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Physico-Chemical Composition and Functional Properties of Blended Flour Obtained from Lentil, Pumpkin and Barley for Development of Extrudates

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Abstract

Barley based extruded snacks containing pumpkin and lentil was produced using twin screw extruder. Response surface methodology were used to optimize and evaluate the effect of three independent variables viz. feed composition (50% to 90% barley flour; 2.5% to 42.5% lentil flour and 7.5% pumpkin flour), moisture content (13% to 21%) and barrel temperature (115°C to 155°C) on lateral expansion, bulk density, water absorption index, water solubility index, SME and breaking strength of extrudates. Low barrel temperature and low moisture content were found to enhance the lateral expansion (37-70.8) whereas low barley content significantly reduced lateral expansion of extrudates. A significant increase in water absorption index was (5.34 g/g to 6.23 g/g) observed at high moisture content. The negative regression coefficients of feed composition, barrel temperature and moisture content revealed that these parameters reduced water solubility index of extrudates. Higher moisture content depicted positive effect on breaking strength (178.71-325.77 N) whereas increased barley content significantly reduced effect on breaking strength. Lower values of bulk density were observed at lower values of moisture content. Low moisture content significantly reduced effect on bulk density. The specific mechanical energy of barley based extrudates ranged in between 221.07 to 327.45 W hr/kg, a significant decrease in specific mechanical energy was observed at low moisture content. Feed composition, high moisture content and high barrel temperature enhanced the luminosity, redness and yellowness of extrudates. The extruded samples were evaluated organoleptically for appearance, texture, flavour and overall acceptability by semi trained panel of 10 judges using 5-point scales.

Keywords: Barley; Extrusion process; Lentil; Pumpkin; RSM

Introduction

Snack foods have become an important part of the diets of many individuals including children. Cereal grains are generally used as major raw material in extruded snack foods. Nutritious snack foods can be produced by incorporation of legumes, vegetables and fruits into the formulation. Studies have shown that consumption of grains, fruits and vegetables may reduce risk of chronic diseases and/or promote general human health. Barley is the world's fourth most important cereal crop, after wheat, maize (corn), and rice. Barley is the most prominent crop in feeding livestock as well as it is a main ingredient in beer or other malted beverages. Barley is high in carbohydrates, with moderate amounts of protein, calcium and phosphorus. It also has small amounts of the B vitamins. Scientific evidence indicates that including barley in a healthy diet can help reduce the risk of coronary heart diseases by lowering LDL and total cholesterol levels. It has superior nutritional qualities due to presence of beta-glucan (an anticholesterol substance), acetylcholine (a substance which nourishes our nervous system and recovers memory loss), easy digestibility (due to low gluten contents) and high lysine, thiamine and riboflavin. Barley food product provides cooling and soothering effect in body sustained for a longer time. Its alternate uses in malt and beer industry and health tonics have proved that barley is an important crop of the present era [1].

Lentil is one of the early domesticated plant species, as old as those of corn, wheat, barley and pea. Because of its high average protein content and fast cooking characteristics lentil is the most desired legume in many regions. Lentil seeds contain 1% to 2% fat, 24% to 32% proteins and minerals (iron, cobalt and iodine) and vitamins (lysine and arginine). Pumpkins are rich in carotene, vitamins, minerals and dietary fiber. β-carotene present in pumpkin is converted to vitamin A in the body and plays a crucial role in the prevention of chronic diseases during adult life due to their antioxidant abilities [2].

Materials and Methods

The present investigation was carried out in the Department of Food Technology at Islamic University of Science and Technology. This section enlists the raw materials used and elaborates the processing techniques, analytical procedures, organoleptic evaluation and statistical methods followed during the research.

Experimental raw material

Raw materials used in the investigation: The barley was procured from local market in Kargil. The lentil was procured locally. The lentil was grinded into fine powder in FPTC lab in grinder. The pumpkin was procured locally. It was dried in hot air drier in FPTC lab at 70°C and grinded in grinder into fine flour. All the three flours were sieved through 200 µm sieve.

Physico-chemical characteristics of blended flours

Moisture content (%), Ash content (%), crude protein, crude fibre and fat

Standard AACC procedures [3] were followed for the determination of moisture content, ash content, crude protein, crude fibre and fat.

Bulk density (g/cc): Bulk density was determined using the mass/volume relationship by filling a cylindrical container of 500 ml volume and tare weight with the grain by pouring from a constant height, striking off the top level and weighing.

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Rheological/pasting properties

Pasting properties of flours and their blends were determined, using rapid visco-analyzer (RVA Starch Master TM, Newport Scientific, Warriewood, Australia). Flour sample (3.45 g, 12% mb) was taken in RVA aluminium canister and 25 ml of distilled water was added to it. It was then subjected to a programmed heating and cooling cycle where samples were held at 50°C for 1 min, heated to 95°C for 7.5 min and held at 95°C for 2 min. It was then cooled to 50°C in 7 min and then held at 50°C for 2 min. The centrifuge rotating speed was maintained at 160 rpm. Parameters including pasting temperature, peak viscosity, breakdown, trough, setback, and final viscosity were recorded. Tests were performed in triplicates.

Preparation of sample

Blend of barley, lentil and pumpkin was made, in which pumpkin content was kept constant (7.5%) in all the five treatments. Barley content varied from 50% to 90% and lentil content varied from 1.2% to 42.5%. All the ingredients were weighed separately according to treatments and then mixed in Food Processor (make: Inalsa, 600 W) with mixer attachment for a period of 20 min. The mixtures were passed through a 200 mm sieve to reduce the lumps formed. After mixing, samples were stored in PET bottles at room temperature for 48 hours. The moisture content of all the samples was estimated using the hot air oven method [3].

Extrusion process

The extrusion experiment was performed in a BTPL lab model twin screw extruder [NMFP- MOFPI (GOI), SIDCO (J&K], Division Post Harvest Technology, SKUAST-Kashmir, Shalimar Campus, Srinagar. The barrel diameter and its length to breadth ratio (l/b) were 2.5 mm and 16:1 respectively. The extruder barrel is divided into four zones. Temperature of first, second and third zone was maintained at 30°C, 60°C and 90°C respectively, throughout the experiment, while the temperature at the fourth zone was varied to the experimental design. The extruder was equipped with a torque indicator, which showed per cent of torque in proportion to be current drawn by the drive motor.

Physico-chemical characteristics of extruded products

Specific Mechanical Energy (SME): Specific mechanical energy (Wh/kg) was calculated from rated screw speed (682) rpm), motor power rating, actual screw speed% motor torque and mass flow rate (kg/ h) as per the following formula [4].

Bulk density (g/cc): Bulk densities of extrudates were determined by volumetric displacement procedures as described by Patil et al. [5]. The volume of expanded sample was measured by using a 250 ml graduated cylinder by rapeseed displacement. The volume of 20 g randomised sample was measured for each test. The ratio of sample weight and the replaced volume in the cylinder was calculated as density (w/v).

Water Solubility Index (WSI) and Water Absorption Index (WAI): WSI and WAI were determined according to the method developed for cereals. The ground extrudate was suspended in water at room temperature for 30 min, gently stirred during this period, and then centrifuged at 3000 g for 15 min. The supernatant was decanted into an evaporating dish of known weight. WAI was the weight of gel obtained after removal of the supernatant per unit weight of original dry solids. WSI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample.

Lateral expansion: The ratio of diameter of extrudate to the diameter of die was used to express the expansion of extrudate [6,7]. Six lengths of extrudate (approx. 60mm) was selected at random during the collection of each of the extruded samples and allowed to cool to room temperature. The diameter of the extrudates was then measured, at 5 different positions along the length of each of the ten samples, using a digital Vernier Calliper (Diginatic Solar Mitutoya, Japan).

Colour: Colour was determined by using Hunter Lab Colorimeter (Model SN 3001476, Accuracy Micro Sensors, New York). The instrument was calibrated with the user supplied black plate calibration standards that were used for zero setting. Minolta supplied white calibration setting was used for white calibration. The samples were uniformly packed in clean Petri plates with lids. The instrument was placed on the plate and their exposure at different places was conducted. Readings were displayed as L^*, a^*, b^* colour parameter according to the CIELAB system of colour measurement. L^* (Luminosity or brilliance) varies from black (zero) to white (100), a^* from green (+100) to red (-100) and b^* from blue (-100) to yellow (+100).

Breaking strength: The hardness of the extrudates was checked by using texture analyzer (Model TA-TX, Stable Micro systems ltd, UK) equipped with 500 kg load cell and texture expert system for data collection. An extrudate 40 mm long was compressed with a probe SMS-P/75-75 mm diameter at a crosshead speed 5mm/s to 3mm of 90% of diameter of the extrudate. The compression generated a curve with force over distance. The highest first peak value was recorded as this value indicated the first rupture of snack at one point and this value of force was taken as a measurement for hardness [8].

Sensory quality: Extruded snacks after mixing spices were evaluated for sensory attributes (colour, flavour, texture and overall acceptability) by a panel of 10 semi trained judges using 5-point scale. The proforma used for sensory evaluation by ten semi-trained panellists for colour, texture, flavour and overall acceptability is given in Appendix-1.

Optimization: Numerical optimization of the process variables was performed with the help of Design Expert version 9.0.

Experimental design

Response Surface Methodology (RSM) was adopted in the experimental design as it emphasizes the modelling and analysis of the problem in which response of interest is influenced by several variables, and the objective is to optimize this response [9]. The main advantage of RSM is to reduce number of experimental runs needed to provide sufficient information for statistically acceptable results. A five level, three factor central composite rotatable design was employed. The independent variables selected for experiment were: Feed proportion (Barley Flour: Lentil flour: Pumpkin flour) (A), 50:42.5:7.5, 60:32.5:7.5, 70:22.5:7.5, 80:12.5:7.5 and 90:2.5:7.5; Moisture content (B), 13, 15, 17, 19 and 21% and barrel temperature (C), 115, 125, 135, 145 and 155°C. The actual value of each level is detailed in the Tables 1-3.

Results and Discussion

The present investigation entitled "Studies on lentil and pumpkin incorporated barley extrudates" was carried out in the department of Food Technology at Islamic university of science and technology awantipora. The results obtained during investigation are given in Tables 4 and 5.

Proximate analysis of raw materials

Physico-chemical characteristics of flour blends: The data in Table 4 revealed the proximate composition of blended flour.

Independent variables	Code	Levels in coded from				
		-1.68	**-1**	**0**	**+1**	**+1.68**
Feed composition (ratio)	A	50:42.5:7.5	60:32.5:7.5	70:22.5:7.5	80:12.5:7.5	90:2.5:7.5
Feed moisture (%)	B	13	15	17	19	21
Barrel temperature (°C)	C	115	125	135	145	155

Table 1: Values of independent variables at five levels of the CCRD design.

S. No.	Composition (B: L: P)	Moisture content (%)	Barrel temperature (°C)
1.	60:32.5:7.5 (-1)	15.00 (-1)	125 (-1)
2.	80:12.5:7.5 (+1)	15.00 (-1)	125 (-1)
3.	60:32.5;7.5 (-1)	19.00 (+1)	125 (-1)
4.	80:12.5:7.5 (+1)	19.00 (+1)	125 (-1)
5.	60:32.5:7.5 (-1)	15.00 (-1)	145 (+1)
6.	80:12.5:7.5 (+1)	15.00 (-1)	145 (+1)
7.	60:32.5:7.5 (-1)	19.00 (+1)	145 (+1)
8.	80:12.5:7.5 (+1)	19.00 (+1)	145 (+1)
9.	50:42.5:7.5 (-1.68)	17.00 (0)	135 (0)
10.	90:2.5:7.5 (+1.68)	17.00 (0)	135 (0)
11.	70:22.5:7.5 (0)	13.00 (-1.68)	135 (0)
12.	70:22.5:7.5 (0)	21.00 (+1.68)	135 (0)
13.	70:22.5:7.5 (0)	17.00 (0)	115 (-1.68)
14.	70:22.5:7.5 (0)	17.00 (0)	155 (+1.68)
15.	70:22.5:7.5 (0)	17.00 (0)	135 (0)
16.	70:22.5:7.5 (0)	17.00 (0)	135 (0)
17.	70:22.5:7.5 (0)	17.00 (0)	135 (0)
18.	70:22.5:7.5 (0)	17.00 (0)	135 (0)
19.	70:22.5:7.5 (0)	17.00 (0)	135 (0)
20.	70:22.5:7.5 (0)	17.00 (0)+	135 (0)
(B) Barley flour: (L) Lentil flour: (P) Pumpkin flour			

Table 2: Central composite rotatable experimental design (in coded and uncoded levels of three variables and five levels) employed for development of barley, lentil and pumpkin based extrudates.

Coded variables			Combinations	Replications	No. of experiments
A	**B**	**C**			
±1	±1	±1	8	1	8
±1.68	0	0	2	1	1
0	±1.68	0	2	1	1
0	0	±1.68	2	1	0
0	0	0	6	6	10
Code '0' is for centre point of the parameter range investigated, '±1' for factorial points, and '±1.68' for star points; $_A$-Feed Composition (%), B-Feed Moisture (%) and C-Barrel temperature (°C)					

Table 3: Experimental design in coded form for response surface analysis.

Components	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Fibre
Barley	9.5	2.44	2.20	15.03	4.02
Lentil	10	3.1	3.03	22.18	4.4
Pumpkin	9.9	15.98	2.3	3.07	11.46
CD at P<0.05	**0.269**	**201.094**	**0.70**	**321.695**	**60.51**

Table 4: Physico-chemical characteristics of individual flours.

Treatment	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	Fibre	Bulk density (g/cc)
T_1 (50B:42.5L:7.5P)	9.75	3.71	2.41	17.16	4.73	0.57
T_2 (60B:32.5L:7.5P)	9.69	3.64	2.33	16.44	4.69	0.54
T_3 (70B:22.5L:7.5P)	9.64	3.57	2.25	15.74	4.65	0.50
T_4 (80B:12.5L:7.5P)	9.59	3.51	2.16	15.02	4.61	0.46
T_5 (90B:2.5L:7.5P)	9.54	3.44	2.08	14.3	4.57	0.44
CD at P<0.05	**NS**	**0.33**	**0.41**	**3.36**	**0.19**	**0.15**
B: Barley flour; L: Lentil flour; P: Pumpkin flour						

Table 5: Physico-chemical characteristics of blended flours.

Treatment	Pasting temperature (°C)	Peak viscosity (cP)	Final viscosity (cP)	Breakdown viscosity (cP)	Setback viscosity (cP)
T_1 (50B:42.5L:7.5P)	73.45	1197	1852	139	794
T_2 (60B:32.5L:7.5P)	75.05	1120	1797	47	724
T_3 (70B:22.5L:7.5P)	75.05	1198	1964	66	832
T_4 (80B:12.5L:7.5P)	86.40	1038	1859	84	905
T_5 (90B:2.5L:7.5P)	85.50	1369	2350	106	1087
CD at P<0.05	**18.629**	**385.90**	**223.05**	**112.56**	**436.50**

B: Barley flour; L: Lentil flour; P: Pumpkin flour

Table 6: Pasting/Rheological properties of blended flours.

Regression	SME (Wh/kg)	Bulk density (g/cc)	WAI (g/g)	WSI (%)	Expansion Index	Break strength (N)
Adequate precision	22.717	8.802	9.952	26.025	24.611	9.079
R square	0.9709	0.8490	0.9055	0.9815	0.9796	0.8080
Adjusted R square	0.9447	0.7131	0.8204	0.9649	0.9612	0.6351
Predicted R square	0.8787	0.4733	0.7078	0.9141	0.8808	0.3409
C.V. (%)	2.76	17.82	1.94	5.04	3.84	7.69
Lack of fit (p value)	0.6497	0.7711	0.8675	0.4986	0.2484	0.8610

Table 7: Analysis of variance for the Fit of experimental data to response surface models.

FC (%) B: L: P	MC (%)	BT (°C)	SME (Whr/kg)	BD (g/cc)	EI	WAI (g/g)	WSI (%)	Hardness (N)
(-1)	(-1)	(-1)	304.72	0.08	42.4	5.34	0.255	240.49
(+1)	(-1)	(-1)	281.71	0.039	70.8	5.55	0.15	181.41
(-1)	(+1)	(-1)	227.25	0.15	37	5.89	0.15	301.18
(+1)	(+1)	(-1)	249.78	0.18	54.6	5.85	0.125	261.66
(-1)	(-1)	(+1)	327.45	0.09	68	5.7	0.22	217.49
(+1)	(-1)	(+1)	271.39	0.083	69.8	6.06	0.15	261.45
(-1)	(+1)	(+1)	221.07	0.098	49	5.66	0.13	275.89
(+1)	(+1)	(+1)	234.22	0.18	49.54	5.54	0.12	256.87
(-1.68)	(0)	(0)	290.56	0.125	46	5.61	0.23	264.34
(+1.68)	(0)	(0)	257.29	0.142	68.4	5.95	0.15	226.43
(0)	(-1.68)	(0)	326.75	0.07	72	5.85	0.21	214.68
(0)	(+1.68)	(0)	208.46	0.161	39.32	6.16	0.1	289.99
(0)	(0)	(-1.68)	255.55	0.13	45	5.45	0.125	245.15
(0)	(0)	(+1.68)	262.93	0.074	62.2	5.47	0.12	262.13
(0)	(0)	(0)	284.12	0.142	64.6	6.23	0.135	212.57
(0)	(0)	(0)	266.15	0.166	61.31	5.98	0.15	211.34
(0)	(0)	(0)	274.73	0.11	63.21	5.95	0.135	247.92
(0)	(0)	(0)	284.12	0.142	64.6	6.23	0.135	212.57
(0)	(0)	(0)	266.15	0.166	60.02	5.98	0.15	211.34
(0)	(0)	(0)	274.73	0.11	63.23	5.95	0.135	262.13

FC (%): Feed Composition (B: Barley; L: Lentil; P: Pumpkin); MC (%): Moisture Content; BT (°C): Barrel Temperature; SME (wh/Kg): Specific Mechanical Energy; BD (g/cc): Bulk Density; WAI (g/g): Water Absorption Index; WSI (%): Water Solubility Index; EI: Expansion Index; N: Hardness

Table 8: Effect of processing conditions on product characteristics of lentil and pumpkin incorporated barley based extrudates.

Pasting/rheological properties of blended flours

Significant differences (p<0.05) were observed among pasting properties of flour samples of blend of barley, lentil and pumpkin as presented in Table 6. Pasting temperature (73.45°C to 86.40°C), Peak viscosity (1038-1369 C_p). Blended flours recorded peak viscosity, breakdown viscosity and final viscosity, set back viscosity as given in Table 6.

Extrusion processing

Experimental design: Response Surface Methodology (RSM) software dxt trail 9.01 version was used to investigate the effects of processing conditions on product characteristics. The independent variables included the feed composition (50% to 90% barley flour; 2.5% to 42.5% lentil flour; 7.5% pumpkin flour), moisture content (13% to 21%), and barrel temperature (115°C to 155°C). Response variables were-specific mechanical energy (SME), bulk density (BD), water absorption index (WAI), water solubility index (WSI), expansion index (EI), texture (Hardness) and instrumental colour (L^*, a^*, b^*, hue angle and chrome).

Effect of independent variables on product characteristics of lentil and pumpkin incorporated barley based extrudates: Models for all parameters were significant and all parameters were significantly affected by lentil and pumpkin incorporation, moisture and barrel temperature. None of the models showed significant lack of fit, indicating that all second order polynomial models correlated well with the measured data. Adequate precision (signal to noise ratio) greater than 4 is desirable (Table 7). All the parameters showed high adequate precision. A reasonable good coefficient of determination (R^2=0.97, 0.84, 0.97, 0.90, 0.98, 0.84 for SME, bulk density, expansion index, WAI, WSI and texture (hardness) respectively) indicated that models developed for product response appeared to be adequate. The predicted R-square was found in reasonable agreement with adjusted R-square for all the parameters.

System extruder property

Specific Mechanical Energy (SME): The mean values of SME under different extrusion conditions listed in Table 8 ranged between 221.07 to 327.45 whr/kg with an average value of 268.456 whr/kg. Regression analysis and response surface plots (Figure 1) showed the negative effect of feed composition and moisture and positive effect of barrel temperature. During extrusion higher the SME, higher is the degree of gelatinization. Since mechanical energy favours gelatinization by promoting rupture of intermolecular hydrogen bonds [10].

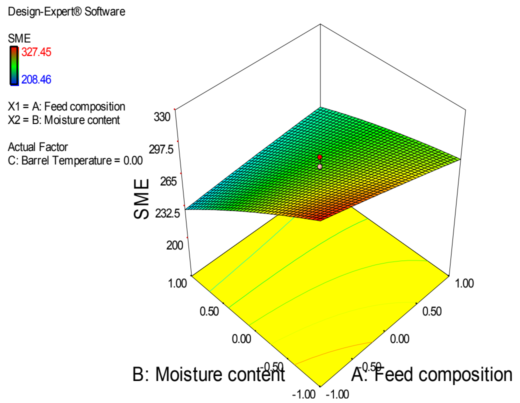

Figure 1: Effect of feed composition and moisture on SME of lentil and pumpkin incorporated barley extrudates.

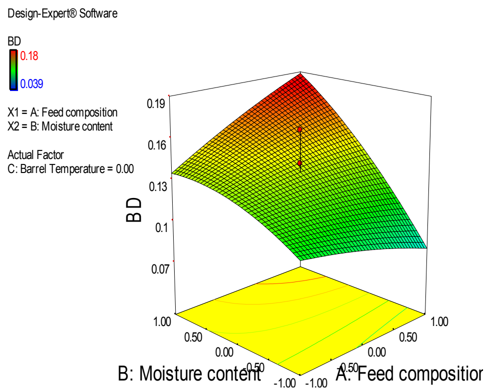

Figure 2: Effect of feed composition and moisture content on BD of lentil and pumpkin incorporated barley extrudates.

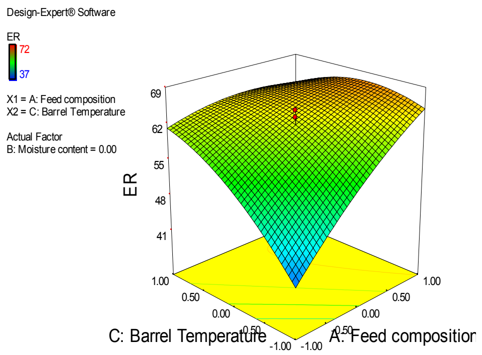

Figure 3: Effect of feed composition and barrel temperature on lateral expansion of lentil and pumpkin incorporated barley extrudates.

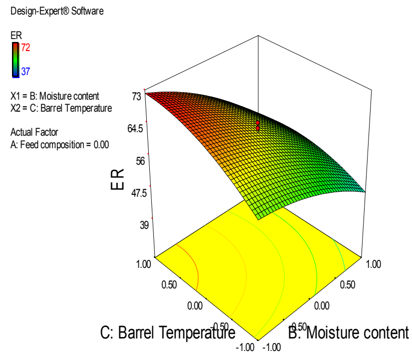

Figure 4: Effect of moisture content and barrel temperature on lateral expansion of lentil and pumpkin incorporated barley extrudates.

Physical properties of extruded snacks

Bulk density: The maximum bulk density (0.18 g/cc) of extrudates was about 4.6 times more than the minimum bulk density (0.039 g/cc) and the average value of bulk density was 0.121 g/cc. It showed the positive relation of feed composition and moisture content and inverse relation of temperature with bulk density. Similar reports were observed by Shivani et al. [11] that increased feed moisture content during extrusion may reduce the elasticity of the dough through plasticization of the melt, therefore reduced gelatinization and increasing the density of extrudate (Figure 2).

Lateral expansion: The mean value of expansion index under different extrusion conditions listed in Table 8 ranged from 37 to 70.8. Regression analysis and response surface plots (Figures 3-6) showed the positive effect of composition and temperature, while the negative effect of moisture on expansion index. Similar reports were observed by Omohimi et al. [12], that there was an appreciable increase in lateral expansion as barrel temperature increases. High input of thermal energy due to high residence time leads to the creation of enhanced level of superheated steam; hence the product will have good expansion which creates flashy and porous structures due to formation of air cells. When extrusion cooked melt exits the die, they suddenly go from high pressure to atmospheric pressure. This pressure drop causes a flash-off of internal moisture and the water vapour pressure, which is nucleated to form bubbles in the molten extrudate, allows the expansion of the melt.

Water Absorption Index (WAI): Water absorption index of extrudates varied in the range of 5.34 to 6.23 g/g with an average value of 5.82 g/g. Change in feed composition, increase in moisture content and increase in barrel temperature increased the water absorption index. Similar reports were observed by Shivani et al. [11] that water absorption index increased with the increase in temperature probably due to increased dextrinization at higher temperature [12].

Water Solubility Index (WSI): Water solubility index of extrudates ranged from 0.1% to 0.25% with an average value of 0.13%. The analysis of variance and response surface plots (Figures 7 and 8) showed the negative influence of feed composition, moisture content and barrel temperature. Vilma et al. [13] reported that Water solubility index (WSI) is used as a measure for starch degradation; it means that at lower WSI there is minor degradation of starch and such condition leads to less numbers of soluble molecules in the extrudates. Higher moisture content in extrusion process can diminish protein denaturation and starch degradation.

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Breaking strength: The maximum breaking strength (325.77 N) was about 1.82 times more than the minimum breaking strength (178.71 N) and the average value of breaking strength was (242.89 N). The regression analysis and response surface plots (Figures 9-11) showed the negative effect of feed composition and moisture content and positive effect of barrel temperature.

Effect of processing conditions on colour coordinates and sensory attributes (overall acceptability) of lentil and pumpkin incorporated barley based extrudates

Models for all colour coordinates were significant and all coordinates were significantly affected by lentil and pumkin incorporation, feed moisture and barrel temperature. None of the models showed significant lack of fit, indicating that all second order

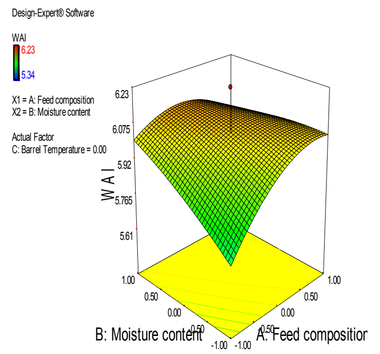

Figure 5: Effect of feed composition and moisture content on WAI of lentil and pumpkin incorporated barley based extrudates.

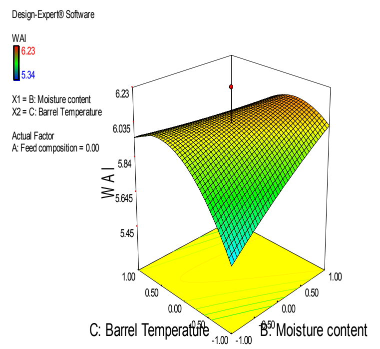

Figure 6: Effect of moisture content and barrel temperature on WAI of lentil and pumpkin incorporated barley based extrudates.

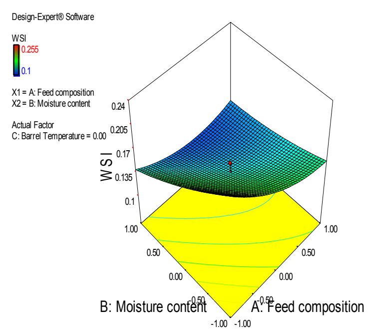

Figure 7: Effect of feed composition and moisture content on WSI of lentil and pumpkin incorporated barley based extrudates.

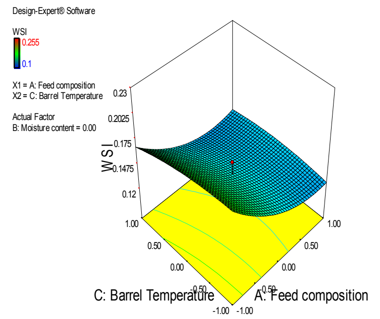

Figure 8: Effect of feed composition and barrel temperature on WSI of lentil and pumpkin incorporated barley based extrudates.

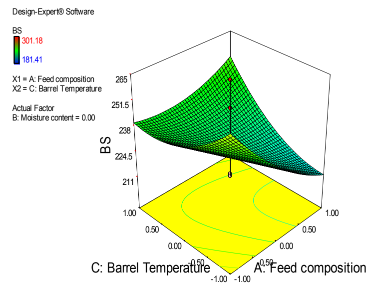

Figure 9: Effect of feed composition and barrel temperature on breaking strength of lentil and pumpkin incorporated barley extrudates.

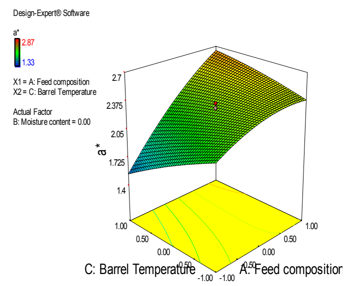

Figure 10: Effect of feed composition and barrel temperature on a* of lentil and pumpkin incorporated barley extrudates.

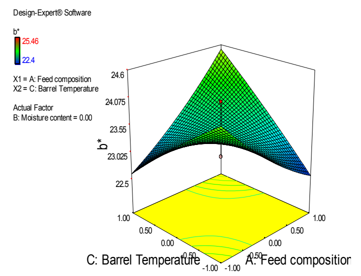

Figure 11: Effect of feed composition and barrel temperature on b* of lentil and pumpkin incorporated barley extrudates.

polynomial models correlated well with the measured data. Adequate precision (signal to noise ratio) greater than 4 is desirable (Table 9). All the parameters showed high adequate precision. A reasonable good coefficient of determination (R^2=0.34, 0.99, 0.85, 0.99, 0.85 for L*, a*, b*, hue angle and chrome value respectively) indicated that models developed for product response appeared to be adequate. The predicted

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Regression	L*	a*	b*	Hue angle°	Chrome
Adequate precision	2.253	46.783	8.694	113.763	9.125
R square	0.3445	0.9923	0.8596	0.9990	0.8577
Predicted R square	-0.7837	0.9560	0.3360	0.9942	0.3169
Adjusted R square	-0.2454	0.9853	0.7331	0.9981	0.7296
C.V. (%)	5.87	2.06	2.11	0.044	2.07
Lack of fit (p value)	0.9247	0.2029	0.4554	0.2503	0.4359

Table 9: Analysis of variance for the Fit of experimental data to response surface models.

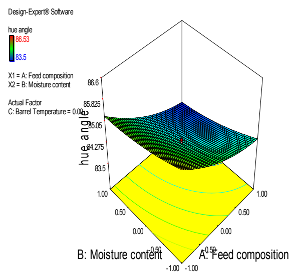

Figure 12: Effect of feed composition and moisture on hue angle of lentil and pumpkin incorporated barley based extrudates.

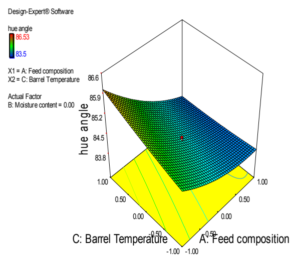

Figure 13: Effect of feed composition and barrel temperature on hue angle of lentil and pumpkin incorporated barley based extrudates.

FC (%) B: L: P	MC (%)	BT (°C)	L*	a*	b*	HA	CH
(-1)	(-1)	(-1)	44.82	1.99	25.11	85.46	25.18
(+1)	(-1)	(-1)	46.23	2.22	23.32	84.56	23.42
(-1)	(+1)	(-1)	45.41	2.34	25.31	84.71	25.41
(+1)	(+1)	(-1)	44.63	2.61	23.09	83.55	23.23
(-1)	(-1)	(+1)	42.2	1.33	22.4	86.60	22.43
(+1)	(-1)	(+1)	46.6	2.39	24.56	84.44	24.67
(-1)	(+1)	(+1)	46.4	1.72	24.25	85.94	24.31
(+1)	(+1)	(+1)	43.68	2.87	25.19	83.50	25.35
(-1.68)	(0)	(0)	43.09	1.44	23.28	86.46	23.32
(+1.68)	(0)	(0)	42.97	2.61	24.35	83.88	24.48
(0)	(-1.68)	(0)	43.38	2.06	25.39	85.36	25.47
(0)	(+1.68)	(0)	46.7	2.6	25.46	84.16	25.59
(0)	(0)	(-1.68)	42.66	2.33	22.81	84.16	22.92
(0)	(0)	(+1.68)	44.51	2.14	23.74	84.84	23.83
(0)	(0)	(0)	47.06	2.27	22.94	84.34	23.05
(0)	(0)	(0)	50.18	2.3	23.22	84.34	23.33
(0)	(0)	(0)	42.71	2.35	24	84.40	24.11
(0)	(0)	(0)	47.06	2.27	22.94	84.34	23.05
(0)	(0)	(0)	50.18	2.3	23.22	84.34	23.33
(0)	(0)	(0)	42.71	2.35	24	84.40	24.11

FC (%): Feed Composition (CF: Corn Flour; WCF: Water Chestnut Flour); MC (%): Moisture Content; SS (rpm): Screw Speed; BT (°C): Barrel Temperature; OAA: Overall Acceptability

Table 10: Effect of processing conditions on colour coordinates of lentil and pumpkin incorporated barley based extrudates.

S.no.	A: Composition (B:L:P) (%)	B: Moisture (%)	C: Barrel temperature (°C)	Overall acceptability
1	60:32.5:7.5	15	125	3.01
2	80:12.5:7.5	15	125	3.73
3	60:32.5:7.5	19	125	3.06
4	80:12.5:7.5	19	125	2.57
5	60:32.5:7.5	15	145	3.18
6	80:12.5:7.5	15	145	3.13
7	60:32.5:7.5	19	145	3.12
8	8:12.5:7.5	19	145	3.03
9	50:42.5:7.5	17	135	3.29
10	90:2.5:7.5	17	135	3.11
11	70:22.5:7.5	13	135	3.17
12	70:22.5:7.5	21	135	3.24
13	70:22.5:7.5	17	115	2.94
14	70:22.5:7.5	17	155	3.04
15	70:22.5:7.5	17	135	2.96
16	70:22.5:7.5	17	135	2.72
17	70:22.5:7.5	17	135	3.32
18	70:22.5:7.5	17	135	2.96
19	70:22.5:7.5	17	135	2.72
20	70:22.5:7.5	17	135	3.32

B: Barley; L: Lentil; P: Pumpkin

Table 11: Scores given by subjective method of evaluation.

R-square was found in reasonable agreement with adjusted R-square for all colour coordinates.

Colour- an important quality factor is directly related to the acceptability of food products. L^* indicates the brightness, a^*-the redness and b^*-the yellowness of extrudates. The mean values of L^*, a^* and b^* of extrudates depicted in Table 9 was found in the range of 42.2 to 50.18, 1.33 to 2.87 and 22.4 to 25.46 respectively. The colour change during the extrusion process can also be an indicator to evaluate the intensity of the process in terms of chemical and nutritional changes [14]. The most prominent effect on the lightness of extrudates is of temperature which may be due to the non-enzymatic browning (Maillard reaction and Caramelization). Colour of extruded products is influenced by temperature, raw material composition, residence time; pressure and shear force [15].

L^*, a^*, and b^*-values: Change of feed composition increase in moisture content and increase in barrel temperature increases L^* value. With the change in feed composition and increase in moisture content, a^* value increases, whereas increase in barrel temperature will decrease a^* value. Change in feed composition, increase in moisture content and extrusion temperature will increase the b^* value of blended extrudate i.e., the intensity of yellowness of the extrudates increases.

Hue angle and chrome value: The analysis of variance (ANOVA) and response surface plots (Figures 12 and 13) showed that hue angle increased with increase barrel temperature and decreased with change in feed composition and increase in moisture content. With the change in feed composition, increase moisture content and increase in extrusion temperature the chrome value also increased.

Sensory evaluation (overall acceptability)

The extruded samples were evaluated organoleptically for appearance, texture, flavour and overall acceptability by semi trained panel of 10 judges using 5 point scale. Out of 20 samples only 6 samples at serial numbers 4, 13, 15, 16, 18 and 19 were found fair with less than three overall acceptability score (Table 10).

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Optimization

Optimization can be defined as the processing conditions that give the optimum value of a function of certain decided variables subjected to constraints that are imposed. Optimization may be the process maximizing a desired quality or minimizing an undesired one. The values of the processing variables that produce the desired optimum value are called optimum conditions. Product responses such as SME, bulk density, WAI, WSI, expansion index and hardness are major parameters that determine the quality of extruded products (Table 11). Therefore, optimum conditions for the development of lentil and pumpkin incorporated barley blended snacks were determined to obtain the minimum bulk density, hardness and maximum SME, WAI, WSI and expansion ratio. The desirability function for obtaining optimal conditions in extrusion cooking of lentil and pumpkin incorporated barley blended flours of the response surface is shown in (Figures 14 and 15). The desirability obtained was 0.975. The optimum lentil and pumpkin incorporation, moisture and barrel temperature were 12.5%, 7.5%, 15% and 125°C respectively (Tables 12 and 13).

Summary and Conclusion

Cereal grains are generally used as major raw material in extruded snack foods. Barley is high in carbohydrates, with moderate amounts of protein, calcium and phosphorus. In order to enhance the nutritional value of barley based extrudates, an attempt has been made to incorporate lentil and pumpkin in extrudates. Lentil is a rich source of lysine whereas pumpkin being a good source of fibre. Twin screw extruder was used for production of extrudates at varying conditions (feed composition (50% to 90% barley flour; 2.5% to 42.5% lentil flour and 7.5% pumpkin flour), moisture content 13% to 21% and barrel temperature 115°C to 155°C). Higher moisture content was found to enhance the water absorption index of extrudates. Lower moisture content had negative effect on bulk density. Lateral expansion of extrudates were found to decrease with increase in barrel temperature and barley content. An inverse effect of feed composition, barrel temperature and moisture content on water solubility index of extrudates were observed. The color characteristics of barley based extrudates enhanced at higher extrusion conditions. The extruded samples were evaluated organoleptically for appearance, texture, flavour and overall acceptability, the optimised results were found at feed composition 80% barley flour, 12.5% lentil flour and 7.5% pumpkin flour; moisture content 15% and barrel temperature 125°C. Low barrel temperature and low moisture content were found to enhance the lateral expansion (37-70.8) whereas low barley content significantly reduced lateral expansion of extrudates. A significant increase in water absorption index was (5.34 g/g to 6.23 g/g) observed at high moisture content. The negative regression coefficients of feed composition, barrel temperature and moisture content revealed that these parameters reduced water solubility index of extrudates. Higher moisture content depicted positive effect on breaking strength (178.71 N-325.77 N) whereas increased barley content significantly reduced effect on breaking strength. Lower values of bulk density were observed at lower values of moisture content. Low moisture content significantly reduced effect on bulk density. The specific mechanical energy of barley based extrudates ranged in between 221.07 to 327.45 W hr/kg, a significant decrease in specific mechanical energy was observed at low moisture content. Feed composition, high moisture content and high barrel temperature enhanced the luminosity, redness, and yellowness of extrudates.

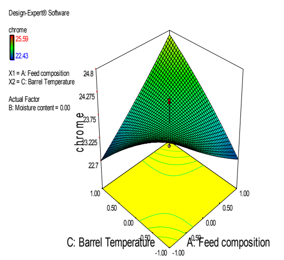

Figure 14: Effect of feed composition and barrel temperature on chrome of lentil and pumpkin incorporated barley based extrudate.

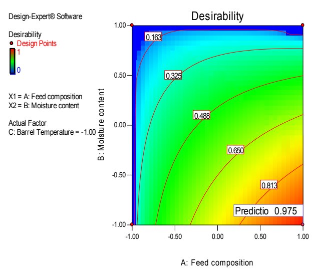

Figure 15: Desirability function response surface for lentil and pumpkin incorporated barley blended extrudates.

Values	SME Wh/kg	Bulk density (kg/m³)	WAI (g/g)	WSI (%)	Lateral Expansion (%)	Breaking strength (N)
Predicted values	277.67	0.041	5.60	0.15	70.21	187.96
Actual values	281.71	0.040	5.55	0.15	70.80	181.41
Variation (%)	3.48	2.43	0.89	0	0.83	3.48

Table 12: Predicted response levels and actual response levels.

Parameters	Mean ± SD
Moisture (%)	5.5 ± 0.288
Protein (%)	8.69 ± 0.034
Fat (%)	1.32 ± 0.011
Ash (%)	2.03 ± 0.017
Fibre (%)	2.65 ± 0.028
L*	46.23 ± 0.017
a*	2.22 ± 0.017
b*	23.32 ± 0.017
Hue	84.56 ± 0.034
Chrome	23.42 ± 0.011
Breaking strength (N)	181.41± 0.23

Table 13: Proximate composition of final extruded snacks.

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