Research Paper

Volume : 3 | Issue : 7 | July 2014 • ISSN No 2277 - 8179

Efficacy of Extrusion Process Variables and its Optimization For Ready to Eat Defatted Soy and Carrot Pomace Incorporated Wheat Based Snacks

Food Technology

KEYWORDS : Extrusion, wheat flour, defatted soy flour, carrot pomace powder, RSM

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ABSTRACT

The present investigation was carried out to develop soy-carrot pomace incorporated wheat based nutritionally rich snacks. Different experimental combinations of extrusion process variables i.e. die temperature, screw speed, and wheat flour in the feed formulation of wheat, defatted soy flour and carrot pomace powder, were tried using Box-Behnken design of experiments. Response surface methodology (RSM) was used to investigate the effect of die temperature (120-180°C), screw speed (300-500 rpm) and wheat flour (65-85%) with soy-carrot pomace blend in equal proportion on product responses like bulk density (BD), expansion ratio (ER), water absorption index (WAI) and water solubility index (WSI). An analysis of variance (ANOVA) revealed that, among the process variables wheat flour percentage in feed formulation had significantly higher effect on BD, ER, WAI and WSI. Die temperature and screw speed were observed to have significantly lower effect on the selected responses. In order to develop an extruded product with desired product quality, the extrusion conditions were optimized and desirability of 0.785 was accomplished.

INTRODUCTION

Carrot is one of the most important seasonal root vegetable, usually orange in color with a woody texture and grown extensively in India. It contains high moisture (more than 85% w.b.), carbohydrate (approx 10%) and is low in acids. The carrot juice is used in fabricated baby foods, which are most popular throughout the world. Carrot pomace is a by-product obtained during carrot juice processing. The juice yield in carrots is only 60–70%, and even up to 80% of carotene may be lost with left over carrot pomace [1]. So far, the left over pomace after juice extraction has not found its proper utilization. Dried pomace has β carotene and ascorbic acid in the range of 9.87 to 11.57 mg and 13.53 to 22.95 mg per 100 g respectively [2]. The dried carrot pomace can be used to develop high fiber extruded products.

Extrusion is a modern high temperature-short time process is being adopted to replace traditional food processing techniques [3]. It is an important technology for processing grain-based products and adds immense value to raw material ranging from corn, wheat and rice to sorghum, oats and soybeans. Wheat is the major food crop next to rice in Indian sub continent. A large number of population is adapted to the taste of wheat. Hence, wheat can be used as a base to manufacture healthy snacks. The extruded products content could be improved in its overall nutritional content and taste by incorporation of protein rich ingredients. Legumes not only holds great promise in meeting the protein needs of poor population, but also contributes to solving some health- related problems of the world [4]. Hence, defatted soybean flour, rich source of protein could also be used to further nutritionally enrich the food. Incorporation of legume flour has been shown to cause a positive impact on levels of proteins and dietary fiber of extruded snacks [5]. With changes in formulation and control of extrusion parameters, an acceptable expanded ready-to eat snack could be produced [6]. An attempt has been made to prepare a nutritious extruded snack using wheat flour, carrot pomace powder and defatted soybean flour and process parameters have been optimized using response surface methodology techniques.

MATERIAL AND METHODS

Experimental design

A three factor box behnken design was employed for the experiment. The independent variables included the proportion of defatted soy flour and carrot pomace powder in wheat flour (15-35%), die temperature (120-180°C) and screw speed (300-500 rpm). Response variables were bulk density, expansion ratio, water absorption index and water solubility index. The formulation of wheat flour: defatted soy flour: carrot pomace powder was in the ratio of 65:17.5:17.5, 75:12.5:12.5 and 85:7.5:7.5, respectively for the preparation of extruded snacks. Sugar @10 % was added in every sample to enhance the flavor of the snacks. The blends were mixed in equal proportion in a food processor with mixture attachment. A laboratory scale co-rotating twin-screw extruder with intermeshing (Model BC2; Clextral, Firminy Cedex, France) was used for extrusion. The product was collected at the die end and packed in polythene bags for further analysis.

Product quality responses

Bulk density (BD, g/cm3) of extrudates was determined by using average diameter and an average length of extrudate samples and calculated using method given by Stojceska et al. [6]. The ratio of diameter of extrudate and the diameter of die was used to express the expansion ratio (ER) of extrudates [7]. Water absorption Index (WAI) and water solubility index (WSI) were determined according to the method suggested by Anderson et al. [8]

RESULTS AND DISCUSSION

The data on values of physical properties of extrudates is presented in Table 1. The final equation of the fitted model for the selected parameters is depicted in Table 3 along with the R2 values. The regression models for bulk density, expansion ratio, WAI and WSI were highly significant ($P < 0.0001$), with a high correlation coefficient (R2 = 0.85, 0.91, 0.84 and 0.95 respectively). Results and observations with respect to the relationship of independent variables with individual dependent variable are being presented as follows:

Bulk Density (BD)

Table 1 shows the effect of independent variables on the bulk density (BD) of the extrudates. BD values ranged from 0.224-0.405 g/cc (Table 1). At a given temperature, BD values were significantly affected by wheat flour in the composition. At 150oC DT, BD values displayed a variation from 0.327 g/cc at 300 rpm SS and 65% WF in the composition; 0.287 g/cc at 400 rpm SS and 75% WF in the composition; and, 0.272 g/cc at 500 rpm and 85% WF in the composition depicting negative relationship of BD values with WF in the composition. This relationship is further confirmed by ANOVA table and regression equations (Table 2 and 3). The effect of DT, SS and WF ($p<0.01$) was negative on BD values. The product terms of DT*SS, SS*WF and DT*WF had positive effect on BD of the extrudates. The quadratic model of WF had significantly positive effect on BD values ($p<0.05$).The significance of coefficient of fitted quadratic model was evaluated by using F-test and P- value. Identical results were shown by other researchers for extrusion of chick pea flour [9] and rice [10].

Expansion Ratio (ER)

The experimental values of expansion ratio (ER) of extrudates under different designed extrusion conditions are shown in Table 1. The values of expansion ratio of extrudates varied between 2.22 and 2.77 on the basis of combinations of extrusion process variables.

The highest expansion ratio of 2.77 was observed at extrusion processing of 150oC DT, 500 rpm SS, and 85% WF in the composition (7.5% carrot pomace powder). On the other hand, the lowest expansion ratio of 2.22 was processed at 150oC DT, 400 rpm SS and 65% WF in the composition (12.5% carrot pomace powder). The effect of linear terms of DT ($p<0.01$) was significantly negative, however, SS and WF ($p<0.01$) had positive effect on ER values. It was further confirmed from the ANOVA table and regression coefficients (Table 2 and 3). The product terms of DT*SS and SS*WF was positive whereas that of DT*WF was negative on ER values. The quadratic effect of SS and WF was positive on expansion ratio. The results were consistent with the studies done by Faubion & Hoseney [11] and Ilo et al. [12].

Water absorption index (WAI)
WAI values for the extrudates ranged between 3.882 and 4.590 g/g (Table 1). DT and WF ($p<0.01$) was found to have positive effect on WAI values. However, SS had negative effect on the WAI values. The product terms of DT*SS and SS*WF had positive while DT*WF had negative effect on WAI values. The quadratic terms of all the variables had negative effect on WAI values. The mathematical equation representing the effect of process variables on WAI values is depicted in Table 3. Water absorption index increased with the increase in temperature probably due to increased dextrinization at higher temperature [13].

Water solubility index (WSI)
The index amounts to the soluble polysaccharides released from the starch after extrusion (Ding *et al.,* 2006). With respect to the effect of independent variables on the WSI values, a positive effect on WSI values was observed (Table 3). The range of WSI values of the extrudates varied between 19.2 and 24.8% (Table 1). The minimum value of 19.2% was the result of combination of processing at 150°C DT, 300 rpm SS and 65% WF in the composition. The maximum value of 24.8% was observed at 180°C DT, 400 rpm SS and 85% WF in the composition. The effect of wheat flour was prominent and was further confirmed by the ANOVA table (Table 2). With respect to product terms of DT*SS, SS*WF and DT*WF; DT*WF had negative effect on WSI values. The quadratic effect of DT and SS revealed significant positive effect on WSI values. Badrie and Mellowes [14] and Hernandez- Diaz et al. [15] reported similar findings.

Optimization and validation
Multi-response optimization technique was adopted to determine the workable optimum conditions for the development of extruded product using design expert software (Statease, DE 9.0). The process parameters were optimized for minimum BD and WSI values whereas maximum for ER and WAI values.

Predicted values of BD (0.255 g/cc), ER (2.657), WAI (4.5 g/g) and WSI (21.1%) were obtained from the optimization. Best extrusion conditions were 145oC DT, 388.9 rpm SS, and 80.83% WF having desirability value of 0.785 (Fig. 1). The model was validated by developing the extruded snack at optimized process parameters where BD, ER, WAI and WSI values ranged within the predicted range ($p<0.05$).

CONCLUSION
Response surface methodology was effective in optimizing process parameters for twin-screw extruded snacks prepared from wheat flour, defatted soybean flour and carrot pomace powder at 120-180 oC die temperature, 300-500 rpm screw speed and 65-85 % wheat flour in the composition. The regression equations obtained can be used for optimum conditions for desired responses within the range of conditions applied in this study. The optimum extrusion conditions for extruding snacks were 145oC DT, 388.9 rpm SS, and 80.83% WF in the composition for maximum expansion ratio and WAI; and minimum bulk density and WSI values.

Table 1. Experimental data of extrudates for response surface analysis using four factor three level Box-Behnken design

Extrusion Process Variables			Product quality responses			
DT (°C)	SS (rpm)	WF (%)	BD (g/cc)	ER	WAI (g/g)	WSI (%)
150(0)	400(0)	75(0)	0.287	2.66	4.268	20.12
180(+1)	500(+1)	75(0)	0.224	2.37	4.184	23.54
180(+1)	300(-1)	75(0)	0.304	2.30	4.138	23.2
120(-1)	400(0)	65(-1)	0.405	2.44	3.992	19.6
150(0)	300(-1)	65(-1)	0.327	2.36	4.270	19.2
120(-1)	400(0)	85(+1)	0.279	2.72	4.472	23.7
180(+1)	400(0)	85(+1)	0.271	2.61	4.590	24.8
120(-1)	300(-1)	75(0)	0.312	2.68	4.358	23.12
150(0)	300(-1)	85(+1)	0.245	2.71	4.582	23.4
180(+1)	400(0)	65(-1)	0.398	2.22	4.154	20.4
150(0)	400(0)	75(0)	0.241	2.49	4.318	19.86
150(0)	400(0)	75(0)	0.275	2.55	4.457	20.12
150(0)	400(0)	75(0)	0.258	2.52	4.267	19.45
120(-1)	500(+1)	75(0)	0.271	2.63	4.010	22.09
150(0)	500(+1)	85(+1)	0.272	2.77	4.216	23.8
150(0)	400(0)	75(0)	0.264	2.48	4.552	19.2
150(0)	500(+1)	65(-1)	0.310	2.50	3.882	21.6

Table 2. Analysis of variance of extrusion process variables on the selected responses

Extrusion process variables	Responses (F- value)			
	BD (g/cc)	ER	WAI (g/g)	WSI (%)
Die Temperature (DT)	6.12×10^{-3} (4.494)	0.1163 (22.526)	0.5885 (0.4266)	1.4706 (3.7173)
Screw Speed (SS)	1.54×10^{-3} (0.7412)	0.0067 (1.3126)	0.0068 (8.6875)	0.556 (1.4067)
Wheat Flour (WF)	0.0174 (1.837)	0.2080 (40.3040)	0.1394 (19.008)	27.751 (70.148)
DT*SS	3.80×10^{-3} (21.0749)	0.00374 (0.726)	0.3050 (2.4187)	0.469225 (1.1861)
DT*WF	2.500×10^{-7} (0.4602)	0.0029 (0.5608)	0.0389 (0.03016)	0.0225 (0.0569)
SS*WF	4.611×10^{-3} (3.0254×10^{-3})	0.0019 (0.375)	0.00048 (0.0075)	1.000 (2.527)
DT^2	4.11×10^{-3} (0.5581)	0.0178 (3.448)	0.00012 (1.2027)	11.9015 (30.0838)
SS^2	1.44×10^{-3} (4.9761)	0.0017 (0.3359)	0.0193 (4.5862)	10.1975 (25.776)
WF^2	7.43×10^{-3} (1.7439)	0.0021 (0.4090)	0.0736 (0.00191)	2.02648 (5.1224)
CV (%)	9.87	2.84	2.96	2.91
S.D. (5% LSD)	0.029	0.072	0.13	0.63

The data in parenthesis are the p-values.

Table 3. Adequacy of model fitted

Parameters	Fitted models	R2	P value
Bulk Density (g/cc)	BD = + 0.265 - 0.00875 *DT - 0.01377 *SS - 0.046656375 *WF -0.00975 * DT*SS - 0.000250 *DT*WF + 0.0107 *SS*WF + 0.0312 *DT2- 0.0185 * SS2 + 0.04200 * WF2	0.85	0.0761

Expansion Ratio	ER= + 2.54 - 0.12055 *DT + 0.0291 *SS + 0.1612 *WF + 0.03059 *DT*SS + 0.0269 *DT*WF - 0.022 * SS*WF - 0.0650 * DT2 + 0.02029 * SS2 + 0.022 *WF2	0.91	0.4152
Water Absorption Index (g/g)	WAI= + 4.37 + 0.02925 *DT - 0.132 *SS + 0.19525 *WF + 0.0985 **DT*SS - 0.011 * DT*WF + 0.0054 * SS*WF - 0.0677 * DT2 - 0.132 * SS2- 0.0027 * WF2	0.84	0.4815
Water Solubility Index (%)	WSI= + 19.75 + 0.42875 *A + 0.26375 *B + 1.8625 *C + 0.3425 * *DT*SS + 0.0750 * DT*WF - 0.5 * SS*WF + 1.681 * DT2+ 1.556 * SS2 + 0.693 * WF2	0.95	0.1029

Table 4. Optimum values of extrusion process parameters and responses

Process Parameters	Target	Experimental Range		Optimum value	Desirability
		Min	Max		
Die temperature (^{0}C)	range	120	180	145	
Screw speed (rpm)	range	300	500	384	
Ingredients proportion					
Wheat flour (%)	range	65	85	80.8	
Carrot pomace powder (%)	range	7.5	17.5	9.9	
Deffated soy flour (%)	range	7.5	17.5	9.9	
Responses				Predicted values	
BD (g/cc)	minimize	0.224	0.405	0.255	0.785
ER	maximize	2.22	2.77	2.657	
WAI (g/g)	in range	3.882	4.59	4.50	
WSI (%)	In range	19.2	24.8	21.09	

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