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Development of honey incorporated snacks using extrusion technology

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Abstract
The growing nutritional awareness among the people has encouraged the snack production sector to produce nutritionally rich and healthy snacks. The objective of this study was to explore the suitability of incorporating different concentrations of honey powder into the corn based extruded 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 apple 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. specific mechanical energy (SME), bulk density (BD), expansion ratio (ER) 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 ($R^2>0.95$).

Keywords: corn, honey, extrusion, RSM, snacks.

Introduction
Recent awareness and interest in health and wellness has shifted focus on healthy eating and life style. Snacks have become an integral part of daily food intake of majority of population. With the growing awareness about health and nutrition, people are gradually shifting towards healthy snacking. Many attempts are made to improve the nutrient profile of snacks. 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. Incorporation of honey in extruded snacks shall give a new perspective and alternative for healthy snack production.
Food extrusion is one of the efficient multidimensional food processing techniques. 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) [17]. Due to its versatility, cost effectiveness, efficiency and quality of end product (Easmant, *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).

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 %).

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 1^{st}, 2^{nd}, and3^{rd} was maintained at 20, 30 and

40^0C, 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 ^{0}C, 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

System extruder property

- **SME (Specific Mechanical Energy)**

Specific mechanical energy (Wh/kg) was calculated from rated screw speed, motor power rating (8.5 kw), actual screw speed, per cent motor torque and flow rate (kg/hr) using following formula (Pansawat *et al.*, 2007)

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

Physical properties of extruded snacks

- **Bulk density (weight/unit volume)**

The bulk densities of extrudates were determined by volumetric displacement procedures as described by Patil *et al.* (2007) [16]. The volume of expanded sample was measured by using a 100-ml graduated cylinder by rapeseed displacement. The volume of 20 g randomized sample was measured for each test. The ratio of sample weight and the replaced volume in the cylinder was calculated as bulk density (w/v).

- **Expansion ratio**

Expansion ratio was determined (Halek and Chang, 1992) [9] by using a Digital Vernier Calliper (Diginatic Solar Mitutoya, Japan). The average thickness of ten randomly selected pieces of extrudates from each test was calculated. The expansion ratio was determined as the ratio between the thickness of the extrudate and the die diameter.

ER = D/d

Where, D = diameter of the extrudate, and d = diameter of the die hole

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.

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.

Economics

The cost study of the snacks prepared by twin-screw extruder was carried out on the basis of raw materials cost, processing cost and profit margin.

Results and discussion

Effect of independent variables on product characteristics and specific mechanical energy (SME)

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 with the measured data. Adequate precision (signal to noise ratio) greater than 4 is desirable. All the parameters showed high adequate precision (Table 2). A reasonable good coefficient of determination (R^2=0.92, 0.95, 0.96) for SME, bulk density and expansion ratio, 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	SME	BD	ER
Adequate precision	14.750	15.263	1.505
R- square	0.9262	0.9352	0.9656
Adjusted R square	0.8623	0.8747	0.9601
Predicted R square	0.5901	0.6266	0.9462
CV	7.72	11.06	0.12
Lack of fit	NS	NS	NS

NS: non-significant

Physical characteristics of snacks.
Determination of system response
Specific mechanical energy (SME)

The mean values of SME under different extrusion conditions ranged between 76.62 and 136.82Wh/kg (Table 3). Regression analysis was carried out to fit the mathematical models to the experimental data. The significant predicted model for SME can be described by the following equation (1) in terms of coded levels. Analysis of variance (ANOVA) was performed to study the effect of independent variables on SME (table 2).

$$SME = +89.5 - 4.90 B -19.79D + 3.80 B^2 + 5.49 D^2 \quad (1)$$

The above regression equation (1) and response surface plots depicted in Fig. 1 indicated that SME decreased with the increase in moisture (B) and barrel temperature (D).

The negative coefficients of the linear terms of moisture and barrel temperature indicates that SME decreases with increase in these variables. At high moisture content a lubricating effect is produced within the dough which reduces the friction of screws, resulting in less torque and subsequently reduced SME. Similar results were reported by Govindsamy *et al.* (1997) [8]. Higher temperature favours the reduction of melt viscosity, flow characteristics of melt transform from solid flow to viscoelastic flow, which leads to reduction of torque and consequently lower SME (Ruiz *et al.*, 2008) [18]. Ryu and Ng (2001) [19] have reported that higher temperature at the die exit lowered the SME of wheat flour and whole corn meal. Lin *et al.* (2000) [12] found that increasing water content and temperature led to decreasing torque and pressure during the extrusion process of soy protein.

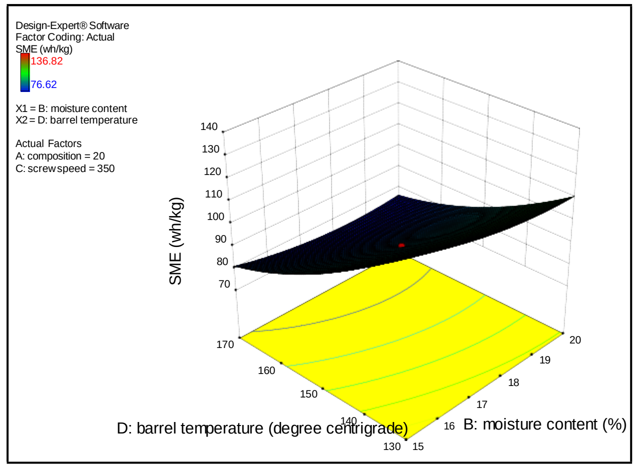


Fig 1: Response surface plot for SME as function of barrel temperature and moisture content.

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)	SME (Wh/kg)	Bulk density (kg/m^3)	Expansion ratio
1	90:10	15	250	130	131.91	228	2.47
2	70:30	15	250	130	128.28	433	1.89
3	90:10	20	250	130	119.98	246	2.38
4	70:30	20	250	130	112.96	452	1.8
5	90:10	15	450	130	136.82	204	2.53
6	70:30	15	450	130	134.78	423	1.91
7	90:10	20	450	130	124.23	239	2.42
8	70:30	20	450	130	121.16	441	1.87
9	90:10	15	250	170	82.74	181	2.68
10	70:30	15	250	170	80.64	338	1.98
11	90:10	20	250	170	79.92	168	2.58
12	70:30	20	250	170	77.14	352	1.94
13	90:10	15	450	170	84.98	151	2.71
14	70:30	15	450	170	83.88	281	2.00
15	90:10	20	450	170	80.01	193	2.66
16	70:30	20	450	170	79.8	311	1.96
17	100:0	17.5	350	150	84.41	139	2.7
18	60:40	17.5	350	150	87.32	428	1.78
19	80:20	12.5	350	150	110.54	339	2.26
20	80:20	22.5	350	150	86.14	417	2.23
21	80:20	17.5	150	150	85.82	417	2.22
22	80:20	17.5	550	150	91.73	393	2.29
23	80:20	17.5	350	110	133.6	407	2.21
24	80:20	17.5	350	190	76.62	225	2.32
25	80:20	17.5	350	150	89.25	401	2.24
26	80:20	17.5	350	150	89.25	401	2.24
27	80:20	17.5	350	150	89.25	401	2.24

28	80:20	17.5	350	150	89.25	401	2.24
29	80:20	17.5	350	150	89.25	401	2.24
30	80:20	17.5	350	150	89.25	401	2.24

(C: H) = corn: honey, SME (Wh/kg) = Specific mechanical energy, BD (kg/m^3) = bulk density, ER=Expansion ratio.

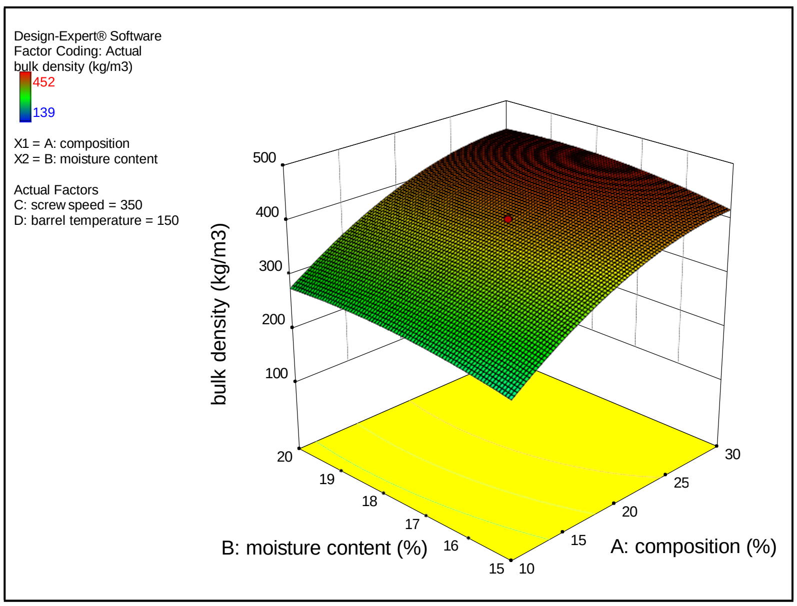
Physical properties of extruded snacks

Bulk density (BD)

In present study bulk density of extrudates ranged between 139 and 452 kg/m^3 (table 3). The significant quadratic model for the relation between bulk density and independent variables obtained in terms of coded variables is presented below (equ.2). The response was analyzed using ANOVA and data is present in table 2.

Bulk density = +401 +83.29A - 43.96 D - 38.64 A^2- 15.01 B^2- 30.51 D^2 (2)

Composition had positive effect on bulk density while temperature had negative effect. The bulk density of extrudates increased with the increased concentration of honey powder in the blends. The presence of sugar tended to reduce the availability of water or water activity, which affect the bulk density of extrudate (Moore *et al.*, 1990) [14]. With the increase in temperature, the bulk density decreased. Fletcher *et al.* (1985) [7], Lawton *et al.* (1985) and Mercier and Fillet (1975) reported that with an increase in the die temperature, there was increase in degree of superheating of water in the extruder encouraging bubble formation with decrease in melt viscosity, leading to increased expansion and decreased bulk density. Case *et al.* (1992) [4] with advance in gelatinization, the volume of extruded product increases resulting in decrease in bulk density which is in agreement with our observations.



(a)

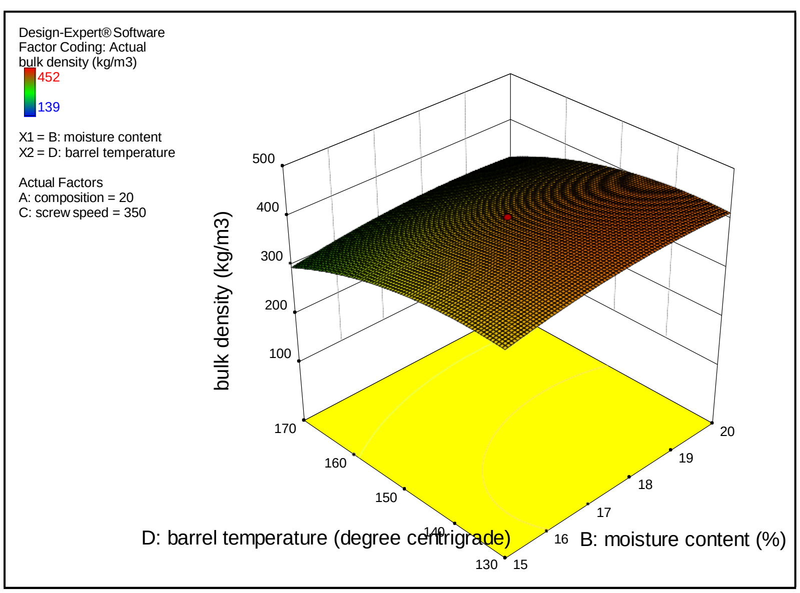


Fig 2: (a) Effect of moisture content and composition on bulk density (b): Response surface plot for bulk density as function of barrel temperature and moisture content

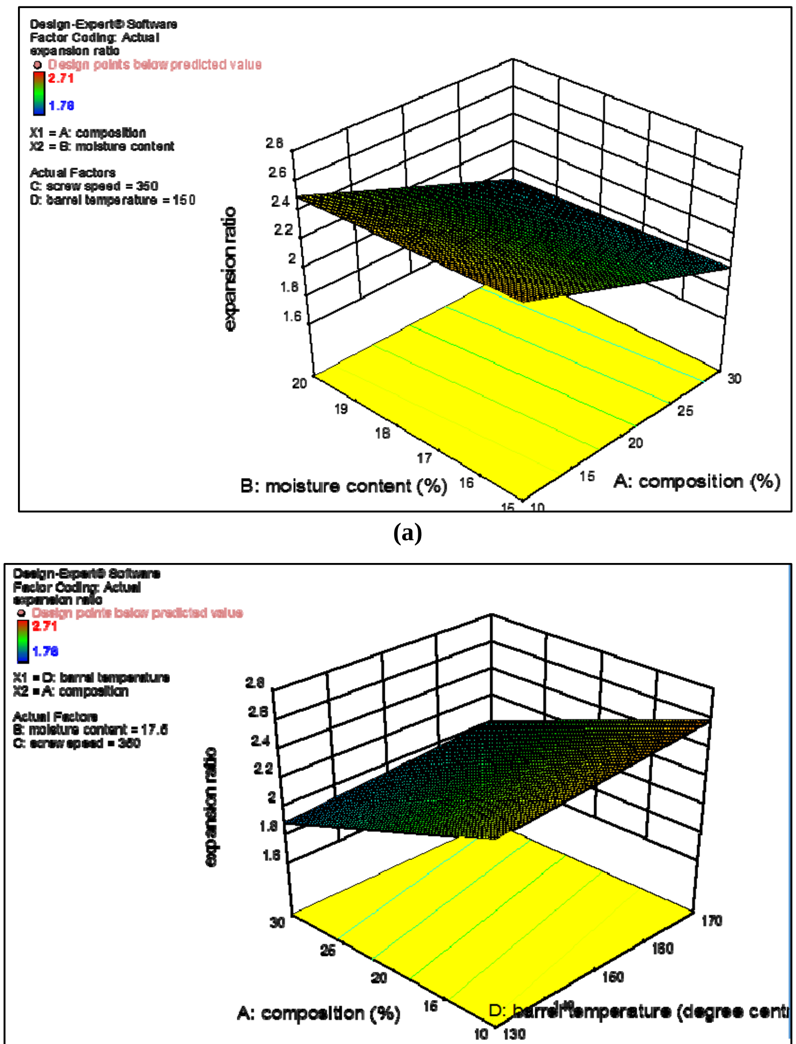
Expansion ratio (ER)

The mean value of expansion ratio varied between 1.78 -2.71 (Table 3). The significant model for expansion ratio in terms of coded independent variables is given below.

Expansion ratio = +2.24 -0.29A - 0.026B + 0.061 D (3)

The regression equation (3) and response surface plots (Fig. 3) indicated the significant linear positive effect of barrel temperature (D) and negative effect of composition (A) and moisture content (B) on expansion ratio. Analysis of variance was performed to study the effect of independent variables on expansion ratio (table 2).

With increased concentration of honey powder resulted in reduced the expansion of extrudates. Jin *et al.* (1994) [10] and Barret *et al.* (1995) [3] reported that the presence of sugar reduced the availability of water, resulting in abbreviated gelatinization and thus decreased expansion of extrudates. Expansion ratio was also found to get decreased with the increase in moisture content. Alvarez-Martinez *et al.* (1988) [1] suggested that the excess of water may greatly reduce elastic characteristics of amylopectin network thereby decreasing sectional expansion. The positive effect of barrel temperature might be due to augmented vapour pressure generation at higher temperatures which favors sufficient bubble formation and greater expansion. The results found in this study agree with those reported by Dehghan *et al.* (2010) [5] for the directly expanded extruded snacks made from rice flour, wheat bran, and corn grits, and enriched with tomato lycopene. These authors believed that as temperature was increased, a higher amount of moisture was lost from the product at the outlet of the extruder die, becoming a less dense product.



(a)

(b)

Fig 3: (a) Response surface plot for expansion ratio as function of composition and moisture content (b) Response surface plot for expansion ratio 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 83.572 SME Wh/kg, 156.333 BD kg/m^3 and 2.636 ER could be produced. These optimum conditions can be used to produce extrudates with the highly desired physical and textural characteristics.

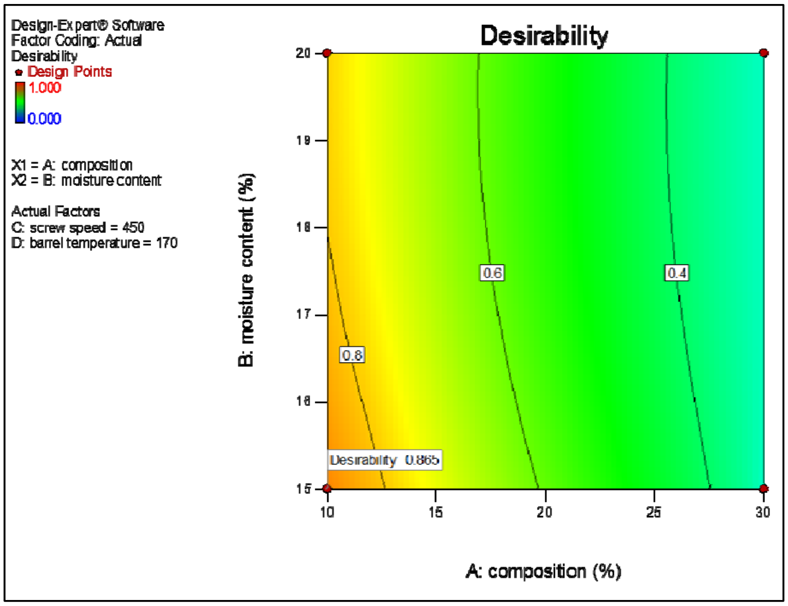


Fig 4: Desirability function response surface for development of honey incorporated corn-based extrudates.

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). 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

Sensory evaluation (overall acceptability)

The extruded samples (honey + corn) were evaluated organoleptically for appearance, texture, flavor, colour and overall acceptability by semi trained panel of 10 judges using 5-point scale. The overall acceptability score of 30 samples was found good. Maximum overall acceptability score of 4.6 (table 5) was found in extrudates obtained from following conditions: honey powder incorporation = 10%, moisture content =15%, screw speed = 450rpm and barrel temperature 170^{o}C.

Table 5: Sensory scores of extrudates produced at different process conditions

S. No.	Composition (%)	Moisture (%)	Screw speed (rpm)	Barrel temp. (ºC)	Overall acceptability
1	90:10	15	250	130	4.2
2	70:30	15	250	130	3.0
3	90:10	20	250	130	4.1
4	70:30	20	250	130	2.8
5	90:10	15	450	130	4.3
6	70:30	15	450	130	3.0
7	90:10	20	450	130	4.1
8	70:30	20	450	130	2.9
9	90:10	15	250	170	4.5
10	70:30	15	250	170	3.3
11	90:10	20	250	170	4.4
12	70:30	20	250	170	3.1
13	90:10	15	450	170	4.6
14	70:30	15	450	170	3.4
15	90:10	20	450	170	4.4
16	70:30	20	450	170	3.2
17	100;0	17.5	350	150	3.05
18	60:40	17.5	350	150	2.6
19	80:20	12.5	350	150	4.0

20	80:20	22.5	350	150	3.5
21	80:20	17.5	150	150	3.6
22	80:20	17.5	550	150	3.9
23	80:20	17.5	350	110	3.7
24	80:20	17.5	350	190	3.5
25	80:20	17.5	350	150	3.8
26	80:20	17.5	350	150	3.8
27	80:20	17.5	350	150	3.8
28	80:20	17.5	350	150	3.8
29	80:20	17.5	350	150	3.8
30	80:20	17.5	350	150	3.8

Economics of apple incorporated corn based snacks

The product formulation involved two types of costs - one fixed cost and another variable cost.

Fixed costs are those which run over lay period and only part of services of these assets are utilised in a single production period while as variable costs are those which get transformed into the ultimate production during a period season. Thus in our situation fixed costs related to machinery and equipments while as the variable cost involved expenses on chemical, raw material etc. the cost stream in respect of fixed and variable costs was drawn, break-even point was identified and margin of safety estimated.

The break-even point is a costing technique that helps in profit planning. Under break-even analysis, the break-even point is defined as volume of activity at which total sales revenue exactly equals total cost of the output produced or sold.

Margin of safety is the difference between total sale and break-even point and indicates the extent to which sales may decrease before any enterprise suffers a loss.

$$\text{Break-even point} = \frac{\text{Fixed Cost}}{\text{P/V Ratio}} = 2518891.69$$

Table 6: Margin of safety

Production (in units)	Total sale (in Rs.)	Total cost (in Rs.)	Profits (in Rs.)	Margin of safety (in units)	Margin of safety (in Rs.)
10000	1750000	2360000	-610000	-	-
12000	2100000	2432000	-332000	-	-
14000	2450000	2504000	-54000	-	-
14393.668	2518891.69	2518891.69	(BEP)	(BEP)	(BEP)
15000	2625000	2540000	85000	606.332	106108.31
15500	2712500	2558000	154500	1106.332	193608.31

Conclusions

The objective of this research was to explore the possibilities of improving nutritional quality of snacks by incorporating honey to the corn based extrudates. It was found that the incorporation of honey in corn resulted in extrudates of lower fat content, which has positive contribution on the nutritional excellence of developed snacks. This study suggests that more healthier and nutritional snacks can be produced by the incorporation of honey powder without affecting quality parameters negatively.

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