FRACTIONATION OF BARLEY AND MALTED BARLEY FLOURS BY AIR CLASSIFICATION[1]

J. R. VOSE and C. G. YOUNGS, National Research Council of Canada, Prairie Regional Laboratory, Saskatoon, Sask. S7N 0W9

ABSTRACT

Cereal Chem. 55(3): 280-286

Methods were developed for dehulling commercial brewers' malted barley involving roller milling and screening. The resulting product obtained in 77% yield and also similar products derived from dehulling field barley cultivars were then pin milled. These flours were partitioned by air classification into their more dense, low-fiber starch fractions (84% yield) and their less dense, low-fiber, high-protein flours (16% yield). Examination of the malt starch granules by scanning electron microscopy demonstrated their relative freedom from damage following pin milling of the germinated and kilned malt. The α-amylase activity was partly concentrated into the dense starch fraction; the malt aroma and flavor were partitioned into the less dense fractions.

For many years the milling industry has separated cereal grain flours by air classification into fractions containing differing proportions of protein, starch, fiber, and other components (1,2). Recently, Pomeranz *et al.* (3) have reported that commercial malt flours could be partitioned into fractions of differing particle size with a laboratory microclassifier. They failed, however, to demonstrate any significant shift in protein following air classification of a commercial barley malt flour. We have pursued similar studies on both malted barley and barley grain, and have achieved successful fractionation of their components into three streams, namely, high-fiber, starchy, and intermediate protein flours.

MATERIALS AND METHODS

Processing

Samples of commercial brewers' malted barley were obtained from Molson Breweries Ltd., Montreal. The barley (cultivar Betzes) was obtained from Dr. B. L. Harvey, and the waxy barley (C.I. 4382), from A. Wenhardt, of the Crop Science Department, University of Saskatchewan, Saskatoon.

The malted barley was first dehulled by a double pass through a smooth roller mill (0.008-in. clearance); the fibrous hull fraction was then removed on a Sweco screen (28 mesh). Barley and waxy barley were dehulled using a Hill grain thresher (4) with a stone speed of 735 rpm and a process feed rate of 1,000 lb/hr.

The dehulled grains from either the malted or unmalted barley were milled in an Alpine pin mill, Model 250 CW, at a rotor speed of 6,000 rpm on the door side of the mill and a counter rotation speed of 11,500 rpm on the opposing pins. The feed rate was 400 lb/hr. The flours thus produced were then separated into fine and coarse fractions using an Alpine air classifier, Type 132 MP, at vane settings to yield an approximate 15-μm cut size. The feed rate to the classifier was about 45 lb/hr.

[1]Issued as NRCC No. 16357.

0009-0352/78/000032$03.00/0

Analytic Methods

The nitrogen content of the flours was determined using a Hewlett-Packard 185 B CHN Analyzer; a conversion factor of 6.25 was used to convert percent of nitrogen into an estimate of protein. The amino acid content of the flours was determined by hydrolyzing samples in a sealed tube under a nitrogen atmosphere with 5.7*N* HCl for 20 hr at 110°C. Hydrolysates were evaporated to dryness *in vacuo* and made up to the appropriate volume in 0.01*N* HCl. Aliquots of these solutions were analyzed using a Beckman amino acid analyzer, Model 120 C.

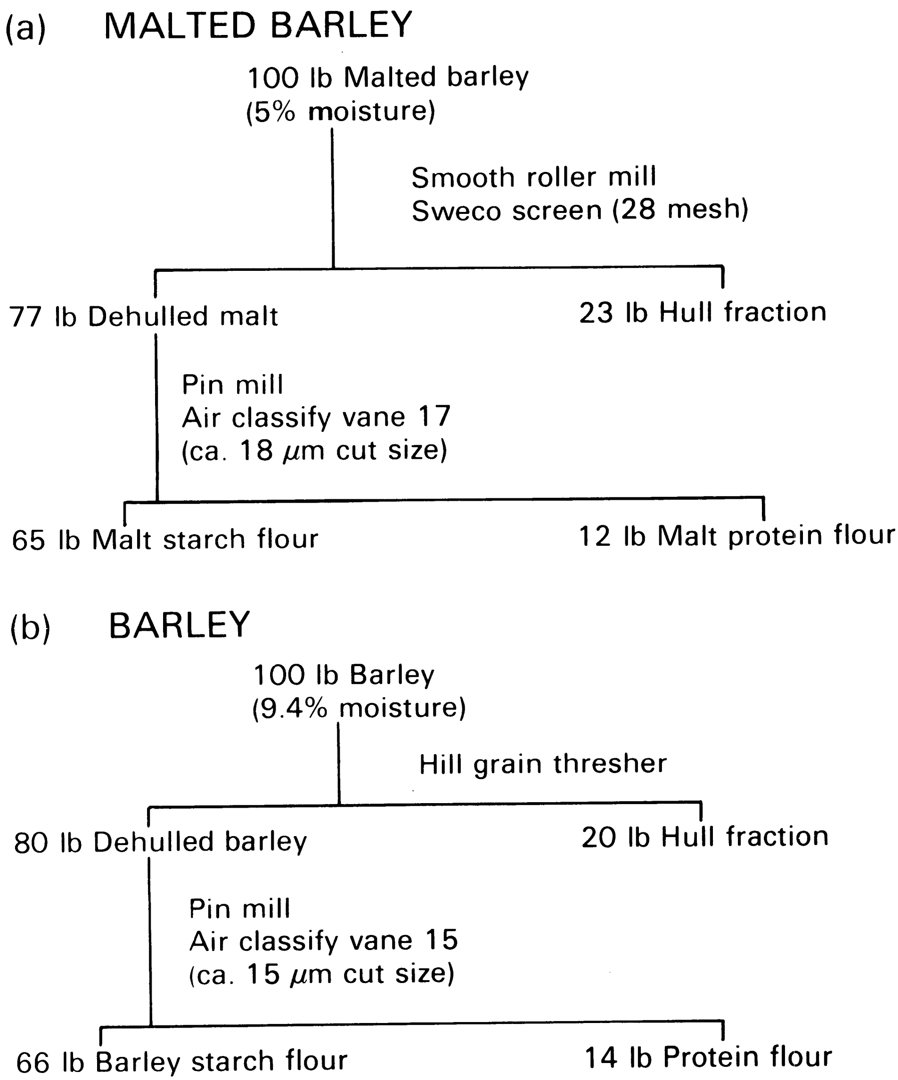

Fig. 1. Schematic flow diagram for processing of barley and malted barley.

The starch content of these flours was determined by the AACC polarimetric method 76-20 (5); these results agreed with the dual enzyme starch assay (6). Moisture was determined as described in AACC approved method 44-15A (5), and crude fiber by the procedure that Stringham *et al.* (7) described, a micromodification of AACC approved method 32-15. Analysis for insoluble dietary fiber (neutral detergent fiber) was according to the AACC proposed analysis procedure, which is based on the method of Goering and Van Soest (8). Starch is hydrolyzed by reaction with 2.5% w/v α-amylase (Sigma A6880, Sigma Chemical Co., St. Louis, MO). Results are presented on a dry-weight basis.

Sieve analyses were made using an Allen-Bradley sonic sifter with the appropriate screens.

Amylolytic activity of malt samples was determined by incubation of 9.8 ml of a 1% w/v gelatinized corn starch suspension with 0.2-ml aliquots of a malt flour, protein, or starch fraction suspension (50 mg mixed thoroughly with 2 ml of water). The reaction was allowed to proceed for 60 min at 50° C, and the quantity of reducing sugar produced from the hydrolyzed starch was assayed by the dinitrosalicylic acid procedure (9). Results were expressed in terms of grams of reducing sugar produced from 100 g of cornstarch/hr at 50°C per 1-g malt sample. The specific amylolytic activity was calculated as above and expressed on a basis of protein content of the malt flour sample.

Amylographs were prepared on a Brabender Viscoamylogram with a 700 cm-g sensitivity cartridge at 75 rpm. The procedure used was according to AACC Approved Method 22-10 (5) with a heating and cooling rate of 1.5°C/min.

Structural characteristics of the flours examined in this work were determined with a scanning electron microscope (SEM) (Cambridge Stereoscan Mark II). Samples were dusted onto adhesive tape attached to circular (1.3-cm diameter) aluminum studs prior to coating with approximately 100 Å of gold.

RESULTS AND DISCUSSION

The processes used in this study are shown in Fig. 1. Results with the waxy barley were similar to those achieved with the normal barley. The malted kiln-dried barley was friable, and due to excessive kernel shattering, could not be effectively dehulled in the Hill grain thresher. Grinding through the smooth roller mill followed by removal of the hulls by screening proved effective. The actual hull content measured by hand dehulling of the barley and waxy barley was 13%, while the malted barley hull content was 15%. Mechanical dehulling resulted in barley flours containing 1.5 to 2.0% crude fiber. The level of fiber as assayed by the neutral detergent fiber procedure (8) was 38.5 and 47.6% for the hull fractions obtained from malted barley and barley, respectively.

The coarse dehulled malt or barley grains were then pin milled to yield a fine flour. These flours were then air classified to yield a dense fraction containing about one-third of the protein content of the less dense fractions. The results achieved with the waxy barley were comparable to those from the processed barley flour. The starchy flour fractions were obtained in 65% yield from the whole grains, and were low in both protein and fiber.

The Brabender Viscoamylograms of the two barley starchy flours are shown in Fig. 2. The amylose content of the waxy barley cultivar was 2%; the gels from this low amylose starchy flour obtained by air classification demonstrated a characteristic lack of retrogradation compared with similar fractions obtained from Betzes barley. Malted barley starch I was saccharified during the pasting process; there was no viscosity development.

Pomeranz *et al.* (3) previously reported that in the fractionation of commercial malt flour, the coarse fraction (>250-μm diameter) was higher in protein (12.5%), diastatic power, and α-amylase activity than was the finer (<250 μm), low-protein (9.1%) fraction. Their commercial malt flour sample yielded 46% over a 250-mesh Tyler screen. These authors subjected the finer fraction (through a 250-μm screen) to classification with a Bahco microparticle classifier (a combination air centrifuge-elutriator). The coarse, medium, and fine fractions produced contained 10.5%, 7.6%, and 10.8% protein, respectively. The diastatic power of the coarse fraction was almost double that of the fine fraction.

The results reported in Table I demonstrate that a significant shift in protein from starch can be achieved with application of the technique of air classification to pin milled dehulled barley and malted barley flours. The commercial malt

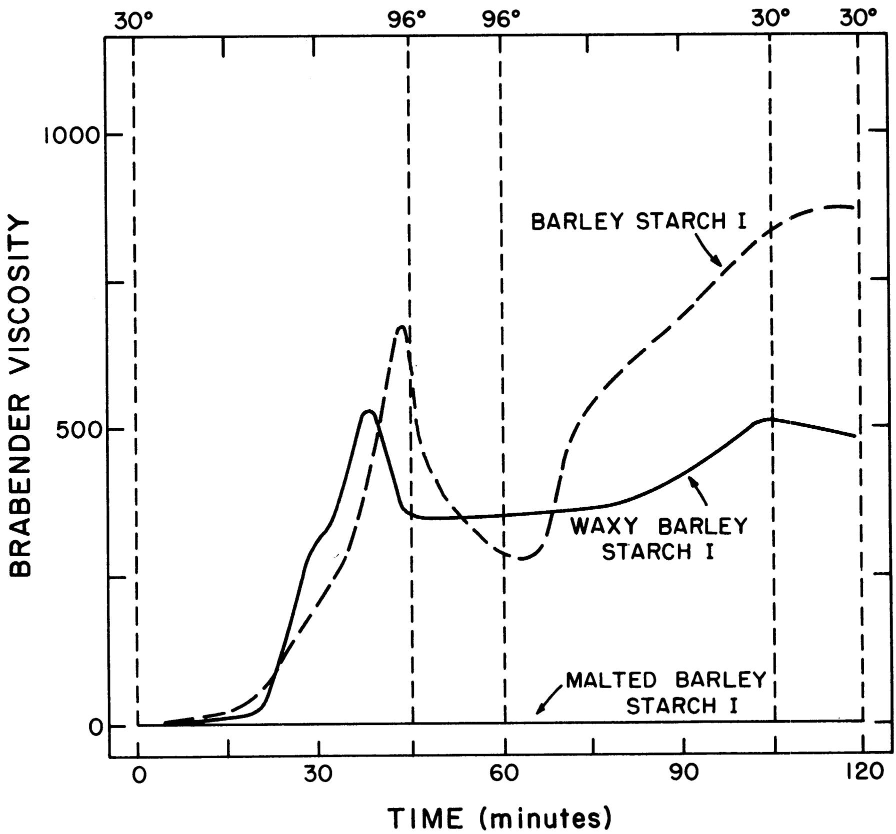

Fig. 2. Viscoamylogram of barley and waxy barley starchy flour fractions (8% w/v) obtained by air classification.

flour that Pomeranz *et al.* (3) used was presumably too coarse for a successful partition of the protein by air classification. Pin milling of malted barley or barley grain resulted in fine flours (80% through a 63-μm screen) suited to fractionation in a spiral airstream as evidenced in Fig. 1.

Although these results were expected with flour obtained from barley grain, the apparent resilience of the malt starch to processing by pin milling was of considerable interest. SEM studies of malted barley flours (10,11) have indicated that after malting, the induced amylases have had only minor effects on the integrity of the starch granules. Further, while the starch granules are freed from the embedding matrix during the germination period of malting, there is little indication of structural changes in the granules except immediately adjacent to the scutellum (12). Examination of SEM micrographs showed that the process of malting barley involving steeping, germination, and kilning followed by a pin milling procedure resulted in only some granular surface pitting and exfoliation of the starch grains. A predominance of intact large and small granules were observed in these flours.

The amylolytic activity of the fractions obtained by air classification of malt flour is shown in Table II. The enzymatic potential of the malt starch fraction to

TABLE I
Proximate Analysis of Air-Classified Malted Barley and Barley Flours

Sample	Protein (N × 6.25) (%)	Starch (%)	Crude Fiber (%)
Malted barley	11.1	53	5.6
Dehulled malt	11.7	60	1.8
Hulls	11.5	32	12.6
Malt protein flour	26.8	38	1.9
Malt starch flour	9.5	64	2.5
Barley	15.2	57	3.7
Dehulled barley	14.8	68	1.6
Hulls	14.3	13	12.1
Barley protein flour	40.1	34	1.6
Barley starch flour	10.2	72	1.6

TABLE II
Amylolytic Activity of Malted Barley Fractions Obtained by Air Classification

Sample	Protein (%)	Amylolytic Activity[a]	Specific Activity[b]
Malt flour	11.1	45	41
Malt protein	20.3	51	25
Malt starch	9.3	44	56

[a]Grams of reducing sugar produced from 100 g of corn starch per hour at 50°C per 1 g of malt sample.
[b]Grams of reducing sugar produced from 100 g of corn starch per hr at 50°C expressed on a basis of equivalent sample protein content.

TABLE III
Amino Acid Composition of Malted Barley and Barley Grain Protein Factors Produced by Air Classification of Pin-Milled Malted Barley and Barley Grain Flours[a]

Amino Acid	Malt Protein	Barley Protein
Aspartic acid	7.06	5.62
Threonine	3.70	3.41
Serine	4.22	4.22
Glutamic acid	16.59	21.68
Proline	10.20	12.41
Glycine	4.00	3.68
Alanine	4.69	3.65
Cystine	1.42	1.82
Valine	4.58	4.51
Methionine	2.67	2.22
Isoleucine	3.28	3.28
Leucine	6.78	7.15
Tyrosine	3.10	3.51
Phenylalanine	2.05	3.17
Lysine	4.87	3.90
Histidine	2.49	2.37
Arginine	7.60	6.67

[a]Grams of amino acid per 16 g of nitrogen.

hydrolyze gelled corn starch was not significantly decreased when compared with the dehulled malt flour control. When the results are calculated on the basis of the protein content of these flours, the air classification process apparently resulted in a concentration of the amylolytic enzymes into the more dense starchy fractions.

The data in Table III show the amino acid composition of the protein fraction obtained by air classification of the malt flour and barley grain flour. This analysis accounted for 89.3 and 93.3% of the nitrogen in the samples, respectively; the balance was presumably comprised of nonprotein nitrogen compounds.

The characteristic aroma and flavor of the malt were evaluated subjectively and found to be partitioned into the less dense, higher protein fraction. This fraction was readily dispersible in cold water, but a bitter peptide-like flavor developed after a 15-min incubation period. Development of this flavor in aqueous suspensions of this malt fraction could be prevented by pretreatment of the flour with heat. This is done by exposing the samples to a 30-sec heating period in a continuous 2,450-MHz microwave cooker at a 1.5-kw power level.

The process of air classification of dehulled pin milled malt barley or barley flours results in production of low-fiber, low-protein starch flours in 65% yield. Such air classified flours from malted barley have amylolytic properties comparable to the original dehulled flours. Any benefit accrued from use of these defibered starchy malt or barley flours in a brewing operation would have to compensate for the extra processing costs incurred in this operation, plus any potential returns from the malt or barley fiber and protein flours.

Acknowledgments

We thank D. Dymond, B. Panchuk, and K. Simpkins for expert technical assistance and M. Farmer, of the Department of Animal Science, University of Saskatchewan, for amino acid analyses.

We also acknowledge the support of the Electrical Engineering Division of the National Research Council, Ottawa, for loan of the continuous microwave apparatus.

Literature Cited

1. GRAHAM, J. C. The use of air classification in the flour milling industry. Milling 144: 215 (1965).
2. HAYASHI, M., D'APPOLONIA, B. L., and SHUEY, W. C. Baking studies on the pin-milled and air-classified flour from four hard red spring wheat varieties. Cereal Chem. 53: 525 (1976).
3. POMERANZ, Y., FINNEY, K. F., BOLTE, L. C., and SHOGREN, M. D. Classifying malt by sieving and air centrifuging: Elutriating techniques. Cereal Chem. 53: 956 (1976).
4. REICHERT, R. D., and YOUNGS, C. G. Dehulling cereal grains and grain legumes for developing countries. I. Quantitative comparison between attrition and abrasion type mills. Cereal Chem. 53: 829 (1976).
5. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved methods of the AACC. Method 22-10, approved May 1960; Method 32-15, approved April 1961; Method 44-15A, approved May 1960; and Method 76-20, approved January 1969. The Association: St. Paul, Minn.
6. BANKS, W., GREENWOOD, C. T., and MUIR, D. D. The characterization of starch and its components. 2. The semi-micro estimation of the starch content of cereal grains and related materials. Staerke 22: 105 (1970).
7. STRINGHAM, G. R., McGREGOR, D. I., and PAWLOWSKI, S. H. Chemical and morphological characteristics associated with seed coat color in rapeseed. Proceedings of the 4th International Rapeseed Conference: Giessen, Germany (1974).
8. GOERING, H. K., and VAN SOEST, P. J. Forage fiber analyses. USDA Agricultural Handbook #379. p. 5, 6, 8. U.S. Government Printing Office: Washington, DC (1970).
9. SUMNER, J. B., and HOWELL, S. F. A method for determination of invertase activity. J. Biol. Chem. 108: 51 (1935).
10. POMERANZ, Y. Scanning electron microscopy of the endosperm of malted barley. Cereal Chem. 49: 5 (1972).
11. PALMER, G. H. Morphology of starch granules in cereal grains and malts. J. Inst. Brew. 78: 236 (1972).
12. DICKSON, J. G., and SHANDS, H. L. Cellular modification of the barley kernel during malting. Amer. Soc. Brew. Chem. Proc. p. 1 (1941).

[Received July 7, 1977. Accepted October 17, 1977]