VITAL WHEAT GLUTEN BY DRUM DRYING
II. Pilot-Plant Studies and Cost Estimates[1]

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ABSTRACT

Conditions and equipment suitable for the production of dry vital wheat gluten by drum-drying wet gluten dispersed in dilute acetic acid were studied. In these tests a satisfactory product was obtained by completely dispersing wet gluten in dilute acetic acid at a pH from 4.3 to 5.1 and a solids concentration of 12–20% by weight, by drum-drying the dispersed gluten at atmospheric pressure and a temperature about 260°F. (127°C.), and by grinding the dried material in an attrition or hammer mill. The process uses standard equipment, and it can be readily adapted in industrial plants to make dry vital gluten for baking or other food purposes, or for the preparation of industrial chemicals. Cost estimates for drying 6 million lb. of vital gluten product annually by this process show a total drying cost of 4 cents per lb. of dry material in a plant costing about $477,000.

Descriptions of processes for producing vital dry gluten by drum-drying are limited. Miley *et al.* (3) patented a process in which wet gluten is dispersed in a mixture of water and carbon dioxide under pressure and the resulting dispersion is dried in a drum-dryer, spray-dryer, etc. Tuomy and Slotter (5) described a method in which wet gluten is dispersed in ethanol and dried on a drum-dryer. An earlier article (4) discussed preliminary investigations of drum-drying wet gluten dispersed in dilute acid. This paper describes pilot-plant investigations employing various types of equipment and optimum process conditions. Cost estimates are presented for drum-drying vital gluten on a commercial scale.

Equipment

Laboratory dispersions of gluten in dilute acetic acid were prepared in a 1-gal. Waring Blendor[2] (Waring Products Co., New York, N. Y.) Model CB-3 operated at 20,000 r.p.m. Pilot-plant dispersions were prepared with the following: a stainless-steel ribbon blender having a capacity of about 19 gal. and a rotational speed of 70 r.p.m.; a pump recirculation system comprising a 1-1/4-in. Bump Pump (Ulrich Mfg. Co., Roanoke, Illinois) Model 15 (single-lobe offset impellers

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[2] Mention of trade names or equipment does not constitute endorsement by the U. S. Department of Agriculture over others of a similar nature not mentioned.

operating at 160 r.p.m.) and a 40-gal. stainless-steel tank; a Cowles Dissolver (Morehouse-Cowles, Inc., Los Angeles, Cal.) Model 7VT equipped with a 10-in. stainless-steel impeller rotating at 1,800 r.p.m.; a Morden Stock Maker (Morden Machines Co., Portland, Ore.) Model MLB-4 equipped with a vaned conical rotor and a stator with variable clearance, having a maximum capacity of 1.5 gal., and operated at 1,400 r.p.m.; a Premier Colloid Mill (Premier Mill Co., Geneva, N. Y.) Model UB-5, equipped with a 3-in. tapered disk rotating at 17,000 r.p.m. in an adjustable stator; and a Manton-Gaulin Homogenizer (Manton Gaulin Mfg. Co., Everett, Mass.) Model 25 M-3BA, of the orifice type, operating with homogenizing pressure up to 5,000 p.s.i.g.

Drum-drying of gluten dispersions was carried out on Buflovak laboratory and pilot-plant double drum-dryers (Buffalo Machine and Foundry Co., Buffalo, N. Y.) at atmospheric pressure. The rolls of both models were constructed of chrome-plated cast iron. The laboratory drum-dryer had two rolls each 6 in. in diameter by 7⅝ in. long with a total area of 2.0 sq. ft. Rolls in the pilot-plant dryer were 2 ft. in diameter by 3 ft. long and had a total area of 36 sq. ft. Steam pressure was adjustable from 2 to 120 p.s.i.g. for both dryers; clearance between the drums could be varied for each, and rotational speed was variable from 2 to 18 r.p.m. for the laboratory dryer, and from 1 to 8 r.p.m. for the pilot-plant dryer.

Drum-dried gluten was ground in a Mikro-Samplmill (Pulverizing Machinery Co., Summit, N. J.) equipped with screens having 0.020-, 0.042-, and 0.0625-in. holes, in a Raymond hammer mill (Combustion Engineering, Inc., Chicago, Ill.) equipped with a screen having 0.033-in. holes, and in a Labconco Heavy-Duty Attrition Mill (Laboratory Construction Co., Kansas City, Mo.) using a fine clearance.

Experimental Methods

To ensure that a wide range of physical characteristics was covered, patent, straight, first-clear, and second-clear flours were used to prepare wet gluten by the "batter process" as described by Anderson, Pfeifer, and Lancaster (2). These flours ranged in ash content from 0.41 to 1.95% on a dry basis. Wet glutens were produced containing 67 to 70% moisture and 60 to 85% total protein on a dry basis for these drying tests.

Prior to pilot-plant drying, samples of wet gluten were tested from each run to determine their dispersibility. Dispersibility tests were made by mixing wet gluten, distilled water, and glacial acetic acid in the Waring Blendor for about 4 minutes at several pH levels. The dispersed gluten samples were drum-dried, and the dry products tested for rehydration properties. The optimum pH level as shown by this test was used in the pilot-plant for that particular gluten. A sample of the wet gluten from each batch was also dried in a vacuum oven at 100°F. (38°C.) at 1 cm. Hg absolute for 16 hours for use as a vital gluten standard to determine the comparative quality of drum-dried products.

Pilot-plant dispersions were prepared by a variety of batch and continuous methods, using between 1.5 and 7.5% glacial acetic acid, based on the weight of dry gluten.

In the batch methods wet gluten was mixed with equal weights of ion-exchange water (hydrogen-cycle) containing the proper amount of acetic acid, and the dispersions were made as follows: in the ribbon blender, 3½ hours; Bump recirculating system, 2½ to 3 hours; Cowles dissolver, 30 to 90 minutes; Morden Stock Maker, 15 to 17 minutes; Premier colloid mill at 0.010-in. clearance, recirculation of a premixed slurry from the Cowles dissolver; Manton-Gaulin mill at 3,500 p.s.i.g. homogenizing pressure, recirculation of a premixed slurry from the Cowles dissolver.

In the continuous methods, wet gluten and dilute acetic acid were premixed batchwise in the Cowles dissolver for 7 to 9 minutes until the mixture became a uniform and fluid slurry. This slurry, containing about 16.5% solids, was fed to either the Morden or the Manton-Gaulin mill. When the Morden mill was used, the slurry was fed into the bottom of the Stock Maker until it was full. After 10 minutes, dispersion feed was pumped into the mill at such a rate that the dispersed gluten was displaced in about 10 minutes. The gluten dispersion was removed continuously from the top of the mill. When the Manton-Gaulin homogenizer was used, the slurry was recirculated and homogenized for 5 minutes, after which feed was pumped into the bottom of the mill container at a continuous rate so as to displace the homogenized gluten in 5 minutes. The gluten dispersion was removed from a constant level near the top of the homogenizer container.

Dispersed gluten was dried at a steam pressure of 20 p.s.i.g., either on the laboratory dryer at a rotational speed of about 12 r.p.m. or at 6 r.p.m. on the pilot-plant dryer, to produce 0.8 lb. or more of dry material per sq. ft. of drying area per hour. The roll clearance was set wide enough to give a dry gluten containing about 6% moisture. The vital product was scraped from the rolls and ground in an attrition or hammer mill at a temperature below 122°F. (50°C.). (See Fig. 1.)

The quality of the standard vacuum-dried and drum-dried glutens

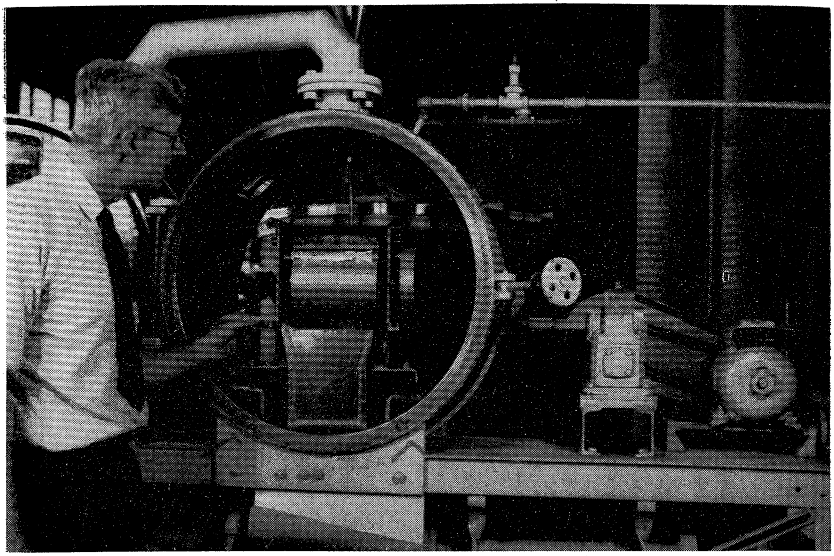

Fig. 1. Gluten dispersed in dilute acetic acid is dried on a laboratory drum-dryer at atmospheric pressure to yield a vital product.

was estimated from their nitrogen solubility in 0.1*N* acetic acid, the stretch and feel of gluten when rehydrated with water or buffer (4), and the results of baking tests. The vacuum-dried control usually has a nitrogen solubility of 95 to 98% and is arbitrarily assigned a rehydration value of 4. Rehydration is expressed on an arbitrary scale of 0, 1, 2, 3, or 4. Zero describes material so completely denatured that the gluten will not agglomerate, and 4 describes materials that behave like the vacuum-dried product. Baking quality of the glutens was determined by mixing dried gluten with a 13.5% protein spring wheat flour to obtain a blend of approximately 19.1% protein content. This proportion was equivalent to 10% of dried gluten (containing 75% protein, dry basis) and 90% of flour. The improved Kjeldahl method for nitrate-free samples (1) was used to determine protein (N × 5.7). Moisture was determined by heating a 2-g. sample in a vacuum oven at 100°–110°C. for 4 hours.

Results and Discussion

Effect of Type of Water Used in Dispersion. Hard, distilled, or deionized water, as well as water treated by ion-exchange (hydrogen-cycle) or by zeolite (sodium-cycle) can be used with glacial acetic acid in dispersing gluten for drum-drying (Table I). These dispersions were made in a Waring Blendor and were drum-dried with a roll

TABLE I

EFFECT OF WATER USED TO DISPERSE GLUTEN[a] PRIOR TO DRUM-DRYING

Type of Water Used for Dispersion in Waring Blendor	pH of Water	Dispersion[b]		Drum-Dried Gluten[c]	
		HAc Used, Percent of Dry Gluten	pH	Rehydration Test	Nitrogen Soluble in 0.1N HAc
		%		arb. units	%
Distilled	6.4	3.8	4.4	3[d]	84[d]
Deionized	6.1	3.8	4.4	3	86
Ion-exchange, hydrogen cycle	3.3	3.8	4.4	3	88
Zeolite-treated (sodium cycle)	7.1	5.0	4.3	3	87
Tapwater (500 p.p.m. total hardness)	7.2	5.0	4.3	3	86

[a] Gluten from second-clear flour; ash content 1.32%, protein content 73% (d.b.).
[b] Dispersions contained 16.5% by wt. solids.
[c] Dried gluten contained 72.7% total protein (d.b.).
[d] Soluble nitrogen 96% and rehydration value 4 for vacuum-dried gluten.

temperature of 267°F. (130°C.). However, zeolite-treated (sodium-cycle) and hard water required more acid than the other types. For preparing dispersions hydrogen-cycle ion-exchange water is recommended.

Effect of Dispersing Equipment. Either the Morden Stock Maker or the Manton-Gaulin homogenizer used in the batch or continuous methods is suitable for dispersing gluten in dilute acid as shown in Table II. Their vigorous action minimizes dispersing time and gluten degradation. The Cowles dissolver is suitable for preparing a gluten premix for further processing in a disperser. Batch methods for dispersing gluten using the ribbon blender, the pump recirculating system, or the Cowles dissolver required a long time to disperse the gluten and the product lost elasticity because of degradation. Long dispersion times usually resulted in drum-dried products of reduced rehydration values, although nitrogen solubilities were usually satisfactory.

In most cases dispersions made with high-protein gluten, 80% or higher dry basis, gave the best drum-dried products. Dispersions containing up to 20% solids can be made with high-protein gluten in the Morden Stock Maker, and drum-dried products of good quality are obtained.

Drum-Dryer Operating Conditions. Laboratory results indicate that highest drying rates were obtained at low steam pressure, wide roll clearance, high rotational speed, and with a feed puddle maintained between the rolls (Table III). More gluten was dried per sq. ft. of area at a lower temperature than at a higher one because a thicker gluten film adhered to the rolls. A drying temperature of

TABLE II

Effect of Equipment Used for Dispersing Wet Gluten Prior to Drum-Drying

Flour		Dispersion			Drum-Dried Gluten [a]		
Grade	Ash	Solids Content	Dispersing Time	pH	Total Protein	Rehydration Test	Nitrogen Soluble in 0.1*N* HAc
	% by wt. (d b)	*% by wt.*	*minutes*		*% (d b)*	*arb. units*	*%*
Morden Stock Maker							
Straight	0.41	16.5	15	4.8	79.5	3½ (3)[b]	91 (93)[b]
Second clear	1.32	16.5	17	4.5	72.7	2½ (3½)	85 (85)
Second clear	1.32	20.0	17	4.5	72.7	2½ (3½)	82 (85)
Second clear	1.32	16.5	17	4.6	80.8	3½ (3½)	95 (94)
Second clear	1.32	20.0	17	4.4	80.8	3 (3½)	94 (94)
Second clear	1.50	16.5	12[c]	4.4	81.3	3½ (3½)	91 (93)
Manton-Gaulin							
Second clear	1.50	16.5	5[d]	4.6	78.2	3 (3½)	87 (87)
Second clear	1.50	16.5	21[c]	4.6	76.3	3½ (3½)	89 (85)
Ribbon blender							
First clear	0.79	16.5	210	4.8	84.1	2½ (4)	78 (95)
Pump recirculation							
First clear	0.79	16.5	150	4.8	81.8	3 (3½)	84 (89)
Second clear	1.47	16.5	180	4.5	70.1	1½ (2)	85 (92)
Second clear	1.47	16.5	20	4.5[e]	70.1	1½ (2)	83 (92)
Second clear	1.47	16.5	20	4.5[f]	70.1	1½ (2)	83 (92)
Cowles dissolver							
Patent	0.41	16.5	30	4.5	79.9	3 (3½)	84 (92)
Patent	0.41	16.5	60	4.5	79.9	3 (3½)	88 (92)
Patent	0.41	16.5	90	4.5	79.9	3½ (3½)	92 (92)
Second clear	1.36	16.5	30	4.7	71.6	3 (3)	87 (93)
Second clear	1.36	16.5	60	4.7	71.6	2½ (3)	93 (93)
Second clear	1.36	16.5	90	4.7	71.6	2 (3)	93 (93)

[a] Soluble nitrogen 96% and rehydration value 4 for vacuum-dried glutens.
[b] Parenthesized figures are values obtained with dispersions prepared in Waring Blendor.
[c] Continuous. Gluten and acid premixed with Cowles dissolver for 8 minutes.
[d] Batchwise. Gluten and acid premixed with Cowles dissolver for 8 minutes.
[e] Dispersion passed once through Premier colloid mill.
[f] Dispersion passed once through Manton-Gaulin homogenizer.

TABLE III

DRUM-DRYING RATES FOR GLUTEN DISPERSIONS[a]

Flour		pH of Gluten Dispersion	Drum-Dryer Operation[b]			Drum-Dried Gluten			
Grade	Ash		Roll Clearance	Roll Speed	Rate[c]	Moisture Content	Total Protein	Rehydration Test	Nitrogen Soluble in 0.1*N* HAc
	% by wt. (d b)		*inches*	*rpm*	*lb/hr/ft*^{2}	*%*	*% (d b)*	*arb. units*	*%*
Patent	0.40	4.6	0.028	12	0.90	8.2	79.9	3½[d]	92[d]
	0.41	4.6	0.025	12	0.91	9.0	74.9	3	91
First clear	0.79	4.7	0.018	17	1.27	4.4	81.4	3½	88
	0.79	4.6	0.030	12	0.82	6.7	78.5	4	95
	0.79	4.7	0.028	12	0.90	6.1	83.2	3½	93
Second clear	1.32	4.4	0.047	12	0.84	6.0	80.8	3½	94
	1.32	4.5	0.051	12	0.99	6.0	80.8	3½	92
Second clear	1.32	4.4	0.032	18	1.18	6.2	75.0	3	86
	1.32	4.4	0.042	12	0.94	6.3	75.0	3	86
	1.32	4.5	0.037	12	0.52[e]	6.5	75.0	2½	82

[a] Dispersions contained 16.5% by wt. solids.
[b] Drying temperature 260°F. (127°C.).
[c] Pounds of dry material produced per hour per sq. ft. of roll surface.
[d] Soluble nitrogen 96% and rehydration value 4 for vacuum-dried glutens.
[e] No puddle maintained between the rolls.

about 260°F. (127°C.) was found to be most suitable for drum-drying. To obtain the best drying rate, the roll clearance was set just short of the spacing that gave a slightly damp drum-dried product. The roll clearance required thus roughly indicated the quality of the dried gluten. When a wide clearance could be used, the quality of the product was usually good; when a narrower clearance was required, the quality was usually poor, but the drying rate was increased.

Large batches of dispersed gluten dried on the pilot-plant drum-dryer resulted in products similar to those obtained on the laboratory dryer. However, the rotational speed of 6 r.p.m. on the larger dryer gave a slightly lower drying rate. Increasing the rotational speed of the rolls to 10 or 12 r.p.m. is necessary to raise the drying rate of the pilot-plant dryer to 1 lb. or more of dry material per hour per sq. ft. of drying area.

Grinding of Dry Gluten. Vacuum-dried gluten ground in either the hammer mill or the laboratory Mikro-Samplmill resembles available commercial vital glutens both in bulk density and in particle size (Table IV). When ground in a laboratory attrition mill, the vacuum-dried gluten is too coarse to pass a 100-mesh screen. Drum-dried gluten yields finer products in any of the three mills. Bulk densities vary from 0.42 to 0.57 g. per ml. for drum-dried glutens as compared to 0.79 to 0.82 g. per ml. for commercial vital glutens. To grind drum-dried gluten in the hammer mill, 33 watt-hours were consumed per lb. of dry product, whereas in the laboratory attrition mill only 27 watt-hours were required. When vacuum-dried gluten was ground in the hammer mill, 39 watt-hours were consumed per lb. of dry product.

TABLE IV
GRINDING DRIED GLUTEN IN VARIOUS MILLS

Type	Grinding: Mill	Grinding: Screen Openings	Ground Gluten: Sieve Analysis: Through 100-mesh	Ground Gluten: Bulk Density
		inches	%	*g/ml*
Vacuum-dried	Attrition	....	4	0.76
	Hammer	0.033	62	.76
	Mikro-Samplmill	0.020	51	.78
Drum-dried	Attrition	....	63	.42
	Hammer	0.033	92	.57
	Mikro-Samplmill	0.020	94	.54
Commercial No. 1	....	....	61	.79
No. 2	....	....	68	.80
No. 3	....	....	71	0.82

It is expected that in commercial mills drum-dried gluten would take considerably less power for grinding than would vacuum-dried.

Drum-dried gluten overheated when ground in the Mikro-Samplmill and in the hammer mill equipped with screens having 0.020- and 0.033-in. openings, respectively. The temperature of the product was kept below 122°F. (50°C.) by feeding ground, solid carbon dioxide with the dry gluten into both mills or by putting solid carbon dioxide in a jacket placed around the Mikro-Samplmill. When screens having 0.042-in. or larger openings were used, the product remained cool and about 90% of the particles passed through a 150-mesh sieve.

Baking Quality of Gluten from Different Flours. Drum-dried glutens for baking tests were prepared from eight different types of flour having wide ranges of physical and chemical characteristics and ranging in grade from patent flour to high-ash second-clear flour (Table V). The baking quality scores of vacuum-dried and drum-dried glutens separated from these flours are listed in Table VI. All vacuum-dried glutens and six of the drum-dried glutens exhibited good baking

TABLE V

PREPARATION OF DRUM-DRIED GLUTEN FROM VARIOUS FLOURS

Flour			Dispersion [a]		Drum-Dried Gluten		
Grade	Ash	Protein	HAc Used, Percent of Dry Gluten	pH	Total Protein	Rehydration Test	Nitrogen Soluble in 0.1*N* HAc
	% by wt (d b)	*% by wt (d b)*	*%*		*% by wt (d b)*	*arb. units*	*%*
Patent (HRW)	0.41	14.3	2.3	4.6	85.7	4 [b]	97 [b]
Straight (HRS)	0.41	17.2	1.5	4.8	78.8	3½	92
Second clear							
A	0.84	16.3	2.5	4.6	78.4	3½	93
B	1.26	16.9	3.0	4.6	75.4	3½	94
C	1.26	16.1	2.5	4.6	75.0	3	92
D	1.27	17.9	4.0	4.6	73.4	3	88
E	1.89	19.8	7.5	4.3	73.9	2½	85
F	1.95	19.8	7.5	4.3	71.0	1	78

[a] Dispersions contained 16.5% by wt. solids.
[b] Soluble nitrogen 97% and rehydration value 4 for vacuum-dried glutens.

qualities, but the baking quality decreased with increase in the ash content of the flour. Best results were obtained with glutens from the patent and straight flours.

Although most drum-dried glutens exhibited good baking qualities, they were somewhat below those of the corresponding vacuum-dried controls. The volume score was chiefly responsible for the low-

TABLE VI
Baking Quality of Drum-Dried Gluten from Various Flours

Gluten Used for Fortification	Absorption	Loaf Volume[a]		Volume (15)		Crust Color (5)		Symmetry (5)		Evenness (5)		Texture (15)		Grain (10)		Crumb Color (10)		Aroma (15)		Taste (20)		Total Score (100)	
		DD[b]	VD[c]	DD	VD	DD	VD	DD	VD	DD	VD	DD	VD	DD	VD	DD	VD	DD	VD	DD	VD	DD	VD
	%	*ml*	*ml*																				
Patent (HRW)	72.0	960	1075	10	14	4	4	4	4	4	4	13	13	8	6	9	9	13	13	18	18	83	85
Straight (HRS)	76.0	920	985	8	11	4	4	4	4	4	4	12	13	9	9	9	9	14	14	18	18	82	86
Second clear																							
A	76.0	830	945	5	9	4	4	4	4	4	4	11	13	8	9	7	8	14	14	18	18	75	83
B	74.7	855	950	6	9	4	4	4	4	4	4	12	13	9	9	8	8	14	14	18	18	79	83
C	75.5	905	905	8	8	4	4	4	4	4	4	12	12	8	9	9	8	14	14	18	18	81	81
D	74.7	860	950	6	9	4	4	4	4	4	4	12	12	8	8	9	8	14	14	18	18	79	81
E	74.7	690	920	0	8	4	4	4	4	4	4	9	11	6	7	6	8	14	14	18	18	65	78
F	74.5	690	890	0	7	4	4	4	4	4	4	9	12	6	8	6	8	14	14	18	18	65	79

[a] Loaf volume from standard white flour without fortification, 780 ml.
[b] Drum-dried.
[c] Vacuum-dried.

ered total baking score. Drum-dried glutens from low-ash flour were superior to similar products from high-ash flour. More acid was required to disperse gluten from high-ash flour, and in the case of flours with very high ash content (1.9%), a low-grade product resulted regardless of the amount of acid used.

Drum-dried products of excellent quality can be produced from wet wheat gluten separated from low-ash flours. Good-quality vital products can be made from wet gluten separated from other types of flour except those of very high ash content. The quality of drum-dried gluten from high-ash flours could usually be improved by using a lower solids content or pH of the dispersion, or by increasing the protein content (dry basis) of the wet gluten by better washing during separation.

Optimum Process Conditions

Wet wheat gluten from low-ash flours can be drum-dried commercially to a vital product after batch or continuous dispersion. Gluten premixed in a solution of acetic acid in water from an ion-exchanger (hydrogen cycle) can be dispersed by a Morden Stock Maker or a similar disperser equipped with a stator and adjustable rotor. Power required for such equipment, which imparts vigorous shear and impact action to the gluten in a short time, is approximately 125 watt-hours per lb. of dry gluten for a dispersing cycle of 15 minutes on a suspension containing 16.5% of gluten solids.

This dispersion is fed to a double drum-dryer at a pH ranging from 4.3 to 5.1. The optimum conditions under which 1 lb. of dry gluten per hour per sq. ft. of drying area is obtained are: a drying temperature about 260°F. (127°C.), a rotational speed of the drums about 12 r.p.m. or higher, and a roll clearance determined by the dryness desired. The dry vital gluten is pulverized to a suitable size in an attrition mill or in a hammer mill having a screen with 0.0625-in. holes.

The conditions used for producing vital gluten in the pilot plant can easily be adapted in commercial plants equipped with standard drum dryers, but it would be necessary to obtain suitable stainless-steel equipment for preparing the dispersion. The dried product should be entirely suitable for food uses or for preparing industrial chemicals.

Costs

A cost estimate has been prepared for a plant producing 6 million pounds annually of vital gluten with about 6% moisture by the proc-

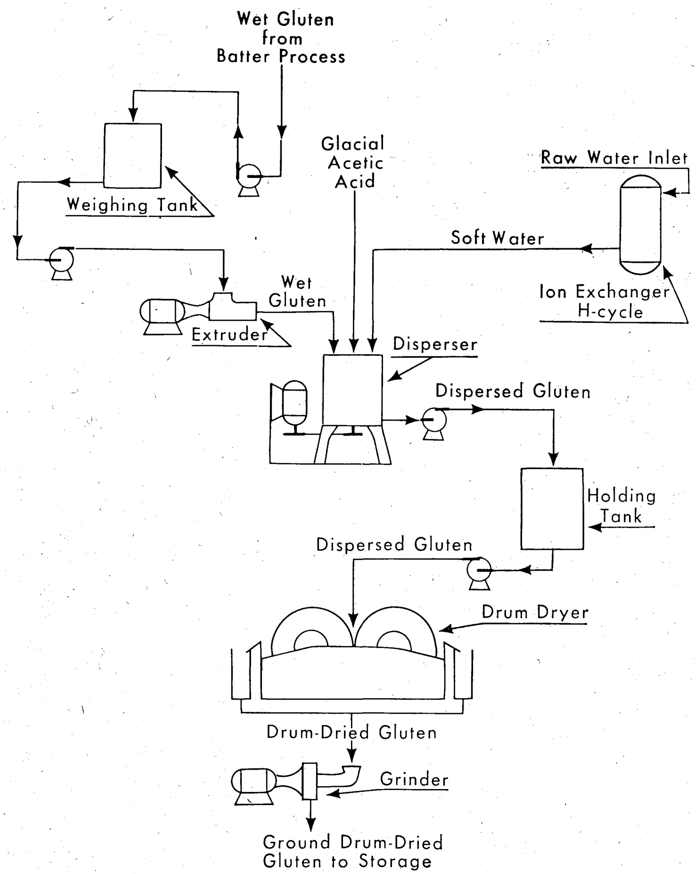

Fig. 2. Flow sheet for production of drum-dried gluten.

ess described. Assumptions made are that the vital gluten plant operates 20 hours per day for 250 days a year and is operated in conjunction with a plant from which wet gluten could be obtained. A flow sheet on which the cost estimate is based is shown in Fig 2. Table VII lists the land, building, and equipment required; the fixed capital investment is $477,000. Stainless-steel equipment is specified where necessary, and drum-dryers must be equipped with chrome-plated cast-iron rolls. Steam-generating facilities are not included as part of the equipment, but a charge for the steam utilized has been included in production costs. Table VIII shows the estimated drying cost to be 4 cents per pound of dry material when the plant is operated with a dryer capacity of 1 lb. of dried gluten per hour per sq. ft. of roll surface. This figure does not include the cost of the wet gluten, working

TABLE VII

FIXED CAPITAL INVESTMENT FOR A PLANT PRODUCING 6 MILLION POUNDS ANNUALLY OF DRUM-DRIED GLUTEN

ITEM	COST	
Land	$ 1,000	
Building (75 by 65 by 12 ft.)	44,000	
Building improvements	7,000	
Total building cost		$ 52,000
Equipment, delivered:		
1 Cation exchanger, 6 cu. ft., high-capacity resin (30 kg/cu. ft.), S.S.	$ 2,800	
4 Drum-dryers, 300 sq. ft., chrome-plated rolls	144,000	
2 Dispersing units, 330 gal/hour, 25 hp., S.S.	20,000	
2 Tanks, 200 gal., S.S.-clad	1,700	
1 Tank, 600 gal., S.S.-clad	2,000	
1 Extruder, 150 lb/minute, 5 hp.	700	
3 Positive displacement pumps, 75 g.p.m., 5 hp., S.S.	9,000	
1 Storage tank, 2,000-gal., S.S. clad	3,500	
1 Storage tank, 100-gal., steel	150	
1 Positive displacement pump, 30 g.p.m., 3 hp., S.S.	2,000	
1 Centrifugal pump, 5 g.p.m., 1/4 hp., S.S.	300	
1 Centrifugal pump, 50 g.p.m., 2 hp., S.S.	1,300	
1 Hammer mill, 50 hp.	5,000	
1 Scale	400	
1 Scale	150	
Conveyors	4,000	
Storage bins	4,000	
Bagger	2,000	
Total equipment cost, delivered		$203,000
Installation of equipment, 25% of delivered cost		50,750
Piping, wiring, instrumentation, 25% of installed cost		63,450
Contingencies, 15% of equipment installed complete with piping, etc.		47,600
Engineering fees, 15% of equipment installed complete with piping, etc.		47,600
Contractors fees, 4% of equipment installed complete with piping, etc.		12,600
Fixed capital investment		$477,000

TABLE VIII

ESTIMATED COST TO PRODUCE 6 MILLION POUNDS ANNUALLY OF DRUM-DRIED VITAL GLUTEN

(Basis 250 operating days per year, 20 hours per day)

ITEM		COST	
		Per Year	Per Pound
Raw material:			
Glacial acetic acid, 222,200 lb., 10 cents/lb.	$22,220		
Sulfuric acid 66° Bé, 9,000 lb., $2.25 per 100 lb.	203		
		$ 22,423	0.0037
Utilities:			
Water 2,031,000 gal. at 7.5 cents/1,000 gal.	$ 153		
Steam 39,771,000 lb. at 80 cents/1,000 lb.	31,817		
Power 1,569,290 kw.-hr. at 1.5 cents/kw.-hr.	25,539		
		$ 55,509	0.0093

(Continued)

TABLE VIII *(Continued)*

Item		Cost Per Year	Cost Per Pound
Labor and supervision:			
3 Men for dispersing, \$2.50/hour	\$15,000		
3 Men for drum-drying, \$2.50/hour	15,000		
3 Men for drum-dryer helper, \$2.25/hour	12,000		
3 Men for grinding and bagging, \$2.50/hour	15,000		
1 Foreman	5,500		
1 Superintendent \$10,000/year, ½ time	5,000		
Overhead	10,125		
		\$ 77,625	0.0129
Maintenance:			
Equipment, 5%/year	\$21,250		
Building, 2%/year	1,040		
		\$ 22,290	0.0037
Fixed charges:			
Depreciation: Building 3%/year	\$ 1,530		
Equipment 10%/year	42,500		
Taxes and insurance, 3%/year	14,310		
		\$ 58,340	0.0098
Miscellaneous factory supplies and expenses		5,000	0.0008
Total		\$241,187	0.0402

capital charges, selling and administrative expenses, interest, income tax, or profit.

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