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Effect of Some Extruder Variables on Physico-chemical Properties of Extruded Rice–Legume Blends*

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ABSTRACT

Jaya rice flour was blended with four legume flours, i.e. bengal gram, black gram, green gram and soybean, in the ratio of 75:25, respectively. Each blend was extruded in a Wenger X-5 extruder using three feed rates (9·2, 15·2 and 27·2 kg/h) and two extruder exit temperatures (60° and 95°C ± 2°C) through a $\frac{1}{8}$ in die. The expansion ratio of all the extruded products increased and density decreased with the increase in extruder temperature, irrespective of feed rate. Incorporation of different legume flours with rice flour increased the crispness and decreased breaking strength of the product. The magnitude of water solubility index (WSI) increased perceptibly with increased temperature of extruder. Higher gelatinization occurred in rice–gram blends at higher temperatures and lower feed rate with a simultaneous increase in reducing and non-reducing sugars and a decrease in water-soluble proteins. In general, the extruded products obtained at 95°C with 27·2 kg/h feed rate were adjudged superior in quality.

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INTRODUCTION

The advent of extrusion technology has allowed food manufacturers to provide a wide range of shaped, precooked texturized foods. Tribelhorn & Harper (1980) emphasized the importance of extrusion cooking over conventional cooking methods because of versatility, efficiency and economy of space and labour. The extrusion technology is being used to process corn/rice along with soybean or other protein sources. Cumming *et al.* (1972) studied the effect of extrusion temperature on product characteristics using defatted soy flour. Taranto *et al.* (1975) investigated the effect of feed rate, screw speed and barrel temperature on extruded product characteristics but using defatted glandless cotton seed meal.

Several workers (Smith, 1979; Corbin *et al.*, 1972; Maurice & Stanley 1978; Olkku & Vainioppa, 1979; Koguchi *et al.*, 1982; Chauhan & Bains, 1985*a,b*; Mosqueda *et al.*, 1986) have applied extrusion technology to process different raw materials and have studied the effect of process variables on the product characteristics. However, information on the extrusion cooking of rice–legume blends is limited and therefore the present study was undertaken.

MATERIALS AND METHODS

Materials

Samples of raw milled Jaya rice and dehulled legumes—bengal gram (*Cicer arietinum*) green gram (*Vigna radiatus*) and black gram (*Vigna mungo*)—were obtained from the local market, the dehulled soybean being procured from the Department of Food Science and Technology, Pantnagar University. Raw milled Jaya rice and different dehulled legumes were ground separately in a pin mill to pass through 80 mesh. Blends of rice and legume flours were prepared by mixing 75 parts of rice flour with 25 parts of legume flours individually using a planetary mixer.

Extrusion processing

Each blend was extruded in a Wenger X-5 using three feed rates (9·2, 15·2 and 27·2 kg/h) and two extruder exit temperatures (60° and 95° ± 2°C) through $\frac{1}{8}$ in die with a water flow rate of 6·8 litres/h. The temperature of product at the exit was measured using a thermocouple inserted in a breaker plate, connecting the other side of the thermocouple to a potentiometer. The extruded products were dried to a moisture content of 5–6% in a tray dryer at 50°C. The products were packed and sealed properly in polyethylene bags until used for analysis.

Analysis

Physical characteristics

Expansion ratio density, water absorption index (WAI) and water solubility index (WSI) were measured by the method of Chiang & Johnson (1977).

Texture

The breaking strength and fracturability were measured using a universal Instron with the following settings:

Chart speed	20 cm/min
Full scale load	20 kg (changed to 50 kg in hard samples)
Cross head speed	5 cm/min
Deformation	3 mm

Chemical analysis

Moisture, protein, fat, ash and water-soluble proteins were estimated using standard methods of the AACC (1976). Amylose content was determined by the method of Juliano (1971).

The extent of gelatinization, i.e. occurring during extrusion processing, was measured by using the AACC (1976) method for the determination of susceptibility of starch to enzymatic digestion with fungal alpha amylase.

Reducing and non-reducing sugars

The AACC (1976) potassium ferricyanide method was followed. Reducing sugars values were expressed as maltose and non-reducing sugars as sucrose.

All the analyses were carried out in duplicate. The average values are reported and the results are expressed on a moisture-free basis.

Sensory evaluation

All the samples of extruded products were presented to a laboratory panel for sensory evaluation as a snack. A hedonic scale of 1–9 points was used for evaluating the samples.

RESULTS AND DISCUSSION

Full fat soy flour had the highest protein, fat, and ash contents, i.e. 45·7, 20·9 and 7·3%, respectively and the lowest amylose content, i.e. 0·4%. Protein

TABLE 1
Water Absorption Index (WAI), Water-Solubility Index (WSI), Gelatinized Starch (GS), Sugars and Water Soluble Proteins (WSP) of Dehulled Legume Flours

Legume/rice	*Water absorption index (g sediment/ g dry matter)*	*Water-solubility index (dry basis) (%)*	*Gelatinized starch (%)*	*Reducing sugar as maltose (%)*	*Non-reducing sugar as sucrose (%)*	*Water soluble proteins (N × 6·25) (%)*
Bengal gram	2·4	25·0	1·1	0·67	1·8	14·4
Black gram	1·8	20·0	1·5	0·76	3·3	14·7
Green gram	1·9	23·0	1·7	0·81	3·4	20·7
Full fat soy flour	3·8	30·0	0·4	1·19	2·5	23·0
Rice (Jaya)	2·4	0·7	6·3	0·16	0·27	0·66

contents of other legumes varied from 25·7% to 29·0%. The amylose contents of other legumes were much higher than soybean.

Table 1 summarizes the physico-chemical characteristics of unprocessed rice and legume flours. Full fat soy flour had the highest water absorption index (WAI) and black gram flour had the lowest. The water solubility index (WSI) ranged from 20% to 30% for various legume flours as compared to 0·7% of rice flour. Damaged starch content of legume flours was considerably lower than that of rice. On the other hand, the legume flours exhibited much higher values for reducing and non-reducing sugars. There was a wide variation in water-soluble protein contents.

Effect of extruder exit temperature and feed rate on physical characteristics

Expansion ratio and density

The expansion ratio of almost all the products increased with the increase in extruder exit temperature and density decreased irrespective of feed rate. The rice–bengal gram and rice–green gram extruded products showed the highest value of 2·5 for expansion ratio at an EET of 95°C with feed rate of 27·2 kg/h (Table 2). The lowest expansion was observed in the rice-full fat soy flour product but the lowest density was also exhibited by this product. This might be attributed to the higher fat content in the rice-full fat soy flour blend as compared to other blends. Faubion & Hoseney (1980) observed the same effect of fat content on the expansion ratio and density of extruded products. Similar effects of extrusion temperature on the expansion ratio were reported by Park (1976), Seiler (1976) and Peri *et al.* (1980).

Fracturability and breaking strength

Incorporation of different legume flours with rice flour decreased the fracturability and breaking strength of the extruded products remarkably as

TABLE 2
Effect of Processing Variables on the Expansion Ratio (ER) and Density of Extruded Rice–Legume Blends (75:25)

Process variables		*Rice–legume blends*[a]							
Feed rate (kg/h)	*Extrusion exit temperature (°C)*	*D*		*E*		*F*		*G*	
		Expansion ratio	*Density (g/ml)*	*Expansion ratio*	*Density (g/ml)*	*Expansion ratio*	*Density (g/ml)*	*Expansion ratio*	*Density (g/ml)*
9·2	60	2·3	0·45	1·9	0·46	—	—	2·0	0·43
9·2	95	2·5	0·42	2·2	0·48	—	—	2·1	0·42
15·2	60	1·7	0·79	1·6	0·95	1·7	0·62	1·7	0·78
15·2	95	1·8	0·77	1·8	0·78	2·3	0·42	1·8	0·70
27·2	60	1·8	0·68	1·8	0·76	1·9	0·45	1·8	0·54
27·2	95	2·4	0·43	0·34	0·44	2·5	0·43	1·9	0·43

[a] Blends: D, Rice + bengal gram; E, Rice + black gram; F, Rice + green gram; G, Rice + full fat soy flour.

compared to rice alone. The decrease in fracturability (increase in crispness) and breaking strength ranged from 43·2% to 79·3% and 33·5% to 56·1%, respectively, on the basis of the corresponding values of extruded rice product (Table 3). This decrease was ascribed to the interspacing of denatured protein matrix in the gelatinized starch system, disrupting hydrogen bonding between hydroxyl groups of starch. Faubion & Hoseney (1980) reported that the textural strength at and above 11% protein declined.

Water solubility index and water absorption index

The magnitude of water solubility index increased perceptibly with the increased temperature of extrusion, whereas the differences for water absorption among various extruded blends were not so conspicuous. At a feed rate of 27·2 kg/h and an EET of 95°C, the WSI of the rice-full fat soy

TABLE 3
Fracturability and Breaking Strength of Rice–Legume Blends (75:25) Extruded at a Feed Rate of 27·2 kg/h and an Extrusion Exit Temperature of 95°C

Blend	*Fracturability (kg)*	*Breaking strength (kg)*
Rice (Control)	15·5	23·0
D Rice + bengal gram	7·4	10·1
E Rice + black gram	8·8	15·3
F Rice + green gram	5·0	10·5
G Rice + full fat soy flour	3·2	14·0

flour product was 9·3% as compared to 13·8, 13·2 and 13·0% for the extruded rice–bengal gram, rice–black gram and rice–green gram products, respectively (Table 4). Mercier & Feillet (1975), Chiang (1975) and Kim & Rottier (1980) also reported that the values of WSI and WAI increased with the increase in extruder temperature.

Effect of extruder exit temperature and feed rate on chemical characteristics

Amylose and degree of cooking

There was a nominal decrease in the amylose content of all the rice–legume extruded products when extruded at a higher temperature as compared to a lower temperature (Table 5). The degree of cooking, as reflected by the damaged starch contents, was higher by 6% to 7% in the products extruded at a higher exit temperature. It is very interesting to observe that the extruded rice–full fat soy flour blend exhibited a notably low degree of starch gelatinization as indicated by the low values of damaged starch, ranging from 22·3% to 25·2% in contrast to 49·7% to 51·1% of the rice–gram extruded blends. The results suggest complexing of starchy components of rice with lipids of soybean, probably resistant to alpha-amylase action. The possibility of an inhibitor in the full fat soy flour interfering with alpha-amylase action, on which damaged starch determination is based, cannot be entirely ruled out.

Reducing and non-reducing sugars

From Table 6 it is seen that the extruded rice–full fat soy blend product had much higher reducing and non-reducing sugars as compared to other blends. The presence of labile oligosaccharides in soybean, i.e. raffinose and stachyose, has been reported in the literature (Smith & Circle, 1972) and therefore it is likely that, during extrusion cooking, due to moist heat, some degradation of oligosaccharides contributed to increased reducing and non-reducing sugars in the extruded rice–full fat soy blend. Similar effects of extrusion cooking on oligosaccharides were suggested by Chiang & Johnson (1977).

Water-soluble proteins

As the EET increased from 60° to 95°C, there was a consistent decrease in the amount of water-soluble proteins in all the extruded products, irrespective of feed rate (Table 7). The decrease in the water-soluble proteins of rice–black gram, rice–green gram and rice–full fat soy flour blends was distinctly higher than that in rice–bengal gram. The decrease was more pronounced with a higher feed rate and a higher temperature which may be attributed to better puffing quality.

TABLE 4

Effect of Processing Variables on the Water Absorption Index (WAI)[a] and Water Solubility Index (WSI) of Extruded Rice–Legume Blends (75:25)

Process variables		*Rice–legume blends*[a]							
Feed rate (kg/h)	*Extrusion exit temperature (°C)*	*D*		*E*		*F*		*G*	
		Water absorption index (g sediment/ g dry matter)	*Water solubility index (dry basis)*	*Water absorption index (g sediment/ g dry matter)*	*Water solubility index (dry basis)*	*Water absorption index (g sediment/ g dry matter)*	*Water solubility index (dry basis)*	*Water absorption index (g sediment/ g dry matter)*	*Water solubility index (dry basis)*
Control	Unprocessed	2·6	7·0	2·5	5·8	2·5	6·4	3·0	8·2
9·2	60	6·7	12·9	5·9	13·0	—	—	5·8	8·7
	95	7·2	19·6	6·6	20·5	—	—	6·5	11·5
15·2	60	6·3	12·5	5·3	12·2	5·8	11·4	5·3	8·5
	95	5·7	17·0	6·2	17·8	6·6	16·1	6·0	10·4
27·2	60	7·0	9·9	5·4	9·5	6·2	9·0	5·5	8·3
	95	7·8	13·8	6·0	13·2	6·5	13·0	6·1	9·3

[a] Blends: D, Rice + bengal gram; E, Rice + black gram; F, Rice + green gram; G, Rice + full fat soybean.

TABLE 5
Effect of Processing Variables on the Amylose and Gelatinized Starch (GS) Contents of Extruded Rice–Legume Blends (75:25)

Process variable		*Rice–legume blends*[a]							
Feed rate (kg/h)	*Extrusion exit temperature (°C)*	*D*		*E*		*F*		*G*	
		Amylose (%)	*Gelatinized starch (%)*	*Amylose (%)*	*Gelatinized starch (%)*	*Amylose (%)*	*Gelatinized starch (%)*	*Amylose (%)*	*Gelatinized starch (%)*
Control	Unprocessed	21·4	5·1	22·3	5·2	26·0	5·3	18·9	5·0
9·2	60	21·5	51·0	22·7	51·6	—	—	18·3	22·3
	95	19·9	53·7	22·7	55·1	—	—	17·4	25·2
15·2	60	20·4	47·7	22·8	47·6	24·9	47·4	18·0	18·9
	95	20·0	51·5	21·6	54·1	24·2	53·0	17·5	24·4
27·2	60	21·1	42·6	22·1	45·3	24·4	44·1	17·8	17·8
	95	20·0	49·7	21·5	52·5	23·4	51·9	17·6	22·3

[a] Blends: D, Rice + bengal gram; E, Rice + black gram; F, Rice + green gram; G, Rice + full fat soy flour.

TABLE 6
Effect of Processing Variables on the Reducing (R) and Non-Reducing (Non-R) Sugars (S) of Extruded Rice–Legume Blends (75:25)

Process variable		*Rice–legume blends*[a]							
Feed rate (kg/h)	*Extrusion exit temperature (°C)*	*D*		*E*		*F*		*G*	
		Reducing sugar as maltose (%)	*Non-reducing sugar as sucrose (%)*	*Reducing sugar as maltose (%)*	*Non-reducing sugar as sucrose (%)*	*Reducing sugar as maltose (%)*	*Non-reducing sugar as sucrose (%)*	*Reducing sugar as maltose (%)*	*Non-reducing sugar as sucrose (%)*
Control	Unprocessed	0·30	0·75	0·32	1·15	0·33	1·18	0·43	0·94
9·2	60	0·36	1·20	0·35	1·67	—	—	2·46	2·22
	95	0·69	1·06	0·42	1·62	—	—	2·59	2·11
15·2	60	0·33	1·10	0·33	1·35	0·31	1·46	2·46	1·90
	95	0·46	1·06	0·41	1·47	0·30	1·58	2·60	1·81
27·2	60	0·39	1·16	0·32	1·36	0·35	1·58	2·31	2·36
	95	0·69	1·06	0·39	1·22	0·28	1·73	2·45	2·22

[a] Blends: D, Rice + bengal gram; E, Rice + black gram; F, Rice + green gram; G, Rice + full fat soy flour.

TABLE 7
Effect of Processing Variables on the Water-Soluble Protein (per cent) of Extruded Rice–Legume Blends (75:25)

Process variable		*Rice–legume blends*[a]			
Feed rate (kg/h)	*Extrusion exit temperature (°C)*	*D*	*E*	*F*	*G*
Control	Unprocessed	3·7	3·7	5·3	5·9
9·2	60	2·4	1·3	—	3·5
	95	1·8	0·9	—	1·5
15·2	60	2·3	1·5	2·7	2·6
	95	1·8	1·3	1·3	1·8
27·2	60	2·0	1·5	2·1	2·5
	95	1·3	1·1	1·5	1·5

[a] Blends: D, Rice + bengal gram; E, Rice + black gram; F, Rice + green gram; G, Rice + full fat soybean flour.

Sensory evaluation

The results of organoleptic evaluation are presented in Table 8. From the results it can be interpreted that the extruded product obtained from the blend of rice–bengal gram flour extruded at 95 ± 2°C with a feed rate of 27·2 kg/h gave the best product when evaluated as a ready-to-eat snack.

From this investigation, it can be concluded that the physico-chemical characteristics of extruded rice–legume blends were altered to a greater extent by extruder exit temperature than feed rate. Therefore, it is suggested that, by manipulating the process parameters during extrusion cooking, one

TABLE 8
Sensory Evaluation of Rice–Legume Snacks (75:25) Extruded at 95 ± 2°C EET with a Feed Fate of 27·2 kg/h through $\frac{1}{8}$ in Die

Product blend	*Average overall organoleptic score*[a]
Rice–bengal gram	9
Rice–black gram	7·0
Rice–green gram	7·5
Rice–full fat soy flour	8

[a] Average of ten panelists.

can tailor a product of any desired attributes. The mixture of rice with bengal gram produced a product of best quality when extruded at an extruder exist temperature of $95 \pm 2°C$ with a feed rate of 27·2 kg/h.

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