Fortification of Spaghetti with Edible Legumes. I. Physicochemical, Antinutritional, Amino Acid, and Mineral Composition[1]

Y. BAHNASSEY, K. KHAN[2], and R. HARROLD[3]

ABSTRACT

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Legume flour was obtained by dry milling nonroasted and roasted seeds of navy bean, pinto bean, and lentil. Protein concentrates were extracted from the legume flours by acid precipitation from dilute alkali solution. Comparison of the chemical composition of the legume flours and their protein concentrates with durum wheat semolina showed that all legume flours contained significantly higher protein, ash, fiber, and fat contents than the durum semolina. Fortified spaghetti was prepared from blends of legume flour or protein concentrates with a strong gluten durum semolina. Protein, ash, and fiber contents of the fortified spaghetti exceeded the levels for the control spaghetti. Trypsin inhibitor and hemagglutinin activities of legume flours and protein concentrates were slightly reduced in the roasted samples. Navy bean contained the highest amount of trypsin inhibitor and hemagglutinin activity followed by pinto bean and lentil. Legume flours also contained higher levels of both activities than protein concentrates. The legume flours and their protein concentrates had a relatively higher level of most amino acids than the durum semolina. The lysine content of legume flours and protein concentrates was about four times greater than that found in durum wheat semolina. However, the content of sulfur amino acids was lower in the legume samples than in the durum semolina. The amino acid composition of spaghetti made with 10 or 15% legume flours or protein concentrates showed a better balance of lysine and sulfur amino acids than spaghetti processed from 100% semolina. Mineral content of legume flour, protein concentrates, and fortified spaghetti was considerably higher than the semolina or control spaghetti. A pronounced shift in higher concentration of phosphorus, calcium, iron, zinc, and sodium into the protein concentrate was evident. Roasted samples showed higher levels of calcium, iron, and zinc than the nonroasted samples.

Legumes are the edible dicotyledonous seeds of plants belonging to the family Leguminosae. This is the second largest family of seed plants, containing about 600 genera with 13,000 species (Aykroyd and Doughty 1964). Legumes are an economical source of protein and calories as well as certain minerals and vitamins essential to human nutrition. The nutritional value of legumes is suggested by the ability of vegetarians to maintain good health on a carefully selected diet and by the fact that severe calorie malnutrition can be cured by an appropriate mixture of cereals and legumes without any source of animal protein (Salami 1982).

Component analysis of legumes includes protein (15–38%), fat (1–2%), moisture, fiber (4–6%), ash (3–4%), minerals, vitamins, and carbohydrates (Miki 1931, Aykroyd and Doughty 1964, Eden 1968, Bhatty 1974, Sathe et al 1984). The dry seeds of legumes generally have a similar chemical composition, with the exception of *Arachis* (peanuts) and *Glycine* (soybeans), which have high fat and comparatively low carbohydrate contents (FAO 1958).

Legumes also contain a number of toxic substances. Perhaps the best known toxic factors are the trypsin inhibitors, so called because of their ability to inhibit the action of the enzyme trypsin found in the digestive tract of man and animals. Aguilera et al (1982) reported that dry roasting of navy bean with a particle-to-particle heat exchanger effectively destroyed antinutritional factors present in the raw beans. Many legumes also contain substances that agglutinate red blood cells; purified preparations of hemagglutinin from plants inhibit growth when incorporated in the diet of rats (Liener 1955). Although the hemagglutinins are thermolabile and should be destroyed after normal cooking, there are indications that this is not always so, because toxic hemagglutinins are more heat resistant than nontoxic hemagglutinins (Jaffe 1974).

Although legume proteins are low in some essential amino acids, they are considered to be one of the cheapest and most convenient high-protein materials to offset the amino acid deficiencies of cereal proteins. It is also well known that legume flours and their protein concentrates are high in lysine. Legume protein concentrates, with superior functional properties and low flavor profiles, have found wider food applications than have legume flours (Patel et al 1980).

The purpose of this study was to evaluate some nutritional components of spaghetti fortified with nonroasted and roasted legume flours or their protein concentrates. This paper provides nutritional information on the physicochemical, antinutritional, amino acid, and mineral compositions of legume flours, protein concentrates, and fortified spaghetti compared with a control spaghetti.

MATERIALS AND METHODS

Legume Samples

Three legumes were studied: navy bean and pinto bean (*Phaseolus vulgaris*) and lentil (*Lens esculenta*).

Durum Semolina

One commercial semolina sample from the durum wheat variety Vic, a strong gluten type, was obtained from the North Dakota State Mill and Elevator, Grand Forks. Vic semolina was blended with legume flours or protein concentrates to produce fortified spaghetti.

Drying and Roasting of Legume Seeds

All legume seeds were dried in a convection-type dryer for 24–30 hr at 94–100° F to lower the moisture content of the seeds from 13.5 to approximately 10.0%. This lower moisture content is required for proper milling because a higher moisture content tends to increase the adhesion between the hull and cotyledon, which interferes with efficient reduction and sifting during the milling process.

Legume seeds were roasted at the Food Protein Research Center, Texas A&M University, College Station, according to the procedure of Aguilera et al (1982).

Milling

The Allis-Chalmers (Allis-Chalmers Manufacturing Co., Milwaukee, WI) and Buhler (Buhler, Englewood, NJ) experimental mills were used for milling the legumes according to the procedure of Watson et al (1975).

Preparation of Protein Concentrates

Protein concentrates were prepared by extracting 500 g of each

[1]Published with the approval of the director of the Agricultural Experiment Station, North Dakota State University, as Journal Series no. 1447.

[2]Graduate research assistant and assistant professor, respectively, Department of Cereal Science and Food Technology, Fargo 58105.

[3]Professor, Department of Animal Science, North Dakota State University, Fargo 58105.

legume flour with 5 L of 0.02% (w/v) NaOH for 1 hr at room temperature. Samples were then centrifuged at 1,500 × *g* for 15 min at room temperature. After a second extraction of the residue (pellet after first centrifugation), the two supernatants were combined and adjusted to pH 4.5 with concentrated HCl to precipitate the proteins. The precipitate was collected by centrifugation (1,500 × *g* for 15 min), gently washed twice by swirling distilled water over it to remove any remaining supernatant, and freeze-dried (Sosulski and Fan 1974). The schematic diagram for alkali extraction of protein concentrates from legume flour is shown in Figure 1.

Analytical Methods

Moisture, ash, protein, and fat were determined according to AACC methods 44-15A, 08-01, 46-11, and 30-10, respectively (AACC 1983).

Insoluble Dietary Fiber

The insoluble dietary fiber (neutral detergent fiber, NDF) of legume flours was determined according to the AACC method 32-20 (1983). A Tecator Fiber Tec system with 1010 heat extractor and 1021 cold extractor was used. This procedure was modified to include 1 mg amyloglucosidase enzyme to provide additional digestion of starch.

Trypsin Inhibitor and Hemagglutinin Activities

Trypsin inhibitor activity was determined utilizing the modified AACC procedure described by Hamerstrand et al (1981). Hemagglutinin activity was determined according to the method of Aguilera et al (1981).

Spaghetti Processing

The method of Vasiljevic and Banasik (1980) was used to prepare spaghetti from semolina control and various blends of semolina and legumes.

Color of Spaghetti

Color of spaghetti was determined with a Hunter Lab D-25-9 color difference meter according to the method of Walsh et al (1969).

Amino Acid Analysis

Amino acids of the samples were analyzed according to the procedure of Spackman et al (1958) which implements a continuous flow colorimeter. The analyses were determined on a Technicon sequential multisample automated amino acid analyzer (model TSM-1), computing the amino acid values on a computer terminal. Norleucine was used as an internal standard according to the procedure developed by Spackman et al (1958). The data were calculated to 100% nitrogen recovery and expressed as grams of amino acid per 16 g of nitrogen.

Mineral Analysis

Legume flours, protein concentrates, and control and fortified spaghetti (2–5 g) were ashed at 500°C overnight. Calcium, potassium, magnesium, iron, zinc, and sodium were then determined by atomic absorption spectroscopy according to the AOAC method (1980). Phosphorus was determined by a colorimetric method (AOAC 1980) using a spectronic-20-colorimeter (Bausch and Lomb).

Statistical Analysis

The Statistical Analysis System (SAS Institute 1982) was used to analyze the data.

RESULTS AND DISCUSSION

Chemical Composition of Legume Flours and Protein Concentrates

Means of the data obtained from the chemical composition of the legume flours and their protein concentrates were compared by Duncan's multiple range test (Table I). Moisture and protein contents differed significantly among all three legume samples, between flour and protein concentrate, and between roasted and nonroasted samples. Roasted samples showed higher protein content than nonroasted samples, perhaps caused by the roasting teatment, which may have rendered the proteins more soluble and/or more digestible during the procedure used for protein determination.

Protein concentrates had significantly higher ash values than legume flours. Fat content differed significantly between navy bean, lentil, and pinto bean, with navy bean products highest in fat content; fat content differed significantly and was much higher in protein concentrates than legume flours. From these results it would appear that the protein concentrate, a nutrient itself, has

TABLE I
Duncan's Multiple Range Test for Chemical Composition of the Different Legume Flours and Their Protein Concentrates

	Mean[a] (%)				
Variable (*n*)	Moisture	Protein	Ash	Fat	NDF[b]
Legume effect (8)					
Lentil	6.03 a	55.33 a	3.64 b	3.80 b	2.18 b
Pinto bean	5.85 b	51.63 b	4.71 a	3.63 b	2.77 a
Navy bean	5.63 c	46.41 c	4.77 a	4.70 a	2.24 b
Flour effect (12)					
Legume flour	9.61 a	24.89 b	3.68 b	2.98 b	4.25 a
Legume protein concentrate	2.06 a	77.37 a	5.07 a	5.10 a	0.54 b
Treatment effect (12)					
Nonroasted	5.98 a	49.87 b	4.19 b	4.66 a	2.50 a
Roasted	5.69 b	52.38 a	4.56 a	3.43 b	2.28 a

[a]Means with the same grouping letter are not significantly different (α = 0.05).
[b]NDF = neutral detergent fiber.

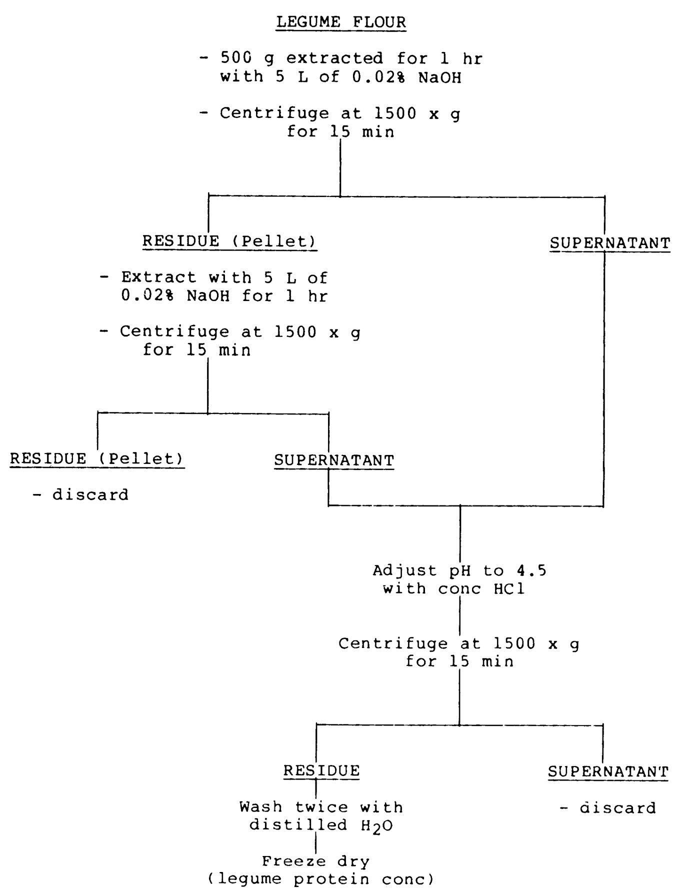

Fig. 1. Schematic diagram for alkali extraction of protein concentrates from legume flours.

additional advantages because the ash and fat components are associated with it. Therefore, use of this fraction even at relatively low levels may enhance the nutritional quality of foods.

No significant differences were found in NDF content between navy bean and lentil or between roasted and nonroasted samples. However, significant differences were found in NDF content between legume flours and their protein concentrates, with flour samples showing much higher levels than protein concentrates. This is most likely a result of the removal of fibrous material during the isolation of protein concentrates from the legume flours (Fig. 1). The three legumes all had higher chemical contents than the durum semolina control, which had 13.4% moisture, 14.0% protein, 0.7% ash, 2.1% fat, and 1.3% NDF.

Quality Components of Spaghetti

The quality components of spaghetti fortified with 10 and 15% legume flours or their protein concentrates were evaluated. However, only the results for the 15% blend are shown in Table II, because the trends for the two levels were very similar. Protein, ash, and fiber contents of the fortified spaghetti exceeded the levels shown for the control spaghetti. As expected, spaghetti supplemented with protein concentrates contained higher levels of protein than spaghetti fortified with legume flours. Ash content was also higher for fortified than for control spaghetti. These results show that the spaghetti made from blends with legume contained higher levels of nutrients than the control spaghetti.

TABLE II
Quality Components of Spaghetti Containing 15% Legume Flour or 15% Protein Concentrate[a]

Sample Description	Moisture (%)	Protein (%)	Ash (%)	Fiber (%)	Fat (%)	Color
Control	8.8	13.9	0.81	1.28	2.4	8.5
Nonroasted, flour						
Navy bean	7.4	19.7	1.31	1.86	2.2	7.0
Pinto bean	8.0	20.2	1.30	1.99	2.1	7.0
Lentil	8.2	20.1	1.02	1.87	2.1	7.5
Roasted, flour						
Navy bean	7.3	19.6	1.33	1.79	2.2	7.5
Pinto bean	7.8	19.8	1.33	1.97	2.1	7.0
Lentil	8.3	19.6	1.16	1.86	2.1	7.5
Nonroasted, protein concentrate						
Navy bean	6.6	27.1	1.52	1.37	2.8	5.5
Pinto bean	7.7	26.2	1.45	1.38	2.5	6.0
Lentil	8.3	26.6	1.10	1.30	2.5	7.0
Roasted, protein concentrate						
Navy bean	6.3	26.9	1.74	1.35	2.7	6.0
Pinto bean	7.5	27.0	1.47	1.35	2.2	7.0
Lentil	8.1	28.3	1.32	1.29	2.1	6.5

[a]Values reported are an average of two determinations and expressed on a dry weight basis.

TABLE III
Duncan's Multiple Range Test for Trypsin Inhibitor of the Different Legume Flours and Their Protein Concentrates

Variable (*n*)	Mean[a] (mg/g)
Legume effect (8)	
Navy bean	14.84 a
Pinto bean	13.46 b
Lentil	3.94 c
Flour effect (8)	
Legume flour	12.38 a
Legume protein concentrate	9.12 b
Treatment effect (12)	
Nonroasted	11.54 a
Roasted	9.95 b

[a]Means with the same grouping letter are not significantly different ($\alpha = 0.05$).

The high yellow pigment content of durum semolina is one of the desirable quality attributes in the production of pasta products. However, color score of the fortified spaghetti decreased as the level of legume flour or protein concentrate was increased in the blends (Table II). The largest decrease in color scores was observed for nonroasted and roasted navy bean protein concentrates. Taste panel evaluations, however, showed that the color of the spaghetti fortified with up to 10% legume samples was quite acceptable (Bahnassey and Khan 1986).

Trypsin Inhibitor Activity

Statistical analysis data for the trypsin inhibitor activity (TIA) of the legume flours and protein concentrates are summarized in Table III. Trypsin inhibitor activity differed significantly among the three legumes in this study, with navy bean containing the highest levels. There was also a significant difference in trypsin inhibitor content between protein concentrate and legume flour, with concentrates showing less trypsin inhibitor activity. The inhibitors may have been inactivated by the alkaline treatment of the flour for solubilizing the protein. The heat treatment used for roasting the seeds significantly reduced the level of inhibitors. It should be pointed out, however, that the statistical analyses of TIA activity seem to portray greater differences than the actual values found for the various legume samples. Because legumes are usually cooked with high heat, TIA is not a problem. If, however, bean ingredients must be utilized in products for consumption treated at low temperatures, further studies would have to be carried out to obtain roasting conditions that would result in greater inactivation of TIA activity than found in this study.

Table IV shows the trypsin inhibitor activity in spaghetti fortified with 10 and 15% legume flours and legume protein concentrates. The highest level of TIA was found in spaghetti fortified with navy bean products, followed by spaghetti containing pinto bean products. The lowest TIA was found in spaghetti containing lentil. Spaghetti containing roasted legume samples showed less TIA than the nonroasted samples. Also spaghetti containing 100% semolina (control) showed very low activity.

Hemagglutinin Activity

In this study hemagglutinin activity was observed clearly for both the nonroasted and roasted legumes samples but was substantially reduced in the roasted sample (Table V). Nonroasted navy bean flour contained twice as much activity as pinto bean or lentil flour. Protein concentrates from the different legume samples showed less activity than the legume flours, perhaps because of the alkali used for extraction of protein concentrates. An attempt was made to determine the hemagglutinin activity in extracts of the semolina sample, but no activity was detected.

Amino Acid Composition

Because protein quality is a function of essential amino acid composition as well as the ratios of amino acids to each other, study

TABLE IV
Trypsin Inhibitor Activity (TIA)[a] of Spaghetti Containing 10 and 15% Legume Flours or Their Protein Concentrates

	TIA (mg/g)			
	10%		15%	
Sample	Nonroasted	Roasted	Nonroasted	Roasted
Control spaghetti	0.83	...	0.83	...
Nonroasted, flour				
Navy bean	2.41	2.40	3.18	2.78
Pinto bean	2.40	2.30	3.00	2.78
Lentil	1.32	1.04	1.63	1.41
Roasted, protein concentrate				
Navy bean	2.00	1.89	2.59	2.41
Pinto bean	1.71	1.67	2.48	1.94
Lentil	1.12	1.00	1.47	1.19

[a]Analyses were performed in triplicate and means reported.

of the amino acid patterns for legume flours and their protein concentrates was of interest. The amino acid compositions of navy, pinto, and lentil flours and their protein concentrates, as well as the semolina sample, are shown in Table VI. Lysine was one of the most abundant of the essential amino acids in the legumes and was present at about four times the value found in the semolina. These data are in agreement with that reported by Patel and Johnson (1974), who showed that lysine content of horsebean flour is 3.8 times greater than that found in wheat flour. Also, Seyam et al (1983) reported that lysine content in navy and pinto bean flours is about four times the value of the semolina control. The semolina sample showed higher values for ammonia, glutamic acid, urea, and the sulfur-containing amino acids (methionine and cystine) than the legume flours and their protein concentrates. Patel and Johnson (1974) reported similar results concerning the total sulfur amino acids (methionine and cystine), the first limiting amino acids in horsebean flour and its protein isolate.

In general, most of the amino acids of the legume flours and their protein concentrates were higher than those of durum wheat semolina. The very high contents of glutamic acid and urea in the durum semolina compared to the legume samples may partly explain why the contents of most of the other amino acids are lower in the former and higher in the latter. It should be noted that the heat treatment used to roast the legumes did not have any adverse effect on the amino acid composition.

TABLE V
Hemagglutinin Activity of Legume Flours and Their Protein Concentrates

Sample Description	Hemagglutinin Activity[a] Nonroasted	Roasted
Flour		
Navy bean	160	40
Pinto bean	80	20
Lentil	80	60
Protein concentrate		
Navy bean	80	20
Pinto bean	20	20
Lentil	40	20

[a]Hu/mg expressed on as is basis (Aguilera et al 1981).

Amino acid composition of spaghetti fortified with 10 and 15% of the three legume flours or their protein concentrates was evaluated. The results showed the same trend as in Table VI for all the legume flours and their protein concentrates when compared to spaghetti processed from 100% semolina. Therefore, only the results for navy beans (Table VII) are reported to illustrate the trends observed for all three legume-semolina blends. These results showed that the spaghetti made from legume-semolina blends had a much better balance especially of the essential amino acids; for example, the sulfur amino acids as well as the lysine content were higher in the fortified spaghetti samples. Therefore, blending cereals with legumes can enhance nutritional quality.

Mineral Composition

Mineral content of legume flours and protein concentrates was considerably higher than for the durum semolina control (Table VIII). The mineral content (mg %) of durum semolina was as follows: P, 202.3; Mg, 60.5; K, 194.5; Ca, 15.9; Fe, 1.7; Zn, 1.2; and Na, 0.91. Compared to semolina, legume flour contained approximately two to three times more zinc, phosphorus, calcium, and magnesium and five to six times more potassium and sodium. Potassium, phosphorus, magnesium, and calcium, in decreasing amounts, were the main mineral elements of legume flour and semolina. In the protein concentrates, phosphorus and potassium were the predominant minerals, and magnesium exceeded calcium. Similar results were reported by Patel et al (1980) for the mineral composition of navy bean protein concentrates obtained by an air-classification technique. There was a pronounced increase in concentration of phosphorus, calcium, iron, zinc, and sodium in the protein concentrates. Sodium content was obviously higher in protein concentrate than flour because of the use of sodium hydroxide in protein extraction (Fig. 1).

Means comparison (Table VIII) showed that phosphorus, iron, and sodium levels were significantly different in all legume types. Roasting had a significant effect on magnesium, potassium, calcium, iron, and sodium, with roasted samples showing higher levels of calcium, zinc, and iron than the nonroasted samples. These higher levels of minerals in the roasted samples cannot be readily explained. However, it should be noted that extra precautionary steps were not taken during the various stages of sample handling and preparation to prevent contamination that may have resulted in higher values.

TABLE VI
Amino Acid Composition[a] of Vic Semolina and Nonroasted and Roasted Legume Flours and Their Protein Concentrates

Amino Acids[b]	Vic Semolina	Nonroasted NBF[c]	PBF	LF	NPC[d]	PPC	LPC	Roasted NBF	PBF	LF	NPC	PPC	LPC
Urea	7.70	2.26	1.95	2.22	...	...	...	2.35	1.94	2.84	...	...	...
Aspartic acid	3.61	11.09	9.38	10.03	13.28	12.50	12.93	11.15	11.27	10.76	13.63	12.65	11.72
Threonine	2.34	4.15	3.37	3.09	4.22	3.66	3.59	4.03	3.54	3.54	4.38	3.37	3.19
Serine	4.21	5.92	5.22	4.82	6.85	6.70	6.11	6.03	5.51	5.10	7.53	6.77	6.17
Glutamic acid	31.38	14.43	13.93	14.43	16.83	17.79	17.56	15.26	16.05	15.21	18.22	18.30	19.86
Proline	4.58	5.42	3.79	6.91	4.77	5.15	2.69	4.71	4.10	6.35	4.93	4.65	2.81
Glycine	2.58	4.03	3.66	3.66	4.05	3.88	3.76	3.92	3.57	3.91	3.86	3.64	3.66
Alanine	2.49	3.97	3.74	3.90	4.33	4.08	4.09	4.12	3.84	4.20	3.92	3.69	3.71
Cystine	1.36	1.08	1.20	1.12	0.90	0.66	0.84	0.95	0.91	1.37	0.70	1.00	0.54
Valine	3.28	4.56	4.39	3.92	5.12	4.77	4.76	4.46	4.01	4.48	5.19	4.59	4.52
Methionine	1.19	1.14	1.39	1.00	1.35	1.37	0.92	1.21	1.45	0.95	0.97	1.12	0.40
Isoleucine	2.65	3.55	3.50	3.27	4.25	4.03	4.15	3.66	3.47	3.48	4.21	3.98	4.00
Leucine	5.56	7.65	7.63	6.94	9.27	8.77	8.74	8.11	7.47	7.31	9.09	8.91	8.82
Tyrosine	1.14	2.58	3.10	2.61	3.51	3.36	3.16	2.96	2.97	2.46	3.33	3.40	3.04
Phenylalanine	3.96	5.56	5.78	5.16	6.21	5.97	5.51	5.96	6.30	5.03	6.27	6.10	5.80
Histidine	2.17	4.00	3.82	2.97	3.20	3.25	2.50	3.41	3.49	2.89	3.13	3.38	2.55
Lysine	1.67	6.71	6.90	6.81	7.37	7.42	7.40	6.92	6.82	6.67	7.05	7.37	6.94
Ammonia	5.23	2.95	3.35	2.86	2.86	2.83	2.82	2.91	2.75	2.45	2.77	3.01	2.92
Arginine	2.75	6.35	7.54	8.40	6.31	7.27	9.40	5.43	7.57	7.03	6.30	7.28	9.82

[a]Grams of amino acid per 16 g of nitrogen corrected to 100% protein recovery; each value is an average of three determinations of the same sample.
[b]Tryptophan was not determined.
[c]NBF, PBF, and LF = navy bean, pinto bean, and lentil flours, respectively.
[d]NPC, PPC, and LC = navy bean, pinto bean, and lentil protein concentrates, respectively.

Means comparison of the mineral composition of spaghetti containing the different legume flours or their protein concentrates is shown in Table IX. As with legume flours and their protein concentrates, spaghetti fortified with legume samples showed higher mineral content than the control spaghetti. The trends observed for the legume effect were slightly different for the fortified spaghetti samples (Table IX) than for the legume samples (Table VIII). Also the differences in mineral contents between nonroasted and roasted samples were less in spaghetti (Table IX) than among the legume samples (Table VIII). It should be noted that a greater number of spaghetti samples was analyzed (16–24, Table IX) compared to the legume samples (8–12, Table VIII).

TABLE VII
Amino Acid Composition[a] of Control Spaghetti and Spaghetti Containing 10 and 15% Navy Bean Flour or Protein Concentrate

		10%				15%			
		Flour		Protein Concentrate		Flour		Protein Concentrate	
Amino Acids[b]	Control Spaghetti	Nonroasted	Roasted	Nonroasted	Roasted	Nonroasted	Roasted	Nonroasted	Roasted
Urea	7.64	4.53	3.59	3.57	2.79	4.37	4.00	3.22	2.52
Aspartic acid	3.14	4.36	4.47	5.86	6.80	4.64	4.87	6.87	7.71
Threonine	2.16	2.41	2.65	2.47	3.07	2.37	2.64	2.78	3.11
Serine	4.01	4.44	4.52	4.71	5.56	4.59	4.83	4.95	5.73
Glutamic acid	27.71	29.54	32.69	28.52	30.14	28.29	30.84	27.13	28.76
Proline	7.97	9.89	9.82	7.79	8.91	10.03	9.68	8.36	8.35
Gycine	2.33	2.66	2.88	2.99	3.10	2.78	2.85	3.04	3.15
Alanine	2.24	2.62	2.79	2.98	3.03	2.67	2.77	3.03	3.08
Cystine	1.20	1.46	1.14	1.43	0.97	1.33	1.26	1.34	0.88
Valine	3.21	3.00	3.61	3.60	3.77	3.13	3.17	3.68	4.06
Methionine	1.16	1.56	1.28	1.46	1.30	1.38	1.44	1.46	1.27
Isoleucine	2.52	2.59	2.93	2.89	3.28	2.62	2.56	2.98	3.29
Leucine	8.82	5.89	6.56	6.93	7.08	5.82	6.13	7.04	7.56
Tyrosine	0.74	1.47	0.78	1.75	0.93	1.66	1.76	1.96	1.09
Phenylalanine	3.57	4.09	4.38	4.38	4.88	4.40	4.35	4.84	5.17
Histidine	1.99	2.17	2.26	2.54	2.51	2.05	2.26	2.62	2.58
Lysine	1.50	2.02	2.21	2.99	3.37	2.24	2.35	3.57	3.90
Ammonia	4.99	6.25	6.34	5.87	5.54	6.36	5.85	5.36	5.12
Arginine	2.92	3.76	3.35	4.23	3.69	3.90	3.68	4.26	4.05

[a]Grams of amino acid per 16 g of nitrogen corrected to 100% protein recovery; each value is an average of three determinations of the same sample.
[b]Tryptophan was not determined.

TABLE VIII
Duncan's Multiple Range Test for Minerals in Legume Flours and Protein Concentrates

	Mean[a] (mg %)							
Legume	P	Mg	K	Ca	Zn	Fe	Na	*n*
Legume effect								
Navy bean	895.69 a	187.17 a	1,432.05 a	34.43 a	5.09 a	14.49 b	102.30 a	8
Pinto bean	846.96 b	184.05 a	1,416.26 a	26.63 b	3.95 b	12.36 c	89.07 b	8
Lentil	696.06 c	84.62 b	758.60 b	31.68 a	5.15 a	17.45 a	52.77 c	8
Treatment effect								
Roasted	804.24 a	142.43 b	1,125.40 b	32.65 a	3.01 a	14.93 a	68.95 b	12
Nonroasted	821.57 a	161.47 a	1,279.29 a	29.18 b	4.46 a	14.60 b	93.80 a	12
Flour effect								
Flour	556.00 b	153.52 a	1,239.79 a	28.78 b	3.31 b	10.46 b	7.73 b	12
Protein Concentrate	1,069.80 a	150.37 a	1,164.90 a	33.05 a	6.15 a	19.08 a	155.02 a	12

[a]Means with the same grouping letter are not significantly different ($\alpha = 0.05$).

TABLE IX
Duncan's Multiple Range Test for Minerals in Fortified Spaghetti

	Mean[a] (mg %)						
Variable (*n*)	P	Mg	K	Ca	Zn	Fe	Na
Legume effect (16)							
Navy bean	290.51 a,b	80.13 a	389.67 a	17.57 a	1.84 a	3.55 b	21.83 a
Pinto bean	277.57 b	73.39 b	340.55 b	16.80 a	1.67 b	3.30 b	20.92 a
Lentil	295.79 a	67.61 c	275.84 c	17.13 a	1.85 a	3.88 a	21.57 a
Treatment effect (24)							
Nonroasted	289.25 a	75.57 a	330.54 a	17.29 a	1.79 a	3.24 b	21.32 a
Roasted	286.66 a	71.86 b	340.16 a	17.04 a	1.77 a	3.92 a	21.56 a
Flour effect (24)							
Legume flour	247.14 b	73.10 a	340.20 a	17.19 a	1.69 b	2.91 a	15.60 b
Legume protein concentrate	328.77 a	74.33 a	330.51 a	17.15 a	1.88 a	4.24 a	27.28 a
Percent effect (24)							
10%	267.50 b	69.48 b	307.21 b	16.56 b	1.67 b	3.27 b	20.22 b
15%	308.41 a	77.95 a	363.50 a	17.78 a	1.90 a	3.88 a	22.66 a

[a]Means with the same grouping letter are not significantly different ($\alpha = 0.05$).

More pronounced increases were observed in spaghetti containing protein concentrate than spaghetti containing legume flour. As expected, mineral contents were higher in the spaghetti from the 15% level of fortification than the 10% level.

CONCLUSIONS

A traditional product, spaghetti, was fortified with legume flours or their protein concentrates. The results of this study clearly demonstrate that fortified spaghetti had superior nutritional properties to spaghetti made from 100% durum semolina, confirming the better nutritional balance of legume-cereal blends. Heat treatment of legumes did not have damaging effects on the nutritional components but rather nutritional advantages because levels of antinutritional factors were reduced. The possible advantages of roasting on nutritional and technological properties of legumes should be investigated further. Because pasta is considered to be a nutrient-dense product, spaghetti fortified with legumes could be targeted for specialized groups of people such as athletes, nutrition-conscious consumers, and people in developing countries.

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