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Development of functional extruded snacks using corn and apple blends

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Abstract
There is increasing concern about the consumption of snacks and its long term implications on health. This study considered whether the incorporation of apple powder into corn based extruded snacks could improve the nutritional value of extruded snacks. To produce nutritionally rich and organoleptically acceptable snacks, it is necessary to understand the changes that occur in physical properties of snacks during extrusion processing. In present study, effect of composition, feed moisture, screw speed and barrel temperature on physical characteristics of corn -based apple incorporated snacks was investigated to optimize the blending levels of corn flour and apple powder for the production of extruded breakfast snacks. Co-rotating twin screw extruder was used for the production of corn based apple incorporated extrudates. Response surface methodology (RSM) at varying apple powder concentration (0-40%), feed moisture (12.5-22.5%), temperature (110-190 °C) and screw speed (150-550rpm) was used to analyze the effect of each process variable on physical parameters viz. specific mechanical energy (SME), bulk density (BD), water absorption index (WAI), water solubility index (WSI), expansion ratio (ER) and breaking strength (BR) of corn- based apple incorporated snacks. Response surface models were established to determine the responses as function of process variables. Regression models were highly significant ($p<0.01$) with high correlation coefficient ($R^2>0.95$). The optimum conditions obtained after response surface analysis for the preparation of corn-based apple incorporated snacks were corn flour to apple powder ratio (90:10), feed moisture (15%), screw speed (450 rpm) and barrel temperature (170 °C).

Keywords: Corn, apple, extrusion, physical parameters, optimization, response surface methodology (RSM)

Introduction
Extrusion cooking technology is a versatile and efficient process for converting raw materials into finished food products. Food extruders provide thermo-mechanical energy (shear) needed to cause physico-chemical changes of foods, implying mixing and homogenization (Anton & Luciano, 2007) [6]. Extrusion is believed to yield safe foods that have a long shelf life. Due to its versatility, low cost, efficiency, product quality and eco-friendliness (Eastman *et al*., 2001) [16], extrusion has been in wide use during the past two decades. Extrusion technology plays a very important role in the preparation of cereal-based snack products (Patil *et al*., 2007) [27]. Corn flour has become an attractive ingredient in the extrusion industry due to its excellent expansion and puffing properties (Gujral *et al*., 2001) [17].
Over the past ten years consumers have become more health conscious and are choosing snacks that claim to be healthier and more nutritious. Therefore, there is a need to manipulate the nutritional status of ready to eat extruded snacks by incorporating raw materials rich in bioactive components (such as minerals, vitamins,dietary fiber, etc.). corn is an important source of dietary fibre, vitamins and minerals. The main vatamins and minerals present in corn are vitamin thiamine, ribolavin, Naicin, Calcium, magnesium, potassium, phosphorus, Zinc, sodium (Kirk *et al*., 1991) [22]. Incorporation of fruits can also improve the nutritional content of the snacks. Phenolics and antioxidants present in fruits have long been associated with health benefits. Factors such as season changes, high price and perishability affect the consumption of fresh fruits. Therefore, it becomes necessary to incorporate beneficial fruit compounds into the diet using other forms of food such as breakfast cereal. One such fruit, apple has the potential of improving the nutritional status of the extrudates. Apple is a good source of monosaccharides, minerals, dietary fibre, and various biologically active compounds, such as vitamins, and certain phenolic compounds which are known to act as natural antioxidants (Gorinstein *et al*., 2001) [18].

In the light of facts it is clear that the blend of culled apple and corn can be very well exploited in extrusion processing for the development of healthy breakfast snacks. However success of extruded products lies in careful control of extrusion processing Conditions. These include control of screw speed, barrel temperature, feed moisture, etc., which determine the overall quality of the product, and finally influence the success of the product. Therefore the aim of present study was to investigate the effect of the extrusion processing variables on using response surface methodology and to establish regression models to predict the product responses as the function of process variables.

Materials and methods

The corn (C-6) variety obtained from division of plant breeding and genetics, Sheri-e-Kashmir University of Agricultural Sciences and technology of Kashmir, India and locally procured culled apple (CV: Red delicious) was dried and milled in lab mill model 3030 (Perten, Sweden) to obtain flour of fineness that passes through 200µm sieve. The moisture content was determined by oven drying method (AACC, 2000) [12] and approximate amount of water was added to adjust the required moisture content of the blended flour as per the experimental design.

Physico-chemical properties.

Moisture, fat, protein, ash, crude fibre were estimated using standard methods (AOAC 2000) [7]. Per cent carbohydrate was determined by the difference method as follows:

Carbohydrate (%) = 100 - (Moisture % + Fat %+ Protein % + Ash %+ crude Fibre %).

Dietary fibre was estimated by the dietary fibre system (fibraplus DF). The method is given by JAOAC (1988) [7]. Analysis of three B group vitamins (thiamin, riboflavin, niacin and pyridoxine) was performed using HPLC. The extract was assayed by ionpair reversed phase HPLC with a buffered mobile phase (methanol–citrate, pH 2.4). Analysis of minerals was done by prescribed AOAC procedures. Minerals i.e. Ca, Mg, P, K and Zn were estimated by using Atomic Absorption Spectrometer (Perkin Elmer, Norvalk, C.T., USA) in air acytelene flame.

Extruder and processing conditions

The extrusion was 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 had four barrel zones, temperature of the 1st, 2nd, and 3rd was maintained at 20, 30 and 40℃, respectively, throughout the study ; while the temperature in last zone (compression and die section) was varied according to experimental design as shown in table 1. The extruder was equipped with torque indicator which showed percent of torque in proportion the current drawn by drive motor. Raw material was metered into extruder with a single screw volumetric feeder (D.s and M, Modena, Italy).

The extruder was thoroughly calibrated with respect to combinations of predicted feed rate and screw speed to be used. The feed rate was varied for optimum functioning of extruder barrel corresponding to screw speed. The moisture content of feed was varied by injecting water into the extruder with a water pump. A cutter with four bladed knives and a die (6mm) made of stainless steel were used for shaping the extrudates.

Experimental design

The central composite rotatable design (CCRD) (Draper, 1982) was used to incorporate four independent variables viz., composition, moisture content, screw speed and barrel temperature. The independent variables and variation levels are shown in table-1. The levels of each variable were established on the preliminary trials. Dependent variables were specific mechanical energy (SME), bulk density (BD), water absorption ratio (WAI), water solubility index (WSI), expansion ratio (ER) and breaking strength (BS). Response surface methodology was used to investigate the individual and interactive effects of independent variables on the product responses. The independent variable levels of apple powder incorporation 0-40%, barrel temperature 110-190℃, screw speed 150-550 rpm and feed moisture 12.5-22.50% considered for the study were selected on the basis of preliminary trials. Experiments were randomized in order to minimize the systematic bias in observed responses due to extraneous factors. The central composite rotatable design (CCRD) (Draper, 1982) was used to incorporate four independent variables viz., composition, moisture content, screw speed and barrel temperature. The independent variables and variation levels are shown in table-1.

Table 1: Process variables used in the central composite rotatable design (CCRD) for four independent variables

Process variables	Code	Variables Level Codes				
		-2	-1	0	+1	+2
Composition (C:A)	A	100:0	90:10	80:20	70:30	60:40
Moisture content (%)	B	12.50	15	17.50	20	22.50
Screw speed (rpm)	C	150	250	350	450	550
Barrel temperature (ºC)	D	110	130	150	170	190

*(C: A)-(Corn: Apple)

Determination of system response

Specific mechanical energy (SME)

Specific mechanical energy (Wh/kg) was calculated from rated screw speed (), motor power rating (), actual screw speed, percent motor torque and mass flow rate (kg/hr) using the following formula. =

$$\text{SME} = \frac{\text{Actual screw speed (rpm)}}{\text{Rated screw speed (rpm)}} \times \frac{\text{\% motor torque}}{100} \times \frac{\text{motor power rating}}{\text{mass flow rate}} \times 1000 \quad (1)$$

Determination of product responses

Bulk density (BD)

Bulk density was measured using displacement method (serker, 2005). 10 g of extrudates were weighed (W_{ext}) and filled in a 100 ml cylinder, mustard seeds were added to fill up the cylinder. The extrudates were taken out and volume of mustard seeds was measured (V_{ym}). BD was calculate as

$$\text{BD} = \frac{\text{Wext}}{100-\text{Vym}} \quad (2)$$

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

WAI and WSI were determined according to the method developed for cereals (Stojceska *et al*., 2008) [32]. The ground extrudate was suspended in water at room temperature for 30 min, gently stirred during this period, and then centrifuged at 3000 g for 15 min. The supernatant was decanted into an evaporating dish of known weight. The WAI was the weight of gel obtained after removal of the supernatant per unit weight of original dry solids. The WSI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample.

WAI (g/g) = $\frac{\text{weight gain by gel}}{\text{dry weight ofextrudate}}$ (3)

WSI (%) = $\frac{\text{weight of dry solids in supernatant}}{\text{dry weight of extrudate}}$ (4)

Expansion ratio

To determine the expansion ratio, 20 pieces from each extrusion run were measured with a vernier caliper The expansion ratio was calculated as the cross-sectional diameter of an extrudate divided by the diameter of the die opening.

Breaking strength

Breaking strength of extrudates were determined by using a TA-XT2 texture analyzer (Stable Micro Systems Ltd., Godalming, UK). A three point breaking test (Zasypkin *et al*, 1992) [34] was used to measure the maximum force required to break the extrudate samples. The compression generated 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) [32].

Data analysis and process optimization

The responses (specific mechanical energy, bulk density, water absorption index, water solubility index expansion ratio and breaking strength of the extrudates) for different experimental conditions were related to coded variables (xi, I = 1, 2,3 and 4) by a second order polynomial regression models as given below:

$$y_i = b_0 + \sum_{i=1}^{4} b_i x_i + \sum_{i=1}^{4} b_{ii} x_i^2 + \sum_{i=1}^{4}\sum_{i=1}^{4} b_{ij} x_i x_j \quad (5)$$

where, xi (i = 1, 2, 3, 4) are independent variables (Composition, Moisture, Screw speed and Barrel temperature respectively) and b_0, b_i, b_{ii}, and b_{ij} are coefficient for intercept, linear, quadratic, and interactive effects respectively. Data was analyzed by multiple regression analysis and statistical significance of terms was examined by analysis of variance (ANOVA) for each response. The adequacy of regression model was checked by correlation coefficients. The lack of fit was used to judge the adequacy of model fit. The statistical analysis of the data of was performed using Design-Expert Software 8(Stat-Ease Inc, Minneapolis, MN, USA). To aid visualization in responses, regression coefficients were used to make statistical calculation to generate series of three dimensional response plots. Optimization was carried out under fallowing constrants: maximize SME, WAI, WSI and ER; minimize BD and Breaking strength.

Sensory analysis

Sensory analysis was conducted for all the samples. Twelve panellists were asked to assess the extruded snacks and mark on a Hedonic Rating Test (1 - poor, 2 – fair, 3-good, 4- very good and 5- excellent) in accordance with their opinion for apperance, color, texture, flavor, mouth feel and overall acceptability scores were averaged.

Results and discussion

Physico – chemical properties

Moisture, fat, protein, ash, crude fibre, carbohydrate, dietary fiber, vitamin and mineral content of corn flour and apple powder is given in table (2).

Table 2: Physico-chemical analysis of raw material

Parameter	Corn flour	Apple powder
Moisture (%)	11.3	14
Crude protein (%)	8.97	0.92
Crude fat (%)	3.38	0.31
Crude fiber (%)	2.6	3.5
Dietary fiber (%)	12.16	13.5
Ash (%)	1.6	1.8
Carbohydrate (%)	74.75	82.97
Mineral profile (mg/100g)		
Ca	7	14
Mg	127	16
K	287	452
P	210	39
Na	35	74
Zn	2.21	0.23
Vitamins (mg/100g)		
Thiamine	0.385	0.00
Riboflvin	0.201	0. 159
Niacin	3.63	0.927

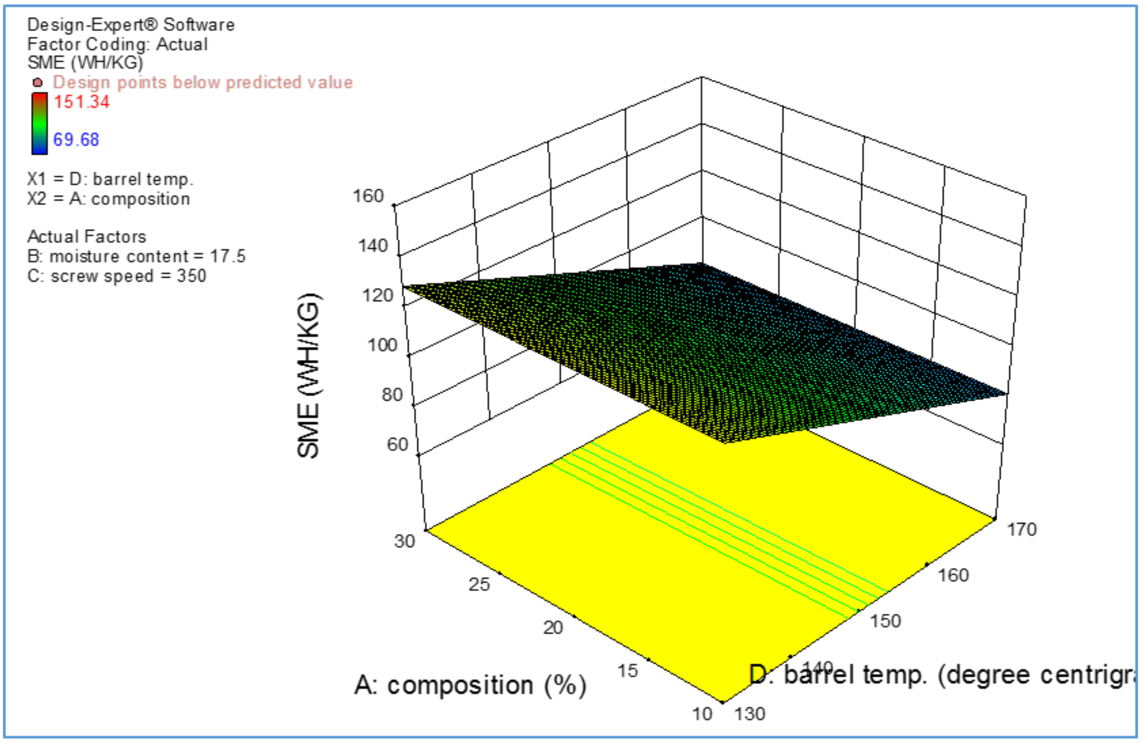
Determination of system response

Specific mechanical energy (SME)

SME is the energy provided by motor drive per unit mass of material in the extruder (Akdogan, 1996) [3]. The amount of mechanical energy delivered to the extruded material plays an important role in starch conversion. Higher SME usually results in greater degree of starch gelatinization and extrudate expansion. Hence higher SME is desired for expanding products. The mean values of SME under different extrusion conditions listed in Table 3 ranged between 81.10 to 149.78 Wh/kg. Analysis of variance (ANOVA) was performed to study the effect of independent variables on SME (table 4). The regression model for SME showed a high coefficient of determination (R^2) of 0.849 and adjusted R^2 of 0.825. The coefficient of Variation was found to be 9.73 Moreover, the adequate precision (23.056) is greater than 4, indicating a good fit of experimental data and the acceptability of the model for prediction purposes. The regression equation for SME depicted below equation 6 indicates the significant linear effects with moisture content (M) and barrel temperature (T).

$$SME = +105.58 - 5.04M - 24.16T \quad (6)$$

The negative coefficient of linear terms of feed moisture and barrel temperature indicates that SME decreases with increase in these variables and positive coefficient for screw speed indicates that SME increases with increase of these variables ($P<0.001$). Figure 1 shows the response plot of SME vs two independent variables with third taken at mid-point. The decrease of SME with increase of feed moisture is due to the fact that higher moisture produces a lubricating effect resulting in reduced use of energy and consequently lower SME (Jin *et al*, 1994) Higher barrel temperature enhances gelatinization of starch, facilitates transformation of solid flow to viscoelastic flow and reduces melt viscosity, which resulted in drop of SME Increase in concentration of ingredients, feed moisture and barrel temperature reduces melt viscosity, hence drop in SME, these results are in agreement with previous work done by Altan *et al*., (2008) [5] in wheat, corn and barley extrudate.



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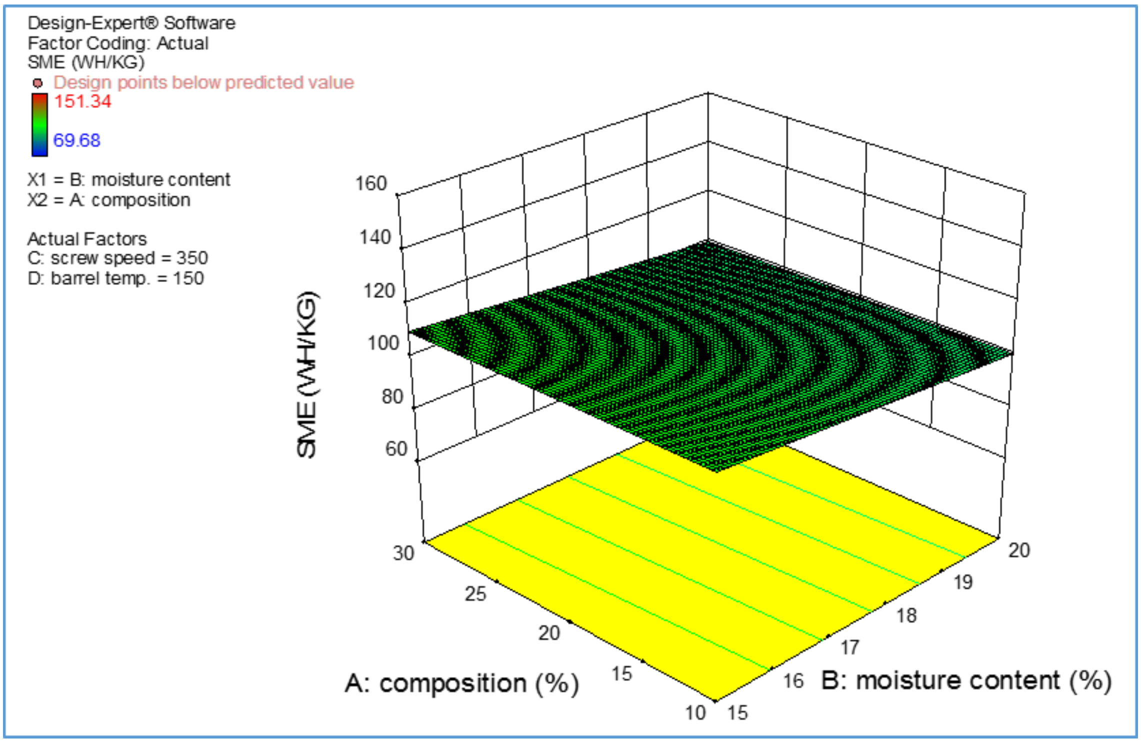


(b)

Fig 1: (a) Response surface plot for SME as function of composition and barrel temperature. (b) Response surface plot for SME as function of composition and moisture content.

Table 3: Central Composite Rotatable Design for Optimizing the Extrusion Condition for SME, BD, ER, BS, WAI and WSI of the Extrudates, Together With Experimental Data.

S. No.	Composition C:A (%)	Moisture (%)	Screw speed (rpm)	Barrel temp. (˚C)	SME (wh/kg)	Bulk density (kg/m³)	WAI (g/g)	WSI (%)	Expansion ratio	Break strength (N)
1	90:10	15	250	130	133.94	218	5.535	10.5	2.89	69.2
2	70:30	15	250	130	144.61	376	3.712	8.5	2.32	154.2
3	90:10	20	250	130	133.43	229	6.160	6.5	2.78	74.9
4	70:30	20	250	130	122.5	380	3.801	10.5	2.26	168.2
5	90:10	15	450	130	151.34	197	5.621	7	2.95	62.8
6	70:30	15	450	130	149.78	373	3.608	13	2.35	146.3
7	90:10	20	450	130	140.24	226	5.334	8	2.83	72.8
8	70:30	20	450	130	137.71	378	3.645	14.5	2.29	163.3
9	90:10	15	250	170	86.99	171	5.011	14	3.53	48.8
10	70:30	15	250	170	84.89	311	3.711	13.5	2.45	119.7
11	90:10	20	250	170	83.96	159	5.201	9.5	2.98	57.5
12	70:30	20	250	170	81.1	322	3.778	17	2.39	134.2
13	90:10	15	450	170	88.91	138	4.775	9.5	3.55	47.6
14	70:30	15	450	170	87.88	261	3.525	19	2.46	112.8
15	90:10	20	450	170	84.01	188	4.841	7.5	3.2	54.6
16	70:30	20	450	170	83.91	288	3.681	16	2.43	126.5
17	100;0	17.5	350	150	88.83	134	5.56	9.5	3.54	46.9
18	60:40	17.5	350	150	91.3	375	3.612	18	2.18	184.8
19	80:20	12.5	350	150	119.86	345	3.805	14.5	2.62	88.9
20	80:20	22.5	350	150	90.11	369	4.601	12	2.62	98.2
21	80:20	17.5	150	150	89.93	369.1	4.582	9	2.56	101.5
22	80:20	17.5	550	150	99.8	354	4.555	9.5	2.66	82.6
23	80:20	17.5	350	110	143.7	362	4.585	4.5	2.48	109.6
24	80:20	17.5	350	190	69.68	270	3.981	16.5	2.74	74.8
25	80:20	17.5	350	150	96.52	359	4.37	10	2.59	94.9
26	80:20	17.5	350	150	96.52	359	4.37	10	2.59	94.9
27	80:20	17.5	350	150	96.52	359	4.37	10	2.59	94.9
28	80:20	17.5	350	150	96.52	359	4.37	10	2.59	94.9
29	80:20	17.5	350	150	96.52	359	4.37	10	2.59	94.9
30	80:20	17.5	350	150	96.52	359	4.37	10	2.59	94.9

*(C:A)= Corn:Apple, SME(Wh/kg) = Specific mechanical energy, BD(kg/m³) = bulk density WAI(g/g) = Water absorption index, WSI(%) = Water solubility index, ER=Expansion ratio, BS(N) = breaking strength

Table 4: Analysis of variance for the Fit of experimental data to response surface models

Term	SME	BD	ER	BS	WAI	WSI
Adequate precision	23.056	12.017	21.617	16.034	25.77	12.564
R- square	0.8492	0.8953	0.9672	0.8839	0.8791	0.9234
Adjusted R square	0.8250	0.7976	0.9365	0.8228	0.8597	0.8519
CV (%)	9.73	12.60	3.44	14.23	6.02	12.24

SME, specific mechanical energy; BD, bulk density; ER, expansion ratio;; BS, breaking strength; WAI, water absorption index; WSI, water solubility index

Determination of product responses

Bulk density

Bulk density (BD) is a major physical property of the extrudate products. Bulk density considers expansion of products in all the directions in contrast to expansion ratio that considers expansion only in direction perpendicular to extrudate flow (Meng *et al*., 2010). In present study bulk density was found in the range of 134-380 Kg/m ^{3} (table 3). The response was analyzed using ANOVA and data is present in table 4. The value of coefficient of determination (R^2) and adjusted R^2 were 0.849 and 0.797 respectively. The coefficient of variation was found to be 12.6. The regression equation for bulk density depicted below in equation 7 indicates significant linear effects with composition (P<0.0001), moisture (P<0.05) and temperature (P<0.0001), further the quadratic quadratic effect of composition, feed moistuire, screw speed and temperature were found to be highly significant (P<0.05).

$$BD = +359.00 +68.54C -30.12T - 35.93C^2 - 20.55T^2 \quad (7)$$

The response plots depicted in figure 2 shows that increasing concentration of apple powder in corn-apple blends significantly increased the bulk density of extrudates. Higher bulk density was observed at 30% apple powder incorporation. According to Seker (2005) interactions of starch with other components could decrease the free expansion of amylopectin chains and inhibit the release of water vapor, thus limiting expansion and increasing density. In the present study BD showed a moderate negative correlation with the barrel temperature. This could be due to increased starch gelatinization at higher temperature which enables more entrapment of water inside the pallets and ultimately results in increased expansion and reduced bulk density of the extrudates. The results found agree with those reported by Dehghan-Shoar *et al*., (2010) for the directly expanded extruded snacks.

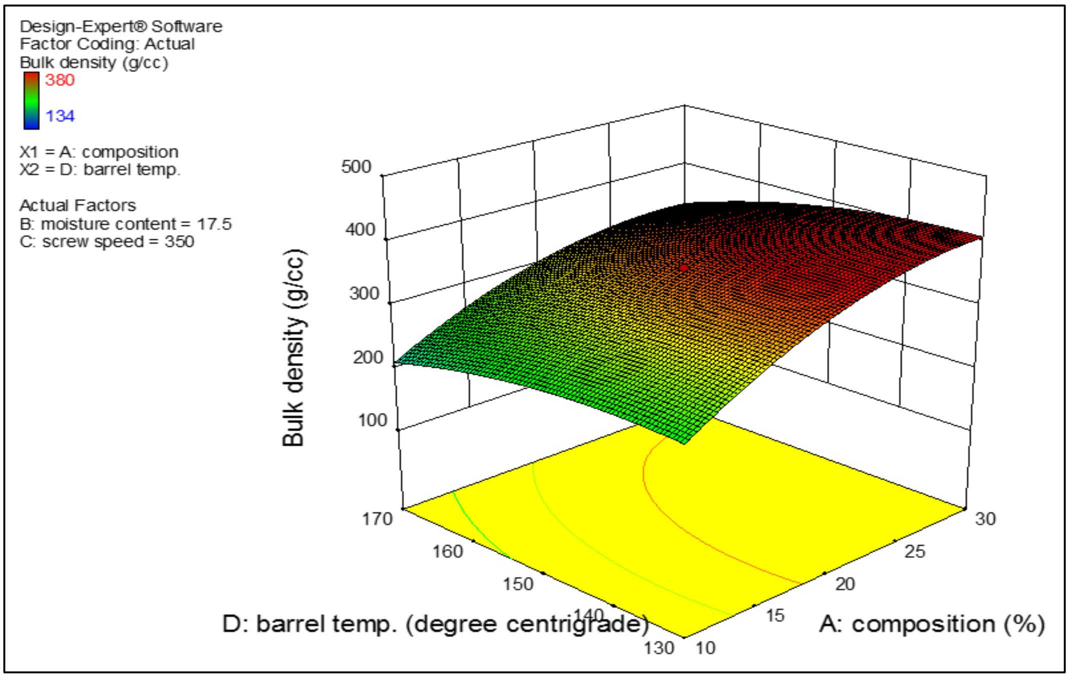


Fig 2: Response surface plot for bulk density as function of barrel temperature and composition

Water Absorption Index

The water absorption index (WAI) measures the increase in volume of starch granules after swelling in excess water, increase in volume is attributed to increase in degree of starch damage, due to gelatinization and extrusion induced fragmentation (Rayas-Duarte *et al*., 1998). In present study values for WAI ranged between 3.525 and 6.16 g/g (table 3). Analysis of variance was performed to study the effect of independent variables on WAI (table 4). The coefficient of determination (R^2) and adjusted R^2 were 0.879 and 0.859 respectively. The coefficient of variation was found to be 6.02. The regression model for WAI shown in equation 8 demonstrates significant linear effects with composition and barrel temperature.

$$WAI = +4.45 - 0.70C - 0.17T \quad (8)$$

The response surface plots shown in figure 3 demonstrates that WAI decreased with the increase in composition and barrel temperature. WAI decreased significantly as the percentage of apple powder increased, Lower WAI with increasing apple powder concentration was probably due to reduction of starch content with increasing apple powder content, which means extent of starch gelatinization is reduced during extrusion and subsequently less water is absorbed. Similarly, Singh *et al*., (2007) reported a decrease in WAI values of extruded rice was due to dilution of starch by addition of pea grits to rice. Higher thermal temperature may lead to enhancement in the extent of starch degradation and increased dextrinization which resulted in decreased WAI (Hagenimana *et al*., 2006) [19].

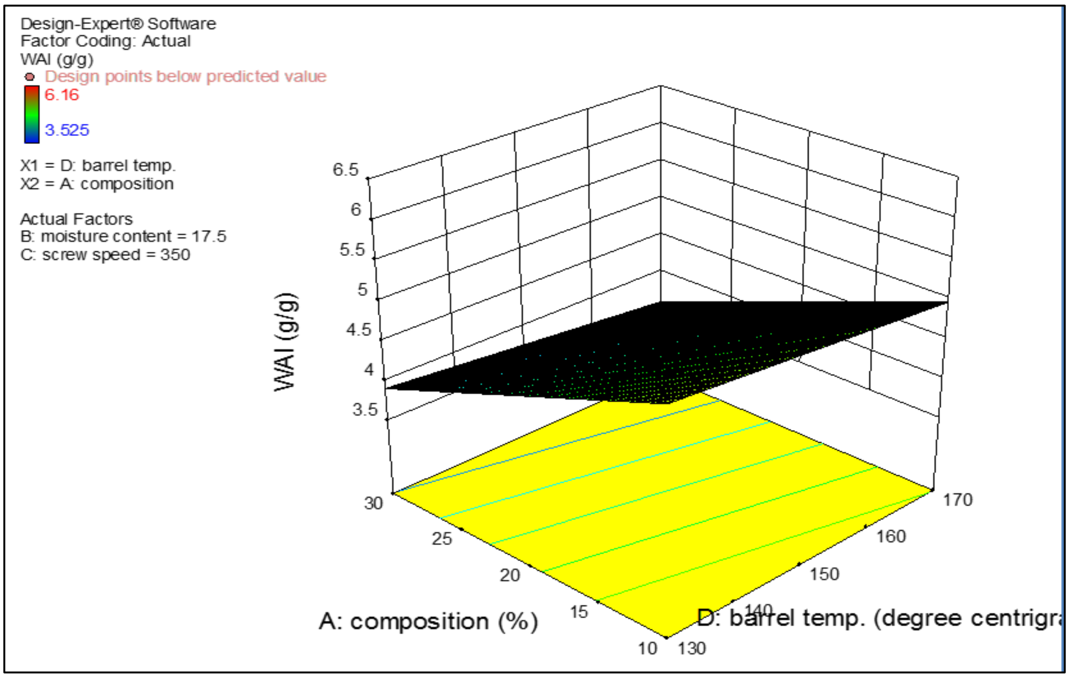


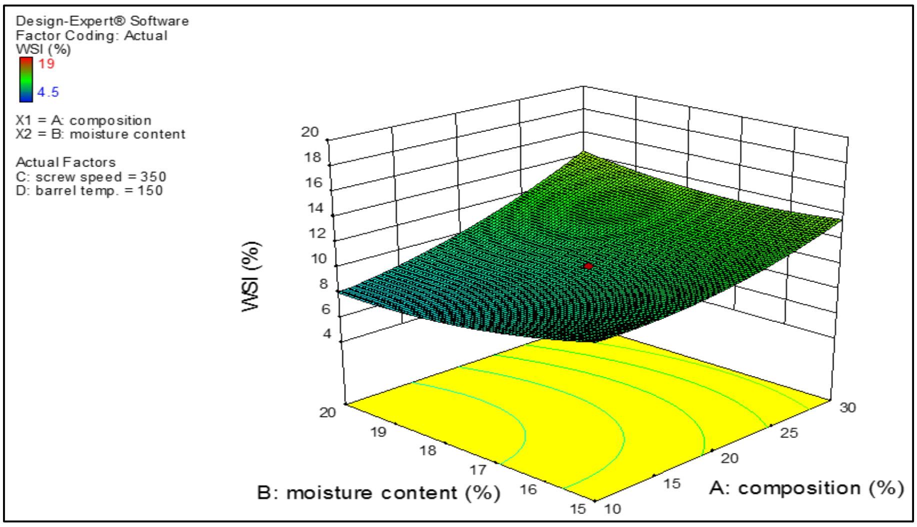
Fig 3: Response surface plot for WAI as function of barrel temperature and composition

Water Solubility Index

Water solubility index (WSI), an indicator of degradation of molecular components (Kirby *et al.*, 1988), measures the amount of soluble polysaccharide released from the extruded starch (Ding *et al*., 2005). WSI ranged from 4.5 to 19 percent (table 3). Analysis of variance was performed to study the effect of independent variables on WSI (table 4). The coefficient of determination (R^2) and adjusted R^2 were 0.923 and 0.859 respectively. The coefficient of variation was found to be 6.02. The fitted regression equation for WSI is reported in equation 9, demonstrating linear effect with composition moisture (P<0.05) and temperature (P<0.0001), interactive effect between composition and screw speed and quadratic effect with composition and feed moisture only (P<0.0001).

$$WSI = +10 +2.57C -0.53M +2.05\,T +1.46\,CS +0.94C^2 + 0.82M^2 \quad (9)$$

The response surface plots of WSI shown in (figure 4) showed the negative influence of moisture and positive influence of composition and barrel temperature. The significant increase in WSI with increasing apple powder concentration can be related to formation of low molecular weight components, which can be separated quite easily from each other under severe processing conditions (Collona *et al.*, 1989). The fiber of apple may disrupt continuous structure of the melt in extruder, impeding elastic deformation during extrusion (Moraru & Kokini, 2003). So, the greatest WSI values may due to disintegration of starch granules and formation of low molecular weight compounds upon extrusion, leading to increase in soluble components. At low feed moisture, more friction could have been occurred inside the extruder, causing high mechanical damage and an increased WSI. Similarly Singh *et al.,* (2001) reported increase in WSI when temperature was increased and decrease in WSI when moisture was increased, during extrusion processing of sweet corn grits. WSI increased with increasing temperature in combination with low feed moisture, at higher temperatures there may be increased degradation of starch and pectin molecules, releasing low molecular weight compounds and thus increasing their solubility in water. Also, at low moisture content, more friction may have occurred inside the extruder, causing high mechanical damage and an increased WSI, this is in agreement with the results reported by Singh *et al*., (2001) for extusion cooking of sweet corn. The significant positive interactive effect of composition and screw speed suggests dominating effect of composition over screw speed.



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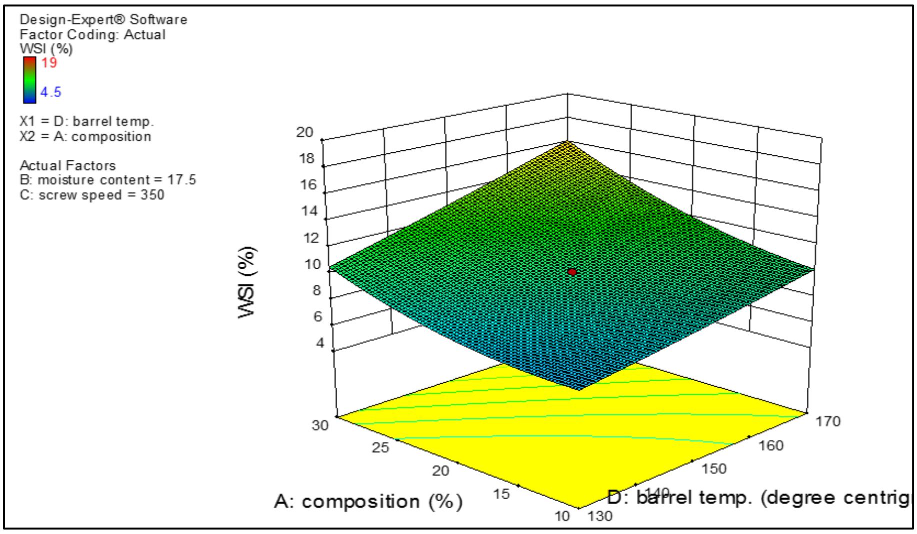


(b)

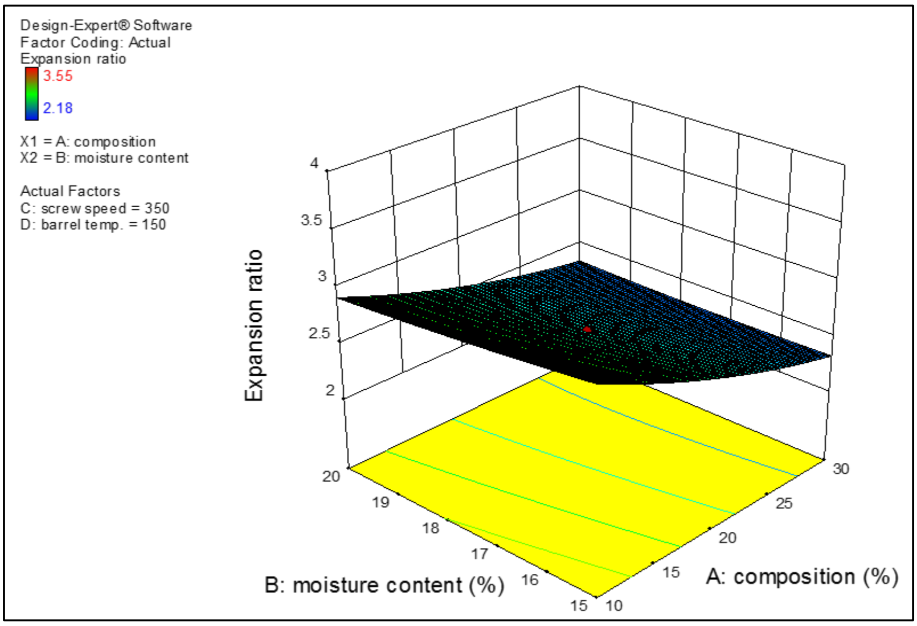
Fig 4: (a) Response surface plot for WSI as function of composition and moisture content. (b) Response surface plot for WSI as function of composition and barrel temperature

Expansion Ratio

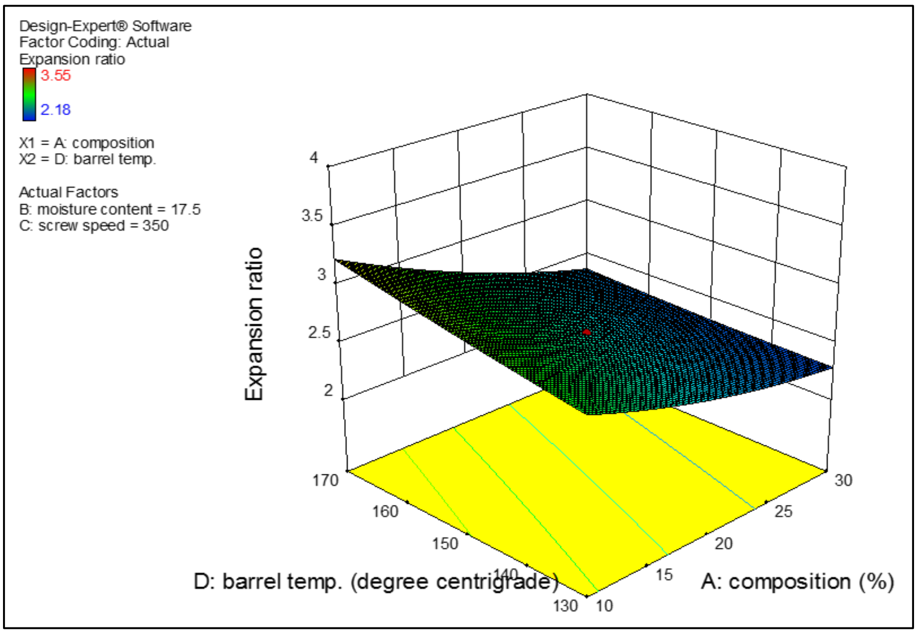
Expansion ratio (ER) indicates the extent of puffing of extruded products. During extrusion cooking, the viscoelastic mass formed is forced through the die, the sudden pressure drop causes part of the water to vaporize, giving an expanded porous structure. Expansion ratio (ER) varied between 2.18 and 3.55 (table 3). An ANOVA was performed to study the effects of the independent variables on expansion. The regression model for expansion ratio showed high coefficient of determination (R2) of 0.968 and adjusted R2 of 0.938 (table 4). The fitted model for ER shown in equation 10 indicating significant linear effects with composition (0.05), temperature (0.0001). Regression analysis also showed that ER was significantly affected by the quadratic effect of composition and barrel temperature only (P<0.0001).

$$ER = + 2.59 - 0.35A - 0.056B + 0.12D + 0.057AB - 0.081AD + 0.076A^2 \quad (10)$$

The response surface plots of ER shown in (figure 5) showed the negative influence of composition, moisture and positive influence of barrel temperature. The reduced expansion of the extrudates upon addition of apple powder might be due to the competition set by apple powder for moisture during the extrusion process affecting the degree of gelatinization (Yanniotis *et al*., 1987). Regression analysis showed that ER was significantly affected by the quadratic effect of both composition and temperature, The increased temperature would yield a lower melt viscosity and increased longitudinal expansion (Launay and Lisch, 1983). Similar observations were reported by Chinnaswamy and Hanna 1988; Ali *et al*. 1996; Hagenimana *et al*. 2006 [19] for effect of temperature on product expansion of corn starch, corn grits and rice flour.



(a)



(b)

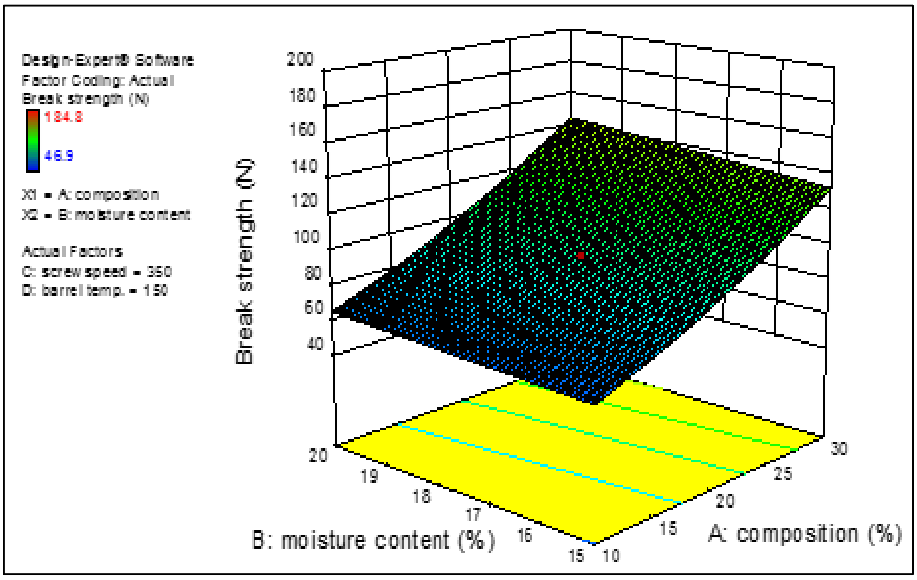
Fig 5(a): Response surface plot for expansion ratio as function of composition and moisture content. 5 (b): Response surface plot for expansion ratio as function of composition and barrel temperature

Breaking Strength

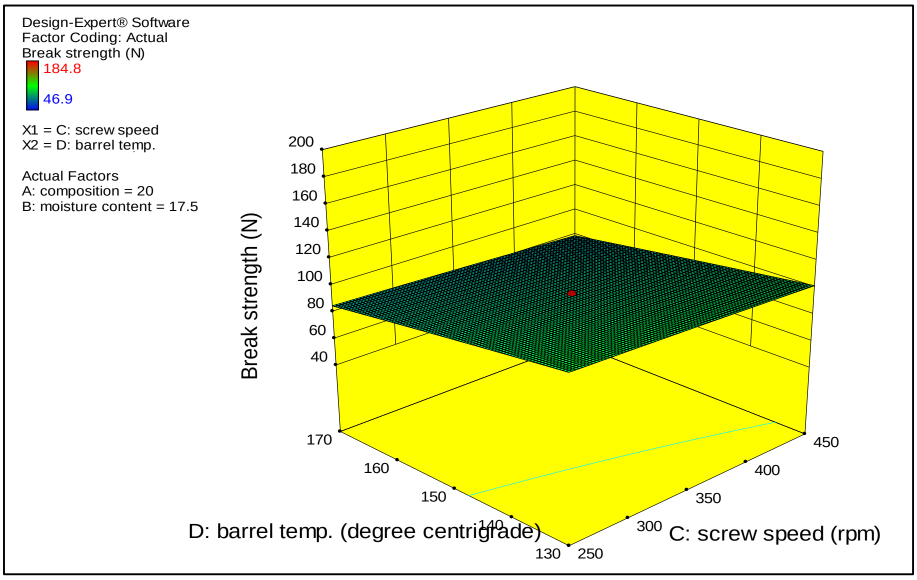
The breaking strength (BS) is the maximum force required to break or snap the snack, and is an indication of snack hardness. Mean values of breaking strength were found in the range of 46.9 to 184.8 N (table 3). ANOVA results for the model of hardness are given in Table 4.Acceptable coefficient of determination (R2) and adjusted R2 value (0.883 and 0.822, respectively) were obtained for significant model of breaking strength with 14.23 of coefficient of variance.The fitted regression model for breaking strength is shown in equation 11 indicating the linear effects of BS with composition, barrel temperature and interactive effect with composition and barrel temperature only.

$$BS = +94.9 + 38.03A + 4.55B - 3.24C - 11.65D - 4.22AD + 5.64A^2$$

The response surface plots of BS shown in (figure 6) showed the positive influence of composition and moisture, negative influence of screw speed and barrel temperature and interactive effect of composition and temperature. The significant increase in BS of extrudates upon increasing the level of apple powder incorporation may be attributed to reduced expansion due to high fibre content of apple powder. Increase in BS with increasing moisture content might be due to the reduced expansion caused by collapse of air bubbles inside the pallet at high moisture content. Similar trends have also been reported by Lee *et al*. (2002) [24]. The effect of screw speed on hardness might be through its influence on extrudate expansion. The decrease in hardness with increasing screw speed has also been reported by b Altan *et al*. (2008) [5] in corn- and barley-based extrudates. Breaking stress had a negative correlation with barrel temperature, when extrusion was performed at high temperatures extrudates became more brittle, thus offered lower breaking strength, further decrease in hardness with increasing barrel temperature is in line with the results of bulk density where reduced density was observed. A low-density product naturally offers low breaking strength. Bhattacharya and Hanna (1987) also reported that a higher degree of gelatinization caused greater expansion but lower breaking strength.



(a)



(b)

Fig. 6: (a) Response surface plot for break strength as function of composition and moisture content. (b) Response surface plot for as break strength as function of barrel temperature and screw speed

Optimization

Numerical optimization of the process variables was done to generate optimum processing conditions and to predict the corresponding responses as well. The main criteria was to maximize the desired parameters (SME, ER, WAI, WSI) and to minimize the undesired parameters (BD, BS). The desirability function for obtaining optimal conditions in extrusion cooking of apple based corn extrudates of the response surface is shown in (Fig 7). The highest desirability of 0.848 was obtained. The optimum conditions of apple powder incorporation, feed moisture, screw speed and barrel temperature were 10%, 15%, 450 rpm and 170 ^{0}C respectively were predicted by RSM. By applying these optimal conditions, extrudates with SME, bulk density, WAI, WSI, expansion ratio and breaking strength as 89.694 (Wh/kg), 143.200 (kg/m^3), 4.796 (g/g), 9.81 (%), 3.453 and 49.479 (N), respectively could be produced. These optimum conditions can be used to produce extrudates with the highly desired physical and textural characteristics.

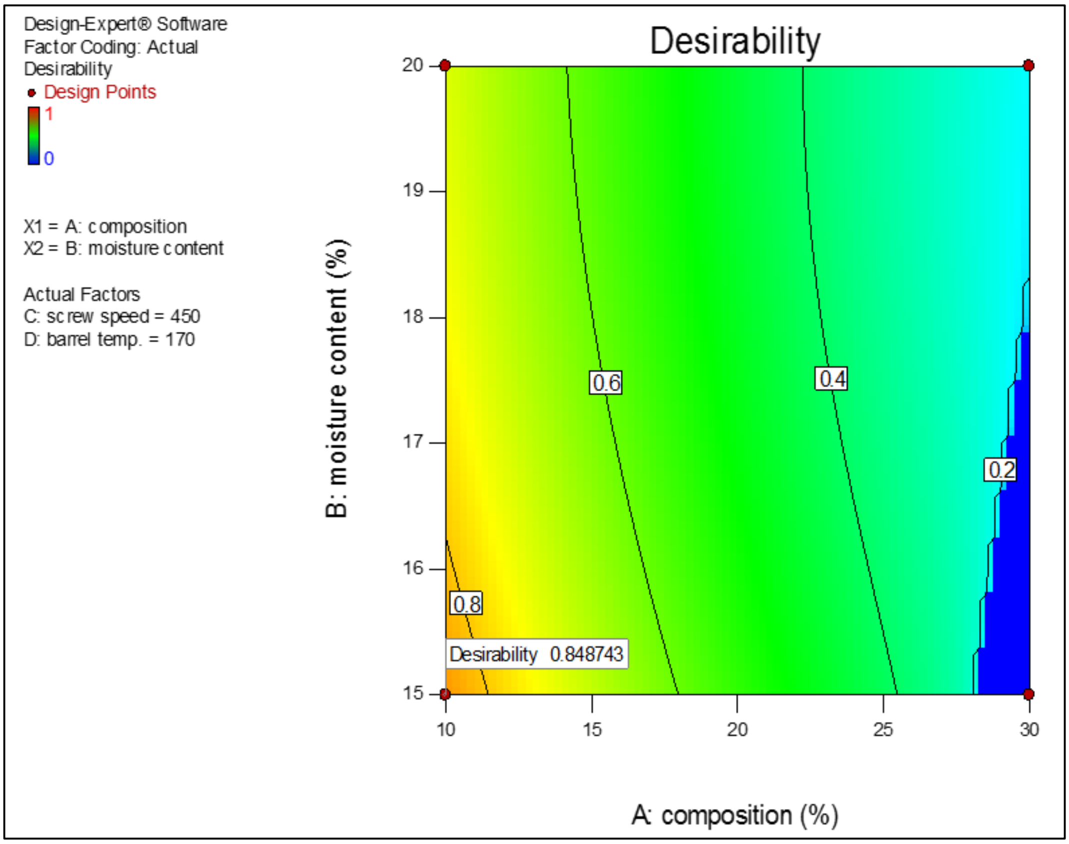


Fig 7: Desirability function response surface for development of corn apple based extrudates

Physico- chemical properties of optimized corn-apple exruded snack

The proximate compositions of extruded snacks are presented in Table (5). Crude fat content of optimized snacks decreased from 3.38 to 1.53 %, whereas a slight decrease in protein content was observed. Hagenimana *et al*., (2006) [19] reported that decreases in the crude fat and crude protein, occurred through the various starch gelatinization and protein denaturation reactions. Extrusion cooking increased the crude and dietary fiber values of optimized extruded snacks as extrusion reduces the moliculer weight of cellulose, hemicellilose molicules resulting in higher solubility. Extrusion processing resulted in maximum retention of minerals and vitamins in the extruded snacks which inturn depends on controlling various parameters during extrusion processing, e.g. moisture, temperature, screw speed. This subject is addressed in reviews on nutritional changes during extrusion (Bjorck & Asp, 1983; Camire *et al*., 1990; Camire, 1998).

Table 5: physico- chemical properties of extruded corn-apple blend.

Parameter	Corn-apple extrudtes
Moisture (%)	3.36
Crude protein (%)	6.46
Crude fat (%)	1.53
Crude fiber (%)	2.28
Dietary fiber (%)	13.82
Ash (%)	1.71
Carbohydrate (%)	84.66
Mineral profile (mg/100g)	
Ca	7.8
Mg	116
K	303.8
P	193.2
Na	38
Zn	2.26
Vitamins (mg/100g)	
Thiamine	0.214
Riboflvin	0.201
Niacin	2.94

Sensory analysis

Whilst the nutritional value of product is of utmost importance, however for the success of product it also needs to be acceptable by the consumers. The general appearance of the extrudates evaluated were found satisfactory and scored between fair and very good. During storage period of three months, under ambient conditions (25 ±2, 60-62 %RH) the organoleptic properties of snacks (colour, texture, appearance, and overall acceptability) were within the acceptable range. The overall score decreased from 4.3 (very good) to 3. 9(good) on a 5 point scale during three months of storage (Table 6). Storage period slightly affected the overall acceptability of the product. Out of all the parameters storage had significant effect on texture, which was particularly noticed in the extrudates upon sensory evaluation. The storage was found to have a non-significant effect on the colour scores in extrudates. The scores for colour remained constant even up to 90th day of storage.

Table 6: Sensory scores of extrudates produced at different process conditions

1	4.5	4.2	2.27	2.2	3.7	4.0
2	2.4	3.2	2.22	3.4	2.4	2.8
	4.3	4.1	2.26	3.2	3.5	3.9
4	2.2	3.1	2.15	3.2	2.3	2.6
5	4.4	4.2	2.20	2.3	3.6	4.1
6	2.3	3.3	2.34	3.3	2.3	2.7
7	4.2	4.0	2.38	2.4	3.4	3.9
8	2.2	3.0	2.46	3.2	2.2	2.7
9	4.6	4.5	3.51	2.6	3.9	4.2
10	2.7	3.8	3.34	3.8	2.9	3.2
11	4.5	4.4	3.55	2.3	3.9	4.1
12	2.5	3.2	3.11	3.5	2.6	2.9
13	4.7	4.6	3.58	2.6	4.0	4.3
14	2.6	3.7	3.19	3.7	2.8	3.3
15	4.5	4.3	3.30	2.2	3.8	4.1
16	2.5	3.1	3.16	3.5	2.7	3.0
17	2.8	2.2	3.49	4.4	2.4	3.01
18	2.0	3.0	2.88	2.1	2.0	2.4
19	3.1	4.9	2.38	3.8	3.5	3.8
20	2.7	4.5	2.24	3.1	2.5	3.4
21	2.8	4.7	2.31	3.3	3.3	3.5
22	2.6	4.6	2.37	3.4	3.3	3.7
23	3.0	4.3	2.30	3.3	3.1	3.6
24	2.7	3.1	2.39	3.2	2.6	3.3
25	2.9	4.7	2.34	3.4	3.1	3.6
26	2.9	4.7	2.34	3.4	3.1	3.6
27	2.9	4.7	2.34	3.4	3.1	3.6
28	2.9	4.7	2.34	3.4	3.1	3.6
29	2.9	4.7	2.34	3.4	3.1	3.6
30	2.9	4.7	2.34	3.4	3.1	3.6

Conclusion

The increasing trend towards snacking and in particular towards the snacks that are high in fats and sugar, has been a contributing factor to poor diet. Initiatives to improve the nutritional profile of snacks created a demand to utilize healthier choices among raw materials. Incorporation of apple into the corn flour not only utilized the less commercially important grades of apple but also increased the value of apple incorporated corn based extrudates. It was evident from this study that the application of response surface methodology (RSM) can be a practical and useful tool for optimization of processing conditions. RSM revealed the significant effect of Apple powder incorporation, barrel temperature on physical properties of the extrudates The effect of Feed moisture was relatively less, while the effect of screw speed was least significant. The relatively low values of BD and BS observed in the present study indicate that the snacks possess expansion characteristics similar to commercially available snacks. Such information could help food processors to predict the optimum operating conditions for the development of extrudates & to exploit raw materials that could be used for the development of novel food products in response to various consumer demands.

References

1. AACC. Approved Methods of American Association of Cereal Chemists. 10th ed. The Association St. Paul, MN, 2000.
2. AACC. Approved Methods of American Association of Cereal Chemists. 10th ed. The Association St. Paul, MN, 2000.
3. Akdogan H. Pressure, torque and energy responses of a twin screw extruder at high moisture contents. Food Research International. 1996; 29:423-429.
4. Ali Y, Milford AH, Chinnaswamy R. Expansion characteristics of extruded corn grits. Lebensmittel Wissenschaft und Technologie. 1996; 29:702-707.
5. Altan A, McCarthy KL, Maskan M. Evaluation of snack foods from barley-tomato pomace blends by extrusion processing. Journal of Food Engineering. 2008a; 84:231-242.
6. Anton AA, Luciano FB. Instrumental texture evaluation of extruded snack foods: A review. CyTA-Journal of Food. 2007; 5:245-251.
7. AOAC. Official Methods of Analysis. Vol II, 15th Edition. 1990. Association of Official Analytical Chemists, Inc., Arlington, Virginia, 1298.
8. Bjorck I, Asp NG. The e_ects of ex- trusion cooking on nutritional value, a liter- ature review. Journal of Food Engineering. 1983; 2(4):281{308. doi:10.1016/0260-8774(83) 90016-X
9. Bhattacharya M, Hanna MA. Extrusion processing of wet corn gluten meal. Journal of Food Science. 1987; 50:1508-1509.
10. Camire ME, Zhao JX, Violette DA. In-vitro binding of bile-acids by ex-truded potato peels. Journal of Agricul-tural and Food Chemistry. 1990; 41(12):2391. {2394. doi:10.1021/jf00036a033
11. Camire M. Chemical changes during extrusion cooking -, Process-induced chemical changes in food. Journal of Agricul- tural and Food Chemistry. 1998; 434:109{121).
12. Chimnaswamy R, Hanna MA. Relationship between amylose content and extrusion-expansion properties of corn starches. Cereal Chemistry. 1988; 65(2):138-143.
13. Colonna PJ, Tayeb J, Mercier C. Extrusion cooking of starch and starchy products. In: Extrusion Cooking. American Association of Cereal Chemists, (Eds. C. Mercier, P. Linko, and J. M. Harper) Inc., St. Paul, MN. 1989, 247-319.
14. Dehghan-Shoar Z, Hardacre AK, Brennan CS. The physico-chemical characteristics of extruded snacks enriched with tomato lycopene. Food Chemistry. 2010; 123:1117-1122.
15. Ding QB, Ainsworth P, Tucker G, Marson H. The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. Journal of Food Engineering. 2005; 66:283-289.
16. Eastman J, Orthoefer F, Solorio S. Using extrusion to

create breakfast cereal products. Cereal Foods World. 2001; 46:468-471.
17. Gujral HS, Singh N. Extrusion behavior and product characteristics of brown and milled rice grits. International Journal of Food Properties. 2001; 5(2):307-316.
18. Gorinstein S, Zachwieja Z, Folta M, Barton H, Piotrowicz J, Zemser M, *et al*. Comparative contents of dietary fiber, total phenolics, and minerals in persimmons and apples. J Agric. Food Chem. 2001; 49:952-957.
19. Hagenimana A, Ding X, Fang T. Evaluation of rice flour modified by extrusion cooking. Journal of Cereal Science. 2006; 43:38-46.
20. Jin Z, Hsieh F, Huff HE. Extrusion cooking of corn meal with soy fiber, salt and sugar. Cereal Chemistry. 1994; 71(3):227-234.
21. Kirby AR, Ollett AL, Parker R, Smith AC. An experimental study of screw configuration effects in the twin-screw extrusion-cooking of maize grits. Journal of Food Engineering. 1988; 8:247-272.
22. Kirk SR, Sawyer R, Egan H. Pearson’s composition and Analysis of foods, 9th edn., Longman, Singapore, 1991.
23. Launay B, Lisch JM. Twin-screw extrusion cooking of starches: flow behaviour of starch pastes, expansion and mechanical properties of extrudates. Journal of Food Engineering. 1983; 2:259-280.
24. Lee EY, Lim K, Lim J, Lim ST. Effects of gelatinization and moisture content of extruded starch pellets on morphology and physical properties of microwave-expanded products. Cereal Chemistry. 2002; 77(6):769-773.
25. Meng X, Threinen D, Hansen M, Driedger D. Effects of extrusion conditions on system parameters and physical properties of a chickpea flour-based snack. Food Research International. 2010; 43:650-658.
26. Moraru CI, Kokini JL. Nucleation and expansion during extrusion and microwave heating of cereal foods. Comprehensive Reviews in Food Science and Food Safety. 2003; 2:147-162.
27. Patil Berrios, Swansons. Evaluation of methods for expansion properties of legume extrudates. Applied Engineering Agriculture. 2007; 23:77-83.
28. Rayas-Duarte P, Majewska K, Doetkott C. Effect of extrusion process parameters on the quality of buckwheat flour mixes. Cereal Chemistry. 1998; 75:338-345.
29. Seker M. Selected properties of native or modified maize starch/soy protein mixtures extruded at varying screw speed. Journal of the Science of Food and Agriculture. 2005; 85:1161-1165.
30. Singh B, Sekhon KS, Singh N. Effects of moisture, temperature and level of pea grits on extrusion behaviour and product characteristics of rice. Food Chemistry. 2007; 100:198-202.
31. Singh-Gujral H, Singh N, Singh B. Extrusion behaviour of grits from flint and sweet corn. Food Chemistry. 2001; 74:303-308.
32. Stojceska V, Ainsworth P, Plunkett A, Ibanoglu E, Ibanoglu S. 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. 2008; 97:554-563.
33. Yanniotis S, Petraki A, Soumpasi E. Effect of pectin and wheat fibres on quality attributes of extruded cornstarch. Journal of Food Engineering. 1987; 80:594-599.
34. Zasypkin DV, Yuryev VP, Alexeyev VV, Tolstoguzov VB. Mechanical properties of the products obtained by the thermoplastic extrusion of potato starch-soybean protein mixtures. Carbohydrate Polymers. 1992; 18:119-124.