A study on noodle dough rheology and product quality characteristics of fresh and dried noodles as influenced by low glycemic index ingredient

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Abstract Low Glycemic Index (LGI) foods help to maintain blood glucose level in diabetic individuals. Pea flour (PF) is known to be one of LGI ingredients used in the food industry. To assess the influence of PF in noodle processing, thermally processed pea flour was incorporated at 20 % and 40 % in the preparation of noodles using Lab scale Noodle Making Machine. Evaluation for Physico-chemical, rheological and noodle making characteristics, in vitro starch digestibility (IVSD) and microstructure of noodles were carried out. Cooking quality did not show any significant difference among the samples, with solid leach out ranging from 6.7 to 7.2 % against control (6.5 %). Colour measurement showed the presence of greenish colour in PF incorporated samples. Texture was firmer in fresh noodles (FN) (5.52 Newton (N), 6.00 N) and dried noodles (DN) (7.60 N, 7.86 N) compared to control (4.38 N-FN, 6.88 N-DN). Sensory analysis of noodles revealed that the samples (FN, DN) were acceptable at 20 % and 40 % levels with overall quality score (>8.5). In vitro analysis revealed that with increase in PF content there was a significant decrease in the availability of glucose in DN followed by FN compared to control. Overall RDS was reduced and SDS was increased in 40 % PF incorporated FN. Scanning-electron microscopy revealed the presence of fiber matrix around the starch granules.

Keywords Low Glycemic Index · Pea flour · In vitro starch digestibility · Noodles · Cooking quality · Microstructure · Rheology · Sensory analysis

Introduction

Wheat (*Triticum* spp.) is a grass, originally from the region of the Near East, but now cultivated worldwide. Wheat is third most-produced cereal after maize and rice. Globally, wheat is the leading source of vegetable protein in human food, having higher protein content than other major cereals. Wheat is one of the oldest food crops grown by man, has achieved central role as a staple food for all nations and cultures, because of its dough characteristic like cohesiveness and thus to be used in the preparation of bread and other wide range of products like noodles, soups, pasta and other foods like biscuits, cookies, cakes, breakfast cereal (Uthayakumaran and Wrigley 2010). The husk of the grain, separated when milling white flour, is bran. Wheat germ is the embryo portion of the wheat kernel. It is a concentrated source of vitamins, minerals, and protein, and is sustained by the larger, starch storage region of the kernel-the endosperm (Bozzini 1988).

Diabetes mellitus generally referred to as diabetes is a group of metabolic disorders in which a person has high blood sugar levels, either because the body does not produce enough insulin, or because cells do not respond to the insulin that is produced. This high blood sugar level produces the symptoms of polyuria (frequent urination), polydipsia (increased thirst) and polyphagia (increased hunger).

In 2010, according to the World Health Organization, at least 2.8 % of the population suffers from diabetes. Its incidence is increasing rapidly, and it is estimated that by 2030, this number will almost double. Diabetes mellitus occurs throughout the world, but is more common; especially type 2 diabetes in the more developed countries. The increase in incidence of diabetes in developing countries follows the trend of urbanization and lifestyle changes, perhaps most importantly a “Western-style” diet (Wild et al. 2004).

Glycemic index (GI) is the standard method of grading the foods based on their effect on postprandial blood glucose response compared with a reference food. Rate of digestion

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or absorption of carbohydrates in food is a major factor influencing GI. The Glycemic Index (GI) of foods is receiving increasing interest in the field of Medical and Nutrition. Nowadays low-GI foods are in great demand as they have several health benefits. Low-GI foods may aid in slow release properties in the upper gastrointestinal tract, resulting in decreased insulin demand (Miller 1994). Another possible mechanism related to their higher content of indigestible carbohydrate (dietary fiber, resistant starch) which increases fermentive activity in colon. Some of the low GI ingredients reported include pea, rajmah, chickpea, raw banana, oats, soybean, broccoli, etc.

Processing of foods also affects the glycemic index of the food products. The more processed the food is, the higher the glycemic response it will produce. But, pasta is an exceptional, (traditional pasta is said to be low-GI) when compared to other cereals, as the starch is slowly digested and absorbed in small intestine, which eventually helps in management of diabetes and other health consequences. Nowadays pasta and noodles are becoming popular in Indian diet, because of its good palatability and ease of preparation. Diet pattern containing low GI foods helps diabetics to maintain blood glucose level. Utilization of these low GI ingredients in our day-to-day life may reduce the risk of diabetes, cardiovascular disease and other health related consequences in healthy individuals.

Wheat flour is a unique material, because a simple addition of water coupled with energy input through mixing enables the formation of dough that can be kneaded and stretched to make noodles and strips. Hard grain with 11–13 % protein content with high dough strength, high water absorption, medium Farinograph dough development time and medium starch-paste viscosity is ideal for yellow alkaline noodles. However, soft and hard grain with protein content of 10–12 % with high starch-paste viscosity, medium water absorption and medium dough development time is suitable for white salted noodles (Uthayakumaran and Wrigley 2010).

In the present study it has been aimed to develop low GI wheat based noodles and to study the influence of Low-GI ingredient on physico-chemical, cooking quality, in vitro starch digestibility (IVSD), microstructure and sensory characteristics of fresh (FN) and dried Noodles (DN).

Materials and methods

Procurement of raw materials and chemicals

Selection of low GI ingredients was done on the basis of the previous reported studies. Dried green pea (*Pisum sativum*) was selected as low GI ingredient and procured from local market along with durum semolina. Former is milled to a fine powder and sieved, latter was milled to coarse flour in a domestic flourmill and stored for further analysis. Enzymes

like amyloglucosidase and α -amylase are procured from Sigma chemicals, USA. All other chemicals were of analytical grade.

Methodology

Thermal treatment

To reduce the rancid effect and increase the shelf life of the product, pea flour was thermally treated (toasted) under the condition of 70°–80 °C for 2 h. Then the pea flour was cooled and packed.

Granulation

Particle size distribution was analyzed using 200 g of flour and blends with Buhler laboratory sifter (Buhler lab sifter, Type MLU 300, Switzerland) attached with different sieves. Sieves with openings 217, 180, 150, 132, 118, 95 and 55 μ m were used for the analysis.

Rheological characteristics of flour blends

Rheological characteristics of durum semolina flour and pea flour blends were carried out using Farinograph (Brabender, Germany), Amylograph (Brabender, Germany) and Alveograph (Chopin, France) according to the standard AACC method (AACC 2000).

Noodle formulation

Thermally treated pea flour was incorporated in 20 % and 40 % levels. Initially durum semolina flour and pea flour were blended to form a uniform flour mixture. This blended flour was then mixed with the appropriate amount of water (around 40 %–45 %) to form firm dough in a noodle mixer. The dough was then rested for some time (10–15 min) and it was sheeted to 5 mm thickness in dough sheeter, this sheeting involves 5–6 steps, which involves reduction in thickness from 10 mm to 5 mm. The sheeted dough was cut into appropriate length comfortable for drying process and then cut into flat noodles in noodle cutter. These flat noodles were dried in cabinet tray drier at 55 °C for 2 h. The dried noodles were cooled and packed until further utilization.

Cooking quality

Cooking quality of the noodles was determined for both FN and DN. Fresh noodles were cooked as soon as they were extruded and cut. Whereas, dried noodles were cooked after the drying process. Procedure of cooking for both of the noodles was from AACC method (66–50). Noodles were cut to approximately 5 cm by length. Twenty five grams of

sample was weighed and put in the 250 ml of boiling water. Timer was started to determine the cooking time. Check the noodle strands at every 30 s intervals for its hydration and cooking by squeezing the sample. Stop cooking when the core portion just disappears, indicating the completion of cooking. The gruel was drained and collected for the solid leach out measurement. Cooked samples were analyzed for its texture, colour and sensory evaluation. Expansion rate of noodles after cooking was determined by measuring the width of the uncooked and cooked noodles.

Proximate composition

Raw materials and prepared noodles were analyzed for moisture, protein, fat, ash and dietary fiber according to the AOAC methods (AOAC 1984). Amount of carbohydrates was calculated by difference using the results of proximate components. Micro-kjeldahl method was used to determine nitrogen contents of both fresh and dried noodles (AACC 2000). In order to calculate protein content from nitrogen determination 5.7 was used. All the values were reported on dry basis.

Instrumental colour measurement

The colour of raw and fresh noodles was measured with Lab scan-XE equipped with a D65 illuminant with a 2° view angle and slit width of 2 nm. The samples were placed in a transparent glass petri plate and placed on the slit opening and the surface colour was measured thrice. The average value of three measurements was reported. Colour readings were displayed as L^* a^* b^* values, where L^* represents lightness/darkness dimension, positive and negative a^* value indicates redness and greenness respectively and b^* indicates yellowness for positive and blueness for negative values (Hutchings 1994). With the above L^* , a^* and b^* values pasta colour index (PCI) was calculated using the following equation (Cavazza et al. 2012).

$$PCI = \sqrt{L^{*2} + b^{*2}}$$

Instrumental texture measurement

Texture analyzer model TA-XDi (Stable Micro Systems) using Warner Bratzler Blade for shear was used to measure the noodle texture. Five noodle strands were arranged adjacent to each other and sheared under the following experimental conditions: Load cell 250 kg, cross head speed 10 mm/min. Peak force required for shearing of the noodles was recorded in Newtons (N). The average of five replicates was reported in Newtons. The data thus obtained were analyzed statistically using Duncan's Multiple Range Test (DMRT) (Duncan 1955).

In vitro starch digestibility assay

In vitro digestibility of starch was analyzed using the method of Englyst (Englyst et al. 1992), with minor modification. Freeze dried and ground sample (50 mg) was dispersed in 4 ml of sodium acetate buffer (pH 4.6, 0.4 M) containing Amyloglucosidase was incubated in water bath for 30 min at 60 °C. Then the enzyme was inactivated by placing the tubes in boiling water bath (100 °C) for 15 min. The tubes were cooled to room temperature and then centrifuged at 5,000 rpm for 10 min. Supernatant was measured for its glucose content using a glucose oxidase-peroxidase (GOD-POD) kit (Autospan, Span Diagnostics limited, India). Absorption was measured at 505 nm and the glucose concentration was converted into starch content using a 0.9 factor. Each sample was analyzed in triplicates.

Analysis of rapidly digestible starch (RDS), slowly digestible starch (SDS), resistant starch (RS) and total starch (TS)

In vitro RDS, SDS, RS and TS were analyzed using the method of Englyst (Englyst et al. 1992). Conversion factor used was 0.9 to convert glucose to starch. Each sample was analyzed in triplicates. Free glucose (FG) and total glucose (TS) were also determined using the method of Englyst (Englyst et al. 1992). RDS, SDS, RS and TS were calculated using the following equations:

$$RDS = (G_{20} - FG) \times 0.9$$

$$SDS = (G_{120} - G_{20}) \times 0.9$$

$$RS = TS - (RDS + SDS)$$

$$TS = (TG - FG) \times 0.9$$

Where,

G_{20} is the value of glucose hydrolyzed during the first 20 min of in vitro digestion

G_{120} is the value of glucose hydrolyzed after 120 min of in vitro digestion

Microstructural characterization

Cooked and freeze dried fresh and dried noodle samples were scanned under scanning electron microscope according to the method described by Prabhasankar et al. (2009). The samples were mounted on the specimen holder and sputter-coated with gold. Then, each sample was transferred to electron microscope (LEO 435 VP, USA) and observed under 2,000× magnification.

Electrophoresis

All freeze dried samples were analyzed by Electrophoresis to know the impact of PF protein on the noodles. Sodium Dodecyl Sulphate-Poly Acrylamide Gel Electrophoresis (SDS-PAGE) was carried out as per the method adopted by Prabhasankar (2002). Thirty percent of acrylamide gel was used to separate the protein fractions and to observe the additional bands incorporated in PF incorporated samples. Gels were stained with coomassie brilliant blue R250.

Sensory analysis

Sensory evaluation of the product is very much important as the aim of the product development is to render the good quality products to the consumer. Product was evaluated for its acceptance. Selected number of trained and semi-trained panelists (female and male; 10–15) were participated in this study. Important sensory attributes were selected preliminarily these attributes were selected based on the panelists' consensus for the product and later they were used for product profiling.

Quantitative descriptive analysis (QDA)

This method of descriptive analysis was developed by Stone (Stone et al. 1974a, b). The training of QDA panels requires the use of product and ingredient references, as with the other descriptive methods, to stimulate the generation of terminology. The respondents groups select the attributes by modality (colour, appearance, aroma, texture etc.), order them within a modality, and develop definitions for each one of them. The subjects also develop a standardized evaluation procedure. Every panelist will be given a scorecard and briefed about the evaluation and samples will be served one by one. The panelists are asked to mark the perceived intensity of each attribute listed on the scorecard by drawing a vertical line on the line scale (15 cm) and writing the code number (which will be on the serving container). Finally, mean value is taken for each attribute of a sample, representing the panel's verdict about the sensory quality of the product. These are graphically represented as 'Sensory Profile'. The findings were subjected to statistical analysis.

Statistical analysis of data

The mean scores of individual attributes of all the tests were calculated according to DMRT (Duncan 1955) to the data to find the significance difference between mean values of the samples using Statistica 99, V 5.5, Stat Soft, USA.

Table 1 Proximate composition of noodles

Ingredients	Fresh noodles *					Dried noodles				
	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrates ** (%)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrates ** (%)
Control	7.98±0.01 ^b	10.89±0.09 ^a	0.94±0.05 ^a	0.73±0.15 ^a	79.46	6.73±0.09 ^c	12.08±0.05 ^a	1.01±0.09 ^a	0.74±0.09 ^a	79.44
2P	6.21±0.00 ^a	11.97±0.11 ^b	1.09±0.10 ^b	1.11±0.15 ^b	79.62	5.96±0.04 ^a	13.24±0.15 ^b	1.05±0.05 ^a	1.23±0.11 ^b	78.52
4P	6.62±0.05 ^a	12.16±0.08 ^b	1.24±0.11 ^c	1.25±0.13 ^b	78.73	6.39±0.18 ^b	14.50±0.12 ^c	1.14±0.11 ^b	1.51±0.08 ^b	76.46

Means in the same column with different letters differ significantly ($p \leq 0.05$) ($n=3$)

Control/ 100 % Durum noodles; 2P 20 % Pea flour in durum noodles; 4P 40 % Pea flour in durum noodles

* Freeze dried

** Calculated by difference

Table 2 Dietary fiber content of noodles

	Fresh noodles*			Dried noodles		
	IDF (%)	SDF (%)	TDF (%)	IDF (%)	SDF (%)	TDF (%)
Control	10.60±1.1 ^a	1.05±0.5 ^a	11.65±1.4 ^a	10.50±1.9 ^a	1.04±0.4 ^a	11.54±2.8 ^a
2P	12.68±1.9 ^b	2.85±0.4 ^b	15.53±1.3 ^b	12.59±2.7 ^{ab}	2.80±0.2 ^b	15.39±2.4 ^b
4P	13.62±1.5 ^b	3.21±0.4 ^b	16.83±1.1 ^b	13.60±2.4 ^b	3.18±0.8 ^b	16.78±1.7 ^b

Means in the same column with different letters differ significantly ($p \leq 0.05$) ($n=3$)

Control 100 % Durum noodles; 2P 20 % Pea flour in durum noodles; 4P 40 % Pea flour in durum noodles; IDF Insoluble Dietary Fiber; SDF Soluble Dietary Fiber; TDF Total Dietary Fiber

Different superscripted letters within a column mean significant difference ($P < 0.05$)

* Freeze dried

Results and discussion

In Indian diet cereals, pulses and tubers contribute majority of the calories. Some of them are having high GI. Hence, for the diabetic individuals these foods are not recommended. Noodles also includes in this list. So, with the addition of some low GI ingredients the quality characteristics of noodles can be changed. Noodle quality is influenced by range of characteristics like physical, chemical, textural and nutritional. For consumers cooking quality is the most important attribute including optimal cooking time, swelling during cooking, texture of the cooked product, extent of disintegration of the cooked product, stickiness, aroma, and last but not the least taste. These cooking factors are related to the gelatinization rates and chemical composition used.

Proximate composition

The protein content increase from 10 to 12 % in FN and from 12 to 14 % in DN with the incorporation of PF at 20 % and 40 % levels. Apart from protein, ash content was also increased reflecting its mineral density (Table 1).

Results of cooking quality, texture and colour are consolidated in Table 4. The results revealed that with incorporation of PF to the noodles has no effect on its solid leach out (cooking loss). Even at 40 % incorporation level, cooking loss was in acceptable range. This may be due to its increased fiber content, which holds the starch granules not to leach out quickly. But in the earlier study (Tudorica et al. 2002) with the incorporation of pea fiber, cooking loss was increased (higher than the control). As the pure form of fiber was added, increase in cooking loss could be due to a disruption of the protein-starch matrix and the uneven distribution of water within the system. Thus preventing starch swelling due to limited water availability. So, PF incorporation resulted in lowering the cooking loss. Simultaneously, expansion rate, which is one of the quality attributes of the noodles was also studied, which revealed that expansion rate increased with PF incorporation with percentage increase of 108 % (Control) to 133 % (40 %).

Dietary fiber content in the noodles increased with the increase in the PF content in the noodles (Table 2). Results clearly indicates that with the incorporation of PF to the noodles there is significant increase in the insoluble dietary fiber (IDF) and also soluble dietary fiber (SDF), accounts for increase in the total dietary fiber (TDF) in both FN and DN. SDF is very much essential in maintaining the blood glucose level, as these SDF makes the absorption slower in the intestine, due to its thickening effect on the digested matter. As the pulses are known to be the richest source of fiber in the form of galactomannans, a polysaccharide which are not digestible by the enzymes. An in vivo study where, reduction of postprandial reduction of blood glucose level with the consumption of pulses was reported (Dilawari et al. 1981).

Granulation

The particle size distributions of flour and blends were determined with a series of standard sieves. The results were expressed as percentage of the sample weight (Table 3). Majority of semolina flour particles and also PF particles should ideally fall within the narrow range, this will aid in homogenous water uptake for noodle dough. As the PF was finer than the

Table 3 Particle size distribution of flours and blends

Mesh size (Microns)	Control <i>T. Durum</i> Semolina)	2P	4P	PF
217	33.83	28.27	24.04	67.92
180	19.69	18.27	15.66	12.50
150	13.86	13.18	11.93	1.52
132	6.87	24.82	23.24	10.57
118	5.24	7.38	6.13	5.04
95	6.40	1.37	1.08	0.67
55	13.14	5.76	15.61	1.03
<55	0.97	0.93	2.29	0.73

Control 100 % Durum noodles; 2P 20 % Pea flour in durum noodles; 4P 40 % Pea flour in durum noodles; PF Pea flour

Fig. 1 Pasting characteristics of different blends; *Con* 100 % Durum semolina flour, *2P* 20 % Pea flour blend in durum, *4P* 40 % Pea flour blend in durum, *PF* Pea flour

semolina flour, so the non-uniformity of the particle size in the blends was observed. Pasta processing will be affected by the rate of hydration of flour, in turn related to particle size. Incomplete hydration of semolina and blends results in poor quality noodles (Dalbon et al. 1996).

Rheological characteristics of flour blends

Rheological properties of the flour blends was carried out using, Amylograph, Farinograph and Alveograph (Figs. 1, 2 and 3). Results of Amylograph showed pasting characteristic of the flour blends. Pasting characteristics was affected by the addition of PF to durum semolina flour. As the results indicated addition of PF decreased peak viscosity values 969–815–715 BU for control, 20 %, 40 % respectively, this may be due to increased enzyme activity as evident by the peak viscosity value of 381 BU for PF (Fig. 1).

Results of the Farinograph indicated that the increased percentage of water absorption from 63.4 % to 64.1 %. Similarly, dough development time was also increased from 3.2 min to

3.7 min. This may be due to the delay in hydration time of the fibers present in PF. On the other hand, dough stability decreased with the increase in the PF content. This may be due to the disruption of the protein and fiber particles (Fig. 2). Results of this may be correlated with the earlier studies, which were reported about the increase in the water absorption and dough development time with the use of multigrain mixture in bread preparation (Indrani et al. 2010). Semolina supplemented with legume flour also showed higher water absorption and dough development time (Bahnassey and Khan 1986). One of the other reasons for the increase in water absorption and decrease in dough stability may be due to delay in gluten hydration and gluten network formation. Similar results with the addition of non-gluten flours were also reported by Susanna and Prabhasankar (Susanna and Prabhasankar 2011).

Results of Alveograph showed significant difference in some of the quality characteristics of the blends. With increase in PF content decrease in deformation energy of dough and maximum overpressure was observed. Whereas, index of swelling increased when compared to control (Fig. 3).

	Water absorption (%)	Dough development time (min)	Stability (min)
Control	63.4±0.1 ^a	3.2±0.3 ^a	3.5±0.1 ^b
2P	64.8±0.2 ^b	3.2±0.3 ^a	2.4±0.2 ^a
4P	64.1±0.2 ^b	3.7±0.3 ^a	2.1±0.2 ^a

Fig. 2 Farinograph of flour blends; **a** 100 % Durum semolina flour, **b** 20 % Pea flour blend in durum, **c** 40 % Pea flour blend in durum. *Control* 100 % Durum semolina flour; *2P* 20 % Pea flour blend in durum; *4P*

40 % Pea flour blend in durum, Means in the same column with different letters differ significantly ($p \leq 0.05$) ($n=3$)

Fig. 3 Alveograph of flour blends. Control 100 % Durum semolina flour; 2P 20 % Pea flour blend in durum; 4P 40 % Pea flour blend in durum

Instrumental colour measurement

Colour analysis indicated that with the incorporation of PF to the noodles there was a slight variation in the lightness values among the noodle samples, indicated by L^* value. Apart from that a^* value decreased to -ve value and b^* value increased in both fresh and dried noodles, which indicates the presence of greenish colour in the sample (Table 4). This may be due to the presence of green pigments present in the PF.

Regarding PCI, there was no significant difference among the noodle samples. PCI is the main indicator for the colour characteristics of pasta and use for pasta quality assessment (Table 4).

Instrumental texture measurement

The textural characteristics of pasta play an essential role in determining the final acceptance by consumers, not only with normal cooking time but also with overcooking (Tudorica et al. 2002). Results of the present study revealed that the firmness of the noodles increased with the incorporation of PF from 4.73 N to 6.27 N in FN and from 5.28 to 8.05 in DN. Stickiness also increased to some extent in PF incorporated noodles (Table 4). The firmness of the noodles may be due to its increase in protein content. However, reduction in firmness

values was obtained for pastas with pea fiber (Tudorica et al. 2002). The general trend observed in this study is a progressive increase in noodle firmness with increasing PF content. The reduction in pasta firmness in the earlier study may be associated with the role of fiber supplements in disrupting the protein-starch matrix within the pasta microstructure.

Sensory analysis

The results of sensory analysis conducted using QDA, revealed that with the increase in the incorporation of PF content, there was a slightly increase in the sensory scores for strand quality and texture (Fig. 4). This may be due to the fiber content present in the sample. Pale green colour of the noodles was appealing for sensory analysis. Overall quality score was more than 8.5 on a 15 cm QDA scale, which indicates the product was acceptable at both 20 % and 40 % levels.

Microstructural characterization

Microscopy techniques have been used to gain information about size, shape, and arrangement of the particles, which can be further correlated with other pasta characteristics such as texture, cooking behavior, and digestibility (Tudorica et al. 2002). Microstructural studies indicated that structural binding of dried noodles was firmer compared to freshly cooked noodles. Apart from this the gelatinization of starch is improved in DN compared to FN (Fig. 5). This firmness is mainly because of the presence of protein matrix in the sample along with this, drying process enables the molecular structure to become firmer with losing water molecules. This is the reason why the dried noodles reduce and shrink its size.

In vitro RDS, SDS, RS and TS determination

Results revealed that with the incorporation of PF to the noodles there was reduction in the RDS and increase in SDS

Table 4 Analysis of pea flour incorporated noodles

		Fresh noodles			Dried noodles		
		Control	2P	4P	Control	2P	4P
Cooked weight (g)		45.6±1.87 ^a	45.9±1.00 ^a	45.8±1.67 ^a	44.3±0.35 ^x	46.2±1.63 ^y	46.4±0.71 ^y
Solid leach out (%)		6.48±0.00 ^a	7.20±0.00 ^b	6.80±0.00 ^{ab}	6.48±0.00 ^x	6.96±0.00 ^y	6.72±0.00 ^y
Texture (N)		4.73±0.76 ^a	5.64±0.05 ^a	6.27±0.30 ^b	5.28±0.33 ^x	7.71±0.13 ^y	8.05±0.10 ^y
Colour	L^*	68.29±0.55 ^b	66.98±0.54 ^{ab}	63.74±1.50 ^a	61.91±0.56 ^{xy}	58.53±1.99 ^x	57.09±0.72 ^x
	a^*	0.35±0.03 ^c	-0.37±0.15 ^b	-1.38±0.60 ^a	0.33±0.01 ^z	-1.04±0.35 ^y	-1.22±0.02 ^x
	b^*	16.90±0.99 ^a	17.13±1.43 ^a	22.46±1.21 ^b	15.55±0.59 ^x	14.93±1.24 ^x	22.66±0.27 ^y
PCI		70.35±4.1	69.14±3.2	67.58±2.5	63.83±3.9	60.40±3.5	61.42±4.2

Means in the same row with different letters differ significantly ($p \leq 0.05$) ($n=3$)

Control 100 % Durum noodles; 2P 20 % Pea flour in durum noodles; 4P 40 % Pea flour in durum noodles; PCI Pasta Colour Index

Fig. 4 Sensory profile of fresh and dried noodles (F)-Fresh, (D)-Dried, Control - 100 % Durum noodles, 2P - 20 % Pea flour in durum noodles, 4P - 40 % Pea flour in durum noodles

content (Table 5). Increase in the SDS indicates the slow hydrolysis of starch in the noodles. On the other hand there was an increase in the RS content. This is accountable for the low glycemic response, as the SDS has increased and also increase in RS. The reason for this may be increase in protein and fiber content in the noodles.

Fig. 5 Microstructure of noodles; **a** 100 % fresh durum noodles, **b** 20 % Pea flour in fresh durum noodles, **c** 40 % Pea flour in fresh durum noodles, **d** 100 % dried durum noodles, **e** 20 % Pea flour in dried durum noodles, **f** 40 % Pea flour in dried durum noodles, S Starch granule, FN Fiber network, PM protein matrix

Table 5 In vitro RDS, SDS, RS and TS content of noodles

Samples	RDS	SDS	RS	TS
Control	85.2±1.2 ^c	5.4±0.9 ^a	1.25±0.2 ^a	91.4±3.2 ^c
2P	58.0±1.9 ^b	21.6±1.1 ^b	3.15±0.9 ^b	82.6±2.9 ^b
4P	31.4±2.3 ^a	45.1±1.5 ^c	3.40±1.0 ^b	79.8±2.1 ^a

Means in the same column with different letters differ significantly ($p \leq 0.05$) ($n=3$)

Control 100 % Durum noodles; 2P 20 % Pea flour in durum noodles; 4P 40 % Pea flour in durum noodles; RDS Rapidly Digestible Starch; SDS Slowly Digestible Starch; RS Resistant Starch; TS Total Starch

Electrophoresis

Results of SDS-PAGE revealed that, with the incorporation of PF to noodles was added reasonable protein content, which can be justified by some of the High Molecular Weight (HMW) and Low Molecular Weight (LMW) proteins molecules appearing in the 2P and 4P lanes (Fig. 6). Whereas, in control lanes these are absent. These additional bands may be contributed by the PF and the same can be observed in the PF lane. The electrophoretic analyses of the samples revealed that addition of PF contributed to significant changes in protein patterns of the noodles. Some qualitative and quantitative

Fig. 6 SDS-PAGE pattern of pea flour incorporated fresh and dried noodles; *M* Molecular marker, *Con* 100 % Durum noodles, *2P* 20 % Pea flour in durum noodles, *4P* 40 % Pea flour in durum noodles, *PF* Pea flour, *Sem* Semolina

changes of the overall protein have occurred with the addition of PF. Hence, the bands that were seen in 2P and 4P lanes of both fresh and dried noodles were found to be altered compared to control.

Relationship between protein pattern, overall quality, texture, percentage of starch released, rheology and microstructure

Incorporation of PF at 20 % and 40 % levels significantly differed from the control in terms of its texture, which was firmer than the control (Table 4). Also increased the ash and protein contents (Table 1). Dietary fiber content in terms of SDF was also increased with the increase in the PF content (Table 2), which is an essential requirement for the diabetic foods. Colour of the PF incorporated noodles was different from the control as the PF imparts a distinct green colour for the sample. Cooking loss was also comparable to control with solid leach out at the acceptable level (Table 4). Addition of PF to the durum noodles disrupted the gluten network as evident in the scanning electron micrographs (Fig. 5), this could be due to the presence of protein and fiber contents of PF. The fiber matrix surrounding the starch granules not only decrease the release of the starch from the noodles but also increased the resistant starch in the noodles (Table 5). Incorporation of PF increased the water absorption in blends, as the fiber absorbs more water to form dough than the control and also decreased the pasting characteristics of the blends due to the interference of the fiber in reducing the swelling properties of starch granules (Figs. 1 and 2). It is also evident that with the increase in the protein content and changing the protein pattern in the food improves the insulin response in vivo (Nuttall et al. 1984). Electrophoresis analysis revealed that, there exists an inclusion of protein molecules in the noodles, which can be observed in the 2P and 4P lanes and are absent in the control lane. This interfering proteins has no

adverse effect on the physico-chemical and organoleptic characteristics. As the overall quality score, color and texture for these PF incorporated noodles were found to be similar and better than control, these may be optimized for commercial preparation.

Conclusion

From the present study it can be concluded that, In vitro RDS of PF incorporated noodles was reduced significantly, without affecting the cooking quality, where in the solid leach out was in the acceptable level (<8). Texture was firmer in the PF incorporated noodles. Overall sensory quality was acceptable even at 40 % incorporation of PF in FN and DN. Incorporation of PF upto 40 % in noodles may be useful for the diabetic individuals by its reduced RDS and increased SDS and RS, with increased protein content.

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