Rheological and nutritional quality of selected dehulled legumes blended rice extrudates

S. Balasubramanian · Anjan Borah · K. K. Singh ·
R. T. Patil

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Abstract Rheological and nutritional quality of ready-to-eat rice (*Oryza sativa*) -legume viz. black gram (*Vigna mungo*), green gram (*Vigna radiata*), lentil (*Lens culinaris*) and peas (*Pisum sativum*) based extrudates were studied using low cost collet extruder. Extrudates were prepared keeping constant feed rate (25 kg/h) and moisture content (14% wb) at 0, 5, 10 and 15% legume incorporation levels. Rheological properties of porridge made of extrudate flour were evaluated using Rapid Visco Analyser (RVA). Maximum and minimum peak viscosity for rice extrudates alone and rice extrudates blended with 15% peas were 697 cp and 523 cp, respectively. There was a decreasing trend in degree of gelatinization with increase in legume incorporation level. Other RVA rheological parameters like trough break down and final viscosity were in the range of 266–226 cp, 431–297 cp and 452–375 cp respectively. Maximum values of protein, fat, fibre and ash contents were found in rice extrudates at 15% legumes blend levels. There was an increasing trend in nutrient contents with legume content in rice extrudates. Degree of gelatinization for rice alone extrudate was 29.4% and showed a decrease in gelatinization with increase in legumes extrudate and was minimum (22.4%) for rice blended with 15% dehulled green gram. Sensory evaluation scores for all extrudates showed the most acceptable range of 6 to 8. Thus, legume blend level (up to 15%) of dehulled legumes fetched good scores and

showed promising trend for the production of low cost expanded extrudates and its instant flour.

Keywords Rice · Dehulled legumes · Extrudates · Sensory quality · Nutrition

Introduction

Extrusion cooking is one of the useful processes for the production of expanded snacks and instant flours. During extrusion cooking, raw materials undergo high shear, thus allowing partial starch hydrolysis (Colonna et al. 1984). The existing extrusion systems involve higher financial investment, production capacity and technical knowledge and are not suitable for developing countries. Single collet extruders/dry extruders that were developed for complementary foods production during early 1980s by the University of Colorado (Harper 1995, Harper and Jansen 1985, Said 2000) are too costly besides high production capacity (about Rs 2.5 million and 1 t/h). Adoption of extrusion cooking processing for instant flour production in developing countries has not still picked up. Thus, application of simple machine having small production capacity is therefore of great potential interest. The possibilities of a low cost collet extruder (about 25–35 kg/h) need to be studied for the production of snack foods and instant flours. Rice (*Oryza sativa*), is one of the most frequently used cereals for making gluten-free food products (Sivaramakrishnan et al. 2004). Legumes are a prime source of plant proteins, calories and other nutrients. Extrusion cooking of legumes increases the digestibility of legume protein. In product development, peak and final viscosities are important parameters, to have an understanding of product behaviour during and

S. Balasubramanian (✉) · K. K. Singh · R. T. Patil
Central Institute of Post Harvest Engineering and Technology,
PAU Campus,
Ludhiana 141 004 Punjab, India
e-mail: balaciphet@yahoo.com

A. Borah
Tezpur University,
Tezpur 784 028 Assam, India

Fig. 1 Low cost collet extruder

after processing. Rapid viscoanalyser can be used to investigate the pasting effects of lipids and amino acids on rice starch and flour (Liang et al. 2002, Liang and King 2003). The compact structure resulting from extrusion process can lead to a dense protein network reducing the availability of starch granules to attack by alpha-amylase (Fardet et al. 1999). Moreover, the physical barrier created by the protein network limits the accessibility of starch to amylase and delays in vitro starch hydrolysis (Hoebler et al. 1999). Various reports suggested that pasting characteristics (Wiesenborn et al. 1994, Lai 2001), rheological

properties of paste and gels (Wiesenborn et al. 1994, Kim et al. 1995) and other functional properties (Wotton and Bamunuarachchi 1978, Zobel 1984) of starches vary with species and variants. Gelatinization properties of starches depend on the type, granular structure, botanical origin and amylose/amylopectin ratio (Sajilata et al. 2006). Waxy and normal rice gelatinize between 60 and 78°C (Thorburn et al. 1987, Jenkins et al. 1994). Many factors affect preference and acceptability of foods. Some factors are intrinsic to the product, such as appearance, taste and flavour; other factors are extrinsic, such as social and

Fig. 2 Parameters of the typical rapid visco analyzer viscosity profile for legumes blended rice extrudates

Table 1 Parameters of viscosity profile

Traits abbreviation	Description (reference of terminology)
PV	Peak viscosity (61-02, Bao and Xia 1999)
T	Trough (61-02)
BD	Breakdown (Bao and Xia 1999, 61-02), decrease in viscosity during cooking at 95°C
FV	Final paste viscosity at the end of final holding period at 50°C

61-02 is the ICC (1995) methods

cultural factors (Deliza et al. 1996). Keeping above points in view, the present work was undertaken to study rheological and nutritional quality of selected dehulled legumes blended rice extrudates.

Materials and methods

Different dehulled legumes viz. black gram (*Vigna mungo*), green gram (*Vigna radiata*), lentil (*Lens culinaris*) and peas (*Pisum sativum*) and polished rice were purchased from local market. After cleaning and grading, the raw materials were coarse ground in plate mill to make grits in the particle size range of 1.65–2.36 mm. Different legume grits were blended at 0, 5, 10 and 15% levels with rice grits. For making extrudates, about 2 kg of blended materials conditioned to 14% (wb) moisture were used.

Low cost collet extruder It is a simple single screw autogenous extruder, driven by a 7.5 kW electric motor. The barrel length is 250 mm with a length to diameter ratio of 6:1 and has a central cylindrical die of 4 mm diam and 5 mm length. The rotating speed of the screw is high (500 rpm) to allow high shear. The screw configuration has constant pitch and flight depth to allow a progressive increase in friction forces and temperature inside the barrel. The screw diam is 42.5 mm and the root diam is 32.5 mm (Fig. 1). The moisture content was kept at 14%. The extruder barrel wall has helical grooves to enhance friction and cooking of the product. To ensure a regular feeding rate, the extruder is equipped with a motorised feeding screw, but it was kept constant (25 kg/h) for this study.

After extrusion, extrudates were ground (particle size < 0.85 mm) and subjected for rheological and nutritional analysis.

Rheological properties Pasting properties of extrudate powders were determined using a Rapid Visco Analyser (RVA) Model 3-D (Newport Scientific Pvt. Ltd, Australia) with Thermocline software (3.0 version) by the Method No. 162 (ICC 1995). Sample suspension was prepared by placing extrudate powder (3 g) in an aluminium canister containing (30 g) distilled water. A programmed heating and cooling cycle was used. Each sample was stirred (960 rpm, 10 s) while heated at 50°C, and then constant shear rate (160 rpm) was maintained for the rest of the process. Temperature was held at 50°C up to 1 min. Then the samples were heated (50–95°C, 3 min 42 s) and held at

Fig. 3 Typical rapid visco analyzer plot for different dehulled blended rice extrudates

Fig. 4 Degree of gelatinization of different dehulled blended rice extrudates

95°C for 2 min 30 s. Subsequently samples were cooled down (95–50°C, 3 min 48 s) and then held at 50°C for 2 min. A RVA plot of viscosity (cP) versus time (s) was used to determine peak viscosity (PV), trough (T), breakdown viscosity (BD) and final viscosity (FV) (Fig. 2, Table 1). Each analysis was done in duplicate.

Nutritional analysis Protein content (Kjeldahl method), fat and ash (Hart and Fischer 1971), and fibre (Sadasivam and Manickam 1992) for different legumes blended rice extrudates were determined. Degree of gelatinization of extrudates was done according to Wootton et al. (1971).

Sensory evaluation A semi-trained panel consisting of 11 members evaluated the extrudates. The sensory attributes such as color, flavour, surface finish, taste, crispiness and over all acceptability of extrudates were evaluated using a 9-point Hedonic scale (1–4 dislike extremely to slightly, 5–

neither like nor dislike, 6–9 like to slightly extremely). Samples were served to panelists immediately after conditioning the extrudates (105°C, 3 min).

Statistical analysis The data reported are mean of ten observations and subjected to MS EXCEL 2000.

Results and discussion

Effect of low cost collet extruder on viscosity profile of extrudates All viscosity parameters determined decreased with increased legume levels in blend as compared to rice extrudates alone (Fig. 3). But the decrease was not much pronounced in green gram based extrudate. The breakdown viscosity was maximum in peas whereas it varied in the range of 288–297 cp and was lower in all the cases. The final viscosity declined in all cases but the decrease was much higher in green gram where it varied from 437 to 404 cp. Similar observations were recorded for peak viscosity also. When extrudates powder suspensions were heated above a certain temperature, water penetrated into the granules and weakened the hydrogen bonds in starch segments and reflected a degradative RVA profile as compared to its corresponding raw material due to mechanical input. The viscosity increased during heating at constant temperature (95°C), continued to decrease during cooling and the profile finalized with a plateau for different legumes and incorporation levels, but showed a slightly increasing trend at the end of the process. All the viscosity-temperature profiles of the studied systems showed a similar pattern. The maximum viscosity was

Table 2 Nutritional analysis of different dehulled legumes blended rice extrudates

Legumes	Legumes,%	Protein,%	Fat,%	Fibre,%	Ash,%
Black gram	0	8.6	0.86	0.19	0.56
	5	9.2	0.90	0.25	0.62
	10	9.8	0.96	0.27	0.78
	15	10.5	1.03	0.29	0.96
Green gram	0	8.6	0.86	0.19	0.56
	5	9.7	0.90	0.24	0.74
	10	10.1	0.96	0.26	0.88
	15	10.9	1.02	0.28	0.98
Lentil	0	8.6	0.86	0.19	0.56
	5	9.7	0.90	0.23	0.66
	10	10.1	0.96	0.25	0.76
	15	11.2	1.03	0.27	0.88
Peas	0	8.6	0.86	0.19	0.56
	5	9.0	0.90	0.32	0.66
	10	9.6	0.96	0.39	0.78
	15	10.2	1.03	0.50	0.86

attained when the granules were in their most swollen state, still intact resulting in peak viscosity and this continued heating of paste at this point, however, caused the granule to rupture and accompanied by the fall in viscosity (Kearsley and Sicard 1989). The secondary increase in viscosity (setback) during the cooling phase which is associated with the retrogradation phenomenon and related to amylose content was observed.

Effect on degree of gelatinization Degree of gelatinization for rice extrudate was 29.4%. The degree of gelatinization ranged from 22.4 to 29.4% (Fig. 4). The legumes blended extrudates showed a lower degree of gelatinization compared to rice extrudates. Although there was no marked difference in degree of gelatinization among the legumes blended extrudates, the black gram and green gram showed lower values (22.4% and 22.6%) followed by peas (23.3%) and lentil (23.2%) at 15%. Partial starch dextrinisation is desirable because it reduces swelling during gruel preparation, thus allowing an appropriate semi-fluid consistency to be maintained at a higher concentration, i.e. higher energy density. This signified that the extrusion cooking has increased the degree of gelatinization of the extrudates. According to Lin et al. (1997) fat content of extrudates was shown to interfere significantly with starch gelatinization. Thus, decrease in gelatinization with legumes addition could be due to the increased level of protein and fat as compared to rice.

Effect on nutritional value The rice (raw milled), black gram, green gram, lentil and peas consist of 6.8, 24, 19.7, 25.1 and 19.7% protein (Gopalan et al. 1991). The combination of rice with legume forms a protein rich food.

The legumes blended rice extrudates showed a protein content ranging from 8.6 to 11.15% (Table 2). Among the extrudates, rice extrudates showed low protein content as compared to legumes blended extrudates. The protein content increased depending upon legume type. This may be attributed to their inherent higher content of proteins in the legumes. The lentil blended (15%) with rice extrudate showed highest protein content. Extrudates made of rice alone and legumes blended rice extrudate showed a lower fat percentage ranging from 0.86 to 1.03% as compared to raw rice (0.5%) and legumes viz., black gram (1.4%), green gram (1.2%) lentil (0.7%) and peas (1.1%). There was no significant difference ($p \leq 0.5$) in fat content between legumes except green gram, which showed a lower value (1.03). Fibre content of rice and legumes blended rice extrudate ranged from 0.19 to 0.50%. The fibre content of extrudates showed an increasing trend with increase in legume content because of the higher fibre content of legumes than rice. Pea blended rice extrudates at higher level of blend showed higher fiber values. The ash content of extrudates increased with increase of legumes levels. Ash content ranged from 0.56 to 0.98%. Black gram and green gram blended extrudates showed higher ash content (0.96% and 0.98%) followed by lentil (0.88%) and pea (0.86%).

Effect on sensory attributes Sensory score was significantly affected by the blend levels in all the cases (Fig. 5). However, black gram and pea blended extrudates did not show much variation among overall acceptability as compared to green gram and lentil based extrudates. The colour was affected by the blend levels of lentil and pea, which may be attributed to the inherent colour character-

Fig. 5 Hedonic scores of extrudates made of different dehulled blended rice extrudates

istics of the legumes. However, the blend levels of black gram (15%), peas (15%), green gram (10%) and lentil (10%) were found acceptable without altering the overall acceptability score as compared with rice extrudate alone.

Conclusion

The low cost collet extruders with a small production capacity will be suitable to process and produce legume blended rice expanded snack foods and instant flour with low moisture content (<14%, wb) and low lipid content. Extrudate flours which are partially dextrinised and gelatinized during the treatment, yielding instant flour showed the scope for preparation of higher energy density gruels. The lower viscosity profile of extrudate flour as compared to its raw composite flour and higher nutritional and sensory values expressed the usefulness and possibility of product development, especially for diet and weaning foods.

References

- Colonna P, Doublier JL, Melcion JP, De Monredon F, Mercier C (1984) Extrusion cooking and drum drying of wheat starch. I. Physical and macromolecular modifications. *Cereal Chem* 61:538–544
- Deliza R, Macfie H, Hedderley D (1996) Information affects consumer assessment of sweet and bitter solutions. *J Food Sci* 61:1080–1083
- Fardet A, Abecassis J, Hoebler C, Baldwin PM, Buleon A, Berot S (1999) Influence of technological modifications of the protein network from pasta on in vitro Starch Degradation. *J Cereal Sci* 30:133–145
- Gopalan C, Rama Sastry BV, Balasubramanian SC (1991) Nutritive value of Indian foods. National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, pp 47–48–95–96
- Harper J (1995) Low-cost extrusion: possibilities for Africa. *The South-African J Food Sci Nutr* 7:142–147
- Harper J, Jansen G (1985) Production of nutritious precooked foods in developing countries by low-cost extrusion technology. *Food Rev Int* 1:27–97
- Hart FL, Fischer HJ (1971) Análisis moderno de los alimentos. In: Acibia, Zaragoza, p 249
- Hoebler C, Karinthe A, Chiron H, Champ M, Barry JL (1999) Bioavailability of starch in bread rich in amylase: metabolic responses in healthy subjects and starch structure. *Eur J Clin Nutr* 53:360–366
- ICC (1995) Rapid pasting method using the Newport rapid visco analyser. ICC-Draft Standard No. 162, International Association for Cereal Science and Technology
- Jenkins DJA, Jenkins AL, Wolever TMS, Vuksan V, Rao AV, Thompson LU, Josse RG (1994) Low glycemic index: Lente carbohydrates and physiological effects of altered food frequency. *Am J Clin Nutr* 59:706S–709S
- Kearsley MW, Sicard PJ (1989) The chemistry of starches and sugars present in food. In: Dobbing J (ed) *Dietary starches and sugars in man: a comparison*. Springer, London, pp 1–34
- Kim SY, Wiesenborn DP, Orr PH, Grant LA (1995) Screening potato starch for novel properties using differential scanning calorimetry. *J Food Sci* 60:1060–1065
- Lai HM (2001) Effects of hydrothermal treatment on the physico-chemical properties of pregelatinized rice flour. *Food Chem* 72:455–463
- Liang XM, King JM (2003) Pasting and crystalline property differences of commercial and isolated rice starch and added amino acids. *J Food Sci* 68:832–838
- Liang XM, King JM, Shih FF (2002) Pasting property differences of commercial and isolated rice starch with added lipids and β -cyclodextrin. *Cereal Chem* 79:812–818
- Lin S, Hsieh F, Huff HE (1997) Effect of lipids and processing conditions on degree of starch gelatinization of extruded dry pet food. *Lebens Wiss Technol* 30:754–761
- Sadasivam S, Manickam A (1992) *Biochemical methods for agricultural sciences*. Wiley, New Delhi, pp 20–21
- Said NW (2000) Dry extruders. In: Riaz MN (ed) *Extruders in food applications*. Technomic, Texas, pp 51–62
- Sajilata MG, Singhal RS, Kulkarni PR (2006) Resistant starch- a review. *Comp Rev Food Sci Food Safety* 5:1–17
- Sivaramakrishnan HP, Senge B, Chattopadhyay PK (2004) Rheological properties of rice dough for making rice bread. *J Food Eng* 62:37–45
- Thorburn AW, Brand JC, Truswell AS (1987) Slowly digested and absorbed carbohydrate in traditional bushfoods: a protective factor against diabetes? *Am J Clin Nutr* 45:98–106
- Wiesenborn DP, Orr PH, Casper HH, Tacke BK (1994) Potato starch paste behaviour as related to some physical/chemical properties. *J Food Sci* 59:644–648
- Wotton M, Bamunuarachchi A (1978) Water binding capacity of commercial produced native and modified starches. *Starch/Stärke* 33:159–161
- Wootton M, Weedon D, Munk N (1971) A rapid method for the estimation of starch gelatinization in processed foods. *Food Technol Australia* 23:612–615
- Zobel HF (1984) Gelatinization of starch and mechanical properties of starch pastes. In: Whistler RL, BeMiller JN, Paschall EF (eds) *Starch: chemistry and technology*, 2nd edn. Academic, London, pp 285–309