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**Research Paper**

# Standardization and evaluation of RTE extruded corn-pearlmillet snacks incorporated with kidney bean or green gram flour: A comparative study

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## ABSTRACT

**The presentstudy aimed to develop ready-to-eat extruded snacks by incorporating kidney bean flour (0-25%) or green gram flour (0-25%) in a corn-pearlmillet (70:30) flour blend. All flours were tested for their compositional and nutritional parameters (crude fibre, carotenoid, phyticacid, polyphenols, iron, zinc, and total dietary fibre). Evaluation of pasting characteristics, water absorption, and dough extensibility of flours and physical (bulk density, expansion ratio, sectional expansion index, and hardness) and sensory properties of extruded snacks weredone. The addition of pulses reduced pasting values, resistance to extension, and extensibility of flour while increasing water absorptions significantly ($p$<0.05). Physical properties and sensory characteristics of extrudates were also significantly ($p$<0.05) reduced by pulses addition. However, considering nutritional aspects, kidney bean flour up to 15% or green gram flour up to 10% is recommended to be incorporated for obtaining extrudates of desirable quality. Both pulses hadsimilar effects on product quality, but the use of green gram flour is preferred over kidney bean due to its minimum anti-nutritional factors available in the resulting product.**

***Key words:*** Extrusion, Corn, Greengram, Kidney bean, Pearlmillet

## INTRODUCTION

Extrusion technique is applicable in food sector for the manufacturing of expanded snacks, and it is also advantageous over other manufacturing techniques due to its versatility, flexibility, low cost and continuity of production (Guzmán-Ortíz *et al.* 2014). In general, starchy components like wheat, rice, or corn are used to produce these expanded snacks. Demand for healthy, nutritious, palatable and ready-to-eat snacks is increasing because of consumer health concerns and their lifestyle. Extrusion cooking is a low-cost, high-temperature, quick processing technique that results in food products with good nutrition (Rolandelli *et al.* 2020, Jing *et al.* 2013). Extrusion process boosts the bioavailability of numerous nutrients while reducing a number of anti-nutritional factors such tannins, phytate, and trypsin inhibitor (Thavarajah *et al.* 2010). Extrusion cooking is a popular method for processing food that uses both protein and starch as basic materials to create high-quality food items for pet feeds, cereals, and snacks (Lin *et al.* 2000). Corn flour is the most used ingredient for the development of extruded snacks with a crispy structure (Guzmán-Ortíz *et al.* 2014). Compared to other cereals, corn has comparable nutritional components: 28-80 % carbohydrate, 9.1–15% protein and 10-15% fiber (Singleton *et al.* 1965). Characteristics of corn also favor extrusion process for making snacks which are more popular among children (Prasadi *et al*. 2020).

Multigrain, legumes, and millets can be used into the formulation process to increase the nutritional value of corn-based extrudates (Ainsworth *et al.* 2007). Pearlmillet (*Pennisetum glaucum*), a drought-resistant crop containing 11% protein, 5% fat, 67.5% carbohydrate, 1.2% fibre and 2.3% mineral can be incorporated in corn-based snacks for improving nutrition. Pearl millet is also helpful in reducing blood glucose level (Kaur *et al.* 2015). Pearl millet contains more oil than maize, due to which is referred to as a “high-energy” grain (Krishnan *et al.* 2018). An important source of iron and zinc, pearl millet offers an easy way to address micronutrient deficiency in millet-eating countries and has the potential to be used to make dishes that are high in nutrients. Methionine and lysine content in pearl millet is 40% higher than in maize (Leder 2004). Incorporation of 25% pearl millet to corn extrudates improved microstructural, nutritional and physicochemical characteristics of extrudates. Protein, crude fibres and bulk density were increased while total carbohydrates, hardness and expansion ratio were reduced (Saini 2015).

Due to their high concentration of important amino acids lysine and tryptophan, pulses are also frequently added to cereal blends to increase their protein content. Although kidney bean flour (*Phaseolus spp. L.)* is well known for its fiber, mineral, and protein contents, its nutraceutical benefit in the prevention of chronic diseases has not yet received as much attention (Dinelli *et al.* 2006). *Phaseolus vulgaris* L., a type of red kidney bean, is rich in dietary fiber, carbohydrates, vitamins, minerals, and a wide range of phytochemicals. However, its high protein content, which is 2-3 times that of cereal grains, is the most significant aspect of its nutritional relevance (Mindi and Aluko 2012). Numerous studies on the addition of legumes to baked goods and other food products to improve their nutritional and functional properties have been conducted (Awolu et al. 2017). Green gram (*Vigna radiata*), also known as mung bean is a drought-tolerant crop of Pakistan and India. It contains 20-22% protein content, making it one of the easily digestible legumes (Fuller *et al.* 2001).

The goal of the current study was to develop and compare protein-rich RTE extruded snacks made by incorporating kidney bean flour or green gram flour to corn-pearl (70:30) millet flour blend. The question is whether the physicochemical, sensory and nutritional characteristics of produced ready-to-eat extruded snacks are affected.

## MATERIALS AND METHODS

Corn (HQPM-I) was procured from the Regional Research station, Uchani, Karnal. Pearlmillet (WHC-901-445), green gram (MH-421) and kidney beans were procured from the Department of Plant Breeding, CCSHAU, Hisar. Corn and pearl millet grains were cleaned for extraneous matter and flour was prepared by milling using Brabander Quardamat Junior Mill. Pulses were cleaned, sorted, conditioned, dried, de-hulled andground to obtain Kidney Bean Flour (KBF) and Green Gram Flour (GGF).

### *Methodology*

Raw materials were studied for their compositional and nutritional parameters (crude fibre, carotenoid, phyticacid, polyphenols, iron, zinc and total dietary fibre). Based on preliminary studies, mixture of corn and pearl millet flours in the ratio of 70:30 was considered as the base flour (control) for incorporating kidney bean flouror green gram flour. Different blends of flourwere made by incorporating kidney bean flour (0-25%) or green gram flour (0-25%) in base flour. Evaluation of pasting characteristics, water absorption and dough extensibility of flour blends and physical (bulk density, expansion ratio, sectional expansion index and hardness) and sensory properties of extruded snacks made using these different flour blends was done. Extruded snacks made using the best selected corn-pearl millet-kidney bean or corn-pearl millet-green gram flour blends were further tested for compositional and nutritional properties.

### *Analytical procedures*

Crude protein, crude fat, ash, crude fibre, carbohydrate, total dietary fibre and energy were analyzed using AOAC method (AOAC 1995). Energy was calculated using a factorial method.

Energy (Kcal/100g)= 4.0× (% protein)+ 4.0 × (% carbohydrate) +9.0 × (% fat)

Phytic acid was analyzed using the procedure described earlier (Huag and Lantzsch 1983). Total polyphenol was found using Folin-Ciocalteu reagent method (Sharma *et al.* 2022). Mineral content was analyzed using a wet digestion procedure. The filtrate was then studied for minerals by using Atomic Absorption Spectrophotometer (Lindsay and Norwell 1969). Pasting characteristics (Rapid Visco Analyzer, Newport Scientific Australia), water absorption and dough extensibility and texture (TA XT Plus Texture analyzer, Stable Micro System, UK) were studied as per standard method (AACC 1995). Bulk density was determined according to the method described by earlier (Pandey *et al.* 2009). Expansion ratio was analyzed using the procedure described by Harper (1981). The Sectional Expansion Index was analysed employing the method described by Alvarez-Martinez *et al.* (1988). Sensory evaluation was employed using 9-point Hedonic scale by a panel of eight semi-trained judges. Total carotenoid was estimated calorimetrically as per the standard procedure(AOAC 1980).

### *Preparation of ready-to-eat extruded snacks*

Control sample contains corn-pearlmillet (70:30) flours. Incorporation of kidney bean flour (0-25%) or green gram flour (0-25%) in corn-pearl millet base flour was done and resulting flour blends were processed using twin screw extruder (BTPL, India). Feed moisture and feed rate were maintained at 10-18 % and 11-19 kg/hr, respectively. Material was heated to 100-150ºC for 10-20 sec and forced to nozzle where pressure varied from 20-40 atm. Resulted extrudates were cuts into pieces using rotating cutter fixed at nozzle and collected in a trough. Ready-to-eat extrudates were then packed and stored for further analysis (Singh *et al.* 2024).

### *Statistical analysis*

Results have been presented as ± SD. Data analysis was done by one-way analysis of variance through the IBM SPSS Statistics 21. Tukey's test was performed for checking the significance of differences between the mean values ($P$< 0.05).

## RESULTS AND DISCUSSION

### *Analytical results of cereals and pulses flours*

Nutritional profile of cereals and pulses flours is represented in Table 1. Pearlmillet flour was found nutritionally dense as compared to corn flour, thus, making it desirable for its inclusion in corn-based extruded snacks. Corn comprised of 11.2g protein 2.2g crudefat, 1.5g ash, 2.4g crude fibre and 82.7g carbohydrates per 100g, which are in agreement with results reported earlier (Singh 2006). Pearlmillet contained 13.8g protein, 4.6g fat, 2.5g ash and 1.5g fibre per 100g which are consistent with earlier finding (Pan *et al.* 1998). Phytic acid is storage form of phosphorus contributing 1-5% to weight of phosphorus available in cereals, legumes, oil seeds, and nuts (Wang *et al.* 2002). It is considered as an anti-nutrient due to its ability to form chelate with other micronutrients present in food, thereby, hindering their absorbance and bioavailability (USDA 2019). Phytic acid content of corn and pearl millet was 179 and 140 mg/100g, respectively. Polyphenols may be responsible for bitterness, astringency, color, flavor, odor and oxidative stability of foods. A polyphenol-rich diet can significantly slow the onset and progression of a number of chronic pathological illnesses including cancer, diabetes, cardiovascular disease, and aging (Britton and Hornero-Méndez 1997). Polyphenol content of corn and pearlmillet was 62 and 79.4 mg/100g, respectively. Carotenoids, molecules of lipophilic nature contribute to yellow, orange, and red colors to foods. Cereals have lower levels of carotenoids than fruits and vegetables. Yellow-genotype corn (*Zea mays*) may be named as the grain with the highest concentrations (up to 6.3 mg/100g) of these phytochemicals (Moros *et al.* 2002, Ikeda *et al.* 2006). Total carotenoid content of corn was found to be1.97mg/100g. Cereals and their derivatives are considered to be good dietary sources of several minerals. Iron and zinc content of corn flour was 2.6 and 0.9 mg/100g, respectively. While iron and zinc content of pearlmillet flour was 8.1 and 2.2 mg/100g, respectively which is higher than that in corn flour. Thereby, incorporation of pearl millet will also enhance these minerals in snacks. Ikeda *et al.* observed 4.46 and 2.70 mg/100g iron and zinc in corn flour, respectively (Ikeda *et al.* 2006). Though, Nambiar *et al.* (2011) found 8.0 and 3.1 mg/100g iron and zinc in pearlmillet flour, respectively. Dietary fibres are defined as "carbohydrates with a degree of polymerization of 3 or more that naturally occur in foods of plant origin and that are not digested and absorbed by the small intestine". Cereals are among good sources of dietary fibres (www.canada.ca accessed on 28 July 2023). Total dietary fibre content of corn and pearl millet was 9.8 and 16.4 g/100g, respectively. Prasadi and Joye reported that dietary fibre of corn grains varies from 3.7% to 19.9% (Pasandi and Joye 2020). Results of corn flour are also consistent with the report presented by USDA (USDA 2019). Therefore, substitution of corn flour with pearl millet flour will result in a product with higher nutritional value.

Kidney bean flour contained 21.5g protein, 2.3g fat, 2.5g ash and 2.5g fibre. Hiran *et al.* (2011) also reported 21.68g protein, 1.74g fat, 4.96g ash and 2.34g fibre in kidney bean flour. Variation in proximate composition might be due to difference in varieties used and other climatic factors. Green gram flour contained 22.7g protein, 1.8g fat, 2.5g ash, 4.1g fibre. Similar values were observed earlier (Banerjee and Chakraborty 2009). Phytic acid and polyphenol were about two times higher in kidney bean flour in comparison with that in green gram flour. Khattab and Arntfield observed phyticacid and polyphenol content in various varieties of kidney bean in the range of 1158-1188 and 2666-6709mg/100g, respectively (Khattab and Arnfield 2009). Green gram had higher amount of Fe and Zn as compared to that in kidney bean flour while total dietary fibre was found higher in kidney bean flour. Results indicate that pearl millet and green gram are more nutritious than corn and kidney bean, respectively.

### *Pasting characteristics of flour blends*

Results of these characters are presented in Fig. 1. RVA is a useful tool for assessing the viscosity

**Table 1**. Analytical results of cereals and pulses flours per 100g

| Parameter | Corn flour | Pearlmillet flour | Kidney bean flour | Green gram flour |
|---|---|---|---|---|
| Crude protein, g | 11.2±0.25$^{a}$ | 13.8±0.5$^{b}$ | 21.5±0.05$^{c}$ | 22.7±0.15$^{d}$ |
| Crude fat, g | 2.2±0.25$^{a}$ | 4.6±0.04$^{b}$ | 2.3±0.25$^{a}$ | 1.8±0.2$^{a}$ |
| Ash, g | 1.5±0.03$^{a}$ | 2.5±0.04$^{b}$ | 2.5±0.03$^{b}$ | 3.6±0.4$^{c}$ |
| Total dietary fibre, g | 9.8±0.5$^{a}$ | 16.4±1.2$^{b}$ | 16.5±0.3$^{b}$ | 14.8±0.2$^{b}$ |
| Crude fibre, g | 2.4±0.25$^{b}$ | 1.5±0.01$^{a}$ | 2.5±0.1$^{b}$ | 4.1±0.1$^{c}$ |
| Carbohydrate, g | 82.7±0.20$^{d}$ | 77.6±0.2$^{c}$ | 71.2±0.12$^{b}$ | 67.8±1.4$^{a}$ |
| Energy, kcal | 395.4±4.05$^{bc}$ | 407.0±2.44$^{c}$ | 391.5±2.93$^{b}$ | 378.2±8.0$^{a}$ |
| Phyticacid, mg | 179.0±1.2$^{b}$ | 140.0±0.5$^{a}$ | 1120.0±1.2$^{d}$ | 580.0±2.0$^{c}$ |
| Polyphenols, mg | 62.0±0.05$^{a}$ | 79.4±0.1$^{b}$ | 4300.0±1.1$^{d}$ | 420.0±0.5$^{c}$ |
| Iron, mg | 2.6±0.1$^{a}$ | 8.1±0.5$^{d}$ | 4.2±0.2$^{b}$ | 7.2±0.4$^{c}$ |
| Zn, mg | 0.9±0.4$^{a}$ | 2.2±0.15$^{bc}$ | 1.8±0.02$^{b}$ | 2.6±0.3$^{c}$ |

Values are mean±SD of three replicates. Different superscript letters in same row are significantly ($p<0.05$) different.

**Table 2.** Effect of pulses flours on flour blends and end-product quality

| Pulses | Level (%) | Water Absorption (%) | $R_M$ (kg) | E | Bulk density (g/cc) | Expansion Ratio | Sectional Expansion Index | Hardness (kg) | Overall acceptability* |
|---|---|---|---|---|---|---|---|---|---|
| **Kidney bean flour** | 0 | 58.5±0.3$^{a}$ | 0.0163±0.0002$^{d}$ | 19.04±0.02$^{c}$ | 0.056±0.001$^{a}$ | 3.83±0.02$^{e}$ | 14.55±0.20$^{e}$ | 5.76±0.08$^{a}$ | 8.3±0.20$^{d}$ |
| | 5 | 58.5±0.4$^{a}$ | 0.0161±0.0002$^{cd}$ | 18.84±0.02$^{bc}$ | 0.063±0.001$^{b}$ | 3.63±0.04$^{d}$ | 13.15±0.31$^{d}$ | 6.18±0.06$^{ab}$ | 8.3±0.30$^{cd}$ |
| | 10 | 59.5±0.2$^{b}$ | 0.0156±0.0002$^{bc}$ | 18.76±0.02$^{abc}$ | 0.067±0.001$^{c}$ | 3.53±0.04$^{d}$ | 12.46±0.31$^{d}$ | 6.68±0.01$^{bc}$ | 7.9±0.02$^{cd}$ |
| | 15 | 60.5±0.2$^{c}$ | 0.0150±0.0010$^{b}$ | 18.76±0.03$^{abc}$ | 0.070±0.001$^{c}$ | 3.35±0.05$^{c}$ | 11.22±0.32$^{c}$ | 6.84±0.02$^{c}$ | 7.8±0.01$^{c}$ |
| | 20 | 61.0±1.0$^{c}$ | 0.0140±0.0000$^{a}$ | 18.41±0.05$^{ab}$ | 0.077±0.001$^{d}$ | 3.19±0.05$^{b}$ | 10.15±0.32$^{b}$ | 7.30±0.00$^{d}$ | 7.4±0.35$^{b}$ |
| | 25 | 62.5±0.5$^{d}$ | 0.0138±0.0000$^{a}$ | 18.37±0.10$^{a}$ | 0.079±0.002$^{e}$ | 2.81±0.02$^{a}$ | 7.89±0.14$^{a}$ | 8.31±0.01$^{e}$ | 6.6±0.40$^{a}$ |
| **Green gram flour** | 0 | 58.5±0.3$^{a}$ | 0.0163±0.0000$^{d}$ | 19.04±0.10$^{c}$ | 0.056±0.001$^{a}$ | 3.83±0.02$^{e}$ | 14.55±0.20$^{e}$ | 5.76±0.08$^{a}$ | 8.3±0.01$^{d}$ |
| | 5 | 58.5±0.3$^{a}$ | 0.0152±0.0000$^{cd}$ | 18.94±0.20$^{bc}$ | 0.066±0.001$^{b}$ | 3.46±0.01$^{d}$ | 11.99±0.10$^{d}$ | 6.13±0.02$^{ab}$ | 7.9±0.03$^{cd}$ |
| | 10 | 59.5±0.4$^{b}$ | 0.0151±0.0001$^{bc}$ | 18.85±0.35$^{abc}$ | 0.074±0.001$^{c}$ | 3.27±0.04$^{d}$ | 10.69±0.30$^{d}$ | 6.54±0.02$^{bc}$ | 8.1±0.20$^{cd}$ |
| | 15 | 60.5±0.3$^{c}$ | 0.0145±0.0001$^{b}$ | 18.77±0.05$^{abc}$ | 0.078±0.001$^{c}$ | 2.96±0.05$^{c}$ | 8.76±0.30$^{c}$ | 7.89±0.00$^{c}$ | 7.7±0.12$^{c}$ |
| | 20 | 61.0±1.0$^{c}$ | 0.0127±0.0001$^{a}$ | 18.77±0.40$^{ab}$ | 0.082±0.002$^{d}$ | 2.69±0.06$^{b}$ | 7.26±0.31$^{b}$ | 9.14±0.02$^{d}$ | 6.3±0.08$^{b}$ |
| | **25** | **62.5±0.5$^{D}$** | **0.0122±0.0000$^{A}$** | **18.60±0.40$^{A}$** | **0.095±0.002$^{E}$** | **2.54±0.05$^{A}$** | **6.44±0.23$^{A}$** | **9.95±0.03$^{E}$** | **6.0±0.12$^{A}$** |

$R_M$ represents Resistance to extension, i.e., maximum force represent Extensibility, i.e., distance at maximum force. Values are mean±S.D. of three replicates (*eight replicates). Different superscript letters in same column are significantly ($p<0.05$) difference

of food samples and for establishing correlation between functionality and structural characteristics. Peak, trough, breakdown, final viscosity and set back viscosity of control sample was 1004, 751, 253, 2019 and 1268cP, respectively. With increase in level of kidney bean flour, peak, trough, breakdown, final and setback viscosities decreased significantly however no significant differences in peak time, pasting temperature and gelatinization temperature were observed. The possible reason behind the reduction in pasting characteristics might be the dilution of cereal starch with complex carbohydrates of pulse flours and nature of legume starches (Krishnan and Meera 2018). Higher protein level in legumes can inhibit the swelling of starch granulethereby reducing the viscosity (Hamid *et al.* 2015).

**Table 3.** Nutritional information of RTE extruded snacks per 100g

| Parameter | Control | C | B |
|---|---|---|---|
| Protein, g | 11.80±0.06$^{a}$ | 13.44±0.09$^{c}$ | 12.95±0.12$^{b}$ |
| Fat, g | 2.82±0.09$^{a}$ | 2.84±0.46$^{a}$ | 2.62±0.22$^{a}$ |
| Moisture, g | 2.83±0.92$^{a}$ | 2.42±0.49$^{a}$ | 2.96±0.84$^{a}$ |
| Ash, g | 1.80±0.18$^{a}$ | 1.83±0.13$^{a}$ | 2.12±0.08$^{a}$ |
| Crudefibre, g | 1.87±0.11$^{ab}$ | 1.62±0.21$^{a}$ | 2.28±0.18$^{b}$ |
| Carbohydrate, g | 80.42±0.30$^{a}$ | 79.47±0.36$^{a}$ | 79.35±0.78$^{a}$ |
| Energy, kcal | 394.23±1.78$^{a}$ | 397.20±4.56$^{a}$ | 385.29±8.86$^{a}$ |
| Total dietary fibre, g | 11.60±0.53$^{a}$ | 11.69±1.15$^{a}$ | 11.54±0.03$^{a}$ |
| Totalcarotenoids, mg | 0.83±0.06$^{a}$ | 0.86±0.47$^{a}$ | 0.89±0.06$^{a}$ |
| Minerals | | | |
| Fe, mg | 3.31±0.13$^{a}$ | 3.41±0.10$^{a}$ | 3.40±0.04$^{a}$ |
| Zn, mg | 1.30±0.01$^{a}$ | 1.40±0.16$^{a}$ | 1.51±0.11$^{a}$ |
| Antinutritionalfactors | | | |
| Phyticacid, mg | 57.28±0.21$^{a}$ | 84.97±0.48$^{c}$ | 62.96±0.19$^{b}$ |
| Polyphenols, mg | 14.19±0.17$^{a}$ | 62.81±1.17$^{c}$ | 34.87±0.50$^{b}$ |

Control-Corn: pearlmillet (70:30), C-sample having 15% kidney bean flour, B- sample having 10% green gram flour. Values are mean± S.D of three replicates. Different superscript letters in same row are significantly ($p<0.05$) different.

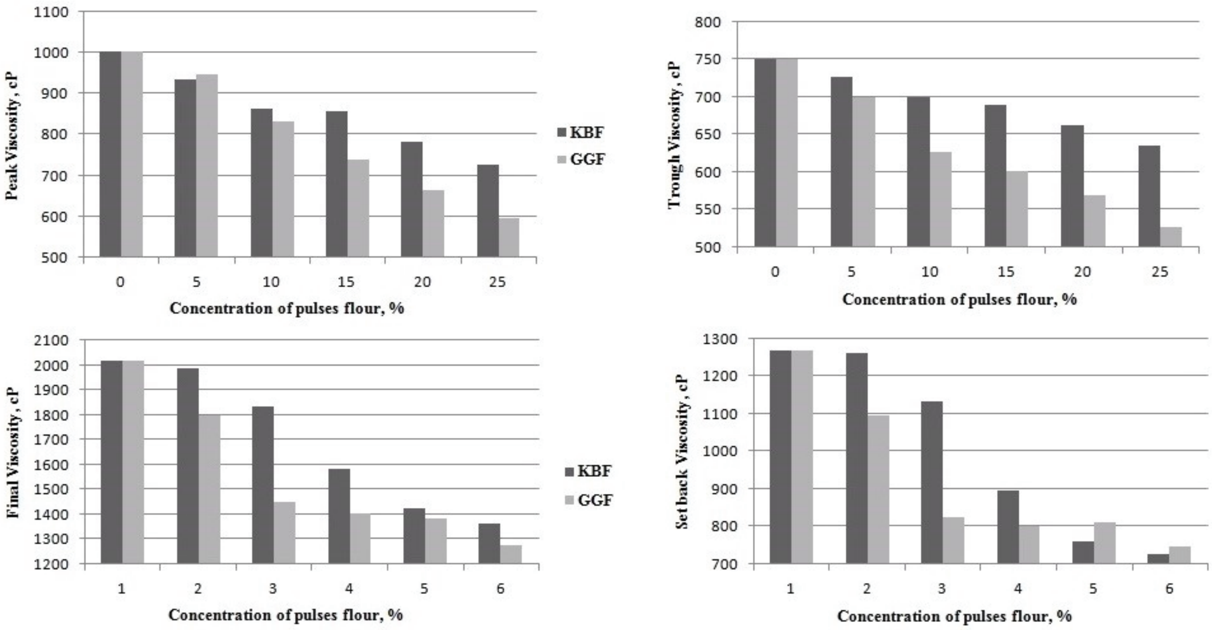


**Fig. 1.** Effect of addition of kidney bean flour (KBF) and green gram flour (GGF) on the pasting characteristics of corn-pearl millet (70:30) flour.


**Fig. 2.** Representation of extruded product where Control- Corn: pearlmillet (70:30), C-sample having 15% kidney bean flour, B- sample having 10% green gram flour.

***Water absorption and dough extensibility of flour blend***

The effects of pulse flour on flour blends and its end-product quality are summarized in Table 2. $R_M$ represents resistance to extension, i.e., maximum force E represents extensibility, i.e., distance at maximum force. Water absorption of control sample was 58.5%. With increasing addition of kidney bean flour, water absorption increased gradually, however, significant increase was noticed at and above 15%. Similar results regarding water absorption were observed with the incorporation of green gram flour (5, 10, 15, 20 and 25%). Force required to break dough and distance at maximum force of control sample were 0.0163 kg and 19.04 mm, respectively. A significant decline in the force required to break dough was observed with every 5% increment in pulses flours. While no significant change in the distance at maximum force of dough was observed after adding either kidney bean or green gram flour. Results indicate that with the incorporation of different pulses flours, dough had less resistance to extension and no change in extensibility was seen. The reason for this decline is the dilution of gluten starch network as nature of pulse protein differs from that of cereal protein. Coțovanu and Mironeasa (2021) also observed the decline in wheat dough extensibility when the percentage of amaranth flour and its particle was increased from 5% to 20%. Dilution of the gluten network due to increase in proportion of amaranth flour possible reason as stated by the researchers.

***Physical properties of extruded snacks***

Physical properties play an important role in selecting extruded food for a particular application. End-product quality parameters such as bulk density, expansion ratio, sectional expansion index, hardnessare presented in Table 2. Degree of expansion or puffing in the extruded food is indicated by bulk density. Expansion is also an important physical aspect for extrudates greatly influencing consumer acceptability (Asare *et al.* 2004). Hardness is the peak force required for a probe to break the extruded snacks. The higher the value of maximum peak force required, higher will be the hardness of snacks. The bulk density, expansion ratio, sectional expansion index and hardness of control extrudates were 0.056g/cc,3.83, 14.55 and 4.08kg, respectively. With every 5% increase in level of kidney bean flour; bulk density and hardness were increased significantly whereas expansion ratio and sectional expansion index were found to be reduced significantly. Similar pattern in bulk density, expansion ratio, sectional expansion index and hardness of extrudates was observed when green gram flour (5, 10, 15, 20 and 25%) was used. Similar results have been reported by Anton *et al.* (2009) who assessed the physicaland nutritional effects of use of common beans in corn starch based extruded snacks. Reduced corn starch and increased protein and fibres after pulse flour use may be the cause for lower expansion. Interaction between these components and starch resulted in the products with lower expansion (Brennan *et al.* 2008). Higher protein leads to less expansion (Lakshmi *et al.* 2012). When soybean and green gram were experimented for formulating cereal-based extrudates, slight decline in the expansion ratio and an increase in volume with every 5% increase in the level of density and hardness with protein inclusion and additional pulses were observed which resulted in a stiff structure and greater resistance to shearing (Sreerama *et al.* 2008).

***Overall acceptability of extruded snacks***

Overall acceptability of extruded snacks is presented in Table 2. Average scores of colour and appearance, taste, aroma, texture and overall acceptability of control RTE extruded snacks were 8.0, 8.5, 8.5, 8.0 and 8.3, respectively. With the incorporation of kidney bean flour up to 10%, no significant change in any of the sensory attributeswas observed. Further increasing the level of kidney bean flour decreased the average scores for texture and taste. Thereby, overall acceptability was found to be decreased. Therefore, extrudates containing 20% kidney bean flour were adjudged by the sensory panelists. Similarly, Agathian *et al.* (2015) developed an optimized formula of extruded snacks with kidney bean flour where overall acceptability was 8.4 with 11.73% of kidney bean flour, on the contrary, it decreases to 6.1 hedonic score when snack was formulated with 68% of kidney bean flour. Thus, it was deduced that increasing percentage of kidney bean flour results in the decline of overall acceptability of developed extruded snacks.

With the incorporation of green gram flour up to 10%, no significant change in any of sensory attributes except color and appearance was witnessed. A furtherrise in level of green gram flour reduced scores for taste, aroma and texture. Thereby, overall acceptability was found to be decreased. Extrudates containing 15% GGF were adjudged by the judges. Therefore, to prepare value added RTE extruded snacks, the formulation 70:30 (corn: pearlmillet) containing 15% kidney bean or 10% green gram flour were found better for attaining quality extrudates.

***Nutritional information of extruded snacks***

The nutritional profile of extruded snacks are summarized in Table 3. As compared to control sample, incorporation of pulses flour either kidney bean or green gram, increased protein content and phytic acid and polyphenol levels in the resulted products. Availability of higher concentration of these compounds is due to the addition of pulses with anti-nutrients. While, comparing kidney bean and green gram extrudates, RTE extruded snacks having green gram or mung bean were found more nutritious because these have less anti-nutrients than snacks containing kidney bean flour. Apart from being rich source of protein, vitamins, minerals and dietary fibers, green gram also contains appreciable amount of galactooligosaccarides considered as prebiotics (Mekkaranikarthil *et al.* 2021). In addition to being a healthy diet, green gram has significant beneficial effects such antioxidant, antiinflammatory, anti-cancer, and hypolipidemic actions (Pastor-Cavada *et al.* 2011), thus serving as a potential nutraceutical in the diet.

## CONCLUSION

In conclusion, pulses can be the potential ingredient to develop protein-rich extruded snacks. However, to consider its anti-nutritional factors and sensory impact on end-product, it was manifested that kidney bean flour up to 15% or green gram flour up to 10% can only be incorporated in extruded snacks made from blend of corn and pearlmillet flour. While green gram is highly recommended due to its less anti-nutrients as compared to kidney bean. Though, effects of incorporation of some vegetables or pre-treatments of pulses on quality of snacks can be further investigated.

## DISCLOSURE OF INTEREST

The authors report there are no competing interests to declare.

## REFERENCES


AACC. 1995. Approved methods of AACC. American Association of Cereal Chemists, Ed. St. Paul,MN. J.M. Harper,CRCPress, Boca Raton. Florida, USA, Pp 5-28.

Agathian G, Semwal AD, and Sharma GK. 2015. Optimization of barrel temperature and kidney bean flour percentage based on various physical properties of extruded snacks. Journal of food science and technology **52**: 4113-4123.

Ainsworth PI, Banoglu S, Plunkett AI, Banoglu E, Stojceska V. 2007. Effect of brewers spent grain addition and screw speed on the selected physical and nutritional properties of an extruded snack. J Food Eng **81**(4): 702-709

Alvarez-Martinez L, Kondury KP and Harper JM. 1988. A General Model for Expansion of Extruded Products. Journal of Food Science **53**(2): 609-615.

Anton AA, Fulcher RG and Arntfied SD. 2009. Physical and nutritional impact of fortification ofcorn–starch based extruded snacks with common beans (*Phaseolus vulgaris*) flour: Effect of bean addition and extrusion cooking. Cereal Chem **113**: 989-996.

AOAC. 1980. Official Methods of Analysis. Association of Official Analytical Chemists, Washington, D.C. USA.

AOAC. 1995. Official methods of analysis 15thEdn. Association of official Analytical Chemist Washing, D.C.

Asare EK, Sefa-Dedeh S, Sakyi-Dawson E and Afoakwa EO. 2004. Application of response surface methodology for studying the product characteristics of extruded rice-cowpea-groundnut blends. International Journal of Food Sciences and Nutrition **55**: 431-439.

Awolu OO, Omoba OS, Olawoye O and Dairo M. 2017. Optimization of production and quality evaluation of maize-based snack supplemented with soybean and tiger-nut (*Cyperus esculenta*) flour. Food Science and Nutrition **5**(1): 3-13.

Banerjee S and Chakraborty P. 2009. Optimization of extrusion process for production of expanded products from green gram and rice a response surface methodology. J Scientific and Industrial Research **68**: 140-148.

Brennan MA, Monro JA and Brennan CS. 2008. Effect of inclusion of soluble and insoluble fibres into extruded breakfast cereal products made with reverse screw configuration. Int J Food Sci and Technol **43**: 2278-2288.

Britton G and Hornero-Mendez D. 1997. Carotenoids and colour in fruit and vegetables. In: Tomás-Barberán, F.A., Robins, R.J. (eds). Phytochemistry of fruit and vegetables, Clarendon Press, Oxford, Pp 11–27.

Coțovanu I and Mironeasa S. 2021. Impact of different amaranth particle sizes addition level on wheat flour dough rheology and bread features. Foods **10**(7): 1539.

Dinelli G, Bonetti A, Minelli M, Marotti I, Catizone P and Mazzanti A. 2006. Content of flavonols in Italian be (*Phaseolus vulgaris* L.) ecotypes. FoodChem. **99**(1): 105-114.

Fuller DQ, Korisettar R and Venkatasubbaiah, PC. 2001. Southern Neolithic cultivation systems: a reconstruction based on archaeobotanical evidence. South Asian Studies **17**(1): 171–187

Guzman-Ortiz FA, Hernandez-Sánchez H, Yee-Madeira H, San Martín-Martínez S, Robles-Ramírez MC and Rojas-López M. 2014. Physico-chemical, nutritional and infrared spectroscopy evaluation of an optimized soybean/corn flour extrudate. Journal of Food Science and Technology **52**(7): 4066–4077.

Hamid S, Muzaffar S, Wani IA and Masoodi FA. 2015. Physicochemical and functional properties of two cowpea cultivars grown in temperate Indian climate. Cogent Food & Agriculture **1**: 1-11.

Harper JM. 1981. Extrusion of Foods, vol. 1, CRC Press, Boca Raton, Pp 1-19.

Haug W and Lantzsch HJ. 1983. Sensitive method for the rapid determination of phytic acid in cereals and cereals products. Journal of the Science of Food and Agriculture **34**: 1423-1426.

Health Canada List of Dietary Fibres Reviewed and Accepted by Health Canada's Food Directorate- Canada.ca. [(accessed on 28 July 2023)]; Available online: https://www.canada.ca/en/health-canada/services/publications/food-nutrition/list-reviewed-accepted-dietary-fibres.html

Hiran P, Kerdchoechuen O and Laohakunjit N. 2011. Change of Nutritional Value and Antioxidant Activity of Fermented Germinated Red Kidney Bean. J Agric Sci **42**(2): 321-324.

Ikeda S, Yamashita Y, Tomurai K and Kreft I. 2006. Nutritional comparison in mineral characteristics between buckwheat and cereals. Fagopyrum **23**: 61-65.

Jing Y and Chi YJ. 2013 Effects of twin-screw extrusion on soluble dietary fibre and physicochemical properties of soybean residue. Food Chem **138**(2-3): 884–889.

Kaur A, Kaur S, Singh M, Singh N, Shevkani K and Singh B. 2015. Effect of banana flour, screw speed and temperature on extrusion behaviour of corn extrudates. J Food Sci Technol **52**(7): 4276–4285.

Khattab RY and Arnfield SD. 2009. Nutritional quality of legume seeds as affected by some physical treatments. J Food Sci Technol **42**: 1113-1118.

Krishnan R and Meera MS. 2018. Pearl Millet Minerals: Effect of Processing on Bioaccessibility. Journal of Food Science and Technology **55**: 3362-3372.

Lakshmi DN, Shobha S, Alavi S, Kalpana K and Soumya M. 2012. Utilization of extrusion technology for the development of millet based complementary foods. Journal of Food Science and Technology **51**(10): 2845–2850.

Leder I. 2004. Sorghum and millets. In: Fuleky G, editor. Cultivated plants, primarily as food sources. Oxford: Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers.

Lin S, Huff HE and Hseih F. 2000. Texture and chemical characteristics of soy protein meat analogextrudate at high moisture. J Food Sci **65**: 264-269.

Lindsey WL and Norwell MA. 1969. A new DPTA-TEA soil test for zinc and iron. Agron. Abstr. **61**: 84-90.

Mekkaranikarthil Sudhakaran S and Bukkan DS. 2021. A review on nutritional composition, antinutritional components and health benefits of green gram (*Vigna radiata* (L.) Wilczek). Journal of Food Biochemistry **45**(6): e13743.

Mindi S and Aluko RE. 2012. Physicochemical and functional properties of kidney bean albumin and globulin protein fractions. Food Research International **48**(1): 299-306.

Moros EE, Darnoko D, Cheryan M, Perkins EG and Jerrell J. 2002 Analysis of xanthophylls in corn by HPLC. J Agric Food Chem **50**: 5787-5790

Nambiar VS, Dhaduk JJ, Sareen N, Shahu T, Shah H and Desai R. 2011. Potential Functional Implications of Pearl millet (*Pennisetum glaucum*) in Health and Disease. Journal of Applied Pharmaceutical Science **1**(10): 62-67.

Pan Z, Zhang S and Jane J. 1998. Effects of extrusion variables and chemicals on the properties of starch-based binders and processing conditions. Cereal Chem **75**: 541-546.

Pandey KB and Rizvi SI. 2009. Plant polyphenols as dietary antioxidants in human health and disease. Oxid Med Cell Longev **2**(5): 270-278.

Pastor-Cavada E, Drago SR, Gonzalez RJ, Juan R, Pastor JE, Alaiz M and Vioque J. 2011 Effects of the addition of wild legumes (*Lathyrus annuus* and *Lathyrus clymenum*) on the physical and nutritional properties of extruded products based on whole corn and brown rice. Food Chem **128**(4): 961-967.

Prasadi NVP and Joye IJ. 2020. Dietary Fibre from Whole Grains and Their Benefits on Metabolic Health. Nutrients **12**(10): 3045.

Rolandelli G, Garcia-Navarro YT, Garcia-Pinilla S, Farroni AE, Gutierrez-Lopez GF and Buera MDP. 2020. Microstructural characteristics and physical properties of corn-based extrudates affected by the addition of millet, sorghum, quinoa and canary seed flour. Food Structure **25**: 100140.

Saini CS. 2015. Preparation of corn flour based extruded product and evaluate its physical characteristics. Int J Food Sci Nutr **9**(8): 934-941.

Sharma R, Sharma S, Makroo HA and Dar BN. 2022. Role of pulses to modulate the nutritive, bioactive and technological functionality of cereal-based extruded snacks: a review. International Journal of Food Science & Technology **57**(7): 3882-3891.

Singh V. 2006. Development of value added products from Quality Protein Maize. Ph.D. Thesis submitted to CCS, Haryana Agricultural University, Hisar.

Singh Y, Grewal RB, Malik M, Dewan A and Luthra A. 2024. TOPSIS for Selecting Appropriate Combination of Corn and Pearl Millet Flours for Making RTE Extruded Snacks. Annals of Agri-Bio Research **29**(1): 158-162.

Singleton VL and Rossi JA. 1965. Colorimetry of Total Phenolics with Phosphomolybdic-Phosphotungstic Acid Reagent. American Journal of Enology and Viticulture **16**: 144-158.

Sreerama Y, Sasikala VB and Pratape VM. 2008. Nutritional implications and flour functionality of poPped/expanded horse gram. Food Chem **108**: 891-89.

Thavarajah D, Thavarajah P, See CT and Vandenberg A. 2010. Phytic Acid and Fe and Zn Concentration in Lentil (*Lens Culinaris* L.) Seeds Is Influenced by Temperature during Seed Filling Period. Food Chem **122**(1): 254–259.

US Department of Agriculture. 2019. Cereal Grains and Pasta, Food Data Central, Corn Flour. https://fdc.nal.usda.gov/fdc-aPp.html#/food-details/170290/nutrients

Wang J, Rossel CM and Barber CB. 2002. Effect of addition of different fibres on wheat dough performance and bread quality. Foodchem **79**(2): 221-226.