Particle Size and Particle Size Distribution of Wheat Samples Prepared with Different Grinders[1]

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ABSTRACT

Using customary equipment and methods, wheat samples were ground in several European and North American laboratories for sedimentation and falling number analysis. Samples were investigated for variation in modulus of fineness, modulus of uniformity, number of particles per unit weight, and total surface area. Laser illumination was used to measure the small particle fractions. All grinding procedures reduced most of each sample to the fine particle size range. Control of particle size distribution, for sample preparation, could be a means of achieving improved agreement among laboratories for analysis in which particle size can affect the results.

Preparation of grain samples for analysis is a commonly discussed topic, and recommended procedures have been published in several languages. Because agreement among laboratories can be influenced by sample preparation, sampling procedures are important nationally and internationally. Therefore some degree of standardization is desirable. Throughout the world, sample preparation, especially grinding and sieving, is performed with a variety of equipment, and developing a standard method is difficult. The results of several tests used regularly to characterize wheat are reported to be modified significantly by particle size differences. Examples of tests that may have modified results are falling number, sedimentation, agtron color, and near infrared spectroscopy applications. Consequently, the International Association for Cereal Chemistry established a study group to investigate the grinding and sieving equipment and procedures used in cereal laboratories in several countries.

The study was not designed to compare grinding and sieving equipment or analytical accuracy based on sample preparation. The purpose was to obtain information regarding normal variation in particle size of wheat samples prepared for analyses by routine procedures in laboratories in several countries.

[1] Report based on data obtained from International Association for Cereal Chemistry Study Group 28, Grinding and Sieving.

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MATERIALS AND METHODS

Collaborators in laboratories in 12 countries agreed to receive three wheat samples to be routinely ground and sieved for falling number and sedimentation tests (AACC 1969, IACC) Collaborators were asked to return 250 g of ground wheat from each of the three samples to the committee chairman to permit particle size analyses of all samples under identical conditions. Collaborators were to provide the names of the grinder and sifter equipment used. Because of difficulties with international shipping and encounters with various custom systems, results were not obtained from all collaborators. Also some who agreed to participate do not regularly use either the falling number or the sedimentation test. The information is therefore less than was originally anticipated. However, sufficient information was obtained to provide insight into grinding and sieving procedures in common use in several countries and into the extent of particle size variations.

The collaborators reported using the following grinders: Brabender Quadrumat, Braun Grinder, Glen Creston, Kamas-Slago, Labconco, Miag, Sidimat, Tag Heppenstall, and Udy. Methods of particle-size reduction among the grinders included attrition, rolls, and hammer action.

Three types of sifters were used: Simon, Rotap, and Miag. This diversity of equipment used for sample preparation is disconcerting when standardization is sought. However, different equipment need not necessarily result in significant particle size differences.

RESULTS AND DISCUSSION

Using procedures recommended by the American Society of Agricultural Engineers (1971) for determining the moduli of particle size and of particle size uniformity, the ground wheat samples returned by the collaborators were tested. The method of expressing results was based on the percentage of the sample remaining on each of seven sieves and the pan of a Ro-Tap shaker. Screen numbers and sizes were: 3/8 in. (9,510 μ), No. 4 (4,760 μ), No. 8 (2,380 μ), No. 16 (1,190 μ), No. 30 (595 μ), No. 100 (149 μ), and pan. Table I shows results for the falling-number test samples and Table II for the sedimentation test samples.

The modulus of uniformity is expressed by three figures, representing coarse, medium, and fine particles. The modulus of

TABLE I
Influence of Grinding and Sieving Methods on Sample Particle Size as Prepared for Falling-Number Tests

Sample	Collaborator	Modulus of Uniformity[a] C	M	F	Modulus of Fineness	Particle-Size Diameter (μm)	Standard Deviation
1	1	0	1	9	1.67	225	2.16
	2	0	0	10	0.65	176	2.30
	3	0	1	9	1.28	230	2.13
	4	0	0	10	0.59	211	1.59
	5	0	0	10	0.62	191	1.72
	6	0	3	7	1.68	253	2.23
	7	0	0	10	0.87	200	2.30
	8	0	0	10	0.47	179	2.19
	9	0	0	10	1.72	277	1.52
	10	0	0	10	0.90	188	2.16
	11	0	0	10	1.33	222	2.31
	12	0	0	10	0.47	203	1.60
	13	0	0	10	0.98	211	1.98
	14	0	4	6	1.70	155	2.15
2	1	0	1	9	1.65	220	2.20
	2	0	0	10	0.80	146	2.28
	3	0	1	9	1.08	234	2.32
	4	0	0	10	0.55	144	2.10
	5	0	0	10	0.41	166	2.01
	6	0	3	7	1.71	253	2.15
	7	0	0	10	0.68	193	1.97
	8	0	0	10	0.56	199	2.02
	9	0	3	7	1.82	278	1.57
	10	0	0	10	0.90	198	1.87
	11	0	0	10	1.26	211	2.06
	12	0	0	10	0.46	164	1.93
	13	0	0	10	0.92	213	2.31
	14	0	4	6	1.92	155	2.15
3	1	0	1	9	1.22	213	2.15
	2	0	0	10	0.77	155	2.40
	3	0	1	9	1.14	229	2.27
	4	0	0	10	0.69	150	2.02
	5	0	0	10	0.83	169	1.89
	6	0	3	7	1.74	246	2.28
	7	0	0	10	0.83	200	1.88
	8	0	0	10	0.54	175	1.91
	9	0	4	6	1.88	191	1.89
	10	0	0	10	0.76	188	2.03
	11	0	2	8	1.55	233	2.44
	12	0	0	10	0.55	146	2.00
	13	0	0	10	1.00	213	2.36
	14	0	5	5	1.98	156	2.13

[a]C, coarse; M, medium; F, fine.

TABLE II
Influence of Grinding and Sieving Methods on Sample Particle Size as Prepared for Sedimentation Tests

Collaborators	Sample 1 Modulus of Uniformity[a] C	M	F	Sample 1 Modulus of Fineness	Sample 2 Modulus of Uniformity[a] C	M	F	Sample 2 Modulus of Fineness	Sample 3 Modulus of Uniformity[a] C	M	F	Sample 3 Modulus of Fineness
1	0	2	8	1.5	0	2	8	1.5	0	2	8	1.5
2	0	0	10	1.3	0	0	10	1.1	0	0	10	1.3
3	0	0	10	1.5	0	1	9	1.3	0	1	9	1.1
4	0	6	4	2.5	0	5	5	2.4	0	6	4	2.5
5	0	0	10	1.3	0	0	10	1.1	0	0	10	1.3
6	0	7	3	2.6	0	7	3	2.4	0	3	7	1.0
7	0	3	7	1.7	0	6	4	2.0	0	5	5	2.4

[a]C, coarse; M, medium; F, fine.

fineness, based on the same sieve analysis, is represented by one number. Most of the grinders reduced the wheat samples to the fine particle size range. There were no coarse particles and only a few of medium size among the samples ground for the falling number test; the modulus of fineness values ranged from 0.41 to 1.88. Samples prepared for the sedimentation test contained no coarse particles, but most contained both medium and fine particles. All moduli of fineness values exceeded 1.0; they ranged up to 2.5.

Recently the ASAE Recommendation R 246.1 was discontinued. Since then sieving data have been used to calculate a log-normal particle size distribution parameter (Pfost and Headly 1976). The size of a particle is the dimension that best describes its degree of subdivision. For a spherical particle, the diameter is that dimension and therefore its size (Irani 1961). For ground grain, the particle size distribution is not normal. When weight distribution data obtained from sieve openings expressed in microns are used, a log-normal distribution can be obtained by taking the logarithm of a particle size to the base 10.

The particle size diameters and the standard deviation of the three samples prepared for the falling number test are shown in Table I. The average particle size on a sieve is calculated as the geometric mean of the diameter of the sieve through which the particle passed and of that on which it was retained. The difficulty with the use of the sieving data for log-normal particle size distribution parameters of the collaborators' samples was the fineness of the grind. Ground material could be collected only on screens No. 48 (297 μ), 100 (149 μ), and the pan (less than 149 μ); however, the procedure recommends at least six screen values for the particle size mean diameter calculation.

The correlation coefficient between the moduli of fineness and the particle diameter of the collaborators' samples was 0.487. Poor relationships between these two procedures for expressing particle size resulted in the ASAE recommendation abandoning modulus of fineness values for expressing particle size of ground grain.

The analyses of variance in particle diameter due to collaborator and sample are shown in Table III.

TABLE III
Analyses of Variance for Particle Diameter

Source	DF[a]	SS[b]	Variance
Collaborator	13	40,042.31	9.26[c]
Sample	2	2,375.19	3.55[d]
Error	26	...	...

[a] DF = degrees of freedom.
[b] SS = sum of squares.
[c] Significant at 0.01 level.
[d] Significant at 0.05 level.

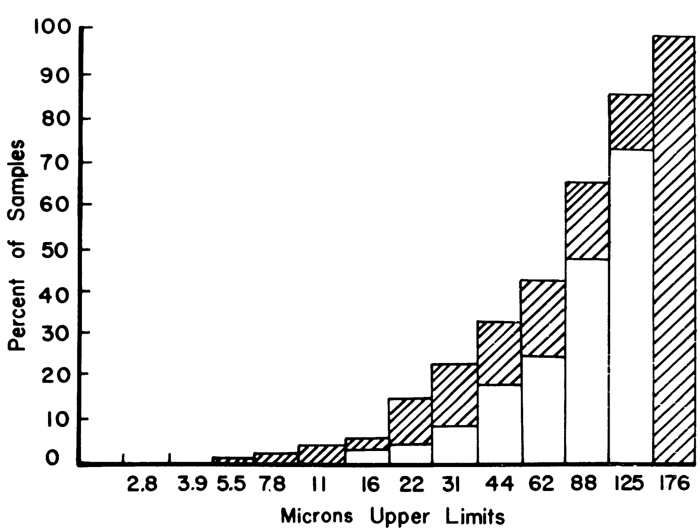

Fig. 1. Cross sectioned area includes average range of fine particles (0.176 μ) of the three samples prepared in Falling Number Analysis by all collaborators.

Fine Particle Analysis

Because the collaborators' grinding procedures produced a preponderance of fine particles, information was obtained on the percentages of particles of certain dimensions between 165 and 2.8 μm. A recent adaptation of light-scattering technique by laser illumination for measuring various parameters of small particles was used (Wertheimer et al 1977). This method has been applied to the measurement of flour particle size (Mann 1977) by passing a dry sample in a current of air through the laser light beam. With a Leeds and Northrup Particle Size Analygen,[2] particle sizes can be measured in 13 channels ranging from 125 to 1.9 μm. The collaborators' samples prepared by laboratory grinders contained some particles beyond the range of measurement; therefore this technique was not applicable for the entire sample. The finer particles were sifted through 70GG (236 μm) mesh screen and particle size analyses made and reported as a percentage within the 13 channels from 176 to 2.8 μm (Fig. 1). The channels selected give points equally spaced along a log axis; otherwise the abscissa would be logarithms.

The distribution of the various small particles for all samples from all collaborators formed the pattern shown in Fig. 1, which is an average value. The significance of small shifts in particle size distribution in the smaller particle size range, in relation to analytical results, needs to be more thoroughly investigated.

CONCLUSION

Standardizing grinding and sieving procedures for grain samples is difficult because of the diversity of equipment used. Presently recommended procedures used to prepare grain samples for analyses reduce the sample mostly to medium and fine particle sizes. A practical procedure to employ, where sample particle size is of proven importance to achieve reproducible results, is the specification of a particle-size range. Specific grinding and sieving equipment would not be required, but these operations would be conducted as required to obtain the specified particle size distribution.

Methods now available and methods being developed will permit particle size determinations to be made rapidly and accurately; consequently this variable will be more easily controlled.

Modulus of fineness procedure should no longer be used to describe particle size of laboratory ground samples. Diameter values should be used for particle size.

[2] Microtrac Particle Size Analyzer, Leeds and Northrup, North Wales, PA 19454.

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