Amino Acid and Mineral Profile of Air-Classified Navy Bean Flour Fractions[1]

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ABSTRACT

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Navy bean flour (NBF) was fractionated into protein concentrate (PC) and starch residue (SR), using an Alpine Microplex air classifier. NBF and the resulting fractions were analyzed for amino acids and minerals. The overall yields of the PC and the SR were 34.7 and 61.9%, respectively. The NBF and its fractions had a relatively high lysine content and the low sulfur amino acid content characteristic of legume proteins. Compared to the flour, the PC was lower in cystine, methionine, and tryptophan but higher in valine. Compared with the FAO reference amino acid pattern, the total sulfur amino acids were the first limiting whereas all other essential amino acids considerably exceeded the reference pattern in the NBF and in both fractions. The NBF and the two fractions contained from two to 17 times more minerals than did wheat flour. Pronounced shifting of all minerals except calcium into the PC fraction was noted.

Dried legumes constitute a chief source of dietary protein for large segments of the world's population, particularly in those countries where consumption of animal protein is limited because of its nonavailability or prohibitive cost or because of religious, cultural, or health reasons. Traditionally, mature legume seeds other than soy have been cooked and consumed whole or made into pastes, purees, or soups.

Although processing of dry legumes into lysine-rich flour extends the potential for the fortification of cereal-based traditional or novel foods, the high carbohydrate and low protein content of these flours limits the amount that can be incorporated without serious adverse effects on the functionality and flavor of food systems (Patel et al 1977, Patel and Johnson 1974). Legume protein concentrates or isolates with superior functional properties and low flavor profile have found wider food application than have flours. Preparation of protein isolate from horsebean (Patel and Johnson 1975), navy and pinto bean,[5] and lima beans (Maneepun et al 1974), based on protein precipitation at isolectric pH, has been studied. The major drawbacks of this technique appear to be low yield, high cost, and the problem of waste effluent disposal. Air classification has been used to tailor-make flours meeting specific requirements such as protein content or granularity. High protein flours from wheat (Stringfellow and Peplinski 1964), corn, sorghum, and soy (Pfeifer et al 1960), rice (Stringfellow et al 1961), barley (Pomeranz et al 1971), and triticale (Stringfellow et al 1976) have been fractionated with varying effectiveness.

The twofold purpose of this study was to produce a navy bean protein concentrate through air classification and to assess the impact of processing on the amino acid and mineral distribution in the resulting flour fractions.

MATERIALS AND METHODS

Processing

Navy beans were a composite of the varieties grown in Canada. Clean whole seeds were ground in an Alpine 250 CW contraplex pin mill, operating at 12,000 rpm on the mill side and 6,000 rpm on the door side for a differential speed between the pins of 18,000 rpm. The flours were then fractionated into protein (PI) and starch (SI) fractions using an Alpine 132 MP Microplex air classifier at a setting (air flow control) of 15. The SI fraction was remilled and fractionated into protein (PII) and starch fractions. The two protein fractions were combined to give an overall separation of the original flour into protein concentrate (PC) and starch residue (SR). The resulting fractions and the composites of fractions were analyzed for moisture, protein, and ash.

Analytical Methods

Protein and Amino Acids. The nitrogen content of the flour fractions was determined by the standard AOAC Kjeldahl method (1975). To determine the amino acid content of the flour and the fractions, 10–15 mg of oven-dried samples were hydrolyzed in a sealed tube under a nitrogen atmosphere with 6 *N* HCL for 22 hr at 110°C. Norleucine solution (2.5*M*, 1 ml) was added to the hydrolysates as an internal standard. The hydrolysates were evaporated to dryness in vacuo and made up to the appropriate volume with citrate-hydrochloric acid buffer (pH 2.2). Aliquots of 0.2 ml were analyzed, using a Model 120C Beckman amino acid analyzer (Moore et al 1958; Moore and Stein 1954, 1963). Cystine and methionine were analyzed according to the procedure of Lewis (1966) and Schram et al (1954). Tryptophan determinations were made by the procedure of Spies (1967) and Spies and Chambers (1948). Amino acid content is expressed in terms of 100% protein recovery.

Dry Ashing Procedure. Navy bean or wheat flour samples of approximately 0.5 g were ashed at 525° F for 24 hr. For the analyses of all minerals except potassium, 5 ml of 10% HNO_3 was added to the ash samples and the assay conducted according to the standard AOAC atomic absorption spectrophotometric procedure (1975).

TABLE I
Yield, Protein, and Ash Content of Air-Classified Navy Bean Flour Fractions

	Yield (%)	Moisture (%)	Protein[a,b] (%)	Ash[a] (%)
Flour	100	8.9	30.4	3.85
Fraction				
Starch I	80.6	···	21.9	···
Protein I	19.4	···	63.8	···
Starch II[c]	65.3	···	10.7	···
Protein II[c]	15.3	···	60.0	···
Overall				
Protein concentrate[d]	34.7	5.8	61.9	7.23
Starch residue	65.2	6.3	10.7	2.09

[a]Moisture-free basis.
[b]N × 6.25.
[c]From remilling of Starch I fraction.
[d]Combination of Protein I and Protein II.

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TABLE II
Amino Acid Compositions[a] of Navy Bean Flour (NBF), Navy Bean Protein Concentrate (PC), and Navy Bean Starch Residue (SR)

Amino Acid[b]	NBF	PC	SR	Net Change, NBF to PC (%)	Net Change, NBF to SR (%)	Percent of FAO Pattern[c] NBF	PC	SR
Lysine	7.39	7.36	7.28	− 0.4	− 1.5	134	134	132
Histidine	3.01	3.24	3.08	+ 7.6	+ 2.3	···	···	···
Arginine	8.10	8.45	7.55	+ 4.3	− 6.8	···	···	···
Aspartic acid	12.08	12.09	13.52	0.0	+11.9	···	···	···
Threonine	4.66	4.52	4.73	− 3.0	+ 1.5	116	113	118
Serine	6.85	6.22	5.16	− 9.2	− 24.7	···	···	···
Glutamic acid	15.43	13.90	16.04	− 9.9	− 4.0	···	···	···
Proline	4.16	4.33	4.61	+ 4.1	+10.8	···	···	···
Glycine	3.43	3.25	3.58	− 5.2	+ 4.4	···	···	···
Alanine	3.82	3.70	4.01	− 3.1	+ 5.0	···	···	···
Cystine[d]	2.02	1.58	3.16	−21.8	+56.4	···	···	···
Valine	5.00	6.03	4.89	+20.6	0.0	100	121	98
Methionine	1.37	1.21	1.58	−11.7	+15.3	···	···	···
Isoleucine	4.74	4.75	4.41	0.0	− 7.0	119	119	110
Leucine	8.44	8.58	7.78	+ 1.7	− 7.8	121	122	111
Tyrosine plus phenylalanine	10.06	10.46	8.90	+ 4.0	−11.5	168	175	148
Total sulfur amino acids	3.39	2.79	4.74	−18.6	+39.8	97	80	135
Tryptophan[e]	1.26	1.14	1.37	− 9.5	+ 8.7	126	114	137

[a]Grams of amino acid per 16 g of nitrogen.
[b]Grams of amino acid per 100 g of protein corrected to 100% protein recovery.
[c]FAO/WHO (1973).
[d]Cystine and methionine by oxidation (Lewis 1966, Schram et al 1954).
[e]Tryptophan by colorimetric method (Spies 1967, Spies and Chambers 1948).

TABLE III
Mineral Composition of Navy Bean Flour (NBF), Navy Bean Protein Concentrate (PC), and Navy Bean Starch Residue (SR)[a]

Element	Wheat Flour[b]	NBF	PC	SR	Net Change NBF to PC (%)	Percent of Wheat Flour NBF	PC
Ca[c]	0.08	0.71	0.47	0.86	− 34	788	488
K[c]	0.20	0.76	1.42	0.34	+ 46	280	610
Mg[c]	0.07	0.60	0.94	0.50	+ 57	757	1243
P[c]	0.35	1.74	2.27	0.71	+ 30	400	554
Al[d]	···	6.60	15.40	3.20	+126	680	1540
B[d]	0.27	3.49	5.08	2.94	+ 46	1192	1781
Cu[d]	0.84	4.14	8.59	2.03	+108	393	923
Fe[d]	7.20	42.60	93.10	26.40	+118	492	119
Mn[d]	2.20	8.10	17.20	4.40	+112	268	682
Zn[d]	2.60	8.20	13.30	5.40	+ 62	215	411
Na[d]	55.9	88.5	129.6	75.7	+ 46	58	132

[a]Expressed on a moisture-free basis.
[b]Pastry flour (total ash 0.52% moisture free basis), King Kookie obtained from King Milling Co., Holland, MI.
[c]Percent of total grams.
[d]Percent (mg) of total grams.

To determine potassium, flour samples of approximately 0.25 g were extracted in 50 ml of distilled water for 2 hr with periodic agitation, followed by filtration through Whatman No. 1 filter paper. Potassium in the extract was analyzed by the AOAC flame emission spectrographic procedure (1975) on a Model B Beckman flame emmission spectrophotometer.

RESULTS AND DISCUSSION

Yield and protein content of air-classified NBF fractions are summarized in Table I. Protein fractions PI and PII, with yields of 19.4% (63.8% protein) and 15.3% (60% protein), respectively, were obtained from air-classified whole NBF. Combination of the two protein fractions obtained from the two passes through the air classifier produced an overall 34.7% yield of PC (61.9% protein) from NBF. This yield was 8–10% lower than the air-fractionated protein concentrates derived from field peas or horse bean (Vose et al 1976), but the protein contents were similar. Even after two air classifications, substantial quantities of protein (10.7%) remained in the SR; this amount was twice as high as in field peas or horse bean starch fractions (Vose et al 1976). In the air-fractionated products, shifts in protein were accompanied by shifts in ash.

The amino acid profiles of NBF and its fractions (Table II) illustrate the relatively high lysine content (7.28–7.39 g per 16 g of N) and the low sulfur (S) amino acid content (2.79–4.74 g per 16 g of N) characteristic of grain legume proteins. With the exception of the S-amino acids, no major variation occurred in the amino acid composition of the fractions. Major shifts of S-amino acids (40%) into the starch fraction suggest that flour proteins containing S-amino acids may be more resistant to grinding than are other protein fractions consequently fractionating along with the coarse starch fraction.

Compared to the flour, the PC was lower in cystine, methionine, and tryptophan (by 22, and 10%, respectively) but higher (21%) in valine. The lysine and S-amino acid contents of the navy bean PC were similar to that of the air-classified horse bean PC but 6% lower than the pea PC (Vose et al 1976). In comparison with the FAO reference amino acid pattern (1973), the total S-amino acids were the first limiting, whereas all other essential amino acids considerably exceeded the reference pattern in the flour and in each fraction.

Mineral analysis data (Table III) indicate that the mineral contents of NBF and of its PC and SR fractions were considerably higher than those in wheat flour. Phosphorus, potassium, calcium, and magnesium, in decreasing order, were the main mineral elements of wheat flour and of NBF. Phosphorus and potassium were the predominant minerals in the PC, and the magnesium content exceeded calcium. The SR contained the highest percentage of calcium and the lowest percentage of potassium.

In comparison with wheat flour, NBF contains approximately two to four times more potassium, manganese, zinc, and sodium; five to seven times more phosphorous, copper, aluminum, and iron; and nine times more calcium and magnesium. NBF proved to be a rich source of iron, a mineral generally in low amounts in cereal flours.

Pronounced concentration of all minerals except calcium into the PC fraction was evident. Compared to the flour, the PC contained greater quantities of iron and aluminum (118–126%), copper and manganese (107–112%), magnesium and zinc (57–62%), potassium, sodium, and boron (46%), and phosphorus (30%).

In conclusion, air-classification data of NBF indicate the feasibility of protein concentrate production with good yield at a relatively low cost. A protein concentrate with a desirable amino acid and mineral profile has potential as a protein supplement in cereal-based products such as breads, pasta, and extruded or fabricated snacks. The starch fraction may function as a binding agent in extruded noncereal products or may be channeled into nonfood applications.

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