Cooked Corn Germ: Composition of Fractions Separated According to Particle Size by Sieving and Air Classification

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ABSTRACT

Corn germ tempered at 30% moisture was cooked on gas-fired flaking rolls set at 350° F. (177° C.). The cooked germ flakes were defatted and separated into fractions by a combination of sieving, pin milling, and air classification. Compositional data collected for the sized fractions indicated that generally a separation of endosperm and germ tissue occurred. The largest particles were most characteristic of endosperm and the smallest, germ tissue. Endosperm material found in cooked germ flakes was due to endosperm fragments common to the dry-milled germ fraction. Starch content in the largest particle fraction was 46%, while the two finest fractions contained only 9%. Some of the finest fractions had 27% protein composed of more than 5% lysine and only 3 to 4% fiber. There was also a striking separation of ash content among the fractions; the finest particle contained 14% ash and the largest, 5%.

The nutritional value of corn germ lies in its potential as a protein supplement. The amino acid composition of germ protein is more favorable for human nutrition (1,2) than that of the endosperm. Garcia et al. (2) air-classified uncooked flours prepared from defatted corn germ and compared the results with flour from defatted wheat germ. Previous work (1) demonstrated that corn germ improved in flavor when cooked on heated rolls. We used this method to prepare cooked germ flakes, which were subsequently hexane-defatted. The defatted flakes were separated according to particle size through standard sieves and by air-classification techniques. Cooked germ separated differently from uncooked germ (2).

MATERIALS AND METHODS

Separation Techniques

The germ stream from a commercial dry mill, an identical sample used earlier (2), was fractionated according to the flow scheme in Fig. 1. The selected germ fraction was tempered at 30% moisture and cooked at 350° F. (177° C.) on gas-fired flaking rolls as described before (1). Hexane was used to defat the flakes in a large-scale Soxhlet extractor. Additional sized fractions were prepared by the procedure shown on the flow diagram. The fine germ fraction (−10 mesh) was ground by three passes through an Alpine pin mill at 14,000 r.p.m. Five fractions were separated from the flour fed to a Pillsbury laboratory model classifier by collecting a fine fraction, readjusting the classifier for a coarser cut, reclassifying the coarse fraction, and repeating this procedure until four fine fractions and one coarse residue were obtained. Cut points were approximately 15, 18, 22, and 30 μ (2).

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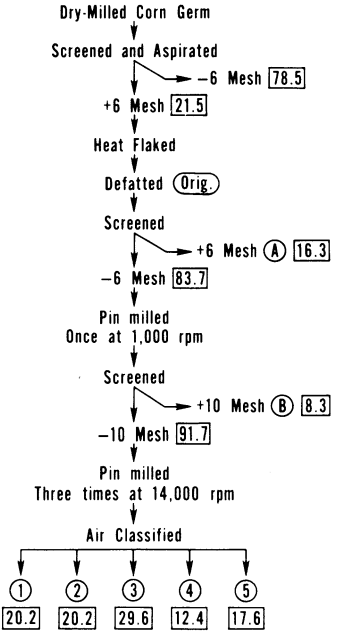

Fig. 1. Flow diagrams for processing cooked germ. Encircled numbers or letters identify the samples. Numbers in the boxes are percentage yield values for each step in the process. The air-classified fractions increase in particle size with increase in number.

Analytical

The samples were analyzed for phosphorus, starch, pentosans, amino acids, and sugars by methods Garcia et al. (2) described. Protein was calculated as 6.25 × N from values obtained by a micro-Kjeldahl method (Method 46-13) (3). Ash content was determined by ignition in a platinum dish at 575° C. for at least 16 hr. Fiber values were obtained according to a standard procedure (Method 32-15) (3). Particle-size distributions were determined with a Sharples Micromerograph (4) air-sedimentation apparatus and reported in terms of the mass median diameter (MMD), at which size 50% of the fraction weight is undersize.

RESULTS

Germ Enrichment Before Cooking

Dry-milled germ streams contain a considerable amount of endosperm pieces that can be largely removed by screening through a No. 6 mesh sieve. The material retained on the sieve, mostly intact germs, was aspirated to remove pericarp. Some broken germ particles passed through the No. 6 sieve with the endosperm, but from this finer material a reasonably pure germ could be collected on a No. 10 sieve in 30% yield. The −6 +10 fraction contained slightly more endosperm mixed with it than the +6 fraction. Although the −6 +10 fraction was disregarded in this study, it could possibly have been used to increase the amount of germ from dry-mill streams.

TABLE I. PARTICLE-SIZE DISTRIBUTIONS OF CORN GERM FRACTIONS

Germ Fraction	Particle Size MMD[a] μ
A	(+6 mesh)
B	(−6 +10 mesh)
1	10
2	15
3	18
4	21
5	54

[a]Mass median diameter.

Separation After Cooking

After undergoing heat-flaking and hexane-defatting, the flakes were screened through a No. 6 mesh sieve. Whereas the germ tissue tended to crumble, the endosperm flakes were more tactile and were largely retained on the screen. That a considerable portion of the +6 particles (fraction A) was endosperm flakes actually could be assessed visually. The gelatinized starch in the endosperm flake may be the key factor to the selective separation of endosperm into larger sized fractions. Another fraction of large particle size (fraction B) was obtained by sieving through a No. 10 mesh screen after a preliminary grinding. The −10 fines were ground to a flour suitable for air classification. Five air-classified fractions were collected, No. 1 being the smallest particle size and No. 5 the largest. Particle size distributions are given for all seven fractions in Table I.

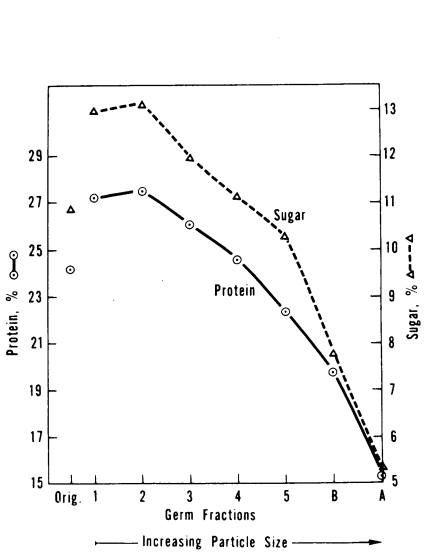

Fig. 2 (left). Protein and sugar values in germ separated as to particle size by sieves (fractions A and B) and air-classification (fractions 1 to 5).

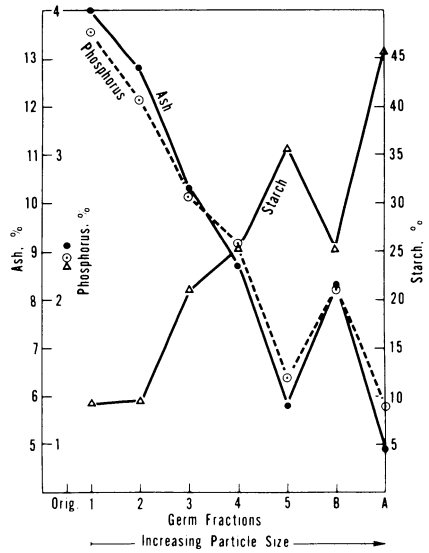

Fig. 3 (right). Ash, phosphorus, and starch values in germ fractions separated as to particle size by sieves (A and B) and air-classification (1 to 5).

Composition

Generally, protein and sugar content of the various fractions depended on particle size (Fig. 2). After a slight initial increase, both sugar and protein content diminished in a remarkably parallel manner as particle size increased. The protein in the finest fractions was enriched in lysine, being 5.3 and 5.1% of the total protein in fractions 1 and 2, respectively, as compared with 4.7% lysine in the original.

Similar to sugar and protein values, ash and phosphorus content also decreased as particle size increased (Fig. 3); however, the slight initial rise in values in fraction 2 noted in Fig. 2 was not observed and the amounts in fraction B increased significantly. Starch in the sized fractions was inversely related to ash and phosphorus content (Fig. 3).

Fibrous matter, usually measured by fiber and pentosan content, did not separate into any recognizable pattern (Table II). Fractions A and B yielded particularly large values possibly owing to the sieving out of pericarp fragments. Germ tissue itself reportedly contains 14.7% hemicellulose (5), a percentage sufficient to account for the rather high and evenly distributed pentosan content of the fractions. Pentosan and fiber contents largely paralleled one another as might be expected.

DISCUSSION

Compositional data fully confirmed the postulate that separation was based on tissue types—predominantly germ vs. endosperm. To emphasize our postulate, a compositional comparison of defatted germ (devoid of endosperm) and endosperm is made in Table III. Data for fractions 1 and 2 are similar to the reported composition of defatted germ; that is, high in protein, ash, and sugar, and low in starch. Sugar was lower than would be expected because heat-flaking undoubtedly destroyed some sugars. There was some heat loss of lysine as well, since lysine content dropped from 5.9% of the protein in uncooked germ to 4.7% in cooked germ. As particle size increased, the composition became more characteristic of endosperm like that in fraction A.

The ash and starch composition of fraction B was somewhat deviant from the trend of values established for the other fractions (Fig. 3). The reason for the deviation is not clear, but may be a result of the way fraction B was obtained (retention on a No. 10 mesh screen after a light grind). Flakes composed of

TABLE II. FIBROUS COMPOSITION OF CORN GERM FRACTIONS[a]

Germ Fraction	Pentosans %	Fiber %
Original	12.7	4.8
A	16.7	5.9
B	16.3	5.7
1	11.8	3.1
2	13.5	4.0
3	11.2	3.1
4	10.9	3.5
5	10.8	3.0

[a]Results on a dry weight basis.

TABLE III. COMPOSITION OF DEFATTED CORN GERM AND ENDOSPERM COMPARED TO FRACTIONS WITH THE FINEST (1) AND LARGEST (A) PARTICLE SIZE

Analysis	Composition, %			
	Germ[a,b]	Fraction 1	Endosperm[a]	Fraction A
Protein	28.7	27.2	9.5	15.4
Ash	15.4	14.0	0.31	4.9
Sugar	16.5	13.0	0.65	5.3
Starch	12.5	9.2	87.0	45.7

[a]Calculated on dry weight-defatted basis from data by Earle et al. (6).

[b]Essentially devoid of endosperm.

TABLE IV. CORRELATION BETWEEN COMPONENTS OF COOKED AND UNCOOKED[a] GERM FLOUR SEPARATED INTO FRACTIONS BY AIR CLASSIFICATION[b]

Components	Correlation Coefficient (r)	
	Cooked	Uncooked
Phosphorus vs. sugars	0.97	0.60
Sugars vs. starch	−0.99	−0.46[c]
Phosphorus vs. starch	−0.98	−0.97

[a]Data for uncooked samples taken from Garcia et al. (2).

[b]Data from the five air-classified fractions were used in all calculations.

[c]Significant difference (5% level) between correlations for cooked vs. uncooked.

endosperm may have crumbled by pin milling almost as readily as germ flakes; thus, there may not have been as much fractionation of endosperm from germ material by sieving the resulting fines. However, one would expect tip caps and pericarp to be concentrated in fraction B, which is borne out by the high fiber and hemicellulose content (Table II).

Evidence indicates no fractionation at a subcellular level in the cooked germ flours. However, this observation is not true of uncooked germ flours, which Garcia et al. (2) thought also separated at the subcellular level. The major differences between air-classified fractions of cooked and uncooked germ can be readily evaluated by correlating certain compositional data (Table IV). The parameters chosen for correlation—sugar, phosphorus, and starch contents—are most characteristic for purposes of comparing endosperm with germ. The sugar vs. starch correlation coefficient in the uncooked fractions was particularly low, whereas all the correlations were very high in the cooked fractions. Thus we confirmed the postulate that cooked germ flour separates according to tissue types and that uncooked germ flour separates according to additional factor(s).

Cooking before size separations obviously has utility in isolating germ-rich fractions. Perhaps initial sieving of the dry-mill germ stream before cooking would not be necessary to produce germ flours in the smallest particle fractions; this possibility should be studied further. Subcellular fractionation does not occur after cooking, probably because the cellular order has become homogenized. Gelatinization of the large amount of starch in the endosperm is

obviously a factor in cementing together endosperm tissue into larger fragments.

Some of the air-classified fractions could be considered as potential food supplements. Unlike corn endosperm, the germ is composed of high-quality protein (1,2). As shown in Fig. 2, fractions 1 and 2 are composed of more than 27% protein. Because the protein in the finest fractions was high in lysine, that protein could not have been derived from lysine-deficient endosperm. Since fiber content of all the air-classified fractions is not especially high, fiber is no deterrent for germ to be used as human food. However, the unusually high phosphorus content undoubtedly reflects the amount of phytate present. Phytate in the diet is not recommended for long periods since it is known to scavenge metal ions from the digestive tract. Cooking the germ may have an added advantage of changing its water absorption properties, improving flavor, and inactivating enzymes as reported previously for full-fat germ flakes (1).

Acknowledgments

We gratefully acknowledge the technical assistance of W. L. Deatherage, Dora L. Miller, C. C. Harris, and C. Vojnovich. Statistical analyses were by W. F. Kwolek (Biometrician, Biometrical Services, U.S. Department of Agriculture, stationed at the Northern Laboratory).

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[Received September 26, 1972. Accepted December 8, 1972]