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Composition of Air-Classified Defatted Corn and Wheat-Germ Flours¹

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ABSTRACT

Commercial corn and wheat germ were each separated into five fractions by air classification. Compositional data show that mineral, carbohydrate, and amino acid concentrations vary among the five fractions from each germ. In both separations mineral enhancement occurs in the first two air-classified fractions. Mineral data are given for phosphorus, potassium, magnesium, calcium, sodium, iron, copper, and zinc. Conversely, an enhancement of carbohydrate occurs in air-classified fractions 3, 4, and 5. The major shift in carbohydrate content is due primarily to starch and secondarily to pentosans. Carbohydrate differences between wheat and corn germ are due mainly to a higher sugar content in wheat germ. Protein quality for both types is essentially equivalent, although corn germ contains less protein. Amino acid composition of the fractions from each germ is similar; significant minor variations occur in the first and fifth air-classified fractions.

Corn and wheat germ are cereal fractions that are relatively high in minerals, sugars, pentosans, protein, fat, and certain amino acids. Wheat germ has long been used for human consumption, whereas corn germ has only been considered a potential food supplement (1). Either germ could be used to upgrade nutritional quality of foods. Pomeranz et al. (2) applied air classification to wheat germ to determine its effect on composition of germ lipids and protein fractions. Our purpose was to determine major differences in composition between commercial corn and wheat germ. The effect of air classification was then investigated as a physical means for the modification of germ constituents, especially as it affected the mineral and carbohydrate composition as well as protein quality. In our study, commercial-grade dry-milled germ was used because it would represent the product available for future development.

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MATERIALS AND METHODS

Source of Germ

A selected portion of the germ streams from commercial mills was defatted in the laboratory before it was ground and air-classified by a procedure similar to that described by Stringfellow and Peplinski (3). A forthcoming paper describing in detail the grinding, screening, and other operations associated with air classification will include proximate-analysis data.

Flow diagrams for both corn and wheat that identify the samples in this study are shown in Fig. 1. The two schemes are not identical regarding treatments before air classification. The sample designated "orig" on both schemes represents the first defatted product from the commercial dry-milled germ. The germ fraction from dry milling of corn is usually mixed with considerable quantities of endosperm fragments which are principally removed by screening through a 6-mesh screen. After defatting, an additional fraction retained on a 14-mesh screen was removed. Removal of these two fractions resulted in a purer germ fraction.

Mineral Elements

Mineral elements were determined by atomic-absorption techniques as previously described (4), except for phosphorus, which was done colorimetrically (5). A Perkin-Elmer model 303 atomic absorption spectrophotometer and a Beckman model DB spectrophotometer were used. The germ samples were wet-ashed with nitric acid, and the ash was finally dissolved with HCl and diluted with water to give a solution having a 4% HCl concentration. This solution, or

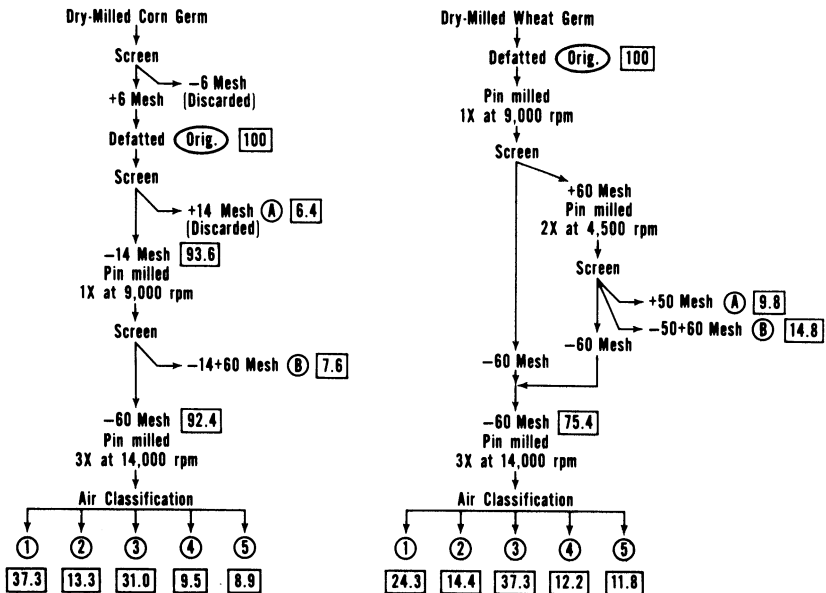


Fig. 1. Flow diagrams for processing of corn and wheat germs. Encircled numbers or letters identify samples used in study. Numbers in boxes indicate percentage yield values at respective places in the processes.

dilutions thereof, was used for direct aspiration in the atomic-absorption spectrophotometer.

Starch

Starch was measured polarimetrically with 90% dimethyl sulfoxide (DMSO) as the solvent. A Bendix electronic polarimeter model 143 equipped with a 0.5-dm. cell was used for optical-rotation measurements at 546 nm. (mercury green), as previously described (6). A 1-g. germ sample, ground to pass 40 mesh, was weighed into a screw-cap glass vial and 20.0 ml. 90% DMSO was added. After a steeping period of 1 day, the mixture was ground in a Udy grinding chamber (7) for 6 min. The vial and grinding chamber were rinsed with three successive washes (20.0 ml. each) of 90% DMSO. The ground sample and washes were combined in a 4-oz. glass bottle, where the mixture was shaken on a reciprocal shaker for 24 hr. The starch-DMSO extract (supernatant) was separated by centrifugation. Starch was precipitated by adding 15 ml. of the starch-DMSO extract (slowly, with stirring) to 45 ml. 100% ethanol. After centrifugation, the precipitated starch was redissolved with 30.0 ml. 90% DMSO. The starch content of the germ samples was computed from the observed optical rotation of the redissolved starch solution (6).

Additionally, the amylose content in starch was determined by taking 0.5 ml. of redissolved starch-DMSO extract for color development in aqueous medium (7).

Pentosans

Pentosans were determined by a volumetric bromine method (8). Furfural from a 1-g. germ sample was distilled from 12% HCl. The furfural was reacted with a potassium bromate-potassium bromide reagent solution. Excess reagent was titrated with a 0.1N sodium thiosulfate solution. A blank containing all reagents was run for each set of samples.

Sugars

Germ samples (1.0 g.) were soaked overnight in 25 ml. 80% ethanol. The mixture was boiled and then filtered through fritted glass. The residue was extracted twice with 15 ml. hot 80% ethanol. The combined extracts were evaporated almost to dryness and quantitatively transferred to 20/32 Visking dialysis tubing. The tubing was double tied at each end and immersed in one liter (total volume) of 15% ethanol. Phenol (0.1 ml.) was added to inhibit microbial growth while the solution was stirred for 24 hr. at room temperature. The total dialyzed sugars were analyzed by the phenol- H_2SO_4 method (9) modified for 15% ethanol solutions instead of aqueous solutions customarily used.

The individual dialyzed germ sugars were identified by thin-layer chromatography based on boric acid-impregnated silica gel and solvent systems reported by Lato et al. (10). One solvent system, isopropanol-water (4:1), gave quantitative results within 10% error when coupled with char densitometry (11).

Amino Acids

Amino acid analyses were performed in a Phoenix amino acid analyzer by the procedure of Benson and Patterson (12). Samples (100 mg.) were hydrolyzed before analysis by refluxing in 200 ml. of constant-boiling HCl for 24 hr. HCl was removed by evaporating the solution to dryness several times. Integration of peaks and calculation of results were performed automatically by the procedure of Cavins and Friedman (13).

EFFECT OF AIR CLASSIFICATION

On Mineral Constituents

Oxides of the three major mineral elements (phosphorus, potassium, and magnesium) make up almost all the mineral ash of corn and wheat germs. Corn germ contains more of these three major minerals than does wheat germ, and air classification significantly modifies the concentration of these elements, especially in corn germ (Table I). Although wheat germ also showed an enrichment of these minerals in air-classified fractions 1 and possibly 2, levels in the remaining three fractions (3,4,5) were lower than in the original germ material. Combined percentage values for phosphorus, potassium, and magnesium for both corn and wheat germ are plotted in Fig. 2.

TABLE I. DISTRIBUTION OF THREE MAJOR MINERAL ELEMENTS IN CORN- AND WHEAT-GERM FRACTIONS^a

Defatted Germ Fraction	Phosphorus		Potassium		Magnesium	
	Corn %	Wheat %	Corn %	Wheat %	Corn %	Wheat %
Orig.	2.42	1.69	2.32	1.36	1.44	0.43
A	...	1.77	...	1.69	...	0.63
B	1.80	1.60	1.87	1.41	0.88	0.40
1	4.41	1.84	3.79	1.55	2.14	0.51
2	3.36	1.62	3.25	1.41	1.56	0.44
3	1.53	1.29	1.85	1.12	0.51	0.32
4	1.18	1.26	1.62	1.10	0.45	0.30
5	0.81	1.22	1.30	1.11	0.27	0.28
Feed to classifier ^b	2.75	1.46	2.42	1.26	1.23	0.38

^aResults on moisture-free basis.

^bCalculated values corrected for yield of air-classified fractions 1 to 5.

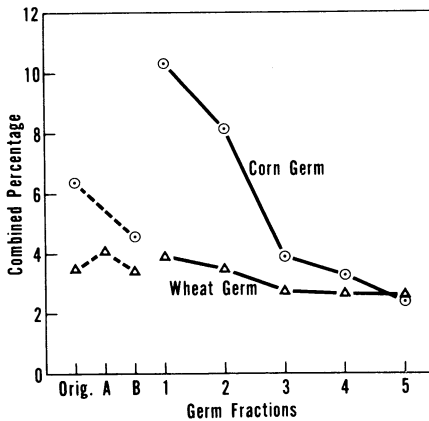


Fig. 2. Influence of air classification on combined percentage values for the three major mineral elements (phosphorus, potassium, and magnesium) in corn and wheat germs. Dotted lines connect values for non-air-classified fractions; solid lines connect values for air-classified fractions.

As a group, the five minor elements (sodium, calcium, iron, zinc, and copper) represented approximately 0.13 and 0.10% of the original samples for corn and wheat germ, respectively (Table II). By contrast, the three major elements represented 6.18 and 3.48% of the corn and wheat germs, respectively. Obviously, differences in mineral composition between corn and wheat germs occur primarily in the three major mineral elements. Table II also shows the influence of air classification on the concentration of the minor mineral elements. As a group, the five minor elements follow the same general trend as the major elements as a result of air classification.

Sodium values for both types of germ and zinc values for wheat germ only were the only exception to the trend of declining values in the first three air-classified fractions. Concentrations were quite constant in fractions 4 and 5, except for the increased amount of copper in fraction 5 from corn germ.

On Carbohydrates

Starch contents for the original defatted corn- and wheat-germ samples were about the same (22.9 and 20.2, respectively). Air classification had the effect of starch enhancement in fractions 3 and 4 for both corn and wheat germs and also fraction 5 for corn germ. Amylose determinations indicated that no fractionation of starch constituents had occurred during air classification. Mean percentage amylose values in the starch for all fractions circled in the flow diagrams (Fig. 1) were 28.3 ± 0.7 and 27.8 ± 2.2 for corn- and wheat-germ samples, respectively.

Starch is separated from sugars and other optically-active constituents by precipitation from the DMSO extract. Thus, interference from sugars is eliminated in the polarimetric starch measurement. The ethanol-DMSO mixture (supernatant fraction) separated from the precipitated starch gave an optical rotation equivalent to approximately 7% sucrose in the original corn germ. This observed optical rotation demonstrated that the sugars had been removed in the starch precipitation procedure.

Pentosan values were considerably higher in corn germ than in wheat germ (Table III). Apparently the pentosans are removed during screening operations (fractions A and B). Air classification had only a minor effect in modifying pentosan content, but it did enrich the residual fifth fraction.

Sugar content of wheat germ was approximately double that in corn germ. Air

TABLE II. DISTRIBUTION OF FIVE MINOR MINERAL ELEMENTS IN CORN- AND WHEAT-GERM FRACTIONS^a

Defatted Germ Fraction	Sodium		Calcium		Iron		Zinc		Copper		Combined	
	Corn %	Wheat %	Corn %	Wheat %	Corn %	Wheat %	Corn %	Wheat %	Corn %	Wheat %	Corn %	Wheat %
Orig.	0.067	0.018	0.021	0.058	0.019	0.013	0.018	0.020	0.0018	0.0018	0.127	0.111
A	...	0.014	...	0.109	...	0.017	...	0.016	0.0016
B	0.087	0.017	0.024	0.051	0.015	0.011	0.016	0.026	0.0018	0.0011		
1	0.081	0.021	0.027	0.077	0.032	0.016	0.028	0.021	0.0015	0.0013		
2	0.078	0.027	0.022	0.056	0.023	0.013	0.021	0.023	0.0011	0.0011		
3	0.059	0.028	0.013	0.032	0.009	0.009	0.009	0.021	0.0010	0.0007		
4	0.075	0.022	0.014	0.030	0.010	0.009	0.009	0.017	0.0012	0.0007		
5	0.080	0.026	0.014	0.031	0.010	0.009	0.007	0.018	0.0024	0.0008		
Feed to classifier ^b	0.073	0.025	0.020	0.046	0.020	0.011	0.018	0.020	0.0013	0.0009	0.132	0.103

^aResults on moisture-free basis.

^bCalculated values corrected for yield of air-classified fractions 1 to 5.

TABLE III. STARCH, PENTOSANS, AND SUGARS IN CORN- AND WHEAT-GERM FRACTIONS^a

Defatted Germ Fraction	Starch		Pentosans		Sugars	
	Corn %	Wheat %	Corn %	Wheat %	Corn %	Wheat %
Orig.	22.9	20.2	12.5	9.0	11.8	24.6
A	...	8.9	...	26.4	...	10.5
B	7.9	3.9	23.1	10.7	9.0	30.3
1	9.3	17.9	10.7	7.3	14.8	23.6
2	12.0	20.6	13.3	6.8	15.6	24.5
3	24.0	32.9	14.5	5.8	15.2	23.1
4	23.7	30.6	15.1	6.6	14.2	23.5
5	23.0	18.1	18.2	9.4	11.8	26.8
Feed to classifier ^b	16.8	25.5	13.3	6.8	14.7	23.9

^aResults on moisture-free basis.

^bCalculated values corrected for yield of air-classified fractions 1 to 5.

TABLE IV. PERCENTAGE SUGAR COMPOSITION IN CORN AND WHEAT GERMS

Sugar	Corn Germ	Wheat Germ
Sucrose	67	64
Raffinose	15	32
Glucose	10	...
Glucose + maltose	...	2
Fructose	7	< 1
Other	< 1	2

classification had little or no effect in modifying sugar content (Table III). Comparative compositional sugar values between corn and wheat germ are given in Table IV. The dialyzed germ sugars were identified by thin-layer chromatography.

Because the phenol-H₂SO₄ method gives slightly different color intensities for different sugars, colorimetric data were acquired on individual major sugars found in the germ samples. In addition, composition percentage values of germ sugars (Table IV) were used to calculate the expected deviation from germ-sugar data derived when only sucrose was the standard. Absorbance data based on sucrose standards are approximately 1.5% and 3.5% higher than actual sugar contents of the respective corn and wheat germs.

Figure 3 shows the total carbohydrate contents of corn- and wheat-germ fractions. Air classification had similar effects in both with a reduction of carbohydrate content in fractions 1 and 2 and enhancement in fractions 3, 4, and 5.

On Amino Acid Constituents

Table V contains the mean amino acid values and the standard deviation for all fractions. Maximum and minimum values are given and the fraction in which they occurred is also shown. It can be seen that variation between fractions was not great, but a preponderance of extreme values occurred in air-classified fractions 5 and 1. No extreme values occurred in the starting material designated "orig." A slight alteration of the amino acid pattern did occur because of air classification.

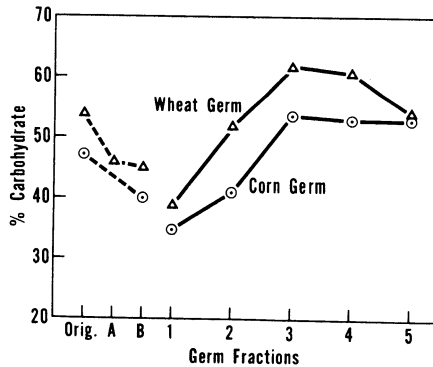


Fig. 3. Effect of air classification on carbohydrate content (starch + pentosans + sugars) in corn and wheat germs.

TABLE V. COMPARISON OF AMINO ACID CONTENTS FOR DEFATTED CORN- AND WHEAT-GERM FRACTIONS

Amino Acid	g./16 g. Nitrogen					
	Corn ^a	Wheat ^b	Corn		Wheat	
			Max.	Min.	Max.	Min.
Lysine	5.64 ± 0.34	6.36 ± 0.87 (B) ^c	5.92	(5) 4.98	(3) 7.35	(5) 4.81
Histidine	3.13 ± 0.17	2.64 ± 0.21 (1)	3.31	(4) 2.91	(1) 2.90	(5) 2.31
Ammonia	1.91 ± 0.15	2.38 ± 0.17 (5)	2.11	(1) 1.71 (A)	2.68	(5) 2.20
Arginine	10.3 ± 1.0	9.99 ± 0.51 (1)	11.6	(5) 8.50	(1) 10.76	(5) 9.23
Aspartic	8.44 ± 0.34	8.61 ± 0.65 (4)	8.99	(1) 8.02	(5) 9.29	(1) 7.41
Threonine	4.10 ± 0.16	4.26 ± 0.31 (4)	4.33	(1) 3.83	(5) 4.68	(1) 3.76
Serine	4.77 ± 0.06	4.46 ± 0.14 (5)	4.85 (B)	(1) 4.72 (A)	4.69 (1)	(2) 4.32
Glutamic	14.1 ± 0.5	16.5 ± 1.7 (5)	14.7	(B) 13.2 (A)	18.84	(B) 14.40
Proline	4.13 ± 0.52	3.23 ± 0.46 (5)	5.15	(2) 3.60 (A)	4.20 (B)	2.76
Glycine	6.35 ± 0.27	6.23 ± 0.32 (4)	6.70	(1) 5.97 (2)	6.68	(1) 5.56
Alanine	6.75 ± 0.25	6.35 ± 0.52 (5)	7.23	(1) 6.53 (5)	7.04	(1) 5.54
Cystine	1.68 ± 0.40	0.89 ± 0.45 (5)	2.19	(B) 1.10 (1)	1.53 (5)	0.24
Valine	8.65 ± 0.23	7.63 ± 1.03 (4)	8.95	(2) 8.40 (5)	8.63	(2) 5.89
Methionine	2.20 ± 0.19	1.91 ± 0.14 (3)	2.48	(4) 1.94 (5)	2.14	(2) 1.75
Isoleucine	3.22 ± 0.17	3.46 ± 0.13 (5)	3.46	(2) 3.03 (5)	3.65	(1) 3.22
Leucine	6.96 ± 0.64	6.68 ± 0.22 (5)	8.29	(2) 6.45 (5)	6.98	(1) 6.32
Tyrosine	3.35 ± 0.39	3.00 ± 0.13 (5)	3.86	(2) 2.93 (A)	3.26	(1) 2.80
Phenylalanine	3.89 ± 0.13	3.74 ± 0.17 (5)	4.16 (2)	(3) 3.80 (A)	4.13	(3) 3.58

^aRepresents the mean and standard deviation of five air-classified fractions: "orig." and B fractions (7 samples).

^bRepresents the mean and standard deviation of five air-classified fractions: "orig.", A, and B fractions (8 samples).

^cIn parentheses are shown the fractions where the maximum or minimum values occurred.

Cystine values show a large deviation; this is probably attributable to variations in analytical techniques rather than to air classification. Although corn germ contains less protein than wheat germ, the protein quality based upon amino acid composition is essentially the same for both. Nitrogen values (percent) for the five air-classified fractions ranged from 4.3 to 3.2 and 6.0 to 5.0 for corn and wheat germs, respectively; the highest values occurred in air-classified fraction 1.

GENERAL DISCUSSION

A review of the data indicates that at least two types of fractionation take place as a result of air classification: a) separations characteristic of such tissue as germ, endosperm, and pericarp; and b) separations at a subtissue or subcellular level. Strong evidences of tissue-type fractionation are the dramatic enhancement of mineral constituents, which are preponderantly of germ origin especially in corn, in the first air-classified fraction. The low mineral concentrations in fractions 3 through 5 from both types of germ occur where starch concentrations are the highest and thus represent endosperm. Since minor mineral elements are associated with the major mineral elements probably as phytates, air classification may serve as a separation technique for phytates in germ. Further evidence of germ-endosperm fractionation is demonstrated by the occurrence of maximum and minimum amino acid values in certain fractions. Amino acids, such as lysine and arginine, that are characteristic of germ show their lowest values in the fifth air-classified fraction. On the other hand, leucine, alanine, and phenylalanine that are characteristic of endosperm show their highest amino acid values in the fifty air-classified fraction.

Almost all pentosans, which probably originated in the pericarp or tip cap, were removed during screening operations performed before air classification. Any that were not probably remained to a large extent in the residual fifth fraction. Pentosans associated with pericarp were also separated on a tissue-type basis.

Evidence of separation at a subtissue or subcellular level is exemplified by the sugars. Although almost all sugars originate in the germ, they were distributed evenly throughout all the air-classified fractions. As with the sugars, distribution of pentosans originating in the germ probably was also unaffected by the air-classification step. The small differences in pentosan content between air-classified fractions are probably the result of pentosans of pericarp origin. In conclusion, for both types of germ certain germ-oriented constituents were enhanced in the first two air-classified fractions, whereas endosperm-oriented constituents were enhanced in the last three air-classified fractions.

Acknowledgments

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