Fortification of Spaghetti with Edible Legumes. II. Rheological, Processing, and Quality Evaluation Studies[1]

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ABSTRACT

Spaghetti was prepared from durum wheat semolina, blended with 3% vital wheat gluten, and fortified with 0, 5, 10, 15, 20, and 25% of nonroasted or roasted navy, pinto, or lentil flours or their protein concentrates to increase protein quantity. Supplementing semolina with legume flours or protein concentrates caused an increase in farinograph water absorption, except for blends containing 25% of the nonroasted and roasted pinto bean flour, in which a slight decrease was noticed. Dough development time and stability were higher for blends containing navy or pinto bean flours. A decrease in the mechanical tolerance index was obtained for blends containing different levels of navy or pinto bean flour or protein concentrates. Fortified spaghetti shattered earlier than control spaghetti. Cooked weight of fortified spaghetti showed a decrease as the level of fortification increased. Cooking time significantly affected cooked weight of spaghetti: the longer the cooking time, the higher the cooked weight. Cooking loss of fortified spaghetti was higher as the level of substitution increased and higher for spaghetti containing protein concentrates than for spaghetti containing legume flours. Firmness scores of the fortified spaghetti increased with the level of fortification. Taste panel evaluation showed that spaghetti supplemented with up to 10% of legume flours or protein concentrates was acceptable for all the parameters tested. All panel members showed preference for spaghetti containing legume flours over the spaghetti containing legume protein concentrates. However, spaghetti containing 10% protein concentrates was also acceptable. Spaghetti made from roasted samples was preferred over nonroasted samples. A beany taste was reported for spaghetti containing 25% of nonroasted legume flours or their protein concentrates.

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One of the great challenges today is to develop inexpensive foods that are nutritionally superior and at the same time acceptable to the intended consumer. Wheat is abundant in some areas of the world and is one of the least expensive cereals available for creating fabricated foods high in nutrition. Pasta, whether it be in the form of flat noodles, elbow macaroni, or spaghetti, is consumed world wide. It is also economical, easy to prepare, shelf stable, and can be served in many different ways. Because pasta is extruded, additives can be easily blended into its formula. The amounts and types of additives permitted in pasta are controlled by the U.S. Food and Drug Administration (FDA) as published in the Federal Register (1980). Pasta, therefore, can be used as a vehicle for production of novel formulated foods.

Breen et al (1977) showed that soybean protein isolate and soybean flour are good additives to macaroni as judged by color, cooking loss, cooked weight, and firmness. At high levels of supplementation, the taste panel evaluation rated the soy-wheat pasta lower than the control. Hopkins (1980) found that pasta produced from soy products was dark, slightly bitter, and had reduced elasticity. Rice noodles fortified with up to 30.9% soy flour were acceptable to children in Thailand (Siegel et al 1975). Noodles were produced from various flours fortified with fish protein concentrate (Kwee et al 1969, Woo and Erdman 1971). Soy flour was used to supplement protein in macaroni products (Paulson 1960) and to produce a quick-cooking pasta product (Kinsley 1965).

The object of this study was to develop a fortified spaghetti from semolina blended with nonroasted and roasted legume flours and their protein concentrates. Semolina from a strong gluten durum variety was used because of its superior technological properties (Quick et al 1979). The effects of fortification on various quality parameters of spaghetti such as rheological properties, spaghetti cooking quality, and consumer acceptance (taste panels) were evaluated.

MATERIALS AND METHODS

Samples and Concentrates

The legume samples used in this study were described previously (Bahnassey et al 1986). The legumes used included roasted and nonroasted navy bean, pinto bean, and lentil. The durum semolina was obtained from the strong gluten durum wheat variety Vic.

Protein concentrates were prepared from the various legumes according to the procedure outlined by Bahnassey et al (1986).

Pasta Processing and Quality Evaluation

Preparation of blends. Navy, pinto, and lentil flours and their protein concentrates were blended with semolina from the durum wheat variety Vic and 3% vital wheat gluten at 0, 5, 10, 15, 20, and 25% levels, respectively. A total of 2,000 g of each blend was prepared.

Farinograph studies. The procedure of Irvine et al (1961) was employed. The absorption, dough development time (peak time), stability, and mechanical tolerance index were measured.

Spaghetti processing. Spaghetti was prepared from semolina control and the different blends of semolina and legumes according to Bahnassey et al (1986).

Spaghetti quality evaluation. Spaghetti color was determined according to Bahnassey et al (1986). The cooking quality of the spaghetti was determined according to the method of Vasiljevic and Banasik (1980). Cooked weight (in grams) was determined after the spaghetti was drained.

Cooking loss was determined by collecting the cooking and rinse waters in a preweighed Erlenmeyer glass beaker, which was then placed in an air oven at 100° C and the water evaporated to dryness. The residue was weighed and reported as a percentage of dry spaghetti (starting materials).

Spaghetti firmness was measured by shearing two strands of cooked spaghetti at a 90° angle with a special Plexiglas cutting tooth as described by Walsh (1971). A continuous recording of distance versus force was traced by an Instron universal testing instrument, type Tm-M (Instron Corp., Canton, MA 02021). An automatic integrator (Instron model G90-21) was used to calculate the area under the curve (g·cm), which was the amount of work required to shear the two strands of cooked spaghetti. The firmness reading was the average of three replicate determinations. Firmness score was calculated according to the procedure of Vasiljevic and Banasik (1980).

Sensory Evaluation

Samples for sensory evaluation were cooked to optimum cooking time in distilled water, drained, and served warm to sensory panelists. A score sheet was developed for judging the spaghetti on color, mouthfeel, external appearance, and general

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acceptability, using a hedonic scale of 1 to 7 with 7 being excellent and 1 being poor.

Statistical Analysis

The Statistical Analysis System (SAS Institute 1982) was used to analyze the cooking quality and sensory evaluation data of this study.

RESULTS AND DISCUSSION

Protein Concentrates

Color and yield of navy, pinto bean, and lentil protein concentrates are summarized in Table I. The color of the protein concentrate from the roasted samples was slightly darker than that of the nonroasted samples, perhaps attributable to browning reactions that may have occurred during roasting. Roasted samples showed lower yields of protein concentrates than nonroasted samples, probably because of the reduced solubility of legume proteins from heat treatment in roasting.

Farinograph Studies

The farinograph characteristics of the blends of semolina with different legume flours or their protein concentrates are presented in Table II. Supplementing semolina with legume flours or their protein concentrates caused an increase in water absorption, with the exception of the blends containing 25% roasted or nonroasted pinto bean flour, in which a slight decrease in absorption was observed. The increase in water absorption was probably a result of the higher protein content of the blends causing greater hydration capacity. These results are in agreement with those found by D'Appolonia (1978), Lorenz et al (1979), McConnel et al (1974), Patel and Johnson (1975), and Sathe et al (1981). Dough development time and stability were higher for blends containing navy and pinto bean flour (Table II) and for their protein concentrates at 15% and higher levels of supplementation. Blends of lentil flour or its protein concentrate did not perform as well as the blends containing navy and pinto bean products. Blends containing different levels of navy and pinto bean flours or their protein concentrates showed a decrease in mechanical tolerance index that indicated better mixing tolerance, especially at higher levels of supplementation.

TABLE I
Color and Yield of Legumes Protein Concentrates

Protein Concentrates Source	Color[a]	Yield[b] (%)
Nonroasted		
Navy bean flour	white-creamy	24.5
Pinto bean flour	white-gray	32.5
Lentil	yellow	21.5
Roasted		
Navy bean flour	creamy	23.0
Pinto bean flour	white-gray	19.5
Lentil flour	green-yellow	15.0

[a] Determined by visual examination.
[b] Calculated on an as is basis as: (weight of protein concentrates/initial material weight) × 100.

Pasta Processing and Cooking Quality of Spaghetti

In general, spaghetti made from incorporating legume flours and protein concentrates with semolina showed more cracking and shattering earlier than spaghetti made from the control (100% semolina). Shattering began about one week after processing. This shattering problem was not investigated further in this study. All sensory and quality evaluations were carried out before onset of shattering. Also differences such as a waxy appearance and rapid drying of spaghetti during extrusion were noticed with samples containing above 15% of the different blends.

Cooking quality, as indicated by cooked weight, cooking loss, and cooked firmness, was determined for the control and for each of the blends, using the standard cooking time of 12 min, optimum cooking time, 5 min over optimum, and 10 min over optimum (Table III). The cooked weight values of the control spaghetti for these times showed a steady increase as follows: 28.4 g, 28.7 g, 32.6 g, and 36.4 g, respectively. However, as the level of supplementation was increased cooked weight decreased (at 12 min cooking time). These results are in agreement with those obtained by Nielsen et al (1980), who found significant lower water

TABLE II
Farinograph Properties of Blends Containing Semolina and Various Levels of Nonroasted or Roasted Legume Flours or Their Protein Concentrates

Sample and Addition Level (%)	Absorption[a] (%)			DDT[b] (min)			MTI[c] (BU)			Stability (min)		
	Navy	Pinto	Lentil	Navy	Pinto	Lentil	Navy	Pinto	Lentil	Navy	Pinto	Lentil
Control (100% semolina)		335.5			3.5			130			1.5	
Flour, nonroasted												
5	36.2	35.6	36.2	3.0	3.5	2.5	110	130	110	1.5	2.0	2.5
10	36.5	36.2	35.8	3.5	3.0	2.5	110	90	100	2.0	2.5	2.0
15	35.9	36.0	35.8	4.0	3.5	3.0	100	80	100	2.0	3.0	2.0
20	35.6	35.6	36.0	4.0	4.0	3.0	90	50	100	3.0	4.5	2.5
25	35.6	35.4	35.2	4.5	4.0	2.5	80	45	90	2.5	6.5	3.0
Flour, roasted												
5	36.4	36.4	36.6	3.0	2.5	2.5	125	110	140	1.5	2.0	1.5
10	36.6	36.0	36.4	3.0	3.0	2.5	130	100	160	2.0	3.0	2.0
15	36.4	36.6	36.6	3.5	3.5	3.0	100	80	150	2.5	4.0	1.5
20	36.6	35.6	37.0	4.5	5.0	3.5	90	50	140	3.0	7.0	2.0
25	36.6	35.2	36.8	5.5	6.0	4.0	50	35	125	7.0	10.0	2.0
Protein concentrate, nonroasted												
5	36.5	37.2	37.4	2.5	2.0	2.0	140	110	150	1.0	1.5	1.0
10	36.2	36.6	37.8	2.0	1.5	1.5	110	100	130	2.0	3.0	1.5
15	36.1	36.6	38.0	3.0	2.5	1.5	85	70	125	2.5	3.0	1.5
20	36.5	37.0	38.2	3.0	3.0	1.5	70	65	110	2.5	2.0	1.5
25	37.0	37.4	38.6	3.5	3.5	2.0	70	60	100	2.0	3.0	2.5
Protein concentrate, roasted												
5	36.8	37.4	37.2	2.0	2.0	1.5	140	140	160	1.5	1.5	1.5
10	36.2	37.4	37.2	2.5	2.0	2.0	95	90	115	2.0	1.5	2.0
15	36.0	37.4	37.2	3.0	2.5	1.5	70	80	90	2.5	2.5	2.0
20	37.3	37.6	37.6	3.5	3.0	2.0	60	65	60	2.5	2.5	2.0
25	36.0	38.4	38.2	3.5	2.0	2.0	50	60	75	3.5	2.5	2.5

[a] Expressed on a 14% moisture basis.
[b] DDT = dough development time.
[c] MTI = mechanical tolerance index.

absorption for spaghetti containing 33% pea flour or 20% air-classified pea protein concentrates. Also Breen et al (1977) showed that the cooked weight of spaghetti made from a bean formula is lower than that of the control. These results showing lower water absorption of the cooked legume-blended spaghetti are in contrast to the higher farinograph water absorption noticed earlier for almost all the legume-semolina blends shown in Table II.

Cooking time had a significant effect on cooked weight of the spaghetti (Table III). The longer the cooking time the higher the cooked weight. Cooked weight of spaghetti was significantly affected by the type of legume used; spaghetti containing navy bean products showed the highest cooked weight, followed by pinto, then lentil products. Roasting had a significant effect, because nonroasted samples showed higher cooked weight than the roasted samples. From the cooked weight values of spaghetti made from legume-semolina blends of nonroasted and roasted samples, it would seem that heat treatment of legume proteins affect their water binding capacity. Spaghetti containing legume flours showed higher cooked weight than spaghetti containing protein concentrates.

Cooking loss of the control spaghetti was 6.0, 6.1, 6.9, and 7.3% at 12 min, optimum (12 min), 5 min over optimum, and 10 min over optimum, respectively. Cooking loss for all legume-semolina blends was higher than the control spaghetti. Means comparison (Table III) of the cooking loss data showed that cooking loss increased significantly with increased cooking time. Spaghetti containing lentil in the blends had the most significant cooking loss, most likely caused by its longer optimum cooking time. Cooking loss of spaghetti was also significantly affected by the incorporation of flour or protein concentrates, by roasting, and by the percentage of substitution. Higher cooking losses were seen for spaghetti containing legume protein concentrates than for those containing legume flours. Roasted samples showed higher cooking losses than nonroasted samples. Cooking loss increased as the level of fortification was increased. These results parallel the cooked weight data in that as cooked weight decreased there was a greater cooking loss of the corresponding sample.

Firmness values (g·cm) of the control spaghetti were 8.7, 8.8, 6.7, and 6.3, at 12 min, optimum (12 min), 5 min over optimum, and 10 min over optimum, respectively. Means comparison of firmness scores (Table III) of all spaghetti showed that as cooking time increased, firmness score decreased. Spaghetti containing navy bean flour or its protein concentrate had the highest firmness score followed by lentil, then pinto bean. All spaghetti containing legume flours or protein concentrates showed a significant increase in firmness as the percent of legume products was increased. Roasted samples showed lower firmness scores than the nonroasted. Spaghetti containing protein concentrates showed higher firmness scores than the ones containing legume flours. As the level of fortification increased, firmness scores generally increased. Similar results were obtained by Nielsen (1980) and Breen et al (1977). In general, all fortified spaghetti gave higher firmness scores than the control spaghetti.

TABLE III
Means Comparison of Various Quality Parameters of Cooked Spaghetti Made From Legume-Semolina Blends

Variable (*n*)	Mean[a] Cooked Weight (g)	Cooking Loss (%)	Firmness (g·cm)
Cooking time effect (126)			
12 min	26.49 d	6.95 d	9.77 a
Optimum	28.08 c	7.63 c	8.89 b
5 min over optimum	31.55 b	8.69 b	8.09 c
10 min over optimum	34.05 a	9.61 a	7.13 d
Legume effect (160)			
Navy bean	30.38 a	8.10 b	8.78 a
Pinto bean	30.24 b	8.14 b	8.32 c
Lentil	29.26 c	8.66 a	8.46 b
Treatment effect (240)			
Nonroasted	30.10 a	8.24 b	8.57 a
Roasted	29.82 b	8.36 a	8.47 b
Flour effect (240)			
Legume flour	31.19 a	8.14 b	8.23 b
Legume protein concentrate	28.73 b	8.45 a	8.81 a
Percent effect (96)			
5%	30.94 a	7.41 e	8.03 e
10%	30.18 b	7.78 d	8.40 d
15%	29.75 c	8.24 c	8.55 c
20%	29.48 d	8.83 b	8.69 b
25%	29.46 d	9.23 a	8.92 a

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

TABLE IV
Means Comparison of Various Parameters of Spaghetti from Taste Panel Evaluation

Variable (*n*)	Mean[a] Appearance	Color	Mouthfeel	Acceptability
Control (50)	6.32 a	6.34 a	6.34 a	6.22 a
Legume effect (120)				
Navy bean	3.83 b	3.97 b	3.43 b	3.46 b
Pinto bean	3.64 b	3.52 c	3.10 b	3.21 b
Lentil	3.34 c	3.37 c	3.35 b	3.34 b
Treatment effect (180)				
Roasted	3.72 b	3.82 b	3.24 b	3.37 b
Nonroasted	3.48 c	3.41 c	3.37 b	3.31 b
Flour treatment (180)				
Legume flour	4.11 b	4.06 b	3.89 b	3.88 b
Legume protein concentrate	3.10 c	3.17 c	2.79 c	2.79 c
Percent effect (120)				
10%	4.40 b	4.34 b	4.15 b	4.14 b
15%	3.61 c	3.55 c	3.23 c	3.33 c
25%	2.80 c	2.96 d	2.51 d	2.54 d

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

Sensory Evaluation

Sensory evaluation data of the fortified spaghetti were statistically analyzed. Means comparison for the parameters appearance, color, mouthfeel, and general acceptability used to evaluate the spaghetti are shown in Table IV. Taste panel members showed preference for spaghetti containing navy bean products or legume flours over protein concentrates. Heat treatment of legumes had a positive effect, because roasted samples were preferred over nonroasted, except for the mouthfeel test in which no preference was indicated. The 10% level of substitution was preferred over the 15 and 25% levels. Above the 10% level of fortification, certain panel members detected a difference in mouthfeel that was not objectionable. With the incorporation of 25% nonroasted bean flour or bean protein concentrates, several panel members commented that the spaghetti had a beany taste and was objectionable.

CONCLUSION

In this study fortified spaghetti was not intended to replace regular spaghetti products, but to provide a nutritious and high-protein staple food for low-income people, developing areas, and for people wishing to improve the nutritional quality of their diet. Spaghetti fortified with heat treated (roasted) legumes can also have desirable organoleptic properties as indicated by taste panel studies. As stated in the Federal Register (1980), protein content of fortified pasta products should not be less than 20% protein by weight (on a 13.0% moisture basis). In this study spaghetti containing 10, 15, 20, and 25% roasted and nonroasted navy, pinto, and lentil protein concentrates met the FDA specification for protein content in a fortified product. As mentioned earlier, spaghetti containing 10% of the roasted and nonroasted legume flours or protein concentrates was acceptable to taste panelists. Therefore, spaghetti containing 10% legume protein concentrates met the FDA specification and was acceptable to taste panel

members. However, the fortified spaghetti shattered earlier than the control spaghetti. This is a problem that needs further investigation.

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