (b) spikelets and kernels

Methods

Determination of physical properties: The principle dimensions of einkorn and emmer were measured using digital vernier calipers with an accuracy of 0.01 mm at 100 replications. The equivalent diameter D_p in mm considering a prolate spheroid shape for a hulled wheat grain, was calculated through the following expression (Mohsenin, 1986, Varnamkhasti et al. 2007):

$$D_p = (L\frac{(W+T)^2}{4})^{1/3} \quad (1)$$

The sphericity (∅) defined as the ratio of the surface area of the sphere having the same volume as that of the grain to the surface area of the grain, was determined through the equation (Mohsenin 1986, Dursun and Dursun 2005):

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (2)$$

Surface area (S) was calculated using equations illustrated below (Al-Mahasneh and Rababah 2007, Varnamkhasti et al. 2007):

$$S = \frac{\pi B L^2}{(2L-B)} \quad (3)$$

$$B = \sqrt{WT} \quad (4)$$

Grain volume (V) was calculated through the following equation (Al-Mahasneh and Rababah 2007):

$$V = \frac{\pi B^2 L^2}{6(2L-B)} \quad (5)$$

The aspect ratio (R_a) was determined through equation below:

$$R_a = \frac{W}{L} \quad (6)$$

Bulk density (ρ_b) was measured using AOAC method, in which a 500 ml cylinder was filled with cereal to 15 cm of height. The excess cereals were removed by sweeping the surface of the cylinder and the grains were not compressed. Bulk density was then calculated as the ratio between the cereals weight and the volume of the cylinder (Sacilik et al. 2003).

True density (ρ_t) was determined using the toluene displacement method. Toluene (C_7H_8) was used in the place of water because it is absorbed by seeds less than water is. The volume of toluene displaced was found by immersing a weighed quantity of cereal in the toluene (Mohsenin 1986, Dursun and Dursun 2005).

The porosity (ε) was calculated by following equation (Mohsenin 1986, Sacilik et al. 2003)

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad (7)$$

For calculating thousand seed weight, thousand seeds were taken from the each sample and the weight of each sample was measured on a precision electronic balance having accuracy of 0.01 g.

The angle of repose (θ) was determined by using a hollow cylindrical mould of 100 mm diameter and 150 mm height. The cylinder was placed on a wooden table, filled with cereals and raised slowly until it forms a cone of seeds. The diameter (d) and height (h) of the cone were recorded (Dursun and Dursun 2005). The angle of repose (θ) was calculated through the following relationship:

$$\theta = \tan^{-1}(\frac{2h}{d}) \quad (8)$$

The terminal velocities (V_t) of hulled wheat were measured using an air column device (Gupta and Das 1997). For each experiment, a sample was dropped into an air stream from the top of the air column. Then airflow rate was gradually increased until the seed became suspended in the air stream. The air velocity which kept the seed in suspension was measured using a pitot tube in conjunction with a micromanometer.

The static coefficient of friction (μ_s) was measured for three structural materials, namely, plywood, stainless steel sheet and concrete. These materials are commonly used for handling and processing grains and construction of storage and drying bins. A plastic cylinder of 100 mm diameter and 50 mm height were placed on an adjustable tilting plate, faced with the test surface and filled with the sample. The cylinder was raised slightly so as not to touch the surface. The structural surface with the cylinder resting on it - was inclined gradually with a screw device until the box just started to slide down. The angle of tilt (α) was read from a graduated scale (Gupta and Das 1997). The coefficient of friction (μ) was calculated through the following relationship:

$$\mu = \tan \alpha \quad \text{....................................(9)}$$

All the experiments were replicated five times, unless stated otherwise, and the average values were reported.

Determination of nutrient contents: About 0.1 g of dried and ground einkorn and emmer kernel was put into a burning cup and 4 ml of pure HNO_3 was added. The sample was incinerated in a Berghof MW-2 Microwave Oven at 150 °C and the solution was diluted with 13 ml pure water. Concentrations of P, K, Ca, Mg, Na, S, Fe, Cu, Zn, Mn and B were determined using an ICP–OES (Perkin Elmer Optima 2100 DV). N concentration was determined according to Kjendahl method.

Results and Discussions

Spikelets; A summary of the physical properties of einkorn and emmer spikelet are illustrated in Table 1. For einkorn and emmer spikelet the average length was 10.88 and 12.36 mm, width 3.33 and 4.97 mm ($P<0.05$), thickness 2.15 and 2.72 mm, equivalent diameter 4.34 and 5.67 mm ($P<0.05$), respectively. The sphericity, surface area, volume and aspect ratio for einkorn and emmer spikelet were calculated as 39 and 45%, 52.22 and 83.91 mm^2, 23.47 and 51.85 mm^3, 0.31 and 0.40, respectively. The bulk and true densities for einkorn and emmer spikelet were determined as 410.64 and 476.79 kg/m^3 ($P<0.05$), 1034.00 and 1003.35 kg/m^3, respectively. The values of porosity for einkorn and emmer spikelet were found to be 60.28 and 52.48%, respectively. For einkorn and emmer spikelet, thousand spikelet weight values were 37.78 and 78.82 g ($P<0.05$), angle of repose values 22.01° and 23.02°, terminal velocity values 4.81 and 5.3 m/s ($P<0.05$), respectively. The values of static coefficient of friction for einkorn and emmer spikelet were determined as 0.507 and 0.413 on plywood, 0.414 and 0.377 on stainless steel and 0.537 and 0.446 on concrete ($P<0.05$), respectively.

Kernels; A summary of the physical properties of einkorn and emmer kernel are listed in Table 2. The average length, width, thickness, equivalent diameter mean values for einkorn and emmer kernel are 6.77, 2.87, 1.88, 3.37 mm and 7.61, 2.64, 2.31, 3.59 mm, respectively. The sphericity, surface area, volume, aspect ratio for einkorn and emmer spikelet were calculated as 49 and 47%, 29.86 and 35.28 mm^2, 11.66 and 14.65 mm^3, 0.43 and 0.35, respectively. The values for bulk and true densities for einkorn and emmer spikelet were found to be 793.02 and 725.00 kg/m^3 ($P<0.05$), 1239.25 and 1248.33 kg/m^3, respectively. Porosity values for einkorn and emmer spikelet were calculated as 36.00 and 41.92% ($P<0.05$), respectively. For einkorn and emmer kernel thousand kernel weights were measured as 30.82 and 37.08 g, angle of repose 22.31 and 24.02°, terminal velocity 5.61 and 5.96 m/s ($P<0.05$), respectively. Static coefficient of friction for einkorn and emmer kernel were determined as 0.419 and 0.442 on plywood, 0.387 and 0.412 on stainless steel, 0.449 and 0.519 on concrete ($P<0.05$), respectively. Some nutritional properties of einkorn and emmer are given in Table 3. As can be seen from Table 3., einkorn kernel has 2.091% N, emmer kernel has 2.236% N. Consequently einkorn and emmer showed high protein content, 13.07 and 13.98%, respectively. In micronutrient, einkorn kernel has 38.34 ppm Zn, emmer kernel has 26.7 ppm Mn in the first rank.

Demirbaş and Dursun (2007), investigated some wheat species' physical properties with image analysis technique. They found averagely 6.66 mm length, 3.09 mm width, 2.68 mm thickness, 3.86 mm geometric mean diameter for bread wheat (10% w.b.) and 7.50 mm length, 3.17 mm width, 3.02 mm thickness, 4.11 mm geometric mean diameter for macaroni wheat (10% w.b.) Tabatabaeefar (2003) studied three varieties of irrigated wheat, and two varieties of dry land wheat. In average, he found 7.08 mm length, 3.27 mm width, 2.98 mm thickness, 4.26 mm geometric mean diameter for 7.4% moisture content. (Al-Mahasneh and Rababah 2007) studied green wheat (frikeh) and they determined 6.23 mm length, 3.64 mm width, 3.38 mm thickness, 4.18 mm geometric mean diameter for 10% moisture content. This study showed that the einkorn and emmer kernels both smaller than common wheat. Al-Mahasneh and Rababah (2007), determined volume values to be 28.89 mm^3 for green wheat. This study showed that the einkorn and emmer kernels' volume values are quite a bit less when compared to green wheat.

Tabatabaeefar (2003), determined 650.3 kg/m^3 bulk density and 1071.8 kg/m^3 true density for wheat and Al-Mahasneh and Rababah, (2007) determined 709.6 kg/m^3 bulk density and 1331.9 kg/m^3 true density for green wheat. This study showed that the einkorn and emmer kernels' bulk density are both greater than common wheat. True density values of hulled wheat are also greater than wheat but lesser than green wheat.

Table 1. Some physical properties of Einkorn and Emmer spikelets

Properties			No. of Obs.	Einkorn spikelet				Emmer spikelet			
				Mean	Max	Min	SD	Mean	Max	Min	SD
Length (mm)	ns	L	100	10.88	12.80	8.72	0.82	12.36	15.10	10.66	0.92
Width (mm)	*	W	100	3.33	3.87	2.78	0.25	4.97	5.94	4.00	0.48
Thickness (mm)	ns	T	100	2.15	2.62	1.34	0.23	2.72	3.36	2.14	0.25
Equivalent diam. (mm)	*	D_p	100	4.34	5.00	3.60	0.27	5.67	6.41	4.95	0.37
Sphericity (%)	ns	∅	100	0.39	0.45	0.31	0.03	0.45	0.52	0.38	0.03
Surface area (mm^2)	ns	S	100	52.22	69.20	36.59	6.29	83.91	105.30	64.84	10.45
Volume (mm^3)	ns	V	100	23.47	36.39	11.77	4.48	51.85	77.94	32.48	10.77
Aspect Ratio	ns	Ra	100	0.31	0.37	0.22	0.03	0.40	0.51	0.30	0.05
Bulk density (kg/m^3)	*	ρ_b	5	410.64	418.38	397.21	8.43	476.79	489.57	467.38	8.41
True density (kg/m^3)	ns	ρ_t	5	1034.00	1055.46	1013.54	16.47	1003.35	1014.67	992.81	8.48
Porosity (%)	*	ε	5	60.28	61.15	59.54	0.68	52.48	52.92	51.75	0.46
1000 spikelets weight (g)	*		5	37.78	40.70	35.80	1.84	78.82	81.80	73.30	3.51
Angle of repose (deg)	ns	θ	5	22.01	23.36	21.27	0.83	23.02	23.92	21.41	1.03
Terminal vel. (m/s)	*	V_t	5	4.81	4.88	4.74	0.06	5.30	5.37	5.22	0.06
Static coef. of friction		μ_s									
plywood	*		5	0.507	0.513	0.500	0.005	0.413	0.423	0.407	0.008
stainless steel	*		5	0.414	0.423	0.407	0.006	0.377	0.383	0.370	0.005
concrete	*		5	0.537	0.543	0.530	0.005	0.446	0.460	0.437	0.009

*: P<0.05, ns: not significant

Table 2. Some physical properties of Einkorn and Emmer kernels

Properties			No. of Obs	Einkorn kernel				Emmer kernel			
				Mean	Max	Min	SD	Mean	Max	Min	SD
Length (mm)	ns	L	100	6.77	7.82	5.50	0.48	7.61	8.68	6.52	0.51
Width (mm)	ns	W	100	2.87	3.34	2.35	0.22	2.64	3.25	2.03	0.27
Thickness (mm)	ns	T	100	1.88	2.79	1.36	0.27	2.31	2.80	1.77	0.23
Equival. diam.(mm)	ns	D_p	100	3.37	3.93	2.90	0.23	3.59	4.16	3.02	0.26
Sphericity (%)	ns	∅	100	0.49	0.55	0.44	0.03	0.47	0.51	0.39	0.03
Surface area (mm^2)	ns	S	100	29.86	40.91	21.73	4.17	35.28	46.26	26.03	4.97
Volume (mm^3)	ns	V	100	11.66	19.23	6.77	2.59	14.65	22.54	8.22	3.29
Aspect Ratio	ns	Ra	100	0.43	0.53	0.36	0.03	0.35	0.41	0.27	0.03
Bulk density (kg/m^3)	*	ρ_b	5	793.02	809.68	769.36	15.62	725.00	736.70	715.43	8.66
True density (kg/m^3)	ns	ρ_t	5	1239.3	1256.4	1218.7	16.6	1248.3	1268.4	1233.1	15.8
Porosity (%)	*	ε	5	36.00	37.17	34.03	1.26	41.92	42.51	41.57	0.36
1000 ker. weight (g)	ns		5	30.82	32.40	29.10	1.38	37.08	39.80	35.10	1.88
Angle of rep. (deg)	ns	θ	5	22.31	22.96	21.87	0.45	24.02	24.57	23.22	0.57
Terminal vel. (m/s)	*	V_t	5	5.61	5.68	5.55	0.05	5.96	6.05	5.85	0.08
Static coef. of friction		μ_s									
plywood	ns		5	0.419	0.427	0.407	0.008	0.442	0.450	0.437	0.005
stainless steel	ns		5	0.387	0.397	0.377	0.008	0.412	0.420	0.403	0.007
concrete	*		5	0.449	0.460	0.437	0.010	0.519	0.533	0.500	0.015

*: P<0.05, ns: not significant

Table 3. Some nutritional content of hulled wheat

		Einkorn	Emmer
P	(%)	0.33	0.25
K	(%)	0.41	0.36
Ca	(%)	0.04	0.026
Mg	(%)	0.097	0.089
Na	(%)	0.0018	0.0021
S	(%)	0.15	0.16
N	(%)	2.091	2.236
Fe	(ppm)	31.6	25.36
Cu	(ppm)	5.42	7.47
Zn	(ppm)	38.34	26.29
Mn	(ppm)	29.88	26.7
B	(ppm)	0.397	0.934
Protein*	(%)	13.07	13.98

*6.25 N

1000 kernel weight (TKW) is a good parameter for evaluation of kernels used as seed material. Tabatabaeefar (2003) found 30.5 g for wheat, Al-Mahasneh and Rababah (2007) determined 32.57 g for green wheat. Brandolini et al. (2007) determined 27.9 g average TKW for eight Turkish origin einkorn kernels and 25 g for sixty-five einkorn accessions. Furthermore they determined 52.7 g TKW for 5 durum wheat species and 32.6 g for 5 bread wheat species. This study showed that the hulled wheat kernels’ TKW is similar to the bread wheat but lighter than durum wheat.

Tabatabaeefar (2003) found that the static coefficient of friction values are 0.384 on plywood, 0.330 on stainless steel for wheat and Al-Mahasneh and Rababah, (2007) determined 0.446 on plywood, 0.241 on stainless steel for green wheat. This study showed that the einkorn and emmer kernels’ static coefficient of friction values both greater than common wheat.

Tabatabaeefar (2003) calculated that the sphericity values are 60.2% for wheat, Al-Mahasneh and Rababah, (2007) determined 68.3% for green wheat and Demirbaş and Dursun (2007) found 58.2% for bread wheat, 54.8% for macaroni wheat (10% w.b.). This study showed that the einkorn and emmer kernels’ sphericity values are quite a bit less than dehulled wheat.

Undesirable materials such as light grains, weed seeds, chaff, plant leaves and stalks can be removed with air flow, when grains, fruits and vegetables are mechanically harvested. In addition, agricultural materials are routinely conveyed using air stream in pneumatic conveyers (Khoshtaghaza and Mehdizadeh 2006). The terminal velocity of the Olympic wheat kernel was measured from 7.5 to 8.5 m/s by the wind tunnel floating technique (Shellard and Macmillan 1978). Bilanski and Lal (1965) measured terminal velocities of wheat kernel and straw by a vertical wind tunnel. They found that the terminal velocity of the wheat kernel was between 8.8 and 9.2 m/s. Khoshtaghaza and Mehdizadeh (2006) determined terminal velocity values 7.38 m/s for Canadian wheat. It is normal that einkorn and emmer kernels’ terminal velocity are lesser than common wheat due to their kernels size are smaller common wheat.

Castagna et al. (1996) determined the flour yield and the percentage of fine particles of all einkorn lines were similar to the bread wheat standard. The protein content ranged from 13.2 to 22.8% and was higher on average than in bread wheats (10.8-13.3%). Brandolini et al. (2007) determined 17% protein content for eight Turkish origin einkorn kernels and 18.2% for sixty-five einkorn accessions. Furthermore they determined 15.2% for 5 durum wheat species and 14.8% for 5 bread wheat species. The high protein content of einkorn seeds is compatible with the values observed in different environments by Vallega (1992), Løje et al. (2003) and is slightly lesser than those reported by Borghi et al. (1996), Abdel-Aal and Hucl (2002). Blanco et al. (1990) found in 50 emmer accessions a protein content ranging from 8.7 to 18%. Perrino et al. (1993) found high mean values of 17.1% in 50 emmer accessions.

Conclusions

As a result of this study, the following conclusions are drawn into physical properties:

1) Hulled wheat species kernels are smaller than common wheat. Especially thickness values cause this result, volumes and sphericity values are affected negatively from this case.

2) Hulled wheat species are denser than common wheat. It is an indicator to quality.

3) 1000 kernel weight of hulled wheat is similar to the bread wheat but lighter than durum wheat.

4) Static coefficient of friction values of hulled wheat are greater than common wheat.

5) The emmer kernels are greater and heavier than the einkorn kernels.

It is recommended that other properties such as mechanical, thermal, and rheological, be investigated for new productions and high nutrient content and organic agriculture potential of these crops must be surely appreciated.

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Notation

L	length of cereal, mm	R_a	aspect ratio
W	width of cereal, mm	ρ_b	bulk density, kg/m^3
T	thickness of cereal, mm	ρ_t	true density, kg/m^3
D_p	equivalent diameter, mm	ε	porosity, %
$\varnothing$	sphericity, %	θ	angle of repose, degree
S	surface area of cereal, mm^2	V_t	terminal velocity, m/s^1
V	volume of cereal, mm^3	μ_s	static coefficient of friction

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