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Extrusion cooking characteristics of soy-wheat blends to produce ready to eat snacks

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ABSTRACT

The snacks constitute an important part of our daily nutrient and calorie intake. Soy-cereal blends such as soy-corn, soy-rice and soy-sorghum have been reported to give good quality snacks with extrusion processing. Soybean is the cheapest source of quality protein and good calorie whereas wheat is a popular cereal in India with 70-85% starch. Extrusion provides expansion of starch, conversion of protein into easily digestible form at relatively lower operating costs. The experiments were conducted with full fat soyflour blended with wheat flour in proportion of 10,20 and 30%, at 3 feed moisture levels of 15, 20 and 25%(wb) and three barrel temperatures of 80, 90 and 100 °C. Analysis of various quality indices of extrudate with process variables indicated optimum condition of 10% blending of full fat soy flour (FFSF), 25% moisture content and 90 °C barrel temperature. The second set of experiment conducted on defatted soyflour, showed optimum condition at 10 % blend, 15% moisture content and 90 °C barrel temperature.

Soybean has great potential to provide good quality protein and calorie at low price and help in combating protein calorie malnutrition in the country. It is one of the major sources of protein per hectare than any other legume/pulse crop. It contains 40% good quality protein, 23% carbohydrates and 20% oil and is the most economical source of dietary protein. Soy-protein is rich in lysine but deficient in sulfur bearing amino acids. The cereals which contain adequate quantity of sulfur bearing amino acids are deficient in lysine, hence the soy cereal combination in appropriate proportions improves the nutritional value of the product considerably.

Wheat provides about one fifth of all calories consumed by human. Wheat flour is a popular material for preparing snack foods. It contains approximately 70-85% of starch, 8-13% protein, 0.8 to 1.5% fat, 1.5 to 2% sugar and 0.3 to 0.6% minerals. Wheat starch contains amylose and amylopectin. The high amylose content of about 23% gives good expansion characteristics.

The combination of both these sources of protein and calorie can be combined effectively into snack which is regularly consumed during tea time or for break fast. The technology of extrusion cooking allows this at high speed and at low production cost providing wide rage of shapes of the finished products. Extrusion cooking is a high temperature short time process which can modify vegetable protein and starches and produce the variety of foods with

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expansion, conversion of protein into easily digestible form. After extrusion cooking and drying the extrudate develops rigid structure and maintain porous structure.

The study was conducted with soybean and wheat flour with the objectives (a) to study the effect of blending ratio on product quality at different process parameters and (b) to compare the extrusion characteristics of defatted soyflour blending with that of full fat soyflour blends

The extrusion characteristics of legume-cereal blends have been studied for several raw materials like soybean, fababean, corn, potato, tapioca and sorghum etc. Patil et al(1992) studied the dry extrusion cooking for production of snacks with full fat soy rice blends of 30:70. The optimum moisture was found to be 12% giving highest puffing having bulk density of 266.3 kg/m^3 and water absorption index of 4.09. The product moisture content was 6% which avoided the need for drying. Patil et al (1992) also studied the defatted soyflour-sorghum flour blend in 30:70 proportion with a laboratory extruder to produce crispy snack food. Patil et al (1992) also conducted the studies on extrusion of various types of corn starches to see the effect of amylose content in the starch on expansion with laboratory extruder. Results indicated that high amylose content led to increased expansion and decreased product density. Kulkarni et al (1997) had used the Wenger X-5 laboratory extruder for production of snacks from corn, rice, wheat and potato at 10% blending of defatted soyflour (Fig.1). The expansion ratio ranged form 1 to 13 with lowest for potato and highest for corn starch.

Njoki and Faller, 2001 developed weaning food from plantain/soy/corn blend by extrusion cooking. The study was conducted at three levels of moisture content (22, 26 and 30 percent) and three levels of relative residence time (RRT :1, 0.75 and 0.6). They found that feed moisture content had greater effect on product attributes than RRT. Water absorption index reached a maximum (3.05) at feed moisture content of 26 per cent and decreased again as the moisture increased further. Water solubility index was not affected by RRT or feed moisture. Product discolouration decreased with decreasing feed moisture content, whereas trypsin inhibitor activity decreased with increasing feed moisture.

MATERIALS AND METHODS

The soybean (Punjab 1) and wheat (Lok 1) grown on the experimental farm of CIAE during 1997 was used in this study. Extrusion of soy-wheat blends was done on Wenger X-5 model (3 hp) laboratory extruder. The low moisture ingredient combined with water in a high speed blending section brings the material to 100 °C by application of steam. It is scaled down version of the commercial extruders developed by Wenger Inc. USA. The barrel of the extruder was built in modular or section design so that shorter and lower screws can be used with the same machine. The air locks and conical shaped screw provided discontinuities which disrupted flow patterns down the barrel for improved mixing. The diameter of the die was kept at 3.44 mm and L/D ratio was of 20:1. The moisture content of feed ranged between 15 to 25%. The temperature was varied from 80 to 100 °C. The details of the experimental design are given below :

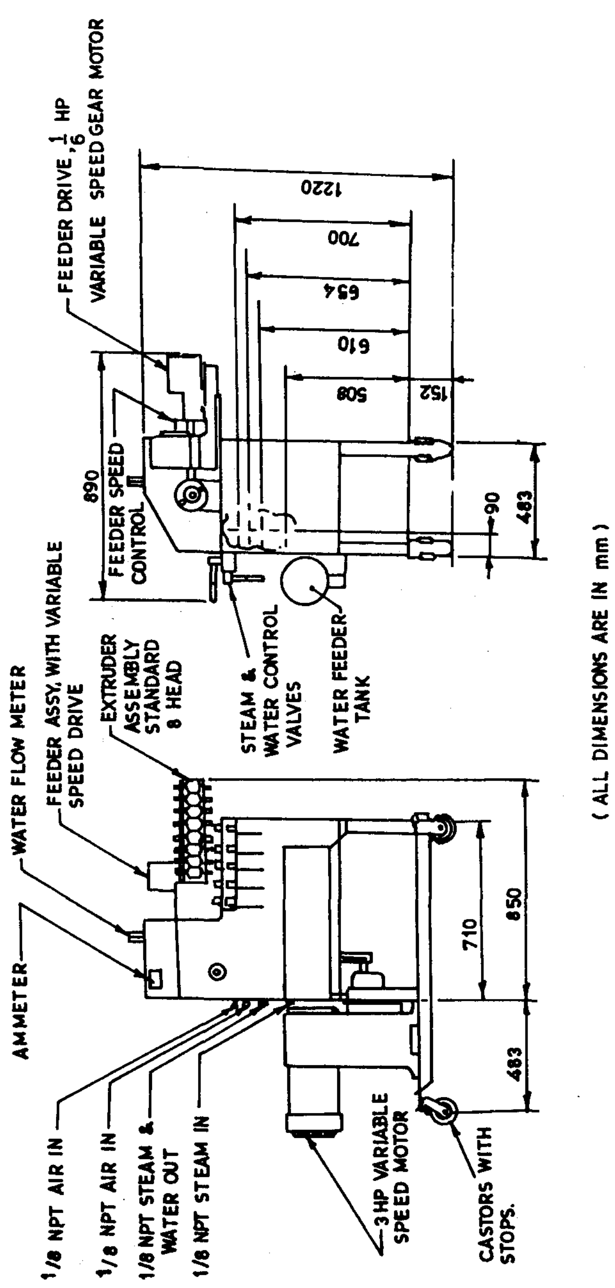

Fig. 1 Wenger lab extruder (Installed weight 275 kg)

Independent variables		
Parameters	Level(s)	Values
Percentage of full fat soyflour in blend, %	3	10,20,30
Cereals in blend	1	Wheat
Dough moisture content, % wb	3	15,20,25
Barrel temperature, °C	3	80,90,100
Screw speed, rpm	1	410
Die diameter, mm	1	3.44
Screw compression ratio	1	3 : 1
Feed rate, kg/h	1	15

Dependent variables

Mass flow rate, g/s	$\frac{\text{Wt. of sample collected, g}}{\text{time of collection, s}}$
Moisture content of extrudate, %	by exposing the extrudate at 105 °C for 18 hours in an air oven
Specific length, mm/g	$\frac{\text{length of specimen, mm}}{\text{weight of specimen, g}}$
Sectional expansion index	$\left[\frac{\text{Diameter of extrudate}}{\text{Diameter of the die}}\right]^2$
Longitudinal expansion index	$\frac{\delta d * (1 - Md)}{\delta e * (1 - ME)}$
Volumetric expansion index	$\frac{\delta d * (1 - Md)}{\delta E * (1 - ME)}$
Specific density	$\frac{\text{Mass of extrudate, g}}{\text{Volume of extrudate, cc}}$
Bulk density, g/cc	$\frac{\text{Wt. of tapped sample in 5 stages of 100 ml measuring clyinder, g}}{100}$
Water absorption index	$\frac{\text{Difference of wt. after water absorption, g}}{\text{initial weight of 10 g}} \times 100$

Where δd=density of melt taken at 1250 kg/m^3, δE=density of extrudate, kg/^{3}, Md=Moisture content of feed in decimal, wet basis, ME= moisture content of extrudate in decimal, wet basis

The soybean was dehulled, blanched and dried following the process developed at CIAE (Patil et al, 1987). The soyflour was obtained by grinding the processed soysplits in burr mill. The initial moisture contents of full fat soyflour and wheat flour were determined by standard air oven method at 106 °C for 18 hours. The moisture content of the soy wheat blends were adjusted to desired levels by adding calculated amount of water with an additional amount of 20% as allowance for evaporation loss during mixing. The moisture equilibration of the samples was done by keeping the blends in cold chamber at 4°C for 24 hours.

To test this hypothesis that expansion is better at low fat content using the commercially available defatted soyflour in place of full fat soyflour was used. Since 10% blending of full fat soyflour was found to be the best in the first set of experiment, for effective comparison the blending ratio of defatted soyflour was also kept at 10% level.

RESULTS AND DISCUSSION

Extrudate properties with FFSF blending

The consolidated results on the quality of the extrudate in terms of longitudinal expansion index, VEI, SEI, WI and densities are given in Table 1. It was found that expansion of the material was higher at higher extrusion temperatures. However at 90 °C, the operation was very consistent as the expansion of material was uniform. At 100 °C the expansion was disturbed due to frequent changes required in the control of steam over total length of

Table 1 Variation in properties of extrudate with barrel temperature and moisture content of raw material

% Soy in blend	m.c., wb of feed	Temp °C	Average dia of extrudate	m.c. of extrudate, % wb	Mass flow rate, g/s	Water absorption index	Specific density, g/cc	Specific length, mm/g	SEI	LEI	VEI
10	15	80	5.27	10.52	5.61	176	0.70	65.50	2.35	0.82	1.93
10	15	90	5.49	6.35	5.76	188	0.60	70.00	2.55	0.88	2.24
10	15	100	5.25	11.18	5.80	172	0.75	62.40	2.33	0.78	1.82
10	20	80	5.22	18.2	5.36	365	0.82	57.00	2.30	0.71	1.63
10	20	90	5.26	17.27	5.67	325	0.63	48.90	2.34	0.91	2.13
10	20	100	5.24	13.43	5.77	355	0.76	61.20	2.32	0.96	2.23
10	25	80	7.02	14.16	3.26	347	0.79	34.40	4.16	0.40	1.66
10	25	90	6.86	23.05	3.53	325	1.09	25.00	3.98	0.31	1.23
10	25	100	6.84	19.53	3.66	327	0.97	28.00	3.95	0.35	1.38
20	15	80	4.64	14.19	4.22	187	0.93	63.40	1.82	0.80	1.46
20	15	90	4.60	20.79	5.34	165	0.97	62.60	1.79	0.79	1.41
20	15	100	4.54	12.79	4.34	159	0.98	63.30	1.74	0.80	1.39
20	20	80	4.06	18.73	4.60	166	1.00	77.70	1.39	0.97	1.35
20	20	90	4.28	17.96	4.40	159	1.07	65.50	1.55	0.82	1.27
20	20	100	4.08	14.44	4.63	166	1.00	78.10	1.41	0.96	1.35
20	25	80	3.68	24.42	5.54	171	1.59	62.50	1.15	0.73	0.84
20	25	90	4.08	22.07	4.37	155	0.93	82.50	1.41	1.02	1.44
20	25	100	3.72	25.56	5.63	175	0.87	63.20	1.17	1.32	1.54
30	15	80	4.80	20.99	4.21	171	0.75	74.00	1.95	0.92	1.79
30	15	90	4.06	17.40	3.60	131	1.00	77.40	1.39	0.97	1.35
30	15	100	4.10	14.56	3.83	218	0.89	85.70	1.42	1.08	1.53
30	20	80	4.82	16.74	4.37	174	0.79	69.70	1.96	0.87	1.71
30	20	90	4.26	18.43	4.10	142	0.98	71.70	1.53	0.89	1.36
30	20	100	4.76	25.87	3.91	137	0.77	73.10	1.92	0.91	1.75
30	25	80	5.84	25.80	4.14	159	0.99	39.30	2.88	0.47	1.35
30	25	90	6.26	29.06	4.00	164	0.94	6.84	3.31	0.43	1.42
30	25	100	4.48	24.04	4.20	178	0.90	3.46	1.70	0.87	1.48

barrel to maintain the extruder going. The effect of temperature was predominant at 10% blending of full fat soyflour. At higher levels of full fat soyflour the expansion was not appreciable even at high temperatures. This reflected in the data on the average diameter of extrudate and various expansion indices. The variations in these properties as effect of barrel temperature for various proportions and feed moisture content are given in Table 1. The mathematical model for estimated values of these parameters at different temperatures were of the form of second degree polynomial equation. From the Figures 2 to 4, it can be seen that maximum expansion of the product is achieved at 10% blending of full fat soy flour at feed moisture content of 25% and at all the three temperatures. The extrudate was ground to see the water absorption capacity which is an important criteria for making its use as an ingredient in weaning foods. The graph showing the water absorption index as affect of barrel temperature is shown in Fig. 5. For different feed moisture content and at 10% full fat soyflour blends, WAI was highest, with the value of over 325%. The overall observation was that lower the level of full fat soyflour blend in the sample, better was the expansion and WAI of the extrudate. The reason for this may be that the soybean contains 18-20% fat

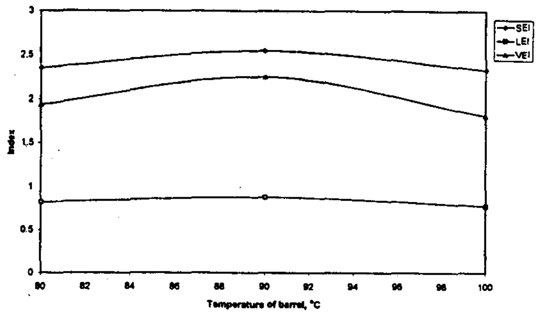

Fig. 2 Variation in expansion indices with barrel temperature at 15% m.c and 10%

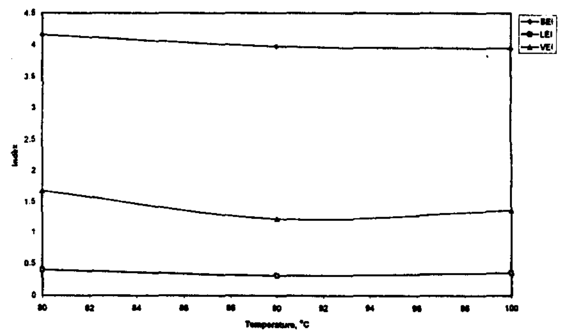

Fig. 4 Variation in expansion indices with barrel temperature at 25% m.c. and 10%

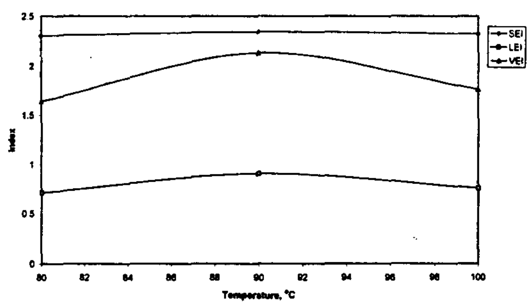

Fig. 3 Variation in expansion indices with barrel temperature at 20% m.c. and 10%

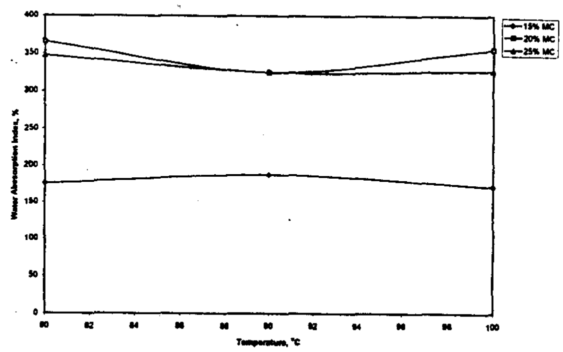

Fig. 5 Variation in water absorption index with temperature for 10% FFSF blending

which is available in full fat soyflour. Hence, the fat content of the blend at 30% FFSF was at 5.8% where as at 10% it came down to 3.4%. As reported by the other researchers the effect of fat per cent in reducing the expansion (Perks, 1979) of the extrudate was confirmed in the present experiment. Hence the optimum condition for production of snacks with FFSF and wheat flour were 10% blending, 25% moisture content and 90 °C temperature.

Based on the results it could be concluded that starch, protein mixtures could expand significantly through extrusion cooking process if the fat content is lower.

Extrudate properties with defatted soyflour blending

The average values of the replicated data for this set of experiment are given in Table 2. The effect of temperature on extrusion characteristics are also given Fig. 6. The data followed second order polynomial relationship between independent and dependent variables. It was observed that the diameter of the extrudate was much higher in these experiments as compared to using the full fat soyflour. The diameter of the extrudate ranged between 9.34 to 10.38 mm, SEI ranged from 6.94 to 9.11, VEI ranged from 2.85 to 4.32 and WAI ranged from 352 to 552% (Fig. 7).

The moisture content of the feed ranged from 15 to 25%. It was observed that similar to earlier experiments the expansion characteristics were better at higher temperatures. However, smooth and uniform results were obtained at 90 °C. It was seen that the best expansion was achieved at 15% moisture content, 10% DFSF blending and 90 °C temperature.

The effect of feed moisture content on expansion of extrudate can be visualized as that of heating of moisture inside the barrel which increases the vapour pressure and sudden release of this pressure through the die, lets it evaporate and escape causing porous structure, expansion and drying of the extrudate. The optimum level of moisture content is therefore essential so that the expanded extrudate is stable. This might be the reason why the expa-

Table 2 Variation in properties of extrudate with barrel temperature and moisture content of raw material(DFSF) on the basis of summary of all the observations and results obtained

% Soy in blend	m.c., wb of feed	Temp °C	Average dia of extrudate	m.c. of extrudate, % wb	Mass flow rate, g/s	Water absorption index	Specific density, g/cc	Specific length, mm/g	SEI	LEI	VEI
10	15	80	10.34	13.65	3.86	544	0.36	33.50	9.04	0.42	3.82
10	15	90	10.20	14.24	3.70	552	0.38	31.90	8.79	0.41	3.61
10	15	100	10.38	14.62	4.36	552	0.31	39.50	9.11	0.47	4.32
10	20	80	10.08	16.56	3.96	463	0.39	32.30	8.59	0.40	3.45
10	20	90	10.22	21.53	3.93	476	0.39	31.60	8.83	0.39	3.45
10	20	100	10.10	19.43	9.83	502	0.39	32.00	8.62	0.40	3.41
10	25	80	9.06	22.13	3.56	352	0.47	31.70	6.94	0.41	2.85
10	25	90	9.50	23.50	3.86	390	0.42	31.10	7.63	0.42	3.19
10	25	100	9.34	21.92	3.52	382	0.45	33.10	7.38	0.40	2.98

SEI - Sectional Expansion Index, LEI - Longitudinal expansion Index, VEI - Volumetric expansion Index

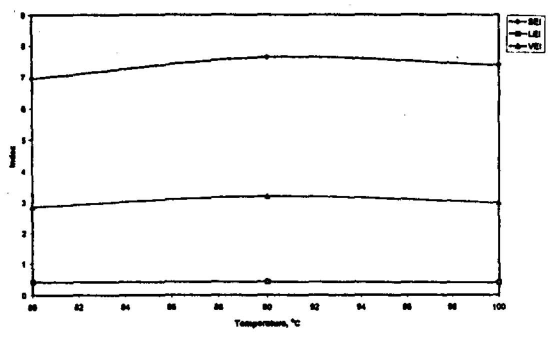

Fig. 6 Variation in expansion indices with barrel temperature at 25% m.c. and 10% DFSF blending

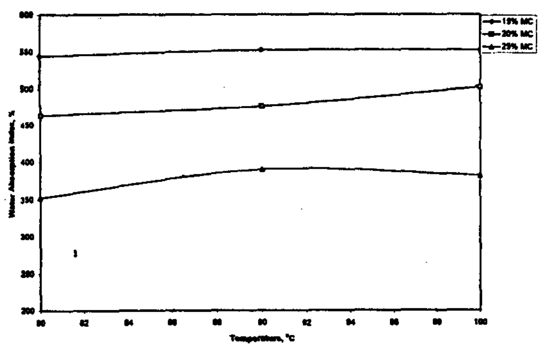

Fig. 7 Variation in water absorption index with barrel temperature for 10% DFSF blending

ssion was higher at 15% moisture content compared to 25% moisture content where the material was wet and expansion was short-lived and unstable. However, such kind of extrudate (high moisture and partially expanded) has scope for further expansion if deep fried. The extrudate obtained from this experiment was further ground to see the water absorption capacity. The results indicated that at all levels of moisture content and at all temperatures the WAI was higher than 325% as obtained in case of FFSF blending. However, the best WAI of about 550% was achieved at 15% moisture content and 90 °C melt (metering section) temperatures.

CONCLUSIONS

From the studies following conclusions could be drawn :

1. The fat content was important factor which was detrimental for the expansion of the extrudate.
2. For blending with full fat soyflour, the optimum conditions were 25% moisture content, 90 °C temperature and blending of FFSF at 10% level,
3. For blending with defatted soyflour, the optimum conditions were 15% moisture content, 90 °C temperature and blending of DFSF at 10% level.

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