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Full Research Article

Response Surface Methodology for Development and Characterization of Extruded Snack Developed from Food-by-products

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Abstract

The aim of the present study was to optimize the extrusion process for pineapple-based snacks using response surface modelling approach. A blend of pineapple waste pulp powder (0–20%), broken rice (0–80%) and pigeon pea (0–20%) were extruded in a twin-screw extruder. The effects of feed moisture, barrel temperature, screw speed on product responses viz., specific mechanical energy (SME), bulk density (BD), water absorption index (WAI), water solubility index (WSI), hardness and expansion ratio (ER) was studied using response surface methodology. The formulation was extruded at different moisture content (14–18%), screw speed (400–550 rpm) and die temperature (120–180 °C). The extrudates developed under optimized conditions contains 5.27% of moisture wb, 4.96% of protein, 3.05% of fibre, 2.18% of ash and colour L-value of 66.18, a-value of 1.91, b-value of 16.71. Feed moisture had significant effect on all products responses, whereas pineapple pomace level and barrel temperature, both independent variables, had significant effect on SME, WSI and hardness of the product. Increase in feed moisture reduces SME and WSI and increases BD, WAI and hardness. Increase in pineapple pomace level decreases the BD, WAI and hardness of the snacks, whereas increase in barrel temperature decreases the SME, BD, WAI and hardness but increases the WSI. Optimized extrusion parameters for preparation of snacks were 17.16% moisture, 120° temperature and 6% pineapple pomace powder.

1. Introduction

Fruit and vegetable wastes are inexpensive, available in large quantities, characterized by a high dietary fibre content resulting with high water binding capacity (Serena and Kundsen 2007). Several researchers have used fruits and vegetable by-products viz., apple, pear, orange, peach, blackcurrant, cherry, artichoke, asparagus, onion, carrot pomace (Grigelmo-Miguel and Martin-Belloso, 1999; Ng et al., 1999; Nawirska and Kwasnievska, 2004) as sources of dietary fibre supplements in refined food. Dietary fiber consumption prevents some health problems such as diverticular disease, cardiovascular disease and colorectal cancer (Martinez-Flores et al., 2008). For this reason, dietary fiber becomes the 3rd most sought after health information in supermarkets in countries like India, Australia, Western Europe and North America (Mehta, 2005).

Rice flour has become an attractive ingredient in the extrusion industry due to its unique attributes such as bland taste, attractive white colour and ease of digestion (Kadan et al., 2003). The basic investigation of extrusion variables on properties of rice extrudate is still in need, though there have been some reports on rice flour mixed with other ingredients (Ilo et al., 1999; Mouquet et al., 2003). The main by-products of rice mills are rice broken, husk and bran, do not have mass acceptability in the country. Broken rice, possibly due to non-availability of technology for its conversion to value added products are used in flour form in traditional recipes or used as animal feed.

Red gram is the second largest pulse crop in India accounting about 20% of total pulse production. It is a protein rich pulse and contains about 22% protein, which is almost three times that of cereals. Pulse powder is a by-product of milling process which has a high protein content (22%) like *dal* (an Indian dish) and easily available at relatively lower cost as compared to red gram pea *dal*.

The pineapple (*Annanus comusus*) mainly processed in to canned products is processed into various products such as jam, jelly, beverage and concentrate, which produced a large amount of solid waste such as skin, core and residual pulp. This waste in generally has been dumped into the environment and consequently, caused the environment problem as water and air pollution. This is mainly due to the selection and elimination of components unsuitable for human consumption. Besides, rough handling of fruits and exposure to adverse environmental conditions during transportation and storage can cause upto 55% of product waste (Nunes et al., 2009).

Extruded snacks available in the Indian market are generally made from cereal flours and having high carbohydrate and fat contents while lower protein content. Now-a-days, consumer demand for natural and functional foods has been growing. Response surface methodology (RSM) is a statistical method used to describe the relationship between process variables and product quality characteristics (Giovanni, 1983). RSM is effectively used in several extrusion studies to relate the product characteristics to extrusion variables (Chen et al., 1991; Park et al., 1993; Altan et al., 2008; Pansawat et al., 2008; Aylin et al., 2008; Altan et al., 2009). In advance to this, the conversion of this by-product into fiber-rich extruded snack food by the application of novel and versatile technique of extrusion can be very useful both in terms of economic point of view and health benefits. The incorporation of cauliflower trimmings, tomato and grape pomace, and carrot pomace were reported by Upadhyay et al. (2008); Stojceska et al. (2008); Altan et al. (2008a, b); Kumar et al. (2010a, b) respectively. Limited information is available on extrusion processing of pineapple by-products. So, the present study was undergone to optimized the process parameters i.e. barrel temperature, pineapple pomace powder level and the moisture content for extrusion.

2. Materials and Methods

2.1. Raw materials

Ingredients comprised of rice flour (prepared from the rice broken procured from the local market Ludhiana, Punjab, India), pulse powder (a by-product from the pulse mill) and pineapple pomace obtained from pineapple (variety:*Kew*) available at local market in Ludhiana, Punjab, India was chosen for the experimental study. The experiment was conducted during the month of February, 2015.

2.2. Juice extraction

The pineapples were washed in a running tap water two times and leafy top were removed by twisting off with hands. Then it was set aside, using a plane stainless steel knife, eyes were removed then the fruit and trimmed to remove extra hard material. The juice was extracted using a grinder (Make:Sujata 750 W) to extract pineapple juice. The pineapple waste pulp was collected for further studies.

2.3. Dry pineapple pomace powder preparation

The pomace left after pineapple juice extracted was pre-treated with 1% w/v citric acid. The pre-treated pomace was then kept in a tray dryer at 65 °C to bring the desired moisture content of dried pineapple pomace to 6.0% d.b. The dried pomace was ground to powder using the same grinder (Make:Sujata 750 W). The pomace powder was stored in sealed laminated aluminium films for further use.

2.4. Sample preparation

Rice flour (R) was replaced with pulse powder (P) at levels from 6–20%. In each sample, Pineapple Pomace (PP) was added at the level from 6–20%. Composite flour (500 gm) was prepared for each sample. 3% salt was added to each sample to enhance the taste of the product. After mixing, samples were stored in polyethylene bags at refrigerated temperature for 24 h (Stojceska et al., 2008). The moisture content of all the samples was determined after preparation by halogen moisture analyzer (Make:Mettler Toledo, HR83 Halogen) prior to extrusion experiments.

2.5. Extrusion process

Extrusion experiments were performed on a co-rotating intermeshing twin screw extruder Model BC 21 (Clextral, Firminy, France). The barrel diameter and its length to diameter ratio (L/D) were 2.5 mm and 16:1, respectively. The extruder was powered by an 8.5 kW motor with speeds variable from 0 to 682 rpm. The extruder was equipped with a torque indicator, which showed percent of torque in proportion to the current drawn by the drive motor. The moisture content of the feed was adjusted by injecting water (approximately 30 °C) into the extruder with a pump. A variable speed die cutter with four bladed knives was used to cut the extrudates.

2.6. Product properties

2.6.1. Expansion ratio

The ratio of diameter of extrudate to the diameter of die was used to express the expansion of extrudate (Kollengode, 1996). Six lengths of extrudate (approximately 60 mm) was selected at random during the collection of 15 each of the extruded samples, and allowed to cool to room temperature. The diameter of the extrudates was then measured, at 10 different positions along the length of each of the six samples, using a vernier caliper. Expansion Ratio (ER, %) was then calculated using the mean of the measured diameters:

$$ER\ (\%)=\frac{\text{Diameter of product-diameter of die hole}}{\text{Diameter of die hole}}\times 100$$

2.6.2. Density

Density is defined as the mass of solid particles of the material divided by the total volume they occupy. The total volume includes particle volume, inter-particle void volume and internal pore volume. Density is not an intrinsic property of a material; in can change depending on how the material is handled. Density ($g\ m^{-3}$) was determined using standard method (Egan et al., 1981).

$$\text{Density } (g\ m^{-3}) = \frac{\text{Mass (g)}}{\text{Volume } (m^3)}$$

2.6.3. Specific mechanical energy (SME)

Specific mechanical energy ($Wh\ kg^{-1}$), the mechanical energy input $unit^{-1}$ mass of the extradite was calculated by dividing the net power input to the screw by the extruded flow rate. SME input was calculated by the following equation (Sokhey et al., 1994):

$$\text{SME } (WH\ kg^{-1}) = \frac{\text{Screw speed (s-1)} \times \text{Torque (Nm)}}{\text{Mass flow rate } (kg^{-1})}$$

2.6.4. Hardness

Mechanical properties of the extrudates were determined by crushing method using a TA-XT2 texture analyzer (Stable Micro Systems Ltd., Godalming, UK) equipped with a 500 kg load cell. An extrudate 40 mm long was compressed with a probe SMS-P/75-75 mm diameter at a crosshead speed 5 mm/s to 3 mm of 90% of diameter of the extrudate. The compression generates a curve with the 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 (Stojceska et al., 2008).

2.6.5. Water absorbency index (WAI) and water solubility index (WSI)

WAI and WSI were determined in triplicate following the method described by (Yagci and Gogus, 2008; Stojceska et al., 2008). Each ground extruded (3 g) was dispersed in 30 ml of distilled water and stirred using a vortex mixer. This dispersion was allowed to stand for 30 min in a water bath at 30 °C. Subsequently, the dispersion was centrifuged at 3000 rpm for 15 min using the centrifuge (Remi Instruments, Bombay, India) . The supernatants were poured into a petridish and dried at 110 °C and weigh. WAI and WSI were calculated using following equations:

$$\text{WAI } (g\ g^{-1}) = \frac{\text{Wt. of hydrated residue}}{\text{Dry wt. of sample}}$$

$$\text{WSI } (\%) = \frac{\text{Wt. of dissolved solids in supernatant}}{\text{Dry wt. of sample}}$$

2.6.6. Experimental design and data analysis

Statistical package Design-Expert Version 7.0 (Statease Inc., Minneapolis, MN, USA) was used to design the experiment. The Central Composite Design CCRD for three independent variables was performed. The independent variables considered were Moisture content (A) Die temperature (B) and Pomace level (C). A rotatable, central composite design (Myers, 1971) was employed to determine the extrusion conditions. Dependent variables were Specific Mechanical Energy (SME), Density (BD), Expansion Ratio (ER), Water Absorption Index (WAI) and Water Solubility Index (WSI) and hardness. Response surface methodology was applied for experimental data, for generation of contour plots and for statistical analysis of experimental data. The Analysis of Variance (ANOVA) tables were generated for each of the response functions.

3. Results and Discussion

3.1. Proximate analysis of the raw materials

The chemical composition of the broken rice flour, Pigeon pea flour and pineapple pomace powder were determined using standard methods and results were expressed as shown in (Table 1). It was observed from the table that the broken rice flour contains 10.13 % wb moisture, 7.23 % crude protein, 0.56% fat, 1.64% ash, 1.29% crude fibre, 79.15% carbohydrates as compared to pigeon pea flour that contains 9.56% wb moisture, 22.87% crude protein, 1.04% fat, 3.29% ash, 6.17% crude fibre, 57.07% carbohydrates. While pineapple pomace powder contains 6.23% wb moisture, 4.76% crude protein, 0.78% fat, 2.26% ash, 26.78% crude fibre, 59.19% carbohydrates.

Table 1: Proximate chemical composition of broken rice flour, pigeon pea flour and pineapple pomace powder

Code		Variable level codes				
		-1.682	-1	0	1	1.682
Broken rice flour	10.13±0.54	7.23±0.05	0.56±0.21	1.64±0.08	1.29±0.05	79.15±0.97
Pigeon pea flour	9.56±0.35	22.87±0.05	1.04±0.06	3.29±0.04	6.17±0.03	57.07±0.49
Pine-apple pomace powder	6.23±0.24	4.76±0.07	0.78±0.09	2.26±0.06	26.78±0.04	59.19±0.65

3.2. Specific mechanical energy (SME)

The amount of mechanical energy delivered to the extruded material plays an important role in the starch conversion. Higher SME usually results in desired greater degree of starch gelatinization and extrudates expansion. Hence, increased SME is desired for expanding products (Meng et al., 2010). Regression analyses were carried out to fit the mathematical models to the experimental data (Table 2, 3 and 4). The predicted model for the SME can be described by the following equation in terms of coded levels.

$$SME = 159.03 - 15.90X_1 - 4.26X_2 - 2.77X_3$$

Where,

Table 2: Process variables used in the central composite design for three independent variables

Code		Variable level codes				
		-1.682	-1	0	1	1.682
Die temperature (°C)	X_1	99.55	120	150	180	200.45
Moisture content (%)	X_2	12.64	14	16	18	19.36
Pomace level (%)	X_3	1.23	6	13	20	24.77

Table 3: Extrusion conditions with actual and coded variable levels for experimental design

Run	Actual and coded levels		
	Die temperature (°C)	Moisture content (%)	Pomace level (%)
1.	150 (0)	16 (0)	24.7725 (1)
2.	150 (0)	19.6 (1)	13 (0)
3.	150 (0)	16 (0)	1.23 (-1)
4.	120 (-1)	14 (-1)	20 (1)
5.	150 (0)	16 (0)	13 (0)
6.	150 (0)	12.64 (-1)	13 (0)
7.	99.5 (-1)	16 (0)	13 (0)
8.	150 (0)	16 (0)	13 (0)
9.	120 (-1)	14 (-1)	6 (-1)
10.	180 (1)	14 (-1)	6 (-1)
11.	120 (-1)	18 (1)	6 (-1)
12.	150 (0)	16 (0)	13 (0)
13.	150 (0)	16 (0)	13 (0)
14.	180 (1)	14 (-1)	20 (1)
15.	150 ()	16 (0)	13 (0)
16.	150 (0)	16 (0)	13 (0)
17.	180 (1)	18 (1)	6 (-1)
18.	120 (-1)	18 (1)	20 (1)
19.	200.45 (1)	16 (0)	13 (0)
20.	180 (1)	18 (1)	20 (1)

X_1=Die temperature (°C); X_2=Moisture content (%); X_3=Pomace level (%)

The significance of coefficient of fitted linear model was evaluated by using F-test and *p*-value. The value of R^2 was found to be 0.9245. T the calculated SME ranged from 133.74 to 180.62 Wh kg^{-1} (Table 5). Moisture, temperature and pomace level had significant effects on SME (p<0.05). The negative coefficients of the linear terms of moisture and temperature level indicated that the SME decreases with increase of these variables. High moisture produced a lubricating effect resulting in less energy use and subsequently reduced SME. High temperature facilitated the transformation from solid flow to viscoelastic flow and reduced the melt viscosity, which resulted in decrease in SME. The SME is related to the degree of product transformation, and influences extrudate properties such as expansion, density and other geometric and

Table 4: Anova results for the responses

Parameters	Sum of squares	df	Mean square	F value
Expansion ratio				
Model	0.92	9	0.10	42.70*
Residual	0.024	10	2.404E-003	
Lack of fit	0.020	5	3.977E-003	4.790
Pure error	4.155E-003	5	8.311E-004	
Core total	0.95	19		
Density				
Model	3.497E-003	3	1.166E-003	132.41*
Residual	1.408E-004	16	8.803E-006	
Lack of fit	1.185E-004	11	1.077E-005	2.41
Pure error	2.234E-005	5	4.469E-006	
Core total	3.638E-003	19		
Specific mechanical energy				
Model	3806.36	3	1268.79	65.26*
Residual	311.05	16	19.44	
Lack of fit	144.63	11	13.15	0.39
Pure error	166.44	5	33.29	
Core total	4117.43	19		
Hardness				
Model	1377.57	3	459.19	96.91*
Residual	75.82	16	4.74	
Lack of fit	62.35	11	5.67	2.11
Pure error	13.46	5	2.69	
Core total	1453.39	19		
Water solubility index				
Model	0.090	3	0.030	16.67*
Residual	0.029	16	1.797E-003	
Lack of fit	0.026	11	2.341E-003	3.90
Pure error	3.003E-003	5	6.007E-004	
Core total	0.12	19		
Water absorbency index				
Model	2.53	9	0.28	47.38*
Residual	0.059	10	5.937E-003	
Lack of fit	0.039	5	7.810E-003	1.92
Pure error	0.020	5	4.064E-003	
Core total	2.59	19		

*Significant at the p<0.05 level

textural characteristics (Iwe et al., 2001). The results are in agreement with the work doneof Dorgan and Karwe (2003), they processed whole quinoa and found that an increase in temperature reduced the SME values. Similar correlations of moisture, temperature and pomace level with SME were reported by Ryu and Ng (2001); Altan et al. (2008) for wheat-corn and barley extrudates respectively.

3.3. *Density*

Density is the measure of how much expansion has occured as a result of extrusion. The heat developed during extrusion can increase the temperature of the moisture above the boiling point so that when the extrudate exits from the die, a part of the moisture would quickly falsh-off as steam and result in a expanded structure with large aveoli and low density. On the other hand, if not enough heat is generated to flash-off enough of the moisture (either through low process temperature or high feed moisture), less expansion occurs resulting in a high density product with collapsed cells which usually disintegrates on cooling. The linear model obtained from the regression analysis for the density (BD) in terms of coded levels of the variables was developed as follows:

$$BD=0.064-0.016\ X_1-2.890E-003\ X_2-1.657E-003\ X_3$$

The density of the extrudates varied between 0.03504 to 0.09582 g cm^{-3} (Table 5). The significance of coefficient of fitted linear model was evaluated by using F-test and P-value. The value of R^2 was found to be 0.9613. Density was significantly affected by die temperature (X_1) and feed moisture (X_2) in linear ($p<0.001$) and squared ($p<0.001$) terms. Density incresed with increases in feed moisture and it decreased with increase in temperature. Pomace level showed a non-significant negative correlation with density. the high dependence of density and expansion on feed moisture would reflect its influence on elasticity characteristics of trhe starch-based materials. Increased in feed moisture during extrusion may reduce the elasticity of the dough through plasticization of the melt, resulting in reduced SME and therefore reduced gelatinization, decreasing the expansion and increasing the density of the extrudate (Mercier and Feillet, 1975). It was observed that an increase in barrel temperature resulted in an extrudate with low density. Density values decreased when the extrusion temperature increaseed, probably due to starch gelatinization. Increase in the barrel temperature decreased the melt viscosity, and reduced the viscosity would favour

Table 5: Central composite rotatable designs with results for responses

Die temp (°C)	Moisture content (%)	Pomace level (%)	Expansion ratio	SME (Wh kg^{-1})	Hardness (N)	Density (g cc^{-1})	WAI (g g^{-1})	WSI (%)
150	12.63641	13	3.945	180.626	69.597	0.09582	4.245	0.525
180	14	20	3.667	173.408	54.208	0.07448	4.955	0.29
180	14	6	3.770	174.262	55.296	0.07756	4.952	0.305
120	14	20	3.776	177.754	58.367	0.07909	4.755	0.32
120	14	6	3.828	179.403	62.332	0.08676	4.654	0.356
200.4538	16	13	3.358	152.765	48.116	0.05764	5.395	0.21
150	16	24.77255	3.384	153.386	48.837	0.05892	5.375	0.21
150	16	13	3.397	153.682	48.861	0.05931	5.34	0.215
150	16	13	3.411	153.682	49.306	0.06165	5.31	0.22
150	16	13	3.425	153.745	49.61	0.06318	5.22	0.255
150	16	13	3.436	157.818	51.597	0.06376	5.22	0.256
150	16	13	3.461	163.569	52.343	0.06452	5.205	0.265
150	16	13	3.472	166.964	52.556	0.06501	5.18	0.275
150	16	1.22745	3.634	169.456	52.85	0.06512	5.105	0.275
99.54622	16	13	3.639	169.916	53.765	0.06697	5.051	0.277
180	18	20	3.223	136.238	35.345	0.04877	5.7	0.185
180	18	6	3.228	137.06	35.949	0.04943	5.595	0.19
120	18	20	3.241	142.866	39.599	0.05369	5.545	0.205
120	18	6	3.311	150.342	46.093	0.05448	5.5	0.21
150	19.36359	13	3.164	133.746	35.095	0.03504	5.76	0.175

SME: Specific mechanical energy

the bubble growth during extrusion thereby decreasing the density (Figure 1).

3.4. Hardness

The hardness of expanded extrudates ia a perception of the human being and is associated with the expansion of the cell structure of the product. The hardness is the peak force required foe a probe or parallel blades (e.g. Kramer Shear Cell) to penetrate the extrudate. The higher the value of the maximum peak force required, the higher the harness of the sample. The regression analysis was carried out to fit the mathematical modelst to the experimantal data. The predicted model can be described by the following equation in terms of coded lelels.

Hardness=+50.81-9.61A-2.57B-1.38C-0.40 AB-0.26AC+1.10BC-0.059A2-0.56B2-0.59 C2

The significance of coefficient of fitted quadratic model was evaluated by using F-test and P-value. The value of R^2 was found to be 0.9616. the hardness of the extrudates ranged from 35.095 to 69.597 N. Feed moisture content and barrel temperature showed highly significant effects on extrudate hardness in linear and quadratic terms (Figure 2). The positive coefficient of the linear term of both the moistue and temperature level indicated that the hardness increases with the increase in moisture as well as the temperature. Increase in hardness with increase in moisture might be due to the reason that, water acts as plasticizer to the starch-based material reducing its viscosity andt the mechanical energy dessipation in the extruder and thus the product becomes dense and bubble growth gets compressed.

3.5. Water absorbtion index (WAI)

Water absorption index has been generally attributed to the despersion of starch in excess water, and the dispersion is incrreased by the degree of starch damage due to gelatinization and extrusion-induced fragmentation, that is, molecular weight reduction of amylose and amylopectin molecules (Yagci and Gogus, 2009). WAI measures the water holding by the starch after swelling in excess water, which corresponds to the weight of the gel formed. WAI depends on the availability of hydrophillic groups and on the capacity of the gel formation of the macromolecule (Gomez and Aguilera, 1984). The quadratic model obtained from the regression analysis for water absorbtion index in terms of coded levels of the variables was developed as follows.

WAI=+5.24+0.41A+0.097B+0.052C-0.031AB+5.750E-003AC-4.750E-003BC-0.074A2+4.026E-003B2+0.010C2

The significance of coefficient of fitted quadratic model was evaluated by using F-test and P-value. The value of R^2 was found to be 0.9771. WAI values for the extrudates ranged between 3.26 to 5.76 g g^{-1}. Regression analysis showed that increase in feed moisture content and temperature resulted in significance decrease in WAI in linear and quadratic terms. Gelatinization, the conversion of raw starch to a cooked and digestaible material by the application of water and heat, is one of the important effects that extrusion has on the starch component of foods. Water is absorbed and bound to the starch molecule with a resulting change in the starch granule structure. Barrel temperature and feed moisture are found to exert the greatest effect on gelatinization (Figure 3). It has been reported earlier that maximum gelatinization occurs at high moisture and low temperature or vice versa. Reduction in WAI with pomace level might be due to its higher sugar content, which limited the gelatinization as compition between stach and sucrose for available water as well as sucrose\starch interaction have been reported (Lund, 1984).

3.6. Water solubility index (WSI)

Water solubility index often used as the indicator of degredation of molecular components (Kirby et al., 1988) measures the degree of starch conversion during extrusion which is the amount of soluble polysaccharides released from the starch component after extrusion. The quadratic model obtained for water solubility index in terms of coded levels of the variables was developed as follows: WSI=+0.25-0.078A-0.017B-0.012C+5.125E-003AB+5.125E-003AC+2.625E-003BC+0.031A^2-6.310E-003B^2-6.664E-003C^2

The significance of coefficient of fitted quadratic model was evaluated by using F-test and P-value. The value of R^2 was found to be 0.9017. The WSI values for the extrudates ranged between 0.175% to 0.525%. The WSI was significantly influenced by moisture content (p<0.01). The WSI is related to the quantity of soluble molecules, which is related to dextrinization (Figure 4). In other words, WSI can be used as an indicator for the degradation of molecular compounds and measures the degree of starch conversion during extrusion (Colonna et al., 1989; Ding et al., 2005). Mercier and Feillet (1975) reported increase in soluble starch with increasing extrusion temperature and decreasing feed moisture.

3.7. Expansion ratio

The quadratic model obtained for expansion ratio in terms of coded levels of the variables was developed as follows:

ER=+3.43-0.25A-0.054B-0.048C+8.250E- 003AB+0.010AC+1.750E-003BC+0.038A^2+0.019B^2+0.022C^2

The significance of coefficient of fitted quadratic model was evaluated by using F-test and P-value. The value of R^2 was found to be 0.9746. the WSI values for the extrudates ranged between 3.164% to 3.945%. The expansion ratio was significantly influenced by barrel temperature and pomace level (p<0.01). The expansion ratio increased progressively with an increase in barrel temperature and the pomace level. During extrusion, high temperature and hig pressure conditions inside the barrel caused the moisture in the sample to superheat

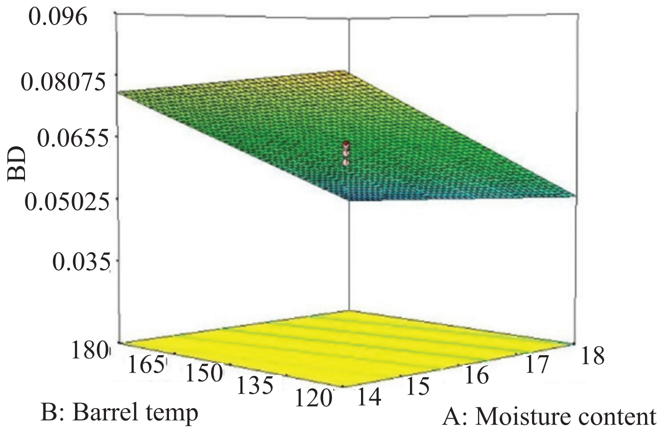

Figure 1: Response surface plot for the bulk density of extrudates as a function of temperature and moisture content

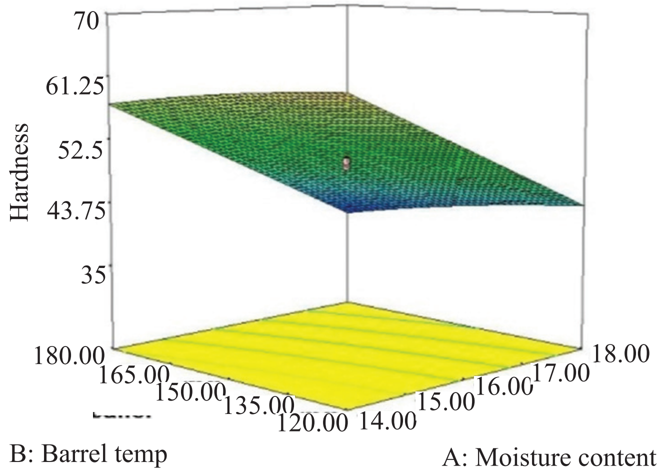

Figure 2: Response surface plot for the hardness of extrudates as a function of temperature and moisture content

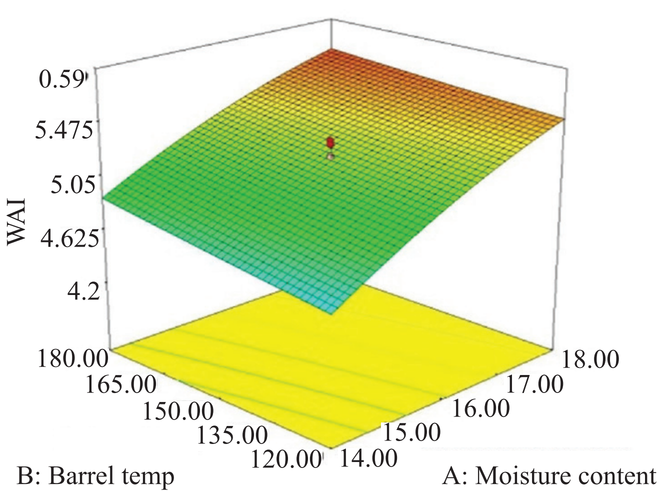

Figure 3: Response surface plot for the water absorbency index of extrudates as a function of temperature and moisture content

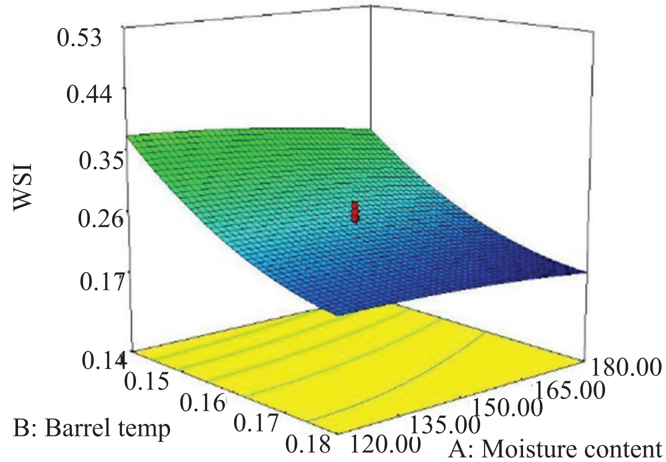

Figure 4: Response surface plot for the water solubility index of extrudates as a function of temperature and moisture content

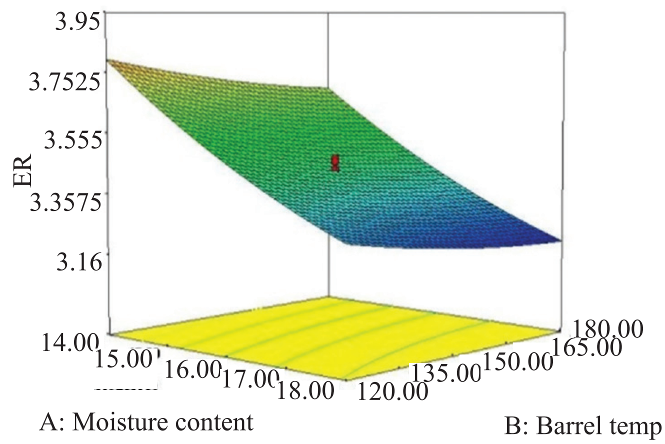

Figure 5: Response surface plot for the expansion ratio of extrudates as a function of temperature and moisture content

(Figure 5). Sudden pressure drop at the exit of the die caused the moisture to evaporate which resulted in expansion of the product (Heldman and Hartel, 1997). Pomace level alone and in interaction with the barrel temperature had a significant effect on the expansion ratio. Several researchers have demonstrated the expansion ratio of extruded cereals depends on the degree of starch gelatinization (Case et al., 1992; Chinnaswamy and Hanna, 1998). The increase in expansion ratio with the addition of pomace might be attributed to the lower gelatinization temperature of the pomace level starch as compared to the rice starch (Zhang et al., 2005).

4. Conclusion

The optimized extrusion parameters for preparation of snacks were 14.94% moistrure, 180 °C temperature and 6% pineapple pomace powder. The developed extrudates contains 5.27% wb of moisture, 4.96% of protein, 3.05% of Fibre, 2.18% of ash and colour L-value of 66.18, a-value of 1.91, b-value of 16.71.

5. References

Altan, A., Mccarthy, K.L., Muskan, M., 2008. Extrusion cooking of barley flour and process parameter optimization by using response surface methodology. Journal of the Science of Food and Agriculture 88(9), 1648–1659.

Altan, A., Mccarthy, K.L., Muskan, M., 2009. Effect of extrusion cooking on functional properties and *in-vitro* starch digestibility of barley-based extrudates from the fruit and vegetable by-products. Journal of Food Science 74(2), 77–86.

Altan, A., Mccarthy, K.L., Maskan, M., 2008a. Evaluation of snack food from barley-tomato blends by extrusion processing. Journal of Food Engineering 84, 231–242.

Altan, A., Mccarthy, K.L., Maskan, M., 2008b. Twin-screw extrusion of barley-grape pomace blends: Extrudate characteristics and determination of optimum processing conditions. Journal of Food Engineering 89, 24–32.

Aylin, A., Mccarthy, K.L., Medeni, M., 2008. Evaluation of snack foods from barley-tomato pomace blends by extrusion processing. Journal of Food Engineering 84, 231–42.

Case, S.E., Hamann, D.D., Schwartz, S.I., 1992. Effect of starch gelatinization on physical properties of extruded wheat and corn based products. Cereal Chemistry 69, 410–404.

Chen, J., Serafin, F.L., Pandya, R.N., Daun, H., 1991. Effect of extrusion conditions on sensory properties of corn meal extrudates. Journal of Food Science 56(1), 84.

Chinnaswamy, R., Hanna, M.A., 1988. Relationship between amylase content and extrusion-expansion properties of corn starches. Cereal Chemistry 65, 138–143.

Colonna, P.J., Tayeb, J., Mercier, C., 1989. Extrusion cooking of starch and starchy products. In: Mercier, C., Linko, P., Harper, J.M. (Eds.), Extrusion cooking. American Association of Cereals Chemists, Inc., St. Paul, MN, 247–319.

Ding, Q., Ainsworth, P., Gregory, T., Hayley, M., 2005. The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice based expanded snacks. Journal of Food Engineering 66, 283–289.

Dorgan, H., Karwe, M.V., 2003. Physicochemical properties of quinoa extrudates. Food Science and Technology International 9, 101–14.

Egan, H., Kirk, R.S., Sawyer, R., 1981. Pearson's Chemical Analysis of Foods, 8th Edition. Longman Scientific and Technical.

Giovanni, M., 1983. Response surface methodology and product optimization. Food Technology 37, 41–45.

Gomez, M.H., Aguilera, J.M., 1984. A physicochemical model for extrusion of corn starch. Journal of Food Science 49, 40–42.

Grigelmo-miguel, N., Martin-belloso, O., 1999. Comparison of dietary fibre from by-products of processing fruits and greens and from cereals. LWT-Food Science Technology 503–508.

HEldman, D.R., Hartel, R.W., 1997. Principals of food processing. Chapman and Hall, Newyork

Ilo, S., Liu, Y., Berghofer, E., 1999. Extrusion cooking of rice flour and amaranth blends. LWT-Food Science Technology 32, 79–88.

Iwe, M.O., Vanzuilichem, D.J., Ngoddy, P.O., 2001. Extrusion cooking of blends of soy flour and sweet potato flour on Specific Mechanical Energy (SME), extrudates temperature and torque. Journal of Food Proceeding and Preservation 25, 251–266.

Kadan, R.S, Bryant, R.J., Pepperman, A.B., 2003. Functional properties of extruded rice flours. Journal of Food Science 68, 1669–1672.

Kirby, A.R., Ollett, A.L., Parker, R., Smith, A.C., 1988. An experimental study of screw configuration effects in the twin-screw extrusion-cooking of maize grits. Journal of Food Engineering 8, 247–272.

Kollengode, A.N., Sokhey, A.S., Hanna, M.A., 1996. Physical and molecular properties of re-extruded starches as affected by extruder screw configuration. Journal of Food Science 61(3), 596–603.

Kumar, N., Sarkar, B.C., Sharma, H.K., 2010b. Development of characterization of extruded product using carrot pomace and rice flour. International Journal of Food Engineering 6, 1–24.

Kumar. N., Sarkar, B.C., Sharma, H.K., 2010a. Development of characterization of extruded product of carrot pomace, rice flour and pulse powder. African Journal of Food Engineering 4, 703–717.

Lund, D., 1984. Influence of time, temperature, moisture, ingredients, and processing conditions on starch gelatinization. Critical Reviews in Food Science 20, 249–273.

Martinez-flores, H.E., Chang, Y.K., Martinez-bustos, F., Sanchez-sinencio, F., 2008. Extrusion-cooking of cassava starch with different fiber sources: effect of fibers on expansion and physicochemical properties. In: Chang, Y.K., Wang, S.S. (Eds.), Advances in Extrusion Technology. Economic Publishing Co. Inc. Lancaster, PA, USA. 271–278.

Mehta, R.S., 2005. Dietary fiber benefits. Cereal Foods World 50(1), 66–71.

Meng, X., Threinen, D., Hasen, M., Driedger, D., 2010. Effects of extrusion conditions on system parameters and physical properties oa a chickpea flour-based snack. Food Research International 43, 650–658.

Mercier, C., Fillet, P., 1975. Modification of carbohydrate component of extrusion cooking of cereal product. Cereal Chemistry 89, 283–295.

Mouquet, C., Salvignol, B., Monvois, N.V.J., Treche, S., 2003. Ability of a very low cost extruder to produce instant infant flours at a small scale in Vietnam. Food Chemistry 82, 8.

Myers, R.H., 1971. Response surface methodology. Allyn and Bacon, Boston, MA.

Nawirska, A., Kwasniewska, M., 2004. Dietary fibre fractions from fruit processing waste. Acta Scientiarum Poltechnology Alimentaria 3, 13–20.

Ng, A., Lecain, S., Parker, M.L., Smith, A.C., Waldron, K.W., 1999.Modification of cell wall polymers of onion waste. III. Effect of extrusion cooking on cell wall material of outer fleshy tissue. Carbohydr Polymers 39, 341–49.

Nunes, M.C.N., Edmond, J.P., Rauth, M., Dea, S., Chau, K.V., 2009. Environmental conditions encountered during typical consumer retail display affect fruit and vegetable quality and waste. Postharvest Biology and Technology 51, 232–41.

Pansawat, N., Jangchud, K., Jangchud, A., Wuttijumnong, P., Saalia, F.K., Eitenmiller, R.R., 2008. Effects of extrusion conditions on secondary extrusion variables and physical properties of fish, rice-based snacks. LWT-Food Science and Technology 41, 632–41.

Park, J., Rhee, K.S., Kim, B.K., Rhee, K.C., 1993. Single-screw extrusion of defatted soy flour, corn starch and raw beef blends. Journal of Food Science 58(1), 9–20.

Ryu, G.H., Ng, P.K.W., 2001. Effect of selected process parameters on expansion and mechanical properties of wheat flour and whole cornmeal extrudates. Starch 53, 147–54.

Serena, A., Kundsen, B., 2007. Chemical and physicochemical characterisation of co-products from vegetable food and agro industries. Animal Feed Science and Technology 139, 109–124.

Sokhey, A.S., Kollengode, A.N., Hanna, M.A., 1994. Screw configuration effects on corn starchexpansion during extrusion. Journal of Food Science 59, 895–898.

Stojceska, V., Ainsworth, P., Plunkett, A., Ibanoglu, E., Ibanoglu, S., 2008. Cauliflower by-products as a new source of dietary fibre, antioxidants and proteins in cereal based ready-to-eat expanded snacks. Journal of Food Engineering 8, 554–63.

Upadhyay, A., Sharma, K.H., Sarkar, B.C., 2008. Characterization and dehydration kinetics of carrot pomace. Agricultural Engineering International: CIRG Journal 10, 1–9.

Yagci, S., Gogus, F., 2008. Response Surface Methodology for Evaluation of Physical and Functional Properties of Exruded Snack Foods Developed from Food-by-Products. Journal of Food Engineering 86, 122–132.

Zhang, P.Y., Whistler, R.L., Bemiller, J.N., Hamaker, B.R., 2005. Banana starch: production, physicochemical properties, and digestibility-a review. Carbohydrate Polymers 59, 443–458.