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RESEARCH PAPER

The effect of extrusion conditions on the functional properties of defatted cake of sunflower-maize based expanded snacks

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Abstract

The effect of extrusion conditions, including feed moisture content (14–20%), screw speed (300-500 rpm), and barrel temperature (120-180ºC) on the functional properties (water absorption index (WAI), and water solubility index (WSI), fat absorption capacity (FAC) and foaming capacity) and sensory properties (color, appearance, flavor, overall acceptability and textural characteristics) of an expanded sunflower snack was investigated. Extruded snacks were prepared by substituting maize flour with developed texturized flour of sunflower at 0-40% levels. Protein content increased to 13.83% in snacks prepared with 10% texturized sunflower meal as compared to the control i.e., 7.55%. Fibre content increased while protein digestibility improved with increased level of incorporation of texturized defatted sunflower flour in extruded snacks making. Increasing feed moisture content results in extrudates with lower expansion, lower WAI, higher WSI, higher hardness and lower sensory acceptability. Increasing screw speed caused slight reduction of density and hardness of sunflower extrudate. Feed moisture had positive while screw speed and barrel temperature had negative influence on WAI. Negative coefficient of linear terms of moisture and screw speed indicated that WSI decreased with increase in these variables. Higher moisture content in extrusion process could diminish protein denaturation which lowered WSI values.

Keywords: Defatted meal, extrusion, functional properties, sunflower, snacks

Grain legumes are important sources of food proteins. In many regions of the world, legume seeds are the unique protein supply in the diet. The purification of vegetable protein involves physic-chemical and thermal processing, affecting the nutritional value of the final products, and also the functional properties, of interest when the proteomic product is destined for food or for non-food purposes. When added to the food protein confers desirable functional properties, such as whipping capacity (WC), viscosity, emulsification and water and oil holding capacities. Proteins also play a decisive role in the nutritional, sensory, physico-chemical and organoleptical properties of the food. Protein content of defatted meals made from dehulled oilseeds depends on the seed and ranges between 35% and 60% (d.b.). Due to their nutritional values and high protein content, sunflower plays a significant role in the manufacturing of extruded snacks. However, little information is available on the functional properties of texturized defatted flour in making extruded snack. Keeping these points in mind, the present study was planned with the objectives to optimize the extension process of and to find out the best level on the basis of functional properties of defatted sunflower-maize flour blends.

Materials and Methods

Raw materials

Maize and sunflower were procured from the Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana.

Oil extraction

The sunflower was cleaned and defatted using laboratory oil expeller. The meal was dried and milled into grits using Super Mill is Perten Instruments, Sweeden. After that, the sample was sieved using mesh screen to separate out the large particles of the seed coat.

Extrusion process for soybean

Texturization of sunflower was carried out by using Clextral BC 21 twin screw extruder (Clextral, Firminy, France). The operating conditions were 14-20% feed moisture, 300-500 rpm screw speed and 120-180^{o}C barrel temperature. Texturized proteins was milled into flour using cyclotec mill (Newport Scientific, Australia) and packed in suitable packaging material for further study. Experimental design Central composite design was to optimize the process. Extrusion process variables (feed moisture content, screw speed and temperature) were coded to the level of -1, 0, +1 such that one factor at a time of experimental design was as follow (Myers, 1971) as shown in following table.

Extension process variables

Extrusion parameters	-1.682	-1	0	+1	+1.682
Moisture content (%)	11.954	14	17	20	22.046
Screw speed (rpm)	231.800	300	400	500	568.200
Barrel temperature (^{o}C)	99.54	120	150	180	200.460

Snacks preparation

The basic raw material i.e. maize was substituted with developed texturized defatted sunflower flour from 0 to 40% level to assess the effectiveness of functional properties.

Functional properties Analysis

Water absorption index (WAI), Water solubility index (WSI) and fat absorption capacities (FAC)

Water absorption index (WAI) was measured according to the Stojceska *et al.*, (2009) method. First, 1g of sample was placed in a previously weighed 50 ml centrifuge tube. Then, 10 ml of distilled water was added and stirred homogeneously with a glass rod and centrifuged at 3000 rpm for 10 min at room temperature (22°C) using a Model T-8BL Laby™ centrifuge (Laby Laboratory Instruments, Ambala Cantt, India). The residue was weighed together with the centrifuge tube. The WAI values were expressed as gram of water absorbed/gram of sample. The supernatant was transferred to previously weighed dish which put in hot air oven for evaporation of water. The residue was weighed. A similar method was used to measure fat absorption capacity (FAC), although a 0.5 g sample was used in this case (Lin *et al.*, 1974).

$$\text{WAI (g/g)} = \frac{\text{Weight of residue}}{\text{Sample taken}}$$

$$\text{WSI (\%)} = \frac{\text{Weight of dry matter in supernatant} \times 100}{\text{Dry weight of sample}}$$

$$\text{FAC (\%)} = \frac{\text{Weight of fat absorbed by sample} \times 100}{\text{Weight of sample}}$$

Chemical analysis

Chemical characteristics of defatted meal and snacks were analyzed using standards procedures (AACC, 2000).

Foaming capacity

One gram of sample was dissolved in 100 ml of distilled water. Then the suspensions were whipped at a low speed in a blender for 1 min at room temperature (22°C). The resulting foam was poured into a 100 ml cylinder. Total foam volume was recorded and foam capacity was expressed as the percent increase in volume. To determine foam stability (FS), foam volume was recorded 30 min after whipping and calculated according to the method proposed by Kabirullah and Wills, (1983).

$$FC = \frac{\text{Final foam volume} \times 100}{\text{Initial foam volume}}$$

Water holding capacity (WHC)

Five gram of sample was placed in a previously weighed 50 ml centrifuge tube. Then, 10 ml of distilled water was added and stirred homogeneously with a glass rod and centrifuged at 2000 rpm for 10 min at room temperature (22°C). The supernatant was decanted and the residue was weighed together with the centrifuge tube (AACC, 2000).

$$WHC\ (ml/g) = \frac{(\text{weight of tube + sediment}) - (\text{weight of tube} + 5.0)}{5}$$

Protein digestibility

The *in-vitro* protein digestibility was estimated using method given by Akeson and Stachman (1964).

Statistical analysis

The statistical analysis was performed using Design Expert software. The main advantage of RSM was that it reduced number of experimental runs needed to provide sufficient information for statistically acceptable results. The results were analyzed by multiple linear regression method which describes the effects of variables in the models derived. Experimental data were fitted to the selected models and regression coefficients were obtained.

Table 1: Effect of texturization on functional properties of defatted sunflower meal

Extrusion parameters			Functional properties				
Moisture content (%)	Screw speed (rpm)	Barrel temperature (°C)	Water absorption index (g/g)	Water solubility Index (%)	Fat absorption capacity (%)	Foaming Capacity (%)	Protein digestibility index (%)
14	300	120	3.28±0.01	4.21±0.02	104.50±0.09	15.12±0.10	22.85±0.04
20	300	120	3.10±0.02	3.41±0.01	91.47±0.02	19.84±0.07	22.67±0.02
14	500	120	3.13±0.02	4.48±0.02	87.17±0.04	8.52±0.03	20.17±0.01
20	500	120	2.72±0.02	3.09±0.03	76.81±0.03	6.23±0.04	22.07±0.05
14	300	180	2.60±0.02	2.25±0.04	73.66±0.03	9.10±0.05	25.46±0.02
20	300	180	3.05±0.04	4.16±0.02	78.89±0.07	9.90±0.02	20.33±0.02
14	500	180	2.64±0.04	2.82±0.02	75.75±0.04	17.89±0.03	25.45±0.04
20	500	180	2.89±0.02	3.51±0.02	82.42±0.03	13.64±0.03	24.21±0.02
17	400	150	3.04±0.02	3.93±0.03	91.29±0.02	14.17±0.03	22.68±0.01
17	400	150	3.13±0.04	3.93±0.02	92.88±0.01	14.53±0.02	21.38±0.03
17	400	150	3.08±0.03	3.82±0.03	91.13±0.03	14.71±0.02	21.65±0.03
17	400	150	3.04±0.01	3.75±0.03	91.61±0.01	14.82±0.54	20.93±0.04
17	400	150	3.11±0.03	3.87±0.02	91.79±0.03	14.73±0.52	21.29±0.02
17	400	150	3.08±0.03	3.94±0.02	91.66±0.05	15.17±0.02	21.03±0.05
11.95	400	150	2.83±0.03	4.14±0.04	98.86±0.01	10.92±0.03	21.48±0.19
22.05	400	150	3.09±0.03	4.48±0.04	86.93±0.03	10.77±0.03	19.51±0.03
17	231.8	150	2.92±0.02	2.47±0.02	82.60±0.04	14.35±0.04	22.33±0.02
17	568.2	150	2.54±0.06	2.12±0.02	71.10±0.05	13.73±0.03	22.39±0.16
17	400	99.54	3.25±0.03	4.47±0.03	96.73±0.01	13.27±0.06	24.27±0.07
17	400	200.5	2.84±0.04	3.52±0.01	75.79±0.02	13.31±0.42	27.87±0.02

Results and Discussion

Texturized defatted sunflower meal was evaluated for functional properties such as water absorption index (WAI), water solubility index (WSI), fat absorption capacity (FAC) and foaming capacity (FC). There significant interaction of feed moisture with screw speed, feed moisture with barrel temperature and screw speed with barrel temperature ($P<0.01$) on fat absorption capacity, water solubility index, water absorption index and foaming capacity was documented. Feed moisture had positive while screw speed and barrel temperature had negative influence on WAI. Water absorption index value for extrudate ranged between 2.58-3.28g/g (Table 1). All the independent variable had significant effect on WAI ($P<0.01$) (Table 2) (eq. 1). Increases in moisture content reduced the water absorption index. Moisture content, acting as a plasticizer during extrusion cooking, reduces the degradation of molecules; this result in an increased capacity for water absorption (Hagenimana *et al.*, 2006). WAI was higher for lower screw speed and lower temperature. It could be expected that more undamaged polymer chains and a greater availability of hydrophilic groups, which could bind more water resulted in higher values of WAI under low shear conditions with lower screw speed (Jin *et al.*, 1995). WAI has been generally attributed to the dispersion of starch in excess water, and the dispersion is increased by degree due to pregelatinization of starch and denaturation of protein (Yagci and Gogus, 2008).

WSI for texturized defatted sunflower meal ranged from 2.12 to 4.48% (Table 1). WSI is used as an indicator of degradation molecular components, measures degree of starch and protein conversion during extrusion. More the water soluble polysaccharide released from starch in solution, more will be WSI. Negative coefficient of linear terms of moisture and screw speed indicated that WSI decreased with increase in these variables (eq 2). Higher moisture content in extrusion process could diminish protein denaturation which lowered the WSI values. It was observed from the regressions analysis that during extrusion cooking, higher moisture contents increased WSI of protein flour. The high mechanical shear caused breakdown of macromolecules to small molecules with higher solubility. The increase in WSI with increasing screw speed was consistent with the results reported by other researchers (Dogan and Karwe, 2003). Also increasing temperature would result in degradation of molecule resulting in an increase in WSI (Ding *et al.*, 2005).

Fat absorption capacity for texturized defatted sunflower meal ranged from 73.66-104.50% (Table 1). Regression analysis showed significant negative influence of feed moisture, screw speed and barrel temperature on FAC. There was a significant interaction of feed moisture with screw speed, feed moisture with barrel temperature and screw speed with barrel temperature (eq 3). Defatting increased protein solubility, water and oil absorption capacity of oil. The capacity of protein to absorb water and oil is determined by its polar and non-polar amino acids composition, respectively. Foams were gaseous droplets encapsulated by a liquid film containing soluble surfactant protein, that resulted in reduced interfacial tension between gas and water. Foaming capacity for texturized defatted sunflower meal ranged from 6.23-19.84% (Table 1). Regression analysis indicated that foaming capacity decreased with increase in feed moisture and screw speed (eq 4). Interaction ($P<0.05$) of feed moisture with screw speed, feed moisture with barrel temperature and screw speed with barrel temperature were found significant (Table 2).

Final Equation in Terms of Coded Factors:

$$WAI = +3.07 + 0.033*A - 0.090*B - 0.13*C - 0.059*A*B + 0.16*A*C + 0.063*B*C - 0.039*A^2 - 0.12*B^2 + 0.0001*C^2 \quad \text{(eq. 1)}$$

$$WSI = +3.89 + 0.065*A - 0.051*B - 0.29*C - 0.23*A*B + 0.61*A*C + 0.012*B*C + 0.14*A^2 - 0.57*B^2 + 0.034*C^2 \quad \text{(eq. 2)}$$

$$FAC = +91.73 - 1.57*A - 3.34*B - 6.17*C + 0.49*A*B + 4.41*A*C + 4.69*B*C - 0.66*A^2 - 5.28*B^2 - 1.95*C^2 \quad \text{(eq. 3)}$$

Table 2: Significance on the coefficient of estimate for sunflower meal

Factors	FAC	WHC	WSI	WAI	BD	FC
Intercept of Model	91.73	2.130	3.890	3.070	0.350	14.880
A: Moisture content	-1.57	-0.050	0.065	0.033	0.009	-0.065
B: Screw speed	-3.34	-0.090	-0.051	-0.090	0.030	-0.640
C: Barrel temperature	-6.17	-0.150	-0.290	-0.130	-0.033	0.026
AB (Moisture content x Screw speed)	0.49	0.073	-0.230	-0.059	0.002	-1.540
AC (Moisture content × Barrel temperature)	4.41	0.270	0.610	0.160	0.011	-0.750
BC (Screw speed × Barrel temperature)	4.69	0.180	0.012	0.063	0.011	4.100
A^2 (Moisture content)^2	-0.66	0.013	0.140	-0.039	-0.018	-1.430
B^2 (Screw speed)^2	-5.28	-0.140	-0.570	-0.120	-0.002	-0.310
C^2 (Barrel temperature)^2	-1.95	-0.026	0.034	0.001	0.006	-0.610
P-Value for lack of fit	0.84	0.47	0.19	0.08	0.35	0.23
R^2	0.99	0.97	0.98	0.96	0.94	0.98

$$\text{Foaming Capacity} = +14.88 - 0.065*A - 0.64*B + 0.026*C - 1.54*A*B - 0.75*A*C + 4.10*B*C - 1.43*A^2 - 0.31*B^2 - 0.61*C^2 \quad \text{(eq. 4)}$$

Where, A = Feed moisture content

B = Screw speed

C = Barrel temperature

Numerical optimization provided nine solutions with desirability value varying from 0.72 to 0.75. Range of predicted values of fat absorption capacity 80.96-90.49, WSI 3.22-3.47, WAI 2.84-3.08, foaming capacity 14.37-16.43 were used to overlay plot graphical optimization (Fig 1).

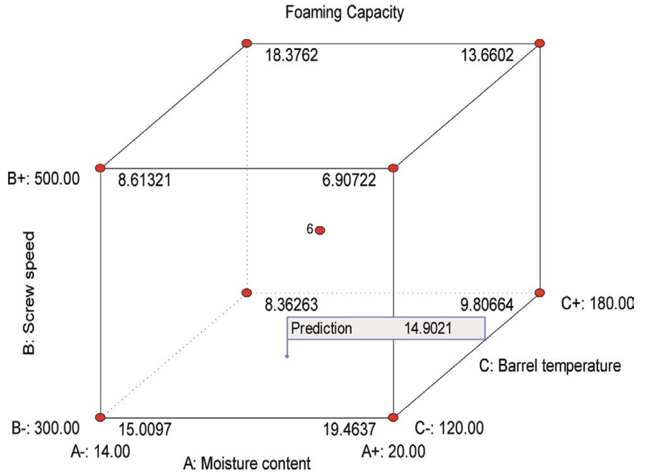

Fig. 1: Graphical reprsentation of product responses

Best extrusion conditions were 16.91 to 18.15% feed moisture content, 300.00-498.89 rpm screw speed and 148.46-180.00^{o}C barrel temperature.

These optimized conditions were used to prepare the texturized defatted sunflower meal. Blends of maize flour with texturized defatted sunflower at 10, 20, 30 and 40% were prepared. Extruded snacks were prepared after incorporation of texturized defatted sunflower meal at 10, 20, 30 and 40% levels in maize flour using optimized extrusion conditions. Protein, fibre and ash content increased while protein digestibility improved with increased level of incorporation of texturized defatted sunflower flour in extruded snacks making. Protein content was maximum in extruded snacks prepared with 40% texturized sunflower meal (Table 3).

Conclusion

Feed moisture had negative while screw speed and barrel temperature had positive influence on water absorption index (WAI) of texturized defatted sunflower meal. Water solubility index of texturized defatted sunflower meal increased with decrease in feed moisture content which increased with increase in barrel temperature. Fat absorption capacity of texturized defatted sunflower meal decreased with increase in feed moisture content, screw speed and

Table 3: Chemical composition of snacks prepared from texturized defatted meal of sunflower, soybean and flaxseed

Sample	Percent	Moisture (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	Protein digestibility (%)
Sunflower	0	4.79±0.021	10.55±0.032	0.12±0.021	2.16±0.035	0.733±0.021	39.30±0.726
	10	4.89±0.038	13.83±0.021	1.30±0.015	6.46±0.050	0.777±0.025	54.42±2.311
	20	4.80±0.035	17.24±0.046	1.45±0.050	9.37±0.015	0.937±0.015	58.63±1.567
	30	4.53±0.036	30.59±1.323	3.69±0.025	12.29±0.018	1.160±0.010	58.64±1.134
	40	4.68±0.030	23.97±0.110	3.73±0.031	15.26±0.021	1.357±0.027	61.55±1.297

barrel temperature. Feed moisture and screw speed had negative while barrel temperature had positive influence on foaming capacity of texturized defatted sunflower meal. Protein digestibility increased by 11.90% for texturized sunflower meal. Protein content increased to 13.83% in snacks prepared with 10% texturized sunflower meal compared to the control i.e., 7.55%.

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