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TOPSIS for Selecting Appropriate Combination of Corn and Pearl Millet Flours for Making RTE Extruded Snacks

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ABSTRACT

The current study aimed at developing ready-to-eat extruded snacks by incorporating pearl millet flour (0-50%) in corn flour. Corn and pearl millet flours were studied for their compositional and nutritional parameters (crude fibre, carotenoid, phytic acid, polyphenols, iron, zinc and total dietary fibre). Different blends of corn and pearl millet flours were made by replacing corn flour up to 50% with pearl millet flour. Evaluation of pasting characteristics of flour blends and physical (bulk density, expansion ratio, sectional expansion index and hardness) and sensory properties of extruded snacks made from different flour blends was carried out/performed. The best combination of corn and pearl millet flour was obtained on applying TOPSIS approach. Extruded snacks made employing best selected flour blend was further analyzed for compositional and nutritional properties. Replacement of 30% of corn flour with pearl millet flour was recommended to obtain quality extruded snacks.

Key words: Extruded, snacks, corn, pearl-millet, TOPSIS technique

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 (Rolandelli *et al.,* 2020). 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 rising in awareness of consumers with respect to nutrition and their willingness to adopt healthy lifestyle. Extrusion cooking is a low-cost, high-temperature, quick processing technique that results in food products with good nutrition (Cuj-Laines *et al.,* 2018). Extrusion process boosts the bioavailability of numerous nutrients while reducing several anti-nutritional factors such tannins, phytate and trypsin inhibitor (Narang *et al.,* 2018). 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 (Shah *et al.,* 2021). Corn flour is the most commonly used ingredient for the development of extruded snacks with a crispy desirable structure (Rolandelli *et al.,* 2020). Compared to other cereals, corn has comparable nutritional components: 28-80% carbohydrate, 9.1-15% protein and 10-15% fiber. Characteristics of corn also favour extrusion process for making snacks which are profoundly relished by children (Karun *et al.,* 2023).

Multigrain, legumes and millets have been employed in the formulation process to increase the nutritional value of corn-based extrudates. Pearl millet (*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 (Karun *et al.*, 2023). Pearl millet contains more oil than maize, due to which is referred to as a "high-energy" grain. 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

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high in nutrients. Methionine and lysine content in pearl millet is 40% higher than in maize (Meena *et al.*, 2022). Incorporation of 25% pearl millet to corn extrudates improved microstructural, nutritional and physico-chemical characteristics of extrudates. Protein, crude fibres and bulk density were increased, while total carbohydrates, hardness and expansion ratio were reduced (Rolandelli *et al.*, 2020).

Multi-criteria decision making (MCDM) is a method in which evaluation of alternatives for the purpose of selection or ranking, using a number of qualitative and quantitative criteria is practised. Technique for order preference by similarity to ideal solution (TOPSIS) is one of the useful MCDM techniques that determine solution alternatives from the positive ideal solution and negative ideal solution and then choosing best alternative (Ozcan and Celik, 2021). Recently Hedayatia *et al.* (2021) used TOPSIS for selecting appropriate hydrocolloids for eggless cakes. They stated that TOPSIS was an effective way to ease comparison and decision. The goal of the current study was to replace corn flour with pearl millet flour for developing ready-to-eat multigrain extruded snacks in order to increase the importance of the underutilized but very nutrient-rich pearl millet. The question was whether the physico-chemical, sensory and nutritional characteristics of produced ready-to-eat extruded snacks were affected.

MATERIALS AND METHODS

Corn (HQPM-I) was procured from the Regional Research Station, Uchani, Karnal. Pearl millet (WHC-901-445) was procured from the Department of Plant Breeding, CCSHAU, Hisar. Grains were cleaned for extraneous matter and flour was prepared by milling the clean grains in Brabander Quardamat Junior Mill.

Raw materials (corn and pearl millet flours) were studied for their compositional and nutritional parameters (crude fibre, carotenoid, phytic acid, polyphenols, iron, zinc and total dietary fibre). Different blends of corn and pearl millet flours were made by replacing corn flour up to 50% with pearl millet flour. Evaluation of pasting characteristics of flour blends and physical (bulk density, expansion ratio, sectional expansion index and hardness) and sensory properties of extruded snacks were made using these different flour blends. The best combination of corn and pearl millet flour was obtained applying TOPSIS approach. Lastly, extruded snacks were made using the best selected corn-pearl millet flour blend were further tested for compositional and nutritional properties.

Crude protein, crude fat, ash, crude fibre, total carbohydrate, total dietary fibre, energy, phytic acid, total polyphenol, iron, zinc, pasting characteristics, bulk density, expansion ratio, sectional expansion ratio, texture, sensory characteristics and total carotenoids were analyzed using standard procedures.

Control sample contained 100% corn flour. Replacement of corn flour was done up to 50% with pearl millet flour 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/h, respectively. Feed was heated to 100-150°C for 10-20 sec and forced to nozzle where pressure varied from 20-40 atm. Resulted extrudates were cut 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. The data were analyzed using ANOVA through CRD.

TOPSIS approach was followed for ranking of different blends of corn and pearl millet flours. So, flour was selected as decision marker. Peak viscosity of flour and expansion, hardness and overall acceptability of RTE extruded snacks were taken as selection criteria. Peak viscosity, expansion and overall acceptability were considered beneficial criteria, while hardness was considered non-beneficial criteria as too much hardness will not be preferred by consumers (Hedayatia *et al.*, 2021).

RESULTS AND DISCUSSION

Pearl millet flour was found nutritionally dense as compared to corn flour making it desirable for amalgamating corn-based extruded snacks. Corn contained 11.2 g protein, 2.2 g crude fat, 1.5 g ash, 2.4 g crude fibre and 82.7 g carbohydrates per 100 g (Table 1). Pearl millet comprised 13.8 g protein, 4.6 g fat, 2.5 g ash and 1.5 g fibre per 100 g. Phytic acid content of corn and pearl millet was 179 and 140 mg/100 g, respectively. Polyphenols may be responsible for bitterness, astringency, colour,

Table 1. Nutritional parameters of corn and pearl millet flours

Parameters/100 g	Corn flour	Pearl millet flour
Crude protein (g)	11.2±0.25	13.8±0.50
Crude fat (g)	2.2±0.25	4.6±0.04
Ash (g)	1.5±0.03	2.5±0.04
Crude fibre (g)	2.4±0.25	1.5±0.01
Carbohydrate (g)	82.7±0.2	77.6±0.2
Energy (kcal)	395	406
Carotenoid (mg)	1.97±0.2	-
Phytic acid (mg)	179.0±1.2	140.0±0.5
Polyphenols (mg)	62.0±0.05	79.4±1.0
Iron (mg)	2.6±0.1	8.1±0.5
Zn (mg)	0.9±0.4	2.2±0.15
TDF (g)	9.8±0.5	16.4±1.2

Corn: HPQM-I, Pearl millet: WHC-901-445 and values represented as mean±SD of three replicates.

flavour, odour and oxidative stability of foods. Polyphenol content of corn and pearl millet was 62 and 79.4 mg/100 g, respectively. Carotenoids, molecules of lipophilic nature contributed to yellow, orange and red colours to foods. Cereals have lower levels of carotenoids than fruits and vegetables. Total carotenoid content in corn was found to be 1.97 mg/100 g. 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/100 g, respectively. While iron and zinc content of pearl millet flour was 8.1 and 2.2 mg/100 g, respectively, which was higher than that in corn flour. Thereby, incorporation of pearl millet enhanced these minerals in snacks. 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”. Total dietary fibre content in corn and pearl millet flour was 9.8 and 16.4 g/100 g, respectively. Therefore, substitution of corn flour with pearl millet flour resulted in a product with higher nutritional value.

RVA is a useful tool for assessing the viscosity of food samples and for establishing correlation between functionality and structural characteristics. The peak, trough, breakdown, set back and final viscosity of corn flour was 822, 788, 34, 1508 and 720 cP, respectively. With every 10% increase in the level of pearl millet flour; peak, breakdown, final and set back viscosities significantly increased; however, no significant difference was noticed in trough viscosity. Peak time, pasting temperature and gelatinization temperature of corn flour was 6.73 min, 76.75°C and 95.15°C, respectively. With the incorporation of pearl millet flour, no significant difference in peak time, pasting temperature and gelatinization temperature was observed (Table 2). Results indicated that higher the percentage of pearl millet flour in the blend higher will be the peak, breakdown, final and set back viscosities with no significant differences in trough viscosity, peak time, gelatinization and pasting temperatures. Amylose content directly affects viscosity. So, this increase in peak, trough, breakdown, set back and final viscosities might be due to higher amylose content in pearl millet flour. Concerning pasting characteristics, Singh *et al.* (2020) also found that combination of corn and pearl millet flour was found suitable for making extrudates.

Physical properties play an important role in selecting extruded food for a particular application. 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 (Jabeen *et al.*, 2022). Starch, being the main component of cereal, plays a

Table 2. Pasting characteristics of corn and pearl millet flour blends

Pasting characteristics	Pearl millet flour (%)						CD at 5% level
	0*	10	20	30	40	50	
Peak viscosity (cP)	822 ±28.34	870±6.9	920±11.3	1004±11.5	1120±23.09	1180±17.32	45.5
Trough viscosity (cP)	788 ± 41	763±11.8	759±4.3	751±5.7	743±6.2	736±6.9	NS
Break down viscosity	34 ±1.41	106±4.2	161±3.2	253±5.7	380±11.8	444±6.2	25.6
Final viscosity (cP)	1508 ±45	1611±14.8	1820±12.3	2019±11.4	2112±21.5	2220±11.4	48.9
Set back viscosity (cP)	720 ±9.40	847±28.4	1061±17.6	1268±5.7	1372±11.4	1484±21.4	63.6
Peak time (min)	6.73 ± 0.0	6.73±0.01	6.84±0.0	6.73±0.01	6.73±0.01	6.84±0.0	NS
Pasting temperature (°C)	76.75±0.0	76.76±0.0	76.75±0.01	76.75±0.01	76.75±0.0	76.84±0.0	NS
Gelatinization temperature (°C)	95.15±0.03	95.20±0.0	95.15±0.01	95.20±0.01	95.20±0.0	95.10±0.0	NS

Values presented as mean±S. D. of three replicates. *100% corn flour. NS–Not Significant.

key role in expansion process (Nagaraju *et al.*, 2020). 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. Bulk density, expansion ratio, sectional expansion index and hardness of control sample were 0.047 g/cc, 4.08, 16.65 and 4.86 kg, respectively (Table 3). Increasing the level of pearl millet flour in corn flour gradually increased bulk density and hardness, while expansion ratio and sectional expansion index were found to be decreased gradually, whereas noticeable change was noticed when used 20-50% pearl millet flour. Expansion properties of pearl millet flour were lower than that of corn due to its higher protein content. Nagaraju *et al.* (2020) also stated that higher protein led to less expansion. Higher amount of pearl millet flour used with corn flour resulted in denser and harder extrudates. So, snacks made using 50% pearl millet flour were denser and harder.

Extrudates prepared from corn flour and by incorporating various levels of pearl millet were assessed for various sensory attributes. 9-point Hedonic scale was used to find the different aspects of sensory evaluation. Mean scores for colour and appearance, taste, aroma, texture and overall acceptability of control ready-to-eat extruded snacks were 9.0, 8.3, 8.5, 8.2 and 8.5, respectively (Table 3). With incorporation of pearl millet flour up to 20%, no significant change in any of the sensory attributes was witnessed. However, increasing the level of pearl millet flour from 30 to 50% in corn flour reduced the average scores for aroma and texture. Thus, overall acceptability was found to be decreased. However, the extrudates containing 30% pearl millet were 'liked very much' to liked 'extremely' by the sensory penalists.

In the current study, suitable level of pearl millet incorporation to corn flour for extruded snacks making were selected on the basis of ranks given by TOPSIS method. It was difficult to select ideal flour blend because of multiple criteria (peak viscosity, expansion ratio, hardness and overall acceptability) affecting quality of extruded snacks. Thus, TOPSIS approach was used for ranking different flour blends. Various distances represented the position of different alternatives for each factor from positive and negative ideal solutions. As per collective responses of panelists, weightage given to peak viscosity, expansion ratio, hardness and overall acceptability was 0.20, 0.30, 0.20 and 0.30, respectively (Table 4). As per distances and proximity of coeficient, top rank was given to 10:90 corn to pearl millet flour blend. However, 100% corn flour got 2nd rank. Keeping in view the nutritional value as well as quality of product, flour blend attaining 4th rank was suggested to use for obtaining healthy and quality extruded snacks.

Table 4. Ranking of flour blends as given by TOPSIS

Level of supplementation (%)	di+	di-	C	Ranks
Pearl millet				
0*	0.0294	0.0469	1.6431	2
10	0.0441	0.2103	4.9737	1
20	0.2125	0.2125	1.2125	3
30	0.2118	0.2118	1.2118	4
40	0.2064	0.2064	1.2064	5
50	0.1962	0.1962	1.1962	6

*100% corn flour.

Control RTE extruded snacks contained 10.9, 2.1, 1.3 and 2.0 protein, fat, ash and fibre per 100 g, respectively (Table 5). Extruded snacks made from composite flour (corn:pearl millet 70:30) had higher fat, protein and ash contents in comparison with that of control. Control RTE

Table 3. Physical and sensory properties of RTE extruded snacks made by using corn and pearl millet flour blends

Level of supplementation (%)		Bulk density (g/cc)	Expansion ratio	Sectional expansion index	Hardness (kg)	Colour and appearance	Taste	Aroma	Texture	Overall acceptability
Pearl millet	0*	0.047±0.003	4.08±0.04	16.65±0.4	4.86±0.05	9.0±0.04	8.3±0.00	8.5±0.20	8.2±0.00	8.5±0.20
	10	0.050±0.001	4.00±0.07	16.00±0.5	4.90±0.10	8.5±0.40	8.3±0.25	8.5±0.02	8.2±0.18	8.4±0.14
	20	0.054±0.001	3.93±0.07	15.45±0.5	5.67±0.02	8.2±0.00	8.0±0.05	8.5±0.15	8.0±0.20	8.2±0.20
	30	0.056±0.01	3.83±0.02	14.55±0.20	5.76±0.05	8.2±0.27	8.0±0.15	8.0±0.15	7.9±0.00	8.0±0.20
	40	0.058±0.00	3.62±0.07	13.10±0.5	6.18±0.50	6.3±0.20	8.0±0.12	7.8±0.20	6.2±0.20	7.1±0.15
	50	0.060±0.004	3.09±0.04	9.55±0.2	6.20±0.01	6.2±0.21	6.6±0.05	7.5±0.21	6.0±0.25	6.7±0.20
C. D. (P=0.05)		0.006	0.144	1.24	0.23		0.63	0.46	0.50	0.45

*100% corn flour.

extruded snacks contained 2.3 and 0.8 mg/ 100 g iron and zinc, respectively. Similarly, snacks made from composite flour contained higher TDF, iron and zinc content as compared to control. Therefore, use of pearl millet is highly recommended for enhancing the nutritional value.

Table 5. Nutritional information of RTE extruded snacks

Parameters	Control	Corn:pearl millet (70:30)
Protein (g)	10.9±0.25	11.8±0.05
Fat (g)	2.1±0.25	2.8±0.10
Ash (g)	1.3±0.03	1.8±0.30
Crude fibre (g)	2.0±0.25	1.9±0.10
Carbohydrate (g)	83.7±0.20	81.7±0.50
Energy (kcal)	399	399
Total carotenoids (mg)	0.96±0.03	0.83±0.05
TDF (g)	9.3±0.25	11.6±0.50
Minerals		
Fe (mg)	2.3±0.14	3.3±0.10
Zn (mg)	0.8±0.40	1.3±0.01
Antinutritional factors		
Phytic acid (mg)	54.0±0.25	57.3±0.20
Polyphenols (mg)	2.3±0.20	14.2±0.15

Values represented as mean±S. D. of three replicates. Control: 100% corn.

CONCLUSION

Pearl millet can be processed and used up to 30% in corn flour for preparation of good quality acceptable RTE snacks. Overall acceptability of snacks was reduced above 30% incorporation level of pearl millet flour. As per TOPSIS ranks, it was also verified that replacing 30% corn flour with pearl millet flour might be beneficial for preparing nutritionally superior value-added ready-to-eat extruded snacks.

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