International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(6): 1109-1116

Received: 04-09-2017
Accepted: 05-10-2017

Jasia Nissar
Division of food science and Technology, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Jammu, Kashmir, India

Tehmeena Ahad
Division of food science and Technology, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Jammu, Kashmir, India

HR Naik
Division of food science and Technology, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

SZ Hussain
Division of food science and Technology, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Jammu, Kashmir, India

Correspondence
Jasia Nissar
Division of food science and Technology, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Jammu, Kashmir, India

Development of honey incorporated snacks using extrusion technology

Jasia Nissar, Tehmeena Ahad, HR Naik and SZ Hussain

Abstract
In present work extrusion processing variables were optimized to study their effect on physical and functional properties of honey based breakfast snacks. Effects of adding different concentrations of honey powder, moisture content, barrel temperature and screw speed was investigated to optimize the levels of extrusion processing conditions for the development of honey powder incorporated extruded snacks. Co-rotating twin screw extruder was used for the production of corn based honey powder incorporated extrudates. Response surface methodology (RSM) at varying honey 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. water absorption index (WAI), water solubility index (WSI), breaking strength (BS) of corn- based honey powder 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 ($R^2>0.95$). Results suggest that honey powder is a promising raw material for the production of functional extruded snacks which are high in bioactive compounds.

Keywords: corn, honey, extrusion, RSM, snacks

Introduction
The growing consumer demand for wholesome and healthier foods has impacted the expanded foods segment and it is driving research and industry towards developing novel ready to eat expanded products Potato chips followed by corn chips dominated the snack food market worldwide (Singh *et al.*, 2011). Most snacks made from cereal grains (oats, rice, corn) are usually low in nutritional components such as vitamins and minerals. Over the past ten years consumers have become more health conscious and are choosing snacks that claim to be healthier and more nutritious. The addition of non cereal products to the basic flour is a growing trend in recent literature. Therefore the snacks that are rich in fibre, vitamins and minerals are more popular and high in demand. Perusal Of literature shows that little work has been conducted regarding the use of honey in snack food production, incorporation of honey in the extruded snack and can be found suitable in the commercial production of highly nutritious and cheap extruded products.
Honey is one of the most widely sought product due its unique nutritional and medicinal properties. Perusal of literature shows that very little work has been conducted regarding the use of honey in snack food production. Honey has a long history in human consumption, it is packed with B-vitamins, rich in minerals, having antioxidant activity. Incorporation of honey in extruded snacks shall give a new perspective and alternative for healthy snack production. Extrusion cooking is one of the most important food processing technologies which have been used for the production of breakfast cereals, ready to eat snack foods and other textured foods. Effects of extrusion cooking on nutritional quality are ambiguous. This technology because of its beneficial effects such as destruction of antinutritional factors, increased soluble dietary fibres, reduction of lipid oxidation and contaminating microorganisms plays an important role in the production of a wide variety of foods and ingredients. As a complex multivariate process, extrusion cooking requires careful control if product quality is to be maintained. Great possibilities are offered to modify the physic-chemical properties of food components by the use of extrusion technology. The extruded food besides being preserved, have an enhanced biological value (Raiz, 2000). Due to its versatility, cost effectiveness, efficiency and quality of end product (Eastman, *et al.*, 2001) [6], extrusion plays an important role in the preparation of cereal based products.

Therefore in this study extrusion processing was employed for the development of honey incorporated snacks.

Materials and methods

The corn (C-6) variety procured from Division of Genetics and Plant Breeding, SKUAST-Kashmir, was milled in mill (Model 3303, Perten Sweden) in the Division of *Food Science and Technology*. High quality spray dried honey powder was procured from renowned company (Kane grade Flavors)

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.*, honey powder incorporation, 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), expansion ratio (ER), Response surface methodology was used to investigate the individual and interactive effects of independent variables on the product responses. The independent variable levels of honey 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 (Corn:honey)	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 (°C)	D	110	130	150	170	190

Extrudate characteristics

Physical properties of extruded snacks

Water absorption index (WAI)

The water absorption index (WAI) measures the volume occupied by the granule or starch polymer after swelling in excess of water. The ground extrudates were suspended in distilled water at room temperature for 30 minutes, gently stirred during this period and then centrifuged at 3000 g for 15 min. The supernatant liquid was poured carefully into tarred evaporating dish. The remaining gel was weighed and WAI was calculated as the grams of gel obtained per gram of solid.

$$\text{WAI (g/g)} = \frac{\text{Weight gain by gel}}{\text{Dry weight of extrudate}}$$

Water solubility index (WSI)

Water solubility index (WSI) was determined from the amount of dried solids received by evaporating the supernatant from the water absorptioin index test described above. WSI was expressed as follows:

$$\text{WSI (\%)} = \frac{\text{Weight of dissolved solids in supernatant}}{\text{Weight of dry solids}} \times 100$$

Breaking strength

Textural quality of the extrudates were examined by using TA-XT2i Texture analyser (Stable Microsystems, United Kingdom). The compression probe (50 mm diameter, aluminum cylinder) was applied to measure compression force required for sample breakage which indicates hardness. Testing conditions were: 1.5 mm/s pre-test speed; 1.5 mm/s test speed; 10 mm/s post-test speed and 8mm distance.

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 (honey powder incorporation, 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.

Proximate composition

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

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

Vitamins

The samples of extrudate were ground to a homogenous state using a food processor. Analysis of three B group vitamins (thiamin, riboflavin, niacin and pyridoxine) was performed using HPLC.

Thiamin analysis. A portion of the sample was acid autoclaved at 121.1˚C, followed by enzymatic digestion to release protein-bound vitamin and break any thiamin–phosphate bonds. The extract was then assayed by ionpair reversed phase HPLC with a buffered mobile phase (methanol–citrate, pH 2.4). The thiamin was oxidized to thiochrome by post-column reaction with hexacyanoferrate (III) and detected by fluorescence.

Riboflavin analysis. A portion of the sample was acid autoclaved at 121 1C, followed by enzymatic digestion to release protein-bound vitamin and break any riboflavin phosphate bonds. The extract was assayed by reversed phase, ion-pair HPLC techniques and detected by fluorescence detection.

Niacin analysis. A portion of the sample was heated with dilute hydrochloric acid to extract the vitamin and hydrolyze the niacinamide to niacin. The extract was cooled, made to a known volume and subjected to HPLC analysis, using reversed-phase, ion-pair techniques and UV detection.

Minerals (mg/100 g)

0.5g of ground samples were taken for digestion. Di acid mixture of Nitric acid: Perchloric acid in 4:1 proportion was added. It was kept for digestion in digestor than 0.5-1 ml aliquot of samples were taken from digestor and diluted with 100ml of double distilled water. Subsequently it was analysed using atomic absorption spectrometer.

Antioxidant activity

The ground samples (0.5 g) were extracted twice with 10 mL of an ethanol: water (80:20 v/v) solution. The first extraction involved stirring for 2 hours at 30_C and the extracts were pooled. Then, the solid was re-extracted under the same conditions for 12 hours. The extracts were pooled and centrifuged at 1500 _ g for 20 minutes. The supernatants (about 20 mL) were transferred into a sample vial for total phenolic content, 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, and reducing power analyses

Results and discussion

Physical properties of extruded snacks

Models for all parameters were significant. None of the models showed significant lack of fit, indicating that all the second order polynomial models correlated well the parameters showed high adequate precision (Table 2.). A reasonable good coefficient of determination (R^2= 0.97, 0.97, 0.94) for WAI, WSI and Breaking strength) indicated that the models developed for product responses appeared to be adequate. The predicted R-squared was found in reasonable agreement with adjusted R-squared for all the parameters.

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

Term	BS	WAI	WSI
Adequate precision	38.366	28.453	22.606
R- square	0.9418	0.9786	0.9748
Adjusted R square	0.9325	0.9586	0.9512
Predicted R square	0.9106	0.8767	0.8547
CV	13.58	2.41	6.91
Lack of fit	NS	NS	NS

NS: non-significant

Physical characteristics of snacks

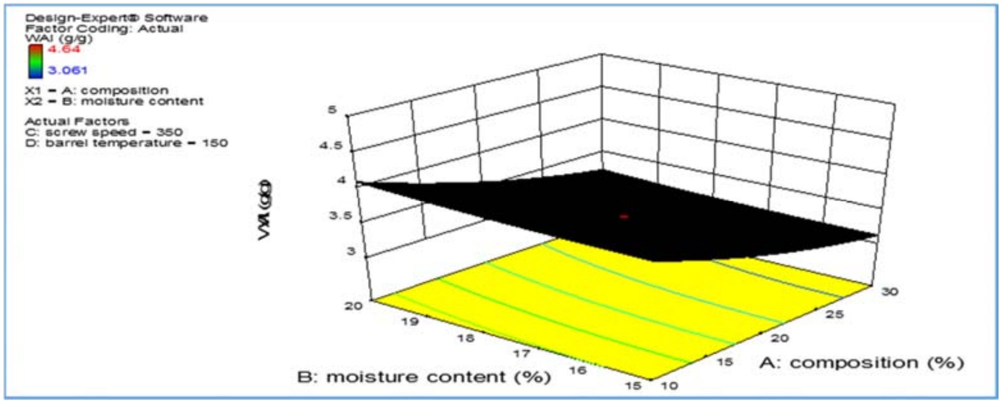
Water absorption index (WAI)

The WAI of extrudates ranged between 3.061 and 4.640 g/g (table.3). The model obtained from regression analysis for water absorption index is shown below (equ.1.)

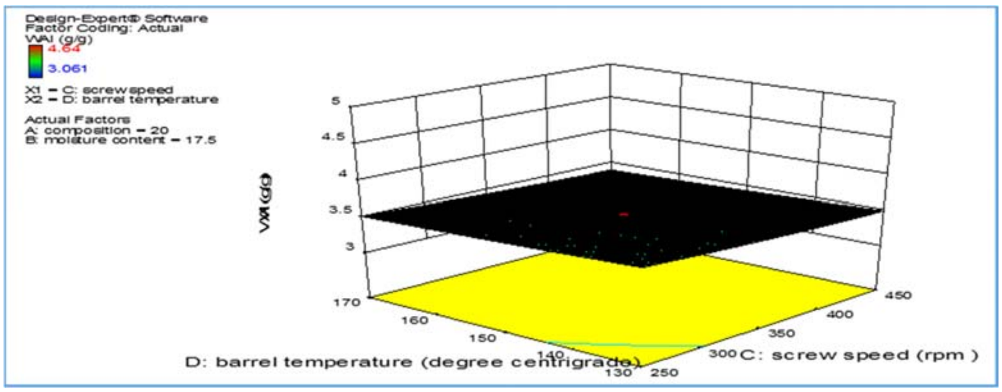
$$WAI = +3.49 - 0.44A +0.053 B -0.070C - 0.058D +0.054 AD +0.099A^2 \quad (1)$$

The regression analysis and response surface plots showed that composition (A), barrel temperature (D) and screw speed (C) had negative linear effect on WAI while moisture content (B) had a positive linear effect. The response was analyzed using ANOVA and data is present in table 2.

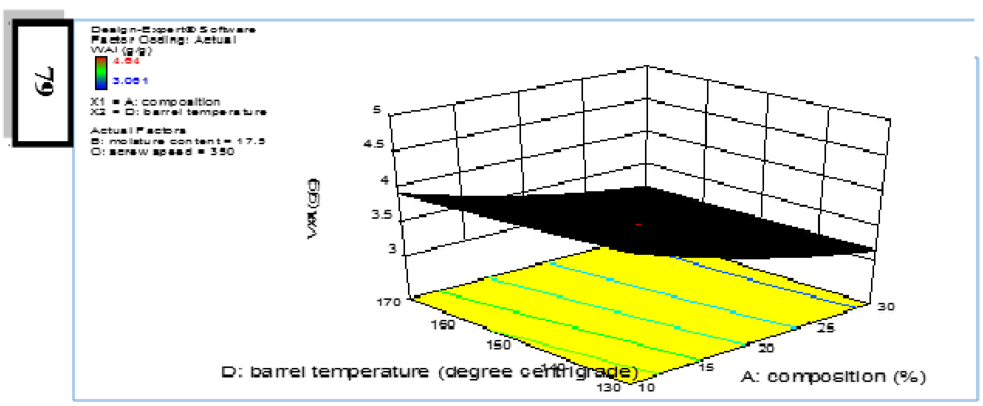
The binding of water due to addition of honey might have limited the availability of water, thus lower WAI. Yanniotis *et al.* (2007) [18] reported that any increase in non-starch component results in extrudates with lower water absorption capacity. Yagcı and Goguş (2008) [8] reported that at high moisture content, the starch viscosity might have decreased, allowing internal mixing and uniform heating which may account for the enhanced water absorption associated to starch gelatinization. Higher screw speeds caused decrease in WAI, probably due to the high shearing action produced at higher screw speed, which may have resulted in depolymerization of starch granules. The increase in WAI with increasing moisture content is in accordance with the observations reported by Ding *et al.* (2005) [5] and Singh *et al.* (2007) [14]. Higher temperatures result in more dextrinization in comparison to gelatinization which inturn leads to lower WAI. Similar results have also been reported by Valentina *et al.* (2010) [16].



(a)



(b)



(c)

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

Table 3: Effect of processing conditions on system parameter and product characteristics.

S. No.	(A) composition (CA:H)	(B) Moisture (%)	(C) Screw speed (rpm)	(D) Temp. (ºC)	WAI (g/g)	WSI (%)	Breaking strength (N)
1	90:10	15	250	130	4.381	9.11	82.4
2	70:30	15	250	130	3.278	9.7	302.1
3	90:10	20	250	130	4.27	7.2	103.4
4	70:30	20	250	130	3.311	11.3	311.6
5	90:10	15	450	130	4.05	8.3	76.8
6	70:30	15	450	130	3.066	13.7	291.2
7	90:10	20	450	130	4.213	8.8	94.6
8	70:30	20	450	130	3.112	16.6	308.4
9	90:10	15	250	170	4.028	15.02	53.3
10	70:30	15	250	170	3.221	17.3	234.8
11	90:10	20	250	170	4.157	10.3	68.7
12	70:30	20	250	170	3.299	17.3	279.6
13	90:10	15	450	170	3.874	11.74	52.8

14	70:30	15	450	170	3.061	20.5	202.6
15	90:10	20	450	170	3.926	9.8	63.7
16	70:30	20	450	170	3.123	18.25	258.5
17	100:0	17.5	350	150	4.64	10.3	53.1
18	60:40	17.5	350	150	3.102	19.8	321.4
19	80:20	12.5	350	150	3.376	16.6	125.3
20	80:20	22.5	350	150	3.785	12.6	178.3
21	80:20	17.5	150	150	3.592	9.6	193.6
22	80:20	17.5	550	150	3.508	10.3	110.5
23	80:20	17.5	350	110	3.616	5.7	198.8
24	80:20	17.5	350	190	3.413	17.4	103.8
25	80:20	17.5	350	150	3.488	10.8	154.6
26	80:20	17.5	350	150	3.488	10.8	156.6
27	80:20	17.5	350	150	3.488	10.8	156.6
28	80:20	17.5	350	150	3.488	10.8	156.6
29	80:20	17.5	350	150	3.488	10.8	156.6
30	80:20	17.5	350	150	3.488	10.8	156.6

(C: H) = corn: honey, WAI (g/g) = Water absorption index, WSI (%) = Water solubility index, BS (N) = break strength

Water solubility Index.

Water solubility index of extrudates ranged between 5.7 and 20.5 %. The significant predicted model for WSI in terms of independent variables (in coded levels) is given below (equ. 2)

$$WSI = +10.80 + 2.64A - 0.58B + 2.45D + 1.07A^2 + 0.95B^2 \quad (2)$$

Regression equation and response surface plots of WSI (Fig. 29.) showed the positive influence of composition (A), barrel temperature (D) and negative influence of moisture content (B) on WSI. The response was analyzed using ANOVA and data is present in table 2. The increase in WSI with increase in honey proportion may due to restriction on starch gelatinization by limited water availability so it promoted more dextrinization in comparison to gelatinization. These results are in alignment with that of Fan *et al.* (1996) [7]. Increasing temperature would increase the degree of starch gelatinization that may increase the amount of soluble starch resulting in an increase in WSI. Ilo *et al.* (1996) [9] reported that the degree of gelatinization of extruded maize grits increased with increasing product temperature.

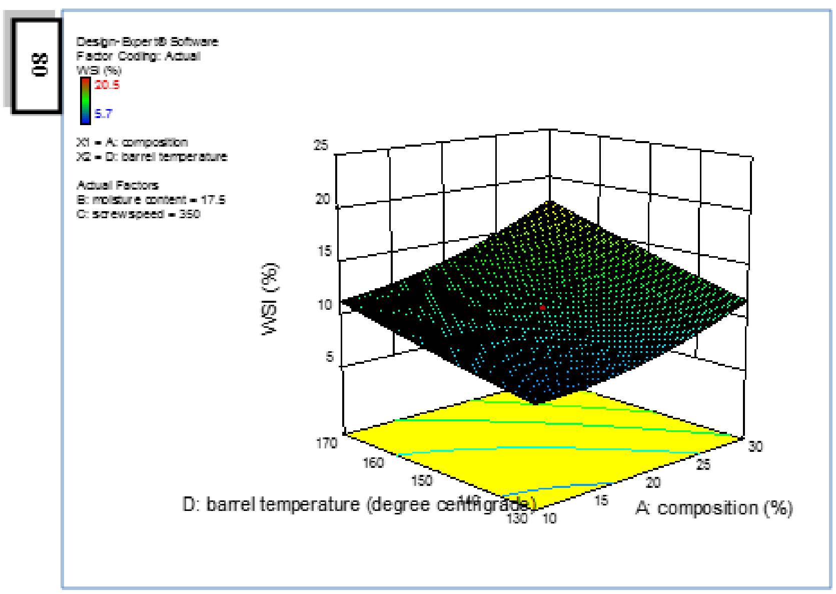


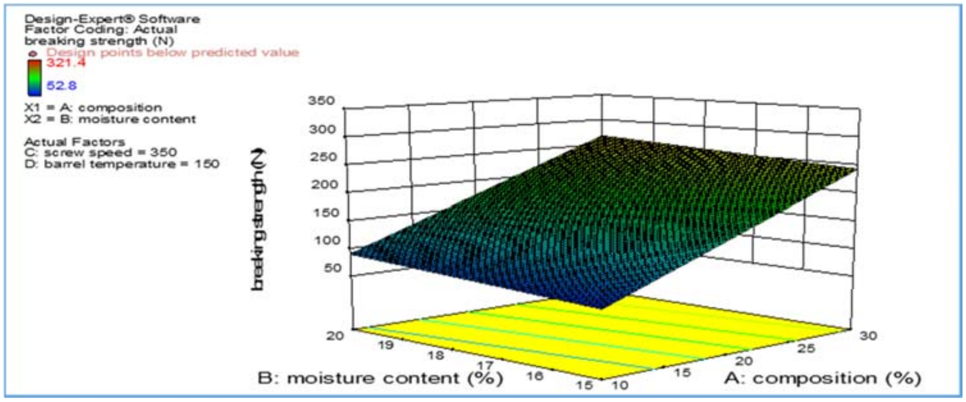
Fig 2: Response surface plot for WSI as function of composition and barrel temperature.

Breaking strength (BS)

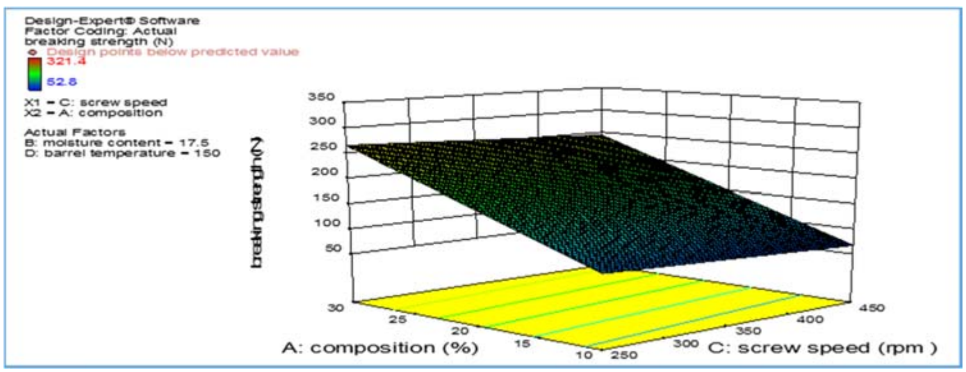
Mean values of breaking strength ranged between of 52.8 and 321 N (table 3). The significant model developed for breaking strength in terms of coded variables is given in the following equation.

$$\text{Break strength} = +16690 + 88.74A + 12.44B - 10.56C - 22.77D \quad (3)$$

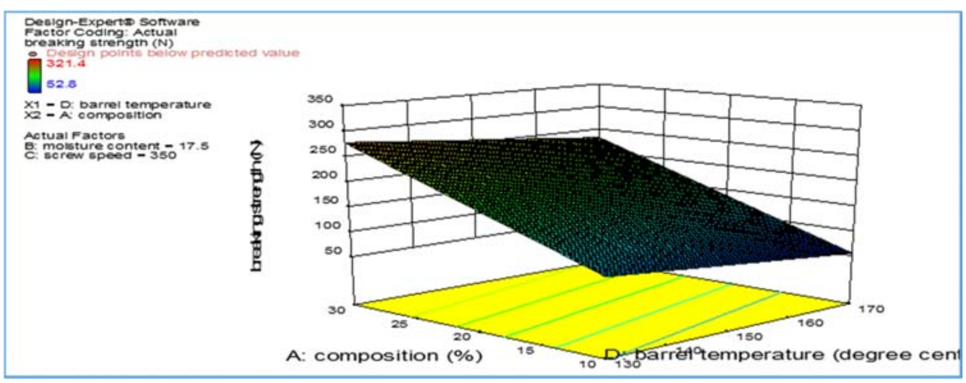
Response surface plots (Fig.3) showed the significant positive linear effect of composition (A), moisture content (B) and negative effect of screw speed (C) and barrel temperature (D) on breaking strength. Breaking strength of extrudates was increased significantly with the increase in composition, moisture content whereas, with the increase in temperature and screw speed, breaking strength was decreased. It is possible that the higher levels of sugar in the formulation as a result of the honey powder may have contributed to the increase in density and reduction in cell size of the extrudates that resulted in increased hardness. This is consistent with the findings of Barrett *et al.* (1995) [3] who reported that increasing sucrose content increases the density and reduces the cell size resulting in a progressive increase in compressive resistance. Water function as a plasticizer in extruder for the starch based material, which reduces viscosity and compresses bubble growth. The compressed bubble growth results in dense products. Similar results were reported by Huth *et al.* (2000) [8]. It is expected that increasing temperature as well as screw speed would decrease melt viscosity, which favors the bubble growth and produce low density products with small and thin cells, thus increasing the crispness of the extrudates. A low density product naturally offers low hardness. Bhattacharya and Hanna (1987) [4] also reported that a higher degree of gelatinization caused greater expansion but lower breaking strength. Similar trends have been reported previously by Ding *et al.* (2005) [5] in barley-tomato pomace blended extrudates and Lin *et al.* (2000) [10], Altan *et al.* (2008) [2] and Meng *et al.* (2010) [11] in corn, barley and chickpea based extrudates respectively



(a)



(b)



(c)

Fig 3: (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 composition and screw speed. (c) Response surface plot for as break strength as function of composition and barrel temperature.

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 and ER) and to minimize the undesired parameters (BD). The highest desirability value of 0.865 was obtained (Fig 4). The optimum conditions for development of final product were - composition (honey incorporation) - 10%, feed moisture-15%, screw speed - 450 rpm and barrel temperature - 170°C, under these conditions the optimum product with WAI, WSI, and breaking strength 3.822 g/g, 12.13 %, and 54.388 N could be produced. These optimum conditions can be used to produce extrudates with the highly desired physical and textural characteristics.

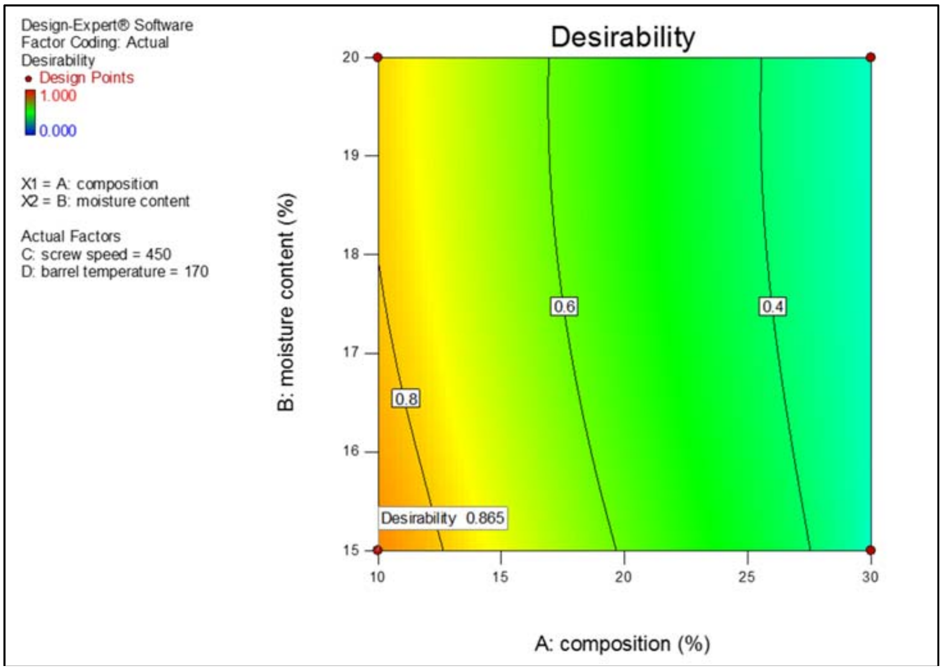


Fig 4: Desirability function response surface for development of honey incorporated corn-based extrudates.

Proximate composition of Snacks.

Protein, fat, ash, moisture, and fibre content of snacks were determined. Addition of 10 % honey powder in the corn flour resulted in snacks with changed biochemical composition. By incorporation of 10% honey powder, the total protein content in the final product decreased. Same trend was reported for crude fat content of snacks, where fat content was 3.38 % in control and 1.1% in honey incorporated snacks (table 4). The increase in carbohydrate content of snacks is attributed to presence of sugars in honey, however part of sugars is lost during millards reaction taking place in extrusion cooking. During extrusion cooking lipid is released from cells due to high temperature and physical disruption of cells (Nierrle *et al.* 1980) [12]. The ash content was slightly higher in honey incorporated snacks. The difference in fibre content of both control and honey incorporated snacks was not significantly different. Moisture content of both wasn't significantly different, as much of the moisture is flash vaporized during extrusion cooking.

Table 4: proximate composition of Snacks.

Parameter (%)	Control (only corn)	Honey incorporated snacks
Protein	8.97	3.35
Ash	1.6	1.70
Fat	3.38	1.1
Carbohydrate	79.83	87.5
Moisture	3.62	3.83
Fibre	2.60	2.62
Vitamins mg /10g		
Thiamine	0.385	0.214
Riboflavin	0.201	0.20
Niacin	3.63	2.95
Minerals mg/100g		
Calcium	7.00	7.88
Magnesium	127	116
Potassium	287	304.8
Phosphorus	210	194
Zinc	2.2	2.32
Antioxidant activity %	37	41

Vitamins

In control and honey powder incorporated snacks degradation of vitamins was observed However vitamins were not degraded to larger extent. Owing to exposure of raw material to high temperature for short span of time. Furthermore vitamins differ greatly in structure and composition, their stability during extrusion is also variable (Camire *et al.*, 1990).

Minerals

Minerals are heat stable and unlikely to become lost in the steam distillate at the die. Mineral content of both control and honey incorporated snacks was not only retained but increased to an extent by extrusion. Extrusion processing might have reorganized dietary fibre and phytate complexes, changing their chelating properties, thereby increasing mineral composition. however lower phosphorus and magnesium content was observed in honey powder incorporated snacks, this is because 10% corn is being replaced by 10% honey powder, the later is comparatively lower in phosphorus and magnesium content.

Antioxidant activity

Antioxidant activity of honey incorporated snacks was higher than the control, probably due to incorporation of phenolic compounds present in honey, which had been shown to posses antioxidant activity. Other explanation for this finding is that, due to the addition of honey powder millard browning might have elevated during extrusion processing, thus increasing the source of antioxidants.

Conclusions

The studies have shown that healthier and nutritional snacks can be developed by the addition of honey powder into the corn based extrudates. Although the addition of honey powder added value to the extruded snacks and reatained vitamins, minerals and antioxidant activity to an extent, methods to improve their retention need to be studied further. Incorporation of honey powder will increase production costs, but the expense may be off set by the more attractive and functional snacks that result

References.

1. AACC. Approved Methods of American Association of Cereal Chemists. 10th ed. The Association St. Paul, MN, 2000.
2. 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.
3. Barret A, Kaletunç G, Rosenburg S, Breslauer K. Effect of sucrose on the structure, mechanical strength and thermal properties of the corn extrudates. Carbohydr. Polym. 1995; 26:261-269.
4. Bhattacharya M, Hanna MA. Extrusion processing of wet corn gluten meal. Journal of Food Science. 1987; 50:1508-1509.
5. Ding QB, Ainsworth P, Plunkett A, Tucker G, Marson H. The effect of extrusion conditions on the functional and physical properties of wheat-based expanded snacks. Journal of Food Engineering. 2005; 73:142-148.
6. Eastman J, Orthofer F, Solorio S. Using extrusion to create breakfast cereal products. Cereal Foods World. 2001; 46(10):468-471.
7. Fan J, John R, Mitchell, Blanshard MV. The effect of sugars on the extrusion of maize grits: I. The role of the glass transition in determining product density and shape. International Journal of Food Science and Technology DOI: 10. 1111/j. 1365-2621. 1996, 22-317.
8. Huth M, Dongowski G, Gebhardt E, Flammet W. Functional properties of dietary fiber enriched extrudates from barley. Journal of Cereal Science. 2000; 32:115-128.
9. Ilo S, Tomschik U, Berghofer E, Mundigler N. The effect of extrusion operating conditions on the apparent viscosity and the properties of extrudates in twin-screw extrusion cooking of maize grits. Lebensmittel-Wissenschaft und Technologie. 1996; 29(7):593-598.
10. Lin D, Huff HE, Hsieh E. Texture and chemical characteristics of soy protein meat analog extruded at high moisture. Food Chemistry Toxicology. 2000; 65:264-269.
11. 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.
12. Nierle W, Elbaya AW, Seiler K, Fretzdorff B, Wolff J. Veranderungen der getreideinhaltsstoffe wahrend der extrusion mit einem doppelschneckenextruder. Getreide Mehl Brot. 1980; 34:73-76.
13. Ning L, Villota R, Riaz MN. Extruders in food applications. Technomic publishing co. Lancaster, Pennsylvania, 2000.
14. 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.
15. Singh-Gujral H, Singh N, Singh B. Extrusion behaviour of grits from flint and sweet corn. Food Chemistry. 2001; 74:303-308.
16. Valentina S, Ainsworth P, Plunkett I, Ibanoglu A, Senol. The Advantage of using extrusion processing for increasing dietary fiber level in gluten-free products. Journal of Food Chemistry. 2010; 121(1):156-164.
17. Yagcı S, Goguş F. Response surface methodology for evaluation of physical and functional properties of extruded snack foods developed from food-by-products. Journal of Food Engineering. 2008; 86:122-132.
18. Yanniotis S, Petraki A, Soumpasi E. Effect of pectin and wheat fibers on quality attributes of extruded cornsnack. Journal of Food Engineering. 2007; 80:594-599.