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THE SEPARATION OF GRAIN BY PROJECTION. II. SYSTEMATIC DIFFERENCES IN PHYSICAL PROPERTIES AND COMPOSITION OF WHEAT FRACTIONS[1]

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ABSTRACT

Analyses for test weight, 500-kernel weight, protein content, ash content, and hardness characteristics of fractions of 15 samples of hard red winter wheat, obtained by spectrometric separation, revealed high negative correlations in most cases between plumpness factors and protein and ash contents, and high positive correlations between plumpness factors and hardness, when the latter is determined with a single-stage instrument. The projection technic appears to provide a means for analyzing commercially mixed wheat for certain qualities of its components and it may be applied practically to separate either high protein fractions or high test weight fractions from ordinary commercial grain.

A preceding paper (3) has described a grain spectrometer capable of separating wheat into numerous fractions differing progressively in test weight. This development prompted a more detailed analysis of the test weight, 500-kernel weight, protein content, ash content, and hardness characteristics of fractions obtained from 15 samples of hard red winter wheat.

Materials and Methods

The 15 samples of hard red winter wheat investigated in this study consisted of pure varieties and commercial grain grown in Kansas, Oklahoma, and Texas in the crop years 1952 and 1953. Description of these samples is given in Table I which includes their origin and test weight. Quantities of 60 lb. of each sample were processed by projection in the grain spectrometer into as many as 16 fractions. The fractions at the extreme ends of the series of receiving hoppers (see Fig. 1 of preceding paper), consisting of less than 100 g. of grain, were discarded. This produced from 12 to 14 fractions of each sample which were subjected to other tests.

Test weight was determined by means of the Boerner weight-per-bushel apparatus. A vacuum counter was used to count out 500 kernels and these were weighed to the nearest 0.01 g. Moisture, protein, and ash contents of the samples were determined as outlined in Cereal

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TABLE I

LIST OF SAMPLES OF HARD RED WINTER WHEAT

Sample	Variety or Kind	Origin	Crop Year	Test Weight
				lb.
A	Commercial sample	Kansas	1952	61.6
E	Unnamed selection	Denton, Texas	1953	62.9
F	Unnamed selection	Denton, Texas	1953	61.5
H	Hd. Federation-Hybrid	Stillwater, Okla.	1953	53.5
I	Blackhull-Hd. Federation	Stillwater, Okla.	1953	54.7
J	Comanche	Stillwater, Okla.	1953	53.0
K	Unnamed selection	Manhattan, Kansas	1953	57.0
L	Cheyenne	Manhattan, Kansas	1953	57.5
M	Unnamed selection	Manhattan, Kansas	1953	56.5
N	Comanche	Manhattan, Kansas	1953	55.5
O	Ponca	Manhattan, Kansas	1953	57.1
P	Commercial sample	Abilene, Kansas	1953	55.3
Q	Commercial sample	Abilene, Kansas	1953	56.6
R	Commercial sample	Abilene, Kansas	1953	57.2
S	Commercial sample	Abilene, Kansas	1953	62.0

Laboratory Methods (2). Tests for hardness were made with the single-stage Brabender hardness tester using 200-g. samples. The curves traced on the farinograph paper were measured for maximum height, and for area by means of a planimeter.

Results and Discussion

Results typical of those obtained with the 15 samples are shown in Table II – data for sample H listed in Table I. The hopper re-

TABLE II

PHYSICAL AND CHEMICAL PROPERTIES OF FRACTIONS OF A SAMPLE OF HARD RED WINTER WHEAT

Hopper No.	Fraction of Original Sample by Weight	Test Weight	500-Kernel Weight	Protein [a]	Ash [a]	Hardness Data	
						Height	Area
	%	*lb.*	*g.*	%	%	*B.U.*	*cm.*^{2}
. .	. . [b]	53.5	8.3	17.0	2.08	380	15.5
1	0.5	. . . [c]	5.2	18.9	2.26	. . . [c]	. . . [c]
2	0.9	46.0	5.2	17.1	2.26	. . . [c]	. . . [c]
3	1.6	48.0	5.4	18.5	2.27	300	13.9
4	2.7	49.0	6.4	18.8	2.28	330	14.4
5	5.0	51.0	6.3	18.5	2.25	330	13.9
6	7.4	51.8	6.8	18.3	2.19	345	14.9
7	11.3	52.7	7.3	17.8	2.16	340	14.1
8	16.4	53.5	8.1	17.5	2.14	360	14.4
9	17.0	54.2	8.5	17.3	2.13	370	15.0
10	16.5	55.1	9.1	16.6	2.10	370	15.1
11	12.4	56.1	9.7	16.0	2.09	385	15.0
12	6.3	57.3	10.4	15.2	2.01	410	16.2
13	1.8	58.0	11.3	14.4	1.97	410	15.6

[a] 14% Moisture basis.
[b] Original sample.
[c] Quantity too small for determination.

ceiving the largest fraction of the sample was No. 9. Considering the data for all of the 15 samples it was observed that this largest fraction could appear in any one of the hoppers numbered 9, 10, 11, or 12. There was a tendency for kernels of low test weight to fall into lower hopper numbers (closer to the point of projection) than did those of higher test weight. The fact that the modal hopper was in all cases beyond the midpoint of the 16 hoppers indicates that either a greater proportion of all the samples had mass characteristics which produced this peculiar distribution, or alternatively that the mechanical characteristics of the spectrometer were responsible for the skewed nature of the distribution. In any event the shape of the distribution curve was surprisingly uniform from sample to sample.

A common characteristic of all samples fractionated was the systematic increase in test weight and 500-kernel weight. Taking the data of Table II as typical, the fractions varied in test weight from 46 to 58 lb., a range equivalent to 22% of the test weight of the original samples. The 500-kernel weight invariably showed a greater range percentagewise, in this case from 5.2 to 11.3 g., which is 73.5% of the original 500-kernel weight.

When plotted against hopper number the 500-kernel weights gave a more nearly linear relation than did test weights. Statistical analysis of both test weight and 500-kernel weights in relation to hopper number indicated that the variation about the linear relationship was less than 5% of the variation in test weight or kernel weight. This implies that for any given wheat whose test weight is known, the test weight of the grain falling into any hopper is predictable with a high degree of accuracy. Values for the 500-kernel weights of fractions can be predicted similarly, with precision equal to or higher than that of the test weight.

The differences in average test weight from one hopper to the next for samples H, J, P, and Q were greater than 1 lb., whereas those for varieties E, K, L, M, N, and O were less than 0.5 lb. Hence, the regression coefficient (the slope of the line relating plumpness to hopper number) is a function of the grain rather than of the machine operation.

The data for protein content are of special interest, since as indicated in Table II this sample, which contained 17.0% protein, could be fractionated into subsamples with a protein content range of 18.9 to 14.4%. It can be calculated from the data of Table II that in one pass through the spectrometer, 64% of the original sample (fractions 1 to 8 inclusive) could be recovered containing 18% protein, which is fully 1% more than that of the original grain. A number of the samples showed a similar wide range of protein in their fractions, but several showed a considerably narrower protein range.

The data for ash also are of interest, particularly from the milling viewpoint, since they indicate that within any sample the ash content, like the protein, decreases with increasing plumpness in terms of test weight, or 500-kernel weight, but to a lesser degree than does the protein content.

The height of the hardness curve as well as its area tends to increase with plumpness rather than with protein content. This is contrary to the usual assumption that protein content and hardness are directly related. These data, as will be indicated in the discussion which follows, suggest that kernel size is the major factor which determines the height and area of the hardness curves when the single-stage tester is used. The relationships apparent by inspection of Table II are indicated more quantitatively for all 15 of the samples, by means of correlation coefficients for various factors, in Table III. For purposes of interpretation, correlation values of less than 0.5 may be considered to indicate little relationship between the variables, values of 0.5 to 0.8 a moderate relationship, and values higher than 0.8 a very strong relationship.[4] The data of Table III show that different samples of hard red winter wheat vary considerably in intensity of correlation when only one set of factors is considered. Thus, for example, the protein-to-test-weight correlation varied from —0.572 to —0.975 among the 15 samples.

All the samples showed uniformly high correlations between test weight and 500-kernel weight, test weight and height of hardness curve, and 500-kernel weight and height of hardness curve. The correlations between test weight and protein content were higher than 0.8 for eight of 15 samples and higher than 0.6 for all but two of the samples, indicating that in most wheat samples of this type, a strong inverse relationship may be expected between protein content and plumpness. Essentially the same conclusion can be drawn for the relationships between plumpness and ash content. The correlations between protein and ash content were somewhat lower, although 10 of the 14 samples showed correlations between these factors of 0.6 or higher. The relations between protein content and height and area of hardness curve were rather variable from sample to sample, although in eight of 14 samples correlation values for protein and height were 0.8 or higher. High correlations between protein and curve height

[4] A sample correlation coefficient which exceeds the value 0.553 for these data could occur by chance only five times in 100 if the two measurements were completely unrelated, and only once in 100 times if the calculated value exceeds 0.684.

TABLE III

CORRELATION COEFFICIENTS FOR PHYSICAL AND CHEMICAL CHARACTERISTICS OF FRACTIONS OF 15 HARD RED WINTER WHEATS[a]

	SAMPLE														
	A	E	F	H	I	J	K	L	M	N	O	P	Q	R	S
TW-500K	0.93	0.99	0.97	0.97	0.98	0.98	0.98	0.99	0.97	0.98	0.97	0.98	0.97	0.97	0.97
TW-Pro	–0.57	–0.59	–0.70	–0.77	–0.90	–0.87	–0.63	–0.80	–0.90	–0.10	–0.81	–0.97	–0.98	–0.94	–0.98
TW-Ash	–0.06	0.25	–0.66	–0.95	–0.95	–0.91	–0.20	–0.97	–0.51	–0.31	–0.60	–0.77	–0.96	–0.91	–0.73
TW-Ht	0.93	0.89	0.88	0.97	0.97	0.99	0.89	0.81	0.73	0.88	0.88	0.97	0.91	0.93	0.94
TW-Area	0.64	0.22	0.56	0.83	0.95	0.45	0.22	0.89	–0.17	–0.33	0.13	0.87	–0.00	0.83	0.67
500K-Pro	–0.71	–0.61	–0.79	–0.87	–0.96	–0.94	–0.60	–0.86	–0.91	–0.23	–0.91	–0.99	–0.96	–0.99	–0.98
500K-Ash	–0.03	0.29	–0.62	–0.97	–0.95	–0.97	–0.23	–0.94	–0.49	–0.24	–0.69	–0.72	–0.92	–0.89	–0.63
500K-Ht	0.93	0.91	0.93	0.98	0.95	0.99	0.89	0.79	0.78	0.90	0.81	0.98	0.97	0.90	0.97
500K-Area	0.60	0.24	0.55	0.86	0.94	0.51	0.31	0.86	–0.09	–0.33	–0.04	0.89	0.19	0.77	0.80
Pro-Ash	0.04	–0.73	0.34	0.91	0.91	0.96	–0.33	0.74	0.36	0.00	0.78	0.73	0.94	0.89	0.66
Pro-Ht	–0.09	–0.51	–0.82	–0.94	–0.94	–0.93	–0.45	–0.54	0.57	–0.68	–0.60	–0.99	–0.92	–0.90	–0.93
Pro-Area	–0.06	0.27	–0.66	–0.84	–0.95	–0.57	–0.03	–0.67	0.25	–0.04	0.21	–0.89	–0.10	–0.73	–0.69
Ash-Ht	–0.07	0.14	–0.64	–0.96	–0.96	–0.94	–0.30	–0.78	–0.60	0.14	–0.59	–0.86	–0.86	–0.70	–0.61
Ash-Area	–0.05	–0.19	–0.54	–0.86	–0.97	–0.53	0.10	–0.88	–0.52	0.41	0.08	–0.86	–0.05	–0.72	–0.21

[a] Abbreviations used in table headings are as follows: TW, test weight in pounds per bushel; 500K, weight in g. of 500 kernels; pro, protein content in %, 14% moisture basis; Ash, ash content in %, 14% moisture basis; Ht, maximum height of hardness curve in Brabender units; Area, Area of hardness curve in $cm.^2$.

were found more frequently than were high correlations between protein and curve areas.

The finding of a strong inverse relationship between kernel plumpness and protein and ash content when individual samples are fractionated is in marked contrast to the virtually complete lack of correlation of these variables among different individual samples of wheat of the same class noted by Bailey and Hendel (1) as well as by Mangels and Sanderson (4). In view of the wide variation in physical and chemical properties of individual kernels within any single sample of wheat, as demonstrated in this study, the lack of correlation found by earlier workers between these factors, when *different* unfractionated samples are considered, is understandable.

The fact that the single-stage Brabender hardness tester indicated kernel plumpness to be a major factor affecting apparent hardness suggests that a study of this kind should be repeated with the two-stage tester. With this machine, all samples are ground to a uniform coarse meal prior to hardness testing.

The most significant practical implication of this study is that even grain grown on test plots is a heterogeneous mixture as regards physical properties and composition of individual kernels. The technic described makes it possible to separate commercial wheat into fractions of various protein contents, either greater or less than the protein content of the original sample. During a crop year when wheat of desirable protein content is scarce, the advantage of performing such a separation is obvious. In such a crop year kernel plumpness is usually greater than normal, and it may therefore be expected that fractions containing higher protein levels would have satisfactory plumpness characteristics. Commercial wheat which has been discounted because of low test weight can be processed also to segregate significant amounts of high test weight material, thus considerably enhancing the commercial value of a high percentage of the total.

For many years millers have sought means to separate wheat into so-called thin and plump fractions with the idea that these fractions should be processed separately in the initial or break phase of milling operations. By this means it was hoped that greater production efficiency could be attained. It would appear that the projection technic provides a practical means to accomplish this purpose. The technic might also be useful to millers for analyzing commercially mixed grain before purchase to determine the quality characteristics of the components of the mixture.

From an agronomic point of view it would seem of interest to determine the reason for the wide range of differences in wheat characteristics, as indicated in the correlations of Table III in relation to varietal, environmental, and soil factors.

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