EFFECT OF ADDITION OF FENUGREEK SEED POWDER AND OAT FLOUR ON EXTRUDATES PRODUCTS PROCESS VARIABLE ON PHYSICAL PARAMETERS

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ABSTRACT

The study of effect of fenugreek seed powder and oat flour on macrostructure and physical properties of extruded products viz. bulk density, lateral expansion, water absorbance index, water sorption index. Based on Preliminary evaluation, proportions of fenugreek seed powder and oat flour were varied in the range of 1% to 5% and 3% to 15%. As increased in fenugreek seed powder and oat flour results increased in lateral expansion and decreased water solubility index. While water absorption index decreased with increased in fenugreek seed powder and increased with oat flour addition.

Keywords : *Extrusion, Fenugreek seed powder, Oat flour, Macrostructure*.

INTRODUCTION

The main role of extrusion is conveying and shaping of processed raw materials, such as dough and pastes, and produce a wide range of products such as snack, baby-foods, breakfast, noodle, pasta and cereals based blends **(Semaska et al., 2010).** Extruders lower the operating costs and have increases productivity and cooking process, **(Ficarella et al., 2004).** Corn is a major ingredient for extruded foods, such as RTE breakfast cereals and snacks **(Gujral et al., 2001).(Altan et al., 2009)** investigated effect of extruded screw on properties of barley extrudates and reported that severe screw configuration produced expanded product with low bulk density than medium screw configuration. Also extrusion processing has been described as a resent technique for introducing fruit and vegetable by-products into RTE products and there is need for further research on functional and nutritional properties.

Fenugreek contains 4-hydroxyisoleucine, which is important for the insulin production in human body, when blood sugar level is high and lowering the cholesterol level. It may reduce the amounts of calcium oxalate in kidney, otherwise it may lead to kidney stone, lessen the colon cancer by blocking action of certain enzyme **(Bash et al., 2003,Srinivasan, 2006).** Fenugreek seeds also have antioxidant activity and have been shown as neutralization of free radicals and enhancement of antioxidant properties. Fenugreek gum also has exhibited hypoglycemic effects, especially in persons and animals with diabetes type 1 and diabetes type 2 diabetes mellitus **(Hannan et al., 2007).** Due to the distinct bitter taste, inclusion of fenugreek flour is not acceptable at levels more than 2% in extruded product **(Shirani et al., 2009)**. Oats provides important health benefits. The cereal dietary fiber β-glucan has outstanding functional and nutritional properties, because of its viscosity nature in the intestinal tract was studied (**Dongowski et. al., 2004)**. It protects from cardiovascular diseases (CVD) and some types of cancer due to its dietary fiber complex, antioxidants and phytochemicals **(Thompson, 1994; Jacobs et al., 1998; Slavin et al., 2000)**. It has ability to lower blood cholesterol by lowering the LDL (low density lipoprotein) and the intestinal absorption of **glucose (Malkki, 2001; Wood, 1994).**Rice is staple diet for more than half of the world population and a part in extruded product. Chickpea is another legume, grown in tropical and subtropical areas that have a functional ingredient for the food industry. Chickpea is valued for its nutritive value with high protein content 25.3-28.9 % after dehulling **(Hulse, 1991; Huisman and van der poel, 1994).** Corn is staple food in all over the world, consumed in daily diet. Corn contains 39.08% protein, 3.88% fat, 0.03% ash, 76.80% carbohydrate, vitamin and amino acid (**Santosa et al., 2005).** Extrusion processing of corn and oatmeal has been

very well studied **(Bhattacharya and Hanna 1987)** and well commercialized especially in the category of breakfast cereals.

The objective of this research was to study the effect of fenugreek seed powder and oat flour on macrostructure and physical properties of extrudates product.

Table 1 Values of independent variables as per CCRD design

Indepen-dent variables	Coded	Levels in coded form				
		-1.414	-1	0	1	1.414
Fenugreek Seed Powder	A	1.586	2	3	4	4.414
Oat Flour	B	4.758	6	9	12	13.242

2.4 Product analysis

2.4.1 Bulk density:

The bulk density (BD) g/cm^3 was calculated by measuring the actual dimensions of the extrudates (Thymi et al., 2005). The diameter and length of the extrudates were measured using digital vernier caliper (model CD-12"C, Mitutoyo Corp. Japan) with least count of 0.1 mm. The weight per unit length of extrudate was determined by weighing measured lengths (about 1 cm). The bulk density was then calculated using the following formula, assuming a cylindrical shape of extrudate. Ten pieces of extrudate were randomly selected and average was taken.

$$BD=4m/\Pi d^2L \quad \text{..... (1)}$$

Where, m (g) is the mass, L (cm) is length of extrudate and d is diameter of the extrudate .

2.4.2 Lateral expansion:

The ratio of diameter of extrudate and the diameter of die was used to express the expansion of extrudate (Fan, 1996; Ainsworth et al., 2006). Six lengths of extrudate (approximately 120 mm) was selected at random during collection of each of the extruded samples, and allowed to cool to room temperature. The diameter of the extrudates was then measured, at 10 different positions along the length of each of the six samples, using a vernier caliper. Lateral expansion (LE, %) was then calculated using the mean of the measured diameters:

LE = (diameter of product – diameter of dia hole) / diameter of dia hole × 100 ..... (2)

2.4.3 Water solubility index (WSI) and water absorption index (WAI):

The WSI and WAI were measured using a technique developed for cereals (Ding et al., 2006) 2.5 gm of ground extrudate was suspended in 25 ml water at room temperature for 30 min, with intermediate stirring, and then centrifuged at 4000 rpm for 15 min. (Shirani et al., 2008) The supernatant was decanted into an evaporating dish with a known weight. The WSI is the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample, whereas WAI is the weight of gel obtained after removal of the supernatant per unit weight of original dry solids. These were calculated using following formulas,

WAI (g/g) = Weight gain by gel / Dry weight of extruded ..... (3)

WSI (%) = Weight of solid supernatant / Dry weight of extrudates ..... (4)

3. RESULTS AND DISCUSSION

The effect of fenugreek seed powder and oat flour on macrostructure and physical proportion reported on table 2.

Table 2 Effect of fenugreek seed powder and oat flour on macrostructure and physical proportion of extruded product.

Sr.No.	Fenugreek seed powder	Oat flour	B.D.	L.E.	W.A.I.	W.S.I.
1	+1	+1	0.064	201	1.114	4.1
2	+1	-1	0.0653	199	1.101	4.15
3	-1	+1	0.0614	192	1.294	4.3
4	-1	-1	0.0711	194	1.125	4.12
5	+1.414	0	0.0659	199.5	1.246	4.1
6	-1.414	0	0.0711	194	1.125	4.2

7	0	+1.414	0.0737	200.5	1.402	4.01
8	0	-1.414	0.0646	199	1.208	4.3
9	0	0	0.0717	189	2.54	4.45
10	0	0	0.0862	189	2.668	4.43
11	0	0	0.0825	188.5	2.062	4.43
12	0	0	0.0829	188.5	2.684	4.43

3.1 Bulk Density (Table 3 Figure.1)

Bulk density of extruded product ranged from 0.0098 to 0.0825 g/cm^3 .The resulting polynomial equation (7).

B.D 14% = +0.083 -0.0010*A +0.00047* B -0.0079* A^2 -0.0076* B^2 +0.0018*A*B ….equ.(7).

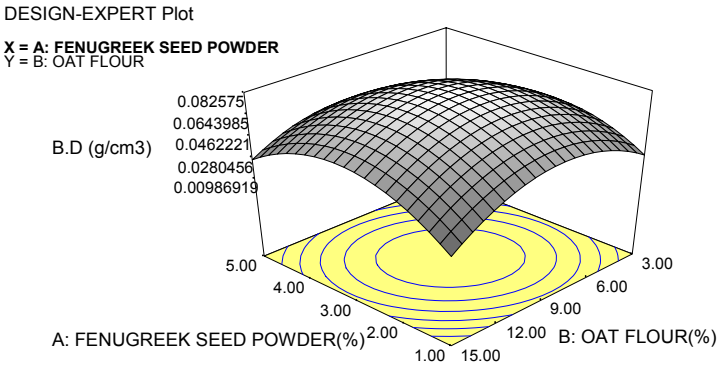
In linear term, fenugreek seed powder (A) and oat flour (B) were found to be significant (P<0.05). F-value for linear terms fenugreek seed powder (A) and Oat flour (B) were 0.47and 0.089 and P-value was found to be 0.5191 and 0.7756 (P<0.05) respectively form table 3, validating that terms were significant. Quadratic terms of fenugreek seed powder (A^2) and oat flour (B^2) had shown significant effect. F-value for quadratic terms fenugreek seed powder (A^2) and oat flour (B^2) were 20.25 and 18.63 and p- value was found to be 0.0041 and 0.0050 (P>0.05) respectively. The interaction term form fenugreek seed powder and oat flour (AB) gave non-significant effect P-value was found to be 0.4453 (P<0.05) and it shows the positive effect on the interaction term. F-value found to be 0.67 in table 3.

Counter plots shows the effect of fenugreek seed powder and oat flour on bulk density is showed in Figure.1 as fenugreek seed powder increased then bulk density decreased and oat flour content of the extruded product was increased then bulk density of the extruded product was increased.

Table 3 Anova of bulk density showing effect of fenugreek seed powder and oat flour.

Response	Source	DF	Sum of squares	Mean squares	F-value	P-value
BD	Regression	5	0.00067	0.000134	6.73**	0.0190
	A	1	0.0000093	0.0000093	0.47	0.5191
	B	1	0.0000017	0.0000017	0.089	0.7756
	A^2	1	0.0004045	0.0004045	20.25**	0.0041
	B^2	1	0.0003721	0.0003721	18.63**	0.0050
	AB	1	0.0000133	0.0000133	0.67	0.4453
	Pure error	3	0.00002827	0.0000094		
	Lack of fit	3	0.00009156	0.0000305	3.24*	0.1801
	Residual	6	0.0001198	0.0000199		
	Total	1	0.0007916			

R^2 0.8486, *Significant at P < 0.1, **Significant at P < 0.05,



Figure–1: Counters plot for bulk density of extruded product as affected by propration of fenugreek seed powder and oat flour.

3.2 Lateral expansion (Table 4, Figure.2)

Lateral exapansion of extruded product ranged from 187.10% to 232.72%. The resulting polynomial equation (8).

L.E.= +187.75 +3.16* A +0.70* B +3.84* A^2 +5.34* B^2 +0.13*A*B ……(8)

In linear term, fenugreek seed powder (A) and oat flour (B) were found to be significant (P<0.05). F- value for linear terms fenugreek seed powder (A) and Oat flour(B) were 13.28 and 0.65 and P-value was found to be 0.0108 and 0.4486(P<0.05) respectively form table 4, validating that terms were significant. Quadratic terms of fenugreek seed powder (A^2) and oat flour (B^2) had shown significant effect (P<0.05) .F-value for quadratic terms fenugreek seed powder (A^2) and oat flour (B^2) were 15.72 and 30.38 and p- value was found to be 0.0074 and 0.0015

(P<0.05) respectively. The interaction term form fenugreek seed powder and oat flour (AB) gave significant effect P-value was found to be 0.9221 (P<0.05) and it shows the negative effect on the interaction term and F-value found to be 0.010 in table 4. Counter plots shows the effect of fenugreek seed powder and oat flour on L.E.R. is showed in Figure.2 as fenugreek seed powder content product was increased then lateral expansion of the extruded product was found to be increased and oat flour content of the extruded product was increased then lateral expansion of the extruded product was found to be increased.

Table 4 Anova of lateral expansion effects of fenugreek seed powder and oat flour.

Response	Source	DF	Sum of Squares	Mean squares	F-value	P-value
L.E.R.	Regression	5	317.97	63.59	10.57**	0.0062
	A	1	79.87	79.87	13.28**	0.0108
	B	1	3.94	3.94	0.65	0.4486
	A^2	1	94.55	94.55	15.72**	0.0074
	B^2	1	182.75	182.75	30.38**	0.0015
	AB	1	0.062	0.062	0.010	0.9221
	Pure error	3	10.25	3.416		
	Lack of fit	3	25.83	8.611	2.52	0.2339
	Residual	6	36.08	6.013		
	Total	11	354.06			

R^2=0.9124 *Significant at P < 0.1, **Significant at P < 0.05,

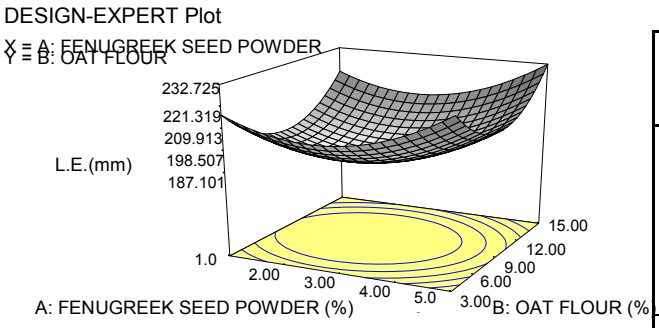


Figure- 2 .Counters plot for L.E. of extruded product as affected by propration of fenugreek seed powder and oat flour.

3.3 Water Absorption index (WAI) (Table 5, Figure.3)

W.A.I. of extruded product ranged from 1.1077 to 2.6885%. The resulting polynomial equation (9).

W.A.I. =+2.49 -0.006485* A +0.055* B -0.67 *A^2 - 0.61* B^2-0.034*A*B……(9)

Fenugreek seed powder (A) and oat flour (B) were found to be non-significant (P<0.05) respectively F- value for linear terms fenugreek seed powder (A) and Oat flour (B) were 0.0069 and 0.50 and P-value was found to be 0.9362 and 0.5078 shows non-significant effect respectively with (P<0.05) respectively table 5. Quadratic terms of fenugreek seed powder (A^2) and oat flour (B^2) had shown significant model (P<0.05). F-value for quadratic terms fenugreek (A^2) and oat (B^2) were 59.92 and 49.74 and p- value was found to be 0.0002 and 0.0004 shown significant (P<0.05) respectively. The interaction term form fenugreek seed powder and oat flour (AB) gave significant effect P-value was found to be 0.7657 (P<0.05) and it shows the positive effect on the interaction term. F-value found to be 0.097 in table 5.

Counter plots shows the effect of fenugreek seed powder and oat flour on W.A.I. is showed in Figure.3 as fenugreek seed powder content of extruded product increased then W.A.I. decreased and oat flour of the extruded product increased W.A.I. first increased then decreases.

Table 5 Anova of hardness showing effect on fenugreek seed powder and oat flour

Response	Source	DF	Sum of Squares	Mean squares	F-value	P-value
W.A.I.	Regression	5	4.44	0.89	18.42**	0.0014
	A	1	0.00033	0.00033	0.0069	0.9362
	B	1	0.024	0.024	0.50	0.5078
	A^2	1	2.89	2.89	59.92**	0.0002
	B^2	1	2.40	2.40	49.74**	0.0004
	AB	1	0.00469	0.00469	0.097	0.7657
	Pure error	3	0.25	0.085		
	Lack of fit	3	0.034	0.011	0.13	0.9329
	Residual	6	0.29	0.048		
	Total	11	4.73			

R^2=0.9388 *Significant at P < 0.1, **Significant at P < 0.05

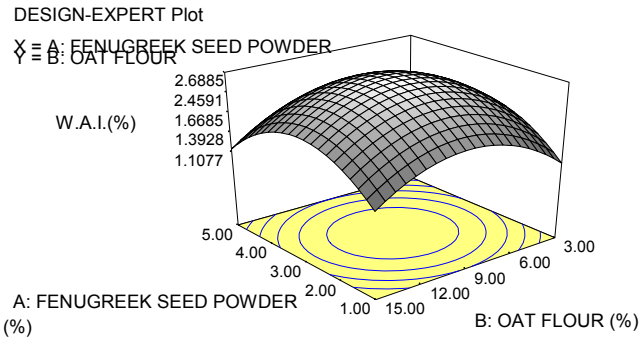


Figure-3 Counters plot for WAI of extruded product as affected by proportion of fenugreek seed powder and oat flour.

3.4 Water Solubility Index (WSI) (Table 6, Figure.4)

W.S.I. of extruded products ranged from 2.967 to 4.4372 The resulting polynomial equation (10).

$$W.S.I.14\% = +4.44 - 0.039*A - 0.035*B - 0.14*A^2 - 0.14*B^2 - 0.057*A*B \ldots\ldots (10)$$

Fenugreek seed powder (A) and oat flour (B) were found to significant (P<0.05). F- value for linear terms fenugreek seed powder (A) and Oat flour (B) were 1.95 and 1.58 and P-value was found to be 0.2122 and 0.2559 shows non-significant effect respectively with (P<0.05) table 6. Quadratic terms of fenugreek seed powder (A^2) and oat flour (B^2) had shown significant model (P<0.05) .F-value for quadratic terms fenugreek (A^2) and oat (B^2) were 19.81 and 19.10 and p- value was found to be 0.0043 and 0.0047 respectively shown significant (P<0.05) effect. The interaction term for fenugreek seed powder and oat flour (AB) gave non-significant effect since P-value was found to be 0.1951(P<0.05) and it shows the negative effect on the interaction term. F-value found to be 2.13.

Counter plots shows the effect of fenugreek seed powder and oat flour on W.S.I. is showed in Figure.4 as fenugreek seed powder content of the extruded product was increased then water solubility index of the extruded product was decreased and oat flour content of the extruded product was increased then water solubility index of the extruded product was decreased.

Table 6 Anova of hardness showing effect on fenugreek seed powder and oat flour.

Response	Source	DF	Sum of square	Mean squares	F-value	P-value
W.S.I.	Regression	5	0.24	0.012	7.62**	0.0141
	A	1	0.012	0.012	1.95	0.2122
	B	1	0.0098	0.0098	1.58	0.2559
	A^2	1	0.12	0.12	19.81**	0.0043
	B^2	1	0.12	0.012	19.10*	0.0047
	AB	1	0.013	0.013	2.13*	0.1951
	Pure error	3	0.0003	0.0001		
	Lack of fit	3	0.037	0.012	123.40**	0.0012
	Residual	6	0.037	0.0062		
	Total	11	0.27			

R^2=0.9780 *Significant at P < 0.1, **Significant at P < 0.05

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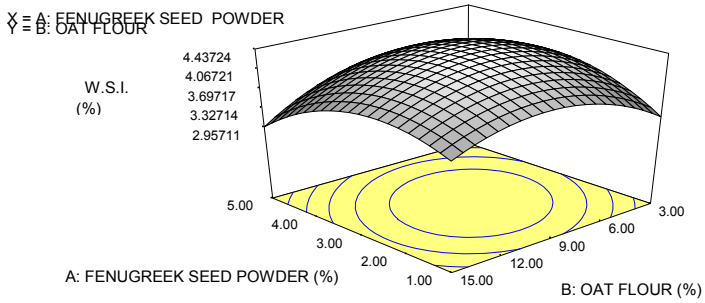

Figure-4 Counter plot for W.S.I. of extruded product as affected by proportion of fenugreek seed powder and oat flour.

4. Optimization

A numerical multi-response optimization technique was applied (Park *et al.,* 1993) to determine the optimum combination of fenugreek seed powder and oat flour.

4.1 Compromised optimum condition for experiment

The assumptions were to develop a product which would have maximum score in Overall acceptability so as to get market value and acceptance, minimum bulk density, maximum lateral expansion,

minimum WAI, minimum WSI, maximum specific length and maximum expansion ratio. Therefore, among responses, these parameters were attempted to be maintained whereas other parameters were kept within range. Under these criteria, the uncoded optimum operating conditions for development of fenugreek seed powder and oat flour extruded snack were 118°C of barrel temperature, 250 rpm of screw speed, 14% of feed moisture 2.28% fenugreek seed powder and 4.76 oat%. The responses predicted by the design expart-6 software for these optimum process conditions.

Table 9 Multi response optimization constraints of experiment

Parameters	Goal	Low limit	Up limit	Low Weight	Up Weight	Importance
F.S. powder	is in rang	1.586	40414	1	1	3
Oat flour	is in range	4.758	13.242	1	1	3
BD	minimize	0.0614	0.0862	1	1	3
LER	maximize	188.5	201	1	1	3
WAI	minimize	1.101	2.284	1	1	3
WSI	minimize	4.01	4.84	1	1	3

4.2 Verification of results

The suitability of the model developed for predicting the optimum response values was tested using the recommended optimum conditions of the variables and was also used to validate experimental and predicted values of the responses.

Table 10 Optimized condition for experiment

Process variable	Fenugreek seed flour	Oat flour	Screw speed	Temperature
Un-coaded	2.28 %	4.76 %	250 rpm	118°C

Table 11 Predicted and actual values of the responses at the optimized condition of experiment

Responses	Predicted value	Actual value	Variation %
BD	0.06520	0.059	9.50%
LER	197.021	185.000	6.10%
WAI	0.81136	1.58	9.47%
WSI	4.01015	3.665	8.60%

5. CONLUSION

By applying RSM to find out the effects of fenugreek seed flour and oat flour on different responses used in RSM, As fenugreek seed powder and oat flour contents increases then similarly, lateral expansion increased and water solubility index decreased and show a significant effects ($P<0.05$). Similarly developed antioxidants rich extruded product by supplement with fenugreek seed powder and oat flour.

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