FRACTIONATION OF DEFATTED WHEAT- AND CORN-GERM FLOURS BY AIR CLASSIFICATION

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ABSTRACT

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Wheat- and corn-germ samples from commercial mills were defatted, fine-ground, and air-classified to produce germ flour fractions which differed in particle size and in composition among themselves and from the original material. Finest fractions were produced in a yield of about 33%, with a protein content of 40% for wheat and 27 to 29% for corn, 7 and 15 to 19% for the respective ash contents, and fiber levels normally of 0.5% or less. Removal of some fibrous material by moderate grinding and screening ahead of air classification lowered the fiber content of some fractions. Fine grinding and air classification provide a means for selectively extending and varying the composition of cereal germ flours. Fractions of higher protein and ash contents are more obtainable from the defatted germ flour than from the corresponding endosperm flour of wheat or corn.

Air classification is being used by the wheat-milling industry to tailor-make flours meeting specific requirements such as protein content or granularity (1). Although wheat endosperm flour is the principal material processed by this method, flours from the endosperm of sorghum, corn, and other grains can also be fractionated with varying effectiveness (2–8). Endosperm flour from certain cereals such as rice does not show any significant protein shift among its air-classified (AC) fractions, but does show a change in concentration of other components such as ash and fat (9). Thus, flour fractions higher in selected natural mineral nutrients than the original flour, or potentially more flavor stable because of a lower fat content, can be produced by air classification.

Cereal grain flours not only show a variation in air-classification response between types of grain but also between classes of a particular grain (10). Workers at the Northern Regional Research Laboratory have found leading varieties of the soft red winter (SRW) wheat class more responsive to air classification than the hard red winter (HRW) varieties (11,12). A variation in the response for flour produced from different parts of the kernel for any one class of wheat would also appear likely, based on differences in vitreousness and chemical composition within the kernel (13). Variations in these properties are essential factors for air classification.

The germ from cereal grains has a greater concentration of high-quality protein, fat, minerals, vitamins B and E, and fiber than does the endosperm (14,15). Because of the comparatively high level and nutritional quality of these nutrients, germ *per se* is a potential raw material for use in a variety of blended and snack-type food products. Inasmuch as a high fiber content would be a drawback for some food uses, such as those for infants and geriatrics,

[1]The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

experiments were conducted to learn if fractions of low fiber content could be produced by fine grinding and air classification of the germ recovered in dry milling wheat or corn.

Data were also obtained on extent of the accompanying protein and ash enrichments. Garcia *et al.* (16) have reported on the variation in mineral, amino acid, and carbohydrate contents of the AC fractions obtained from the defatted flour of the wheat germ and from one of the corn-germ stocks (A) used in the current work. Those materials are identified as W2 and CA2 in this report. Pomeranz *et al.* (17) reported previously on composition of the lipids and proteins in fractions prepared by fine grinding and air classification of whole and defatted wheat germ obtained from a commercial mill processing wheat of unidentified origin. Gardner *et al.* (18) reported on AC fractions from cooked corn germ.

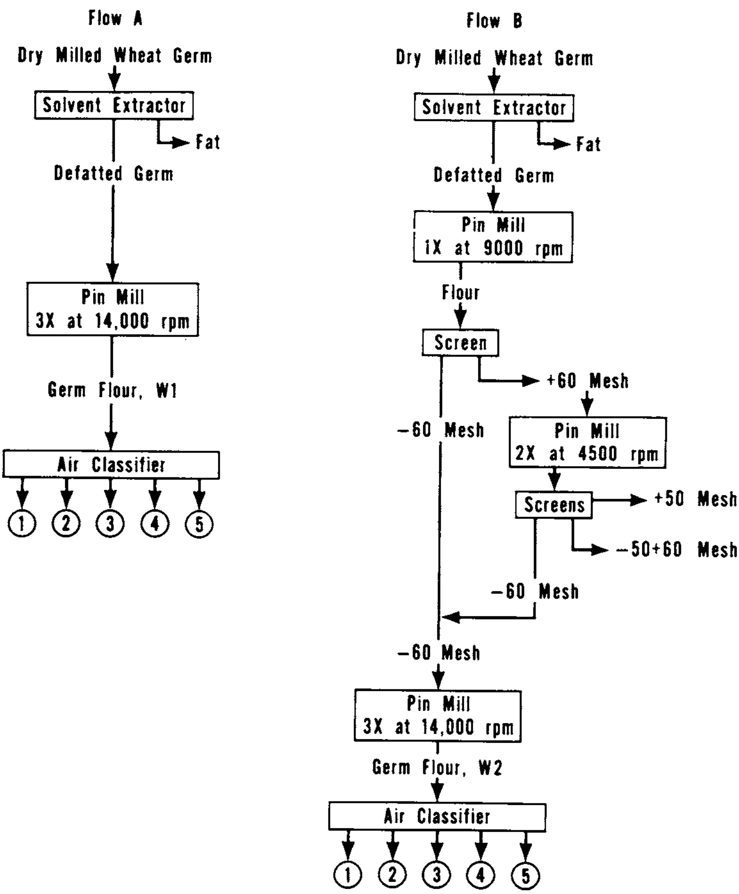

Fig. 1. Flow diagrams for processing wheat germ. Screens are U.S. standard mesh (19).

MATERIALS, METHODS, AND EQUIPMENT

Germ Stocks

Wheat-germ stock typical of that from a commercial mill operating on SRW wheat, and corn-germ stock typical of that from two dry-milling plants, designated A and B (operating on yellow dent corn) served as starting materials. The wheat germ and corn germ B were used without preliminary screening. All germ stocks were stored at 34° F until used within a 6-month period.

Milling Procedures

Wheat Germ. The flaked wheat-germ stock was solvent-defatted with hexane at room temperature and then finely ground (flour W1) and air-classified into five fractions in accordance with flow A shown in Fig. 1. Three passes of the stock through an Alpine pin mill, model 160Z Kolloplex, operating at 14,000 rpm were used for the grinding step, and a Pillsbury laboratory model air-classifier for the

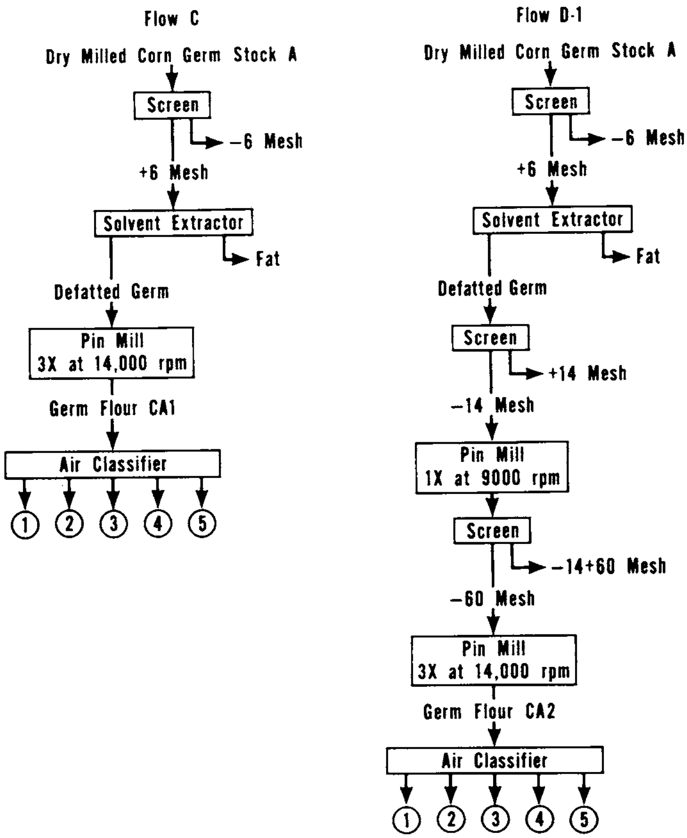

Fig. 2. Flow diagrams for processing corn-germ stock A. Screens are U.S. standard mesh (19).

classification step. Each pass through the classifier produced a fine fraction and a coarse fraction. The coarse fraction was recycled through the classifier with the cut point changed to take off a fine fraction of successively larger particle size. Successive passes gave a total of four such fractions and a coarse residue. Classifier cut points were approximately 15, 18, 24, and 30 μ. Particle-size distribution for AC fractions was determined in a Sharples Micromerograph air-sedimentation apparatus.

In flow B, Fig. 1, the defatted germ was subjected to repeated, moderate grinding and screening in an effort to remove part of the fiber before the wheat germ was finely ground (flour W2) and air-classified as in flow A. By this operation, the fiber content was reduced from 2.2 to 1.0%, and quantity of the classifier feed was reduced by 25%. All screens used and referred to were equivalent to U.S. standard mesh sizes (19).

Corn-Germ A. Because of the large amount of small endosperm particles in

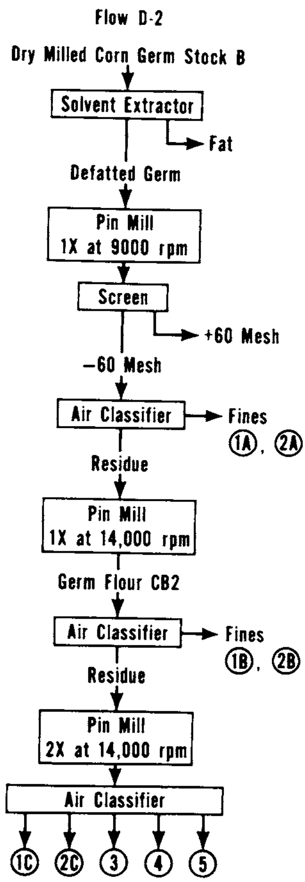

Fig. 3. Flow diagram for processing corn-germ stock B. Screens are U.S. standard mesh (19).

granular corn-germ stock A, it was first screened in a simple box sifter to remove a −6-mesh fraction, which was discarded. The +6-mesh fraction was solvent-defatted with hexane at room temperature, finely ground by three passes through the pin mill operating at 14,000 rpm (flour CA1), and then air-classified into five fractions with the same cut points as used on the wheat germ (flow C, Fig. 2).

By a modification of flow C, fiber content of the defatted germ was reduced from 5.0 to 4.3%, while quantity of the classifier feed was lowered from 100 to 87 parts. The modification involved moderate pin-mill grinding and screening of defatted germ stock A before fine grinding (flour CA2), and air classification as in flow C (see flow D-1, Fig. 2).

Corn-Germ B. Germ stock B was also processed by flow C, except the initial screening with a 6-mesh sieve was omitted because this germ stock was relatively free of endosperm particles (flour CB1).

Further procedural changes intended to prevent overgrinding were incorporated in another experiment made with corn-germ B. The flow resembled that of D-1, Fig. 2, except that (a) screening of the defatted germ over a 14-mesh sieve was omitted; and (b) there was a change in sequence for fine-grinding and classifying operations so only the more vitreous material received maximum grinding (flour CB2). Pin-mill grinding one time at 9000 rpm was followed by air-classifier removal of fine fractions at cut points of 15 and 18 μ from the −60-mesh material; the coarse fraction, +18 μ, was ground once at 14,000 rpm and two fine fractions were taken off at cut points of 15 and 18 μ. The residue was ground twice at 14,000 rpm and then air-classified into five fractions using same cut points as before. All −15-μ fractions were combined to form fraction 1, and the +15−18-μ fractions combined to form fraction 2. Fraction 3 included the −18+24-μ particles, fraction 4 included the −24+30-μ particles, and fraction 5 consisted of the coarse residue. This later procedure was designated flow D-2, Fig. 3.

Analytical Methods

Fiber, ash, and fat were determined by standard AACC methods (20). The AACC method for fiber (20) was slightly modified; a filter cloth was used instead of an alundum filter. The fiber was washed into an evaporating dish, dried, weighed, and corrected for ash. Protein [calculated as percentage nitrogen × 5.8 for wheat germ (21); and percentage nitrogen × 6.25 for corn germ (21)] was determined by an AutoAnalyzer method (22). Analyses are reported on a dry basis.

RESULTS AND DISCUSSION

Quantities for all materials are expressed as parts/100 parts of defatted germ. Air-classifier product recovery ranged between 98 and 100% of the feed with 99% predominant. No attempt was made to correct recoveries for incidental losses due to loss of moisture or to other factors.

Wheat Germ

Air classification of the defatted and finely ground wheat-germ flour, W1, gave fractions whose fiber content increased from 0.4 to 6.4% as particle size of the fractions increased (Table I). At the same time, protein content of the individual fractions decreased from 40 to 27%, and ash content from 8 to about 5%. Variation in fat content was minimal. Yield of the two protein-enriched fractions (1 and 2) was 33%, and they accounted for 10% of the fiber along with 38% of the protein and 42% of the ash, based on total quantities found in the AC fractions (Table II). Yield of the coarse residue was 18% and it contained 57% of the fiber, 15% of the protein, and 17% of the ash. These yields and the ash and protein contents are in overall general agreement with those reported by Pomeranz *et al.* (17), who used less intense grinding than we did.

Screening, moderate pin-mill grinding, and rescreening of the defatted germ preceding air classification (flow B, Fig. 1) removed two fractions: (a) a +50-mesh fraction relatively high in fiber and fat but low in protein content, and (b) a −50+60-mesh fraction that was much like flour W1 except it had a higher protein content (Table I). About 60% of the fiber initially present in the defatted germ

TABLE I
Fractionation of Defatted Wheat-Germ Flour

Material	Yield[a]	Fiber % db	Protein % db	Ash % db	Fat % db
Germ stock from mill	112	2.1	30	5.3	11.0
Flow A. Classification of Flour W1					
Defatted flour as fed to classifier	100	2.3	33	5.6	0.2
Fraction					
1	20	0.4	40	8.0	0.3
2	12	0.9	38	6.5	0.3
3	34	1.0	34	5.1	0.2
4	15	2.1	30	4.6	0.2
5	18	6.4	27	5.4	0.2
Composite of fractions 1–5 (calc.)	100	2.0	34	5.8	0.2
Flow B. Screening Results					
+50-mesh fraction	10	10.0	20	7.6	0.5
−50+60-mesh fraction	15	2.8	39	6.3	0.1
−60-mesh fraction	75	1.2	34	5.8	0.1
Flow B. Classification of Flour W2					
Defatted flour as fed to classifier	75	1.0	33	5.7	0.1
Fraction					
1	18	0.1	36	6.9	0.1
2	11	0.2	36	6.3	0.1
3	28	0.5	31	4.9	0.1
4	9	1.3	30	4.7	0.1
5	9	2.3	34	5.1	0.1
Composite of fractions 1–5 (calc.)	75	0.7	33	5.6	0.1

[a]Based on 100 parts of defatted germ.

was eliminated by this operation. As a result of the pregrinding and screening steps, the quantity of flour (W2) fed to the classifier was only 75 parts as against 100 for W1.

Air classification of W2 resulted in fractions 1–5 having lower fiber contents than their W1 counterparts, lower protein contents in fractions 1, 2, and 3, and a higher protein level in fraction 5. Ash and fat levels in the fractions obtained from W1 and W2 were comparable. The profile for protein values of the W2 fractions was similar to that in AC fractions from wheat endosperm flour; W1 fractions exhibited a successive decline in protein content in contrast to the minimum in protein content in intermediate fractions of W2. Based on weight of the defatted germ, yield of the two protein-enriched fractions from W2 was slightly less than that of the comparable W1 fractions. A smaller portion of the total fiber appeared in the coarse residue from W2 than from W1, and more appeared in fractions 3 and 4.

Corn-Germ Stock A

The defatted flour (CA1) from this stock was considerably lower in protein content and higher in fiber, fat, and ash contents than wheat-germ flour W1 (Table III). Air classification of CA1 (flow C) gave fractions with relatively large fiber, ash, and fat gradients, but a rather small protein gradient. Yield of the two high-protein fractions totaled 33%. Each had a fiber content of 0.1% and the two

TABLE II
Percentage Distribution of Selected Constituents Among Air-Classified Fractions from Defatted Germ Flours

Fraction	Wheat Germ		Corn-Germ A		Corn-Germ B	
	W1	W2	CA1	CA2	CB1	CB2
			Fiber			
1	4	4	1	14	2	3
2	6	4	1	12	1	5
3	17	29	31	44	34	36
4	16	23	17	14	17	20
5	57	40	51	16	47	35
			Protein			
1	24	27	22	45	37	43
2	14	16	16	14	18	20
3	34	35	25	25	20	11
4	14	11	12	9	8	6
5	15	12	25	8	17	10
			Ash			
1	28	30	29	61	56	57
2	14	16	18	16	20	31
3	29	33	23	16	14	6
4	12	10	11	4	4	3
5	17	11	19	3	5	3

contained 2% of the total fiber, 38% of total protein, and 47% of total ash (Table II).

The moderate grinding and screening of defatted corn-germ stock A (flow D-1) removed 6 parts of a +14-mesh fraction that visually appeared to be principally endosperm particles, and 7 parts of a −14+60-mesh fraction with a somewhat lower ash content than CA1. Fiber level in germ flour CA2 was thus reduced by 14%, and the fat content was reduced by about 85%. The removal of some fibrous material and fat led to a rather large and desirable increase in yield of the two protein-enriched fractions upon subsequent air classification, along with small increases in their protein and ash contents and a reduction in their fat content. However, based on comparison of the CA1 fractions with CA2 fractions, flow D-1 led to an undesirable and unexpected increase in fiber content of the high-

TABLE III
Fractionation of Defatted Flour from Corn Germ, Stock A

Material	Yield[a]	Fiber % db	Protein % db	Ash % db	Fat % db
Germ stock from mill	632	6.1	15	5.7	13.3
Flow C. Classification of Flour CA1					
Defatted flour (from +6-mesh fraction) as fed to classifier	100	5.0	24	10.3	2.8[b]
Fraction					
1	18	0.1	28	16.3	4.3
2	15	0.1	25	12.6	3.5
3	28	4.0	22	8.5	2.4
4	13	4.9	23	8.5	2.4
5	26	7.2	23	7.5	2.2
Composite of fractions 1−5 (calc.)	100	3.6	24	10.2	2.8
Flow D-1. Screening Results					
+14-mesh fraction	6	...	...	...	...
−14+60-mesh fraction	7	...	22	6.5	...
−60-mesh fraction	87	4.3	25	11.6	0.4
Flow D-1. Classification of Flour CA2					
Defatted flour as fed to classifier	87	4.3	25	11.6	0.4
Fraction					
1	32	1.4	30	18.4	0.5
2	12	3.2	26	13.8	0.5
3	27	5.1	20	5.7	0.3
4	8	5.6	22	5.1	0.3
5	8	6.8	22	3.8	0.3
Composite of fractions 1−5 (calc.)	87	3.6	25	11.3	0.4

[a]Based on 100 parts of defatted germ.
[b]+6-mesh fraction had fat content of 28.8% before defatting.

protein fractions, since they contained 26% of the total fiber as against only 2% for the CA1 fractions (Table II). For the coarse residue, the fiber distribution was reversed; the percentages were 16 and 51 for CA2 and CA1, respectively. The reduction in yield of CA2 coarse residue accounted for part of the reduction. As will be shown later, less intense pin-mill grinding of the −60-mesh fraction, which contained a relatively high level of fibrous material, corrected the problem. Overall, the CA2 fractions had somewhat larger protein and ash gradients than the CA1 fractions, minimal variation in fat content, and reduced yields for fractions 4 and 5. Fractions 1 and 2 from CA1 contained 38 and 47% of the total protein and ash, respectively, while the CA2 fractions contained 59 and 77% (Table II).

Corn-Germ Stock B

The germ flour from stock B was lower in protein, ash, and fat than flour from A, and appears more responsive to air classification (flow C) as indicated by the

TABLE IV
Fractionation of Defatted Flour from Corn Germ, Stock B

Material	Yield[a]	Fiber % db	Protein % db	Ash % db	Fat % db
Germ stock from mill	130	4.4	17	7.1	24.8
Flow C. Classification of Flour CB1					
Defatted flour as fed to classifier	100	5.7	21	9.2	2.3
Fraction					
1	26	0.2	32	19.8	3.8
2	17	0.2	24	11.4	2.5
3	25	4.5	18	5.1	1.5
4	10	5.3	18	4.0	1.3
5	21	7.4	18	2.4	1.0
Composite of fractions 1–5 (calc.)	100	3.3	23	9.4	2.2
Flow D-2. Screening Results					
+60-mesh fraction	26	6.0	21	8.3	1.6
−60-mesh fraction	74	3.8	21	9.9	2.4
Flow D-2. Classification of Flour CB2					
Defatted flour as fed to classifier	74	3.8	21	9.9	2.4
Fraction					
1	24	0.2	28	17.3	2.6
2	22	0.3	21	10.6	2.6
3	12	3.6	14	3.3	1.1
4	6	4.0	14	3.0	1.0
5	10	4.3	16	2.2	0.8
Composite of fractions 1–5 (calc.)	74	1.7	21	9.8	2.0

[a]Based on 100 parts of defatted germ.

larger protein and ash gradients and by the higher yield and protein content of fraction 1 (Table IV). Fiber and fat gradients of fractions from the two flours were fairly comparable.

Moderate grinding and screening to remove a +60-mesh fraction (flow D-2) resulted in removal of more material from stock B than from A (Tables III and IV), and lowered the fiber content of defatted germ flour B from 5.7 to 3.8%.

Air classification of CB2 flour by flow D-2 produced protein-enriched fractions containing 0.15 and 0.3% fiber, a level comparable to that of the CB1 fractions and definitely less than that of the corresponding CA2 fractions. Fiber levels in fractions 3–5 from CB2 were lower than those for the CB1 fractions. CB2 fractions generally ran slightly lower in protein, ash, and fat than their CB1 counterparts. Fractions 1 and 2 from CB1 accounted for 55% of the protein and 76% of the ash; percentages for the CB2 fractions were 63 and 88%, respectively (Tables II and IV).

Selection for a Specific Product Characteristic. A plot of fiber content *vs.* cumulative yield of the various AC fractions of corn germ is shown graphically in Fig. 4. A similar plot for protein content is shown in Fig. 5, and one for ash content is shown in Fig. 6. In each case, the yields are expressed as a percentage of the defatted corn germ. With these graphs, the fiber, protein, and ash contents for a specific product yield can be readily determined. Or, if a particular level for one of the components is specified, then the level for other components and yield of

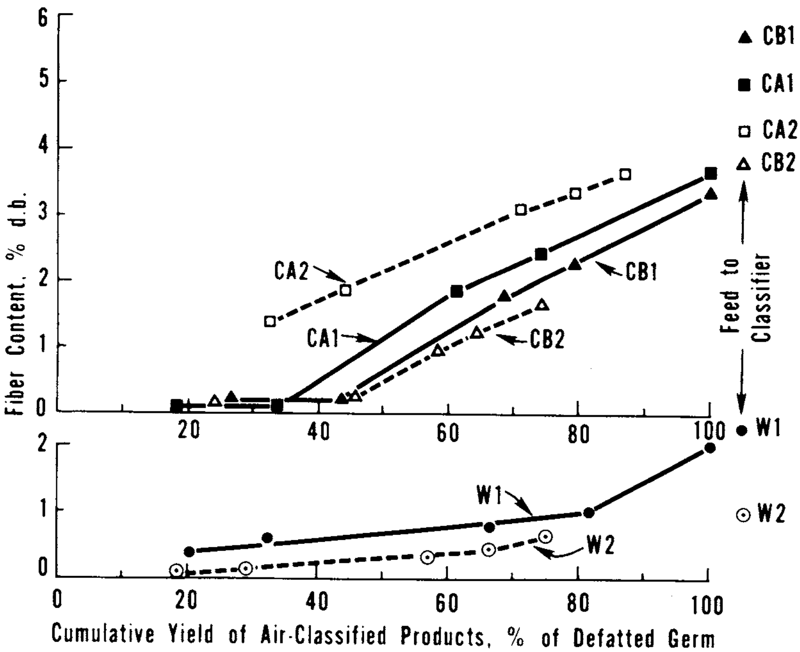

Fig. 4. Fiber content *vs.* cumulative yield for air-classified wheat- and corn-germ flours. Flours are indicated by the following abbreviations: W1 = wheat germ, flow A; W2 = wheat germ, flow B; CA1 = corn germ, stock A, flow C; CA2 = corn germ, stock A, flow D-1; CB1 = corn germ, stock B, flow C; and CB2 = corn germ, stock B, flow D-2.

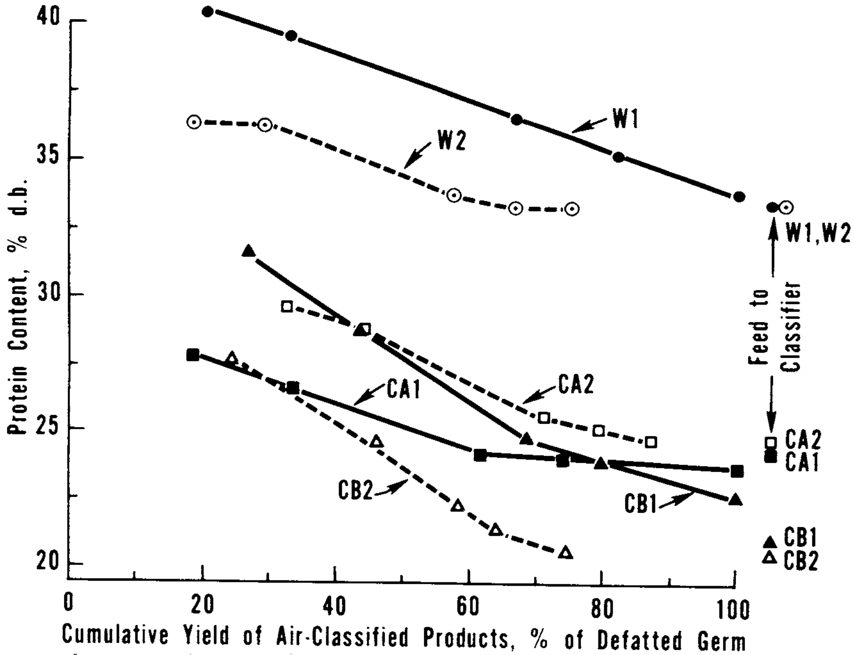

Fig. 5. Protein content *vs.* cumulative yield for air-classified wheat- and corn-germ flours. Legend for symbols same as Fig. 4.

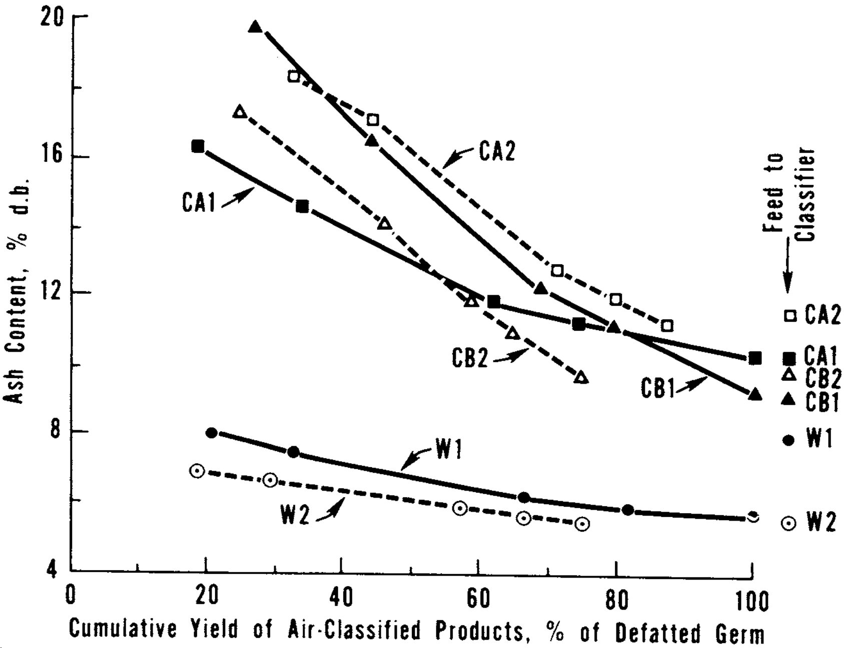

Fig. 6. Ash content *vs.* cumulative yield for air-classified wheat- and corn-germ flours. Legend for symbols same as Fig. 4.

the product from the various germ stocks obtained by these process procedures can be ascertained.

Differences in Response Obtained by Intensive Grinding and Air Classification. Differences were noted in the air-classification response for the two types of germ flour, 1 and 2, obtained from the same grain (*i.e.*, W1 and W2 or CA1 and CA2), and also between flours of the same type obtained from either wheat germ or corn germ (*i.e.*, W1 and CA1). Flour 2 always had the lowest amount of coarse residue and greatest yield for the two protein-enriched fractions, based on flour fed to the classifier. Although combined yield of the protein-enriched fractions from the type 2 flours was relatively large, their protein levels were not as high as those for the corresponding fractions from type 1 flours.

The improved protein shift for type 1 flour may be due to the presence of tough, more fibrous particles which tend to resist the grinding, while the associated material is more friable and proteinaceous and is broken off as very fine particles, much as occurs in fractionation of endosperm flours (23). The premilling and screening in preparation of type 2 flour remove some of the coarser, tough, fibrous particles and the remaining material is somewhat softer and more uniform in size than the original. This remaining material tends to disintegrate more readily and more uniformly during impact-grinding in the pin mill, and with less preferential disintegration of the protein.

The protein shift index is a convenient measure for comparing the fractionation results for cereal endosperm flours, and considers both protein content and yield of the fractions (24). The protein shift indexes tabulated below are quite low and are in the range for flours from HRS and HRW wheats rather than that for the more responsive soft and club wheat flours. Corn-germ flour was more responsive to protein change than wheat-germ flour. Stock B gave somewhat better results than stock A, but this is not unusual because materials from different commercial sources often show some difference in response. Although wheat-germ flour showed a lower response than either of the corn-germ flours, it produced enriched fractions with the highest protein levels (near 40%), and at a good yield of 33%. The greater disintegration of type 2 flour did not improve the protein shift index except for corn-germ flour from stock A.

Defatted Germ Flour	*Protein Shift Index, %*	*Protein-Yield Units, db*
W1	11	370
W2	7	240
CA1	9	190
CA2	15	410
CB1	24	520
CB2	24	480

Protein-yield units are also included. They provide an alternate index which can be used to indicate the relative extent that protein is transposed by air classification of these different materials. Protein-yield units are the cumulative sum of the products obtained by multiplying the percentage yield of each fraction by the difference between its protein content and that of the flour fed to the classifier. Protein-yield units are not dampened or affected by usual wide variations in the magnitude of coarse residue yields from different types of material.

Fiber Values. A comparison of fiber contents indicates that the value calculated for the composite was always less than that of the classifier feed. The difference was 13 to 30% for the wheat-germ series, about the same for corn-germ A series, and increased to 42 to 55% for corn-germ B series. The greater difference usually occurred whenever the defatted germ was subjected to further grinding. The data suggest that intensive grinding reduced part of the fiber to a particle size where it was not completely recoverable in the standard analytical procedure used for fiber determination of the classified fractions.

CONCLUSION

In general, this study of cereal germ fractionation showed that further processing of whole germ, when compared with similar treatment for a finer fraction from the same germ, gave a significant improvement in protein shift for wheat but not for corn. Differences were also found in the relative changes for ash and fiber values for corresponding flour fractions from the different grains.

These fractions of high protein and good mineral content have potential for use in beverages because of the fine particle size and easy suspension, or in other vegetable protein-enriched products now on the market such as breads, pasta, and new processed foods.

Acknowledgments

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