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Effect of extrusion variables and chickpea flour incorporation on physical properties of Corn-cauliflower waste based extruded snacks

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Abstract
In the present study different levels of chickpea flour (10-40) were added to optimized level (90:10) of Corn and cauliflower waste blend. The independent variables included were composition (10-40), moisture content (9-13%), screw speed (137-387 rpm) and barrel temperature (85-185 ºC). Response variables were Bulk density, Expansion ratio (ER) and hardness. Response surface models were established to determine the responses as function of process variables. Results indicate that increase in composition leads to increase in bulk density, & hardness. Temperature had negative effect on Bulk Density, and hardness. Moisture had positive effect on Bulk Density and hardness.

Keywords: extrusion, cauliflower waste, chickpea flour

1. Introduction
Snack foods are highly subjected to impulse buying and have gained popularity today due to: growing urban population, increase in number of nuclear families, increase in the number of working women, media penetration leading to attraction for novel food, and higher disposable incomes. Extrusion process is the choice of technology of choice due to its versatility and ability to change the intrinsic taste, texture and structural characteristics of products. Cereal grains tend to be low in protein and are usually fortified with pulse protein to produce nutritious snack foods. Among food legumes, Chickpea (*Cicer arietinum*) is one of the oldest and most widely consumed legume in the world due to relatively high protein content and wide adaptability as a food grain. It is the second most widely grown legume in the world (FAO, 2008) [12]. Chickpeas are good source of carbohydrates (41.10% - 47.42%) and proteins (21.70% - 23.40%). It has high protein digestability and is rich in vitamins and minerals (Muzquiz and Wood, 2007) [17]. Iron is the most abundant mineral present in chickpea (4.6-10.5%) followed by zinc (2.2- 6.8%).

2. Material and methods
The present investigation was carried out in the Division of Food Science and Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K), Shalimar.

2.1 Raw materials used in the investigation
The corn (C-6) variety was obtained from division of plant breeding and genetics, SKUAST-K, Chickpea flour was procured from local market and Cauliflower waste was collected from Food Processing and Training centre (FPTC) SKUAST- K Shalimar where it is an main byproduct produced during vegetable pickle making.

2.2 Extrusion process
Extrusion experiments were performed in a co-rotating twin screw extruder (Basic Extrusion Technology Pvt. Ltd., Kolkatta, India). The length to diameter ratio (l/d) was 8:1. The extruder has three barrel zones. Temperature of first and second zone was maintained at 65 and 75 °C throughout the experiment, whereas in third zone (die section) it was varied according to experimental design. The circular die of 6.0 mm was used. Blends were prepared from Corn flour and Cauliflower waste powder in definite ratios for carrying out 30 runs in the extruder. Moisture content of corn flour and blends was determined by oven drying method (AACC-2000) and adjusted for different blends according to the experimental runs.

2.2.1 Experimental design

The central composite rotatable design (CCRD) for the four independent variables was performed. The independent variables considered were composition (A), moisture content (B), screw speed (C) and Barrel temperature (D). The independent variables and variation levels are given below in Table 1.

Response surface methodology was applied for experimental data and the results were analyzed by a multiple linear regression method to describe the effects of variables in the models derived. Experimental data were fitted to the selected models and regression coefficients were obtained. The Analysis of Variance (ANOVA) tables were generated for each of the response functions. The individual effect of each variable and the effects of interaction term in actual levels of variables were determined (Table 2).

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+ Cauliflower waste: Chickpea)	A	100:0	90:10	80:20	70:30	60:40
Moisture content (%)	B	9.0	10	11.0	12.0	13.0
Screw speed (rpm)	C	137	200	262	325	387
Barrel temperature (ºC)	D	85	110	135	160	185

Table 2: Response surface experiment in terms of actual levels.

Standard	Composition (Corn+Cauliflower waste: Chickpea)	Moisture%	Barrel temperature (ºC)	Screw speed (rpm)
1.	90:10	10	200	110
2.	70:30	10	200	110
3.	90:10	12	200	110
4.	70:30	12	200	110
5.	90:10	10	325	110
6.	70:30	10	325	110
7.	90:10	12	325	110
8.	70:30	12	325	110
9.	90:10	10	200	160
10.	70:30	10	200	160
11.	90:10	12	200	160
12	70:30	12	200	160
13.	90:10	10	325	160
14.	70:30	10	325	160
15.	90:10	12	325	160
16.	70:30	12	325	160
17.	100:00	11	262	135
18.	60:40	11	262	135
19.	80:20	9	262	135
20.	80:20	13	262	135
21.	80:20	11	137	135
22.	80:20	11	387	135
23.	80:20	11	262	85
24.	80:20	11	262	185
25.	80:20	11	262	135
26.	80:20	11	262	135
27.	80:20	11	262	135
28.	80:20	11	262	135
29.	80:20	11	262	135
30.	80:20	11	262	135

Responses obtained as a result of the proposed experimental design were subjected to regression analysis in order to assess the effects of composition, moisture content, screw speed and barrel temperature on product characteristics. Second order polynomial regression models were established for the dependent variables to fit experimental data for each response using statistical software Design-Expert 9 (Stat-Ease Inc, Minneapolis, MN, USA).

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

where x_i (i = 1, 2, 3, 4) are independent variables (Composition, Moisture, screw speed and barrel temperature respectively) and b_0, b_i, b_{ii} and bij are coefficient for intercept, linear, quadratic and interactive effects respectively. Data was analyzed by multiple regression analysis and statistical significance of the terms was examined by analysis of variance (ANOVA) for each response.

2.3 Physical properties of extruded snacks

2.3.1 Bulk density (weight/unit volume)

The bulk densities of extrudates were determined by volumetric displacement procedures as described by Patil *et al*. (2007) [19]. 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) (Pan *et al*., 1998) [18].

2.3.2 Expansion ratio

Expansion ratio was determined (Halek and Chang, 1992) [14] 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.

$$ER = \frac{\text{Extrudate diameter (mm)}}{\text{Die diameter (mm)}}$$

2.3.3 Break strength

Textural quality of the extrudates were examined by using TA-XT2i Texture analyser (Stable Microsystems, United Kingdom). The compression probe (50 mm diameter, aluminium 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.

3. Results

3.1 Effect of independent variables on product characteristics

Models for all parameters were significant. None of the models showed significant lack of fit, indicating that all 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 3). A reasonable good coefficient of determination (R^2= 0.9785, 0.9926, 0.9948 for bulk density, expansion ratio and break strength respectively) indicated that models developed for product responses appeared to be adequate. The predicted R-square was found in reasonable agreement with adjusted R-square for all the parameters.

Table 3: Analysis of variance for the Fit of experimental data to response surface models

Regression	Bulk density	Expansion ratio	Break strength
R-square	0.9859	0.9035	0.9561
Adj. R-square	0.9728	0.8880	0.9151
Pred. R-square	0.9190	0.8509	0.7472
Adeq. precision	36.88	29.27	18.00

Table 4: Effect of processing conditions on system parameter and product characteristics.

S. No	Composition Corn+CW:C(%)	Moisture content (%)	Screw speed (rpm)	Barrel Temp. (ºC)	BD (kg/m^3)	ER (%)	BS (N)
1	90:10	10	200	110	126	2.4	13.7
2	70:30	10	200	110	329	1.9	20.2
3	90:10	12	200	110	149	2.33	12.8
4	70:30	12	200	110	354	1.6	22.5
5	90:10	10	325	110	137.6	2.5	10.9
6	70:30	10	325	110	326	1.9	19.5
7	90:10	12	325	110	190	2.39	12.7
8	70:30	12	325	110	436	1.85	20.6
9	90:10	10	200	160	190.01	2.65	18.4
10	70:30	10	200	160	246	1.95	18.44
11	90:10	12	200	160	139	2.54	17.5
12	70:30	12	200	160	249	1.92	17.9
13	90:10	10	325	160	126	2.79	12.6
14	70:30	10	325	160	150	1.99	16.4
15	90:10	12	325	160	132	2.64	11.9
16	70:30	12	325	160	215	1.94	17.17
17	100:00	11	262	135	67.8	2.5	11
18	60:40	11	262	135	326	1.79	22.05
19	80:20	9	262	135	245	2.24	12.02
20	80:20	13	262	135	290	2.23	13.9
21	80:20	11	137	135	290	2.21	14.55
22	80:20	11	387	135	293	2.26	11.01
23	80:20	11	262	85	265.5	2.2	18.4
24	80:20	11	262	185	120	2.31	19
25	80:20	11	262	135	303	2.25	18.2
26	80:20	11	262	135	303	2.25	18.2
27	80:20	11	262	135	303	2.25	18.2
28	80:20	11	262	135	303	2.25	18.2
29	80:20	11	262	135	303	2.25	18.2
30	80:20	11	262	135	303	2.25	18.2

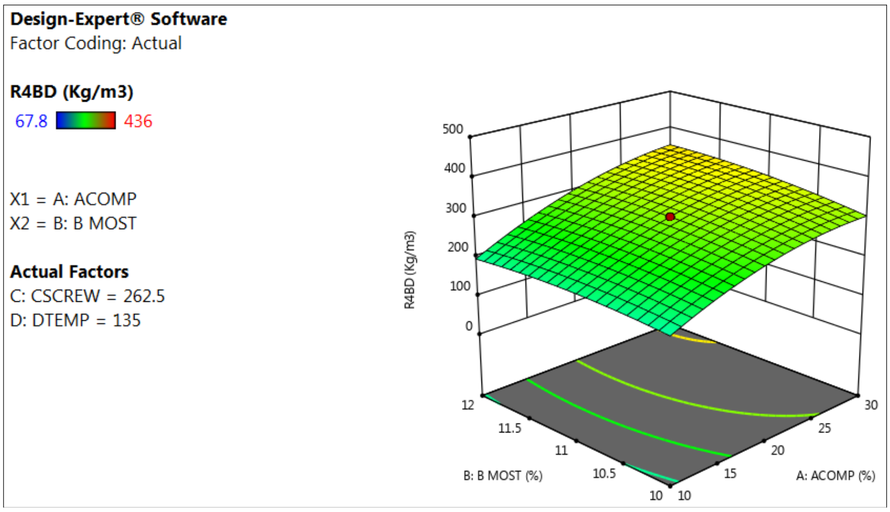
3.2 Physical properties of extruded snacks

3.2.1 Bulk density

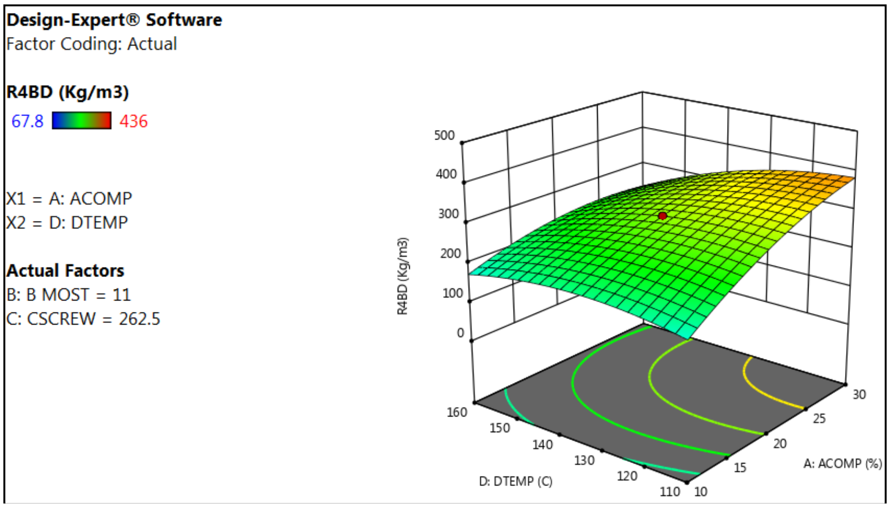
Bulk density ranged from 67.8- 329 (Kg/m^3) (Table 4). The significant regression equation for the relationship between bulk density and independent variables in terms of coded variables is presented below:

$$BD=+303.00+67.99A+13.47B-37.15D+10.79AB-35.59AD+14.59BC-11.71BD-20.79CD-29.65A^2-12.00B^2-6.00C^2-30.69D^2 \quad \ldots 1$$

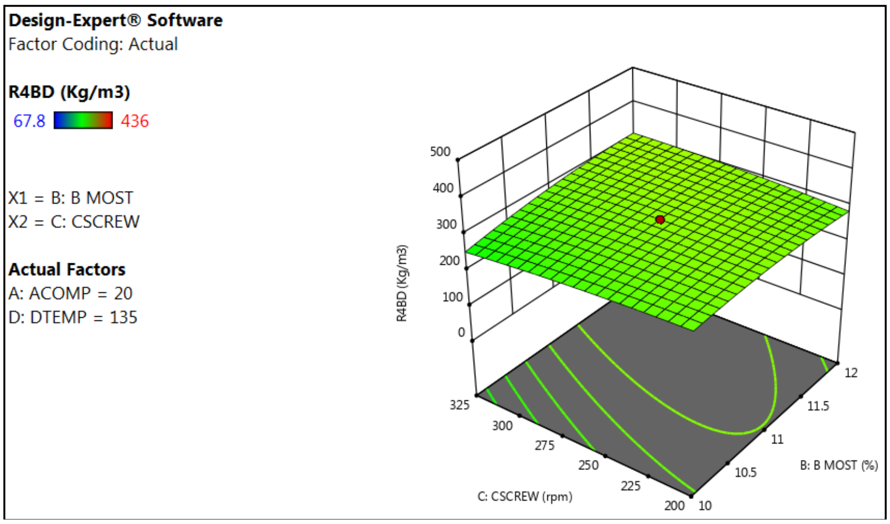
Composition, moisture content and barrel temperature showed a significant linear effect while composition, moisture content, screw speed and barrel temperature had quadratic effect on bulk density as is evident from ANOVA (table 5) Response surface plots (Fig. 1 a, 1b, 1c) indicated positive effect of composition, moisture content and negative effect of screw speed, barrel temperature.



(a)



(b)



(c)

Fig 1: (a) Response surface plots for Bulk Density as function of composition and moisture (b) Response surface plots for Bulk Density as function of composition and temperature(c) Response surface plots for Bulk Density as function of moisture and screw speed

Table 5: ANOVA for BD (Bulk Density)

Factor	Coefficient of estimate	Sum of squares	Standard error	d.f	F-value	P- Value
Intercept of model	303.00	2.277E+005	6.01	14	75.14	< 0.0001
A-Composition	67.99	1.109E+005	3.00	1	512.62	< 0.0001*
B-Moisture content	13.47	4357.55	3.00	1	20.13	0.0004*
C-Screw speed	-2.64	167.53	3.00	1	0.77	0.3928
D-Barrel temperature	-37.15	33122.20	3.00	1	153.04	< 0.0001*
AB	10.79	1862.14	3.68	1	8.60	0.0103*
AC	-2.04	66.38	3.68	1	0.31	0.5879
AD	-35.59	20264.23	3.68	1	93.63	< 0.0001*
BC	14.59	3405.01	3.68	1	15.73	0.0012*
BD	-11.71	2195.16	3.68	1	10.14	0.0062*
CD	-20.79	6914.34	3.68	1	31.95	< 0.0001*
A^2	-29.65	24112.90	2.81	1	111.41	< 0.0001*
B^2	-12.00	3949.65	2.81	1	18.25	0.0007*
C^2	-6.00	987.39	2.81	1	4.56	0.0496*
D^2	-30.69	25829.93	2.81	1	119.34	< 0.0001*

*Significant at P <0.05
**Significant at P <0.05

3.2.2 Expansion ratio

The mean value of expansion ratio ranged from 1.6-2.6 (Table 1.). The significant model representing expansion ratio in terms of coded independent variables is as follows:

ER=+2.22-0.2754A+0.0737D ….2

The analysis of variance (Table 6) showed significant linear effect of composition, & barrel temperature. Regression model and response surface plots (Fig. 2) indicated positive effect of screw speed, barrel temperature and negative effect of composition and moisture content.

Table 6: ANOVA for ER

Factor	Coefficient of estimate	Sum of squares	Standard error	d.f	F-value	P-Value
Intercept of model	2.22	2.01	0.0175	4	55	< 0.0001
A-Composition	-0.2754	1.82	0.0195	1	199.13	< 0.0001*
B-Moisture content	-0.0371	0.0330	0.0195	1	3.61	0.0690
C-Screw speed	0.0338	0.0273	0.0195	1	2.99	0.0961
D-Barrel temperature	0.0737	0.1305	0.0195	1	14.28	0.0009*

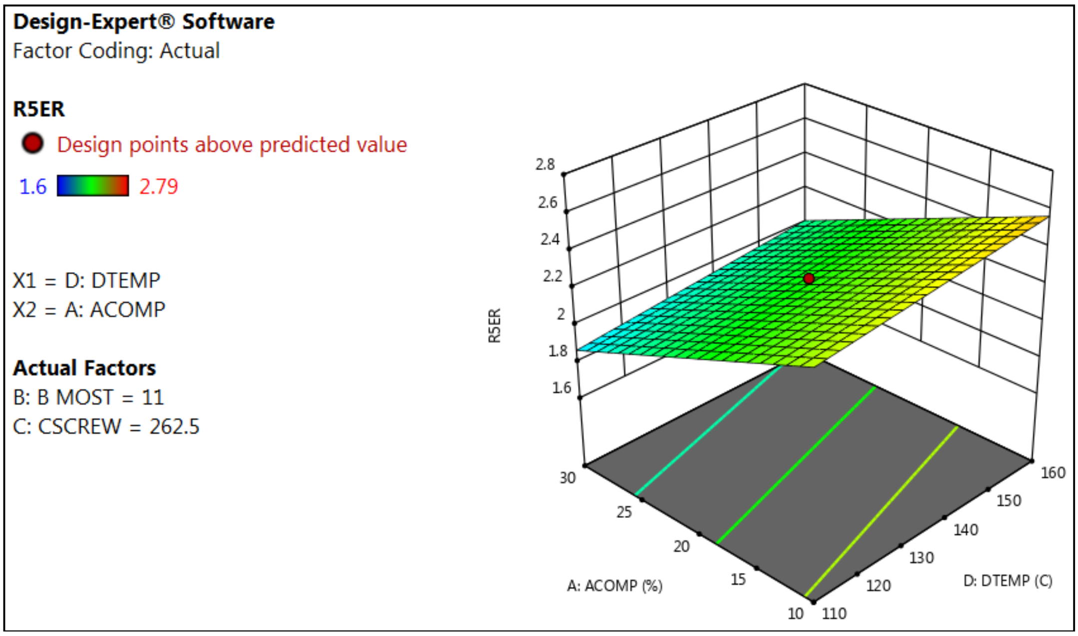


Fig 2: Response surface plots for Expansion ratio as a function of composition and temperature.

3.2.3 Break strength (Hardness)

The mean value of break strength ranged from to 11 to 22.5 N (Table 1). The model developed for break strength in terms of coded variables is given below:

$BS=+18.20+2.71A-1.14C+0.6022AC-1.49AD-1.12B^2-1.16C^2$ …. 3

The analysis of variance (Table 7) showed significant linear effect of composition, screw speed and quadratic effect of moisture and screw speed. Regression model and response surface plots (Fig. 1a, 16, 1c) indicated negative effect of barrel temperature, screw speed and positive effect of composition, moisture content.

Table 7: ANOVA for Break strength

Factor	Coefficient estimate	Sum of squares	Standard error	D.F.	F-value	P- Value
Intercept of model	18.20	323.11	0.4202	14	23.34	< 0.0001
A-Composition	2.71	172.32	0.2101	1	173.27	< 0.0001*
B-Moisture content	0.3081	1.86	0.2101	1	2.24	0.1551
C-Screw speed	-1.14	29.82	0.2101	1	30.90	< 0.0001*
D-Barrel temperature	-0.0285	0.0805	0.2101	1	0.0192	0.8915
AB	0.2266	1.17	0.2573	1	0.8080	0.3829
AC	0.6022	4.98	0.2573	1	5.71	0.0305*
AD	-1.49	33.61	0.2573	1	35.11	< 0.0001*
BC	0.2322	0.5663	0.2573	1	0.8486	0.3715
BD	-0.3984	2.01	0.2573	1	2.50	0.1348
CD	-0.4978	4.70	0.2573	1	3.90	0.0670
A^2	-0.2245	1.29	0.1965	1	1.36	0.2617
B^2	-1.12	33.70	0.1965	1	33.59	< 0.0001*
C^2	-1.16	36.49	0.1965	1	36.36	< 0.0001*
D^2	0.319	2.93	0.1965	1	2.75	0.1180

*Significant at p<0.05

4. Discussion

4.1. Bulk density (BD)

Response surface plots indicated positive effect of composition and moisture content while as negative effect was observed with screw speed, barrel temperature. Bulk density increased with increase in Composition, moisture content while as it decreased with increase in screw speed and barrel temperature respectively. Higher level of chick pea flour resulted in higher bulk density. This could be because of lower expansion at higher level of chick pea which could also be explained by the negative association of bulk density with expansion ratio (r = -0.67, P<0.05). Suksomboon *et al*. (2011) [20] reported similar result while extruding purple rice flour blended with 5-15% soybean. Higher screw speeds may decrease the melt viscosity of the blend, increasing the elasticity of the dough, resulting in a reduction of density of the extrudates (Ding *et al*., 2006) [8]. Temperature (P<0.001) had highly significant negative linear effect, as the temperature increased, BD decreased which is in accordance with the trend observed in rice based snack (Ding *et al*., 2005) [9]. An increase in the barrel temperature and screw speed might increase the degree of superheating of water in the extruder thus enhancing bubble formation and also a decrease in melt viscosity (Fletcher *et al*., 1985; Lawton *et al*., 1985) [11, 15]. Bulk density values decreased when the extrusion temperature and the screw speed increased due to starch gelatinization (Hagenimana *et al*., 2006; Case *et al*., 1992) [13, 6]. As gelatinization increases, the volume of extruded products increases and bulk density decreases.

4.2 Expansion ratio

Composition and moisture content had negative effect while as positive effect of screw speed, barrel temperature was observed. As the temperature increased, ER increased. It has been reported that the expansion ratio of extruded cereals depends on the degree of starch gelatinization (Case *et al*., 1992; Chinnaswamy and Hanna, 1988) [6, 5]. Increase in temperature leads to increased gelatinization, which may favour increase in expansion of the extrudates. Similar results were also reported in the extrudates of corn starch (Chinnaswamy and Hanna, 1988) [5] and in another study where rice and chickpea flour blend was extruded (Bhattacharya and Prakash, 1994) [2]. Avin *et al*. (1992) observed similar effects of temperature for the expansion of red bean extrudates.

4.3 Hardness

The barrel temperature, screw speed had negative effect while as positive effect of composition, & moisture content was found. Increase in composition & moisture leads to increase in hardness while as increase in screw speed and barrel temperature leads to decrease in hardness of the extrudates. The increase in hardness with higher chick pea level could be due to reduced expansion. Cheng *et al*. (2007) also reported increased level of whey protein isolate resulted in increased hardness score while extruding corn starch - whey protein isolate blend. Barrel temperature ((P<0.001) had highly significant negative linear effect on hardness of the extrudates. Increase in temperature significantly decreased the hardness which is in agreement with the results obtained in rice and green gram extrudates (Bhattacharya 1997) [3]. Similar results were obtained by Bhattacharya and Prakash (1994) [2], Ryu and Walk (1995) and Duizer and Winger (2006) [10].

5. Conclusion

The response surface methodology proved to be an good tool for explaining the effect of extrusion variables on physical properties of chickpea incorporated snacks. Incorporation of legume flours has been shown to cause a positive impact on levels of proteins and dietary fibre of cereal based extruded snacks (Berrios, 2006) [4]. By properly selecting extrusion processing conditions and ingredient composition, chickpeas can be used to produce nutritious snack products that have desirable quality attributes and consumer acceptability (Meng *et al*., 2010) [16].

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