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Research Article

Nutritional Evaluation and Glycemic Response of Extruded Products Developed From Cereal Pulse Blends

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Abstract

This study developed extruded ready to eat snack, incorporating oat, barley, soybean and chickpea flours into the whole-wheat flour to see its sensory characteristics, proximate composition and glycemic index (GI). Ten flour combinations were prepared from these flours, whole-wheat flour was kept as control. The sensory evaluation revealed that blend prepared from whole-wheat, barley and chickpea flour (50:25:25) was highly acceptable. Results of proximate analysis showed significantly ($p \leq 0.05$) higher fibre, protein and significantly ($p \leq 0.05$) lower carbohydrate content in the developed products. Product prepared from this blend had significantly ($p \leq 0.05$) lower GI that is 48.7 whereas for control product it was 69.68. Findings showed that increased protein and crude fibre content and decreased carbohydrates resulted in significant ($p \leq 0.05$) reduction in the GI of the developed product. Barley and chickpea flours could be incorporated up to a level of 25 % each in whole-wheat flour to develop extruded snack of acceptable sensory properties with low GI.

Keywords: Extrusion; Glycemic index; Type 2 diabetes; Pulses

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Introduction

Type 2 diabetes is a global health and economic burden, which is increasing year by year. As we know lifestyle changes, and increased intake of refined carbohydrate are the main factors responsible for the upward trend in the prevalence of obesity and type 2 diabetes. The dramatic increase in the incidence of obesity and diabetes in recent decades has stimulated researchers to investigate potential dietary strategies to prevent the development or progression of these conditions. Developing products using cereal/legume blend can play very important role in reducing hunger, malnutrition and in improving nutritional profile of people in developing countries. Cereals are the main staple food with wide range of acceptability. Cereals like oat and barley are very nutrient rich like barley contains nutrients like carbohydrates, low fat, protein, minerals, vitamin E (tocopherol, tocotrienol), antioxidants (polyphenolic compounds) and fibre (i.e. Beta glucans). Beta-glucan is the main bioactive component present in oat and barley, which control blood glucose, cholesterol, and body weight [1]. United States Food and Drug Administration has recommended 3 g of Beta-glucan from oat and barley to reduce the risk of coronary heart disease [2].

Regarding the legumes, chickpea is the second most widely grown legume. The crop is considered important for food security aspect because of its capacity to fix nitrogen [3]. It is a good source of carbohydrate and protein. Its protein quality can be further improved significantly by adding cereals to the diet along with legumes. Chickpea is also a good source of important unsaturated fatty acids like linoleic and oleic acid.

Soybean is known as super legume of the twentieth-century. Soybean contains omega 3 and omega 6 fatty acids such as linoleic acid and alpha-linolenic acid. It contains all essential amino acid. It contains protein, fat, carbohydrate, vitamins, and minerals. Besides these, it contains isoflavones, which are the main active components which exhibit numerous health benefits. Moreover, they also contain phytosterols, which are similar to cholesterol and inhibit the absorption and maintains the level of cholesterol in the blood. Protease inhibitors are anti-nutritional factors but processing of soybean decreases its concentration [4].

There is a need to develop foods, which have good health effects and preventive and managerial role in various diseases. Extruded snack foods prepared using cereal-pulse mixture are accepted by consumers due to good expansion characteristics and its texture.

Extrusion is a short temperature, short-time cooking process in which starch and protein containing food materials are moistened, plasticized and cooked using moisture, pressure, temperature and mechanical shear [5, 6]. Along with this, extrusion cooking also denatures undesirable enzymes and inactivates various anti-nutritional factors (trypsin inhibitors, haemagglutinins) [7, 8].

These days low cost extruded products based on cereals and pulses are seeking the attention of researchers in addressing diabetes and other metabolic disorders. The present study focuses towards the development of various blends using cereals and legumes to develop ready to eat extruded snack and assessing their sensory, nutritional and glycemic properties which would lead to improvement in the glycemic control in patients with diabetes mellitus.

Material and Methods

Materials

The whole-wheat flour and functional food ingredients like oat, barley, soybean and chickpea flour were collected at one lot and stored in airtight plastic containers and used for the entire study.

Samples preparation

Extruded products were prepared from the blends of different flours of cereals and legumes that are oats, barley, soybean and chickpea flour. These have been reported to have low glycemic index (GI) [9]. Ten blends were prepared using the above grain flours in different proportions by incorporating in whole-wheat flour. The proportion of ingredients in each blend to be used to prepare extruded snack is given in **Table 1**.

Table 1 Combinations of flours to prepare extruded snacks

	Whole Wheat flour (g/100g)	**Oat flour (g/100g)**	**Soy flour (g/100g)**
Control	100	-	-
Blend 1	25	50	25
Blend 2	50	25	25
Blend 3	75	-	25
		Barley flour(g/100g)	
Blend 4	25	50	25
Blend 5	50	25	25
		Oat flour (g/100g)	**Chickpea flour (g/100g)**
Blend 6	25	50	25
Blend 7	50	25	25
Blend 8	75	-	25
		Barley flour (g/100g)	
Blend 9	25	50	25
Blend 10	50	25	25

Extrudate preparation

Extrusion experiments were performed on a co-rotating intermeshing twin-screw extruder (Clextral, Firminy, France). Extrudates were dried and then packed in polythene bags. The ingredients for control sample were whole-wheat flour and salt. For the test samples the combination of whole wheat flour, oat, barley, soy bean and chickpea flours were used.

Sensory evaluation of extruded products

A panel of 15 subjects consisted of staff and postgraduate students of department of Food and Nutrition, Punjab Agricultural University, Ludhiana, performed the sensory evaluation of the extruded snacks from different blends. The panelists were naïve to the study objectives. Each product was prepared and tested thrice. The samples were coded to avoid biasness. The panelists scored the samples for different attributes using a 9-point Hedonic Rating Scale. They were provided with a glass of water and instructed to rinse and swallow water between samples. The highly acceptable products along with control were weighed, homogenized and oven dried at 60^{o}C. Dried samples were stored in airtight plastic bags for further analysis.

Nutritional analysis

Moisture, total ash, crude protein, crude fibre and crude fat were assessed using standard methods [10]. The content of carbohydrates was calculated by subtracting the sum of moisture, protein, ash, fat and crude fibre from 100. The energy content was calculated by factorial method.

$$\text{Energy (Kcal)} = (4\times\text{protein}) + (9\times\text{fat}) + (4\times\text{carbohydrate})$$

Assessment of glycemic index of the developed products

Glycemic index of the products was determined for the two selected extrudate samples, one test sample (whole-wheat flour, barley and chickpea, 50:25:25), and one control sample (100% whole-wheat flour) through a scientific approach of determining the glucose response in healthy subjects through meal tolerance test. The subjects for the present work were selected from department of Food and Nutrition, Punjab Agricultural University, Ludhiana, in the age group of 20-40 years (n=10). The glycemic response was analyzed by taking one drop of blood on glucose test strip using Glucometer (PRODIGY® Pocket).

Glucose tolerance test

The subjects were asked to come for blood glucose test after overnight fast. On first occasion, 50 g carbohydrate in the form of glucose (reference) and on subsequent occasion test food providing 50 g available carbohydrate was given to the subjects. Fasting blood glucose was checked. The volunteers were asked to consume test product within 10-12 minutes. The blood samples were drawn and checked after every half an hour interval for two hours for the postprandial level. The blood glucose response curves were plotted for oral glucose tolerance test, test product and control product.

The glycemic index was calculated using the formula given by Wolever and Jenkins [11].

$$\text{Glycemic index} = \frac{\text{Area under glucose curve after test meal} \times 100}{\text{Area under glucose curve after reference meal}}$$

Glycemic load

The Glycemic load (GL) was determined by the method of Salmeron et al [12]. The GL was calculated based on the quantity of the recipe per serving and the respective available carbohydrate content. The following formula was used:

$$\text{Glycemic load} = \text{Available carbohydrates (g) x GI /100}$$

Statistical analysis

The results of sensory evaluation, proximate analysis and glycemic index were statistically analyzed using analysis of variance technique with the aid of Microsoft statistical analysis tool pack. The limit of probability fixed for the test of significance was p=0.05. Wherever the significant results were obtained, the critical difference was calculated.

Results

Sensory evaluation of extrudates

The mean scores of colour, appearance, flavor, texture, taste and overall acceptability of developed blends ranged from 4.92 to 7.74, 4.02 to 7.91, 3.95 to 7.80, 3.98 to 7.92, 4.36 to 7.89 and 4.34 to 7.81 in the extruded products using different blends (**Table 2**).

Maximum scores for colour, flavor, texture, taste and overall acceptability were found in blend 8 containing whole wheat flour and chickpea flour (75 and 25%) whereas maximum scores for appearance were in blend 10 (wheat flour, barley flour and chickpea flour 50+25+25).

There was no significant difference in the scores for colour of blend 8 and 10 when compared with control whereas all other blends had significantly lower ($p<0.05$) scores. But in texture, the scores were significantly lower in all the blends except for the blend 8.

Table 2 Sensory scores of ten blends of extrudates

Blends	Flour combinations	Amount (g/100g)	Colour	Appearance	Flavor	Texture feel	Taste	Overall acceptability
Blend 1	Whole wheat flour+Oat+Soybean	25+50+25	5.52±1.84	5.57±1.55	4.84±1.75	5.36±1.08	5.05±1.76	5.33±1.03
Blend 2	Whole wheat flour+Oat+Soybean	50+25+25	4.92±1.72	4.02±1.52	3.95±1.68	3.98±1.02	4.36±1.91	4.34±0.97
Blend 3	Whole wheat flour+Soybean	75+25	5.56±1.57	5.25±1.67	4.89±1.39	4.5±1.43	4.83±1.70	5.00±1.02
Blend 4	Whole wheat flour+Barley+Soybean	25+50+25	6.20±1.37	5.52±1.77	5.39±1.48	5.07±1.07	5.50±1.85	5.55±0.82
Blend 5	Whole wheat flour+Barley+Soybean	50+25+25	6.00±1.57	5.66±1.48	5.55±1.07	5.34±1.01	5.68±1.57	5.67±0.76
Blend 6	Whole wheat flour+Oat+Chickpea	25+50+25	6.55±1.21	6.59±1.40	6.70±1.34	6.66±1.33	6.70±1.25	6.60±0.98
Blend 7	Whole wheat flour+Oat+Chickpea	50+25+25	7.18±0.97	7.09±1.05	6.95±1.28	7.05±1.08	7.09±1.16	7.06±0.88
Blend 8	Whole wheat flour+Chickpea	75+25	7.74±0.94	7.74±0.85	7.80±0.95	7.92±0.86	7.89±0.91	7.81±0.69
Blend 9	Wholewheat flour+Barley+Chickpea	25+50+25	7.43±0.79	7.75±0.89	7.64±0.72	7.45±0.73	7.59±0.84	7.57±0.53
Blend 10	Whole wheat flour+Barley+Chickpea	50+25+25	7.70±0.85	7.91±0.71	7.77±0.71	7.68±0.80	7.73±0.69	7.76±0.55
Control	Whole wheat flour	100	7.89±0.62	7.96±0.46	7.92±0.69	8.03±0.64	8.06±0.64	7.98±0.45
CD at 5 %			0.34	0.34	0.33	0.28	0.37	0.22

Values are presented as Mean± SD
Key to scores: 9= Like extremely, 8= Like very much, 7= Like moderately, 6= Like slightly, 5= Neither like or nor dislike, 4= Dislike slightly, 3= Dislike moderately, 2= Dislike very much, 1= Dislike extremely.

The extruded product prepared from blend 8 comprising of whole-wheat and chickpea flour (75:25) and blend 10 comprising of whole-wheat flour, barley and chickpea flour (50:25:25) had higher overall acceptability scores than other blends and no significant difference was there when compared with control, so were selected for proximate analysis.

Nutritional evaluation of extrudates

The moisture content in the extruded product varies from 2.30 to 2.40g/100g with maximum content in blend 8 and minimum in blend 10. The test samples had significantly more moisture content when compared with the control. No significant difference was found among the test samples.

The ash content of the samples ranged from 3.25 to 3.59g/100g. The test samples had significantly higher ash content when compared with the control. Within test samples no significant difference was observed. The crude fibre content ranged from 1.93 to 2.25g/100g with maximum content in blend 8 and minimum in blend 10. The fibre content was significantly higher in all the test samples when compared with the control.

The fat content was more in the test samples when compared with the control. The maximum content was in blend 8 and minimum in blend 10. The crude protein content was significantly higher in the test samples when compared with the control. The available carbohydrate content in the test blends ranged from 75.46 to 76.8 g/100g and it was significantly lower than the control sample.

The energy content in the extruded product were 375 and 374 Kcal /100 g in the blend 8 and blend 10. On the fresh weight basis, the fat, protein and fibre content were higher in the test blends than control.

The findings of proximate analysis concluded that supplementation of whole-wheat flour with barley and chickpea flour significantly reduced carbohydrates and increased fibre, fat and protein contents. Moreover these blends also had higher overall acceptability.

Glycemic index

The fasting blood glucose ranged from 67 to 112 in case of reference (glucose). The rise in blood glucose after half an hour, 1 hour, 1 hour 30 minutes and 2 hours ranged from 90 to 162, 96 to142, 96 to127 and 83 to 119 in case of reference glucose. In case of control extrudates, the rise in blood glucose after half an hour, 1 hour, 1 hour 30 minutes and 2 hour ranged from 93 to 144, 86 to 134, 87 to 139 and 82 to 98 mg/dl and for test extrudates, blend 10 which was found highly acceptable, comprising of wheat flour, barley and chickpea flour (50:25:25), the range was 97 to 126, 81 to 124, 84 to 109, 74 to 98 mg/dl (**Figure 1**). The glycemic index came out to be 48.77, which was lower than the control (69.68).

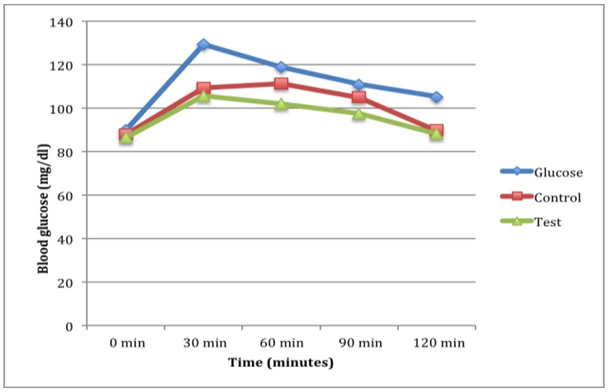

Figure 1 Mean blood glucose curves after consumption of glucose, control and test extrudates containing 50g carbohydrates

Table 4 and 5 displays that the mean GI and GL of the supplemented product were significantly lower as compared to the control samples. Anything with GI value of 70 or more is a high GI food, moderate GI foods ranged from 56 to 69 and low GI foods have scores from 0 to 55 [9]. According to this classification of WHO, the extrudates comprising of whole-wheat, barley and chickpea flour (50:25:25) with 48.77 glycemic index, fall under the low GI foods category with a decrease of 81.4 % when compared with control.

Table 3 Proximate composition of most acceptable blends of extrudates (g/100g on dry weight basis)

Blends	Flour combinations	Amount (g/100g)	Moisture	Total Ash	Crude Fiber	Crude Fat	Crude Protein	Carbohydrate	Energy (kcal)
Blend 8	Whole-wheat flour + Chickpea	75 + 25	2.40 ± 0.33	3.25 ± 0.09	2.25 ± 0.39	1.35 ± 0.04	15.31 ± 0.16	75.61 ± 0.03	375.83
Blend 10	Whole-wheat flour + Barley + Chickpea	50 + 25 + 25	2.30 ± 0.19	3.59 ± 0.20	1.93 ± 0.22	1.11 ± 0.38	14.27 ± 0.14	76.80 ± 0.05	374.27
Control	Whole-wheat flour	100	1.59 ± 0.09	4.47 ± 0.17	0.75 ± 0.07	0.37 ± 0.01	11.68 ± 0.09	81.13 ± 0.40	374.57
CD at 5%			0.60	0.34	0.69	0.45	0.34	1.41	

Blend 8: whole wheat flour, chickpea flour (75+25), Blend 10: whole wheat flour, barley flour, chickpea flour (50+25+25), control: whole wheat flour

Table 4 Glycemic index of control and test extrudates

Product	Quantity administered (grams)	GI	GI Category
Control sample (wheat flour)	64	69.68	Moderate
Test sample (whole-wheat, barley and chickpea flour, 50:25:25)	67.5	48.77	Low

Table 5 Glycemic load of extrudates

Product	GI	Normal serving size (g)	Available carbo-hydrate (g)	Glycemic load (GL)
Extrudates (control)	69.68	25	20	13.94
Extrudates(test)	48.77	25	19	9.26

Increase in protein and crude fibre and decrease in carbohydrates were responsible for lowering the glycemic value of the developed products. The developed products can be included in the regular diets of diabetics for the management of diabetes and to avoid further secondary complications.

Discussion

Scores of overall acceptability showed that the blends containing soy flour and oat flour had lower acceptability as compared to barley and chickpea containing blends. This may be due to the presence of native lipids. Wheat has typical low fat (2%) [13], Oats may contain up to 10 % oil. Oilseeds such as soybean may contain up to 50 % oil by total seed weight. Soybean flour used in the study was full fat. Lipid levels over 5-6 % impair extruder performance [14]. Product expansion is often poor because insufficient pressure is developed during extrusion. This might be the reason for the poor acceptability of oat and soybean flour containing blends.

Sensory scores were in accordance with the findings of Gupta et al [15], where sensory scores of ready-to-eat extruded food with blends of Indian barley and rice having barley flour content (10-30%.) resulted in an acceptable product. The crude protein content in the test samples was higher as compared to control ranging from 14.27 and 15.31g/100gm. Similar results were found in a study of low-cost extruded products based on cereals and pulses [16]. Increase in protein content was due to the addition of pulses. Crude fibre content of the test samples ranged from 1.93- 2.25, which was also near to the results of the same study, which showed the crude fibre content, ranging from 2.70 to 2.89. Values of energy content were also in accordance to the same study [16].

Another study, which included wild legumes in extruded products based on whole corn and brown rice, showed similar trend in fat content and carbohydrates. Ash content in whole-wheat flour, chickpea and barley containing blends increased with the addition of legumes [17]. Carbohydrates content in both the test samples diminished with the addition of chickpea flour in the test samples as compared to control.

Lobato et al [18] used oat bran and soy flour in extruded products and moisture content was found to be 2.5g/100gm. Moisture content in the test samples was higher than the control because fibre and ß-glucan have better water binding capacity [19]. There was decrease in the glycemic index of extruded products containing whole wheat, barley and chickpea flour (50:25:25). ß-glucan is the predominant components of cell walls of cereal grains such as barley and oats. The level of ß-glucan in barley varies from 5-11%, usually range from 2-6 % dry weight [20]. These major fibre constituents of barley have shown implications in reducing the glycemic index. A sharp decline in the postprandial blood glucose level was observed upon consumption of oat porridge enriched with isolated ß-glucan [20]. Dietary fibre also inhibits starch digestibility by increasing the viscosity of intestinal contents and thereby slowing the absorption of carbohydrates from the food [21].

ß-glucan from oat could increase viscosity of dough and reduce glycemic response [22]. Heat treatment given to barley flour inactivate endogenous ß-glucanases so, high molecular weight is retained [23] and consumption of high molecular weight ß-glucan has been shown to increase viscosity in the gut and slow absorption of glucose, resulting in reduction of post prandial glycemic response [24-26].

The lowering of glycemic index can be attributed to the addition of legumes which contains 5-10 % more amylose compared to cereal grains and this amylose is more resistant to digestion. With the incorporation of legumes, the protein content had increased and higher amount of protein may physically encapsulate starch, preventing the enzyme access [27]. Casiraghi et al [28] observed the effect of consumption of crackers and cookies made from barley flour enriched with ß-glucan in comparison with similar products made from wheat flour on fasting and postprandial glucose and found glycemic index values as 78, 81, 49 and 34 for whole wheat crackers, whole wheat cookies, barley crackers and barley cookies, respectively.

Conclusion

This article describes a study which was aimed to develop low GI, ready to eat snack food, incorporating oat, barley, soybean and chickpea flours into the whole-wheat flour, to evaluate sensory characteristics, nutritional composition and glycemic index. From sensory evaluation it was found that blend 10 prepared from whole-wheat, barley and chickpea flour (50:25:25) was highly acceptable. Proximate analysis demonstrated significantly higher fibre, higher protein and lower carbohydrate content in blend 10. GI of the product came out 48.7 so it can be a good ready to eat snack with lower GI for diabetic patients.

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