Antioxidant activity and polyphenolic compound stability of lentil-orange peel powder blend in an extrusion process

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Abstract Lentil contains substantial amount of protein, carbohydrate, fibre and other nutrients and orange peels powder rich in carbohydrate and fiber content. The present study was aimed to investigate the effects of extrusion processing parameter on the level of total phenolic content (TPC), total flavonoid content (TFC), total tannin content and antioxidant activity of lentil-orange peel powder blend, also to investigate the possibility of blend as a candidate for production of protein rich extruded product by using response surface methodology. It was observed that, the physicochemical properties and sensory characteristics of lentil-orange peel based extrudate were highly dependent on process variables. The blend of lentil and orange peel powder has a huge potential for extrusion to produce ready-to-eat extruded with good acceptance. The overall best quality product was optimized and obtained at 16% moisture, 150 °C die temperature and 200 rpm screw speed. Extrusion process increased nutritional value of extruded product with TPC and TFC of 70.4 and 67.62% respectively and antioxidant activity of 60.6%. It showed higher stability at 150 °C with intermediate feed moisture content and despite the use of high temperatures in the extrusion-cooking is possible to minimize the loss of bioactive compounds to achieve products. Thus, results indicated that blend of lentil and orange peel may be used as raw

material for the production of extruded snacks with great nutritional value.

Keywords Lentil · Orange peel powder · Total phenolic content · Total flavonoid content · Antioxidant activity · Extrusion

Introduction

Citrus fruits are an important source of antioxidants such as phenolic compounds and flavonoids, which are important to human nutrition (Jayaprakasha et al. 2008). Orange juice is one of the worldwide consumed beverages today. Most of the agricultural output of oranges is used in the preparation of juice and concentrates. Therefore, the cultivation of oranges has become a major industry and an important economic sector in the Mediterranean countries. An orange peel is a byproduct, remains after juice extraction from orange, constitutes about 50–70% of the fresh fruit weight. It is treated as waste from industry with little economic value. For the future, extruded product with high antioxidant value will need to develop high consumer acceptability in the market, highlight the mouthfeel and texture. In view of the nutritional relevance of antioxidant value, it can be modified with extrusion technology.

The lentil is a member of the *leguminosae* family and important traditional dietary components (FAO 1988). Lentils are considered to be a good source of proteins and carbohydrates. High protein content in lentils makes them vital food source for developing countries (Hoover et al. 2010). The low glycemic response and high fiber content of lentils helps to controlling body weight because increasing satiety to reducing the food intake (Mollard et al. 2011). Fascinatingly, lentils showed the maximum total

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antioxidant activity than other pulses, confirmed by Duenas et al. (2006) who observed that lentils had a greater antioxidant activity than peas due to the presence of phenolic compounds which gives antioxidant activity to the lentil.

Extrusion cooking technology is an efficient and versatile method for the production of expanded snacks. Product quality can vary significantly depending on the extrusion processing, such as extruder type, screw configuration, feed moisture, temperature profile of extruder, screw speed and feed rate. Extruded products are popular worldwide for their unique structure and crispy texture. Their acceptability by consumers depends on structural and textural characteristics (Lazou et al. 2010; Patel et al. 2016). Extrusion parameter and feed composition affect structural and textural characteristics of extruded product. The extrusion behavior of protein-starch systems has been reported previously (Ding et al. 2006), but there is still a lack of knowledge of extrudate properties using legume and legume-fruit blends, and especially products obtained from the whole legume. Therefore, the aim of this study was to investigate the effects of extrusion processing and extrusion parameter on the level of TPC, TFC, TTC and antioxidant activity of lentil-orange peel blend extruded product. The present investigations were also carried out to investigate the possibility of lentil and orange peel powder blend as a production of extruded product with high protein.

Materials and methods

Materials

Commercial lentil (*Lens culinaris* Medik) and freshly harvested oranges fruits were purchased from agriculture produce market committee (APMC), Vashi, Mumbai, India. The lentil was cleaned ground to obtain powder and Orange fruits were washed by distilled water then peeled and their edible portions were carefully separated. The peels were air dried in a ventilated oven at 40 °C for 48 h and ground to a fine powder. Then powder passed through 60 mesh sieve to obtain uniform particle size. All the chemicals used for the study were of AR grade.

Methods

Proximate composition

Moisture content, ash content, protein content, fat content, were carried out by AOAC (1980, 2006) and Carbohydrate was calculated by difference. Starch was determined using

the enzymatic method of amylase/amyloglucosidase. Fibre analysis was also done using the enzymatic method (AOAC 1980).

Sample preparation for extrusion process

Blends were prepared by mixing optimized lentil and orange peel powder in the ratios of 100:0, 95:5, 90:5, 85:15 and 80:20 on a dry-to-dry weight basis. These blends were chosen according to preliminary tests without blocking of extruder and for acceptable physical characteristics of product. The blended samples were conditioned to 14–22% (w.b.) moisture by spraying with a calculated amount of water and mixed continuously using a glass rod in a 500 ml beaker. Mixing was carried out for about 5 min. The samples were put in seal pack polyethylene bag and stored at 4 °C overnight and allowed to equilibrate for 24 h before extrusion process.

Extrusion process

Blend of lentil flour and orange peels powder was extruded in a co-rotating twin screw extruder (KETSE 20/40 Brabender GmbH and Co. KG, Duisburg, Germany) with four independent heating zones. The die diameter was 4 mm and feed rate was kept constant at 16 rpm (20.4 kg/h). The temperature during extrusion was adjusted according to the experimental design by using electric heaters. Extrudates were produced using temperatures in the range of 130–170 °C and three levels of screw speeds (150, 200 and 250 rpm). Temperatures for different zone were Conveying zone (85, 105 and 125 °C), Mixing zone (100, 120 and 140 °C), Cooking zone (115, 135 and 155 °C), High pressure zone (die) (130, 150 and 170 °C). The extrudates were cooled to room temperature, dried in tray dryer at 45 °C for 2 h, packed in polyethylene bags and stored in a desiccator till further analysis (Rathod and Annapure 2015).

Experimental design

The response surface methodology was applied using a central composite design (CCD) for three independent variables (Barros-Neto et al. 2010), namely: the moisture content of the raw material, the extrusion temperature (die temperature) and the screw speed. The dependent variables used were the overall expansion, bulk density (BD), water soluble index, water absorption index and hardness for each compound individually and in total for all the compounds. Twenty tests were performed: eight tests of factorial points (2^3) (three levels for each factor), six axial points (two for each variable) and six repetitions of the central point (Table 1).

Table 1 Variables and their levels employed in central composite design

Experiment	Feed moisture content (X1)		Die temperature (X2)		Screw speed (X3)	
	Coded value	Uncoded value	Coded value	Uncoded value	Coded value	Uncoded value
1	−1	12	−1	130	−1	150
2	1	20	−1	130	−1	150
3	−1	12	1	170	−1	150
4	1	20	1	170	−1	150
5	−1	12	−1	130	1	250
6	1	20	−1	130	1	250
7	−1	12	1	170	1	250
8	1	20	1	170	1	250
9	−1.68	9.27	0	150	0	200
10	1.68	22.73	0	150	0	200
11	0	16	−1.68	116.36	0	200
12	0	16	1.68	183.63	0	200
13	0	16	0	150	−1.68	115.91
14	0	16	0	150	1.68	284.09
15–20	0	16	0	150	0	200

The results from the dependent variables were subjected to multiple regression analysis using design expert software 7.0.0 full version (Stat-Ease, Minneapolis, USA) and coefficients with *p* values below 0.05 were considered significant. Linear and quadratic models were tested to explain the influence of independent variables on the response variables, because in Response Surface Methodology, the relationship between these variables is unknown and, therefore, it is necessary to find an adequate approximation to the true relationship between the response and the independent variables.

Overall expansion

Overall expansion was calculated as the ratio of bulk (apparent) specific volume and true specific volume (Rathod and Annapure 2015).

Bulk specific volume = 1/Bulk density

True specific volume = 1/True density

Bulk density

BD was determined from 10 random measurements on the diameter (*D*, cm) and length (*L*, cm) of the extrudates using digital calipers, and the weight (*m*, g) was determined on an analytical balance. BD was obtained from following formula (Ding et al. 2005; Rathod and Annapure 2015),

$$\text{Bulk Density} = 4 \times m / (\pi D^2 L)$$

Expansion index (EI)

The diameters of 10 extruded products were measured using Vernier calipers (Absolute Digimatic Caliper, Series-500, Innox, Japan). Expansion index of the samples was determined by dividing the average diameter of the products by the diameter of the die nozzle (Ding et al. 2005; Rathod and Annapure 2015).

Porosity

The porosity of extrudates was determined from the bulk and apparent volumes. Porosity was calculated using the equation (Rathod and Annapure 2015):

$$\text{Porosity} = (\text{Bulk volume} - \text{Apparent volume}) / \text{Bulk volume}$$

where, Bulk volume = $(1/\rho_b)$ and Apparent volume = $(1/\rho_s)$

Water solubility index (WSI) and water absorption index (WAI)

Extrudates were ground to powder and passed through the 60 mesh sieve for uniform size distribution. 2.5 g ground powder was suspended in 25 ml water at room temperature for 30 min, with intermediate stirring and then centrifuged

at $3000\times g$ for 15 min. The supernatant was decanted into the reweighed evaporating dish and water was evaporated till constant weight to get dry solids. The WSI is the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample where as WAI is the weight of residue obtained after removal of the supernatant per unit weight of original dry solids (Ding et al. 2005; Rathod and Annapure 2016).

Hardness

Hardness of the extrudate was determined using a Stable Micro System TAXT2i texture analyzer (Serial No. 4650, TEE version no. 2.64 UK). 2 mm cylindrical probe was set to move at a test speed of 3 mm/s for a distance of 50 mm from the sample and penetrate about 5 mm in sample. Maximum force needed to break the sample was recorded and analysed by Texture Exponent software associated with the texture analyser. Measurements are reported as an average of all replicates (Rathod and Annapure 2015).

Sensory analysis

Ten trained students from food engineering department evaluated the extruded snacks for appearance, flavor, texture, taste and overall acceptability in triplicate. Panelists were instructed to eat and swallow each sample and rate the intensity of each attribute using a nine-point scale (ISO 8589:2007). The sessions were performed on the same day (with a minimum 2-h break between the sessions) at the sensory laboratory of the Food Engineering and Technology Department (Mumbai, India) designed in accordance with ISO guidelines (ISO 2007). Assessors were asked not to smoke, eat or drink anything, except water, at least 1 h before the tasting sessions. For each sample, panelists received a sample served in plate coded with a digit number. Participants were provided with mineral water to clean their mouth between tastings. Presentation orders were systematically varied over assessors and replicates in order to balance the effects of serving order and carryover (Sharma et al. 2016; Rathod and Annapure 2015).

Antioxidant activity assay

0.4 g ground lentil-orange blend extrudate samples were extracted by 5 ml methanol: water (80:20 v/v) solution with stirring at room temperature for 5 min, and then placed in a shaking constant temperature water bath at 80 °C and 150 rpm for 2 h. after that centrifuged at $3000\times g$ for 10 min to obtain the supernatant. Same procedure repeated twice with residues under the same conditions and the supernatant collected, combined, filtered

using Whatman No. 1 filter paper, and then concentrated to dryness under reduced pressure using a rotary evaporator (Eyela, N–N series, Tokyo, Japan) at 50 °C. After concentration, the extracts were used for analysis of tannin content, total phenolic content, total flavonoid content and DPPH-scavenging activity (Obiang-Obounou and Ryu 2013).

Determination of total polyphenols content (TPC)

The total polyphenols were determined colorimetrically using Folin-Ciocalteu reagent according to the method described by Ebrahimzadeh et al. (2008a). The extract samples (0.5 ml different dilutions) were mixed with Folin-Ciocalteu reagent (5 ml with distilled water by rate 1:10) for 5 min and 4 ml aqueous Na_2CO_3 (1 M) were added. The mixture was place for 15 min and the polyphenols were determined by an automated UV–Vis spectrophotometer at 765 nm. The standard curve was prepared by 0, 50, 100, 150, 200 and 250 mg/ml solutions of gallic acid in methanol: water (50:50 v/v).

Determination of total flavonoid content (TFC)

Colorimetric aluminum chloride method was used for flavonoids determination according to the methods described by Calabro et al. (2004) and Ebrahimzadeh et al. (2008b). 0.5 ml solution of extrudate extracts was mixed with 1.5 ml methanol, 0.1 ml of 10% aluminum chloride, 0.1 ml of 1 M potassium acetate and 2.8 ml distilled water and stand at room temperature for 30 min. The absorbance was measured at 415 nm with a double beam UV–Vis spectrophotometer. Total flavonoid contents were calculated as quercetin from a calibration curve, which prepared by preparing quercetin solutions at concentrations 12.5–100 mg/ml in methanol.

Determination of total tannin content (TTC)

Finely grounded lentil-orange peel extrudate sample was weighed (0.2 g) into a 50 ml sample conical flask. Ten of 70% aqueous acetone was added and properly covered. The conical flask was put in an ice bath shaker and shaken for 2 h at 300 °C. Then centrifuged and the supernatant stored in ice. 0.2 ml of the solution was pipette out into the test tube and 0.8 ml of distilled water was added. Standard tannin acid solution was prepared from a 0.5 mg/ml of the stock and the solution made up to 1 ml with distilled water. 0.5 ml of Folin-Ciocalteu's reagent was added to the sample and standard followed by 2.5 ml of 20% Na_2CO_3 . Solution was then vortexed and allows incubating for 40 min at room temperature; absorbance was measured at 725 nm against a reagent blank concentration of the same

Table 2 Lentil-orange peel powder blend optimization at optimum conditions 12% moisture content, 150 °C die temperature and 200 rpm screw speed

LF:OPP	Bulk density	Overall expansion	Expansion index	Porosity	WSI	WAI	Hardness	Sensory score
95:5	0.2081 ± 0.06	3.02 ± 0.11	2.86 ± 0.10	68.32 ± 1.64	39.2 ± 0.62	4.24 ± 0.16	1402.6 ± 24.2	7.4 ± 0.14
90:10	0.1824 ± 0.09	3.52 ± 0.19	2.96 ± 0.13	70.64 ± 1.8	41.6 ± 0.58	4.08 ± 0.12	1428.6 ± 36.8	7.3 ± 0.07
85:15	0.1768 ± 0.14	3.76 ± 0.21	3.17 ± 0.12	74.50 ± 2.20	44.8 ± 0.94	4.18 ± 0.19	1424.5 ± 32.4	7.8 ± 0.12
80:20	0.2254 ± 0.16	2.6 ± 0.10	3.03 ± 0.08	71.40 ± 2.26	40.2 ± 1.18	3.78 ± 0.14	1564.2 ± 48.2	6.8 ± 0.09
75:25	0.2432 ± 0.12	2.06 ± 0.15	2.74 ± 0.11	58.94 ± 1.16	34.4 ± 0.56	4.44 ± 0.09	1646.8 ± 42.6	6.2 ± 0.11

All the values are mean ± SD of three individual determinations

solution from a standard tannic acid curve prepared (Rathod and Annapure 2015).

DPPH radical-scavenging activity

Free radical scavenging capacity of lentil-orange peel raw and extrudate extracts was determined according to the previous reported procedure using the stable 2, 2-diphenyl-1-picrylhydrazyl radical (DPPH) as described by Loganayaki et al. (2013) and Kedare and Singh (2011). A freshly prepared DPPH solution in 0.5 ml ethanol were added to 3 ml of diluted each orange peel extract to start the radical antioxidant reaction. The final concentration was 100 µM for DPPH. The decrease in absorbance was measured at different intervals (i.e. 0, 0.5, 1, 3, 5, 10 and 15 min.) at 517 nm. The remaining concentration of DPPH was calculated from a standard calibration curve. The absorbance measured at 5 min of the antioxidant-DPPH radical reaction was used to compare the DPPH radical scavenging capacity of each extract.

Statistical analysis

The response surface methodology Design-Expert 6.0.10 software (Stat-Ease 2003) was applied using a central composite design (CCD) for three independent variables. The results were expressed as a mean (±SD) for each analysis. The comparative statistical analysis between means with ANOVA was calculated to assess the significant differences between treatments.

Results and discussion

Proximate composition

Lentil and orange peel, respectively contained 1.03 and 0.55% of fat, 23.86 and 3.28% of protein, 65.52 and 24.08% of carbohydrate, 54.78 and 18.26% of starch, 9.06

and 67.75% of moisture, 10.84 and 63.48% of total fiber and 0.53 and 4.34% of ash content.

Optimization of blend sample

Blends for lentil and orange peel (100:0, 95:5, 90:5, 85:15 and 80:20 on a dry-to-dry weight basis) were processed in twin screw extruder. Table 2, it was observed that the blend of lentil and orange peel (85:15) was optimized and extrudates were evaluated for physicochemical and sensory properties.

Overall expansion (OE) and bulk density (BD)

The overall expansion and BD of extrudates indicated the degree of puffing. High density product showed the uniform and continuous protein matrix therefore the extrudate were dense with no air pockets and did not become spongy upon hydration (Ghumman et al. 2016; Rathod and Annapure 2015). BD increased with increase in moisture content and screw speed. It was due to the increase in moisture content which brought about an increase in the BD while reduction in protein decreased the BD. Further, it was observed that when barrel temperature increased gradually, the BD of extrudate decreased and overall expansion increased. This may be because the high barrel temperature evaporated more moisture and reduced BD. This could be due to the effect of high temperatures on viscosity and starch degradation resulting in less expansion. Similar results were reported by Koksel et al. (2004).

From ANOVA, it was observed that the process variables had a significant influence on the physical properties of extrudate ($p < 0.05$). The feed moisture (A) and die temperature (B) showed the highest effect and on the expansion ($p \leq 0.0104$) and inverse significant effect on BD ($p \leq 0.0012$) of extrudate as well as feed moisture (A) and screw speed (C) had significant effect on the extrudate OE ($p \leq 0.0398$). A high OE is desirable in a production of expanded snacks. The measured OE and BD of the

Design-Expert® Software

Overall Expansion

3.76557
1.28068X1 = A: Moisture
X2 = B: Die TemperatureActual Factor
C: Screw Speed = 200.00

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Bulk Density

0.513132
0.161329X1 = A: Moisture
X2 = B: Die TemperatureActual Factor
C: Screw Speed = 200.00

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Expansion Index

3.16667
1.1X1 = A: Moisture
X2 = B: Die TemperatureActual Factor
C: Screw Speed = 200.00

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Porosity

74.5083
15.067X1 = A: Moisture
X2 = B: Die TemperatureActual Factor
C: Screw Speed = 200.00

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WAI

4.184
2.15333X1 = A: Moisture
X2 = B: Die TemperatureActual Factor
C: Screw Speed = 200.00

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WSI

44.8
11.8667X1 = A: Moisture
X2 = B: Die TemperatureActual Factor
C: Screw Speed = 200.00

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Hardness

2890.86
1420X1 = A: Moisture
X2 = B: Die TemperatureActual Factor
C: Screw Speed = 200.00

Fig. 1 3D surface plots for effect of moisture and die temperature on extrudate properties as overall expansion (a), bulk density (b), expansion index (c), porosity (d), WAI (e), WSI (f) and hardness (g)

extrudates varied between 1.28–3.76 and 0.1613–0.5131 respectively as shown in Fig. 1a, b. Response model equations with R^2 for OE and BD are 0.9710, 0.9533 respectively are,

$$\begin{aligned}\text{Overall expansion} = & +3.76 + 0.22 * A + 0.29 * B \\ & - 0.015 * C - 0.23 * A * B \\ & + 0.17 * A * C - 0.091 * B * C \\ & - 0.51 * A^2 - 0.78 * B^2 - 0.19 * C^2\end{aligned}$$

$$\begin{aligned}\text{Bulkdensity} = & +0.18 - 0.016 * A - 0.045 * B - 5.739E \\ & - 003 * C + 0.060 * A * B \\ & - 7.550E - 003 * A * C - 0.023 * B * C \\ & + 0.067 * A^2 + 0.11 * B^2 - 4.990E - 004 * C^2\end{aligned}$$

Expansion index (EI)

Expansion Index is an important physical attribute for the extruded snacks that significantly affected consumer acceptability. As moisture content increased (with increasing protein content and decreasing starch), the EI decreased. Further, it was observed that when barrel temperature and screw speed increased, EI increased (Ghumman et al. 2016; Rathod and Annapure 2016). This may be due to a reduction in viscosity, which resulted in less mechanical damage to starch, thus enabling dough to expand more and at faster rate. Starch became fully cooked at higher temperature, thus better able to expand (Kaur et al. 2015). This was consistent with results reported by Ding et al. (2006).

Figure 1c showed the effect of moisture and die temperature on EI. Die temperature is one of the most important factors that contribute to starch modification during extrusion although excessive starch degradation decreases expansion (Rathod and Annapure 2015). From the ANOVA it was observed that, the feed moisture (A) and die temperature (B) had most significant effect on the EI ($p \leq 0.0001$) of extrudate as well as feed moisture (A), screw speed (C) ($p \leq 0.0009$) and die temperature (B), screw speed (C) ($p \leq 0.0367$) showed significant effect on EI. The measured EI of lentil extrudates varied from 1.1 to 3.16. Response model equation with R^2 (0.9942) is,

$$\begin{aligned}\text{Expansion Index} = & +3.17 + 0.20 * A + 0.22 * B - 0.063 * C \\ & - 0.17 * A * B + 0.11 * A * C \\ & + 0.059 * B * C - 0.31 * A^2 \\ & - 0.61 * B^2 - 0.17 * C^2\end{aligned}$$

Porosity

Porosity of extrudates decreased with decrease in die temperature and increase in feed moisture content as shown in Fig. 1d. Process conditions and material composition influenced the porosity, in contrast with the expansion ratio that revealed the same behavior as reported by Rathod and Annapure 2016.

From ANOVA, it was observed that the process variables, singularly or in combination, had a significant influence on the physical properties of extrudate ($p < 0.05$). The feed moisture (A) and screw speed (C) the most significant effect on the porosity ($p \leq 0.0211$) while feed moisture (A) and die temperature (B) had significant effect on the extrudate porosity ($p \leq 0.0334$). Response model equation with R^2 (0.9638) is,

$$\begin{aligned}\text{Porosity} = & +74.40 + 5.18 * A + 6.74 * B + 0.067 * C \\ & - 4.67 * A * B + 5.17 * A * C - 3.45 * B * C \\ & - 10.84 * A^2 - 18.60 * B^2 - 1.97 * C^2\end{aligned}$$

Water absorption index (WAI) and water solubility index (WSI)

The result showed that an increase in moisture (A) and die temperature (B) was significant at $p < 0.01$ and the screw speed led to a decrease in WAI. The die temperature (B) and screw speed (C) had significant effect on the porosity ($p \leq 0.02$). WAI of the extrudates was in the range of 2.15–4.18 as shown in Fig. 1e with R^2 (0.9921). The corresponding second-order response model equation is,

$$\begin{aligned}\text{WAI} = & +4.18 + 0.086 * A + 0.11 * B + 0.026 * C \\ & + 0.034 * A * B + 0.040 * A * C + 0.100 * B * C \\ & - 0.64 * A^2 - 0.70 * B^2 - 0.39 * C^2\end{aligned}$$

From the ANOVA, It was observed that the die temperature (B) and screw speed (C) had the most significant effect on the WSI of extrudates $p \leq 0.02$. And the moisture content (A) and die temperature (B) ($p \leq 0.02$) as well as the moisture content (A) and screw speed (C) ($p \leq 0.04$) had significant effect on the WSI of extrudate. The

extrudates exhibited WSI in the range of 11.86–44.8% shown in Fig. 1f.

Response model equation with R^2 (0.9812) is,

$$\begin{aligned} \text{WSI} = & +44.72 + 2.23 * A + 3.15 * B - 0.94 * C \\ & - 1.98 * A * B + 1.70 * A * C \\ & + 2.08 * B * C - 6.44 * A^2 - 9.84 * B^2 - 3.62 * C^2 \end{aligned}$$

Table 3 Predicted and experimental values of the responses at optimum conditions 16% moisture content, 150 °C die temperature and 200 rpm screw speed

Responses	Predicted value	Experimental value ^a
Overall expansion	3.76	3.77 ± 0.10
Bulk density	0.1762	0.1769 ± 0.01
Expansion index	3.15	3.17 ± 0.08
Porosity	74.40	74.51 ± 1.26
WSI	44.76	44.8 ± 0.16
WAI	4.14	4.18 ± 0.21
Hardness	1408	1420 ± 24.0

^a All the values are mean ± SD of ten individual determinations

Hardness

Result showed that, hardness of extrudates increased with increase in feed moisture at low die temperature while it decreased with increase in feed moisture content at higher die temperature (Rathod et al. 2016). Extrudates with low density with higher overall expansion had lower hardness. From the ANOVA it was observed that, die temperature (B) ($p < 0.0099$) was found to have the most significant effect on hardness of extrudates. The die temperature (B) and screw speed (C) had the most significant effect on the WSI of extrudates ($p \leq 0.0001$). Hardness of extrudates ranged from 1420 to 2890.86 (Fig. 1g). Response model equation with R^2 (0.9921) is,

$$\begin{aligned} \text{Hardness} = & +1417.65 + 43.26 * A - 59.18 * B \\ & - 0.22 * C - 7.20 * A * B - 13.09 * A * C \\ & - 171.06 * B * C + 422.56 * A^2 + 483.59 * B^2 \\ & + 204.45 * C^2 \end{aligned}$$

Verification of results

The suitability of the model developed for predicting the optimum response values was tested using the

Table 4 TPC, TFC, TTC and antioxidant activity of raw lentil: orange peel powder blend sample and extrudates made from blend sample using different extrusion temperature and feed moisture

Extrusion temperature (°C)	Feed moisture (%)	TPC (mg GAE/g)	TFC (QE mg/g)	TTC (mg eq.cat/100 g dry matter)	Antioxidant activity (%)
130	12	39.76 ± 0.2 (84.9%)	159.11 ± 0.04 (79.2%)	51.4 ± 0.04 (6.92%)	94.1 ± 0.8
	16	40.01 ± 0.24 (85.4%)	160.48 ± 0.01 (79.88%)	49.02 ± 0.01 (6.6%)	93.8 ± 0.13
	20	40.38 ± 0.01 (86.2%)	161.88 ± 0.02 (80.58%)	46.65 ± 0.02 (6.28%)	93.6 ± 0.12
150	12	35.78 ± 0.3 (76.38%)	147.62 ± 0.01 (73.48%)	31.34 ± 0.01 (4.26%)	84.7 ± 0.6
	16	36.05 ± 0.2 (76.94%)	148.55 ± 0.03 (73.94%)	30.01 ± 0.03 (4.04%)	84.5 ± 0.16
	20	36.27 ± 0.3 (77.42%)	149.27 ± 0.01 (74.3%)	27.63 ± 0.01 (3.72%)	84.2 ± 0.11
170	12	32.85 ± 0.2 (70.12%)	134.1 ± 0.01 (66.75%)	15.82 ± 0.01 (2.12%)	61.12 ± 0.1
	16	32.98 ± 0.2 (70.4%)	134.78 ± 0.02 (67.09%)	14.26 ± 0.02 (1.92%)	60.9 ± 0.09
	20	33.17 ± 0.12 (70.8%)	135.85 ± 0.02 (67.62%)	8.69 ± 0.02 (1.17%)	60.6 ± 0.4
Lentil: orange peel powder (control)		46.85 ± 0.64	200.9 ± 1.6	742.8 ± 2.8	95.6 ± 0.7

All the values are mean ± SD of three individual determinations. Figures in the parenthesis indicate % TPC, TFC, TTC and antioxidant activity. Whereas, *TPC* total phenolic content, *TFC* total flavonoid content, *TTC* total tannin content

Table 5 Sensory results for lentil-based extrudates

Trial no.	Appearance	Taste	Flavor	Texture	Overall acceptability
1	7.09 ± 0.11	6.62 ± 0.13	7.24 ± 0.08	7.09 ± 0.16	7.01 ± 0.14
4	6.59 ± 0.12	6.84 ± 0.18	7.19 ± 0.19	7.14 ± 0.20	6.94 ± 0.11
7	7.58 ± 0.14	7.22 ± 0.11	7.26 ± 0.22	7.30 ± 0.17	7.34 ± 0.13
11	5.49 ± 0.10	5.9 ± 0.21	7.12 ± 0.27	5.13 ± 0.09	5.91 ± 0.10
15	8.06 ± 0.16	7.80 ± 0.18	7.54 ± 0.23	7.88 ± 0.12	7.82 ± 0.11

All the values are mean ± SD of ten individual determinations

recommended optimum conditions of the variables and was also used to validate experimental and predicted values of the responses. Table 3 shows the predicted and experimental values of the responses at optimum conditions.

Total phenolic, flavonoid and tannin contents

Lentil-orange peels extrudates were an excellent source of phenolic compounds as shown in Table 4 compared to raw lentil-orange peel powder. Gallic acid is a strong antioxidant, antimutagenic and anticarcinogenic agent (Sun et al. 2014), and high content in blend extrudates renders it attractive. American Cancer Society recommends a 100 mg flavonoid contents per day as a sufficient amount for the prevention of cancer and degenerative illness (Upadhyay et al. 2015; Obiang-Obounou and Ryu 2013). From the result it was observed that TPC and TFC was remained stable up to 70.8 and 67.72% respectively. Also increase in temperature negatively affected the total phenolic compound, this may have undergone decarboxylation at higher temperature and may promoted polymerization of polyphenolic compound which led to reduced extractability and antioxidant activity (Brennan et al. 2011). However, in the actual study, the level of bioactive compounds in extruded products increased with thermal and mechanical extrusion process (Zielinski et al. 2001; Obiang-Obounou and Ryu 2013). Similar result were observed, which showed that an increase in moisture content positively affected the total phenolic content. Increase in moisture content with high temperature in extrusion process reduced polyphenolic compound as compare to other thermal processes due to short time process. Therefore lentil-orange peel blend extrudates were an excellent source of polyphenols with sensorial acceptance.

Antioxidant properties

The antioxidant activity of raw material and extrudate were evaluated through DPPH radical scavenging activity showed in Table 4. Results revealed that radical-scavenging activity of raw to extrudate reduced from 95.6 to 60.6% at selected extrusion conditions that means antioxidant activity remained stable up to 60.6% during extrusion

process. Extrusion process significantly increased the antioxidant properties of lentil-orange extrudate. High Phenolics are mostly recommended in food industry to improve the quality and nutritional value of food by retarding oxidative degradation of lipids (Srivastava and Chaturvedi 2008; Obiang-Obounou and Ryu 2013). From the result it was also observed that an increase in moisture content and extrusion temperature reduced antioxidant activity.

Sensory evaluation

The sensory scores for overall acceptance obtained for lentil-orange peel powder blend extrudates were 7.01, 6.94, 7.34, 5.91 and 7.82 for runs (12%, 130 °C, 150 rpm), (20%, 170 °C, 150 rpm), (12%, 170 °C, 250 rpm), (16%, 116 °C, 200 rpm) and (16%, 150 °C, 200 rpm) respectively which was summarized in Table 5. From these outcomes, it is clear that extrudates with good sensory acceptability can be produced from blend of lentil and orange peel powder. Extrudate with moisture content of 16% with a die temperature of 150 °C at 200 rpm was found to be most acceptable using both sensory evaluation and statistical analysis.

Conclusion

The present investigation showed the effect of extrusion processing on polyphenolic compound stability. Antioxidant activity of extruded products made from blend of lentil and orange peel powder was not affected significantly by the extrusion process. Further, it was revealed that the blend of lentil and orange peel powder has a huge potential for extrusion to produce ready-to-eat extruded with good acceptance. The physicochemical properties and sensory characteristics of lentil-orange peel based extrudate were highly dependent on process variables, feed moisture content, die temperature and screw speed. RSM was used to found the correlation between these process variables, and physical properties of extruded product. It was proved that extrusion process increased nutritional value of extruded product with sustaining Polyphenolic component.

The overall best quality product was optimized and obtained at 16% moisture, 150 °C die temperature and 200 rpm screw speed. The sensory evaluation showed that the optimized extrudate was the most acceptable. Thus, results indicate that blend of lentil and orange peel may be the good candidate to be used as an industrial raw material for the production of extruded snacks with great nutritional value.

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