STATISTICAL EVALUATION OF PHYSICAL PROPERTIES OF COOKED WHEAT FOR PREDICTING BULGUR YIELD

BULGUR VERİMİNİ TAHMİN ETMEK AMACIYLA PİŞMİŞ BUĞDAYIN FİZİKSEL ÖZELLİKLERİNİN İSTATİSTİKSEL OLARAK DEĞERLENDİRİLMESİ

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ABSTRACT: Grains of 26 Turkish wheat cultivars and advanced breeding lines (20 of durum and 6 of bread wheat) were used in this study. Simple correlations between bulgur yield and certain physical properties of cooked wheat were determined. Significant correlations between bulgur yield and the sum of the grain over 2.8+2.5 mm sieves were obtained for both cooked durum and bread wheat samples ($p<0.01$). Multiple regression analyses showed that the model involving two variables (the grain over 2.8 mm sieve and the legth of the grain for cooked durum wheat samples) resulted in the highest R value.

ÖZET: Bu çalışmada 26 Türk buğday çeşidi ve ileri ıslah hatlarından (20 durum ve 6 ekmeklik buğday) örneklerle çalışılmıştır. Bulgur verimi ile pişmiş buğdaya ilişkin bazı fiziksel özellikler arasındaki basit korelasyonlar belirlenmiştir. Pişmiş durum ve ekmeklik buğday için bulgur verimi ile 2.8+2.5 mm elek üstü toplamı arasınnda önemli korelasyonlar elde edilmiştir. ($p<0.01$). Çoklu regresyon analizleri, iki değişkeni içeren (pişmiş durum buğday örnekleri için 2.8 mm elek üstü ve tane uzunluğu) modelin en yüksek R değerini verdiğini göstermiştir.

GİRİŞ

Bulgur is a parboiled, dry and partially debranned whole wheat product. In Turkey and Near Eastern countries it has been a staple food for centuries. In the literature, much useful information on the bulgur composition (SARAÇOĞLU, 1953; SHAMMAS and ADOLPH, 1954; ADOLPH *et al.* 1955; SABRY and TANNOUS, 1961) and effects of raw materials and processing techniques (FERREL and PENCE, 1962; SMITH *et al.* 1964; SHEPHERD *et al.* 1965; FERREL *et al.* 1966a; FERREL *et al.* 1966b; FISHER, 1972; ELGÜN *et al.* 1990; ÖZBOY ve KÖKSEL, 1998; KÖKSEL *et al.* 1999) on bulgur properties have been accumulated. Bulgur production involves time-consuming processing by a series of steps of soaking, cooking, drying, cracking and sieving. Hence, a laboratory method for testing bulgur yield would be too laborious to test the suitability of a large number of raw materials for bulgur quality and yield. Simple methods using small sample size with reasonable accuracy and reproducibility, capable of distinguishing wheats in terms of quality and yield are required by the bulgur manufactures during the grain receipt. Thus, the main objective of this study was to statistically evaluate the physical properties of cooked wheat for predicting bulgur yield of durum and bread wheat samples.

MATERIALS AND METHODS

Materials

Grains of 26 Turkish wheat cultivars and advanced breeding lines (20 of durum and 6 of bread wheat) were used in this study.

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Analytical Methods

The hectoliter weights of the cooked wheat (whole) samples were determined using an Ohaus test weight apparatus and reported on an as is moisture basis. The thousand-kernel weight was determined by counting the number of kernels in 20 g of cooked wheat sample and reported on a dry basis. All of the tests on the cooked wheat samples were performed at least in triplicate. Two sizes (2.5 mm and 2.8 mm) of sieves were used and the percentage of cooked wheat that would not pass endwise through each sieve was determined. Values of length (L; mm), thickness (T; mm) and width (W; mm) of cooked wheat samples were determined by using calipers. These values were given as the average of six replications. Samples were ground using a coffee grinder for protein and ash content analyses. Moisture, ash and protein contents of the samples were determined using AACC Approved Methods (ANONYMOUS, 1995). The data were analyzed using the SPSS for Windows, Release 5.0.1. (SPSS, Inc., Chicago, IL).

Bulgur-Making Process

The wheat (1 kg) was soaked to raise the moisture content to about 45% by adding water (1.3 L) and kept in water bath at 60°C for 3 hr. The soaked grain was cooked in an autoclave (Funke Gerber, Webeco, Germany) under a steam pressure of 20 p.s.i., at 121°C for 15 min, which was sufficient to gelatinize the starch completely. After cooling for 10 min, cooked product was dried at 60± 2 °C to a moisture content of 10-12 %. Dried product was conditioned with 2% additional water for half an hour. The loose outer bran was removed by hand rubbing and beating in a plastic mortar. The debranned product was used in the whole form and called as cooked wheat for the physical quality determinations. The debranned product was also cracked by using Falling Number Laboratory Mill Type-KT 30 (adjusted to produce the coarsest particle size), aspirated to remove residual bran material and sifted through a 0.5 mm sieve to remove the fine particles for the bulgur yield determination.

RESULTS AND DISCUSSION

Cooked Wheat Characteristics

Minimum, maximum and average values for cooked grains of 26 Turkish wheat cultivars and advanced breeding lines (20 of durum and 6 of bread wheat) for eleven technological criteria (physical and chemical properties) are studied and presented in Tables 1 and 2. In general, most of the variables investigated showed large variations. All of the cooked bread wheat samples had lower protein contents than those of the cooked durum wheat samples. The average ash contents of the cooked wheat samples from both durum and bread wheats were found to be the same.

The average hectoliter and thousand kernel weights of the cooked wheats from durum wheat samples were higher than those of the cooked bread wheat samples. Two different sieves, 2.8 mm, 2.5 mm and

Table 1. Statistical Data For The Cooked DurumWheat Samples

Parameters	Mean± S.D.	Min.	Max.
Chemical properties			
Protein (%) (Nx5.7)[a]	14.0±1.28	11.5	16.6
Ash (%)[a]	1.58±1.32	1.17	2.11
Physical properties			
Hectoliter weight (kg/hl)	68.3±3.0	64.6	74.4
Thousand kernel weight (g)[a]	32.3±5.69	21.8	45.1
Sum of the grain over 2.8+2.5 mm sieves (%)	96.6±4.89	84.0	99.1
The grain over 2.8 mm sieve (%)	64.5±13.05	45.8	86.2
The grain over 2.5 mm sieve (%)	26.1±8.83	12.7	42.7
Length (L; mm)	6.8±0.58	5.8	8.0
Thickness (T; mm)	2.8±0.10	2.6	3.1
Width (W; mm)	3.3±0.23	2.9	3.8
Bulgur Yield (%)	91.1± 2.35	87.0	96.0

a : Dry basis

also the sum of the grain over 2.8 mm plus 2.5 mm sieves were used to determine the kernel size distribution of cooked wheat samples. For the cooked durum wheat samples, the sum of the grain over 2.8 plus 2.5 mm sieves and the grain over 2.8 mm sieve were found to be higher that those for the cooked bread wheat samples. Kernel size was determined by using three different dimensions (i.e.; length, width and thickness of the cooked wheat samples). The length values of the cooked wheats from durum samples were higher than those for the cooked bread wheat samples. For the durum wheat samples, the bulgur yield values found to be higher than those for the bread wheat samples.

Table 2. Statistical Data For Cooked Bread Wheat Samples

Parameters	Mean± S.D.	Min.	Max.
Chemical properties			
Protein (%) (Nx5.7)[a]	12.6±1.23	11.3	14.5
Ash (%)[a]	1.58±1.30	1.19	1.89
Physical properties			
Hectoliter weight (kg/hl)	67.8±2.5	63.7	70.4
Thousand kernel weight (g)[a]	27.7±5.16	19.7	35.2
Sum of the grain over 2.8+2.5 mm sieves (%)	88.1±8.71	72.6	96.2
The grain over 2.8 mm sieve (%)	54.5±17.12	34.7	80.6
The grain over 2.5 mm sieve (%)	33.6±10.73	15.2	45.7
Length (L; mm)	6.0±0.26	5.6	6.3
Thickness (T; mm)	2.8±0.10	2.6	2.9
Width (W; mm)	3.5±0.20	3.2	3.8
Bulgur Yield (%)	88.3±2.77	84.5	91.0

a : Dry basis

During the transition from wheat to bulgur there were no differences found in the protein and the ash contents of the durum and bread wheats. As a consequence of cooking, there was a decrease for each of the values of hectoliter weight, thousand-kernel weight, the grain over 2.5 mm sieve, the length of grain; while an increase was observed for the values of the sum of grain over 2.8+2.5 mm sieves, the grain over 2.8 mm sieve and the width of grain in both durum and bread wheat samples. Thickness of the grain found to be the least affected physical value during the transition from wheat to bulgur (data not presented).

Correlation between bulgur yield and certain physical properties

Simple correlation coefficients between bulgur yield and physical quality parameters of cooked wheat samples were determined. The correlation coefficients for each data set are presented for the durum and bread wheat samples in Tables 3 and 4, respectively. As expected, there were high correlation coefficients between bulgur yield and the grain over 2.8 mm sieve, the sum of the grain over 2.8+2.5 mm sieves and the length of the cooked wheat samples significant at the 1% level and also significant at the 5% level for the thousand-kernel weight, the grain over 2.5 mm sieve and the thickness of the cooked whole durum wheat samples (Table 3).

Table 3. Simple Correlation Coefficients[a] Between Bulgur Yield and Physical Parameters of Cooked Durum Wheat

	L	W	T	SC	SB	SA	TKW	HLW
Bulgur Yield (BY)	0.636**	0.215	0.506*	0.632**	0.614**	-0.557*	0.478*	-0.019
Hectoliter Weigth (HLW)	-0.062	0.519*	0.429	-0.072	-0.186	0.235	0.356	1.00
1,000-Kernel Weigth (TKW)	0.520*	0.707**	0.345	0.703**	0.557*	-0.434	1.00	
The Grain Over 2.5 mm Sieve (SA)	-0.390	-0.339	-0.190	-0.791**	-0.973**	1.00		
The Grain Over 2.8 mm Sieve (SB)	0.472*	0.440	0.225	0.910**	1.00			
The Sum of the Grain Over 2.8+2.5 mm Sieve (SC)	0.557*	0.561*	0.255	1.00				
Thickness of the Cooked Wheat (T)	0.465*	0.426	1.00					
Width of the Cooked Wheat (W)	0.230	1.00						
Length of the Cooked Wheat (L)	1.00							

a *= Significant at the 5.0% level of confidence; **= Significant at the 1.0% level of confidence.

However, for the bread wheat samples, only the correlation coefficient between bulgur yield and the sum of the grain over 2.8+2.5 mm sieves was found to be significant at the 1% level (Table 4). These correlations do not indicate a single determining factor. We may assume that the main determining factors for bulgur yield are each of thousand kernel weight, the sum of the grain over 2.8 mm sieve and the length of grain for both durum and bread wheat samples. Highly significant correlation coefficients were also found between various physical quality parameters in both the cooked durum and bread wheat samples.

Table 4. Simple Correlation Coefficients[a] Between Bulgur Yield and Physical Parameters of Cooked Bread Wheat

	L	W	T	SC	SB	SA	TKW	HLW
Bulgur Yield (BY)	0.486	0.663	0.734	0.891**	0.785	-0.545	0.145	0.025
Hectoliter Weigth (HLW)	-0.125	-0.122	-0.049	0.008	-0.228	0.370	0.271	1.00
1,000-Kernel Weigth (TKW)	0.785	-0.594	-0.090	-0.100	-0.405	0.565	1.00	
The Grain Over 2.5 mm Sieve (SA)	-0.025	-0.741	-0.846*	-0.545	-0.905*	1.00		
The Grain Over 2.8 mm Sieve (SB)	0.090	0.901*	0.830*	0.851*	1.00			
The Sum of the Grain Over 2.8+2.5 mm Sieve (SC)	0.146	0.858*	0.589	1.00				
Thickness of the Cooked Wheat (T)	0.428	0.538	1.00					
Width of the Cooked Wheat (W)	-0.274	1.00						
Length of the Cooked Wheat (L)	1.00							

a *= Significant at the 5.0% level of confidence; **= Significant at the 1.0% level of confidence.

Simple and multiple regression analyses were used to find equations that best predict the relationship between various quality parameters of cooked wheat samples and bulgur yield. Significant correlation coefficients for durum wheat samples were found between bulgur yield and each of the thousand kernel weight, the thickness (T) and length (L) of the cooked wheats, the grain over 2.5 mm sieve, the grain over 2.8 mm sieve and the sum of the grain over 2.8+2.5 mm sieves. These equations are presented in Table 5. The regression equations were derived by using the "Enter" procedure from the SPSS for Windows, Release 5.0.1.

Multiple regressions were also constructed in which bulgur yield was expressed as a function of various parameters for durum wheat samples. Some of these regression equations are also presented in Table 5. The evaluation of regression equations shows that the model involving two variables; the grain over 2.8 mm sieve and the length of the grain for durum wheat samples resulted in highest R value. The 53% of the total variation for the cooked durum wheat samples in bulgur yield could be accounted for by a linear function of these two variables (R2= 0.53). For the bread wheat samples, there was a high positive correlation between bulgur yield and the

Table 5. Regression Equations of Bulgur Yield as a Function of Physical Parameters

Regression formula	R
Durum wheat samples	
BY=0.19 TKW + 84.71	0.478
BY= 11.46 T + 58.61	0.506
BY= -0.15 SA+ 94.78	0.557
BY= 0.11 SB+ 83.75	0.614
BY= 0.30 SC+ 63.34	0.632
BY= 2.55 L+ 73.72	0.636
BY=0.08 TKW + 2.13 L+ 73.92	0.659
BY=-0.09 SA+ 1.98 L+ 80.07	0.719
BY=0.19 SC+ 1.65 L+ 62.18	0.719
BY=0.07 SB + 1.78 L+ 74.15	0.729
Bread wheat samples	
BY= 0.28 SC + 63.27	0.891

BY : Bulgur yield
TKW : Thousand kernel weight
SA : The grain over 2.5 mm sieve
SB : The grain over 2.8 mm sieve
SC : The sum of the grain over 2.8+2.5 mm sieves
T : Thickness of the grain
L : Length of the grain

sum of the grain over 2.8+2.5 mm sieves. The 79% of the total variation for the cooked bread wheat samples in bulgur yield could be accounted for by a linear function of this variable (R2=0.79). The introduction of more independent variables into the regression equations did not improve the models to a significant extent in the case of both the durum and the bread wheat samples. This study showed that there is a good relationship between physical properties of cooked wheat samples and bulgur yield. According to the literature (IRVINE, 1971), the larger the kernel size, the greater should be the ratio of endosperm to bran and therefore large kernels are expected to give higher yields of bulgur.

CONCLUSIONS

To the best of our knowledge there is no research carried out investigating the relationship between bulgur yield and the physical properties of cooked wheat. In this study, highly significant correlations between the bulgur yield and the various physical properties of cooked wheats were obtained. For the cooked durum wheat samples, the model involving the two variables (the grain over 2.8 mm sieve and the length of the grain) resulted in the highest R value. For the bread wheat samples, there was a high positive correlation between bulgur yield and the sum of the grain over 2.8+2.5 mm sieves. It can be concluded from the present study that physical properties of wheat, in general, are the useful indices of bulgur yield and they can be used for the selection of suitable raw material for bulgur production.

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