CORN FLOUR: REDUCTION OF PARTICLE SIZE[1]

S. M. BADI,[2,3] R. C. HOSENEY,[3] and W. D. EUSTACE[3]

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ABSTRACT

The particle size of corn flour (−50W) could be reduced by repeated roller milling or pin milling. Both methods, however, increased starch damage. Hydrating corn flour with water followed by air drying also reduced particle size. Lyophilizing similar samples instead of air drying them resulted in materially finer particle size, indicating that air drying may induce agglomeration. Mercaptoethanol, an effective solvent for certain corn proteins, effectively reduced particle size of flour samples dried by either lyophilization or solvent drying (ethyl alcohol). Using ethanol to dry the sample resulted in about one-third of the corn protein being solubilized. Samples dried by lyophilization gave a definite protein shift during air classification. Combining treatment with mercaptoethanol and mild wet grinding produced a sample with 83% of the particles finer than 50μ. Repeated treatments with sodium bisulfite gave a sample in which 96.5% of the particles were finer than 50 μ.

Milling of the corn kernel is difficult due to irregularity in size and shape of kernels from the same ear, variation in kernel size and shape and in composition of different hybrids, and artificial drying of corn under conditions that adversely affect its milling quality (1,2).

The usual products from a dry corn mill are grits, flour, oil, and feed (3). Corn flour and grits have been fractionated by fine grinding and air classification (4,5), but variation in composition was not pronounced. Weiss (6) recently patented a process that aids in air classifying corn grits, and Spanheimer *et al.* (7) used chemicals and enzymes (8) to produce a protein shift during air classification of corn flour.

In this study, we attempted to reduce, without excessive grinding, the particle size of corn flour to that of starch. We anticipated that the reduction in particle size would aid in air classifying corn flour and improve performance of corn flours in cookie production.

MATERIALS AND METHODS

Preparation of Corn Flour

Most work was done with corn flour (stock material, −50W) produced from a commercial No. 2 yellow corn. The corn was degermed and experimentally milled (Fig. 1) so that 65% of the whole corn passed through a 50 wire sieve.

Analytic Methods

Sieve analysis was performed by sieving for 2 min on Rotap (100 g) and Smico (200 g) laboratory sifters equipped with 70GG, 9XX, 10XX, 11XX, and 100W sieves. Protein, moisture, and starch damage were determined by standard

[1]Contribution No. 971j, Department of Grain Science and Industry, Kansas Agricultural Experiment Station, Kansas State University, Manhattan, KS 66506.

[2]Present address: Food Research Center, Khartoum North, Sudan.

[3]Graduate research assistant, professor, and associate professor, respectively, Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66506.

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procedures (9). Samples were air classified with a Bacho Microparticle classifier model 6000. The Bacho had five throttles, or settings (No. 16, 14, 12, 8, and 4), to give a cutoff at sizes ranging from 5 to 50 μ. Sample size in the Bacho was 10 or 20 g; the samples were run for 10 or 20 min. Both fine and coarse fractions were collected for protein analysis. For evaluation of particle size, only the coarse fraction was collected and weighed, because the fine fraction could not be recovered quantitatively.

RESULTS AND DISCUSSION

Table I shows sieve analysis of the stock material (−50W) ground either by repeated passes through a roller mill or by pin milling until essentially everything passed a 70GG sieve. The pin milling was more effective in reducing particle size than was roller milling. Pin milling was particularly effective at reducing the amount of the larger fraction (+9XX), but the pin-milled sample was higher in starch damage (11.55%) than was the roller-milled sample (7.45%).

Previous work (10) with grain sorghum showed that hydrating the stock material with distilled water followed by drying at room temperature effectively reduced particle size. Likewise, hydrating corn (the stock material, −50W) for 6 hr with an equal weight of water followed by drying at room temperature and grinding for 30 sec in a Stein mill (treated) reduced the particle size (Table II) compared with particle size in the control (unhydrated, stock material ground for

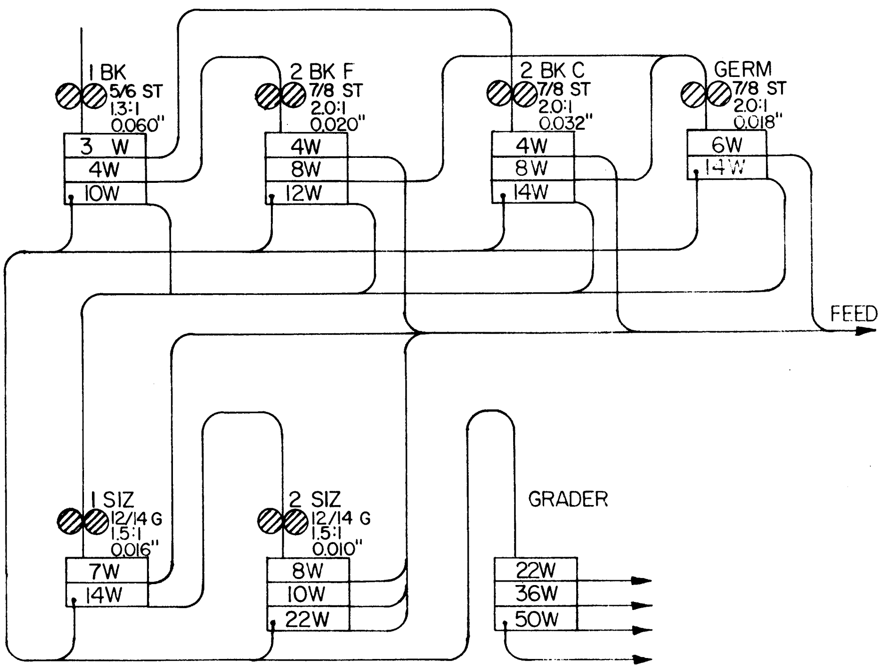

Fig. 1. Flow sheet for corn milling.

30 sec in a Stein mill). The treatment, however, was not nearly as effective with corn as it had been with grain sorghum (10). Repeated treatments on the coarse fraction (Fig. 2) showed that additional treatments would produce more throughs, but at a decreased rate of effectiveness.

Drying temperature, temperature of hydration water, and removal of the hydration water by centrifugation did not significantly alter the sieve analysis. Lyophilizing the hydrated flour rather than air drying it, however, gave a significantly finer product (Table II), indicating that perhaps air drying caused particles to agglomerate.

Treatment With Mercaptoethanol

Mercaptoethanol (ME) ($HO \cdot CH_2 \cdot CH_2 \cdot SH$) has been reported to be an effective solvent for certain corn proteins (11). Assuming that the protein-starch bond in endosperm particle must be weakened to obtain a fine particle size, we investigated ME for its effectiveness in weakening that bond.

TABLE I
Sieve Analysis of Repeatedly Milled Corn Flour (−70GG)

Sieve Fraction	Roller-Milled (%)	Pin-Milled (%)
+9XX	46	22
−9XX, +10XX	30	33
−10XX, 11XX	18	33
−11XX	6	12

TABLE II
Effect of Air Drying and Lyophilization of Corn Flour (−50W) on Particle Size

Sieve Fraction	Unhydrated (%)	Hydrated and Air Dried (%)	Hydrated and Lyophilized (%)
+70GG	73.0	38.8	11.2
−70GG, +9XX	16.0	27.1	37.8
−9XX	11.0	34.1	51.7

TABLE III
Air Classification and Protein Analysis for Hydrated[a] and Lyophilized Flour (−50W)

Bacho Fraction	Particle Size (μ)	Weight (g)	Protein (%)
No. 16 fine	< 5	6.0	10.3
No. 4 fine	5–50	56.0	4.0
No. 4 coarse	>50	38.0	7.5

[a]Hydrated with 0.6% mercaptoethanol.

The stock material (−50W) was hydrated with water (1:1) containing 0.6% ME for 6 hr and then air dried. After Stein milling (30 sec), the product appeared fine. A similar treatment using 4 vol of 95% ethanol for drying instead of air drying produced a fine flour even before grinding on the Stein mill.

Air classification (Bacho) of an ME treated and an ethanol-dried sample

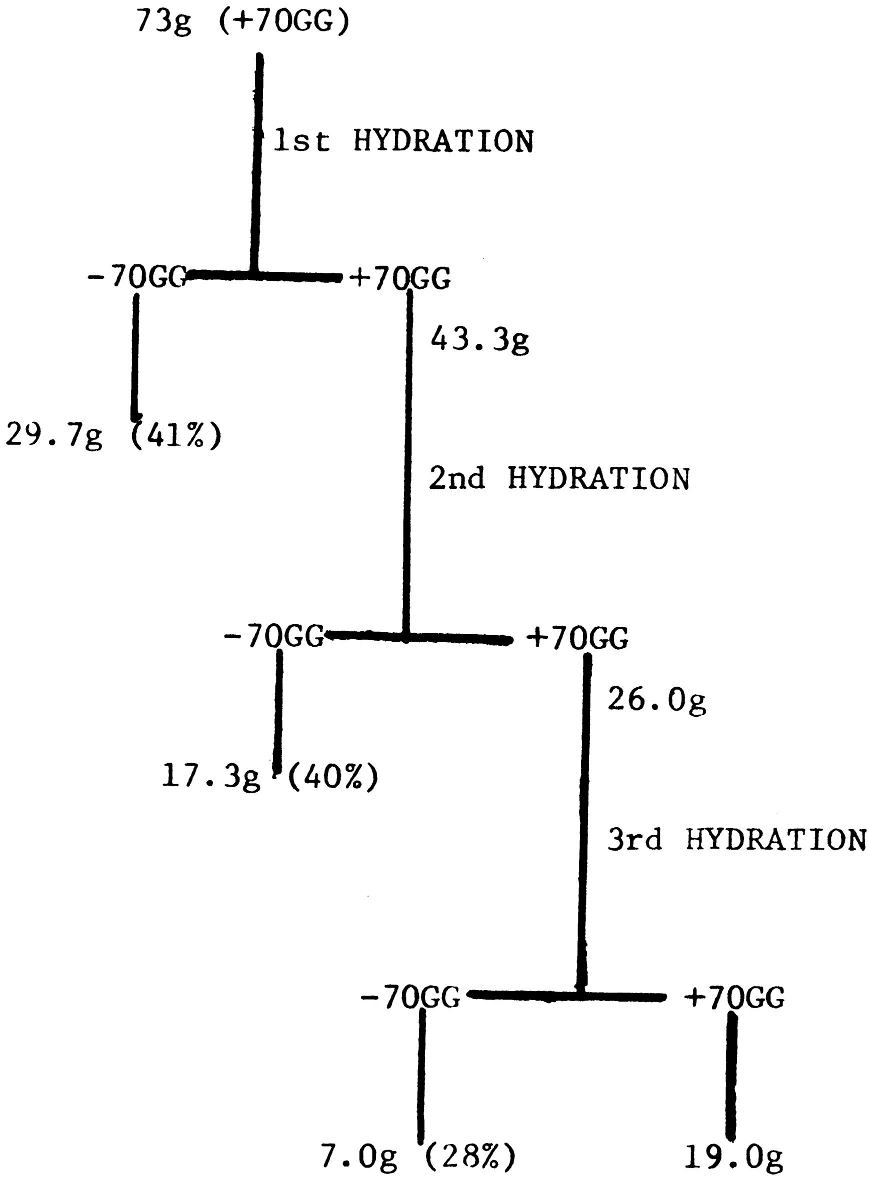

Fig. 2. Effectiveness of repeated hydration treatments on particle size.

showed about 40% of the particles to be greater than 50 μ in diameter. Protein analysis showed that the stock material contained 6.1% protein; the ME-treated and ethanol-dried material, 4.1% protein. Thus, the ME-ethanol treatment appeared to solubilize about one-third of the corn protein (presumably removed with the ethanol) so that the coarse fraction (>50 μ) from the air-classified sample contained 2.7% protein.

Treating the stock material (−50W) with 0.6% ME in water (100% based on corn weight) for 6 hr and drying it by lyophilization gave a product similar in appearance to the ethanol-dried product. Air classification (Bacho) and protein data for that product are given in Table III. Although the amount of coarse material (>50 μ) was similar to that obtained with ethanol drying, the protein content was much higher (7.5% compared with 2.5%).

In an effort to reduce the amount of coarse fraction further, we treated the stock material with 0.6% ME as indicated above, except that the material was given a mild wet grinding with a modified Hobart coffee mill prior to being lyophilized. Results of air classification and protein analysis are given in Table IV. The amount of coarse fraction (>50 μ) was reduced to 17.0%.

Treatment With Sodium Bisulfite

Preliminary work indicates that sodium bisulfite ($NaHSO_3$) is effective in weakening the starch-protein bond and thus in producing a fine product. The effect of $NaHSO_3$ concentration, pH, hydration time, and amount of water was

TABLE IV
Weight and Protein Analysis of Air-Classified Treated[a] Flour

Bacho Setting	Weight (%)	Protein (%)
No. 16 fine	6.5	10.7
No. 14 fine	11.5	5.0
No. 12 fine	36.0	3.9
No. 8 fine	25.5	6.4
No. 4 fine	4.0	9.3
No. 4 coarse	17.0	11.4

[a]Treated with 0.6% mercaptoethanol and wet grinding.

TABLE V
Effect of Repeated Treatment With $NaHSO_3$ on Corn Flour

Treatment No.	Percentage of Starting Material	
	> 50 μ (%)	< 50 μ (%)
1	40.0	60.0
2	17.6	82.4
3	9.9	90.1
4	5.9	94.1
5	3.5	96.5

studied by using response surface methodology, which Box and Wilson (12) developed. The optimum treatment of 0.5% $NaHSO_3$ with 100% water for 6 hr followed by lyophilization produced samples with as little as 25% coarse material (>50 μ).

To study the effectiveness of repeated treatment with $NaHSO_3$, we treated the stock material (−50W) with 0.5% $NaHSO_3$ (based on weight of flour), 100% water, for 6 hr at room temperature. After the sample was lyophilized and air classified (Bacho), the coarse fraction (>50 μ) was recycled (by the above process). Four recycles (Table V) reduced 96.5% of the stock material to less than 50 μ. Thus, successive treatment with $NaHSO_3$ is beneficial in producing fine corn flour.

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