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Quality, microstructure, biochemical and immunochemical characteristics of hypoallergenic pasta

S Susanna and P Prabhasankar

Abstract

Celiac disease is an immune-mediated enteropathy, characterized by lifelong intolerance to gluten in genetically susceptible individuals. This study aims to develop hypoallergenic pasta using blends of *Triticum durum semolina*, 40% of other non-wheat flours and additives. Formulated pasta samples were evaluated for product quality characteristics and also subjected to biochemical analysis. Results showed that cooking loss ranged from 6.9% to 7.4%, which were within the acceptable range of 8%. Color change was low and in vitro protein digestibility of the pasta was found to be insignificant. Pasting characteristics of the hypoallergenic flour showed the increased peak viscosity and decreased gelatinization temperature. The scanning electron microscopy results demonstrated less-affected microstructure of gluten network. Texture profile analysis and descriptive sensory analysis revealed that optimized hypoallergenic pasta with xanthan gum as additive was acceptable and comparable with control. SDS-PAGE pattern showed distinct protein profile and decreased intensity, which was supported by Dot-Blot. In conclusion, the hypoallergenic pasta prepared by replacing *T durum* flour by 40% of other non-gluten flours could be useful for celiac patients because of its low antigenic activity.

Keywords

pasta, gluten, non-gluten flours, celiac disease

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INTRODUCTION

Wheat is a major cereal grain and is the staple food of many countries (Oishi et al., 2009). Wide acceptance of wheat is largely due to its nutritional value and unique property of viscoelasticity of the dough when mixed with water (Shewry et al., 1986). Gluten, a cohesive, viscoelastic proteinaceous mass has storage proteins known as prolamines that comprises alcohol-soluble monomeric gliadins (α , β , γ and ω gliadins) and the polymeric glutenin (Tatham and Shewry, 1995; Zorzi et al., 2007). Unfortunately, wheat is known to cause potential and immunoglobulin E (IgE)-mediated

allergic reactions in specific individuals. The prolamines present in the wheat are the elicitors of immunological adverse reactions in the individual genetically susceptible to gliadin.

Celiac disease (CD) is a chronic inflammatory condition of the proximal small intestinal mucosa or it can be described as immune-mediated enteropathy triggered by the ingestion of gluten-containing cereals in genetically susceptible individuals. Murray (1999) found that CD is due to genetic predisposition, environmental factors and immunologically based inflammation. In recent times,

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there is a need for novel foods designed to manage various chronic disease conditions and reducing the risk of various diseases (Handoya et al., 2006). As the food allergy/gluten allergy is a serious worldwide problem, several food-processing techniques have been applied to foods in order to eliminate their allergenic proteins or to reduce their levels (Saito et al., 2003). Watanabe et al. (2000) have proposed a method for preparing hypoallergenic wheat flour by controlled enzymatic modification. Studies have been done to find out the effect of thermal treatment on allergenicity of wheat flour (Leszczynska et al., 2003).

Pasta is a widely used food product. It has a vital role in human nutrition as it can be used with several integrations to make important nutritional modifications to suit the needs of the community (Chillo et al., 2008). Food and drug administration (FDA) consider pasta as a good vehicle for the addition of nutrients. Pasta was one of the first foods for the FDA-permitted vitamin and iron enrichment in the 1940 (Marconi and Carcea, 2001).

Hence, the present study was taken up with the objective to develop hypoallergenic pasta products by blending wheat flour with non-gluten cereal flours and to evaluate its product quality. Study also aimed at the Sodium Dodecyl Sulphate–Poly Acrylamide Gel Electrophoresis (SDS-PAGE) and Dot-Blot evaluation of the pasta product to understand change in the allergen profiles.

MATERIALS AND METHODS

Materials

Raw materials. *T. durum semolina* and other non-wheat flours such as maize oats and sorghum flours were procured from local market. Gliadin was procured from Sigma chemicals, USA. Molecular marker for SDS-PAGE and Goat anti-rabbit immunoglobulin G (IgG)-alkaline phosphatase conjugate were procured from Bangalore Genie, India. All other chemicals used were of analytical grade.

Methods

Pasta processing. Hypoallergenic flour was prepared by replacing 40% of the *T. durum flour* by other non-wheat cereal flours along with additives. Hydroxypropylmethyl cellulose (HPMC), ascorbic acid, locust bean gum and xanthan gum were mixed at different proportions. Flour was mixed in Hobart mixer (model N-50, Ontario, Canada) using low speed of 59 rpm with optimal 30% of water and mixed for 7–10 min. Mixed samples were extruded using La moniferrino (Model Dolly, Asti, Italy) extruder and the samples were dried at 70°C for 3 h in Sakar Drier (Shirsat Electronics, Mumbai).

Proximate analysis. Proximate compositions of all the flours used in the pasta preparation were evaluated using standard methods. Moisture, ash and protein content were estimated by standard AACC method (AACC, 2000).

Cooking quality. Optimization of cooking time and determination of cooking loss of pasta samples were determined according to Bureau of Indian Standards (1976).

Color. Color of the raw and cooked pasta was measured using Hunter color measurement (Color measuring Labscan XE system, USA). Color readings were expressed by hunter values for L^* , a^* and b^* .

Microstructure of pasta. Transversely sectioned cooked, freeze-dried pasta samples were scanned to understand microstructure of pasta samples using scanning electron microscopy (SEM) at both higher and lower magnification. The samples were mounted on the specimen holder and sputter-coated with gold. Then each sample was transferred to microscope for observation. This procedure was applied to gain information about the arrangements of particles that correlates with the pasta characters. SEM study was carried out with optimized cooked pasta samples as per procedure of Prabhasankar et al. (2009).

Pasting characters. Pasting characters of all the blends and pasta samples were studied using Brabender-visco-amylo-graph (Brabender OHG, Duisburg, Germany), following the AACC methods (AACC, 2000).

In vitro protein digestion. The cooked freeze-dried and finely ground pasta was incubated with pepsin and pancreatin according to the method described by Akeson and Stahmann (1964), with slight modifications. A total of 2 g of freeze-dried samples were incubated with 1.5 mg of pepsin in 15 mL of 0.1 N HCl at 37°C. After 3 h, the samples were neutralized with 0.5 N NaOH. The sample was then incubated with pancreatin (4 mg) in 0.2 M phosphate buffer (pH 8) and then 0.005 M sodium azide was added. After overnight incubation, 10% TCA was added and centrifuged at 3000 rpm for 20 min. The supernatant was subjected to protein estimation by Kjeldal method.

Electrophoresis. Cooked and freeze-dried pasta samples along with respective blends and *T. durum semolina* flour were analyzed by electrophoresis. SDS-PAGE was carried out as per the method adopted by Prabhasankar (2002). Twelve percent acrylamide gel was used to separate the protein fractions of the

Table 1. List of descriptors generated during panelist training

Attributes	Definitions
Cream	The intensity or strength of the color from light to dark
Moist	The feel of wetness when chewed
Sheen	The amount of light reflected from the surface of the product
Firmness/soft	The force required to compress while chewing the mass of pasta
Chewy	Number of chewings minimum required before swallowing
Leathery	The feel of layers of pasta when it is being chewed
Sticky	The tackiness of the coating left in the mouth
Cooked cereals	Any other cooked cereal flavor like wheat or rice
Any other taste	Any other taste imparting from other added ingredients of the pasta
After taste	Any off-taste of flavor imparting the foreign taste or flavor other than pasta

hypoallergenic pasta. Gel was stained with Coomassie brilliant blue R250.

Sensory evaluation. Quantitative descriptive analysis (QDA) was used to measure the sensory attributes of hypoallergenic pasta samples prepared with different additives. The texture profile analysis (Stone et al., 1974) was adapted to follow the generic consensus method described by Lawless and Heymann (1998). Fifteen experienced judges in descriptive analysis from the Institute participated. Panelists participated in three, 1-h training sessions. In session one, panelists were asked to develop a list of textural attributes to describe the pasta samples that were representative of the sample set. During second session, panelists were asked to work as a group to generate and define texture attributes to describe the complete texture profile of the pasta samples. In total, panelists developed a list of 10 major textural attributes as listed in Table 1. In the third and final training session, panelists were familiarized with line scale usage and practiced using the attributes developed. A structured scale of length 15 cm was used to record the sensory perceptions. Any perception that is low tends to zero while high intensity attains the maximum of the scale. Sensory analysis was conducted in individually partitioned booths. Samples were evaluated after cooking and served in porcelain cups coded with three-digit random numbers. Panelists were asked to rinse the mouth with water between each sample. Three samples were assessed per session according to a completely randomized design.

Production of polyclonal antibodies. Immunization of rabbit with gliadin was done according to the method of Prabhasankar (2002).

Dot-Blot analysis. Dot-Blot analysis was carried out according to the method described by Prabhasankar (2002); 2.0 mg of hypoallergenic flour was extracted

with 70% ethanol and 4 μ L of extract (10 μ g) was spotted on Nitro Cellulose Membrane (NCP) (sigma chemicals, USA) followed by blocking with 2% gelatin in phosphate buffered saline, pH 7.4 containing 0.05% Tween (PBS-T). This was followed by treating with anti-gliadin antibodies. The blot was then washed with PBS-T and treated with goat anti-rabbit IgG-ALP conjugate. Finally, the blot was treated with 5-bromo- 4-chloro- 3-indoyl phosphate/nitro blue tetra-Zolium (BCIP/NBT) substrate.

Statistical analysis. Each of the analytical measurements described above were carried out in two replicates and results are reported as the mean values and standard deviation. All the data were subjected to statistical analysis using least significant difference giving p value and $p < 0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Proximate analysis

Table 2 shows the proximate composition of different flours and the hypoallergenic flour and pasta. The protein content of the hypoallergenic flour was almost similar (10.03%) compared with that of control semolina flour (10.83%). Among non-wheat flours maize showed the lowest protein content of about 6.3% and oats had high content of 9.5%. Sorghum flour showed 8.2%. Similarly, ash content of the hypoallergenic flour did not vary much from the control. The protein content of the hypoallergenic pasta was 10.92% whereas control pasta had 12.35%. This shows that the nutritional composition of the hypoallergenic flour and pasta did not vary much from the control. The composition that was maintained might be because of the addition of the other cereal flours, especially the protein content. Addition of other cereal flours improves the amino acid composition of the flour. Apart from this, it

Table 2. Chemical composition of hypoallergenic wheat flour

Flours	Moisture (%)	Ash (%)	Protein (%)
<i>T durum</i> wheat flour	9.32 ± 0.0 d	0.99 ± 0.11 b	10.83 ± 0.06 cd
Oat flour	7.44 ± 0.25 a	1.45 ± 0.01 d	9.45 ± 0.12 c
Sorghum flour	7.59 ± 0.06 b	1.22 ± 0.02 c	8.00 ± 0.1 b
Maize flour	9.35 ± 0.05 d	1.30 ± 0.00 c	6.17 ± 0.06 a
Hypoallergenic flour	8.50 ± 0.04 c	1.09 ± 0.00 b	10.03 ± 0.06 c
Control pasta	8.29 ± 0.09 c	1.00 ± 0.00 b	12.32 ± 0.06 f
Hypoallergenic pasta	7.29 ± 0.04 a	0.10 ± 0.00 a	10.92 ± 0.00 c

Note: Mean values within a column followed by different letters are significantly different ($p < 0.005$).

Table 3. Color of the hypoallergenic pasta

	<i>L</i>	<i>a</i>	<i>b</i>	<i>E</i>
Pasta-raw				
Control	36.04 ± 0.99 c	0.57 ± 0.00 a	18.09 ± 0.65 c	55.83 ± 0.84 a
Pasta A	30.66 ± 4.28 b	1.66 ± 0.34 b	10.89 ± 1.92 b	65.99 ± 3.91 c
Pasta B	30.55 ± 2.39 b	2.59 ± 0.07 c	11.92 ± 0.36 b	61.8 ± 2.29 b
Pasta C	31.64 ± 1.53 b	1.98 ± 0.25 b	11.55 ± 0.53 b	60.24 ± 1.42 b
Pasta D	24.08 ± 0.26 a	1.35 ± 0.33 b	8.59 ± 0.65 a	67.14 ± 0.29 c
Cooked pasta				
Control	44.84 ± 0.01 c	-0.98 ± 0.00 d	11.13 ± 0.04 d	47.04 ± 0.00 a
Pasta A	37.28 ± 0.04 b	0.24 ± 0.02 b	9.17 ± 0.02 b	54.11 ± 0.04 b
Pasta B	33.93 ± 0.00 a	0.51 ± 0.01 c	8.89 ± 0.03 a	57.39 ± 0.01 a
Pasta C	32.16 ± 0.12 a	-0.21 ± 0.00 b	8.23 ± 0.05 a	59.03 ± 0.12 d
Pasta D	39.97 ± 0.15 b	0.12 ± 0.05 a	10.12 ± 0.03 c	57.62 ± 0.15 c

HPMC: hydroxypropylmethyl cellulose; Pasta A: with HPMC; Pasta B: with xanthan gum; Pasta C: with locust bean; and Pasta D: without any additive a values indicates red color when positive and green when negative, b values indicates yellow when positive and blue when negative.

maintains the fiber content thereby improving the overall nutritional composition of the flour.

Cooked weight and starch loss

Starch loss related to solid leaching is one of the common predictor of overall cooking quality and also most important feature of the pasta. Present study results indicated that the optimal cooking time of all the samples ranged between 3.90 and 4.42 min (Table 2). Among them, the hypoallergenic pasta prepared with locust bean gum had higher cooked weight of 65.9 g and all other pasta samples ranged similarly. The starch loss of the pasta samples were almost comparable to each other ranging from 6.9% and 7.4%. Pasta prepared without additive showed the higher loss of 7.4% whereas others were lesser than 7.0% and comparable with that of control pasta having 5.6%. Pastas with xanthan gum and locust bean gum had less cooking loss among hypoallergenic pasta samples. Cooking loss lower than 7–8% is acceptable

according to Dick and Youngs (1988). The main role of the gluten is the formation of the protein network that holds the starch particles together. The replacement of durum flour with other non-gluten flour dilutes the strength of gluten network and hence the higher value of starch loss compared to control. The differences in the cooking quality of the noodle among treatments could be attributed to the differences in the protein and carbohydrate composition (Khouryieh et al., 2006). Resmini and Pagani (1983) reported that cooking quality of the pasta was attributed to the interactions of these two biopolymers in the presence of water. The present study results were corroborated with the findings of Brennan and Tudorica (2007). Another study by Edwards et al. (1995) suggested that xanthan gum could form network around the starch granules trapping them in place during cooking and restricting excessive diffusion of amylose. This explains the results of less cooking loss of Pasta with xanthan gum and locust bean gum than the pasta without additive.

Color of the pasta

Lightness (L) values of uncooked pasta with additives, xanthan gum and locust bean ranged similarly

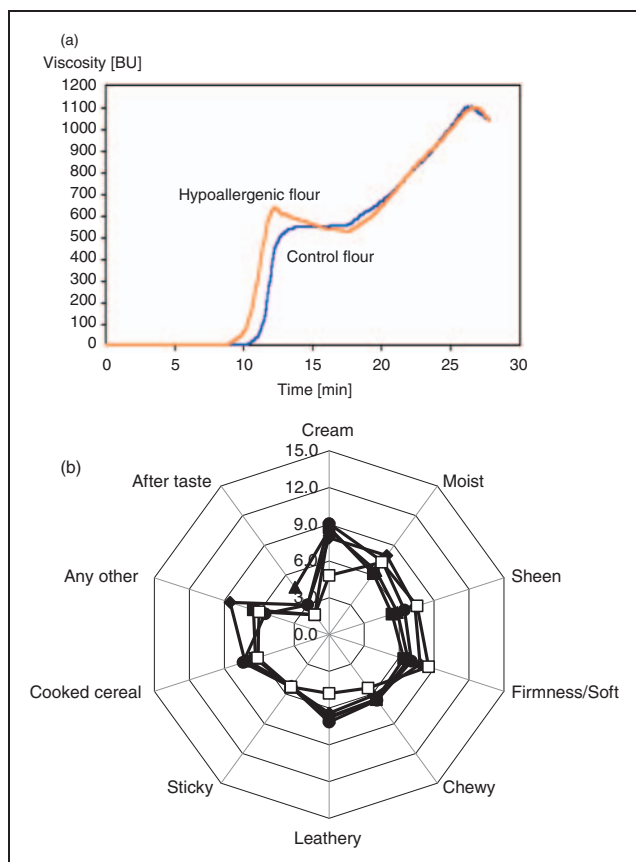


Figure 1. (a) Amylograph correlation graph of control and hypoallergenic pasta. (b) Descriptive sensory analysis of hypoallergenic pasta. (◆) sample 1, (●) sample 2, (▲) sample 3, (■) sample 4 and (□) sample 5.

(31.64–30.05) whereas pasta with hydroxypropylmethyl cellulose as additive showed less 24.08, but the control pasta showed higher value of 36.04 (Table 3). But the L values of cooked pasta increased than the uncooked pasta ranging from 32.16 to 39.97 and cooked control pasta had 44.84. The color of the pasta was affected by the replacement of semolina with non-gluten cereal flours. As shown in Table 3, the product color became darker, redder and less yellow. Yellowness of cooked hypoallergenic pasta was increased due to the presence of pigments giving yellow color in the non-gluten cereals, especially in maize added. Low L values were obtained for pasta with different gums than control pasta. Acevedo et al. (2009) reported similar results in their study and stated that partial replacement of semolina with various food ingredients had an important effect on the color parameters. Similar kind of observations was reported by Marconi et al. (2000). His study reports lower L values, b values and higher a values of pasta incorporated with barley than control pasta. The results obtained by Zhao et al. (2005) supported the above mentioned observation of low L and b values and higher a values in spaghetti containing 5–30% milled flours of green pea, yellow pea, chick pea and lentil flours.

Pasting characteristics of the pasta

The gelatinization temperature of the pasta decreased from 80.9 to 75.5°C (Figure 1(a)). The values of maximum viscosity, cold paste, hot paste viscosity, breakdown and setback were increased. The maximum viscosity was increased from 604 to 640 and cold paste and hot paste viscosity was increased from 497 to 633 and 1047 to 1066, respectively. Similar way, the breakdown and set back values were increased from 1 to 110 and 429 to 530, respectively. The decrease in the

Table 4. Cooking quality characteristics and texture profile analysis of hypoallergenic pasta

Sample	Cooking time (min)	Cooked weight (g)	Starch loss (%)	Hardness force (N)	Shear force (N)	Stickiness force (N)	Protein digestibility (%)
100% <i>T durum</i> pasta	4.25 ± 0.00 c	56.5 ± 0.77 a	5.66 ± 0.51 a	28.37 ± 1.40 a	1.28 ± 1.06 c	−0.81 ± 0.15 a	91.34 ± 0.00 c
Hypoallergenic Pasta A	4.25 ± 0.06 c	58.7 ± 0.80 b	7.00 ± 0.23 b	49.76 ± 1.14 a	1.27 ± 1.01 c	−2.36 ± 0.28 c	92.78 ± 1.61 c
Pasta B	4.42 ± 0.00 c	58.6 ± 0.65 b	6.88 ± 0.14 b	62.08 ± 1.59 d	0.50 ± 0.00 a	−2.99 ± 0.34 c	78.43 ± 1.00 a
Pasta C	3.98 ± 0.62 b	65.9 ± 0.85 b	6.98 ± 0.11 b	29.43 ± 1.22 a	0.69 ± 0.23 b	−1.94 ± 0.48 b	80.06 ± 1.93 b
Pasta D	3.37 ± 0.53 a	54.5 ± 0.28 a	7.42 ± 0.13 c	34.11 ± 1.66 b	0.68 ± 0.01 b	−2.50 ± 0.42 a	81.28 ± 1.85 b

HPMC: hydroxypropylmethyl cellulose; Pasta A: with HPMC; Pasta B: with xanthan gum; Pasta C: with locust bean; Pasta D: without any additive.

Note: Mean values within a column followed by different letters are significantly different ($p < .005$).

gelatinization temperature could be attributed to early onset of initial viscosity. Similar results were observed by Indrani et al. (2010) when multigrain mixture was incorporated to bread. The study reported that increase in the cold paste viscosity indicates a strong tendency for retrogradation of starch molecules and increased break down values represents the resistance of starch granules to thermal treatment and mechanical shearing.

In vitro protein digestion

As shown in the Table 4, hypoallergenic pasta with different gums showed decreased digestibility than the pasta without gums and control pasta. The decrease in digestibility could be due to interference of added gums in hypoallergenic pasta samples during digestion. The control and hypoallergenic pasta without additive had 91.34% and 92.78% of protein digestibility whereas hypoallergenic pasta with different gums showed 78.43%–81.28%. Xanthan gum, locust bean gum falls under the category of soluble non-starch polysaccharides. These two gums have the potential to form hydrated polysaccharide gum system within a food, altering the internal structure of that food and forming complex associations or (matrixes) with protein and starch components (Brennan and Tudorica, 2007). May be these characteristics of the gums could be reason for decreased protein digestibility of pasta with gums.

Texture profile analysis

Texture plays an essential role in determining the final acceptance by the consumer and it is one of predominant criteria for assessing pasta quality (Acevedo et al., 2009). The hardness values indicated by the maximum peak of the first compression varied from 28.37 to 62.08 N while the stickiness varied from 0.81 to 2.99 N indicating wide variations in texture of pasta samples studied (Table 2). Highest peak force or hardness and stickiness were observed for pasta sample with xanthan gum, while lowest stickiness and hardness was observed for control pasta sample. The high hardness value was observed for pasta with xanthan gum. This could be probably due to its differential water absorption rate and capacity. It can hold water more than flour particle, thus by making water not available for other dough components, resulting in high hardness and stickiness values of pasta. The hardness value was lowest in control sample due to the absence of additives. Highest stickiness found in the pasta with xanthan gum is because xanthun gum imparts stickiness to the product after cooking. Similar trend was also observed for stickiness while control and pasta

without gums showed same stickiness values due to absence of additives. A study by Brennan and Tudorica (2007) showed that pasta containing locust bean gum or xanthan gum had moisture similar to or higher than the control pasta and at same time their firmness showed increased values. Study suggests that locust bean gum and xanthun gum contribute to the structure strength. Hypothesis could be also related to values obtained for cooking losses indicating a well-formed structure of which little solids are released during cooking. Raina et al. (2005) reports that the hydrophilic components of hydrocolloids interact with proteins as a result of ionic charges and improve the structure of the pasta.

Descriptive sensory evaluation

The data supports the trend observed for texture profile analysis (Figure 1(b)). The desirable cream color was affected by the addition of additives and other cereal flours. The values were varied significantly ($p < 0.05$) and it ranged from 4.8 to 9.1, clearly indicating the color increased in the samples depending upon the additives. Another important parameter the firmness also showed variation, which ranged from 6.4 to 8.5. Leathery was more in pasta sample with xanthan gum probably due to the addition of xanthan gum, which is also reflected in the after-taste. Leatheriness was low in pasta without additives D, which have it. Overall quality indicated that samples prepared with hypoallergenic pasta were comparable with that of control.

Biochemical characterization of hypoallergenic pasta

The SDS-PAGE pattern of hypoallergenic flour showed less-intense protein bands corresponding to allergen profile than the control flour (Figure 2(a)). In lane 4 which shows the pattern of hypoallergenic flour, some smaller bands seen at 97.4 k Da and 66 k Da might be coming from other non-gluten flours as the lane 3 representing control pasta and lane 5 shows the hypoallergenic pasta, respectively. Hypoallergenic pasta also showed similar and less-intense protein bands corresponding to allergen profile as shown in the hypoallergenic flour. Kieffer et al. (1982) observed the less-intense bands of other cereal promalines bands in the same region as wheat omega and gamma gliadins, but little or nothing in the β region. They reported that maize, oat and rice prolamines are characterized by different less-intense bands in the regions other than the gliadin region and reported low anti-genic activity.

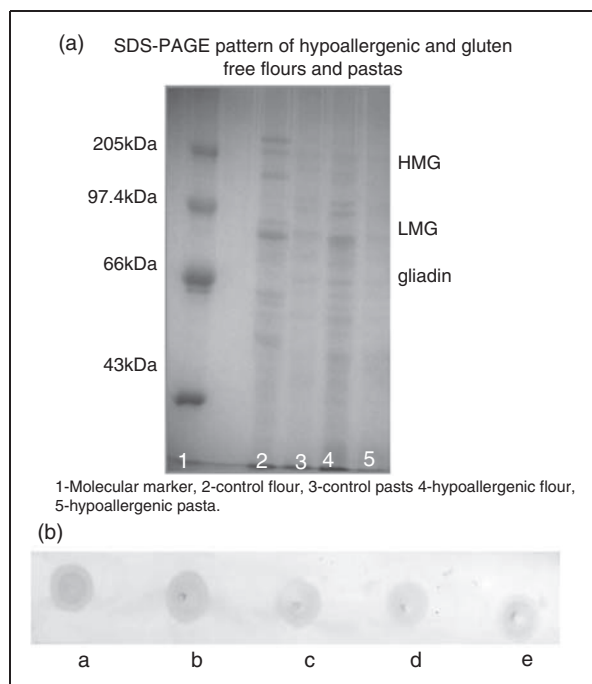


Figure 2. SDS-PAGE and Dot-Blot pattern of hypoallergenic flour and pasta. (a) 1-molecular marker, 2-Semolina flour, 3-control pasta, 4-hypoallergenic flour and 5-hypoallergenic pasta. (b) a-gliadin, b-control pasta, c-hypoallergenic pasta and d and e in vitro digested control and hypoallergenic pasta.

Immunochemical characterization of hypoallergenic pasta

The intensity of the color developed in spot of hypoallergenic pasta was less compared to spot of control pasta and gliadin alone (Figure 2(b)). This indicates that immunological features of the wheat flour are affected when replaced by the non-gluten flours. Similar kind of observations was made by Pasini et al. (2001) in their study. They reported that both physicochemical and immunological features of the wheat flour and its digested products were affected after modifications like heat treatment. This supports the data of SDS-PAGE and indicates that the optimized hypoallergenic pasta contains less allergen compared to control pasta.

Scanning electron micrographs

Figure 3(A) represents the standard pasta prepared with durum semolina, which clearly shows the gelatinized starch granules trapped between the thin protein films of gluten matrix. The gluten matrix is of continuous nature. Figure 3(B) shows the image of the hypoallergenic pasta without any additives that shows the matrix with discontinuous network because of dilution

of gluten by the addition of other cereal grains. Figure 3(C) and (D) shows the images of control flour and hypoallergenic flour. The micrographs highlight the importance of continuous protein network in the entrapment of starch and good cooking quality. Changes in the protein network results in the increased cooking loss (Cleary and Brennan, 2006). The image of hypoallergenic pasta shows the small granules of starch coming from other non-gluten sources, which supports the data of difference in the particle size distribution may affect the pasting characteristics and cooking loss of pasta. Indrani et al. (2010) reported that increase in the level of incorporation of multigrain mixture in preparation of bread interrupt the continuity of the matrix. They also observed thin protein matrix owing to the disruption of continuity because of higher level of incorporation of the multigrain mixture. Ryu (1999) studied the influence of additives on preparation of waxy barley and wheat flour bread. SEM images of bread demonstrated non-continuous, loose protein-starch matrix where in starch granules were dispersed. But more continuous structure was observed in the dough made with barley flour along with additives like hydroxypropylmethyl cellulose (Indrani et al., 2010). Findings of Prabhasankar et al. (2009) supports the data by reporting that incorporation of seaweed beyond 2.5% level disturbs the microstructure of pasta.

Relationship between cooking quality and functional and biochemical characteristics of hypoallergenic pasta

The quality of the pasta mainly depends on its protein content, especially gluten content of the flour. Cooking quality of the pasta is attributed to the interactions of two biopolymers namely starch and protein (Resmini and Pagani, 1983). The difference in the cooking quality of extruded product could be attributed to the difference in the protein and carbohydrate composition (Khouryieh et al., 2006). Even though the protein content of the hypoallergenic pasta was nearly equal to the protein content of the control, there was a little change in the protein starch matrix when studied under SEM. This explains the higher cooking loss of the hypoallergenic pasta than the control. But by the addition of the gums like xanthan gum and locust bean gum, acceptable range of cooking loss could be achieved. The microstructure studies also support the data by showing less disturbed gluten matrix, which was improved by the addition of the gums. Pasting characteristics predicted the higher cooking loss with increased peak viscosity. Krishnan and Prabhasankar (2010) also had observed similar results in their study on the influence of the sprouted finger millet flour and green banana flour on the pasting characteristics. The texture profile and descriptive

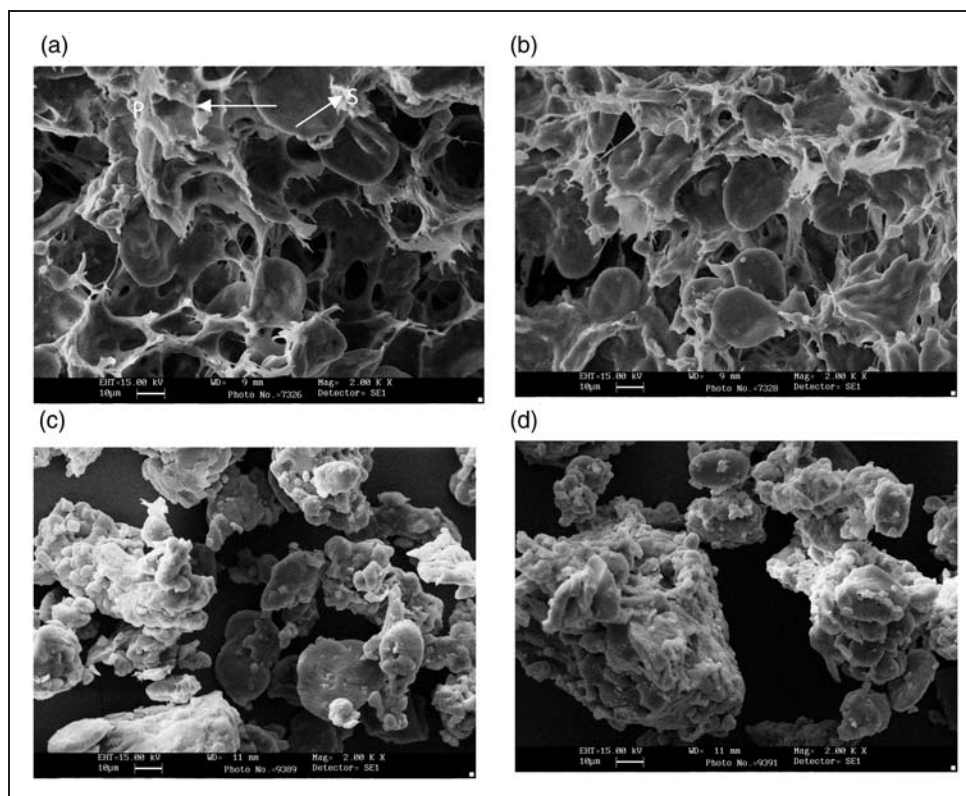


Figure 3. Scanning electron micrograph of control pasta and hypoallergenic pasta. a: control pasta, b: hypoallergenic pasta, c: semolina flour, d: Hypoallergenic flour, S: Starch granules and P: Protein matrix.

sensory analysis also shows the same trend and reveals that with the addition of gums the quality of hypoallergenic pasta is acceptable. This was supported by the biochemical data. SDS-PAGE shows the distinct allergen profile and the Dot-Blot confirms the low antigenic activity of the optimized hypoallergenic pasta.

CONCLUSIONS

The study represents an attempt to develop hypoallergenic pasta using blends of non-durum wheat flour and 60% *T. durum* semolina with combination of additives. The study indicated that developed hypoallergenic pasta had acceptable limits of cooking and sensory attributes. Among different variations, the hypoallergenic pasta prepared with xanthan gum as additive was comparable with control in all attributes. There was not much decrease in the protein content of the hypoallergenic pasta as well as *in vitro* protein digestibility of the pasta. The results also indicated that the cooking loss was within the acceptable range. Texture and sensory studies also revealed the overall quality of the hypoallergenic pasta was acceptable and comparable with pasta. Biochemical evaluation by SDS-PAGE and Dot-Blot revealed the low content of gliadin proteins was found in hypoallergenic pasta. Study aims at

the use of other effective methods to reduce allergenicity efficiently and in development of hypoallergenic pasta suitable for celiac patients.

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