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Research Paper

Nutritional composition, phytochemical analysis and *in vitro* digestibility of pigeon pea supplemented pasta

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ABSTRACT

Twin screw co-rotating extruder was used for HTST treatment/ preparation of pigeon pea supplemented pasta. The effect of legume (pigeon pea) level (10-30%), feed moisture (28-36%) and barrel temperature (70-110°C) were assessed using regression analysis. The fitted model revealed a desirability of 0.917 at optimum conditions. Legume supplementation upto 20% level and higher feed moisture displayed predominant impact on cooking quality. However, the incorporation of non-gluten legume protein weakened the structure of pasta which ultimately increased cooking loss. The degree of gelatinization exhibited a positive connection with feed moisture and barrel temperature. Total phenolics content and antioxidant activity revealed a positive co-relation with feed moisture whereas decline in the total flavonoid content upon extrusion cooking was noted. Extrusion processing significantly enhanced *in vitro* protein and starch digestibility of prepared pasta. Luminosity, redness and yellowness increased with increasing feed moisture. Rheological studies revealed lower peak and final viscosity with increased feed moisture and barrel temperature. Firmness of cooked pasta elevated with barrel temperature. Acceptability score of pasta on the basis of sensory attributes was 8 as inferred from hedonic scale.

Key words: Extrusion, in vitro digestibility, pasta, pigeon pea, response surface methodology.

Pasta products, to a great extent devoured everywhere throughout the world are customarily made from durum wheat semolina, known to be the best crude material for pasta production (Nilusha *et al.,* 2019). However, the growing promoting quality of the healthy convenience foods like pasta has led researchers to enhance pasta quality in terms of nutrition and ease of preparation. Functional pastas are made of composite flours since they are produced by substituting a fraction of semolina with starches, root, cereal and proteinaceous flours (Guy, 2001). Augmentations of non-conventional raw materials like legumes represent an intriguing source of proteins, fibres, vitamins and minerals. Legumes are grown all through the world, and their dietary and financial significance is internationally valued and perceived. Among the legumes, pigeon pea (*Cajanus cajan* L.) is one of the nutritionally important grain legume of the tropical and subtropical regions of the world (Singh and Eggum, 1984). India is the major producer of pigeon pea, approximately, 82% of total production is grown in India (Indian pulse and grain association 2015). Apart from India, eastern Africa and Central America are the world's main pigeon pea producing regions. Protein quality is of prime significance in pigeon pea items utilized for human sustenance (Salunkhe *et al.,* 1986).

The amino acid composition of wheat is quite unbalanced, lacking the essential amino acids like lysine, threonine and methionine whereas legume proteins are high in lysine. Thus, legume and grains are nutritiously integral (Duranti, 2006), hence legume flours can halfway substitute durum wheat semolina in pasta. However, substitution of legume to the pasta is a bit troublesome process as addition of non-gluten proteins and insoluble strands (fibre) could debilitate the general structure of pasta (Torres *et al.,* 2007)

Proteins demonstrate an extensive extrusion behaviour that is most likely identified with huge contrasts in their association properties. New peptide bonds, framed by free amino and carboxylic groups of the protein, were proposed as being responsible for the cross-linking that happens in protein extrusion. Severity of processing conditions may alter the protein digestibility by denaturation of the protein and protein cross-linking, racemisation, degradation and formation of complexes with sugar (Friedman & Masters, 1980). Nutritional quality of a protein is related both to its amino acid content and the capacity of digestive enzymes to liberate them.

Starch digestibility has increased new significance, on account of its commitment to obesity as well as in light of the fact that a secondary consequence of obesity is the metabolic syndrome for which a characterizing highlight is glucose intolerance – a disabled capacity to control blood glucose concentrations after a carbohydrate meal. Degree of gelatinization has direct impact on starch digestibility, as gelatinization includes swelling and scattering of starch molecules, in this manner making them available to stomach related catalysts, and the glycemic effect of the starch rises drastically. Starch granule pores may help by permitting water to attack profoundly into the granule inside

The present study is based on supplementation of pigeon pea (arhar) to wheat semolina in order to enhance nutritional value of pasta. For this purpose, high temperature short time processing using twin screw extruder (instead of single screw extruder) was carried out.

MATERIALS AND METHODS

Raw Material: Raw material (Semolina and pigeon pea) were procured from local market, Ludhiana, India. The raw material was passed through a 60 mesh sieve (BIS) which corresponds to the particle size of 250µ, the over-tailings are again milled to pass through the 60 mesh sieve.

Proximate analysis: The proximate analysis (carbohydrate, protein, crude fat, crude ash and fibre) was carried out using standard procedures (AACC, 2000).

Extrusion: High Temperature Short Time processing (HTST) were performed on a co-rotating intermeshing twin screw extruder model BCH (Clextral, Firminy, France). The barrel diameter and its length to diameter ratio (L/D) were 2.5 mm and 16:1, respectively. Temperature of first, second and third zone was maintained at 30°C, 40°C and 50°C, respectively throughout the experiment, while in the fourth zone the temperature was varied from 70°C to 110°C. The screw speed was maintained at 200rpm.The extruder was fueled by 8.5 kW engine with screw rotation variable from 0 to 682 rpm. The extruder was equipped with a torque indicator, which displays percent of torque in proportion to the current drawn by the drive motor.

Experimental design: The effect of HTST processing on product quality was investigated using response surface methodology (RSM). Twenty-seven combinations were generated using factorial design for three independent variables included legume level (10-30%), feed moisture (28–36%) and barrel temperature (70–110°C). Screw speed was kept constant at 200rpm throughout experiment. Samples after treatment at different conditions in extrusion were dried at room temperature until final moisture was less than 10% and assessed for various quality responses included degree of gelatinization, minimum cooking time, water absorption, volume expansion and cooking loss. The selected pasta samples were examined further for pasting properties, color, texture, *in vitro* starch and protein digestibility.

Degree of Starch Gelatinization (Amylose–iodine complex formation): Amylose–iodine complex formation or degree of starch gelatinization (DSG) was determined using colorimetric method (Cai and Diosady, 1993).

Cooking profile: Minimum cooking time, water absorption, volume expansion and cooking loss were determined by AACC (2000).

Color characteristics: The color of dried and cooked pasta samples were measured using a color meter, CR-300 (Minolta Camera Co. Ltd., Japan) Results were expressed in the CIE L*a*b* space as L* (lightness; 0 = black, 100 = white), a* (+a*= redness, -a*= greenness) and b* (+b* =yellowness, -b*= blueness) values (C.I.E. 1986). The value of hue angle (h*) and chroma (C) for each sample was calculated using the following equations.

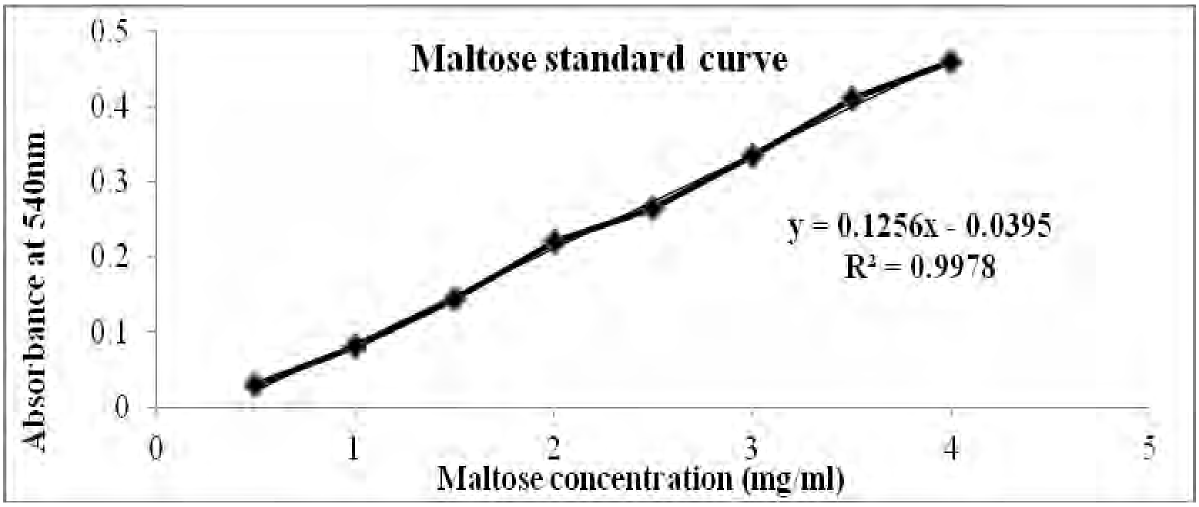
$$\text{Hue Angle } (h^*) = \arctan\left(\frac{b^*}{a^*}\right)$$

$$\text{Chroma } (C) = \sqrt{a^2 + b^2}$$

Pasting properties: Pasting properties of starch were evaluated using Rapid visco analyzer (RVA) model starch Master (Newport Scientific, Warrie Wood, Australia) equipment.

Texture profile analysis: Texture analyzer (TA-XT2) stacked with 50 Kg load cell were utilized for considering textural attributes. Texture profile of pasta were determined on individual piece using a HDP/BSK metal blade. Hardness (peak force of the first compression), cohesiveness (ratio of the area of work during the second compression by the area of work during first compression), springiness (distance of the detected weight of product on second compression, divided by the original compression distance), stickiness (negative area of the first bite), gumminess (hardness x cohesiveness) and chewiness (gumminess x springiness) was determined.

In vitro* starch digestibility*: *In vitro* starch digestibility (SD) of pasta was determined according to the method of Onyango *et al*., (2004a). 100mg finely ground sample was dispersed in phosphate buffer pH 6.9 and incubated with 100mg α-amylase at 37°C in a total volume of 20 ml buffer. The rate of enzymatic hydrolysis of starch was determined by estimating the amount of maltose released upto a period of 2h. After the filtration, 2ml of dinitrisalicylic acid was added to tube (containing 1ml filterate) to arrest the reaction, boiled for 5min, cooled and made volume to 50 ml. Absorbance was read at 540nm, standard curve of maltose was used to calculate mg of maltose released corresponding to absorbance of sample.



Standard curve of maltose at 540nm

In vitro* protein digestibility*: *In vitro* protein digestibility was determined by following Akeson and Stahmann method (1964). The procedure consists of a two-step proteolysis at 37°C, a 2h incubation of the protein with pepsin (5g pepsin in 1 litre of 0.1N HCL) at pH 1.9, followed by pancreatin digestion at pH 8 for more 2h. Few drops of toluene was added to maintain aseptic environment in the system. The contents were then centrifuged at high speed and filtered through Whatman No. 44 filter paper. Macrokjedahl method was used to analyse the residue for N content. The digestibility coefficient was determined by subtracting the residual protein from the initial protein on the basis of 100g of sample.

Bioactive composition (Total Phenol Content, anti-oxidant activity and total flavonoid content): Bioactive compositions was determined by standard protocol. Total phenolic contents in the extracts were estimated using Folin-Ciocalteu reagent (Sharma *et al* 2012) and were expressed as mg gallic acid equivalent (GAE)/100 g dry weight, Antioxidant activity (AOA) was measured using a modified version of the method described by Brand-Williams *et al* (1995). 1,1 -Diphenyl-2-picrylhydrazyl (DPPH) radical scavenging capacities of extracts were estimated by the reduction of the reaction color between DPPH solution and sample extracts.. The total flavonoid content was measured using the Aluminium chloride colorimetric method of Woisky and Salatino (1998).

Sensory Evaluation: Sensory evaluation by panel of judges (semi-trained panelist 30) was conducted for sensory attributes (appearance, color, texture, flavor, and overall acceptability) for the prepared products using 9- point hedonic scale. (Larmond, 1970).

Statistical analysis and optimization: The responses acquired of the proposed experimental design were subjected to regression analysis keeping in mind the end goal to survey the impact of legume level, feed moisture and barrel temperature on quality parameters of HTST processed semolina-legume pasta. Multiple regression analysis was used for data analysis and statistical significance was examined by analysis of variance (ANOVA) for each response. The sufficiency of regression model was checked by regression coefficient (R^2) and F-value. Automatic reduction algorithms were applied to reduce the number of insignificant terms in the models. To aid visualization of variation in responses with respect to processing variables, series of three-dimensional response surfaces plots were drawn. In addition to the response surface models, Duncan's tests were calculated using SPSS (PASW version 18.0, Inc., USA).

RESULTS AND DISCUSSION

Proximate analysis: The proximate composition of semolina and pigeon pea (arhar) was expressed on 14 per cent moisture basis. The semolina used was found to contain 10.08% protein, 1.79% crude fat, 0.54% ash, 1.02% crude fibre, 72.57% carbohydrate whereas pigeon pea (arhar) contained 20.50% protein, 2.78% crude fat, 3.70% crude fibre, 3.63% ash and 55.39% carbohydrate.

Degree of Starch Gelatinization: HTST processing in twin screw extruder leads to starch gelatinization; starch a polysaccharide is insoluble in cool water yet swell when warmed in a fluid medium. As the temperature of aqueous medium is raised intermolecular hydrogen bonds which keep up the structural integrity of the granule continue to be disrupted and the granule loses its birefringence and finally the micellar network isolates and diffuses into the fluid medium. The procedure is called "gelatinization" and the temperature at which gelatinization happens is known as the "gelatinization temperature. During HTST processing, physical and chemical transformation of starchy and proteineous materials (biopolymers) results in formation of a hot gelatinized mass. Degree of starch gelatinization of semolina legume pasta by amylose- iodine complexing varied from 35.33 to 97.70 percent.

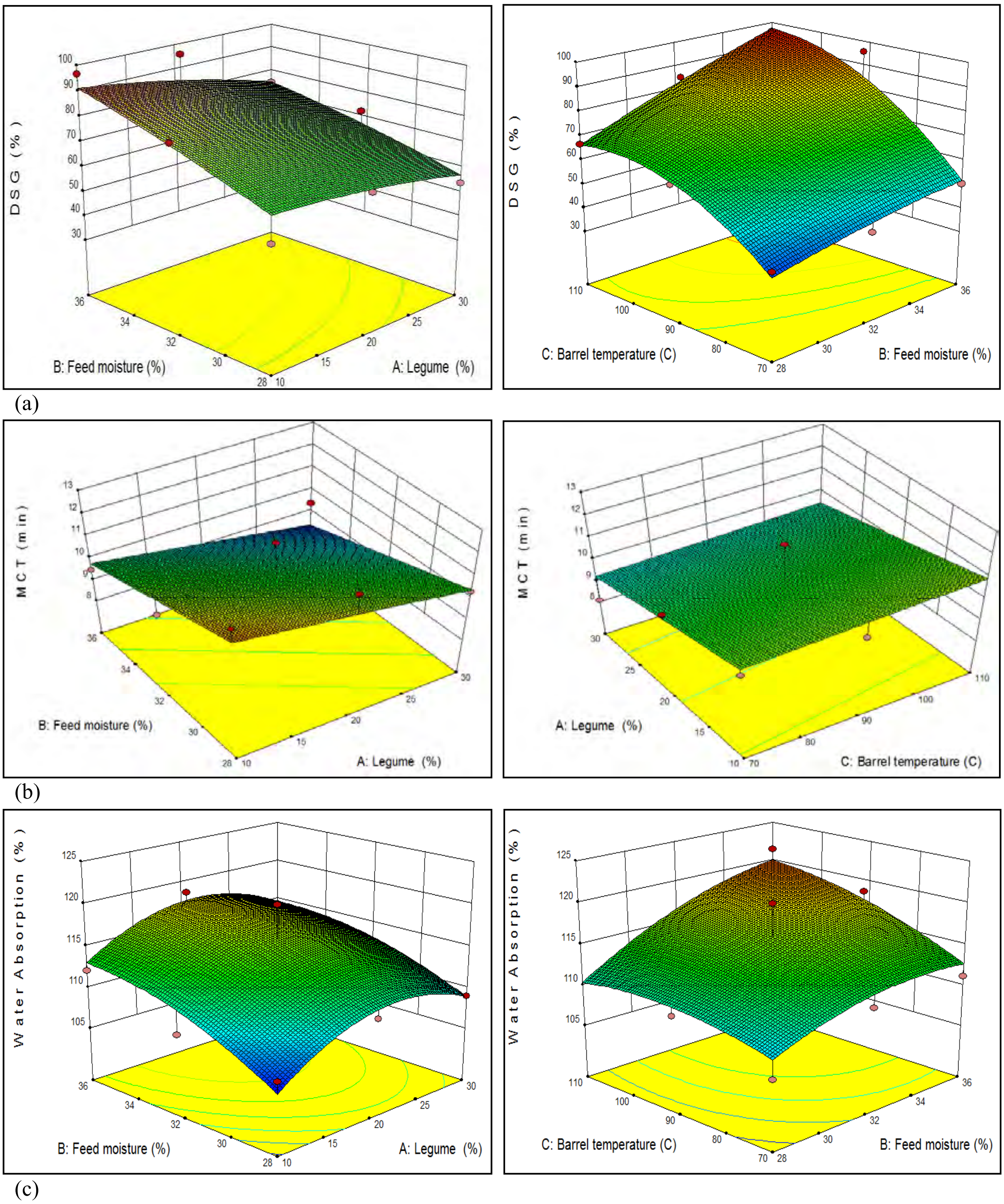
A regression analysis was done to fit mathematical models to the experimental data. From regression coefficients of the models (Table 1), it can be seen that the level of gelatinization of semolina-vegetable pasta was influenced fundamentally by all processing variables. Feed moisture and barrel temperature had positive coefficients revealed that degree of gelatinization of pasta upgraded with increment in these parameters while the effect of legume addition was found to be reverse. Lund, (1989) observed that gelatinisation of starch follows first-order kinetics and is dependent on temperature. Davis & Arnold (1995) also reported an increase in gelatinization of whole wheat, corn flour, rice flour and milo grains with increase in feed moisture. Comparable outcome were further reported by Ding *et al*., (2005) during extrusion of rice-based snacks.

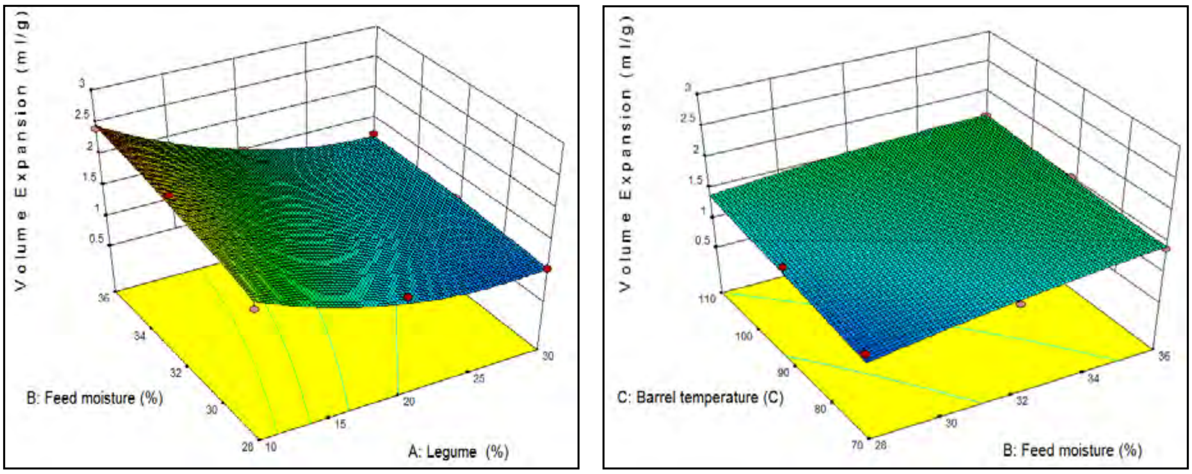
Table 1: Analysis of Variance and Regression Coefficients of Extrusion Process Variables on the Selected Responses of Semolina-Legume Pasta

Process variables	Responses									
	Degree of Starch Gelatinization (%)		Minimum Cooking Time (min)		Water Absorption (%)		Volume Expansion (ml/g)		Gruel Solid Loss (%)/ Solid loss during cooking	
	C	F-value	C	F	C	F- value	C	F- value	C	F- value
L	-6.22	25.1	-0.74	12.98	1.26	5.07	-0.53	421.02	0.34	2.31
FM	10.77	75.46	-1.04	25.46	3.36	36.22	0.17	44.76	0.59	6.99
BT	18.10	213.23	0.11	0.22	2.21	10.67	0.15	23.72	-1.18	19.11
L*FM	-1.67	1.20	-	-	-0.44	0.48	-0.094	10.17	-0.60	5.58
L*BT	-0.34	0.049	-	-	1.43	3.76	-0.049	2.04	0.24	0.65
FM*BT	4.65	9.38	-	-	1.47	3.97	-0.057	2.76	-0.076	0.066
L^2	-1.84	0.73	-	-	-3.78	17.88	0.30	52.97	-2.10	34.46
FM^2	-1.22	0.33	-	-	-1.62	3.26	-0.050	1.45	0.49	1.85
BT^2	·10.29	22.95	-	-	-1.27	1.83	4.667×10^{-3}	0.011	0.21	0.33
Std. Dev.		5.26		0.81		1.94		0.090		0.78
C V (%)		7.90		8.11		1.74		5.93		9.67

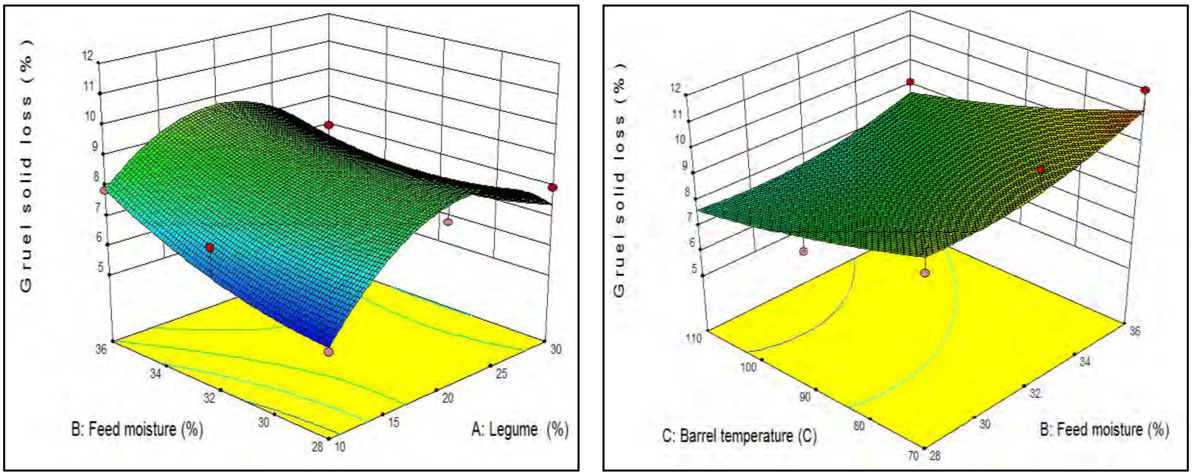
L-Legume; FM - Feed Moisture; BT- Barrel Temperature; C - Regression Coefficients; Std. Dev. – Standard Deviation; CV- Coefficient of variation

Degree of starch gelatinization depicted a significant ($p<0.0001$) F-value. Degree of gelatinization is exceptionally affected by barrel temperature as overted from higher F-value of barrel temperature. Similar findings were reported by Pilli *et al.*, (2009) during production of extruded wheat flour dough. Response surface plots (Fig. 1a) displays the influence of feed moisture and legume level on the extent of gelatinization determined by amylose- iodine complexing method. Degree of starch gelatinization of semolina-legume pasta is explained well by quadratic model. The analysis of variance (ANOVA) interprets a highly significant model ($p<0.0001$) with coefficient of determination (R^2) of 0.9535 and coefficient of variance (CV) of 7.90%.





(d)



(e)

Fig. 1: Effect of extrusion variables on (a) degree of gelatinization (b) minimum cooking time (c) water absorption (d) volume expansion (e) gruel solid loss of pasta

Cooking quality: The effects of HTST extrusion process variables on minimum cooking time (MCT) are displayed in Fig. 1(b). The HTST conditions affected the cooking quality of semolina-legume pasta. Minimum cooking time of pasta ranged from 8 to 13 min. The inter-relationship between cooking quality and process variables obtained from regression analysis is expressed in Table 1.

The R-square (R^2) of the predicted models for MCT was 0.6542. Increased legume level and feed moisture had significant negative effect ($P < 0.05$) on cooking time of pasta. However, barrel temperature showed a significant positive effect on cooking time. Among all process variables, feed moisture depicted higher F-value indicating that MCT is mainly affected by this process variable. Increased cooking time of pasta with increasing dough moisture, barrel temperature or screw speed in twin screw extruder was also reported by Wang *et al*., (1999).

Water absorption (WA) of semolina-legume pasta ranged between 105.4 to 121.5 percent and volume expansion (VE) from 0.81 to 2.63 ml/g. As samples were dried at room temperature, water uptake ratio was more at early stages of cooking. Rafiq *et al.,* (2015) reported similar observations during hydration of parboiled rice. Table 1 explains the impact of processing variables on the water absorption ratio and volume expansion in terms of model regression coefficients. The linear term of legume level, feed moisture and barrel temperature had non-negative coefficient proposing that it enhanced the WA of semolina-legume pasta, parallel effects were also observed for volume expansion. Hussain *et al.,* (2015) and Rafiq *et al.,* (2017) observed similar effects during cooking of refabricated rice and cereal-legume pasta produced by extrusion. Higher F-value of feed moisture indicates that feed moisture had highest effect on water absorption. Extruded cereal products prepared from high moisture dough's showed higher water absorption as reported by Anderson *et al.,* (1969). The interactive effect of feed moisture and barrel temperature together also depicted a significant positive effect on both responses (water absorption ratio and volume expansion). The quadratic term of legume level significantly influenced the volume expansion of semolina-legume pasta whereas quadratic effect of legume level was positive for water absorption. The R-square (R^2) of the predicted models for water absorption ratio of semolina-legume pasta was 0.8878 and for volume expansion R-square (R^2) was 0.9813. Fig. 1 (c) and (d) elucidates response plot surface showing effect of extrusion process variables on water absorption ratio and volume expansion of semolina-legume pasta.

The supplementation of pasta with legume increased cooking loss which can be attributed to poor association between starch and protein molecules. Legume proteins, chiefly made out of globulins and albumins, are poor in sulfur-containing amino acids, particularly cysteine buildups (Alonso *et al.,* 2000). The absence of sulfur groups could clarify the lower capability of legume proteins to tie through disulphide bonds contrasted and gluten proteins (El-Fiel *et al.,* 2002). The linear term of legume level and feed moisture exhibited positive coefficient reveals their positive significant effect on cooking loss whereas barrel temperature showed negative effect on cooking loss. Cooking loss of semolina-legume pasta varied from 5.40 to 11.97 percent. At lower dough moistures, degradation of starch was greater as reported by Colonna and Mercier, (1983), prompting to bring down sub-atomic weight material, would result in increased loss of the extrudates. Higher F-values for legume indicating cooking loss is more at higher legume level. Response surface plots (Fig.1e) depicted the impact of different process factors on cooking loss of semolina-legume pasta.

Optimization of HTST extrusion process conditions: Particular objectives were allotted to every response (degree of starch gelatinization, minimum cooking time, water absorption, volume expansion and cooking loss). Degree of starch gelatinization was target to maximum, water absorption, volume expansion and cooking loss were kept in range and minimum cooking time was targeted to minimum value. The optimized conditions obtained for semolina-legume pasta obtained are legume content (20.31%), feed moisture (36%) and barrel temperature (91.80°C). The selected samples from semolina-legume pasta supplemented with legume level (20%) were further assessed for color, texture profile, pasting properties, and *in vitro* digestibility.

Color characteristics: The optimized semolina-legume pasta was assessed for luminosity (L*), redness (a*) and yellowness (b*) (Table 2). Overall, HTST processing conditions enhanced the L*, a* and b* value of the dried semolina-legume pasta with an increase in feed moisture and legume level but luminosity was suppressed with an increase in barrel temperature. During various extrusion process treatments, a significant variation was observed in hue angle and chroma. Hue angle and chroma values were higher at elevated feed moisture however diminished with an increase in barrel temperature. The high temperature brings out heat induced degradation of feed which might be the reason for increased darkness of product after extrusion. These results are validated by the verdicts of Lamberts *et al.,* (2007) and Singh-Sandh *et al.,* (2007).

Table 2: Color characteristics, bioactive composition, pasting properties and *in vitro* digestibility of optimized pasta

Color	*L**	53.60±1.02
	*a**	0.63±0.19
	*b**	10.23±0.45
	Huge Angle	86.93±0.31
	Chroma	10.25±1.09
Bioactive composition	*Total Phenol Compound (mg GAE/100 g)*	3.87±0.19
	Anti-oxidant Activity (%DPPH)	59.67±1.61
	Total Flavanoid content (µg Quercetin/mg)	573.55±2.11
Pasting properties	*Peak Viscosity (cP)*	249±2.09
	Hold Viscosity (cP)	230±1.43
	Final Viscosity (cP)	830±1.20
	Breakdown Viscosity (cP)	19±1.12
	Setback Viscosity (cP)	811±1.43
Digestibility	*In vitro Starch Digestibility*	22.36±0.18
	In vitro Protein Digestibility	85.70±1.01

Rheological properties: Functional and textural characteristics of starch-based products can be estimated by studying its pasting behaviour (Ajanaku *et al.,* 2012). Rapid visco analyzer was used for studying pasting behaviour of optimized semolina-legume pasta (Table 2). During gelatinization, swelling of starch granules followed by leaching of starch constituent's leads to development of 3-D network (Eliasson 1986). These progressions are responsible for the pasting characteristics exhibited by starch suspensions during heating and shearing. Pasta prepared at optimized conditions did not demonstrate the pasting temperature, may be because of the pregelatinization of starch which had occurred during HTST treatment in extruder. The peak viscosity, hold viscosity, final viscosity, breakdown viscosity and setback viscosity for semolina-legume pasta was 249cP, 230 cP, 830 cP, 19cP and 811Cp respectively. Peak viscosity is the most extreme viscosity that happens prior to the initiation of sample cooling. Now, the dominant parts of starch granules are completely swollen, but intact (Himmelsbach *et al*., 2008). The higher peak viscosity indicated that more granules are available to be hydrated whereas lower values of peak viscosities intimated that a greater amount of gelatinisation had occurred (Ingbian, 2004).

Himmelsbach *et al*., (2008) reported that pregelatinized flours have fewer amounts of native granules available for hydration and subsequently lower peak and trough (or hold) viscosity. The lower final viscosity of semolina-legume pasta depicted that the HTST processing affected the capacity of starch to form a viscous paste after cooking and cooling. A significant decrease in breakdown viscosity was also seen with increment in extrusion temperature. Lai (2001) reported that thermal processing leads to reduction of peak viscosity, final viscosity and breakdown viscosity. The general changed pasting behaviour of semolina-legume pasta can be clarified as the starch granules being disturbed by gelatinisation amid extrusion and in this way not being in a position to swell as much as native cereals.

Textural profile: Consumer acceptability of pasta is determined by its textural characteristics (Raina *et al.,* 2005). Pasta should possess elastic texture which is mainly contributed by gelatinization of starch and protein disruption. Twin screw extruder along with HTST treatment positively contributed to firmness and elasticity of semolina-legume pasta. Fig 2 represents the textural characteristics of cooked pasta at optimized processing conditions. Yunt *et al*., 1996 reported that firmness/ hardness is a predominant factor dictating the texture of cooked pasta. Firmness corresponds to the maximum force in force time graph was found to elevate with increased barrel temperature. Higher HTST treatment enhanced hydrophobic interaction between protein and starch which in turn improved pasta texture. Pasta produced at optimum conditions had firmness, chewiness, adhesiveness and resilience ratio of 13N, 3.2N, 5. 8 N and 1.17N respectively. Wojtowicz, 2012 observed similar results during study of impact of process conditions on selected texture properties of precooked buckwheat pasta.

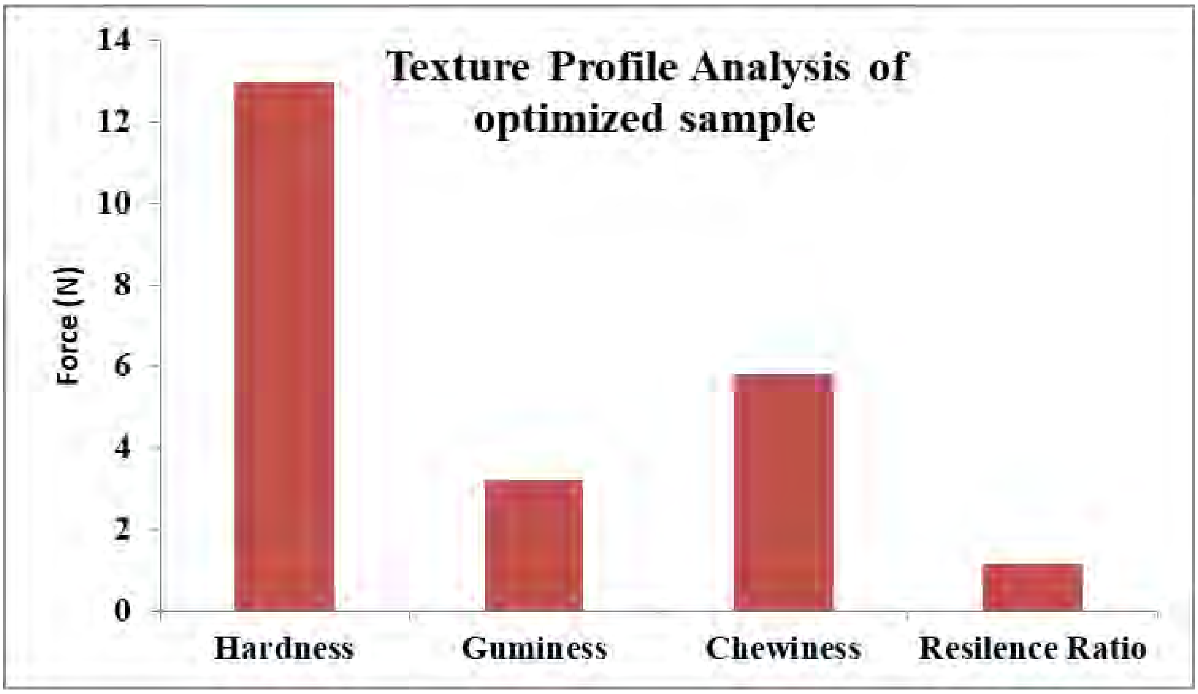


Fig. 2: Textural characteristics of semolina-legume pasta at optimized extrusion conditions.

***In vitro* starch digestibility:** The HTST processing of semolina-legume blends enhanced starch digestibility. The *in vitro* starch digestibility of optimized semolina-legume pasta was 22.36g/100g (Table 2) which is in agreement with those of other researchers (Alonso *et al.,* 2000). Similar results were also observed by Rafiq *et al* (2016) during *in vitro* digestibility of brown rice pasta. McNeill *et al.* (1975) reported that processing methods alter the structure by discharging the starch granules from the protein lattice will enhance their susceptibility to enzyme action and subsequent digestibility. During extrusion cooking, high-temperature and high-shear forces cause a high degree of starch gelatinization, increasing the susceptibility of starch to enzyme hydrolysis (Holm *et al.* 1985), therefore, low levels of resistant starch were expected. They found that extrusion treatment significantly increased the *in vitro* digestibility of pea starch. This may be explained in such a way that the increased shearing action develops heat through dissipation of mechanical energy and causes loss of structural integrity and increases enzyme susceptibility.

***In vitro* protein digestibility:** Proteins demonstrate an extensive extrusion behaviour that is most likely identified with huge contrasts in their association properties. New peptide bonds, framed by free amino and carboxylic groups of the protein, were proposed as being responsible for the cross-linking that happens in protein extrusion. Severity of processing conditions may alter the protein digestibility by denaturation of the protein and protein cross-linking, racemisation, degradation and formation of complexes with sugar (Friedman & Masters, 1980). Nutritional quality of a protein is related both to its amino acid content and the capacity of digestive enzymes to liberate them.

The *in vitro* protein digestibility of optimized semolina-legume pasta was 85.70 g/100g (Table 2). Ruiz *et al.,* (2008) reported higher values of *in vitro* digestibility might be ascribed to protein denaturation during extrusion process which uncover locales and makes protein susceptible to the enzymatic hydrolysis. Comparative outcomes were likewise announced by Ghumman *et al.,* (2016) that *in vitro* protein digestibility of lentil and horse gram extrudates decreased with decrease in extrusion temperature. Benchaar *et al.,* (1994) while researching digestibility of horse beans whole diets. They observed that diets containing extruded whole horse beans increased availability of total essential amino acid in the small intestine compared with diets containing raw whole horse beans.

Bioactive composition: The total phenolic content, antioxidant activity and total flavonoid content of the optimized semolina-legume pasta was 3.87 mg GAE/100 g, 59.67 %DPPH and 573.33 µg Quercetin/mg (Table 2).Antioxidant properties of semolina-legume pasta on the basis of measuring scavenging activity for DPPH (1,1-Diphenyl-2-picrylhydrazyl) radicals using methanolic extracts were evaluated. In the DPPH test, the colored stable DPPH radical is reduced in the presence of an antioxidant or a hydrogen donor into non-radical DPPH-H, and the reduction in color is monitored over time. Korus *et al* (2007) investigated the effect of extrusion on polyphenol content and antioxidant activity of common bean they observed a significant decrease in polyphenol content and antioxidant activity.

Flavonoids have generated interest because of their broad human health promoting effects, most of which are related to their antioxidant properties and to synergistic effects with other antioxidants. Thermal destruction of flavonoids during extrusion cooking was reported by Sharma and Gujral, 2011.

Sensory Evaluation: The pooled scores (out of 9.0) of semolina-legume pasta revealed that pasta prepared at optimum conditions were in very adequate range with general acceptability of 8. The contributing attributes were appearance, color, flavor and texture.

Proximate Analysis of Resultant Pasta: The pasta which has got highest sensory score was evaluated for proximate analysis. The resultant pasta showed 70.49% carbohydrate, 13.57% protein, 1.67% crude fat, 1.20% ash and 1.17% crude fibre.

CONCLUSION

The present study revealed that using response surface methodology (RSM) as a tool for optimization of system and product parameters was proven successful for the development of pigeon pea incorporated pasta. Furthermore, the addition of pigeon pea as protein source to wheat pasta could broaden the market for protein rich pasta and will also add value to underutilized legumes. The results further revealed that during the HTST extrusion processing, all of the four independent variables such as feed composition, feed moisture, screw speed and barrel temperature had significant ($p < 0.05$) effect on all the responses studied. The optimized conditions obtained for semolina-legume pasta obtained are legume content

(20.31%), feed moisture (36%) and barrel temperature (91.80°C). Various processing conditions increased digestibility, total phenols and antioxidant activity and a decline in flavonoid content of semolina-legume pasta was observed. Moreover, HTST treatment enhanced L*, a* and b* values of the semolina-legume pasta with an increase in feed moisture and legume level. The optimized conditions acquired for semolina-legume pasta obtained are legume (20.31%), feed moisture (36%) and barrel temperature (91.80°C).

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