Effect of Seed Moisture Content on the Air Classification of Field Peas and Faba Beans[1]

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ABSTRACT

Starch and protein concentrates were prepared by pin milling and air classifying dehulled samples of field peas and faba beans containing 3.8–14.3% moisture. Seed moisture content affected both the yield and the composition of the air-classified fractions. Reductions in seed moisture were accompanied by declines in starch fraction yield, protein contents of the starch and protein fractions, and starch separation efficiency. In contrast, protein fraction yield, starch contents of the starch and protein fractions, protein separation efficiency, and neutral detergent fiber content of the protein fraction were greater at lower seed moistures. Two measures of seed hardness, one based on grinding time and the other on fineness of grind, revealed an increase in hardness at lower moisture contents. Increases in seed hardness were paralleled by increases in impact milling efficiency. Lower rates of feed to the air classifier (at a particular feed-gate setting) were observed at lower flour moistures. However, no improvement in the sharpness of the separation at lower feed rates was detected.

The moisture content of roller-milled wheat flours has a marked effect on the degree of protein displacement achieved when the flours are fractionated by impact milling and air classification (Kent 1965; Stringfellow et al 1963, 1964). Although air classification has been applied to a number of grain legumes (Colonna et al 1980, Kon et al 1977, Reichert and Youngs 1978, Sosulski and Youngs 1979, Tyler et al 1981, Vose et al 1976, Youngs 1975), the effect of seed moisture content has not been determined. In this article, we present data regarding the air classification of field peas and faba beans pin milled at a range of moisture contents.

MATERIALS AND METHODS

Processing

Smooth-seeded, yellow field peas (*Pisum sativum* L. cv. Trapper) and faba beans (*Vicia faba minor* L. cv. Maris Bead) were obtained from Newfield Seeds Ltd., Saskatoon, Saskatchewan. Both samples were from commercial lots grown in Saskatchewan in the 1979 crop year.

Air-dried samples of each legume were dehulled in a Currier type of plate mill. The hulls were removed by aspiration and the dehulled seed divided into subsamples of approximately 25 kg. Moisture contents were adjusted by gradual addition of water as the samples were agitated in a horizontal, barrel type of mixer or by drying in a forced-air oven at 50°C. The samples were then stored at 20°C in double-walled plastic bags for a minimum of 5 days before milling to ensure uniform moisture distribution. Final moisture contents were 14.3, 12.4, 10.5, 6.9, 5.3, and 3.8% for peas and 14.2, 11.2, 8.8, 5.1, and 3.8% for faba beans.

Samples were pin milled in an Alpine pin mill model 250 CW (Alpine American Corp., Natick, MA) with counterrotating pins operating at 6,000 and 11,500 rpm. The feed rate was approximately 300 kg/hr. Each flour was divided into two subsamples of approximately 12 kg. The replicates were fractionated into starch and protein concentrates, using an Alpine air classifier type 132 MP at feed rates of approximately 50 kg/hr and a vane setting of 20 (corresponding to a cut-point of approximately 18 μm). Because of unavoidable losses in the fines collection system, protein fraction yields were calculated as the difference between the dry weights of the classified flour and the recovered starch fraction. Dry weights were used to negate the effect on fraction yields of moisture changes during air classification.

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Analytical Methods

Moisture, protein, and neutral detergent fiber (NDF) were determined by AACC procedures (1969) and starch by the dual enzyme method of Banks et al (1970). Starch damage was determined by a modification of the method of Vose (1977), using 150-mg samples of vacuum oven-dried, pin-milled flours that were washed with 80% ethanol (to remove reducing sugars) and allowed to air dry before the assay.

Hardness Testing

Two variables were used as indices of seed hardness as a function of moisture content: 1) the time required to grind 4 g of a 6-g sample in a Brabender Micro-Hardness-Tester (C. W. Brabender Instruments Inc., South Hackensack, NJ) at a head setting of 3, and 2) the proportion of a flour that passed through a 38-μm screen when the flour was sifted on an Allen-Bradley sonic sifter (ATM Corporation, Milwaukee, WI) using 250, 180, 150, 106, 74, and 38-μm sieves. The flour was produced by grinding a 5-g sample in a model 1092 Cyclotec sample mill (UD Corporation, Boulder, CO) equipped with a smooth copper liner and a 1-mm screen. To enable the use of the same grinding-head setting on the Brabender instrument for both peas and faba beans and to improve sample feeding characteristics with the Cyclotec mill, samples were first cracked in a Hobart coffee mill (Hobart Manufacturing Co., Toronto, Ont.) at progressively decreasing plate spacings. The material passing through a 6-mesh sieve (Tyler) but retained on a 7-mesh was collected after each cracking and bulked for use in the hardness determinations.

Calculation of Starch and Protein Separation Efficiency

The percentage of the total starch in the pin-milled flour that was recovered in the starch fraction (SF) was used as a measure of starch separation efficiency (SSE). Similarly, the percentage of the flour protein recovered in the protein fraction (PF) was used as a measure of protein separation efficiency (PSE).

Statistical Analysis

Data were subjected to analysis of variance and Duncan's multiple range test (Duncan 1955).

RESULTS AND DISCUSSION

Field peas and faba beans responded in similar fashion to seed moisture variations when pin milled and air classified (Table I). SF yield, the protein contents of the SF and the PF, and SSE declined as seed moisture content was reduced, whereas PF yield, the starch contents of the SF and the PF, PSE, and the NDF content of the PF showed increases. For each of these characteristics, a moisture content existed below which no significant change occurred ($P < 0.05$).

An increase in the PF yield, a decline in protein and increase in starch in the SF, and improved PSE can be explained on the basis of improved milling efficiency at lower moisture contents, resulting in a more complete separation of protein and starch when the flours were air classified. The observed increase in starch in the PF might be expected if the starch granules were more susceptible to damage at lower seed moistures. However, significant increases in damaged starch were not detected (Table I), which may reflect a lack of sensitivity in the starch damage assay. Decreased SSE was the result of both increased starch content of the PF and increased PF yield at lower seed moistures. Increases in starch do not fully account for the decline in protein concentration in the PF; apparently, other seed components were concentrated in the PF to a greater extent at lower moisture contents. The increased concentration of NDF in the PF (Table I), attributable to finer grinding of cell wall material, and the significant correlation coefficients between the NDF levels and PSE ($r = 0.889$ and 0.894, $P < 0.01$, for peas and faba beans, respectively) are indicative of increased dilution of protein in the PF by material other than starch and of improved milling efficiency.

Results of the seed hardness measurements are also shown in Table I. Each method gave significant correlation coefficients with two indices of impact milling efficiency, namely PSE and NDF concentration in the PF (Table II). The trend in the fineness-of-grind data toward decreased yields of very fine (<38 μm particle diameter) material at lower seed moistures may be interpreted as an increase in seed hardness with declining moisture content. This suggests, considering the improved PF yields at lower seed moistures, that impact milling is more efficient as seeds become harder. However, in contrast to the Cyclotec-ground flours, the pin-milled flours contained more finely-ground material (because PF yields were higher) when milled at lower seed moisture contents. This difference in response to moisture variations is probably due to the nature of the grinding processes. The Cyclotec mill relies not only on impact but also on shearing and abrasion for breakdown of the seed. Hence, increased seed hardness might be expected to result in the production of a flour containing less finely-ground material. In the pin mill, seeds are shattered as they strike a hard

TABLE I
Air Classification and Hardness Data[a] for Dehulled Field Peas[b] and Faba Beans[b] at Various Moisture Contents[c]

Seed Moisture (%)	Product Yield (%) SF	Product Yield (%) PF	Protein[d] (%) in SF	Protein[d] (%) in PF	Starch (%) in SF	Starch (%) in PF	DS (%)	SSE (%)	PSE (%)	NDF in PF (%)	Seed Hardness[e] Time (sec)	Seed Hardness[e] Fines (%)
Field Peas												
14.3	81.1 a	18.9 a	13.8 a	51.7 a	68.3 a	7.4 a	3.5 a	97.9 a	46.1 a	5.7 a	26.5 a	33.5 a
12.4	72.2 b	27.8 b	11.8 a	49.1 b	76.3 b	8.4 ab	3.3 a	97.4 ab	62.6 b	7.3 b	30.0 ab	26.5 b
10.5	70.6 b	29.4 b	10.6 a	46.9 b	77.9 b	8.6 ab	3.4 a	96.4 ab	64.8 c	7.8 bc	···	···
6.9	70.6 b	29.4 b	9.6 b	46.5 c	77.7 b	9.8 b	3.3 a	95.7 b	66.1 c	8.3 c	39.0 b	19.6 c
5.3	70.6 b	29.4 b	9.6 b	46.4 c	77.3 b	9.2 b	2.9 a	96.0 b	66.1 c	8.4 c	45.5 b	18.1 cd
3.8	69.7 b	30.3 b	9.4 b	45.8 c	78.3 b	9.9 b	2.9 a	95.1 b	68.0 c	8.4 c	52.5 b	16.8 d
Faba Beans												
14.2	75.6 a	24.4 a	22.0 a	74.1 a	68.0 a	3.7 a	2.5 a	99.4 a	52.3 a	5.1 a	···	···
11.2	70.6 b	29.4 b	16.7 b	71.1 b	73.0 b	3.4 a	2.5 a	99.7 a	63.6 b	5.3 ab	40.5 a	15.3 a
8.8	67.7 b	32.3 b	16.3 b	71.2 b	74.6 b	3.6 a	2.5 a	96.1 b	67.6 c	5.7 b	57.0 a	11.1 b
5.1	66.7 b	33.3 b	15.8 bc	69.5 c	75.0 b	5.1 b	2.3 a	96.4 b	69.5 c	6.0 c	91.5 b	9.0 b
3.8	66.7 b	33.3 b	15.2 c	69.1 c	75.0 b	5.1 b	2.3 a	96.1 b	69.7 c	6.1 c	109.0 b	5.2 c

[a] SF = starch fraction, PF = protein fraction, DS = damaged starch (in the flour), SSE = starch separation efficiency, PSE = protein separation efficiency, NDF = neutral detergent fiber. Product yield, DS, and NDF values are the average of two determinations; protein and starch values are the average of two determinations on each of two replicates; seed hardness values are the average of two determinations. Product yield, protein, starch, DS, and NDF are expressed on a moisture free basis.

[b] Dehulled peas and faba beans contained 21.3 and 33.6% protein, 56.6 and 51.7% starch, and 3.6 and 2.2% NDF, respectively.

[c] Means in a column followed by the same letter are not significantly different ($P < 0.05$).

[d] N × 6.25.

[e] Time = grinding time in Brabender Micro-Hardness-Tester; fines = proportion through 38-μm sieve of sonic sifter.

TABLE II
Correlation Coefficients[a] Between Measures of Impact Milling Efficiency (PSE and NDF)[b] and Seed Hardness Indices (Grinding Time and Flour Fineness)

	Field Peas	Faba Beans
PSE vs grinding time	0.612	0.901
NDF vs grinding time	0.714	0.957
PSE vs flour fineness	−0.938	−0.928
NDF vs flour fineness	−0.984	−0.965

[a] All values are significant ($P < 0.05$).
[b] PSE = protein separation efficiency, NDF = neutral detergent fiber in the protein fraction.

TABLE III
Moisture Contents and Air Classifier Feed Rates for Flours Produced from Dehulled Field Peas by Pin Milling at Various Moisture Contents[a]

Seed Moisture (%)	Flour Moisture (%)	Feed Rate[b] (kg/hr)
14.3	10.3	59
12.4	9.7	56
10.5	8.3	55
6.9	6.3	50
5.3	5.5	47
3.8	4.1	44

[a] Flour moisture and feed rate values are the average of two replicates.
[b] Feed rate established at a feed-gate setting of 9.

surface at high speed. Presumably, at lower moisture contents seeds are more brittle, and more fine material, capable of being fractionated into the PF, is produced. Terms such as "seed brittleness" or "susceptibility to shattering" may be more meaningful then "hardness" when impact milling of legumes is concerned. Grinding time in the Brabender Micro-Hardness-Tester increased at lower seed moisture contents. The opposite effect has been observed with wheat using similar equipment (Kosmolak 1978, Obuchowski and Bushuk 1980); longer grinding times were obtained for softer cultivars and for a particular cultivar at higher moisture contents. We suggest that differences in internal structure between legume seeds and wheat kernels may be responsible for the differences in grinding behavior and that for peas and faba beans, at least, a longer grinding time corresponds to a greater degree of hardness.

Seed moisture content could conceivably affect the air classification process in a manner unrelated to milling efficiency. We observed (Table III) that, despite changes in moisture content during milling, the moisture contents of a pin-milled flour and of the seed used in its production are related and that feed rates to the air classifier (at a particular feed-gate setting) were greater at higher flour moistures. Because similar trends were observed for both legumes, data from peas only are shown. Jones et al (1959) reported that the yield and the protein content of the fine fraction obtained at any vane setting on the Alpine 132 MP classifier were affected by variations in the rate of feed, especially at high feed rates. Similarly, Sullivan et al (1960) stated that as feed rate was increased, the actual cut size obtained increased and the sharpness of the separation deteriorated. In our study, the effects of variations in feed rate, if of sufficient magnitude to affect the separation, would be seen at higher flour moistures as higher PF yields, accompanied by increased starch and decreased protein concentrations in the PF. Because this is in contrast to our observations, variations in feed rate appeared to be less important than was milling efficiency in determining the yield and composition of the air-classified fractions. Kent (1965) adjusted all flours to the same moisture content before air classification to eliminate feed rate variations. In a commercial operation, compensation for flour moisture variations (if required) by feed rate control would probably be more practical.

In conclusion, the moisture content of field peas and faba beans is an important determinant of the yield and composition of the fractions obtained by pin milling and air classification. Employing a double-pass procedure, in which the SF is remilled and subjected to a second air classification (Tyler et al 1981, Vose et al 1976, Youngs 1975), would result in improved PSE and lower protein levels in the SF, as compared to the results obtained in this study using a single milling and classification. However, the maximum yield of the first PF from the double-pass procedure would still be obtained at lower seed moistures. This is desirable, because the first PF generally contains more protein and less starch than the second.

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