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RESEARCH PAPER

Fortification of Pasta with White Button Mushroom: Functional and Rheological Properties

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Abstract

Macaroni (pasta)—a popular extruded product prepared using durum wheat semolina is rich in complex carbohydrate, vitamin-B but deficient in proteins especially lysine and threonine leading to low biological value of the product. The present study was conducted to prepare a nutritionally enriched macaroni by supplementing semolina with white button mushroom. The fresh mushrooms are a rich source of proteins having most of the essential amino acids in good proportions, thus, can be a better option for nutritional enrichment of pasta with 10 to 30% supplementation. The mushroom fortified pasta showed better antioxidant activity of 11.14 percent as compared to 5.61% in control with phenol contents ranging from 0.559 to 0.660% with increased mushroom fortification. A gradual increase in moisture content, carbohydrates was also noticed with decreased crude fibre, crude protein, and fat as well. The SEM study and rheological properties showed the clear picture of protein network, a smooth outer surface, and significant increase in chewiness and springiness that resulted in a desirable mouthfeel during eating. Therefore, on the basis of sensory and rheological properties of mushroom supplemented pasta, the ratio of 80:20 was found to be the best and thus optimized for development of nutritionally enriched macaroni.

Keywords: Macaroni, extrusion, rheological properties, scanning electron microscopy (SEM), nutritionally enriched, antioxidant

Pasta products, traditionally manufactured from durum wheat semolina, which is known as the best raw material for pasta production (Feillet and Dexter, 1998). Pasta is consumed in large quantities throughout the world (Gallegos-Infante *et al.,* 2010). These products are becoming popular in current lifestyle as they are healthy, tasty and convenient for transportation and preparation (Cubadda, 1994). Pasta is highly popular due to its ease of preparation, transportation, handling, cooking and storage properties and also due to its palatability (Tudorica *et al.,* 2002; Petitol *et al.,* 2009). Approximately 12.3 million tons of pasta is produced worldwide with an estimate of 100,000 tons production of India (Anon 2008). Pasta is a source of carbohydrates (74–77%, dry basis) whose interest is increasing due to its nutritional properties, particularly its low glycaemic index (GI) (Monge *et al.,* 1990). Pasta also contains 11–15% (db) proteins but is deficient in lysine and threonine (Abdel-Aal and Hucl 2002; Chillo *et al.,* 2008; Prabhasanker *et al.,* 2007). It comes in different shapes and includes varieties such as ravioli and tortellini that are filled with other ingredients, such as ground meat or cheese (Serventi and Sabban, 2002). Now-a-days, consumers demand certain quality standards for the pasta and noodle products like; firm, elastic, smooth and chewy texture alongwith acceptable taste, nutritional and functional properties

(Li *et al.*, 2012). This provides an opportunity for the use of non-traditional raw materials to increase the nutritional quality of pasta (Del Nobile *et al.*, 2005).

The purpose of adding natural proteins to pasta and noodles is mainly for improving nutritional quality and maintaining a strong dough structure. Some exogenous proteins can impact gluten proteins in the dough, enhancing dough structure and improving the chewiness of the final product (Maforimbo *et al.*, 2008). According to Ferrari and Piazza (2006), the pasta can be supplement with protein rich legume flour, egg, fish, meat which enhances the nutritional value of the final product. The supplementation and fortification of nutritional properties of pasta has been reported by using legumes flour (Collins and Pangloli 1997), 35% of split pea or faba bean (Petitot *et al.*, 2009), bean flour (Gallegos-Infante *et al.*, 2010a, b), mushroom powder (8%), bengal gram *dhal* (15%) and 9% defatted soy flour (Dhillon and Sharma, 2015), chickpea (Osorio *et al.*, 2008). Minerals are other nutrients, which should be supplemented in pasta and noodles as they are usually deficient in wheat flour (Zimmermann and Hurrell, 2007). In addition, vitamins such as A, C, B6, B12, thiamin, niacin, riboflavin, and folic acid are also deficient in wheat flour, as they are lost during the milling process. This insufficiency is usually compensated by incorporating vitamin-rich ingredients as spinach, tomatoes, mushrooms, asparagus, chicken meat into the noodles and pasta (Shim *et al.*, 2003; Kim *et al.*, 2005; Ma *et al.*, 2009; Li *et al.*, 2012b). Kim (1998) prepared wet noodles from wheat flour and 3, 5 and 7 % oyster mushroom and oak mushroom and reported improved protein and fibre contents in noodles with better acceptability. Kaur *et al.* (2011), produced better quality and nutritious pasta enriched with different plant proteins (8% mushroom powder, 15% Bengal gram flour and 9% defatted soy flour). But, the literature on supplementation of pasta with button mushroom is lacking, which contains all the essential amino acids including lysine, methionine and phenylalanine etc. and thus, provides an opportunity to conduct the present study.

MATERIALS AND METHODS

Raw materials

Farm fresh white button mushrooms were procured from the Farm of Dr YS Parmar University Nauni, Solan, Mushroom, followed by washing thoroughly with running water and were blanched for 4 minutes in boiling water. After blanching the blanched mushrooms were converted into paste with the help of a household grinder (Maharaja Whiteline Co.).

Dough preparation: The dough was prepared by adopting the Mondelli (2000) equation for calculating the ingredients as:

$$A = \frac{Ui.I}{100} \qquad K = \frac{Us}{100}$$

$$S = (I - A) + \frac{(I - A)K}{1 - K} \qquad Aa = (A) - \frac{(I - A)K}{1 - K}$$

I = Total weight of dough (g)

Ui = Moisture of dough (%)

A = Total weight of water in the dough (g)

S = Weight of semolina required to make the dough according to desired final moisture of dough (Ui)and to the moisture of semolina (Us)

Aa = Weight of water to be added to semolina to make dough with desired moisture Ui, according to semolina's specific moisture (Us)

K = Semolina moisture coefficient

Preparation of Macaroni

Single screw extruder (La Monferrina Dolly P3 model, Italy) was used for preparing macaroni. The amount of water was calculated as per Mondelli equation. Different treatments like $\mathbf{T_0}$ Semolina (1Kg) + water (280ml); $\mathbf{T_1}$ Semolina (900g) + fresh mushroom (100g) + water (172ml); $\mathbf{T_2}$ Semolina (800g) + fresh mushroom (200g) + water (44ml) and $\mathbf{T_3}$ Semolina (700g) + fresh mushroom (300g). A reduction in water requirement was observed with increase in fresh mushroom supplementation and was restricted to 30 per cent mushroom due to high moisture content, which hindered the dough formation and extrusion process as well. Premixing of semolina and fresh mushroom was done manually, followed by mixing in Dolly P3 extruder, and kneading of the mixture by rotating screw in opposite direction of extrusion process. The temperature of extruded dough was 40±2°C and 1.7 mm diameter die was used to shape the dough and formation of macaroni.

Physico-chemical analysis

Moisture (%), ash (%), crude fiber (%), crude fat content (%), total carbohydrates (%) and energy value (k cal/100 g) were determined according to AOAC (2000). Nitrogen (N) content was determined by Kjeldahl method (Ranganna, 2009) and content of crude protein was determined by multiplying N with conversion factor of 6.25. The amino acids were extracted using methanol and run over TLC silica gel plate along with standard amino acids and compared using RF value according to Thimmaiah (2006).

Total phenols in the mushroom supplemented pasta (macaroni) was determined with the Folin-Ciocalteu reagent using catechol as a standard according to the method of Thimmaiah (2006). Optical density of the sample was recorded at 650 nm with the help of Spectronic 20D (Thermo Fisher Scientific, USA). The antioxidant activity (Free radical scavenging activity) was measured as per the method of Brand-Williams *et al.* (1995). Antioxidant activity was calculated using following equation:

$$\text{Antioxidant activity (\%)} = \frac{Ab_{(B)} - Ab_{(S)}}{Ab_{(B)}} \times 100$$

Where, $Ab_{(B)}$ = Absorbance of blank

$Ab_{(S)}$ = Absorbance of sample

Further, the colour of pasta was analyzed by using Hunter Lab Colorimeter (Hunter Associates Lab, Reston, Virginia). The sample was uniformly packed in clean petriplates with lid. The instrument was placed on the plate and three exposures at different places were conducted. Colour was expressed in terms of L*, a*, b* values.

Rheological Properties

Texture analyses: The textural properties of mushroom supplemented macaroni samples were measured using Texture Analyzer, TAXT2i (Stable 70 Microsystems, UK) using P/75 cylindrical probe. Texture parameters included hardness and stickiness (negative area under the curve). The instrument was operated at pre-test speed = 3.073 mm/s, test speed = 2 mm/s, post test speed = 10 mm/s, distance = 20 mm, strain rate = 60%, trigger force = 3 g, force and data acquisition rate of 150 pps. The cooking loss (%) and water uptake weight increased/water uptake (%) were determined according to method discribed by Olfat *et al.* (1993).

$$\text{Weight increased (\%)} = \frac{\text{(weight increased a macaroni } - \text{ weight uncooked macaroni)}}{\text{weight of uncooked macaroni}} \times 100$$

$$\text{Cooking loss (\%)} = \frac{\text{(weight of drained residue in cooking water)}}{\text{weight of uncooked macaroni}} \times 100$$

Scanning electron microscopy: SEM microstructure of the surface of dried pasta was investigated using a scanning electron microscope (Table top SEM-cube-1000 series model; EmCrafts Co., Ltd. Korea). The mounted sample was first gold coated through a sputter coating device and then, imaged through secondary electron (SE) detector under high vacuum mode.

Sensory Evaluation: A standard method has been elaborated by the International Standards Organization (ISO) for evaluation of macaroni cooking quality by sensory analysis. Sensory characteristics of the cooked macaroni samples were evaluated by a panel of five experts according to the method (Cubadda 1994). The textural properties evaluated were stickiness, firmness and bulkiness (the degree of adhesion of macroni strands after cooking). The sensory scores ranged from 0 to 100 as score of ≤40 is regarded as of poor quality; > 40 to ≤ 50 was not completely satisfactory; > 50 to ≤ 70 was fair; > 70 to 80 was good; > 80 was excellent. The overall value of the cooking quality was obtained by summing the score for each characteristic, multiplying the sum by 33.3 and dividing by 100.

Statistical analysis

Each analysis assay was done three times from the same sample to determine reproducibility. Results were expressed as mean values ± standard deviations. Analysis of variance (ANOVA) was used to test any difference in properties of mushroom fortified macaroni. Significance difference between means was tested using Tukey's test using S-plus for Windows (version 8.0.4). The data pertaining to the sensory evaluation of the mushroom supplemented macaroni were analyzed according to Randomized Block Design (RBD) (Cochran and Cox 1967; Mahony 1985).

RESULTS AND DISCUSSION

Different physico-chemical characteristics of white button mushrooms and semolina were evaluated prior to preparation of mushroom supplemented macaroni (Table 1). White button mushroom were found to contain more moisture (85.00%) as compared to semolina (10.00%), while the total ash, crude fibre and crude fat content were 0.98, 0.77 and 0.52 per cent respectively in semolina with crude protein content and total amino acid content of 11.38 per cent and 0.34 mg/ 100 gm, respectively. However, the total ash, crude fat and crude fibre content were 0.69, 0.19 and 0.73 per cent, respectively in fresh mushroom, with the crude protein content 3.36 per cent and total amino acid content 0.04 mg per 100 gm.

Table 1: Physico-chemical analysis of raw material

Parameter	Semolina	Mushroom (fresh)
Moisture (%)	10.00 ±0.3	85.00 ±0.2
Fat (%)	0.52±0.01	0.19±0.02
Fiber (%)	0.77±0.01	0.73±0.02
Ash (%)	0.98±0.02	0.69±0.01
Crude protein (%)	11.38±0.2	3.36 ±0.2
Carbohydrates (%)	68.9±0.2	7.7±0.3
Total amino acid (mg/100gm)	0.34±0.02	0.04±0.01

* Means ± SD of three replications

Further, the data in Table 2 shows the qualitative estimation of amino acid in fresh mushroom, semolina and mushroom supplemented pasta. Fresh mushroom contains all the nine essential amino acids, while the semolina contained only three essential amino acids. The calculated R_f value for methionine, arginine, tryptophan, threonine, valine, isoleucine, phenylanine, lysine and histidine were 0.51, 0.17, 0.65, 0.23, 0.39, 0.34, 0.53, 0.21 and 0.23, respectively were reported in mushroom supplemented pasta. The supplementation could add value to pasta by incorporating lysine, methionine and arinine contents which are otherwise absent in samolina.

Therefore, supplementation of mushroom in pasta expected to improve the nutritional importance of this popular extruded product. The procedure followed for preparation of mushroom supplemented macroni is detailed in Fig. 1.

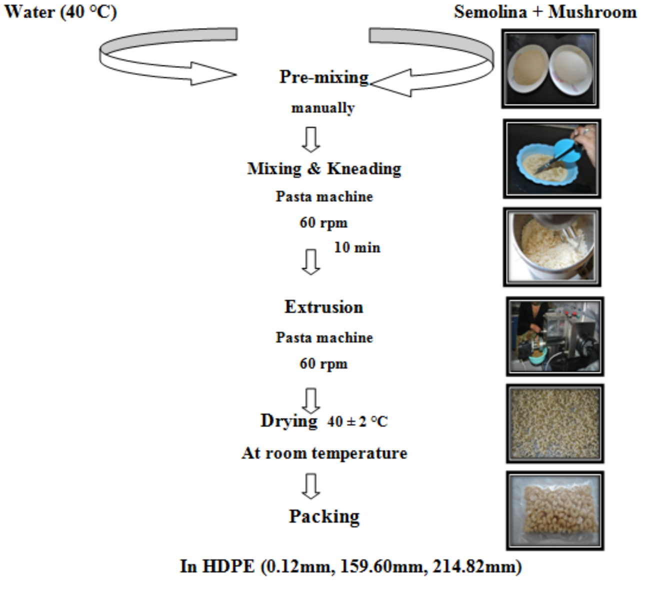

Fig. 1: Preparation of mushroom supplemented pasta (macroni)

Mushroom supplemented macaroni

During this study, the semolina was replaced with mushroom in different proportions and it was observed that the water intake for dough formation was also decreased with increase in fresh mushroom quantity, due to high moisture contents

Table 2: Qualitative Analysis of Amino acid using thin layer chromatography

Distance travelled by Solvent (cm)	Distance at which spot appeared (cm)			Colour of the spot	Rf Value of standard	Calculated Rf value			Amino acid
	Agaricus bisporus	Semolina	Macaroni (pasta)		0.40	*Agaricus bisporus*	Semolina	Macaroni (pasta)	
8.8	4.5	—	4.5	Pink	0.59	0.51	—	0.51	Methionine
8.8	1.5	—	1.6	Blue	0.16	0.17	—	0.18	Arginine
8.8	5.8	5.7	5.8	Brown	0.65	0.65	0.65	0.65	Tryptophan
8.8	2.1	2.0	2.2	Pink	0.25	0.23	0.26	0.24	Threonine
8.8	3.5	3.6	3.5	Pink	0.35	0.39	0.39	0.39	Valine
8.8	3.0	—	3.0	Pink	0.33	0.34	—	0.34	Isoleucine
8.8	4.7	—	4.8	Brown pink	0.50	0.53	—	0.54	Phenylanine
8.8	1.9	—	1.9	Yellow	0.19	0.21	—	0.21	Lysine
8.8	2.1	—	2.1	Orange	0.22	0.23	0.22	0.23	Histidine

available in mushrooms. The developed mushroom supplemented pasta was analyzed for different nutritional characteristics (Table 3) and was compared with the control (semolina). The moisture content increased with the increased mushroom quantity and simultaneously the ash contents decreased from 0.98 to 0.91%. The increase in moisture content (%) might be attributed due to the increase in mushroom in the recipe of supplemented macaroni.

Crude fibre, crude protein and fat contents were decreased with the increase in mushroom supplementation, might be due to lower content of fibre, protein and fat in fresh mushroom. However, the carbohydrates were increased from 77.10 to 79.80 % with an energy value ranging between 367.65 to 366.99 Kcal/100g with increased mushroom supplementation. Since the energy value depends on crude fat primarily and crude protein which are decreasing with the increase in mushroom fortification in macaroni and hence, a decrease in energy value was observed. Further, the qualitative estimation of amino acids presented in the pictorial form shows the presence of essential amino acids mainly in mushrooms (Fig. 2), which supports the supplementation of semolina with fresh mushrooms in pasta.

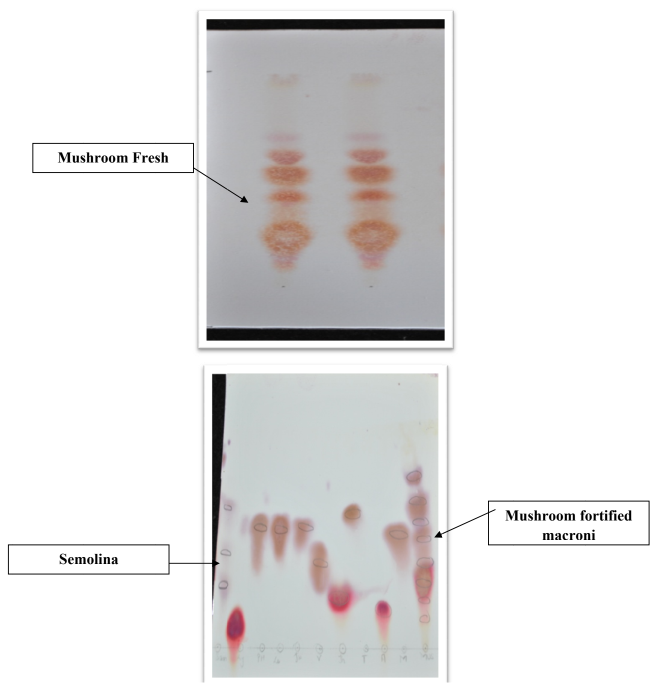

Fig. 2: Qualitative estimation of amino acid (TLC) in fresh mushroom and semolina Methionine (M), Arginine (A), Tryptophan (T), Threonine (Th), Valine (V), Isoleucine (I), Phenyl- alanine (Ph), Lysine (L), Histiline (H).

Cooking quality of pasta: The cooking quality is one of the major attributes to evaluate the quality of macaroni. During the present studies, cooking

Table 3: Physico-chemical characteristics of mushroom (fresh) supplemented pasta (macaroni)

Parameters	Treatment			
	T_0	T_1	T_2	T_3
Physico-chemical parameters				
Moisture (%)	10.00 ±0.1	10.20±0.1	10.30±0.2	10.41±0.3
Ash (%)	0.98±0.01	0.96±0.02	0.92±0.01	0.91±0.01
Crude fibre (%)	0.77±0.02	0.73±0.01	0.72±0.02	0.70±0.01
Crude protein (%)	11.38±0.2	10.56±0.2	9.65±0.1	8.75±0.2
Crude Fat (%)	0.52±0.01	0.48±0.02	0.45±0.01	0.41±0.01
Carbohydrate (%)	77.10±0.2	77.89±0.3	78.89±0.2	79.80±0.2
Energy value (Kcal/100g)	367.65±0.2	367.36±0.3	367.28±0.2	366.98±0.2
Water solubility index (%)	8.10±0.01	9.45±0.03	10.20±0.02	10.72±0.02
Water absorption index (%)	28.00±0.2	25.40±0.3	23.48±0.2	21.60±0.2
Total amino acids (mg/100g)	0.348±0.01	0.303±0.01	0.261±0.02	0.224±0.01
Phenols (mg/100g)	0.559±0.01	0.593±0.02	0.624±0.02	0.660±0.01
Antioxidant activity (%)	5.61±0.02	6.33±0.04	8.31±0.03	11.14±0.03

* Means ± SD of three replications

quality was affected by mushroom supplementation and the data is presented in Table 4. With the increase in fortification level, the cooking weight of macaroni was found to decrease which might be due to decreased starch content (Pinarli *et al.*, 2004). The highest cooking losses (4.7 ± 0.2%) were observed in treatment T_3 (70:30 semolina: mushroom) with least losses in T_0 (100:0) (4.1 ± 0.2%). An increase in cooking losses was observed with increase in mushroom supplementation, which might be due to weakening of network by the protein present in mushroom. Similar studies were reported by Sozer *et al.* (2007). It was demonstrated earlier in pasta that a linear relationship exists between cooking quality and protein content and increasing amount of gluten in pasta decreased the amount of solid residue in the cooking water (Matsuo and Irvine, 1970).

Colour quality of pasta: Pasta colour is essential for assessing the pasta quality. The hunter L*, a*, b* values were measured to characterize the colour which are illustrated in Table 4. L* value corresponds to lightness of the product. a* and b* values indicates redness and yellowness of the product, respectively. Steaming gave a translucent appearance to the pasta as compared to uncooked pasta, which was depicted as bright colour by Hunter Lab Colorimeter. Generally, consumers prefer pasta with a bright yellow colour (Debbouz *et al.*, 1995). Fortification of pasta with mushroom resulted in a decreased brightness (L* value) of uncooked pasta, probably due to the higher moisture of mushroom and ash content of semolina (Oliver *et al.*, 1993). Decrease in pasta brightness may also be related to the development of maillard's reaction and the non-enzymatic browning readily occurring during pasta drying, especially at high and very high temperatures (Anese *et al.*, 1999).

Further, the results in Fig. 3 and 4 show a clear effect of mushroom supplementation in macroni (pasta) as the phenol contents and antioxidant activity of macroni increased with the increased mushroom concentration. Phenols and antioxidants are the major compounds in fresh mushroom that protects from free radicals which cause oxidative stress. Highest total phenols were obtained in T_3 (70:30) and lowest in T_0 (control-semolina). Similarly, Oszmianski and Wojdylo (2009), attributed to increase in total phenolics and as antioxidant activity was attributed to fortification with mushroom.

Table 4: Effect of mushroom supplementation on rheological properties (cooking loss) and colour of pasta

Treatments	Cooking loss	Colour of pasta					
		L*		a*		b*	
	(%, db)	Uncooked	Cooked	Uncooked	Cooked	Uncooked	Cooked
100% semolina (control)	4.1 ± 0.2	67.9 ± 1.1	59.9 ± 0.4	5.0 ± 0.2	1.0 ± 0.8	42.7 ± 6.2	21.0 ± 3.2
90% semolina + 10% fresh mushroom	4.2 ± 0.1	60.7 ± 2.2	61.0 ± 1.3	7.3 ± 0.2	2.2 ± 0.8	40.7 ± 2.6	20.3 ± 0.5
80% semolina + 20% fresh mushroom	4.4 ± 0.1	58.7 ± 1.7	59.2 ± 0.6	11.0 ± 0.4	4.1 ± 0.3	36.8 ± 2.7	19.6 ± 2.9
70% semolina + 30% fresh mushroom	4.7 ± 0.2	57.1 ± 1.4	62.4 ± 1.9	8.4 ± 1.9	4.8 ± 0.6	34.4 ± 6.1	19.4 ± 1.1

* Means ± SD of three replications

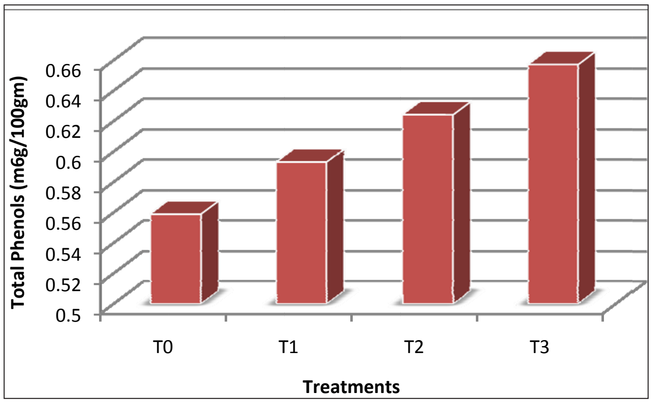

Fig. 3: Effect of supplementation of mushrooms to macaroni in total phenols

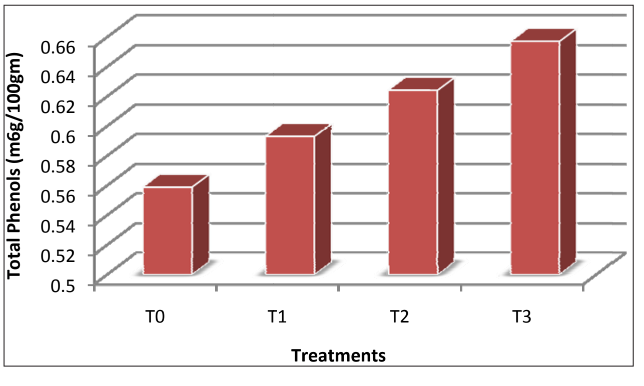

Fig. 4: Antioxidant properties of different mushroom supplemented macaroni

Textural properties of pasta: The textural properties of macroni presented in Fig 5a & b shows that the hardness and stickiness related with the amount of starch and starch gelatinization. The supplementation of semolina with mushrooms resulted in a decrease in hardness.

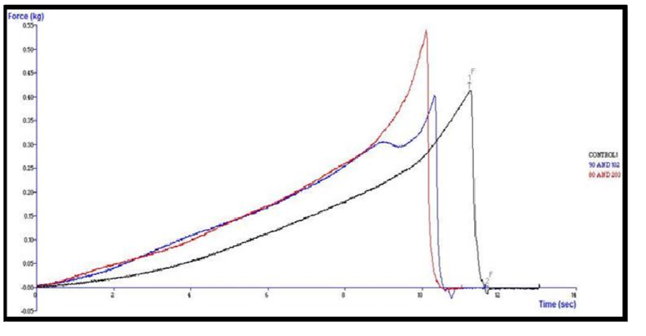

Fig. 5 a: Textural properties of different mushroom supplemented macaroni

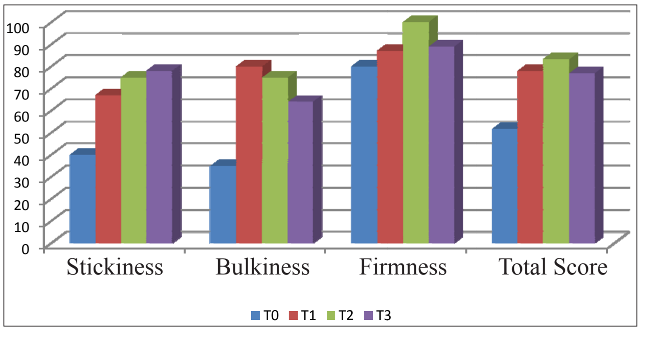

Fig. 5 b: Sensory quality of fresh mushroom supplemented pasta (macaroni) at zero day

During cooking, severe changes in the microstructure of macaroni occured. The uniformity of dry macaroni starts to change by the diffusion of water from outside to the core. Closer to the surface of the macaroni strand, the changes were more drastic, starch granules were no longer intact as in the core and protein matrix starts to break down due to denaturation (Sozer *et al.,* 2007). The decrease in the pasta strength might be due to protein and starch composition of the fresh mushroom supplemented pasta.

SEM Studies: The cooked pasta from semolina + mushroom (80:20) presented a smooth outer surface and the proteins were separately visible in the SEM pictures. A strong protein and amino acids network can be seen but the minor differentiation in the pasta structure could not be differentiated in the SEM pictures (Fig. 6 & 7).

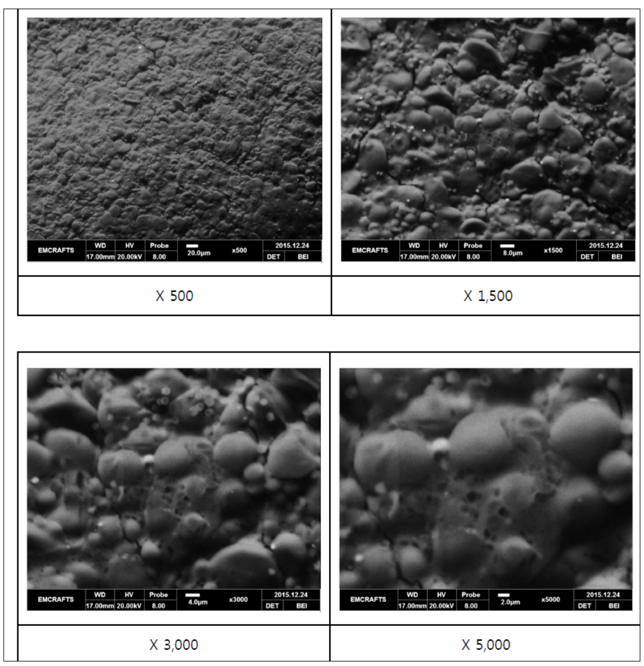

Fig. 6: SEM pictures of cooked semolina: mushroom (80:20) pasta (×500)(×1500) (×3000), (×5000)

Leaching during cooking resulted in higher cooking loss as shown clearly in SEM photographs. Cunin *et al.* (1995) and Pagani *et al.* (1986), also reported a homogeneous and porous structure where some carbohydrates and granules were deeply embedded in a protein matrix. Small holes were apparent on the surface of the uncooked pasta, which could permit the water penetration into pasta during cooking. Cracks and holes were also observed by Cunin, *et al.* (1995) and Dexter *et al.* (1978). This might be due to shrinkage during sample preparation (pasta dough) during drying.

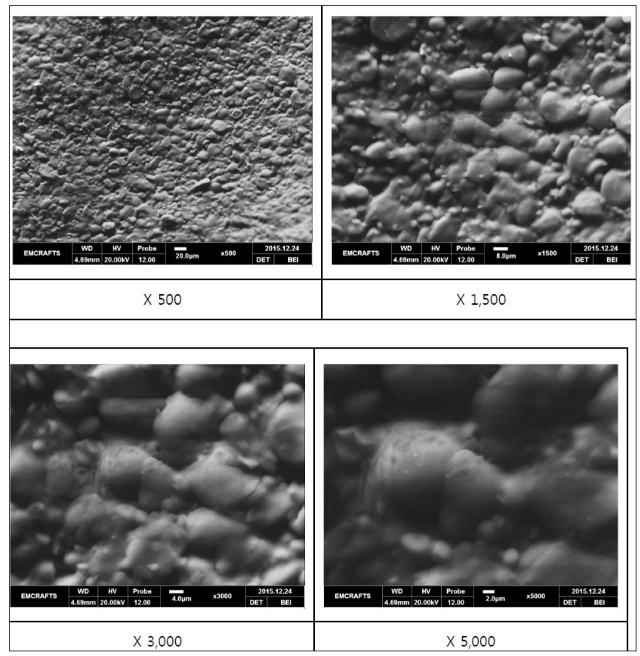

Fig. 7: SEM pictures of uncooked semolina: mushroom (80:20) pasta (×500)(×1500) (×3000), (×5000)

The tight compact structural characteristics of durum wheat semolina become a more open structure, whenever water is added in the mixing stage (Matsuo *et al.,* 1978).

CONCLUSION

Mushroom fortified pasta offer a broader spectrum of products to the people wishing to improve the nutritional quality of macroni in terms of amino acids, proteins, fibres and minerals. Fresh mushroom increased the protein and fibre contents of pasta and keeping the fat at optimum level. On the basis of cooking, textural and sensory quality, pasta when fortified with mushroom (80:20) resulted in better quality and nutritious pasta (carbohydrate content 78.89%, protein content 9.65%, fat content 0.45% and fibre content 0.72%). SEM structure showed the clear picture of strong network of protein in mushroom fortified pasta (cooked), whereas the small holes apparent on the surface of the uncooked pasta could permit the water penetration into pasta during cooking and results in ease of cooking. Mushroom fortified pasta was highly acceptable with respect to sensory attributes and can be used as a nutritious food for low income group in the developing countries.

REFERENCES

Abdel-Aal, E.S.M. and Hucl, P. 2002. Amino acid composition and in vitro protein digestibility of selected ancient wheat and their end products. *J Food Composition Anal.* **15**(6):737–747.

Alm, L. 1982. Effect of fermentation on B-vitamin conetent of milk in Sweden. *J Dairy Sci*, **65**: 353-359.

Anese, M., Nicoli, M.C., Massini, R. and Lerici, C.R. 1999. Effects of drying processing on the maillard reaction in pasta. *Food Res Int*. **32**(3): 193–199.

Anonymous. 2008. Estimate of world pasta production. Union of organizations of manufacturers of Pasta Products of the European Union.

AOAC. 2000. Official Methods of Analysis. Association of official analytical chemists, Washington, DC, USA.

Brand-Williams, W., Cuvelier, M.E. and Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. *Lebe Wiss U Tech.* **28**: 25–30.

Chillo, S., Laverse, J., Falcone, P.M., Protopapa, A. and Del Nobile, M.A. 2008. Influence of the addition of buckwheat flour and durum wheat bran on spaghetti quality. *J Cereal Sci.* **47**:144–152.

Cochran, W.G. and Cox, C.M. 1967. Experimental Designs. 2nd Edn., John Wiley and Sons Inc., New York, pp. 617.

COLE, M.E. 1991. Development of nutritious macaroni with the supplementation of lentil flour. *Int J Food Sci Technol*., **26**: 133-150.

Collins, J.L. and Pangloli, P. 1997. Chemical, physical and sensory attributes of noodles with added sweet potato and soy flour. *J Food Sci.*, **62**: 622–625.

Cubadda, R. 1994. Nutritional value of pasta: effects of processing conditions. *Italian Food Bev Technol.*, **3**: 27-33.

Cunin, C., Handschin, S., Walther, P. and Escher, F. 1995. Structural changes of starch during cooking of durum wheat pasta. *Lebensm Wiss Technol*., **28**: 323-328.

Debbouz, A., Pitz, W.J., Moore, W.R and Appolonia, B.L. 1995. Effect of bleaching on durum-wheat and spaghetti quality. *Cereal Chemist*, **72**(1): 128–131.

Del Nobile, M.A., Baiano, A., Conte, A. and Mocci, G. 2005. Influence of protein content on spaghetti cooking quality. *J Cereal Sci.*, **41**: 347–356.

Dexter, J.E., Dronzek, B.L. and Matsuo, R.R. 1978. Scanning electron microscopy of cooked spaghetti. *Cereal Chemist,* **55**: 23-30.

Dhillon, G.K. and Sharma, S. 2015. Steaming treatment effect on quality of nutritious pasta. *Agric Res J.*, **52**(3): 67-72.

Feilet, P. and Dexter J.E. 1998. Quality requirements of durum wheat for semolina milling and pasta production. In: J.E. Kruger; R.R. Matsuo; J.W. Dick (Eds.), *Monograph on pasta and noodle technology* Saint Paul, USA, *Am Assoc Cereal Chem.*, 95-131.

Ferrari, L. and Piazza, N. 2006. Nutritional value of pasta. *Professional Pasta Newsletter*.

Gallegos-Infante, J.A., Bello-Perez, L., Rocha-Guzman, N.E., Gonzalez-Laredo, R.F. and Ontiveros, A.M. 2010b. Effect of the addition of common bean (*Phaseolus vulgaris L.*) flour on the *in vitro* digestibility of starch and undigestible carbohydrates in Spaghetti. *J Food Sci.*, **75**: 152–156.

Gallegos-Infante, J.A., Rocha-Guzman, N.E., Gonzalez-Laredo, R.F., Ochoa-Martinez, L.A., Corzo, N., Bello-Perez, L.A., Medina-Torres, L. and Peralta-Alvarez, L.E. 2010a. Quality of spaghetti pasta containing mexican common bean flour (*Phaseolus vulgaris L.*). *Food Chemist,* **119**: 1544–1549.

Granfeldt, Y., Bjorck, I. and Hagander, B. 1991. On the importance of processing conditions, product thickness and egg addition for the glyceamic and hormonal responses to pasta: A comparison with bread made from pasta ingredients. *Eur J Clin Nutr*., **45**: 489–499.

Kaur, G., Sharma, S., Negi, H.P.S. and Ranote, P.S. 2013. Enrichment of pasta with different plant proteins. *J Food Sci Technol.*, **50**(5): 1000–1005.

Kim Y.S. 1998. Quality of wet noodles prepared with wheat flour and mushroom powder. *Korean J Food Sci Technol.*, **30**: 1373-1380.

Kim, H., Hong, J., Choi, J., Han, G., Kim, T., Kim, S. and Chun, H. 2005. Properties of wet noodle changed by the addition of Sanghwang mushroom (*Phellinus linteus*) powder and extract. *Korean J Food Sci Technol.*, **37**: 579–583.

Li, M., Luo, L.J., Zhu, K.X., Guo, X.N., Peng, W. and Zhou, H.M. 2012a. Effect of vacuum-mixing on the quality characteristics of fresh noodles. *J Food Eng.*, **110**: 525–531.

Li, M., Zhang, J.H., Zhu, K.X., Peng, W., Zhang, S.K., Wang, B., Zhu, Y.J. and Zhou, H.M. 2012b. Effect of superfine green tea powder on the thermodynamic, rheological and fresh noodle making properties of wheat flour. *LWT – Food Sci Technol.*, **46**: 23–28.

Ma, D.R., Pan, L.J. and Pang, R. 2009. Quality improvement of nutrition noodle with tomato and yam. *Food Sci.*, **30**: 182–185.

Maforimbo, E., Skurray, G., Uthayakumaran, S. and Wrigley, C. 2008. Incorporation of soy proteins into the wheat–gluten matrix during dough mixing. *J Cereal Sci.,* **47**: 380–385.

Mahony, M.O. 1985. Sensory evaluation of food: Statistical Methods and Procedures. Technology & Engineering, Marcel Dekker Inc, CRC Press, New York, pp. 510.

Matsuo, R.R. and Irvine, G.N. 1970. Effect of gluten on cooking quality of spaghetti. *Cereal Chem.,* **47**: 173–180.

Matsuo, R.R., Dexter, J.E. and Dronzek, B.L. 1978. Scanning electron microscopic study of spaghetti processing. *Cereal Chem.,* **55**: 744-753.

Mondelli, G. 2000. Drying pasta: technology in a simple fount. *Professional Pasta Newsletter*, **11**: 10-23.

Monge, L., Cortassa, G., Fiocchi, F., Mussino, G. and Carta, Q. 1990. Glycoinsulinaemic response, digestion and intestinal absorption of the starch contained in two types of spaghetti. *Diabetes Nutr Metab.,* **3**: 239–246.

Olfat Y.M., Yaseen, A.A.E. and Aziza, A.I. 1993. Enrichment of macaroni with cellulose derivative protein complex from whey and corn steep liquor. *Nahrung*, **37**: 544–552.

Oliver, J.R., Blakeney, A.B. and Allen, H.M. 1993. The colour of flour streams as related to ash and pigment contents. *J Cereal Sci.,* **17**(2): 169–182.

Osorio, D.P., Acevedo, A.E., Vinalay, M.M., Tovar, J. and Bello-Pérez, L.A. 2008. Pasta added with chickpea flour: chemical composition, *In vitro* Starch digestibility and predicted glycemic Index. *Cienc Tecnol Aliment*., **6**: 6–12.

Oszmianski, J. and Wojdylo, A. 2009. Effects of blackcurrant and apple mesh blending on the phenolics content, antioxidant capacity and colour of juices. *Czech J Food Sci.,* **5**: 338–351.

Pagani, M.A., Gallant, D.J., Bouchet, B. and Resmini, P. 1986. Ultra-structure of cooked spaghetti. *Food Microstruct.,* **5**: 111-129.

Petitot, M., Brossard, C., Barron, C., Larre, C., Morel, M.H. and Micard, V. 2009. Modification of pasta structure induced by high drying temperatures. Effects on the in-vitro digestibility of protein and starch fractions and the potential allergenicity of protein hydrolysates. *Food Chem.,* **116**: 401-412.

Pinarli, I., Ibanoglu, S. and Oner, M.D. 2004. Effect of storage on the selected properties of macaroni enriched with wheat germ. *J Food Eng*. **64**: 249–256.

Prabhasankar, P.J., Rajiv, D., Indrani and Rao, G.V. 2007. Influence of whey protein concentrate, additives, their combinations on the quality and microstructure of vermicelli made from Indian Durum wheat variety. *J Food Eng*., **80**: 1239-1245.

Ranganna, S. 2009. Handbook of analysis and quality control for fruits and vegetable products. 2nd ed. Tata McGraw Hill Publ. Ltd., New Delhi, India, pp. 1112.

Serventi, S. and Sabban, F. 2002. Pasta: The story of universal food. Columbia University Press.

Shim, J., Kim, K. and Bae, D. 2003. Comparisons of physicochemical and sensory properties in noodles containing spinach juice, beetroot juice and cuttlefish ink. *Food Eng Prog.,* **7**: 37–43.

Sozer, N., Dalgic, A.C. and Kaya, A. 2007. Thermal, texture and cooking properties of spaghetti enriched with resistance starch. *J Food Eng.,* **81**: 476-484.

Thimmaiah, S.K. 2006. Standard methods of biochemical analysis. Kalyani Publishers, p. 545.

Tudorica, C.M., Kuri, V. and Brennan, C.S. 2002. Nutritional and physicochemical characteristics of dietary fiber enriched pasta. *J Agric Food Chem.,* **50**:347-356.

Zimmermann, M.B. and Hurrell, R.F. 2007. Nutritional iron deficiency. *Lancet,* **370**: 511–520.