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Quality protein maize based pasta supplemented with quinoa, soy and corn starch

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Abstract
Non-wheat pasta was prepared with quality protein maize supplemented with 40–80%quinoaflour, 20-60% soy flour and 40-80 % corn starch using response surface methodology (RSM) following central composite design (CCD). Results showed that quinoa flour and corn starch significantly reduced losses in gruel and improved the colour. Soy flour improved the textural attributes i.e. increased breaking stress and decreased stickiness significantly (p=0.0248), though it contributed to slight increase in gruel losses. Based upon the experiments, the optimized level of ingredients was, quinoa flour 40.0 g 100 g^{-1} quality protein maize flour (QPM), soy flour 60.0 g 100 g^{-1} QPM and corn starch 40.0 g 100 g^{-1}QPM ingredients premix with 75 % desirability. The developed pasta reported to contain 14.4% protein, 7.6% fat and 75.2% carbohydrate, respectively.

Keywords: Quality protein maize based pasta supplemented, quinoa corn starch

Introduction

Maize (*Zea mays*) is one of the most important cereal crops in the world agricultural economy both as food for man and feed for animals. It is a miracle crop, as it has very high yield potential. It has thus rightly been called the 'queen of cereals'. Maize is recommended as a safe food for celiac patients since it possesses no gluten and can be used in the production of pasta (Padalino *et al*., 2011) [18]. It has high carbohydrate content, but very low protein content and low levels of lysine and tryptophan. These deficiencies have been addressed through development of maize hybrids (known as Quality Protein Maize-QPM) in which lysine and tryptophan levels are twice that of normal corn (Ruiz *et al*., 2008) [22].

Quinoa (*Chenopodium quinoa* Willd) is native to the Andean region where it has been cultivated for thousands of years. It belongs to the group of crops known as pseudo cereals (Cusack, 1984; Koziol, 1993) [3] that includes other domesticated chenopods, amaranths and buckwheat. The grain has high-protein content with abundance of essential amino acids, and a wide range of vitamins and minerals (Repo-Carrasco *et al*., 2003) [21]. *Chenopodium* spp. has been cultivated for centuries as a leafy vegetable (*Chenopodium album*) as well as an important subsidiary grain crop (*Chenopodium quinoa* and *C. album*) for human and animal foodstuff due to high-protein and a balanced amino-acid spectrum with high lysine (5.1–6.4%) and methionine (0.4–1.0%) contents (Prakash and Pal, 1998; Bhargava *et al*., 2006) [20, 1].

Pasta is a very popular and widely consumed food all over the globe. It has traditionally been prepared with durum semolina which yields a desirable texture owing to gluten network formation as well as an appealing amber coloured product. However, in the past few years, pasta formulations excluding gluten sources have attracted immense attention due a sharp rise in the incidence of celiac diseases among the population.

Limroongreungrat and Huang (2007) [14] prepared pasta products from sweet potato flour with significantly reduced cooking losses. Chillo *et al*., (2009) manufactured spaghetti based on quinoa or oat using two different structuring agents, carboxymethyl cellulose sodium salt (CMC) and pregelatinized starch at three different percentages. Schoenlechner *et al*., (2010) [23] investigated the use of amaranth, quinoa and buckwheat for the production of gluten-free pasta. Susanna and Prabhasankar (2013) [26] developed gluten free pasta with enriched protein content, and evaluated its product quality and allergenicity. Fiorda *et al*., (2013) [4] evaluated the quality (colour, texture and nutritional value) of gluten-free pasta formulated with pre-gelatinized flour made from cassava starch and cassava bagasse (70:30), cassava starch and amaranth flour. Yadav *et al*., (2014) [29] optimized the formulations for wheat-based pasta incorporated with pearl millet flour and vegetables. Flores-Silva *et al*., (2014) [5] developed gluten-free spaghetti with mixtures of chickpea, unripe plantain and maize flours presenting a higher protein, fat and ash content than the control semolina spaghetti.

Shobha *et al*., (2015) [25] developed maize based vermicelli using normal as well as Quality Protein Maize and assessed feasibility of maize flour incorporation and its impact on quality of these convenience foods in terms of sensory, nutritional and storage behaviour. Jalgaonkar and Jha (2016) [9] developed pasta from pearl millet flour and wheat semolina and investigated the effect of particle size and blend composition on product quality. Gimenez *et al*., (2016) [6] determined the nutritional quality of pasta-like product (spaghetti-type), made with corn (*Zea mays*) flour enriched with 30% broad bean (*Vicia faba*) flour and 20% of quinoa (*Chenopodium quinoa*) flour. Jalgaonkar *et al.*, (2018) [10] prepared wheat semolina-pearl millet pasta while incorporating defatted soy flour, carrot powder, mango peel powder, and moringa leaves powder.

Response surface methodology (RSM) was adopted in experimental design and data analysis (Khuri and Cornell 1987) [12]. RSM provided a sequence of designed experiments that resulted in an optimal response. Considering the need to incorporate lesser known crops in India such as quinoa in the food habits of people and also promoting the use of indigenous crops like maize, this study was undertaken to explore the possibility of development of pasta from gluten free flours thereby catering to thegrowing demand for ready to cook nutritious products that are also suitable for the celiac population.

Materials and methods

High Quality Protein Maize (HQPM, *Zea mays*) grains were procured from Krishi Vigyan Kendra farm, Banswara, Rajasthan, India. Soy beans (*Glycine max)*, corn starch and flaxseeds (*Linum usitatissimum)* were procured from Udaipur local market. Quinoa (*Chenopodium quinoa* Willd) flour was provided by the firm ‘Queen’s Quinoa’. All the raw materials were cleaned to make them free from dirt and other foreign particles.

Flour Preparation

QPM grains were ground to fine powder in a domestic mill and sieved using B.S.S. sieve number 8 and used for further study. Quinoa flour was sieved using BSS sieve number 16. Soy beans were boiled in water for 20 minutes at 85±2°C followed by transferring into cold water. After complete draining of water, the beans were dried in a sun dryer for two days. These were then ground in a domestic mill and sieved using B.S.S. sieve number 16 to obtain fine powder.

Preparation of flaxseed gel

Flaxseeds were boiled in water until a gel of TSS 4.4° Brix was obtained followed by cooling to room temperature. The gel was prepared fresh for every batch of pasta.

Experimental design

Response surface methodology was used to optimize the level of quinoa flour, soy flour and corn starch for quality protein maize based non-wheat pasta. After preliminary trials, upper and lower levels for these variables were established. Central composite design (CCD) was used to select variables level in each experiment. The level soft hese variable salon with the experimental plan have been presented in Table 1 and 2, respectively. Full second-order equation was fitted in each response to describe it mathematically and to study the effect of variables. The equation was as follows:

$$Y = \beta_o + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} \beta_{iJ} x_i x_J$$

where, Y=response variable, β_o is the value of the fitted response at the Centre point of the design and βi, βij, βii are the linear, quadratic and interactive regression coefficients, respectively. Xi and Xj are the coded independent variables. The magnitude of the coefficients in second order polynomials showed the effect of concerned variable on the responses.

Table 1: Coded and actual levels of process variables

Independent variables	Coded and actual levels				
	(-2)	(-1)	(0)	(+1)	(+2)
Quinoa flour (A)	26.36	40	60	80	93.63
Soy flour (B)	6.36	20	40	60	73.63
Corn starch (C)	26.36	40	60	80	93.63

Table 2: Central composite experimental design

Run	Q (g 100g^{-1}QPM)	S(g 100g^{-1}QPM)	C(g 100g^{-1}QPM)
1	60	40	60
2	60	40	60
3	26.36	40	60
4	60	40	60
5	60	6.36	60
6	40	60	40
7	40	60	80
8	80	60	80
9	80	20	80
10	40	20	40
11	80	20	40
12	80	60	40
13	60	40	93.63
14	60	40	26.36
15	60	73.63	60
16	60	40	60
17	60	40	60
18	40	20	80
19	60	40	60
20	93.63	40	60

Preparation of pasta

Weighed amount of flour and other ingredients (Table 2, run 1-20) were put into pasta-mixer-extruder (La Parmigiana model ANNA-A45). Freshly prepared flaxseed gel was slowly added, mixed and kneaded into stiff, plastic and homogenous dough. The dough was extruded through the die into fusilli shapeandcutinto4 cm length using a cutter attached to the pasta extruder. The extruded pasta was dried in tray drier with air circulation at 60±2°C for 2 hours to moisture content of 8–9 %, cooled and stored under ambient conditions (20–35°C) in air tight plastic containers.

Cooking of pasta

Pasta sample (25 g) was cooked in 250 mL of boiling water until the Centre core disappeared (checked by pressing between two glass slides). It took approximately 7 minutes to cook the pasta completely. The pasta was subsequently drained using a stainless steel sieve.

Assessment of pasta quality

Colour

Colour of uncooked pasta was measured using hunter lab colorimeter (Colour flex, Hunter Associates Laboratory, model CFLX-DIEF, CLFX-45). Before testing the samples, the instrument was calibrated with standard black and white tiles supplied with the instrument. Colour readings were expressed in terms of Hunter and b.a is purple-red (positive a value) and blue-green (negative value) and b represents yellow (positive b value) or blue (negative b value) colour. Triplicate readings were taken for each sample.

Texture analysis

Textural Analyzer (TA.XT Plus/TA.HD Plus) was used for measuring textural properties of extruded product. Breaking stress for the uncooked samples and stickiness for the cooked pasta were measured.

Bending test by using three point bend rig

The two adjustable supports of the rig base plate were placed at suitable distance apart so as to support the sample. For comparison purpose, this gap was kept constant. The base plate was then secured onto the heavy duty platform. The heavy duty platform was manoeuvred and locked in a position that enabled the upper blade to be equidistant from the two lower supports. The sample was placed centrally over the supports and 3 point bend rig which provided a variable support length up to 70 mm and width up to 80 mm was forced to bend the sample. The test speed was 3 mm/s and the pre and posttest speeds were 2 mm/s and 10 mm/s respectively.

Cutting test

The test involves large deformation measurements on the samples tested. It specifies the use of a knife blade, machined to a 1mm flat across the cutting edge which measures the force required to cut five strands of spaghetti or approximately equivalent width of other pasta forms, positioned adjacent to one another. Firmness is defined in this method as the work in grams-centimetre required to shear one piece of pasta. The negative value of force measured, gives the stickiness of the sample.

In this test, the base plate was secured onto the heavy duty platform. The heavy duty platform was manoeuvred and locked in a position that enabled the upper blade to be at a desired distance from the base plate. During the test, three strands of cooked pasta were placed adjacent to each other, centrally over the base plate. The test speed was 2 mm/s and the pre and posttest speeds were 1 mm/s and 10 mm/s respectively.

Gruel losses

The gruel losses were determined as per the IS 1485 (1993) specifications. 250 ml water was taken in a lipless beaker and heated over a hot-plate till the water boiled. 25 g of the pasta was introduced to the beaker (previously broken into about 10 mm lengths) and stirred thoroughly with a glass rod. It was cooked for 10 minutes with occasional stirring. At the end of 10 minutes the material was drained for five minutes. The volume of gruel collected was measured. 20 ml of the gruel was pipetted out, after stirring well to give an even distribution of the solid content, into a tared petri dish and evaporated to dryness on a water- bath. The petri dish was transferred to a hot air-oven maintained at 105 ± 2°C and dried to constant weight.

Chemical analysis

AACC (2000) methods were used to determine moisture, protein, fat, ash and fibre. Carbohydrate was calculated by subtracting the sum of moisture, protein, fat and ash from 100 (Merrill and Watt 1973) [16].

Statistical analysis

Multiple regression analysis was used to fit the model, represented by an equation, to the experimental data. Maximization and minimization of the polynomial models thus fitted was done using the numerical optimization technique using design-expert version 10.0.3 software (Stat-Ease Inc, Minneapolis, USA).The values were considered statistically significant if $p \leq 0.05$. Numerical optimization technique of design expert software was used for simultaneous optimization of the multiple responses. The software necessitates assigning goals to the chosen variables (within range) and responses (maximize, minimize, target, within range, none) (Mahawar *et al.,* 2018) [15].

Results and discussion

Diagnostic checking of the fitted models

All the main linear, quadratic and interactive effects were calculated for each model. The estimated regression coefficients of the fitted quadratic equation as well as the correlation coefficients for each model are given in Table 3. The models were considered adequate when the multiple coefficients of correlation (R^2) were more than 0.60 and the lack of fit test was insignificant (Henika 1982) [7]. The (R^2) values for the responses i.e. gruel losses, a value, b value, breaking stress and stickiness were, 0.9402, 0.6060, 0.7963, 0.7692 and 0.7732 respectively. The calculated F-values for the responses indicated adequacy of the models at 5 % level of significance. Thus, all the five responses were considered adequate to describe the effect of variables on the quality of pasta samples.

Effect of variables on colour

Colour of the pasta is an important quality factor for consumers. Generally, pasta products made with refined wheat flour had higher desirability.

The ‘a’ values of the extrudate ranged from 0.28 to0.87. Highest a value was observed in standard run 3 (40g quinoa $100g^{-1}$ QPM, 60g soy $100g^{-1}$ QPM and 40g corn starch $100g^{-1}$ QPM). a value was lowest in case of standard run 5 (40g quinoa $100g^{-1}$ QPM, 20g soy $100g^{-1}$ QPM and 80g corn starch $100g^{-1}$ QPM). The a value for optimised product was 0.87 (40g quinoa $100g^{-1}$ QPM, 60g soy $100g^{-1}$ QPM and 40g corn starch $100g^{-1}$ QPM).

In the present investigation, the a-value was found to increase with increasing proportion of quinoa and soy flours. This may be attributed to the colour pigmentation of these flours, Susanna *et al*., (2012). Increasing proportion of Corn starch however, resulted in declining reddish tinge. Similar findings have been reported by Schoenlechner *et al*., (2010) [23].

The b values for the extruded product ranged from 14.11 to 17.51. The maximum b value was observed for the standard run 13(60g quinoa $100g^{-1}$ QPM, 40g soy $100g^{-1}$ QPM and 26.3641g corn starch $100g^{-1}$ QPM). b value was minimum for the standard run 18 (60g quinoa $100g^{-1}$ QPM, 40g soy $100g^{-1}$ QPM and 60g corn starch $100g^{-1}$ QPM). For the optimized product (40g quinoa $100g^{-1}$ QPM, 60g soy $100g^{-1}$ QPM and 40g corn starch $100g^{-1}$ QPM), the b value was 16.95.

In the present investigation, the b-value was found to increase with increasing proportions of soy flour and corn starch while it decreased with the rising proportion of quinoa flour. Fiord a *et al*., (2013) [4] suggested an increase in yellowness of the product with increasing starch content. Schoenlechner *et al*., (2010) [23] also suggested that corn and corn starch based pastas have high a and b- values.

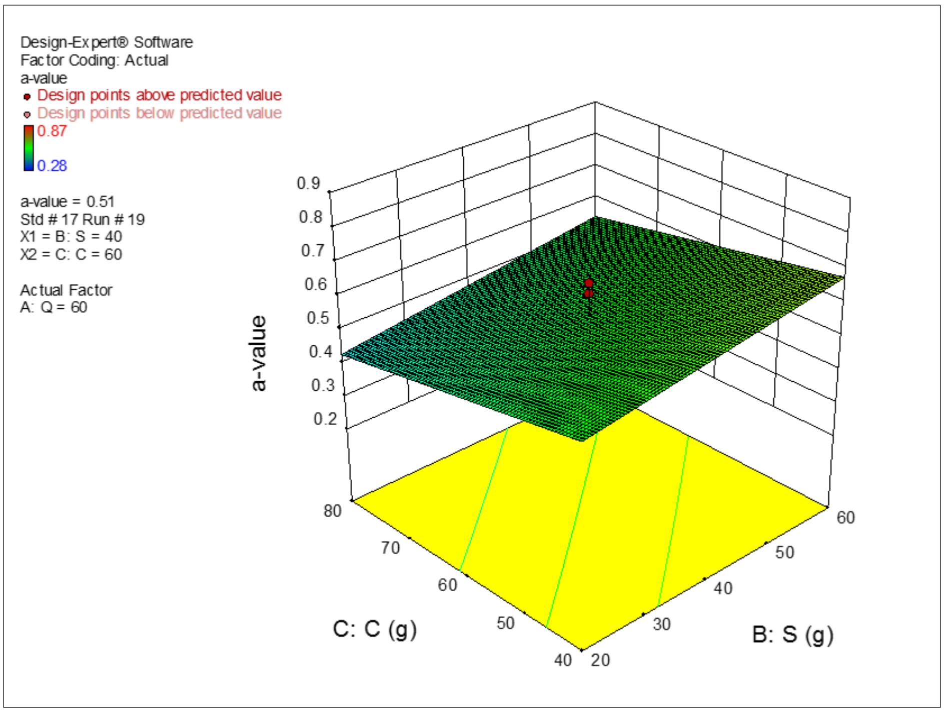

Fig 1: Response surface plot for a-value as a function of proportion of soy flour and corn starch at a centre value of quinoa flour

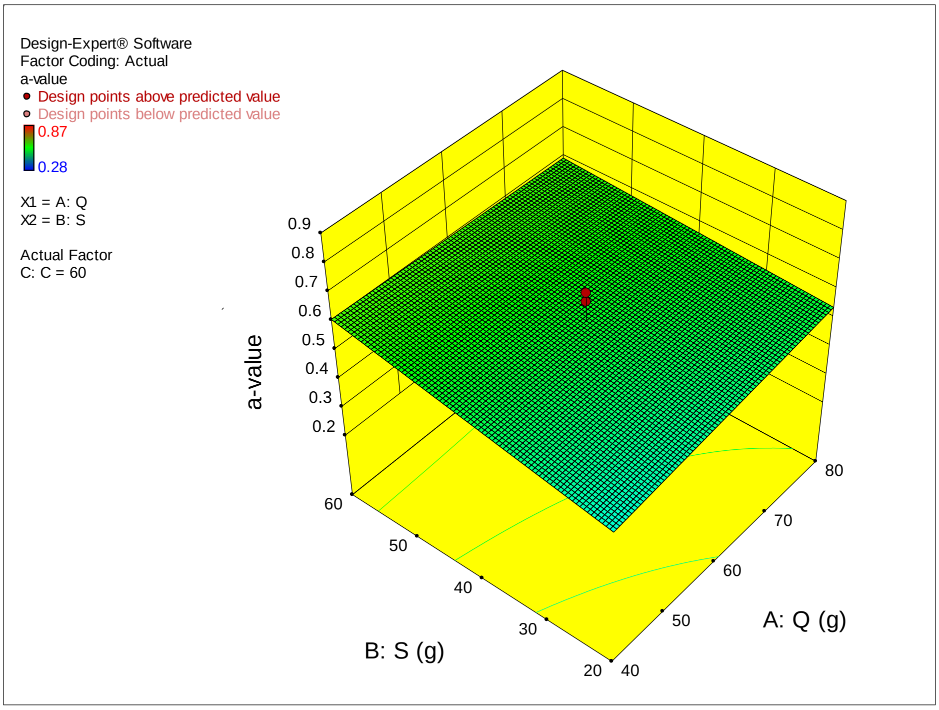

Fig 2: Response surface plot for a-value as a function of proportion of soy flour and quinoa flour at a centre value of corn starch

Effect of variables on texture

The textural property of extrudate was determined by measuring the force required to break the extrudate. The higher value of peak force required in gram, to breakdown the sample, means higher the breaking stress of the sample. The breaking stress and stickiness values have been reported in table 1.The breaking stress of the extrudate varied between 384.7 and 1117.2 g. The minimum breaking stress (384.7 g) was observed for standard run 14 (60g quinoa 100g^{-1} QPM, 40g soy 100g^{-1} QPM and 93.6359g corn starch 100g^{-1} QPM) whereas, maximum breaking stress (1117.2 g) was observed for standard run 12 (60g quinoa 100g^{-1}QPM, 73.6359g soy 100g^{-1} QPM and 60g corn starch 100g^{-1} QPM). Breaking stress of 840.7g was observed for optimized extruded product for standard run 3 (60g quinoa 100g^{-1} QPM, 40g soy 100g^{-1} QPM and 60g corn starch 100g^{-1} QPM).

It was observed that breaking stress decreased with the increasing proportion of both quinoa flour and corn starch, however the increasing proportion of soy flour leads to increase in breaking stress. Similar findings have been reported by Fiord a *et al.*, (2013) [4] which suggests that starch reduces breaking stress. Both Chill o *et al.*, (2008) [2] and Mastromatteo *et al.*, (2011) [18] reported that quinoa decreases the firmness of pasta.

The stickiness of the cooked pasta varied between -79.8 and -23.4 g. The minimum stickiness (-79.8 g) was observed for standard run 13 (60g quinoa 100g^{-1} QPM, 40g soy 100g^{-1} QPM and 26.3641g corn starch 100g^{-1} QPM) whereas, maximum stickiness (-23.4 g) was observed for standard run 16 (60g quinoa 100g^{-1} QPM, 40g soy 100g^{-1} QPM and 60g corn starch 100g^{-1} QPM). Stickiness of -70.23g was observed for optimized extruded product for standard run 3 (60g quinoa 100g^{-1} QPM, 40g soy 100g^{-1} QPM and 60g corn starch 100g^{-1} QPM).

In the present investigation, it was observed that stickiness decreased with increasing proportion of both quinoa and soy flours. It, however, increased with increasing corn starch content. Limroongreungrat *et al.*, (2005) reported a similar finding where stickiness reduced with increasing soy content. Fiord a *et al.*, (2013) [4] suggested that starch contributes towards increasing stickiness. Chill o *et al.*, (2008) [2] also reported that increasing quinoa proportion also reduces stickiness.

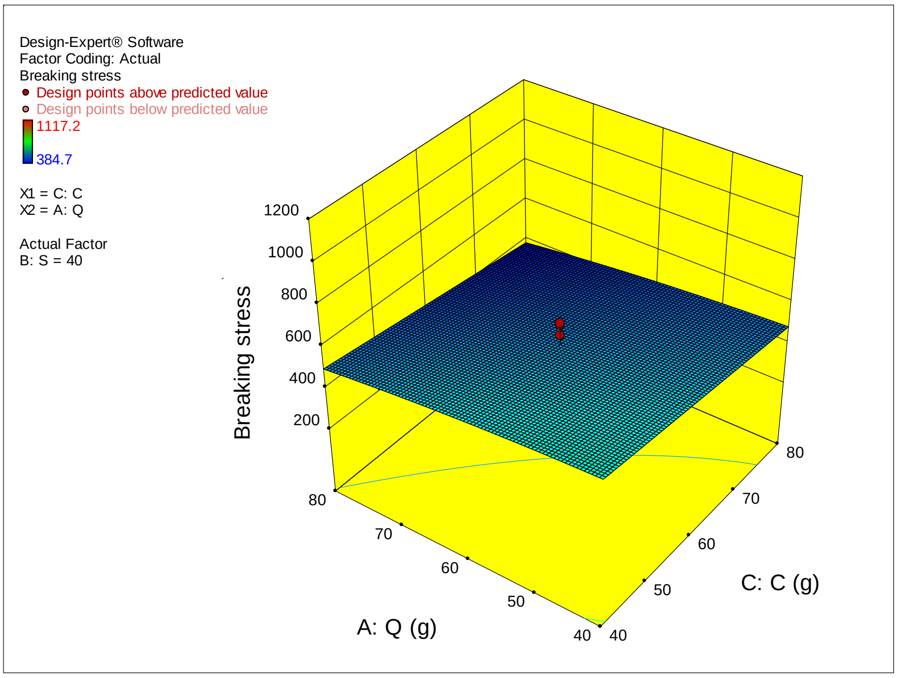

Fig 3: Response surface plot for breaking stress as a function of proportion of quinoa flour and corn starch at a centre value of soy flour

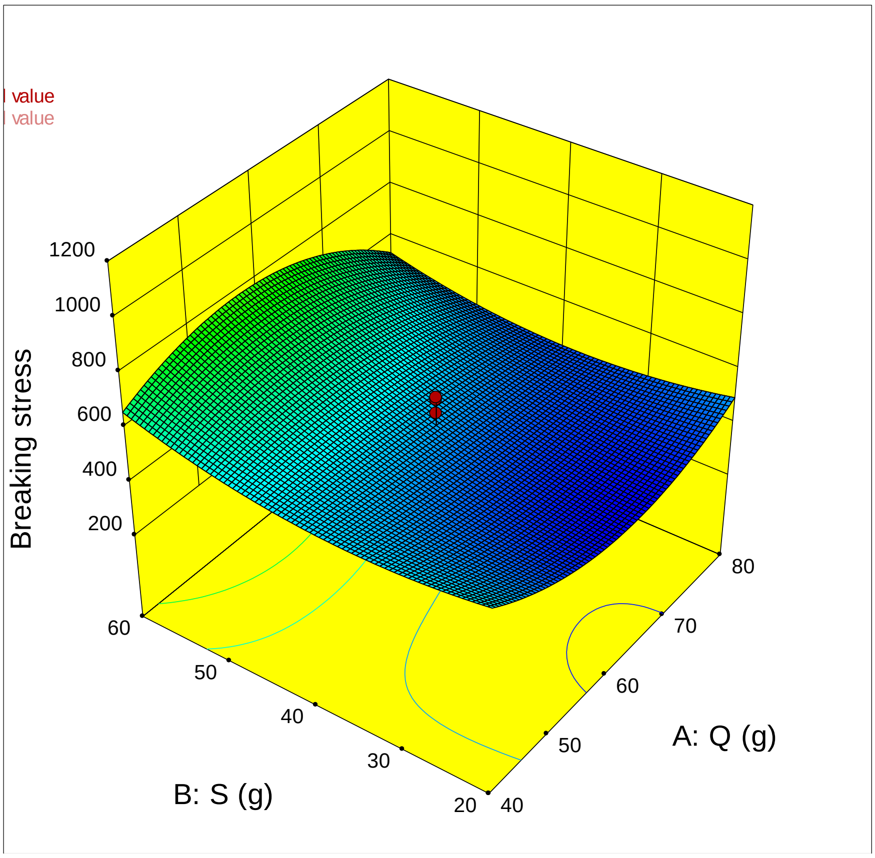

Fig 4: Response surface plot for breaking stress as a function of proportion of quinoa flour and soy flour at a centre value of corn starch

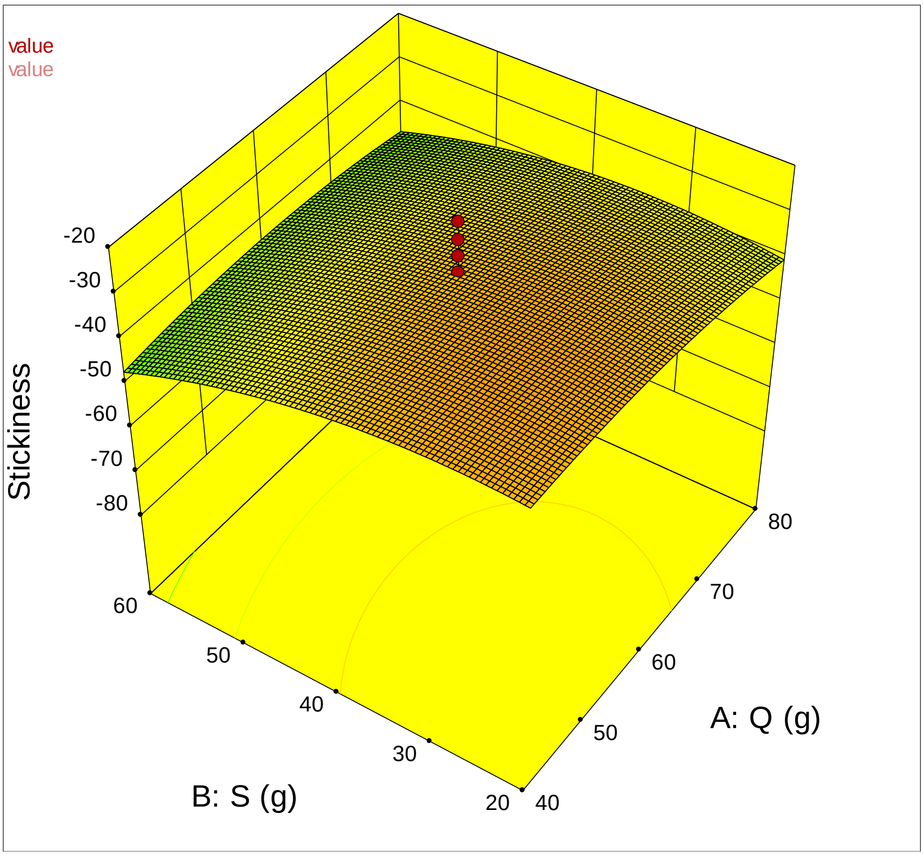

Fig 5: Response surface plot for stickiness as a function of proportion of quinoa flour and soy flour at a centre value of corn starch

Effect of variables on gruel loss

Gruel losses measure the total amount of solids lost in water during cooking of pasta. Good quality pasta should leave clear water after cooking. The gruel losses varied from 5.85 to 10.57 %. Maximum gruel losses were observed for the standard run 5 (40g quinoa 100g^{-1} QPM, 20g soy 100g^{-1} QPM and 80g corn starch 100g^{-1} QPM). Minimum losses were observed in case of standard run 8 (80g quinoa 100g^{-1} QPM, 60g soy 100g^{-1} QPM and 80g corn starch 100g^{-1} QPM).

In case of the optimised product, losses were 7.46% (40g quinoa 100g^{-1} QPM, 60g soy 100g^{-1} QPM and 40g corn starch 100g^{-1} QPM).It was observed that gruel losses decreased after increasing to certain limit with an increase in the proportion of quinoa flour. Mastromatteo *et al*., (2011) [18] reported similar findings and suggested that quinoa flour shows a good ability to form a physical network such as that formed by gluten. However several other authors such as Duarte *et al*., (2010) have suggested increase in gruel losses while working with quinoa. Gruel losses considerably increased with increasing proportion of soy flour. A similar trend has been reported by Kaur *et al*., (2011), Taha (1992) [27] and Limroongreungrat *et al*., (2005). In the present study, gruel losses were observed to be decreasing with increasing corn starch proportion.

Analysis of variance

After selecting the model, analysis of variance was calculated to assess how well the responses represent the data. F-value for all the responses i.e. gruel losses, a value, b value, breaking stress and stickiness was significant ($p \leq 0.05$) (Table 3). Consequently, it can be derived that selected models adequately represented the responses.

Table 3: ANOVA and regression coefficients of the second order polynomial models for the product responses

Response	Gruel Losses	Stickiness	a-value	b-value	Breaking stress
Intercept	7.67	-34.11	0.55	14.91	507.12
A	-0.33**	-1.48	0.01	-0.14	-50.32*
B	0.71***	-4.70	0.05*	0.35**	201.63***
C	-0.22*	3.45	-0.06**	-0.71***	-59.00*
AB	0.02	1.75	-0.02	0.08	-12.3
AC	-0.82***	-7.27*	0.11***	0.37*	
BC	-0.04	5.47	0.001	0.02	
A^2	-0.34**	-2.72		0.23	-13.63
B^2		-4.72		0.16	79.17**
C^2		-12.21		0.30*	
ABC	0.92***				
A^2B	-1.75***				-168.58**
ANOVA					
R^2	0.94	0.77	0.60	0.79	0.76
Model F value	17.48	3.79	3.33	4.34	5.71

Optimization of level of independent variables

Optimization of level of variables was done by selecting the responses i.e. gruel losses, a value, b value, breaking stress and stickiness Responses had direct effect on the quality and acceptability of the pasta as shown by their respective R^2 values. Numerical optimization was done and the results were presented in Table 4. The importance level of three was assigned to each constraint and the optimized values (quality protein maize flour weight basis) were quinoa flour 40%, soy flour 60%, and corn starch 40% ingredient pre-mix. Pasta was prepared using the recommended level of ingredients and the responses were measured. The developed pasta was also analyzed for its nutritional values such as protein, fat and carbohydrates; the corresponding values were 14.4%, 7.6% and 75.2%. The actual and predicted values for the optimised condition have been reported in Table 4. The measured responses had proximity to the predicted ones. The adequacy of the models was thus re-confirmed.

Table 4: Constraints, criteria for optimization, solution along with predicted and actual response values

Constraint	Goal	Lower limit	Upper limit	Predicted values	Actual response values
Quinoa flour	In range	40	80	-	-
Soy flour	In range	20	60	-	-
Corn starch	In range	40	80	-	-
Gruel losses (%)	Minimize	5.85	10.57	6.97	7.46
Colour a*	Maximize	0.28	0.87	0.79	0.87
Colour b*	Maximize	14.11	17.51	17.08	16.95
Breaking stress (g)	Maximize	384.7	1117.2	727.34	840.7
Stickiness (g)	Minimize	-79.8	-23.4	-74.96	-70.20

Conclusion

The study concluded with the formation of acceptable non-wheat pasta from quality protein maize by incorporating quinoa flour, soy flour and corn starch. The optimized level of ingredients was quinoa flour 40.0 g 100 g^{-1} quality protein maize flour (QPM), soy flour 60.0 g 100 g^{-1} QPM and corn starch 40.0 g 100 g^{-1} QPM. Such a product would not only have a high nutritional quality but also be adequate for gluten sensitive people. Moreover, such value added product may be helpful in promoting utilization of maize and quinoa.

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