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Optimisation and studies on lentil and pumpkin incorporated barley extrudates

SAJAD AHMAD SOFI[1*], SAFIYA KHANDAY[2], AWSI JAN[1]

[1]*Sher-e- Kashmir University of Agricultural University of Science and Technology, 2Division of Food Science and Technology, -Jammu India-180009*
[2]*Islamic University of Science and technology, Department of Food Technology, Awantipora , J&K India-192122*

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ABSTRACT

Barley based extruded snacks containing pumpkin and lentil were produced using a twin screw extruder. Response surface methodology was used to optimize and evaluate the effect of three independent variables viz. feed composition (50-90% barley flour; 2.5-42.5% lentil flour and 7.5% pumpkin flour), moisture content (13%-21%) and barrel temperature (115-155 °C) on lateral expansion, bulk density, water absorption index, water solubility index, specific mechanical energy 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 the extrudates. A significant increase in water absorption index was (5.34-6.23 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 the extrudates. Higher moisture content depicted positive effect on breaking strength (178.71-325.77 N), whereas increased barley content significantly reduced breaking strength. Lower values of bulk density were observed at lower values of moisture content. Low moisture content significantly reduced bulk density. The specific mechanical energy of barley based extrudates ranged from 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 a semi-trained panel of 10 judges using a 5 point scale.

Introduction

Snack foods have become an important part of the diets of many individuals, including children (Sing et al., 2015). Cereal grains are generally used as major raw material in extruded snack foods and are low in proteins with a poor biological value because of their limited essential amino acid contents
(Iqbal et al., 2005). Nutritious snack foods can be produced by incorporation of legumes, vegetables and fruits into the formulation. Studies have shown that the consumption of grains, fruits and vegetables may reduce the risk of chronic diseases and/or promote general human health (Bertagnolli et al., 2014). Antioxidants are believed to contribute to the beneficial effects of grains, fruits, and vegetables through several mechanisms, such as directly reacting with and quenching free radicals, chelating transition metals, reducing peroxides, and stimulating the antioxidative defense of enzyme activities
(Emir et al., 2005).
Barley is the world's fourth most important cereal crop, after wheat, maize (corn), and rice. Barley was probably cultivatedabout 10,000 years ago and the world barley production in 2009 was 150.8 million tonnes (FAO, 2009). The average production of barley in Iran was 2.0 million tons in 2009. Barley,

*Corresponding author E-mail:
sajadtec@gmail.com

which is of the genus Hordeum, is a cereal that belongs to the grass family Poaceae. It is a plant whose seed is processed to make malt, breakfast foods and animal feed. Barley is the most prominent crop in feeding livestock, as well as a main ingredient in beer or other malted beverages (Keenan et al., 2004). Barely is mostly preffered for malting because of its physical characteristics and properties (Madhujith and Shahidi, 2007). Barley is high in carbohydrates, with moderate amounts of protein, calcium and phosphorus. It also has small amounts of the B vitamins. High protein barley is best suited for animal feed or malt that will be used to make beer with a large adjunct content. 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 level (Aghajani et al., 2012). Over 136 million tons of barley are produced annually on about 56 million hectares. Due to superior nutritional properties and medicinal importance, barley is considered ahighly needed crop in the present era. It has superior nutritional qualities due to the 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 andriboflavin content (Shewry, 1993). Barley food products provide cooling and soothing effect in body which is 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. Barley has also been mentioned in numerous Ahadith (prophit Muhammad SAW sayings) (Sarfaraz et al., 2012).

Lentil is one of the earliest domesticated plant species, as old as those of corn, wheat, barley and pea. The important lentil growing countries of the world are India, Canada, Turkey, Bangladesh, Iran, China, Nepal and Syria. The total cultivated area in the world is around 4.6 million hectares producing 4.2 million tons of seeds with an average production of 1095 kg/ha. The main lentil producers are Armenia, China, Turkey and Croatia. Because of its high average protein content and fast cooking characteristics, lentil is the most desired legume in many regions. Lentil seeds contain 1-2% fat, 24–32% proteins and minerals (iron, cobalt and iodine) and vitamins (lysine and arginine). Lentils are prepared in several ways including soaking, boiling, sprouting/germination, fermentation, frying and dry-heat methods. Other ways to benefit from it are processed lentils and lentil snacks. Lentil straw is also valued animal feed due to low cellulose content (Alihan et al., 2013). There are numerous protein-calorie malnutrition problems over the world. Legumes may be helpful in solving this problem. Legume crops are rich in essential amino acids, particularly in lysine. It has been demonstrated that legume protein is the natural protein suitable to complement the protein content present in cereal grains and on the other hand, legume grains are an important part of thehuman diet. Legumes are helpful in enhancing the protein content. Legumes have been considered a rich source of proteins throughout the world and contain approximately three times more proteins than cereals. Legumes represent, together with cereals, the main plant source of proteins in the human diet. They are also generally rich in dietary fibre and carbohydrates. Minor compounds of legumes are lipids, polyphenols and bioactive peptides. Legumes, including lentil, beans and chickpea, are important crops because of their nutritional quality. They are rich sources of complex carbohydrates, vitamins and minerals (Simona et al., 2013).

Pumpkin belongs to the family of Cucurbitaceae and is widely grown throughout the world. Pumpkins are sweet when fully matured with yellow or orange flesh rich in carotene, vitamins, minerals and dietary fibre. Carotenoids are the primary source of vitamin A for most of the people living in developing countries, where vitamin A deficiency is still common. Young children with vitamin A deficiency are usually more susceptible to severe infections, particularly dehydrating diarrhoea, complications from measles, and respiratory infection. An infection usually precedes xerophthalmia, making the child more susceptible to vitamin A deficiency, which eventually leads to blindness. One way to increase vitamin A intake of infants is to incorporate high carotenoid food in their diet. 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 (Usha et al., 2010). The aim of the study was to formulate the extruded product from barley and enhance its suitability in the extrusion process. Barley, low in proteins and other essential nutrients, was mixed with pulses, such as lentil and pumpkin. The barely extrude isnutritionally rich and balanced when formulated with lentil and pumkins.

Materials and methods

The raw materials, such as barley and lentil, were procured at the local market and were ground by a pilot mill (pertan lab mill) into fine powder. The pumpkin procured from the market was also dried in a hot air drier at 70 °C and ground in a mixer grinder (Bajaj mix type) into fine flour. All three flours were sieved through a 200 µm sieve. The proximate composition and bulk density were measured according to Standard AACC procedures (AACC, 2000).

Formulation of the sample

Formulation was done by blending barley, lentil and pumpkin. Pumpkin content was kept constant (7.5%) in all five treatments. Barley content varied from 50-90% and lentil content varied from 1.2-42.5%. All the ingredients were weighed separately and sieved using a 200 mm sieve, mixed and stored for further use.

Extrusion process

The extrusion experiment was performed in a BTPL lab model twin screw extruder. 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. The temperature of first, second and third zone was maintained at 30, 60 and 90 °C respectively, throughout the experiment, while the temperature at the fourth zone was varied to the experimental design.

Physico-chemical characteristics of the extruded products

Specific mechanical energy (SME), bulk density, water solubility index (WSI) and water absorption index (WAI) and lateral expansion were studied by methods described by Pansawat et al. (2008), Patil et al. (2007), Anderson et al. (1969), Stojecska et al., (2009), respectively. Colour was determined using the Hunter Lab Colorimeter (Model SN 3001476, Accuracy Micro Sensors, New York). Breaking strength was determined using a texture analyser (Model TA-TX, Stable Micro systems ltd, UK) equipped with 500 kg load cell (Stojecska et al., 2009). Sensory quality was determined on the basis of appearance, texture, flavour and overall acceptability by a panel of 10 semi- trained judges using a 5-point scale.

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 to optimize the several, and the objective is to optimize this response (Montgomery, 2001). 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 the 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 Table 1.

Results and discussions

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 (50-90% barley flour; 2.5-42.5% lentil flour; 7.5% pumpkin flour), moisture content (13-21%), and barrel temperature (115-155 °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).

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

Independent variables	**code**	**Levels in coded form**				
		-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

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 with the measured data. Adequate precision (signal to noise ratio) greater than 4 is desirable (Table 2). All 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 parameters.

Specific mechanical energy (SME)

The mean values of SME under different extrusion conditions listed in Table 3 ranged between 221.07 to 327.45 whr/kg, with an average value of 268.456 whr/kg. Regression analysis and response surface plots (Fig. 1) showed the negative effect of feed composition and moisture and positive effect of barrel temperature. During the extrusion, the higher the SME, the higher the degree of gelatinization, since mechanical energy favours gelatinization by promoting rupture of intermolecular hydrogen bonds (Gropper et al., 2002).

Table 2. Analysis of variance for the Fit of experimental data to response surface models

Regression	SME (Whr/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 3. Effect of processing conditions on product characteristics of lentil and pumpkin incorporated barley based extrudates

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 (whr/kg) = specific mechanical energy, BD (g/cc) = bulk density WAI (g/g) = water absorption index, WSI (%) = water solubility index, EI = expansion index, hardness (N)

Physical properties of the 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 0.121g/cc. It showed the positive relation of feed composition and moisture content and inverse relation of temperature with bulk density. Similar results were observed by Shivani et al. (2013) which reported that increased feed moisture content during extrusion may reduce the elasticity of the dough through plasticization of the melt, therefore reduced gelatinization increased the density of the extrudate.

Lateral expansion

The mean value of expansion index under different extrusion conditions listed in Table 3 ranged from 37 to 70.8. Regression analysis and response surface plots (Fig. 3 and 4) showed the positive effect of composition and temperature, and negative effect of moisture on the expansion index. Similar results were observed by Omohimi et al. (2013), who reported an appreciable increase in lateral expansion as the barrel temperature increased. High input of thermal energy due to high residence time leads to the creation of the enhanced level of superheated steam, which leads to good expansion which creates flashy and porous structures due to the formation of air cells. When extrusion cooked occurs and came out to exit 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, allowing 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 may increase the water absorption index. Similar results were observed by Shivani et al. (2013), who reported that water absorption index increased with the increase in temperature probably due to the increased dextrinization at higher temperature.

Water solubility index (WSI)

Water solubility index of the extrudates ranged from 0.1 to 0.25%, with an average value of 0.13%. The analysis of variance and response surface plots (Fig. 7 and 8) showed negative influence of feed composition, moisture content and barrel temperature. Vilma et al. (2008) reported that water solubility index (WSI) is used as a measure for starch degradation; it means that at lower WSI, there is a minor degradation of starch and such condition leads to a smaller number of soluble molecules in the extrudates. Higher moisture content in the extrusion process can diminish protein denaturation and starch degradation.

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 (Fig. 9) showed the negative effect of feed composition and moisture content and positive effect of barrel temperature.

Effect of processing conditions on colour coordinates 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 pumpkin incorporation, feed moisture and barrel temperature. None of the models showed significant lack of fit, indicating that all second order polynomial models correlated with the measured data. Adequate precision (signal to noise ratio) greater than 4 is desirable (Table 4). All 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 the product response appeared to be adequate. The predicted *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 the extrudates. The mean values of L*, a* and b* of extrudates, depicted in Table 5, were 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, which is used to evaluate the intensity of the process in terms of chemical and nutritional changes (Ilo et al., 1999). Maillard reaction and caramelization affect the brightness of the extrudates. Colour of the extruded products is influenced by temperature, raw material composition, residence time; pressure and shear force (Guy, 2001).

Table 4. Analysis of variance for the fit of experimental data to response surface models

Regression	L*	a*	b*	Hue angle^o	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 5. Effect of processing conditions on colour coordinates of lentil and pumpkin incorporated barley based extrudates

FC (%) B:L:P	MC (%)	BT (^{o}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 (^{o}C) = barrel temperature, L*value, a*value, b*value, hue angle, chrome; OAA = overall acceptability

Table 6. Scores given by subjective method of evaluation

S. No.	A: Composition (B:L:P) (%)	B: Moisture (%)	C: Barrel temperature (^{o}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

L, a*, and b* values*

The change of the feed composition increases the moisture content and an increase in the barrel temperature increases L* value (Table 5). With the change in the feed composition and increase in the moisture content, a* value increases, whereas increase in the barrel temperature will decrease a* value. The change in the feed composition, increases the moisture content and extrusion temperature increases the b* value of the 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 (Fig. 12 and 13) showed that hue angle increased with an increase in the barrel temperature and decreased with a change in the feed composition and increase in the moisture content. With the change in the feed composition, chrome value increased which might be due to increased temperature and moisture.

Sensory evaluation (overall acceptability)

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

Optimization

Optimization can be defined as the processing conditions that give the optimum value of a function of certain 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 the extruded products. 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 for lentil and pumkin extruded product is presented in Fig. 14. The obtained desirability was 0.975. The optimum barely extrudate was blended with lentil and pumpkin, moisture and barrel temperature were 12.5%, 7.5%, 15% and 125°C respectively.

Table 7. Predicted response levels and actual response levels

Values	SME Wh/kg	Bulk density (kg/m^3)	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

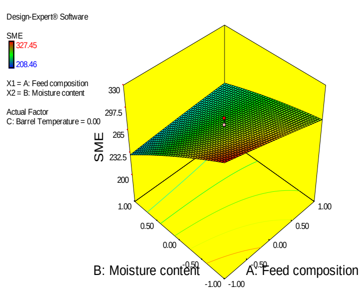

Fig. 1. Effect of feed composition and moisture on SME of lentil and pumpkin incorporated barley extrudates

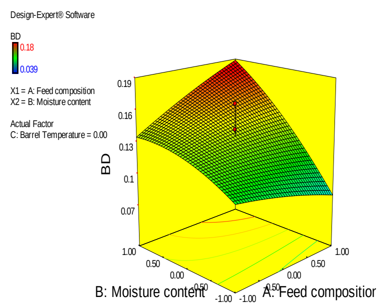

Fig. 2. Effect of feed composition and moisture content on BD of lentil and pumpkin incorporated barley extrudates

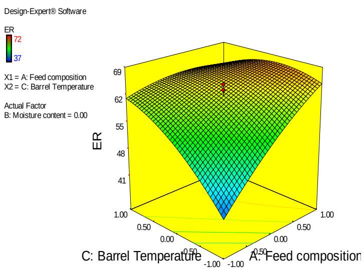

Fig. 3. Effect of feed composition and barrel temperature on lateral expansion of lentil and pumpkin incorporated barley extrudates

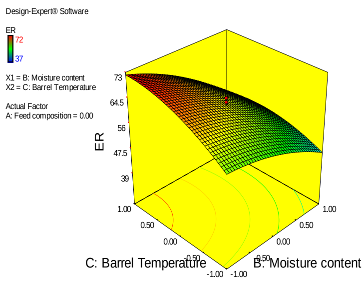

Fig. 4. Effect of moisture content and barrel temperature on lateral expansion of lentil and pumpkin incorporated barley extrudates

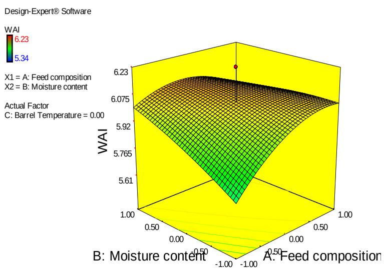

Fig. 5. Effect of feed composition and moisture content on WAI of lentil and pumpkin incorporated barley based extrudates

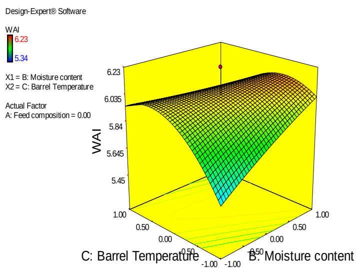

Fig. 6. Effect of moisture content and barrel temperature on WAI of lentil and pumpkin incorporated barley based extrudates

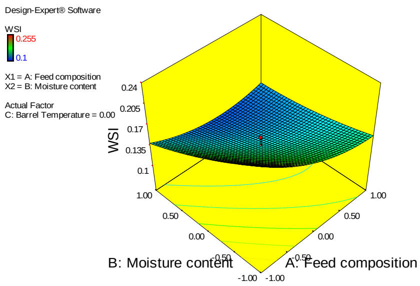

Fig. 7. Effect of feed composition and moisture content on WSI of lentil and pumpkin incorporated barley based extrudates

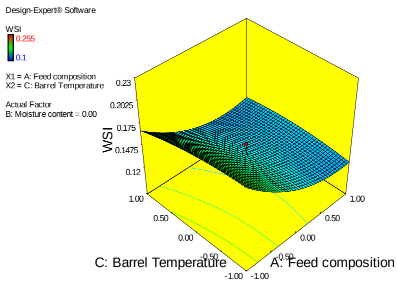

Fig. 8. Effect of feed composition and barrel temperature on WSI of lentil and pumpkin incorporated barley based extrudates

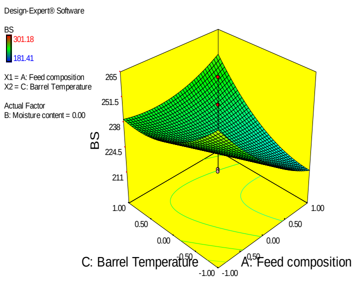

Fig. 9. Effect of feed composition and barrel temperature on breaking strength of lentil and pumpkin incorporated barley extrudates

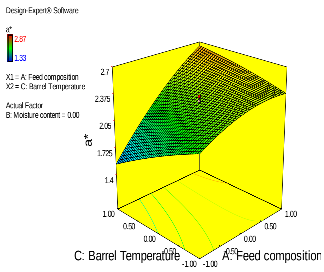

Fig. 10. Effect of feed composition and barrel temperature on a* of lentil and pumpkin incorporated barley extrudates

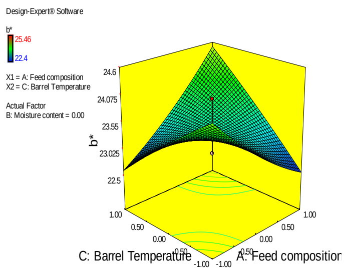

Fig. 11. Effect of feed composition and barrel temperature on b* of lentil and pumpkin incorporated barley extrudates

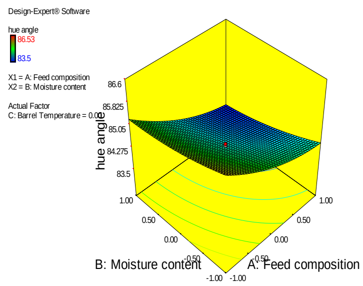

Fig. 12. Effect of feed composition and moisture on hue angle of lentil and pumpkin incorporated barley based extrudates

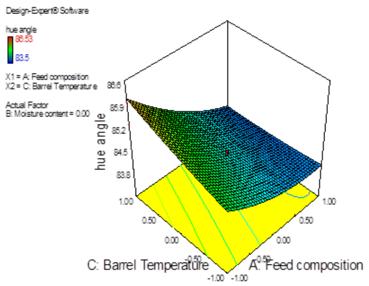

Fig. 13. Effect of feed composition and barrel temperature on hue angle of lentil and pumpkin incorporated barley based extrudates

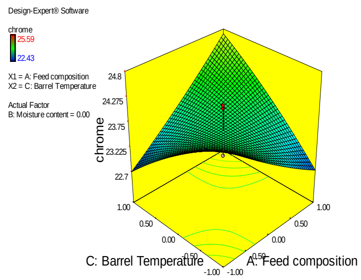

Fig. 14. Effect of feed composition and barrel temperature on chrome of lentil and pumpkin incorporated barley based extrudate

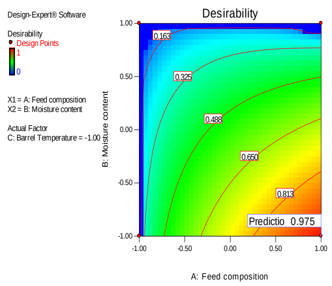

Fig. 15. Desirability function response surface for lentil and pumpkin incorporated barley blended extrudates

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 isa good source of fibre. Twin screw extruder was used for the production of extrudates at varying conditions (feed composition (50-90% barley flour; 2.5-42.5% lentil flour and 7.5% pumpkin flour), moisture content 13-21% and barrel temperature 115-155 °C). Higher moisture content was found to enhance the water absorption index of the extrudates. Lower moisture content had negative effect on bulk density. Lateral expansion of extrudates was found to decrease with the increase in barrel temperature and barley content. An inverse effect of feed composition, barrel temperature and moisture content on water solubility index of extrudates was observed. The colour 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 with a serial number 2 in table 6. Moisture content of the final optimized extruded product was 5.46%, had protein, fat content 1.26%, ash content 2.03% and fibre content 2.42 %.

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