Fine Grinding and Air Classification of Field Pea

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ABSTRACT

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Field pea has ≈23% protein, 48% starch, 8% sugars, 4% lipids, 7% crude fiber, and 3% ash. Pin milling at 1 × 14,000, 3 × 14,000, 9 × 14,000, and 12 × 14,000 rpm followed by air classification according to particle size resulted in fine fractions (<18 µm) with high protein content and coarser fractions (>18 µm) with high starch content. The yield of the high protein fraction increased with the intensity of grinding before air classification. The starch content of the high starch fraction increased with the intensity of grinding and subsequent air classification. Both whole pea and dehulled pea responded well to fine grinding and air classification, and the dehulled pea gave higher protein content and higher starch content than the corresponding fraction from whole pea. The protein fraction had high lysine content and met all the amino acid requirements of the World Health Organization for children older than two years and adults.

Field pea (*Pisum sativum*) is a legume with ≈23% protein and 48% starch on a dry basis. In 2003, the United States contributed 266,490 tons to the total world pea production of 10,248,008 metric tons (http://faostat.fao.org). There is good potential to increase field pea production in the United States, especially by planting field pea before soybean, wheat, or grain sorghum so that two crops can be harvested in one year. Besides starch and protein, Reichert and MacKenzie (1982) reported Trapper field pea had 4% total lipids, 3% ash, and 8% total sugars including 0.7% raffinose, 1.8% stachyose, and 2.4% verbascose. Eclipse field peas contain 2.7% sucrose, 0.5% fructose, and 0.4% each glucose and maltose (N. N. Nichols et al, *unpublished*). Vose et al (1976) found Trapper field pea had 7% crude fiber and Igbasan et al (1997) reported 12 pea cultivars with 19–22% dietary fiber. Chick pea, pea, and cowpeas have similar protein and total carbohydrate content, but chick pea has considerably higher fat content (Meiners et al 1976).

Vose et al (1976) reported air classification of field pea flour yielded a high protein fraction and a crude starch fraction. Tyler and Panchuk (1982) found that reductions in field pea seed moisture were accompanied by declines in starch fraction yield, protein contents of the starch and protein fractions, and starch separation efficiency. Reichert (1982) studied air classification of peas varying widely in protein content. Sosulski et al (1987) compared air classifiers for separation of protein and starch in legumes, including field peas. The physicochemical characteristics of some pea flour fractions have been examined (Maaroufi et al 2000). However, no study of the effect of intensity of grinding on air classification of field peas was available.

Although it is possible to obtain a fraction with higher protein content by wet processing (Madsen and Buechbjerg 1987; Tian et al 1999), air classification is considerably less expensive. The high protein fraction has good functional properties (Sosulski and McCurdy 1987) and can find use in food because there is an increasing interest among vegetarians and health-conscious people to consume plant proteins, which have no cholesterol and low saturated fat content. The crude starch fraction has the potential to yield ethanol by fermentation (N. N. Nichols et al *unpublished*). Here, we describe the effect of intensity of grinding on the separation of field pea protein and starch fractions by air classification.

MATERIALS AND METHODS

Eclipse field pea is a medium-to-late maturing cultivar with medium vine length, reduced seed coat breakage, and resistance to powdery mildew. The Eclipse peas used in this work were grown in Illinois in the United States in 2003. Peas were dried at 55°C overnight in an air oven to reduce the moisture content from 15.2 to 10.2%. Both whole pea and dehulled pea were processed. For whole pea, the pea was cracked for 10 sec in an analytical mill (A10, Glen Mill, Clifton, NJ, USA) until all went through a No. 8 screen (2,380 µm square opening). To dehull pea, the pea was cracked for 5 sec in the A10 analytical mill and separated on No. 12, 20, and 50 screens with square openings of 1,680, 841, and 297 µm, respectively.

Each fraction was then aspirated to remove hull, and the dehulled pea fractions were combined before pin milling. The weight of the hull removed was 8.9% of the whole pea, and the weight recovery for dehulling was 99.5%, as-is.

Pin Milling and Air Classification

The cracked pea was ground in a pin mill (model 160Z, Alpine, Augsburg, Germany) at 14,000 rpm and fractionated in a laboratory model air classifier (Pillsbury, Minneapolis, MN, USA) according to particle size. The classifier was first set at a 15 µm cutpoint to obtain a coarse and a fine fraction. The coarse fraction was then

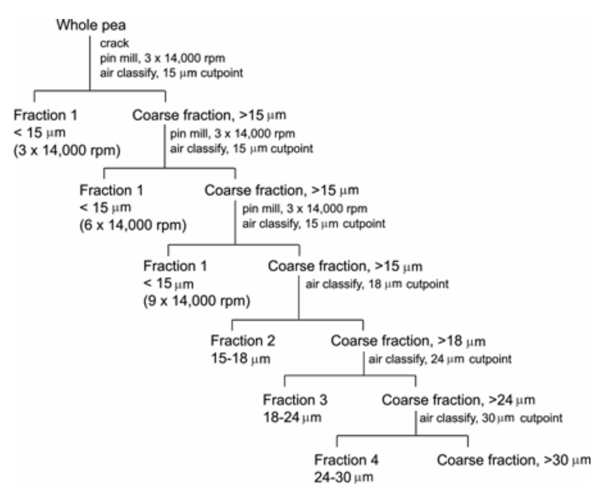

Fig. 1. Scheme for 9 × 14,000 rpm pin milling and air classification of field pea.

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classified successively with 18, 24, and 30 μm cutpoints to obtain four fine fractions (1–4) and a coarse residue (fraction 4 coarse). For 9 × 14,000 rpm pin-milled pea (Fig. 1), the pea after pin milling 3 × 14,000 rpm was air-classified at 15 μm cutpoint to remove the fine fraction, followed by milling of the coarse fraction three more times at 14,000 rpm, and air classification at 15 μm cutpoint. The coarse fraction was ground three more times at 14,000 rpm and air-classified at 15 μm cutpoint. The coarse fraction was then classified successively at 18, 24, and 30 μm cutpoints. This stepwise milling and air classification procedure was used for 9 × 14,000 rpm pin-milled material to minimize the unavoidable loss of fine material (high protein fraction). The weight recovery of pin milling was >95%, and the weight recovery of air classification was also >95%. The combined weight recovery for pin milling 9 × 14,000 rpm and air classification was 91%, as-is, for the scheme shown in Fig. 1. The weight recovery in a commercial process would be higher because less material, as a percent of the total, would be lost in the machinery in a continuous process.

Our Alpine pin mill has a stationary set of pins and a movable set of pins that can operate at up to 14,000 rpm. In contrast, larger capacity Alpine pin mills have two sets of counterrotating pins that can produce a higher intensity of grinding. It is estimated that one pass from the larger pin mill results in at least the same intensity of grinding as three passes in our pin mill operating at 14,000 rpm. Therefore, the number of passes needed in a large mill would be much lower than what was used in these studies. This work was performed to determine the effect of grinding intensity before air classification on protein and starch enrichments and would not necessarily be the procedure employed in a commercial process.

The >30 μm coarse residue (fraction 4 coarse) from 3 × 14,000 rpm pin milling and air classification was further separated by sieves with square openings of 44, 53, 62, 74, 88, 105, 149, 177, 250, 297, and 420 μm to obtain 30–44, 44–53, 53–62, 62–74, 74–88, 88–105, 105–149, 149–177, 177–250, 250–297, 297–420, and >420 μm fractions.

Analyses

Nitrogen, fat, and moisture were determined by AOAC Official Methods (2000). Nitrogen was measured by combustion, crude fat by ether extraction, and moisture by loss on drying at 95–100°C in a vacuum oven. Protein was calculated as N × 6.25. Starch was converted to glucose by amylase digestion, and glucose was measured by a glucose oxidase/peroxidase method (Trinder 1969) to determine the starch content. Samples were hydrolyzed by treatment with 6*N* HCl for 4 hr at 145°C (Gehrke et al 1987), and the amino acids were determined by cation exchange chromatography in a Beckman 6300 amino acid analyzer (San Ramon, CA). Methionine and cystine were oxidized by performic acid before hydrolysis (Moore 1963). Tryptophan was measured by a colorimetric method after enzymatic hydrolysis by pronase (Spies and Chambers 1949; Holz 1972). Duplicate analyses were conducted for nitrogen, fat, moisture, starch, and amino acids.

TABLE I
Air Classification of Whole Eclipse Pea After Pin Milling[a]

Pin Mill (rpm)	Fraction	Size (μm)	Protein (% db)	Starch (% db)	Yield (% db)
1 × 14,000			22.9	46.2	
	1	<15	52.4	3.1	5.8
	2	15–18	48.7	9.9	5.6
	3	18–24	16.1	63.4	21.2
	4	24–30	12.7	68.1	18.2
	4 coarse	>30	21.3	40.1	49.3
3 × 14,000			22.7	47.7	
	1	< 15	55.9	3.6	12.6
	2	15–18	49.6	10.9	9.2
	3	18–24	14.5	66.8	29.0
	4	24–30	9.6	72.0	20.3
	4 coarse	>30	15.5	42.1	28.9
9 × 14,000 stepwise	1 (3 × 14,000)	<15	55.3	2.8	11.0
	1 (6 × 14,000)	<15	52.1	3.7	7.2
	1 (9 × 14,000)	<15	52.5	4.6	4.7
	2	15–18	45.3	15.1	6.0
	3	18–24	12.0	61.9	20.8
	4	24–30	7.8	73.7	21.6
	4 coarse	>30	10.5	49.8	28.7

[a] Pin milling and air classification scheme in Fig. 1.

TABLE II
Air Classification of Dehulled Pea After Pin Milling

Pin Mill (rpm)	Fraction	Size (μm)	Protein (% db)	Starch (% db)	Yield (% db)
9 × 14,000 stepwise	3 × 14,000		24.0	49.5	
	(1 +2) 3 × 14,000	<18	54.2	5.5	19.6
	(1 +2) 6 × 14,000	<18	51.8	8.7	10.1
	(1 +2) 9 × 14,000	<18	48.1	13.4	4.6
	3	18–24	11.4	70.2	23.4
	4	24–30	7.0	77.8	23.5
	4 coarse	>30	8.7	68.0	18.8
12× 14,000 stepwise	(1 +2) 3 × 14,000	<18	50.4	8.0	23.9
	(1 +2) 6 × 14,000	<18	48.7	11.8	9.6
	(1 +2) 9 × 14,000	<18	44.0	17.3	4.4
	(1 +2) 12 × 14,000	<18	40.7	20.5	2.1
	3	18–24	6.9	75.4	30.0
	4	24–30	4.8	78.8	17.4
	4 coarse	>30	5.3	71.4	12.6

The data were treated by analysis of variance. Tukey's Studentized range test was used to determine significant differences from duplicate experiments ($P < 0.05$) (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Air Classification of Whole Pea

The effect of pin milling on air classification results is shown in Table I. When 1 × 14,000 rpm pin-milled pea was air-classified, the <15 and 15–18 μm fractions had high protein content, and the 18–24, and 24–30 μm fractions had high starch content compared with that of the starting material. However, the yield of the >30-μm fraction was 49%, and the yield of the protein and starch contents of that fraction was close to that of the starting material. The fat content ranged from 2.8% in fraction 1 to 0.7% in fraction 4 (not shown). Because we are primarily interested in enrichment of protein and starch, the small amount of fat present in other fractions is not presented.

When 3 × 14,000 rpm pin-milled pea was air-classified, fractions 1 and 2 had high protein content and fractions 3 and 4 had high starch content (Table I). The yields of high protein fractions and high starch fractions, as well as the protein and starch content of the corresponding fractions, were better for 3 × 14,000 rpm pin-milled pea compared with 1 × 14,000 rpm. The large decrease in the fraction 4 coarse fraction from 49 to 29% also reflected the advantage of 3 × 14,000 rpm compared with 1 × 14,000 rpm pin-milling.

The effect of more intense grinding of pea at 9 × 14,000 rpm in a stepwise manner is also shown in Table I. High yield of high protein fractions (<18 μm) was obtained at 9 × 14,000 rpm compared with 3 × 14,000 rpm pin-milled pea. Although the yield of fraction 4 coarse was similar, the protein content was lower and the starch content was higher for 9 × 14,000 rpm compared with 3 × 14,000 rpm pin-milled pea.

Air Classification of Dehulled Pea

Table II lists the result of air classification of dehulled pea after pin milling 9 × 14,000 rpm in a stepwise procedure. Dehulled pea had higher protein (24.0%) and starch (49.5%) contents because the hull fraction had lower protein and lower starch contents than whole pea (not shown). Because <15 and 15–18 μm fractions had high protein contents in Table I, the two fractions were combined in Table II. When dehulled pea was pin-milled 12 × 14,000 rpm, the high protein fractions had higher yield but lower protein content, and the high starch fractions had higher starch and lower yield compared with the corresponding fraction from 9 × 14,000 rpm pin-milled dehulled pea. The major difference between whole and dehulled pea was that fraction 4 coarse for dehulled pea had much lower yield and higher starch content compared with whole pea. The hull fraction was concentrated in the fraction 4 coarse for whole pea, and the removal of hull for that fraction for dehulled pea accounted for the difference in yield and starch content.

Sieving of Air-Classified >30 μm Fraction

Table III shows the yield as well as protein and starch contents of sieving the air-classified >30 μm fraction after pin milling 3 × 14,000 rpm. The 30–44 μm fraction had low protein and high starch content similar to the 24–30 μm fraction in Table I, and the yield of the 30–44 μm fraction was one-third that of the >30 μm fraction or almost 10% of the whole pea. Thus, if highest starch content is desired from 3 × 14,000 rpm pin-milled whole pea, an additional cutpoint at 44 μm or instead of 30 μm from air classification will be desirable. The protein contents of the 44–149 μm fractions, and the starch contents of the 44–62 μm fractions, were close to those of whole pea. The protein and starch contents of >149 μm fractions decreased markedly and are consistent with the composition and yield of the hull fraction (Vose et al 1976).

TABLE III
Sieving of Eclipse Pea Air-Classified >30 μm Fraction After Pin Milling 3 × 14,000 rpm

Particle Size (μm)	Protein (% db)	Starch (% db)	Yield (% db)	
			Fraction 4 Coarse	Pea
30–44	10.2	75.2	33.2	9.6
44–53	23.6	48.0	5.3	1.5
53–62	25.5	44.4	8.3	2.4
62–74	26.3	38.3	6.3	1.8
74–88	26.3	39.4	4.2	1.2
88–105	26.2	38.7	6.5	1.9
105–149	22.6	33.5	7.4	2.1
149–177	15.7	24.2	5.4	1.6
177–250	7.7	11.2	6.1	1.8
250–297	3.8	4.6	2.4	0.7
297–420	2.4	1.4	11.2	3.2
>420	1.4	0.7	3.6	1.0
Fraction 4 coarse	15.5	42.1	99.9	28.8

TABLE IV
Summary of Air Classification of Eclipse Pea

Pea	Pin Mill (rpm)	Particle Size (μm)	Protein (% db)	Starch (% db)	Yield (% db)	Useful Protein Shift (%)	Useful Starch Shift (%)
Whole	1 × 14,000	<18	50.6	6.4	11.4	31.6	19.8
		>18	18.3	51.4	88.7		
	3 × 14,000	<18	53.2	6.7	21.8	60.6	37.3
		>18	13.6	59.0	78.2		
	9 × 14,000	<18	52.0	5.9	28.9	76.8	44.6
	stepwise	>18	10.1	60.6	71.1		
Dehulled	9 × 14,000	<18	52.7	7.5	34.3	81.8	59.4
	stepwise	>18	9.1	72.3	65.7		
	12 × 14,000	<18	48.8	10.6	40.0	86.6	63.1
	stepwise	>18	5.9	75.6	60.0		

Summary of Air Classification

The air classification results for whole and dehulled pea were summarized in Table IV by combining the data from Tables I and II into <18 μm high protein fraction and >18 μm high starch fraction. Useful protein shifting, a calculated value for comparing protein displacement after air classification, equals the sum of the protein shifted into the high protein fractions and out of the low-protein fractions as a percentage of the total protein present in the starting material (Gracza 1959). Likewise, we can calculate useful starch shifting from the sum of the starch shifted into the high starch fractions and out of the low-starch fractions as a percentage of the total starch present in the starting material.

As the intensity of grinding whole pea increased from 1 × 14,000 rpm to 3 × 14,000 rpm, the yield and protein content of the high protein fraction increased with increases in useful protein shift value (Table IV). When intensity of grinding increased further from 3 × 14,000 rpm to 9 × 14,000 rpm, there was an increase in yield of high protein fraction and useful protein shift value. There was a corresponding increase of useful starch shift values for high starch fraction as intensity of grinding increased from 1 × 14,000 rpm to 3 × 14,000 and from 3 × 14,000 rpm to 9 × 14,000 rpm. The 9 × 14,000 rpm pin-milled dehulled pea gave higher yield of high protein fraction, higher starch content for high starch fraction, higher useful protein shift value and higher useful starch shift value compared with those from 9 × 14,000 rpm pin-milled whole pea. When the intensity of grinding increased from 9 × 14,000 rpm to 12 × 14,000 rpm for dehulled pea, the yield of high protein fraction and useful protein shift value increased. The starch content of the high starch fraction and useful starch shift value also increased as the intensity of grinding dehulled pea increased from 9 × 14,000 to 12 × 14,000 rpm.

Amino Acid Composition

The amino acid composition of dehulled pea and air-classified <18 μm high protein fraction was determined (not shown). Eclipse pea had high lysine content (7.2 g/16 g of nitrogen) and met all the amino acid requirements for children older than two years and adults (WHO 1985). The high protein fraction had almost identical amino acid composition as the dehulled pea except for glutamic acid, cystine, and methionine contents. The levels of the three amino acids were reduced 4, 17, and 6%, respectively, in the high protein fraction compared with dehulled pea ($P < 0.05$). Our amino acid composition of Eclipse pea agreed, in general, with that of Solar pea protein reported by Leterme et al (1990). Our amino acid composition for Eclipse pea <18 μm high protein fraction agreed with that of Trapper pea protein concentrate reported by Vose et al (1976).

Field pea, a legume, has characteristically high protein content. Compared with soybeans, field peas have higher leucine and lysine content, and less methionine and tryptophan (Reichert and MacKenzie 1982). Field pea flour has a nitrogen solubility index of 90.4% compared with 85.0% for soybean flour. Water absorption capacity is 118% for field pea flour and 214% for soybean flour, and fat absorption values are 97 and 138% for field pea and soybean flour, respectively (Sosulski et al 1976). Pea protein has good functional qualities and can be incorporated as flour or a high protein fraction into food products and animal feed (Klein and Raidl 1986; Hickling 2003).

CONCLUSIONS

High-intensity grinding and air classification of whole or dehulled pea resulted in good separation of protein and starch into a high protein fraction and a high starch fraction. The high protein fraction can be used in food, and the high starch fraction can be fermented into ethanol.

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