

Rheological and nutritional properties of legumes incorporated corn extrudates

¹*Balasubramanian, S., ²Borah, A. and ²Mahanta, C. L.

¹Central Institute of Post Harvest Engineering and Technology, PAU Campus,
Ludhiana-141004, Punjab.

²Department of Food Processing Technology, Tezpur University, Napaam-784028,
Assam.

Abstract: Rheological and nutritional properties of corn based extrudates incorporated with selected dehulled legumes (black gram, green gram, lentil and peas) made using low cost collet extruder at 5%, 10% and 15% levels were studied. There was a decreasing trend of all viscosity properties and degree of gelatinization with increase in legumes incorporation level. With increase in legumes incorporation, protein content showed an increasing trend and fat, fiber, ash content and sensory score remain almost same. Thus, dehulled legumes (up to 15%) incorporated corn extrudates have showed a promising trend for the production of low cost expanded snacks and instant flour.

Keywords: Corn, extrudates, pasting characteristics and legumes

Introduction

Food extrusion is a versatile HTST process and is an established practice for continuous manufacture of traditional and new products (Smith and Singh, 1996). Legumes are prime source of plant proteins, calories and other nutrients. Cereals are lower in lysine content and on contrary legumes have higher lysine content so act as complementary to each other. 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) and delays in vitro starch hydrolysis (Hoebler *et al.*, 1999). In product development, peak and final viscosities are important to understand the behaviour of product during and after processing apart from nutrient content. Rapid viscoanalyser can be used to investigate the pasting properties of lipids and amino acids on corn starch and flour (Liang and King, 2003; Liang *et al.*, 2002). Sajilata *et al.* (2006) reported that the gelatinization properties of starches depend on its type, granular structure, botanical origin, and amylose/amyllopectin ratio. Thus, many factors affect the reference and acceptability of foods. The objective of this work was to study the rheological and nutritional properties of selected dehulled legume incorporated corn extrudates as compared to raw composite, as well as changes nutritional value of legume incorporated extrudates.

Materials and Methods

Raw materials

Different dehulled legumes viz black gram (*Phaseolus mungo L.*), green gram (*Vigna radiata L.*), lentil (*Lens culinaris L.*) and peas (*Pisum sativum L.*) and corn were purchased from local market. After cleaning and grading, raw materials were subjected to coarse grinding in plate mill to make grits of 1.65-2.36 mm thickness. The legume grits were incorporated with corn grits at 0, 5, 10 and 15 levels. For making extrudates, about 2 kg of blended materials were conditioned to 14% moisture (wb).

Extrusion cooking conditions

Extrusion cooking was performed using a heavy-duty low cost collet extruder (Food extrusion laboratory, CIPHET, Ludhiana (India), driven by 10 hp AC motor. Feed rate was controlled with a 1 hp DC motor. The length to diameter (L/D) ratio of the extruder was 5:1. The barrel was enrobed with cold/tap water circulation to maintain the temperature. The screw speed was kept constant at 500 rpm during extrusion cooking. The extruder barrel was fitted with 4.0 mm die nozzle. After initial laboratory trials, extrudates were prepared keeping constant feed rate of 25 kg/h and feed moisture of 14%, wb (Balasubramanian *et al.*, 2011).

Sample preparation for analysis

Extrudates were ground to particle size less than 0.85 mm and subjected to rheological and nutritional analysis and sensory evaluation.

*Corresponding author.
Email: balaciphet@yahoo.com

Rheological properties

Pasting properties of extrudate powder was determined using Rapid Visco Analyser (RVA) Model 3-D (Newport Scientific Pvt. Ltd, Australia) with Thermocline software (3.0 version) according to ICC (1995). Sample suspension was prepared by placing extrudate powder (3g) in an aluminium canister containing 30g of distilled water. A programmed heating and cooling cycle was used. Each sample was stirred at 960 rpm for 10 s, while being heated at 50°C and then constant shear rate of 160 rpm was maintained for rest of the process. Sample was held at 50°C for 1 min and heated from 50 to 95°C taking 3 min 42 s and held at 95°C for 2 min 30 s. Subsequently samples were cooled down from 95 to 50°C taking 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), minimum viscosity (MV), break down viscosity (BD), final viscosity (FV) and total set back (TSB). Each analysis was done in duplicates.

Degree of gelatinization

It was estimated using the procedure suggested Wotton and Bamunuarachchi (1978). About 0.2g of sample (< 0.85 mm) was dispersed in 100 ml distilled water, stirring for 5 min before being centrifuged for 25 min. Supernatant (1 ml) was diluted with water to 10 ml and 0.1 ml of iodine solution was added. The absorbance at 600 nm was read in UV-VIS spectrophotometer against a reagent blank. Similar type slurry was prepared from 0.2 g of extrudate and 95 ml of water. A 5ml portion of 10 M potassium hydroxide was then added and the mixture was stirred for 5 min and centrifuged for 25 min. Supernatant (1ml) was then diluted with distilled water to 10 ml followed by addition of 0.1 ml of iodine solution. The absorbance was then read as before.

$$\text{Degree of gelatinization} = \frac{\text{Absorbance of fresh solution}}{\text{Absorbance of alkali dissolved solution}} \times 100$$

Nutritional evaluation

Fat, moisture, crude fiber and ash were determined by AOAC (2000) methods. Protein content was determined by measuring available nitrogen in the sample by Micro Kjeldhal method using conversion factor 6.25 (Balasubramanian *et al.*, 2011)

Sensory Evaluation

Extrudates were evaluated for sensory properties according to a descriptive technique using 9-point hedonic scale (Balasubramanian *et al.*, 2011 and Liu *et al.*, 2000). The sensory attributes of color, flavor, surface finish, taste, crispiness and

over all acceptability of extrudates were evaluated by 11 semi-trained panel members. Extrudates were served to panelists immediately after conditioning at 105°C for 3 min. The data reported were mean of ten observations and subjected to MS EXCEL 2000.

Results and Discussion

Effect on viscosity profile

Extrusion cooking caused a reduction in pasting characteristics (Figure 1) of extrudates viz. PV, MV, FV, TSB except BD (increased almost twice by 132 cp) as compared to corn flour. The PV, MV, FV and TSB were found decreased up to 88 cp, 223 cp, 1296 cp and 1074 cp for corn extrudates. During the rise in temperature of extrudate powder suspensions, water penetrates into the granules and weakens the hydrogen bonds in starch segments and reflects a degradative RVA profile as compared to its corresponding raw material (Balasubramanian and Singh, 2008). According to Lockwood *et al.* (2008) amylose content of flour showed greater degree of entanglement and expressed increased viscosity level during cooling phase.

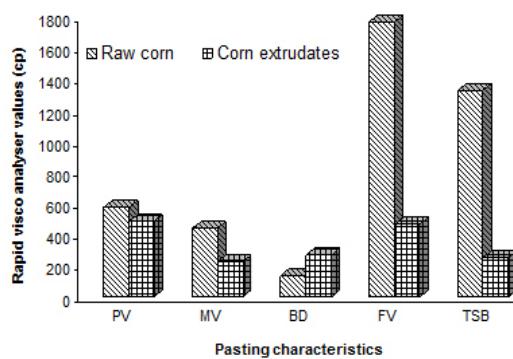


Figure 1. Viscoparameters for raw and corn extrudates.

Incorporation of legumes with corn resulted in decline of pasting characteristics viz. PV, MV, BD, FV, TSB (Table 1). Formation of starch-fat complexes (Ho and Izzo, 1992) and starch-protein complexes (Madeka and Kokini, 1992) might have been significant during extrusion of corn flour with legume composition. Among the selected legumes, black gram incorporation showed a higher PV and significant decrease in MV, BD, FV and TSB (Table 1). The PV for raw composite and corn extrudates at different incorporation levels for black gram (5%, 10% and 15%) were 547.5 cp, 505.0 cp and 478.0 cp and 465.5 cp, 453.5 cp and 420.5 cp, respectively. Sathe *et al.* (1982) reported a very typical visco amylograph pasting profile for black gram starch than most legume starches. At 5% incorporation

black gram showed a decrease of PV by 27.5 cp and 22.5 cp for raw composite and corn extrudates. Incorporation of pea at 5% showed a maximum decrease in PV by 169.5 cp and 94.5 cp for raw composites and corn extrudates, respectively. Among legumes, pea incorporation showed minimum pasting characteristics for both uncooked composites and extrudates. However, MV found to be decreased by 28 to 39 cp for raw corn composites, but for extrudates MV was not prominently pronounced. BD decreased from 30.5 cp to 45.5 cp and 61.5 cp to 95 cp at 15% incorporation level for raw corn composites and extrudates, respectively. The FV of raw composites at 5% incorporation level showed a reduction up to 587.5 cp and FV decreased in greater extent at 10% and 15% incorporation levels. Similarly FV showed a maximum decrease (96.5 cp) for 15% pea incorporated corn extrudates. TSB also observed a decrease from 284.5 cp to 495.5 cp for raw composite and corn extrudates. The RVA parameters of green gram and lentil incorporation also showed a decreasing trend, however these values were well configured with pasting behavior of black gram and pea. Earlier studies reported that lower TSB during the cooling phase of paste due to the greater resistance to its retrogradation (Sanni *et al.*, 2004).

Effect on degree of gelatinization

Degree of gelatinization for corn extrudate alone was found to be 36.4%, while raw corn showed lower degree of gelatinization (13.28%). Legume incorporated raw corn composite showed lower degree of gelatinization compared to corn alone, ranging between 13.28 and 9.23% (Table 2).

Table 2. Degree of gelatinization of dehulled legumes incorporated corn extrudates

| Legume (%) | | | | | | | | | | | | |
|------------|------------|-------|-------|------------|-------|-------|--------|-------|-------|-------|-------|-------|
| | Black gram | | | Green gram | | | Lentil | | | Peas | | |
| | 0% | 5 | 10 | 15 | 5 | 10 | 15 | 5 | 10 | 15 | 5 | 10 |
| Raw | | | | | | | | | | | | |
| 13.28 | 11.45 | 10.69 | 9.23 | 11.23 | 10.94 | 10.40 | 12.88 | 12.10 | 11.48 | 11.29 | 10.74 | 9.84 |
| Extrudates | | | | | | | | | | | | |
| 36.40 | 33.30 | 28.30 | 25.30 | 34.50 | 29.40 | 26.30 | 32.30 | 30.10 | 27.40 | 33.80 | 30.20 | 26.80 |

Similarly, legume incorporated extrudates showed higher degree of gelatinization values in the range of 36.4-25.35%. Although there was no marked difference in degree of gelatinization among the

legumes incorporated extrudates, black gram showed a lowest value (25.3%) followed by green gram (26.3%), peas (26.8%) and lentil (27.4%) at 15% incorporation level, respectively. According to Lin *et al.* (1997), fat content of extrudates was shown to interfere significantly with starch gelatinization. Thus, this partial starch dextrinisation reduces the swelling during gruel preparation i.e. higher energy density with an appropriate semi-fluid consistency. This signified the increase in degree of gelatinization due to extrusion cooking.

Effect on nutritional value

Protein content of raw materials viz., corn, black gram, green gram, lentil and peas are 11.1%, 24.0%, 19.7%, 25.1% and 19.7%, respectively (Gopalan *et al.*, 1991). Protein content of extrudates showed a marginal increase, found to be maximum for lentil from 8.70% to 10.19%, 10.85% and 11.84% at 5%, 10% and 15% incorporation levels respectively (Table 3). This increased protein content of extrudates may be attributed to their inherent higher protein content of legumes. Fat content was found to decrease from 3.45% - 3.02% indicating that extrusion process plays a role in fat reduction. Camire (2000) also reported that the formation of complexes with amylose and protein might be responsible for lower lipid extraction. However lentil showed a lowest value of 3.02%.

Table 3. Nutritional analysis of dehulled legumes incorporated corn extrudates

| Legume | Incorporation levels (%) | Protein (%) | Fat (%) | Fiber (%) | Ash (%) |
|------------|--------------------------|-------------|---------|-----------|---------|
| Black gram | 0 | 8.70 | 3.45 | 1.79 | 0.82 |
| | 5 | 9.84 | 3.42 | 1.75 | 0.87 |
| | 10 | 10.73 | 3.28 | 1.68 | 1.12 |
| | 15 | 11.39 | 3.18 | 1.71 | 1.16 |
| | 0 | 8.70 | 3.45 | 1.79 | 0.82 |
| Green gram | 5 | 9.83 | 3.42 | 1.69 | 0.88 |
| | 10 | 10.17 | 3.25 | 1.62 | 1.14 |
| | 15 | 10.46 | 3.15 | 1.53 | 1.17 |
| | 0 | 8.70 | 3.45 | 1.79 | 0.82 |
| Lentil | 5 | 10.19 | 3.35 | 1.72 | 0.91 |
| | 10 | 10.85 | 3.11 | 1.76 | 1.01 |
| | 15 | 11.74 | 3.02 | 1.72 | 1.13 |
| | 0 | 8.70 | 3.45 | 1.79 | 0.82 |
| Peas | 5 | 9.91 | 3.40 | 1.77 | 0.95 |
| | 10 | 10.26 | 3.28 | 1.75 | 1.08 |
| | 15 | 10.68 | 3.19 | 1.57 | 1.16 |

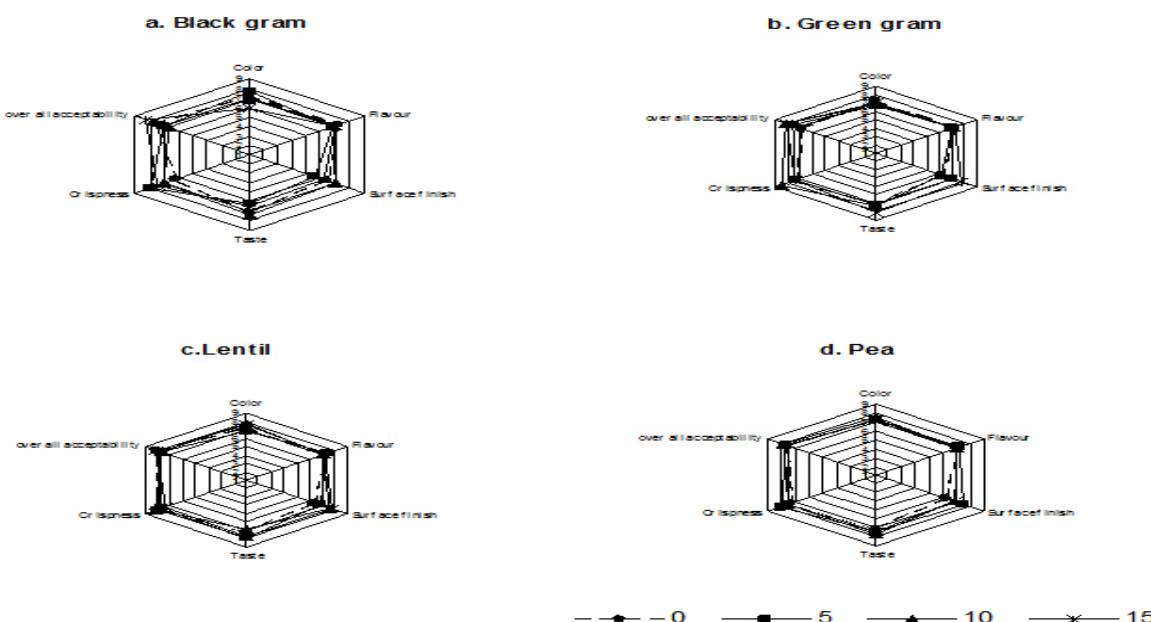


Figure 2. Hedonic scores of corn extrudates incorporated with different legumes.

Extrusion cooking did not result in remarkable change in fiber content of corn extrudates. Fiber content of corn alone and legumes incorporated corn extrudate ranged from 1.79% to 1.53%. Similarly, Varo *et al.* (1983) reported that the same dietary fiber content was found in untreated and twin screw extruded wheat flour and whole-wheat meal. Among legumes, pea incorporated corn extrudates at 15% level showed higher fiber content. Ash content of extrudates increased with increase of legumes levels, ranging from 0.82% to 1.17%. Lentil incorporated extrudates showed comparatively lower ash content (0.86-1.13%). Other legumes viz. black gram, green gram and pea incorporated extrudates showed similar ash content of approximately 1.17% at 15% incorporation level.

Effect on sensory attributes

Extrudates incorporated with selected legumes were rated acceptable for all attributes evaluated (Figure 2). There was no significant difference was found in sensory rating for crispness of selected legumes incorporated extrudates. The flavour, surface finish and taste of legume incorporated extrudates were compatible to that of control. At 15% incorporation level the extrudates incorporated with selected legumes were rated more acceptable than 5% and 10% incorporation levels. The colour score was found to be enhanced by the incorporation level of lentil and lowerd by black gram, though no pronounced effect for green gram and pea incorporation was observed. Among the legumes incorporation of green gram showed better overall acceptability followed by lentil based extrudates.

Conclusions

Extrudates having partially dextrinised and gelatinized characteristics, yielding instant flour showed the scope of higher energy density gruels preparation. The pasting parameters showed a decreasing trend probably due to variation in starch to protein fractions. Degree of gelatinization showed lower value for higher level of legume incorporation. Extrudates incorporated with 15% selected legume were rated highest in sensory score compared to control. Thus, legume incorporated corn extrudates with enhanced protein and nutritional values showed the scope for preparation of higher energy food.

Acknowledgements

This research was supported by FG&OP Division, CIPHET, Ludhiana.

References

- AOAC. 2000. Official Method of Analysis of AOAC, International, Washington, 17th Ed., Vol. II, Association of Analytical Chemists.
- Balasubramanian, S., Borah, A., Singh, K. K. and Patil, R. T. 2011. Rheological and nutritional quality of selected dehulled legumes blended rice extrudates. Journal of Food Science and Technology DOI: 10.1007/s13197-010-0206-y.
- Balasubramanian, S. and Singh, K.K. 2008. Development of technology for health foods from legumes and millets using food extrusion systems. Research Project Report. Central Institute of Post Harvest engineering and Technology, Ludhiana, India.

- Camire, M. E. 2000. Chemical and nutritional changes in food during extrusion. In: Extruders in Food Applications (edited by M.N. Riaz). Pp 127-147. Boca Raton, FL: CRC Press.
- Fardet, A., Abecassis, J., Hoebler, C., Baldwin, P.M., Buleno, A. and Berot, S. 1999. Influence of technological modifications of the protein network from pasta on in vitro Starch Degradation. Journal of Cereal Science 30: 133-145.
- Gopalan, C., Rama Sastry, B.V. and Balasubramanian, S.C. 1991. Nutritive value of Indian Foods. National Institute of Nutrition (NIN), Indian Council of Medical Research, Pp. 95-96, Hyderabad. India.
- Ho, C.T. and Izzo, M.T. 1992. Lipid-protein & lipid-carbohydrate interactions during extrusion. In: Food Extrusion Science and Technology (edited by J.L. Kokini, C.T. Ho, M.V. Karwe) Marcel Dekker: New York. Pp. 415-426.
- Hoebler, C., Karinthi, A., Chiron, H., Champ, M. and Barry, J.L. 1999. Bioavailability of starch in bread rich in amylase: metabolic responses in healthy subjects and starch structure. European Journal of Clinical Nutrition 53: 360-366.
- ICC.1995. Standard Method No. 162, International Association for Cereal Science and Technology.
- Liang, X.M. and King, J.M. 2003. Pasting and crystalline property differences of commercial and isolated rice starch and added amino acids. Journal of Food Science 68: 832-838.
- Liang, X.M., King, J.M. and Shih, F.F. 2002. Pasting property differences of commercial and isolated rice starch with added lipids and β -cyclodextrin. Cereal Chemistry 79: 812-818.
- Lin, S., Hsieh, F. and Huff, H.E. 1997. Effect of lipids and processing conditions on degree of starch gelatinization of extruded dry pet food. Lebensmittel-Wissenschaft und-Technologie 30: 754-761.
- Liu, Y., Hsieh, F., Heymann, H. and Huff, H.E. 2000. Effect of process conditions on the physical and sensory properties of extruded oat corn puff. Journal of Food Science 65: 1253-1259.
- Lockwood, S., King, J.M. and Labonte, D. 2008. Altering pasting characteristics of sweet potato starches through amino acid additives. Journal of Food Science 73: 373-377.
- Madeka, H. and Kokini, J.L. 1992. Effect of addition of zein and gliadin on the rheological properties of amylopectin starch with low-to-intermediate moisture. Cereal Chemistry 69: 489-494.
- Sanni, L.O., Kosoko, S.B., Adebawale, A.A. and Adeoye, R.J. 2004. The influence of palm oil and chemical modification on the pasting properties of fufu flour. International Journal of Food Science 7(2): 229-237.
- Sathe, S.K., Rangneker, P.D., Deshpande, S.S. and Salunkhe, D.K. 1982. Isolation and Partial Characterization of Blackgram (*Phaseolus mungo* L.) Starch. Journal of Food Science 47: 1524-1527.
- Sajilata, M.G., Singha, R.S. and Kukarni, P.R. 2006. Resistance starch-a review. Comprehensive Reviews in Food Science and Food Safety 51: 1-17.
- Smith, A.C. and Singh, N. 1996. New applications of extrusion cooking technology. Indian Food Industry 15: 14-23.
- Wotton, M. and Bamunuarachchi, A. 1978. Water binding capacity of commercial produced native and modified starches. Starch/Starke 33: 159-161.
- Varo, P., Line, R. and Koivistoinen, P. 1983. Effect of heat treatment on dietary fiber: Inter laboratory study. Journal of Association of Official Analytical Chemists 66: 933-938.