Original Research Article

Development of Ready to Cook (RTC) Pasta and vermicelli from Kodo millet *(Paspalumscorbiculatum)* using Cold ExtrusionTechnology

Abstract

Pasta and vermicelli products are in high demand worldwide and serve as effective carriers for delivering nutrition. This study focused on developing pasta and vermicelli using kodo millet and whole wheat flour, by investigating four different formulations. Based on cooking and sensory attributes, the pasta and vermicelli were optimised.With cold extrudates containing 60% ofkodo millet flour and 40% of whole wheat flour (T_4) showed superior characteristics compared to other treatments. The optimised cold extruded products were analysed forphysico-chemical and proximate according to Deshpande and Poshadri (2011), Launay and Lisch (1983), Anderson (1982), AOAC (1980) respectively and 9-point hedonic scale was used to adjudge the sensory characteristicsand also studied cooking characteristics according to standard methodologies.In which they (both pasta and vermicelli) showed similar (on far) physico-functional characteristics. The optimised pasta and vermicelli were then stored in metallized polyester pouches (50 µm thickness) under ambient conditions for three months. During this storage period, parameters such as moisture content and sensory attributes were monitored at 15-day intervals to assess the stability of the cold extruded products. The study provides valuable insights into the development and storage stability of nutritious pasta and vermicelli products made from kodo millet and whole wheat flour.

Keywords: Cooking parameters, moisture content, sensory attributes, storage period

Introduction

Millets are considered ancient grains, domesticated thousands of years ago at the dawn of human history. Some evidence points to the cultivation of millets around 4000 years ago. (Shahidi and Chandrasekara, 2013). Millets, often referred to as “minor cereals”, hold the position of the world’s sixth most important cereal grain (Das *et al*., 2019; Sarita and Singh, 2016). Alongside maize, sorghum, oatsand barley, millets are categorized under “coarse cereals”. Despite accounting for only2% of global cereal production, an overwhelming 95% of the world’s millet production is concentrated in Asia and Africa (FAO, 2018).

Now a days millet grains are becoming more prevalent among food processors, technologistsand nutritionists. Previously regarded as alow-cost food, it is now a popular choice for health-conscious among individuals. One of such ancient millet grains is kodo millet, originally from tropical Africa, is thought to have been cultivated in India some 3000 years ago (de Wet *et al.*, 1983).

Kodo millet (*Paspalumscorbiculatum*)is also known as Indian crown grass, nativepaspalum, ditch millet, or rice grass.In India, it is also known as Kodra or Varagu. Millets are grown in several countries, including India, Pakistan,Philippines, Indonesia, Vietnam, Thailandand West Africa. It is the primary food source for Gujarat’s Deccan Plateau. Kodo millet is mostly produced in India’s Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Bihar, Maharashtra, Gujaratand Orissa (Chouhan*et al.*, 2019).

Kodo millet is notable for its high protein content, comprising 8% of the grain (Sudharshana *et al.*, 1988). This millet contains a significant amount of glutelin protein. In terms of dietary fibre, kodo millet excels with a 9% fibre content, significantly higher than the 0.2% fibre found in both wheat and rice. Additionally, kodo millet is rich in carbohydrates and calories, offering 63.6 grams of carbohydrates and 353 calories per 100 grams of grain. The fat content stands at 1.4%, while the mineral content is 2.6%. Iron concentrations in kodo millet range from 25.86 ppm to 39.60 ppm,and it has the lowest phosphorus content among millets(Ranjan*et al.*, 2023).

The food industry has begun to employ extrusion cooking technology, a high-temperature short-time (HTST) process, to develop new products like breakfast cereals, dietary fibre, cereal-based snacksand modified starch from cereals. This HTST approach removes microbial contamination and deactivates enzymes. The principal preservation strategy for both hot and cold extruded foods is based on the product’s low water activity, which ranges from 0.1 to 0.4(Navale*et al.*, 2015).

Pasta, a traditional food item within the Italian diet, is now globally consumed, becoming animportantsourceof complex carbohydrates(*i.e.*, starch)in many countries(https://internationalpasta.org/). Due to their taste and ease of preparation, pasta and vermicelli are becoming increasingly popular both globally and in India. These common cereal-based foods are made from dough or flour that has been moistened and formed into various shapes such as spaghetti, macaroniand vermicelli. With rising health consciousness among individuals, there is a growing preference for cold extruded products that are nutritious, high in fibre, rich in essential micronutrients, and have a low glycaemic index.

Considering the growing demand for ready-to-cook (RTC) products and the necessity to develop value-added products, this investigation focused on developing pasta and vermicelli using kodo millet flour and whole wheat flour. The primary objective of this experiment was to develop pasta and vermicelli with enhanced nutritional value through the incorporation of kodo millet and whole wheat flours and to assess their cooking, sensory and nutritional characteristics.

Materials and methods

Raw material

The kodo millet rice used in this study were sourced directly from the Regional Cooperative Organic Farmer's Association Federation Limited, Davanagere, Karnataka, India. Other ingredients, such as whole wheat flour, sunflower oil, vegetables, pasta masala mix and salt, were procured from local supermarkets from Bengaluru.

Preparation of kodo millet rice flour

A domestic grain pulveriser was used for milling kodo millet rice into fine flour. The pulveriser was made up of entirely stainless steel and had detachable sieves that made it easier to process raw materials into appropriate-sized flour. The pulverised flour was then manually milled to a uniform particle size with a kitchen grinder before being sieved through a BS 44 mesh sieve and stored in airtight pouches. This flour was primarily utilised for developing cold-extruded products.

Formulation of kodo millet and whole wheat flour blends for pasta and vermicelli production

Composite blends were initially prepared by combining various proportions of kodo millet flourand whole wheat flour to develop pasta and vermicelli products. A formulation consisting of 100% wheat flour served as the control. The detailed formulations for the preparation of the pasta and vermicelli products are presented in Table 1.

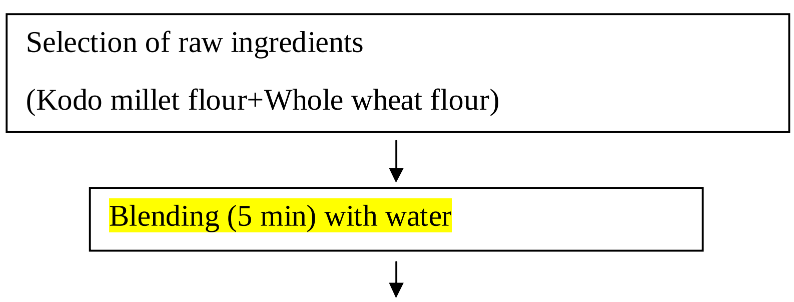
Development of cold extruded products from kodo millet rice flour and whole wheat flour

The development of cold extruded pasta and vermicelli products primarily involved formulating an appropriate flour mix of composite blends containing kodo millet flour and whole wheat flour. The blended mixes, adjusted to the appropriate moisture content, were initially extruded using a Kent noodle and pasta maker machine (model no: 16009) for preliminary tests. The optimized pasta product was subsequently extruded using a laboratory model pasta-making machine (make: La Monferrina, Italy; model: P12).The sieved flours of kodo millet rice flour (BS 44 mesh size) were blended in the extruder for 5 minutes and then kneaded for approximately 45 minutes with the addition of the required amount of water. Once the dough reached optimal characteristics, it was extruded using appropriate dies to form various shapes. The cutter speed was adjusted to the optimal level for each specific shape. The extrudates were cooked at 0.5 kg/cm^2 for 5 minutes, followed by drying in a domestic dehydrator at 50°C for approximately for 3-5 hours. The dried pasta and vermicelli were then packed in metallized polyester pouches(MPP) (50 µm), heat-sealedand stored under ambient conditions. All initial product development studies were conducted under constant extruder operating conditions according to Sudha, 2012. The complete flow chart for the production of millet-based cold extruded ready-to-cook pasta and vermicelli is provided in Fig. 1.

Table 1. Formulations used for the preparation kodo millet based cold extrudates

Formulations	**Level of flours in composite blend (KM + WWF)**		**Composite blend (%)**	**Water (mL/kg)**
	KM (%)	**WWF (%)**		
Control	0	100	100	450
T_1	90	10	100	450
T_2	80	20	100	450
T_3	70	30	100	450
T_4	60	40	100	450

(KM: Kodo millet flour, WWF: Wholewheat flour)



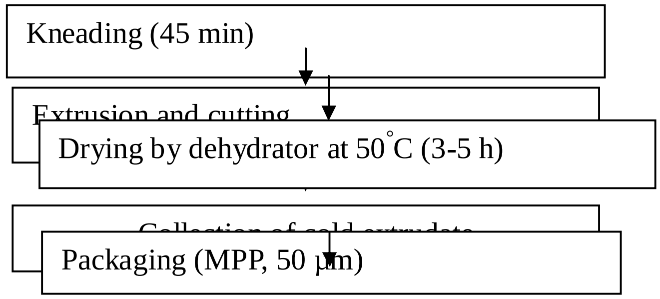


Fig. 1. Process flow chart for production of cold extruded products

Cooking, physical and functional characteristics of cold extrudates

The optimal cooking time and solid loss of pasta and vermicelli were evaluated in accordance with the methodologies described by Jalgaonkar*et al.* (2019). Swelling power measurements were conducted following the protocol established by Schoch (1964). Additionally, various physical parameters were assessed: true density and bulk density according to Deshpande and Poshadri (2011)and Launay and Lisch (1983), respectively. The water absorption index (WAI) and water solubility index (WSI) were determined based on the method proposed by Anderson (1982).

Proximate analysis of cold extrudates

The proximate analysis of optimised cold extrudates, including moisture content, protein content, crude fat content, crude fibre content, ash contentand carbohydrate content, was conducted. These analyses were performed in accordance with AOAC (1980) standard methodologies, with carbohydrate content determined using the difference method.

Sensory evaluation

Four different combinations of ingredients (T_1-T_4) were cold extruded, cooked, and evaluated for acceptability by a panel of 10 semi-trained judges. The evaluation was conducted using a 9-point hedonic scale for sensory parameters including colour, appearance, texture, taste, flavourand overall acceptability. The best accepted pasta and vermicelli were then compared with the control to optimize the formulations.

Colourand textural parameters of cold extruded products

Tristimulus colour measurements of the pasta and vermicelli products were conducted using a Spectrophotometer (Make: Konica Minolta Instrument, Osaka, Japan; Model-CM5). The colour of the samples was measured using the CIE (Commission Internationale de LeClaire, 1976) *L**,*a**,*b** coordinate system, where *L** indicates the lightness of the sample, *a** indicates greenness (-) or redness (+)and *b** indicates blueness (-) or yellowness (+). The textural properties of the extruded products were studied using a Texture analyzer, following the method described by Mochizuki (2001). Colour and textural values were recorded three timesand the mean values were reported for the optimized cold extrudates.

Storage study of cold extrudates

The pasta and vermicelli extruded products were optimised based on their cooking and sensory properties. The optimized products were packed in metalised polyester pouches and stored for three months under ambient conditions. During this storage period, changes in moisture content, sensory evaluationwere assessed to determine the stability and quality of the products.

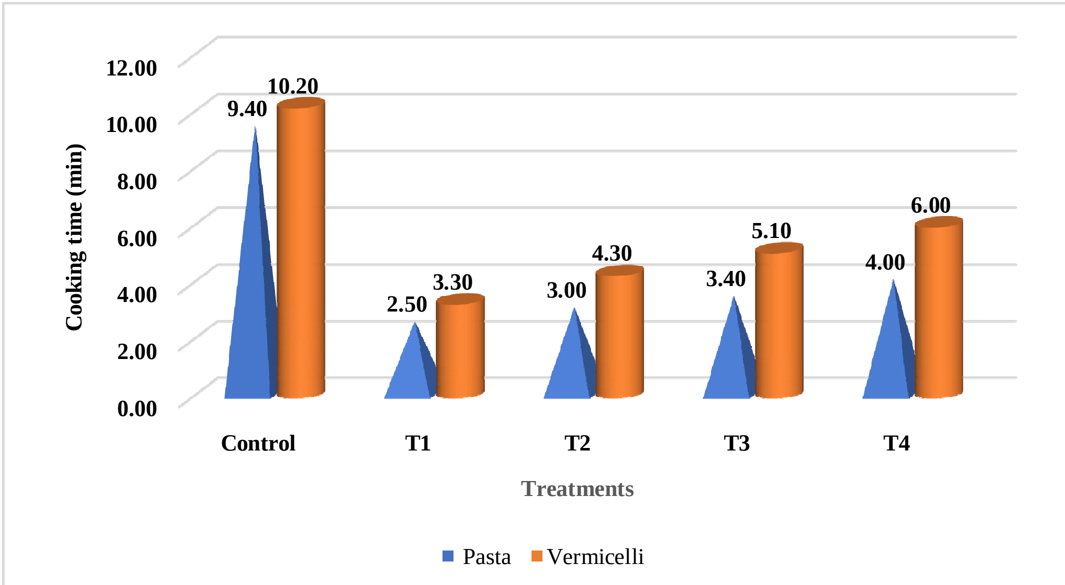
Statistical Analysis

Statistical analysis of experimental data was done using SPSS and OPSTAT software. The data of experiments were analysed using completely randomized design (CRD) and critical difference (CD) was to determine the significant difference among treatments.

Results and Discussion

Cooking properties of cold extrudates

Cooking characteristics in terms of cooking time, swelling power and solid loss for the developed pasta and vermicelli products were evaluated and the data are presented in fig1, 2, 3.The cooking time of different blends ranged from 2.50 min to 4.00 min, in pasta and 3.30 to 6.00 min in vermicelli (shown in Fig. 2). Cooking time required for control pasta was about 9.40 min and 10.20 min for vermicelli.The Swelling power of different blends ranged from 1.25 g/g to 1.76 g/g, in pasta and 1.00 g/g to 1.82 g/g in vermicelli (shown in Fig. 3). Swelling power required for control pasta and vermicelli was about 3.50 g/g and 1.90 g/g, respectively and thesolid loss of different blends ranged from 9.45% to 8.30% in pasta and 4.01% to 3.10% in vermicelli (shown in Fig. 4). Solid loss for control pasta and vermicelli was found to be 6.10% and 2.90%, respectively. The results indicated that the cooking time, swelling power, and solid loss of pasta and vermicelli products varied depending on the flour blends used. The variation in cooking time can be attributed to differences in the gelatinization temperature of the respective starches or blends of starches, as reported by Benhur *et al*. (2015). It was observed that the swelling power of the pasta and vermicelli products increased with higher levels of whole wheat flour, likely due to the cooking process causing the fibre to absorb more water. This is consistent with the higher fibre content in kodo millet flour, which has a high affinity for water (Wang *et al.*, 2002).Moreover, an increase in kodo millet flour levels and a decrease in wheat flour levels led to higher cooking losses. This can be



attributed to the absence of gluten protein in the composite blends. The gluten-protein network is crucial for maintaining the physical integrity of pasta and vermicelli during cooking. A weaker structure results in more solids leaching from the pasta samples into the cooking water, leading to greater cooking residues (Savita *et al.*, 2013).

Fig. 2. Cooking time of different treatments of cold extrudates

Fig. 3. Swelling power of different treatments of cold extrudates

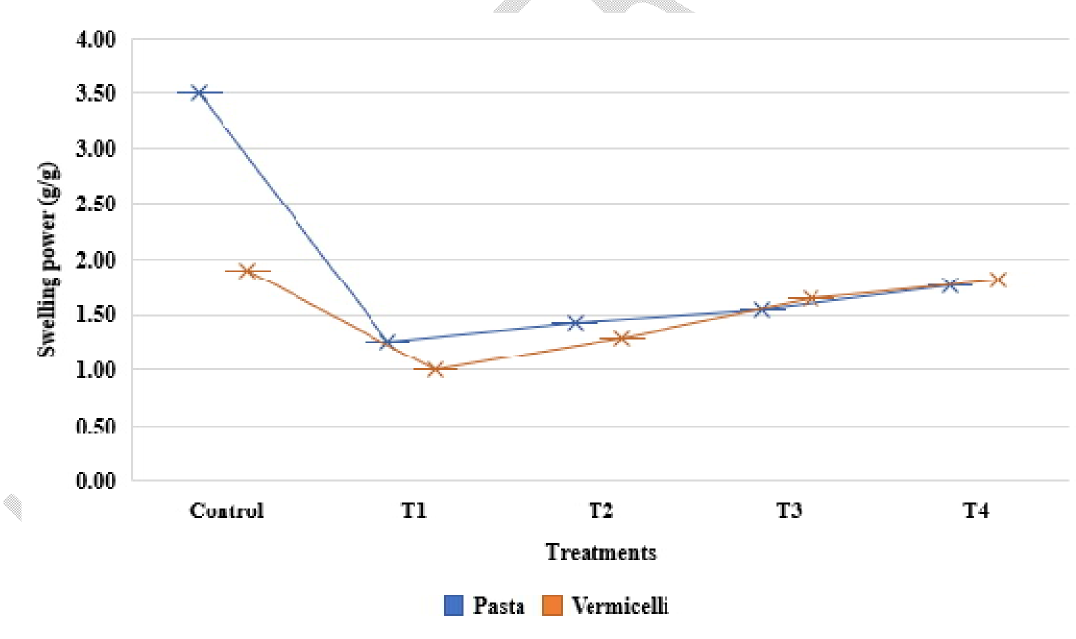


Fig. 4. Solid loss of different treatments of cold extrudates

Sensory qualities of developed cold extrudates

Sensory evaluation was done on parameters like colour, texture,flavour, taste and overall acceptability.The concentration of kodo millet and whole wheat flour to be incorporated in pasta and vermicelli product was evaluated for the final selection of the product. The results for final sensory analysis for pasta and vermicelli samples are depicted in Table. 2 and Fig. 5, respectively.

Table 2. Sensory scores of pasta products

Treatments	Appearance	Colour	Texture	Flavour	Taste	Overall acceptability
T_1	6.58	6.72	6.66	6.66	6.60	6.66
T_2	6.88	6.88	6.82	6.96	6.92	6.90
T_3	6.80	6.80	6.70	7.10	6.90	7.10
T_4	8.00	8.20	8.20	8.20	8.20	8.20
Control	8.20	8.30	8.40	8.30	8.20	8.30
F-Test	*	*	*	*	*	*
CD @ 5%	0.68	0.69	0.78	0.70	0.68	0.70
S.Em. ±	0.22	0.22	0.25	0.23	0.22	0.23

T_1: Kodo millet flour (90 %): Wheat flour (10 %)
T_2:Kodo millet flour (80 %): Wheat flour (20 %)
T_3: Kodo millet flour (70 %): Wheat flour (30 %)
T_4:Kodo millet flour (60 %): Wheat flour (40 %), Control: Whole wheat flour (100 %)
CD: Critical difference, S.Em.±: Standard error of mean, *=Significant

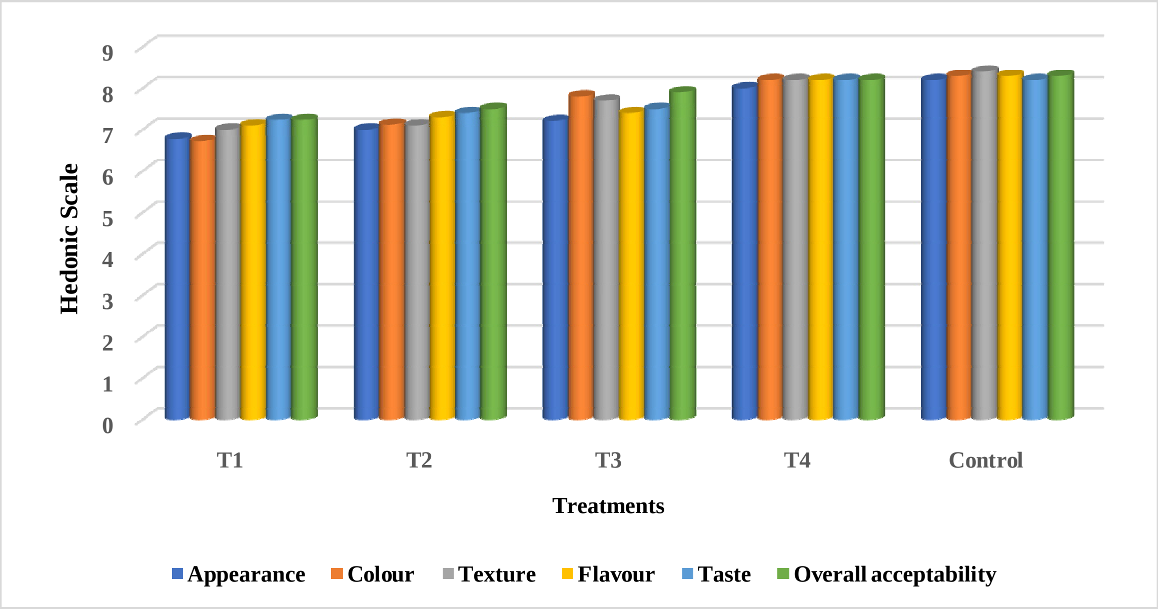


Fig. 5. Sensory scores of vermicelli products

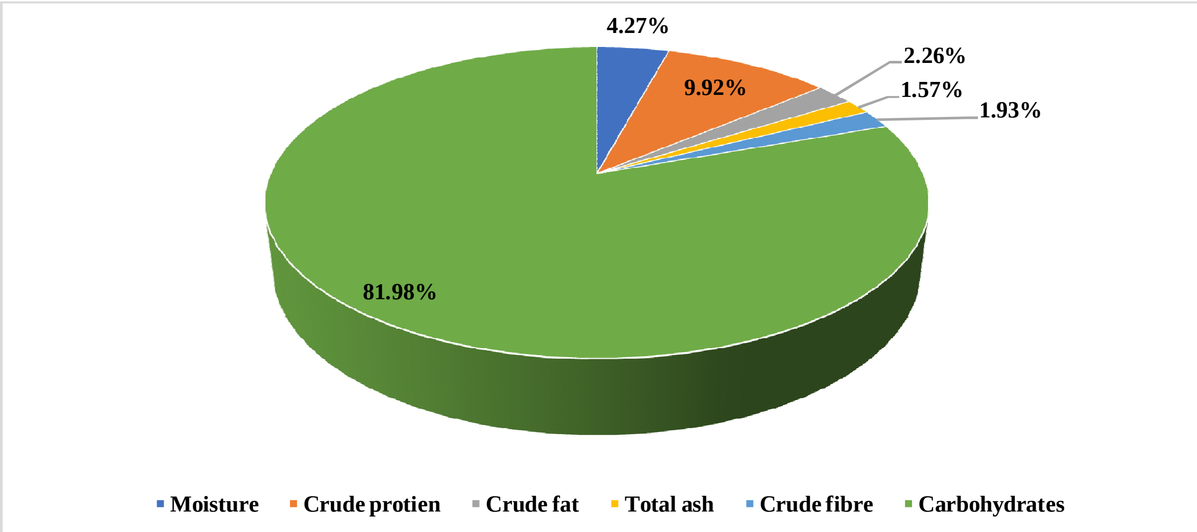
One best pasta and vermicelli products were selected based on cooking and sensory characteristics of cold extrudates. Cooking characteristics revealed that pasta formulated with composite blend (100 %) containing 60 per centkodo millet flour and 40per centwhole wheat flour (*i.e*., Treatment T_4) was found to have optimum cooking characteristics when compared to other formulated pasta and vermicellisamples.

Proximate composition of optimised pasta and vermicelli

The proximate composition of pasta and vermicelli products made from composite flour containing kodo millet flour and whole wheat flour was analysed. It was found that the inclusion of whole wheat flour improved the texture and shape of the cold extruded pasta and vermicelli products.The nutritional composition of the optimized kodo millet pasta product (Treatment T_4) in terms of moisture, crude protein, crude fat, crude fibre, total ashand carbohydrates is presented in Table 3. The moisture content of the product was found to be 4.27%. The crude protein, crude fat, crude fibre, total ash, and carbohydrate contents of the pasta product were found to be 9.92%, 2.26%, 1.57%, 1.93%, and 81.98%, respectively., and the nutritional composition of optimisedkodo millet vermicelli product (TreatmentT_4)in terms of moisture content, crude protein, crude fat, crude fibre, total ash and carbohydrates are presented in Figure6.

Table 3. Proximate composition of optimised pasta product

Parameters	Quantity (%)
Moisture	4.27 ± 0.21
Crude Protein	9.92 ± 0.49
Crude Fat	2.26 ± 0.11
Total ash	1.57 ± 0.07
Crude fibre	1.93 ± 0.09
Carbohydrate	81.98 ± 4.00



Physical and functional characteristics of optimised pasta and vermicelli products

The physical and functional properties of the optimized pasta and vermicelli products, including density, colour, water absorption index (WAI), water solubility index (WSI)and textural properties are presented in Table 4. The true density and bulk density of the kodo millet-based pasta and vermicelli products were found to be 1.03 g/mL and 0.54 g/mL, respectively. The tristimulus colour values (*L**, *a**, *b**) for the kodo millet pasta were approximately 68.96, 2.65, and 13.72, while for the vermicelli, they were about 63.05, 7.27and 13.83, respectively.The WAI and WSI for the pasta were 0.52 g/g and 0.11 g/g, respectivelyand for the vermicelli, they were 0.53 g/g and 0.07 g/g, respectively. The observed differences in WAI and WSI can be attributed to the hydrophilic polysaccharides present in their respective flours (Oninawo and Asugo, 2004).

Table 4. Physical, functional and textural properties of optimised pasta and vermicelli products

Parameters	Pasta	Vermicelli
True density (g/ mL)	1.03	1.03
Bulk density (g/ mL)	0.54	0.54
Colour (*L**, *a**, *b**)	68.96, 2.65, 13.72	63.05, 7.27, 13.83
Water absorption index (WAI)	0.52 g/g	0.53 g/g
Water solubility index (WSI)	0.11g/g	0.07 g/g
Hardness (g)	104.723	73.556
Fracturability (g)	1741.65	4732.5
Adhesiveness (g. sec)	-13.221	-5.311
Springiness	0.047	0.337

The optimised pasta and vermicelli products exhibited similar physical and functional properties but varied in textural properties.

Storage studies on optimised kodo millet cold extrudates

The results of storage study conducted with the selected product, which was stored at ambient conditions for three months in a metalised polyester packaging film (50 µm) are presented below.To maximize the shelf life of processed foods, they must possess good storage qualities. Packaging physically shields food from external influences, making the stability of packaging materials essential for improving food quality and safety, as well as extending the shelf life of foods. Therefore, it is crucial to evaluate the impact of packaging materials on the product's quality characteristics and storage stability.The effects of packaging material on the extrudate's characteristics were investigated. The 90-day study on storage stability was conducted in Bengaluru, Karnataka, India, under ambient conditions (at temperature:24 ± 3 °C, humidity: 65.2 ± 12 %). The quality of the extruded product was seen to be significantly impacted by storage time and packaging type.

Effect of storage period on moisture content of kodo millet based cold extrudate products

For a three-month storage period, the moisture content of optimised pasta and vermicelli products packed in metalised polyester films were assessed. The results are shown in Table 5 and Figure 7. The moisture content steadily increased over the storage period. At the end of the three months, the moisture content increased from 4.27% to 7.68% in pasta and from 4.30% to 8.10% in vermicelli. Analysis of variance for moisture content of pasta, as depicted in Table 5, revealed that the packaging material and storage time had a significant ($P \leq 0.05$) impact on the moisture content of the cold extruded products. The increase in moisture content during storage can be attributed to the hygroscopic nature of the products and the migration of water vapours from the storage environment, due to changes in temperature and relative humidity, into the packaging material (Kocherla*et al*., 2012; Nagi*et al*., 2012).

Table 5. Effect of storage on moisture content (%) of optimised pasta product

Packaging material	Storage period (days)	Moisture content (%)
Metalized polyester	0	4.27
	15	4.56
	30	5.23

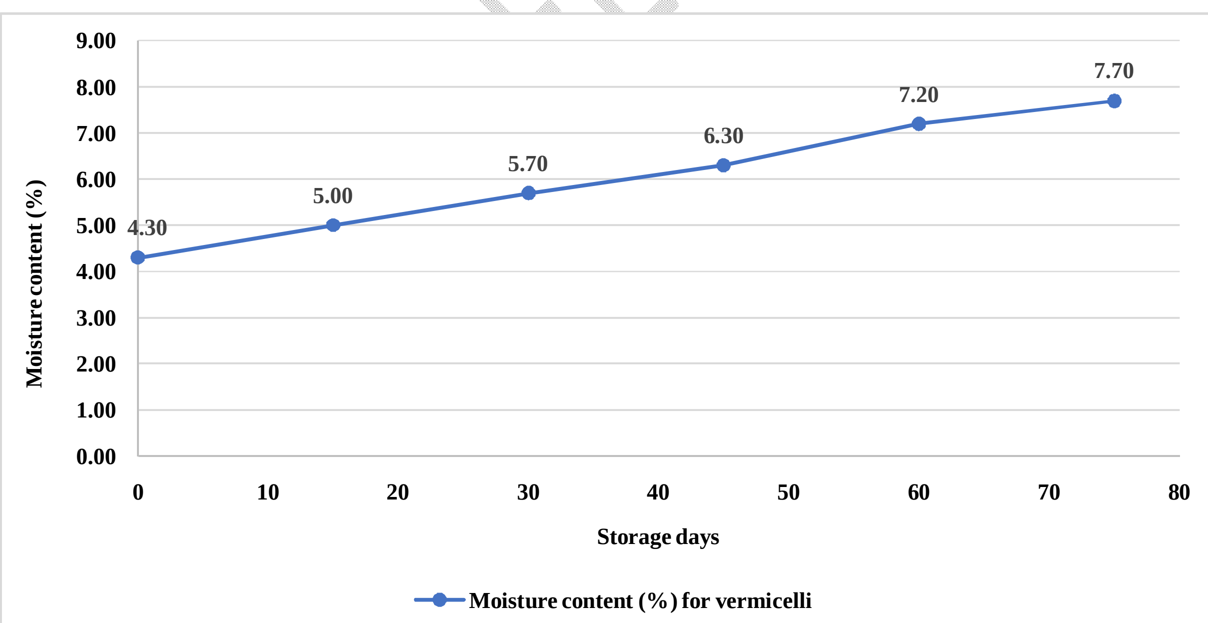
	45	6.10
	60	6.93
	75	7.10
	90	7.68
CD @ 5%		0.55
S.Em. ±		0.18

CD: Critical Difference, S.Em. ±: Standard Error of mean

Fig. 7. Effect of storage on moisture content (%) of optimised vermicelli product

Effect of storage on sensory scores of kodo millet based cold extruded samples stored in metalized polyester film

The sensory scores for the optimised kodo millet based cold extruded products stored in metalized polyester packaging pouch are presented in Table 6 and in Fig. 8.It was observed that, with the increasing storage period, mean sensory scores for overall acceptability of the pasta and



vermicelli productsdeclined from 8.20 to 6.50. The highest average overall acceptability was observed at 0, 1 and 2 months of storage indicated that, pasta and vermicelli were acceptable up to two months of storage. Decreasing trends ($p \leq 0.05$) were observed for all the sensory attributes like appearance, colour, taste, textureand overall acceptability of products during storage.Sensory evaluation of the cold extruded products revealed significant effect of storage period and packaging material on the liking of pasta and vermicelli by the panelists in terms of appearance, colour, texture, flavour, taste, and overall acceptability.The overall change in the sensory acceptability of the products during storage could be due to minorchanges in biochemical parameters (moisture intake, water activity, colour, FFA, peroxide and microbial growth) that took place during storage resulting in lowering of sensory scores.

Table 6. Effect of storage on sensory scores of optimisedpastaproduct

Packaging material	storage days	Appearance	Colour	Texture	Flavour	Taste	Overall acceptability
Metalized polyester film	Initial days	8.00	8.20	8.20	8.20	8.20	8.20
	15	7.90	7.79	7.70	7.80	7.70	7.70
	30	7.80	7.90	7.60	7.90	7.68	7.70
	45	7.00	7.50	7.50	7.60	7.00	7.40
	60	6.90	7.00	7.00	7.00	6.90	7.00
	75	6.90	6.20	6.30	6.80	6.20	6.30
	90	6.90	6.40	6.40	6.20	6.40	6.50
	CD @ 5%	0.69	0.67	0.69	0.69	0.66	0.69
	S.Em. ±	0.22	0.22	0.22	0.22	0.21	0.22

CD: Critical Difference, S.Em. ±: Standard Error of mean

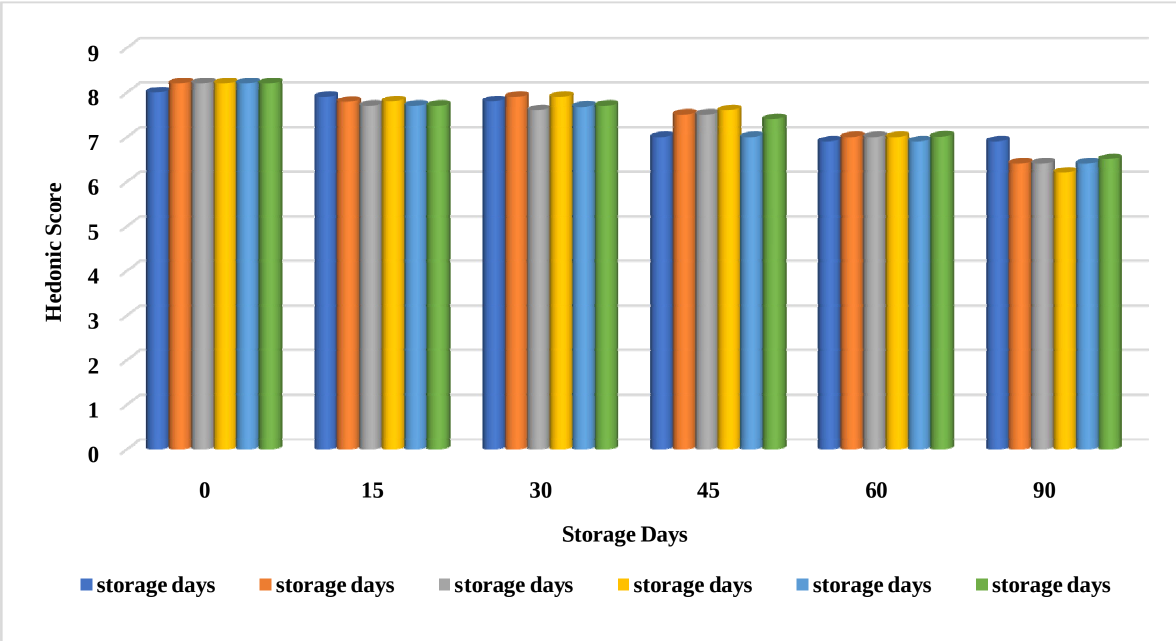


Fig. 8. Effect of storage on sensory scores of optimised vermicelliproduct

Conclusion

The development of kodomillet-based pasta and vermicelli was investigated with a focus on enhancing the nutritional value of the individuals. The evaluation encompassed essential parameters such as cooking time, solid loss, swelling powerand sensory attributes. The findings revealed that using kodo millet flour, being gluten-free, posed a challenge in retaining the ideal shape of pasta and vermicelli during cooking. To address this limitation and improve overall texture, varying levels of whole wheat flour were incorporated into the formulations. This study not only highlights the limitations associated with kodo millet flour in the development of pasta and vermicelli but also provides a practical solution by incorporating whole wheat flour for better shape retention and enhanced sensory qualities. These results offer valuable insights for optimising kodo millet-based pasta and vermicelli, addressing both technical and sensory aspects to improve consumer acceptance.

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