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ORIGINAL ARTICLE

Enrichment of pasta with different plant proteins

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Abstract Effects of supplementation of plant proteins from mushroom powder, Bengal gram flour and defatted soy flour at different levels were assessed on the nutritional quality of pasta. Supplementation of wheat semolina was done with mushroom powder (0–12%), Bengal gram flour (0–20%) and defatted soy flour (0–15%). Mushroom powder and defatted soy flour increased the cooking time of pasta whereas non significant variation was observed in cooking time of Bengal gram supplemented pasta. Significant correlation (r=0.97, $p \leq 0.05$) was observed between water absorption and volume expansion of pasta. Instantization of pasta by steaming improved the cooking quality. Steamed pasta absorbed less water and leached fewer solids during cooking. On the basis of cooking and sensory quality, pasta in combination with 8% mushroom powder, 15% Bengal gram flour and 9% defatted soy flour resulted in a better quality and nutritious pasta.

Keywords Pasta · Mushroom powder · Bengal gram flour · Defatted soy flour · Quality · Protein supplementation

Pasta represents a fast growing segment of the food industry in India because of consumer demands for convenient and nutritious food products. Pasta may have its origin in Asia and the Mediterranean but its growing popularity has made it a healthy food worldwide. As wheat derived staple food, pasta is second only to bread in the world consumption (Mariani-Constantini 1988). Its worldwide acceptance is attributed to its low cost, ease of preparation, versatility sensory attributes, long shelf life and easy to transport (Riley 1987). In India, the use of pasta products, particularly noodles are increasing steadily. Production of pasta was 910 tonnes in 2005, an increase of 14% from year 2004. Pasta can be formulated according to the consumer's demand (Feillet et al. 1996). Bahnassey and Khan (1986) and Collins and Pangloli (1997) used legumes flours to increase the nutritive value of pasta products. Results indicated a significant increase in protein and mineral content of pasta. Legume seed proteins are natural supplement to cereal proteins in producing an overall essential amino acid balance (Singh and Singh 1992). Petitot et al. (2009) produced a nutritionally enhanced spaghetti by adding high amounts of (35%) of legumes (split pea or faba bean) to durum wheat semolina. An increase of furosine and phenolic content in pasta with the addition of bean flour (Gallegos-Infante et al. 2010a, b). Plain semolina pasta showed highest enzymatic hydrolysis rate, spaghetti with a higher level of common bean flour is more slowly available, which has positive health benefits (Gallegos-Infante et al. 2010a, b). High fibre content of legumes provides additional benefits in diet. Mattila et al. (2002) found that *Agaricus bisporus* contained 2% protein (fresh weight) and 4.6% carbohydrates (fresh weight). Osorio et al. (2008) prepared chickpea supplemented pasta,a dietetic alternative for people with low-calorie requirements.

Young-Soo-Kim (1998) prepared wet noodles from wheat flour with 3, 5 and 7% oyster mushroom and oak mushroom with improved protein and fibre contents having

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better acceptability. Mane et al. (2000) used oyster mushroom powder supplement in sweet balls and cookies sweet buns, the substitution contributed to increase amino acid and digestibility coefficient. Keeping in view the nutritive aspects of plant protein, present investigation was aimed to improve the nutritional value of pasta.

Materials and methods

Durum wheat semolina, Bengal gram (*Cicer arietinum*) *dhal,* defatted soy flour (Allegro Brand Super Foods 19, Industrial Area-I, Chandigarh, India) and button mushrooms (*Agaricus bisporus*) were obtained from local market.

Bengal gram *dhal* was dried in oven at 50 °C for 2 h prior to grinding. *Dhal* was ground in cemotac mill-TM1090 (FOSS India Ltd.).

Fresh mushrooms were washed thoroughly and the damaged parts were trimmed out. Mushrooms were cut into small size and placed in 2% brine solution for 4–5 min. Mushrooms were then water blanched at 80 °C for 2 min and treated with 0.5% sodium bisulphate and 0.25% citric acid for 15 min followed by draining. They were loaded in trays at the rate of 1.25 kg/m^2. The trays were placed in cross flow hot air (Frederick-Herbet) cabinet drier. The temperature was initially maintained at 45 °C for 6 h then raised to 55 °C and kept constant till the drying completed. The dried mushroom were ground finely in cemotac mill and sifted 10 mesh size (2000 μm US).

Preparation of blends Semolina was replaced with mushroom powder at 0, 6, 8, 10 and 12% levels. Raw materials were mixed properly by passing through sieve (10 mesh) for 3 times followed by packaging in high density polyethylene (gauge 200) for subsequent study. Bengal gram supplementation was done at 0, 6, 9, 12, 15, 18 and 21% as semolina and defatted soy flour at 0, 6, 9, 12 and 15% levels.

Analysis Moisture, ash, protein and fat were determined as per AACC (2000). Dietary fibre was analyzed as neutral detergent fibre (NDF), acid detergent fibre (ADF) and cellulose as prescribed by Robertson and Van Soest (1981).

Pasta preparation Durum wheat flour (2 kg) was mixed with required amount of water in the mixing chamber of pasta extruder (le monferrina, Masoero Arturo and C.S.N. C., Italy) for 10 min to distribute water uniformly throughout the flour particles. The moist flour aggregate was placed in a metal extruder attachment of pasta machine fitted with an adjustable die (No. 225) having a corrugated type spots of 1.5 mm opening. By adjusting the revolving speed of a sharp blade cutter in front of the pasta die, extruded dough was cut to a desirable shell shape. The noodle sheet was cut into 25–30 cm long sections and then passed through cutter attachment (GT 02DO12) with 2 mm grooves. The dimensions of noodles were 25–30 cm in length 1.3 mm in thickness and 2 mm in width as measured with a hand held micrometer at 10 random portions. The resulted product was steamed for 30 min prior to drying. Drying of pasta and noodles was carried out in hot air oven at 45–50 °C for 4–5 h to attain moisture content of 6.0–6.5%. The dried products of various blends were packed in polyethylene (200 gauge).

Cooking quality of pasta Cooking quality of pasta was determined by minimum cooking time, water absorption, volume expansion and gruel solid loss (AACC 2000).

Sensory evaluation Cooked pasta was evaluated for overall acceptability (appearance, colour, texture, stickiness, flavor and taste) through a panel of 8 semi-trained judges (Larmond 1970).

Statistical analysis Proximate composition was expressed at 14% moisture and all the data collected from different treatments were compared using critical difference (CD). The data collected in triplicates from the study were analysed using Analysis of Variance Proximate (Singh et al. 1991). The means were compared using Duncan's multiple range test (Duncan 1955).

Table 1 Proximate composition of raw materials

Raw material	Crude protein, %	Ash, %	Fat, %	NDF, %	ADF, %	Cellulose, %	Carbohydrate, %
Semolina	11.8^a	0.4^a	0.8^a	4.0^a	–	1.8^a	68.9^c
Mushroom powder	16.8^b	6.7^c	2.3^b	31.5^d	2.3^a	8.1^d	28.6^a
Bengal gram flour	23.5^c	2.5^b	4.6^c	13.0^c	5.6^c	1.9^a	42.3^b
Defatted soy flour	47.4^d	6.5^c	0.7^a	6.4^b	4.2^b	2.8^c	24.9^a
CD ($p\leq0.05$) (n=3)	1.75	0.38	0.20	1.76	0.39	0.32	4.80

Expressed at 14% moisture basis, Values having same superscripts in the column do not vary significantly from each other ($p\leq0.05$), *ADF* Acid detergent fibre, *NDF* Neutral detergent fibre

Table 2 Cooking quality of pasta supplemented with mushroom

Supplement level, %	Cooking time, min			Water absorption %			Vol expansion, ml/g			Solids loss, %			Overall acceptability		
	US	S	Level Mean	US	S	Level Mean	US	S	Level Mean	US	S	Level Mean	US	S	Level mean
0	7.0	4.6	5.8^{a}	119	95	107.0^{a}	1.0	0.9	0.95^{a}	6.4	4.1	5.3^{a}	8.1	8.2	8.1^{b}
6	7.0	5.0	5.9^{ab}	120	98	109.0^{a}	1.0	0.9	0.96^{a}	5.8	4.2	5.5^{a}	8.3	8.4	8.4^{c}
8	7.0	5.0	6.0^{b}	120	104	112.0^{ab}	1.0	0.9	0.98^{a}	7.3	4.3	5.8^{b}	8.1	8.2	8.2^{b}
10	7.1	5.0	6.1^{b}	124	106	115.0^{b}	1.1	1.0	1.01^{a}	7.7	4.5	6.1^{b}	7.9	7.9	7.9^{a}
12	7.2	5.0	6.1^{b}	131	109	120.0^{b}	1.1	1.0	1.02^{a}	7.9	4.5	6.2^{b}	7.8	8.2	8.0^{ab}
CD ($p \leq 0.05$) (n=3)	T=0.14			T=3.66			T=0.52			T=0.52			T=0.22		
	L=0.22			L=5.78			L=NS			L=0.28			L=NS		
	T×L=NS			T×L=NS			T×L=NS			T×L=0.39			T×L=NS		

US Unsteamed, *S* Steamed, *T* Treatment, *L* Levels of supplement, Values having same superscripts indicate stat differences by superscripts a, b,…. for levels of supplement and x, y for treatment; Means with different superscripts in a column (a, b, c…) and in a row (x, y) differ significantly ($p \leq 0.05$), NS: Non significant, Overall acceptability maximum score 9.0

Results and discussion

Proximate composition of raw materials Defatted soy flour had highest protein content followed by Bengal gram flour, mushroom powder and semolina, Table 1. Bengal gram flour has highest fat content among the raw materials. ADF content was higher in Bengal gram flour followed by soy flour and mushroom powder. Mushroom powder contained higher NDF. Bengal gram flour and soy flour were concentrated source of NDF.

Quality of mushroom supplemented pasta Supplementation of mushroom powder significantly increased the minimum cooking time of pasta as compared to control (Table 2). Oh et al. (1985) observed that cooking time of noodles increased linearly with protein content; high protein noodles became stronger and firmer internally when cooked compared to low protein noodles. Cooking time of mushroom supplemented steamed pasta significantly reduced as compared to unsteamed pasta. Steaming resulted in instantization of product due to partial gelatinization of starch. Gelatinized starch in the steamed pasta quickly absorbed water to its core, whereas the unsteamed pasta first absorbed water and then gelatinized slowly from outside to inside and took more time to cook. Addition of mushroom powder above 8% in semolina significantly increased the water absorption in pasta than control.

Steamed mushroom supplemented pasta absorbed 16% less water during cooking than the unsteamed pasta (Table 2). A significant correlation (r=0.96, $p \leq 0.05$) was found between water absorption and volume expansion. Expansion in volume of pasta increased marginally (0.95 to 1.02 ml/g) as compared to control. The volume expansion of steamed pasta was significantly less. Leaching of solids in cooked water increased as the level of mushroom powder was increased in blend. Steamed pasta recorded 40% less loss in solids during cooking as compared to unsteamed pasta. Solid loss in cooking water should not exceed 9%

Table 3 Cooking quality of pasta supplemented with Bengal gram

Supplement level,%	Cooking time, min			Water absorption, %			Vol expansion, ml/g			Solids loss, %			Overall acceptability		
	US	S	Level Mean	US	S	Level Mean	US	S	Level Mean	US	S	Level Mean	US	S	Level mean
0	7.0	4.6	5.8^{a}	119.0	95.0	107.0^{a}	1.00	0.89	0.95^{a}	6.4	4.1	5.3^{a}	7.8	8.2	8.0^{b}
6	6.6	4.5	5.5^{a}	125.0	98.0	111.5^{a}	1.09	0.92	1.0^{ab}	7.1	4.2	5.6^{b}	7.7	8.0	7.9^{a}
9	6.5	4.5	5.5^{a}	129.0	98.0	113.5^{ab}	1.12	0.98	1.05^{b}	7.2	4.2	5.7^{b}	7.9	7.9	7.9^{ab}
12	6.5	4.4	5.5^{a}	133.9	104.0	118.9^{b}	1.15	1.03	1.09^{b}	7.5	4.3	5.9^{c}	7.9	7.9	7.9^{ab}
15	6.5	4.4	5.4^{a}	141.0	107.0	124.0^{b}	1.17	1.07	1.12^{bc}	7.6	4.3	5.9^{c}	8.1	8.4	8.3^{c}
18	6.4	4.4	5.4^{a}	145.0	110.0	127.5^{b}	1.18	1.09	1.13^{c}	7.6	4.3	5.9^{c}	7.7	7.9	7.8^{a}
21	6.4	4.3	5.4^{a}	147.8	115.0	131.4^{b}	1.20	1.12	1.16^{c}	7.9	4.4	6.1^{d}	7.6	7.9	7.8^{a}
CD ($p \leq 0.05$) (n=3)	T=0.21			T=3.8			T=0.03			T=0.07			T=0.17		
	L=NS			L=7.1			L=0.06			L=0.13			L=0.21		
	T×L = NS			T×L=NS			T×L=NS			T×L=0.19			T×L=NS		

US Unsteamed, *S* Steamed, *T* Treatment, *L* Levels of supplement, Values having same superscripts indicate stat differences by superscripts a, b,…. for levels of supplement and x, y for treatment; Means with different superscripts in a column (a, b, c…) and in a row (x, y) differ significantly ($p \leq 0.05$), NS: Non significant, Overall acceptability maximum score 9.0

Table 4 Cooking quality of pasta supplemented with soya flour

Supplement level, %	Cooking time, min			Water absorption, %			Vol expansion, ml/g			Solids loss, %			Overall acceptability		
	US	S	Level Mean	US	S	Level Mean	US	S	Level Mean	US	S	Level Mean	US	S	Level mean
0	7.0	4.6	5.8[a]	119.0	95	107.0[a]	1.0	0.9	0.95[a]	6.4	4.1	5.3[a]	7.8	8.2	8.0[b]
6	7.1	5.1	6.1[b]	139.0	108	123.5[b]	1.1	0.9	1.00[a]	6.6	4.2	5.4[a]	7.5	7.9	7.7[a]
9	7.2	5.1	6.1[b]	139.0	108	123.5[b]	1.1	1.0	1.06[ab]	6.7	4.2	5.4[ab]	8.1	8.5	8.3[c]
12	7.2	5.2	6.2[b]	140.1	109	124.6[b]	1.2	1.0	1.09[b]	6.8	4.2	5.5[b]	7.8	8.3	8.0[b]
15	7.3	5.2	6.2[b]	144.4	111	127.7[b]	1.2	1.0	1.10[b]	6.8	4.3	5.5[b]	7.7	8.0	7.8[ab]
CD ($p \leq 0.05$) ($n=3$)	T=0.13			T=2.79			T=0.05			T=0.11			T=0.17		
	L=0.21			L=4.41			L=0.08			L=0.17			L=0.26		
	T×L=NS			T×L=NS			T×L=NS			T×L=0.24			T×L=NS		

US Unsteamed, *S* Steamed, *T* Treatment, *L* Levels of supplement, Values having same superscripts indicate stat differences by superscripts a, b,…. for levels of supplement and x, y for treatment; Means with different superscripts in a column (a, b, c...) and in a row (x, y) differ significantly ($p \leq 0.05$), NS: Non significant, Overall acceptability maximum score 9.0

(AACC 2000) and the values obtained were within the limits. Overall acceptability score of mushroom supplemented pasta at 6 and 8% levels was higher than control. Pasta supplemented with 8% mushroom powder was selected as best. Overall acceptability of steamed pasta was better than unsteamed pasta.

Quality of Bengal gram supplemented pasta Increase in the level of Bengal gram flour in semolina, increased water absorption (%) in pasta (Table 3). Upto 9% level there was not much variation. An increase of 6, 15 and 29% in water absorption of pasta at 9, 15, and 21% level of supplementation, respectively was observed. Water absorption significantly correlated ($r=0.97$, $p \leq 0.05$) with volume expansion of pasta. Increased water absorption with legume supplementation resulted in significant increased expansion in volume of pasta. There was about 18% more expansion in pasta with 15% addition of Bengal gram flour in semolina compared to control. Supplemented steamed pasta expanded less than raw pasta. There was about 12.5% more solid loss at 15% level of supplementation than control. Bergman et al. (1994) observed higher cooking losses in pasta supplemented with cowpea, as compared to control durum semolina pasta. There was a significant increase in cooking loss of spaghetti when common bean flour (45%) in the composite was added (Gallegos-Infante et al. 2010a, b). Gruel solid losses were reduced significantly in supplemented steamed pasta. Interaction of treatments and levels was found significant in gruel solid loss. Pasta at all levels of supplementation of Bengal gram had a better acceptability. Pasta supplemented with 15% Bengal gram flour had maximum overall acceptability with respect to colour, texture and flavor. Steamed Bengal gram supplemented pasta scored higher for acceptability than unsteamed pasta.

Quality of defatted soy flour supplemented pasta Addition of defatted soy flour in semolina significantly increased the cooking time of pasta (Table 4). Addition of soybean protein isolates up to 20% to wheat flour increased the cooking time of spaghetti (Song and Chul 1998). Steaming

Table 5 Cooking quality of noodles supplemented with plant proteins

Supplement level, %	Cooking time, min			Water absorption, %			Vol expansion, ml/g			Solids loss, %			Overall acceptability		
	US	S	Level Mean	US	S	Level Mean	US	S	Level Mean	US	S	Level Mean	US	S	Level mean
Semolina	4.3	2.3	3.3[a]	195.6	175	185.3[a]	1.5	1.4	1.45[a]	6.9	4.2	5.6[a]	7.8	8.0	7.9[a]
8% MP	4.3	2.3	3.3[a]	198.0	177	187.5[a]	1.5	1.4	1.46[a]	7.5	4.5	6.0[a]	7.9	8.6	7.9[a]
15% BGF	4.2	2.2	3.2[a]	207.0	185	196.0[b]	1.6	1.5	1.54[a]	8.3	4.5	6.4[a]	8.0	8.1	8.0[a]
12%DSF	4.5	2.5	3.5[a]	212.0	179	195.5[b]	1.6	1.5	1.54[a]	7.5	4.4	5.9[a]	7.6	8.1	7.8[a]
CD ($p \leq 0.05$) ($n=3$)	T=0.20			T=4.39			T=0.09			T=0.25			T=0.21		
	L=NS			L=7.16			L=NS			L=NS			L=NS		
	T×L=NS			T×L=NS			T×L=NS			T×L=0.39			T×L=NS		

MP Mushroom Powder, *BGF* Bengal Gram Flour, *DSF* Defatted Soy Flour

US Unsteamed, *S* Steamed, *T* Treatment, *L* Levels of supplement, Values having same superscripts indicate stat differences by superscripts a, b,…. for levels of supplement and x, y for treatment; Means with different superscripts in a column (a, b, c...) and in a row (x, y) differ significantly ($p \leq 0.05$), NS: Non significant, Overall acceptability maximum score 9.0

significantly reduced the minimum cooking time of pasta than unsteamed. An increase of 19% for water absorption was observed as the level of fortification increased from 6 to 15% soy in semolina. High protein pasta expanded more during cooking. Increase in water uptake and volume expansion of pasta could be attributed to the fine particle size and high protein content of soy flour, which had greater hydration capacity. Cooked weight of spaghetti increased by the legume flour supplementation (Bahnassey and Khan 1986).

A significant correlation ($r=0.87$, $p\leq0.05$) was obtained between the values for water absorption and volume expansion of pasta upon cooking. Evidently, the steamed pasta showed lower values for volume expansion than unsteamed pasta. Leaching of solids during cooking was significantly high in soy-supplemented pasta. Zhao et al. (2005) incorporated legume flours at different levels for spaghetti and observed that cooking loss and firmness increased with an increase in legume flour consent. Gallegos-Infante et al. (2010a, b) reported that the cooking time and water absorption diminished in spaghetti pasta with added common bean flour; cooking loss increased and firmness decreased as a function of the bean flour percentage.Gruel solid loss for steamed pasta was less than unsteamed pasta. Soy-supplemented pasta was found highly acceptable at all levels of supplementation. Pasta supplemented with 9% soy flour was liked most by the panelist. Steaming resulted in better acceptability of pasta.

Noodles were prepared from best-selected level of supplementation (Table 5). Cooking time increased with fortification of semolina by mushroom powder and defatted soy flour. Gelatinization of starch in steamed noodles significantly reduced the cooking time as compared to raw noodles. Bengal gram supplemented noodles took less time to cook than control. Higher protein and fiber content of plant proteins resulted in significantly higher water absorption by supplemented noodles and contributed more to expansion of noodles upon cooking. Water absorbed by steamed noodles was significantly less than unsteamed noodles Gruel solid loss marginally increased with the incorporation of plant proteins in semolina. Steaming contributed to higher nutritional value of noodles by reducing solid loss in cooking water.

Conclusion

Mushroom powder, Bengal gram flour and defatted soy flour increased the protein and fibre contents of pasta keeping the fat at optimum level. Supplementation increased the cooking time, water absorption, volume expansion and gruel solid loss than control. Steaming of pasta improved the cooking quality as observed from lower cooking time and lesser gruel solid loss. Fortified pasta was highly acceptable with respect to sensory attributes. Resultant pasta can be used as a nutritious food for low-income group in developing countries.

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