Current Journal of Applied Science and Technology

Volume 42, Issue 47, Page 148-159, 2023; Article no.CJAST.110287
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843,
NLM ID: 101664541)

Development of Functionally Enriched Cold Extruded Product Using Black Bean and Finger Millet

Poorvitha M. [a*], Rita Narayanan [b++], Valli C. [c#] and Mathanghi S. K. [b†]

[a] College of Food and Dairy Technology, Tamil Nadu Veterinary and Animal Sciences University, Chennai (Tamil Nadu), India.
[b] Department of Food Processing Technology, College of Food and Dairy Technology, Tamil Nadu Veterinary and Animal Sciences University, Chennai (Tamil Nadu), India.
[c] Faculty of Basic Sciences, Madras Veterinary College, Tamil Nadu Veterinary and Animal Sciences University, Chennai (Tamil Nadu), India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2023/v42i474325

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/110287

Original Research Article

Received: 15/10/2023
Accepted: 21/12/2023
Published: 22/12/2023

ABSTRACT

Extrusion is a unique method for preparing pasta, which is generally produced from refined wheat flour. However, preparation of pasta from black bean and millets are not prevalent. Millets and Black bean contain good source of protein and fibre. The present study was undertaken to develop pasta which is rich in protein, anthocyanin and dietary fibre. The study conducted included five trials along with control and significant ingredients like Refined Wheat Flour (RWF), Sprouted Finger millet flour

---

[++] *Professor and Head;*
[#] *Dean;*
[†] *Assistant Professor;*
[*]Corresponding author: E-mail: poorvithamagesh97@gmail.com;

(FMF), Black bean flour (BBF) in different proportions as T_1- RWF: F: B - 80: 10: 10 and T_2- RWF: F: B- 60: 20: 20, T_3- 40: 30: 30, T_4- 20: 40: 40, T_5- 0: 50: 50 and control C- RWF: F: B- 100: 0: 0, along with xanthan gum of 2%, salt of 2% and 8% rice bran oil. These ingredients were mixed, kneaded and extruded in a cold extruder at a screw speed of 80 rpm and temperature of 40°C. Before drying, steaming was carried out for 15 mins. The extruded pasta was tray dried at 70^0C for 6 hours, cooled and then stored at room temperature. The standardization of the developed pasta was done using VETSTAT tool by assessing its physical and cooking quality parameters such as water absorption index, water solubility index, cooking time, cooking loss and swelling index. Proximate and sensory analysis were also carried out. Among the trials studied, T_3- RWF: F: B- 40:30:30 was preferred as the standardized treatment based on the physical, cooking quality parameters and higher sensory scores for appearance and color, body and texture, flavour and overall acceptability. Thus, this study proved that indigenous black bean flour and sprouted finger millet flour can be partially substituted for refined wheat flour in the preparation of enriched cold extrudate like pasta. This developed novel product can satisfy the taste, satiety-oriented dieting and promote healthy aesthetic food habits of consumers.

Keywords: Sprouted finger millet; black bean; pasta; extrusion; standardization; overall acceptability.

1. INTRODUCTION

Convenience foods such as ready-to-eat and ready-to-cook items, gained momentum with changes in the socioeconomic structure and consumer consciousness. The simplicity of preparation, versatility, affordability and other factors contributed to the widespread appeal of such convenience foods [1].

One method for creating unique convenience food items like RTE and RTC goods uses extruders with screw and barrel mechanisms. While RTC products consist of pasta in various shapes like pasta, spaghetti, macroni, vermicelli, etc., which must be cooked before consumption, RTE products include puffed products, sweets, pet treats and other items that do not require further processing or cooking [2].

Extrusion can be done in two ways as hot extrusion and cold extrusion. Among them the hot extrusion products are ready-to-eat products and cold extrusion products are ready-to-cook products. In general, cold extrusion is thought to be environmentally favourable, energy-efficient and with little nutrient loss [3].

Pasta is a popular Italian dish that is eaten all over the world. The pasta industry has been driven to create ready-to-eat, shelf-stable, high-quality pasta products as a result of consumer demand for convenient and healthy cuisine. It is prepared using extrusion technology. Extrusion cooking is a multifaceted process that transforms mixtures of materials into products of the desired shape after being mixed with the necessary amount of water. It entails a number of unit processes including mixing, kneading, shearing, cooking, shaping, puffing, cutting, steaming and drying [4]. The dough used to make pasta can be manufactured from any acceptable ingredients, including semolina, durum wheat flour, corn, rice, wheat or any combination of those ingredients and water. Additionally, pasta can be enhanced, fortified or consumed as in most recent novel form of processed products. To increase the quality, a number of additives and substances have been needed to develop those unique products [5]. When making pasta, grains like wheat are used, which are deficient in several necessary amino acids. The supplementing and fortification of such products with protein and vitamins from natural sources like cereals, millets, vegetable products or composite flour is an alternative to boost the nutritional content of those items [6].

India is the world's top producer of several types of small millets, including finger millet (ragi), kodo millet (kodo), foxtail millet (kangni), barnyard millet (sawan), proso millet (cheema) and little millet (kutki), Majumdar et al. [7]. Millets are suitable foods for those with celiac disease, other types of allergies, or wheat intolerance because they are high in nutrients and gluten-free Saravana and Soam [8]. Millets are known as a "power house of nutrients" because they are so filled with nutrients. They are very nutrient-dense and include large amounts of fibre, protein, vitamins and minerals. Because millets are so inexpensive, they are often referred to as "poor man's food grain." Millets are divided into two categories as major millets and minor millets. Major millets include sorghum and pearl millet, while minor millets include finger millet, kodo millet, proso millet, foxtail millet and little millet [9].

Millets are the primary food source in the world and play a significant role in the global diet of people. As millet is a crop with significant drought resistance, it is frequently planted in the semi-arid tropical regions of Africa and Asia and serves as a significant source of protein and carbohydrates for the local population. As a result, millets were found to have good nutritional content and were compared to those of major grains such as wheat and rice [10] this was in addition to their cultivation advantages. The necessary amino acids threonine and lysine are present in millet proteins in good amount, although methionine levels are relatively high [11].

One of the minor cereals, finger millet also known as ragi and mandua in India, is a native of Ethiopia and is widely grown throughout India and Africa. It is a staple food in these nations that provides a significant amount of calories and protein to large portion of the population, especially those in lower socio-economic groups. Karnataka is the largest producer of finger millet in India, accounting for 58% of the country's total production, although few Indians are aware of its nutritional worth and health advantages. Finger millet is the sixth most widely produced crop in India, following the wheat, rice, maize, sorghum and bajra [12].

Diversifying their food applications would be assured by processing them using both traditional and modern techniques for the manufacture of value-added and convenience food items. Utilizing them to create ready-to-use or ready-to-cook goods will encourage non-millet eaters to consume more millets, improving nutritional security. And finger millet due to its useful components, like slowly digesting starch and resistant starch, it has become more significant as the consumption of processed foods and their understanding in health benefits [13].

Verma and Patel [14] reported that the finger millet is a good provider of macro and micronutrients as well as a significant dietary supply of carbohydrates. The creation of new food products aims to produce complementary foods to close the gap between the availability of food and a healthy diet. Nutrient value-added products can be made by adding finger millet as a value addition. For people of all ages, these enhanced foods can be a good source of rapid meal.

A significant portion of the population in these nations relies on finger millet (*Eleusine coracana L.*), which is grown abundantly in many regions of India and Africa. After wheat, rice, maize, sorghum and bajra, it is the sixth most produced crop in India. The seed coat's acidic methanol extracts demonstrated strong antibacterial and antifungal action (Mathanghi *et al.,* 2012).

Pulses are the edible seeds of legume plant species. Whole, split and fractionated pulses, as well as pulse flours, provide a wealth of rich nutrients that are pertinent to chronic disease. They have a very low fat content and are rich in protein, vitamins, minerals, soluble and insoluble fibre and complex carbohydrates. It has a variety of dietary components with the potential to be bioactive that enhance glycemic management and guard against hypercholesterolemia and type 2 diabetes [15].

Beans (*Phaseolus vulgaris L.*), one of the pulses are consumed all over the world. With the rise of vegetarianism and the demand for non-wheat and non-soy proteins in western nations, dry beans are gaining more consumer attention; however, the food industry underutilizes them as an ingredient in novel foods. Black beans contains 24.28g/100g DW of protein, 1.60g/100 g DW of total lipid (fat), 70.07g/100g DW of carbohydrate, 4.05g/100g DW of ash, 17g/100 g DW of fibre Arribas et al. [16].

The most notable black bean related effects include anticancer, antidiabetic and antioxidant properties, which make clear the hidden advantages that this plant species provides. There are signs that black beans have a lot of potential as their usage in processed and novel foods manufacturing with functional properties [17].

Hydrocolloids like xanthan gum are added to the dough to stabilize the gluten-free network, increase intermolecular viscosity and improve the texture of the pasta [18]. Xanthan gum, due to its hydrocolloid nature shield the starch and other constituents of pasta from being soluble by forming strong and firm network [19].

The incorporation of functional ingredients to a maximum extent in the extrusion technology to develop a novel product will enhance and harness the potential health benefits. Now a days the practice was changing with the addition of health promoting ingredients to develop the novel nutritious products. Therefore, the present study was carried out for the maximum substitution of traditional non-conventional ingredients, thus facilitating an enriched cold extruded product.

2. MATERIALS AND METHODS

2.1 Materials

Finger millet, black bean, refined wheat flour, rice bran oil, xanthan gum and salt were procured from the nearby commercial market, Chennai, Tamil Nadu, India.

2.2 Blend Formulation

The black bean procured from the market was cleaned, soaked, dried, roasted and ground into flour. Finger millet grain was cleaned and coarse particles, dirt and dust were removed by proper screening and washed thoroughly. The finger millet grain was sprouted overnight, sundried and ground into flour to about 14% moisture by AACC method. The refined wheat flour, xanthan gum and salt were also used in this formulations. The blend formulation in different proportions and total of 5 trials were carried out (T_1 to T_5), along with C as the control as outlined in Chart 1.

2.3 Pasta preparation

Refined wheat flour was substituted with varying levels of sprouted finger millet flour and black bean flour to develop a functionally enriched product. Xanthan gum and oil were also added for better binding capacity. The different blends of preliminary trials as shown in Chart 1. was taken for the pasta preparation. Cold extruder Dolly La Monferrina (Italy) (2017 model) was used for preparation of pasta with vat capacity of 2.5 kg and extrusion speed of 80 rpm. The raw ingredients of each preliminary trials were mixed properly for uniform distribution of water (35-40ml) and kneaded thoroughly. Ziti shaped pasta was obtained by imparting the dough to cold extrusion using a single screw extruder. The blade cutter with 80 rpm was fixed in front of pasta die. The resultant extrudate was steamed using prestige steamer for around 10- 15 min. Finally, the steamed pasta was tray dried at 70ºC for 5-6 hours. The dried pasta was packed in Polyethylene bags and stored at ambient room temperature for further analysis.

2.4 Cooking Quality Parameters and Physical Properties

The developed extrudates cooking quality parameters and physical properties were determined by AACC Method. Water absorption index, Water solubility index, Swelling index, Cooking time, Cooking Loss or Gruel solid loss was determined by standard methods.

i) Optimal cooking time

Pasta samples (10 g) were cooked in accordance to AACC [20] method. Pasta samples were initially cooked in 200 ml boiling water for adequate time. Optimum cooking time was determined by removing pasta at 30 sec intervals and pressing between two glass slides to check for opaqueness in the inner core [20]. The optimum cooking time was the time required for complete disappearance of the white core, thereby indicating complete gelatinization of starch.

Chart 1. Composition of enriched formulated blends Refined Wheat Flour (RWF), Sprouted Finger Millet Flour (FMF), Black Bean Flour (BBF)

Treatments	RWF (g)	FMF (g)	BBF (g)	Xanthan gum and Salt	Rice bran oil
C	100	-	-	2%	8%
T_1	80	10	10		
T_2	60	20	20		
T_3	40	30	30		
T_4	20	40	40		
T_5	0	50	50		

ii) Cooking Loss

Cooking loss of pasta was estimated by standard methods [20]. For this 20 ml aliquot from cooking water was taken in a pre-weighed petridish, followed by drying in a hot air oven at 105°C. The amount of solid residue in petridish was expressed as percent cooking loss.

$$\text{Cooking loss (\%)} = \frac{\text{Weight of dry solids x volume of cooking water x 100}}{\text{Aliquot taken x Weight of raw sample}}$$

iii) Swelling index

Swelling index was calculated as per the method adopted by AACC [20]. The swelling index was calculated as follows:

$$\text{Swelling index (g/g)} = \frac{\text{(Weight of cooked product)} - \text{(Weight of dried pasta)}}{\text{(Weight of dried pasta)}}$$

iv) Water absorption index and Water solubility index

Water solubility index (WSI) and water absorption index of extruded products were determined by the method followed by Yagci and Gogus [21]. Distilled water (10 ml) at 25°C was placed in a centrifuge tube and 0.5 g of powdered extrudate was dispersed in water. After standing for 30 min (with intermittent shaking every 5 min), the sample was centrifuged at 1800 rpm for 15 min. The supernatant was decanted and dried at 105°C until constant weight was obtained. The weight of the gel remaining in the centrifuge tube was noted. The results were expressed as.

$$\text{WAI (g/g)} = \frac{\text{Weight gain of gel}}{\text{Dry weight of extrudate}}$$

$$\text{WSI (\%)} = \frac{\text{Weight of dry solids in supernatant}}{\text{Dry weight of extrudate}} \text{x 100}$$

v) Bulk density

Bulk density of the ideal extrudates were determined by Dharmaraj et al. (2016). Ten grams of uncooked pasta was taken in a 100ml measuring cylinder. The cylinder was tapped until no visible decrease in volume of sample was noticed.

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of the sample}}{\text{Volume occupied by the sample}}$$

2.5 Color

Using Hunter Lab colorimeter, the developed extrudates color readings were measured by Hunter values for L, a* and b*. L values measure black to white (0-100); +a= red, -a= green; +b= yellow, -b= blue.

2.6 Texture

Texture analyzer (TA XT plus, Stable Microsystems, UK) was used to measure the texture profile of the enriched pasta samples. TA. XT plus measures products textural characteristics such as hardness, springiness, adhesiveness, cohesiveness and extensibility of foods. With the easy-to-use Exponent software, this versatile instrument is extraordinarily well-engineered for long-term reliability and accuracy.

2.7 Sensory Analysis

The overall acceptability of the developed extrudate was evaluated based on the sensory attributes like (color and appearance, body and texture, flavor and overall acceptability) by cooking and serving hot for sensory analysis by a panel of semi-trained judges (n=7).

2.8 Storage Stability

Based on the physical properties, cooking quality parameters and organoleptic characters, one best sample was chosen to study the storage stability against the control sample (C). The standardized treatment T_3 was packed in polyethylene bags and stored at ambient room temperature (20-30°C) for further storage studies like water activity, peroxide value and free fatty acid content at an interval of 30 days.

2.9 Statistical Analysis

Six trials were undertaken for each parameter and VETSTAT tool was used to carry out an analysis of variance. The results were expressed as mean ± SE and the least significant difference at $P < 0.05$ was calculated at different proportions using significant differences in results.

3. RESULTS AND DISCUSSION

3.1 Sensory Analysis of Pasta

The sensory analysis of the cooked functionally enriched pasta using sprouted finger millet flour and black bean flour conducted by a panel of semi-trained judges is presented in Table 1. The overall acceptability of the developed extrudate was evaluated based on the sensory attributes like colour and appearance, body and texture and flavour. T_3 pasta sample scored the highest followed by control T_1, T_2, T_4 and T_5 in that order. Due to the incorporation of sprouted finger millet flour and black bean flour, there was a highly significant difference in colour and appearance, body and texture, flavour and overall acceptability between control and all the treatments. From the table it was concluded that T_3 scored maximum in appearance and colour, flavour and hence in overall acceptability when compared to the other treatments. The results obtained in this study are in accordance with the work of Shukla and Srivastava [22] who reported that 30% finger millet flour incorporated noodles had optimum sensory quality with better functional properties. The findings are also in accordance to the findings of Dod et al. (2003) who used pearl millet flour, chickpea flour and refined wheat flour in various ratios and concluded that vermicelli with -Type 1 (50:30:20), Type V (50:50:0) and Type VI (60:40:0), were highly acceptable in their distinctive appearance and texture.

Statistical analysis from Table 1 revealed that T_3 scored maximum overall acceptability of 8.66±0.18, followed by control, T_1, T_2, T_4 and the least for T_5.

3.2 Cooking Quality Parameters of Pasta

Cooking time was measured by squeezing the cooked sample between glass plates and with the complete disappearance of white core indicating complete starch gelatinization. The results indicated that there was a highly significant difference in the cooking time between control and the treatments as shown in Table 2. The cooking time of pasta ranged between 5.46±0.26 min for control to 10.16±0.53 min for T_5 sample. The cooking time increased with increase in substitution of FMF and BBF. The results were found to be in correlation with the results of Kaur et al. [19], who stated that due to the addition of fibre rich grains, an altered gluten matrix was developed thus making starch more exposed to heat treatment and hence rapid gelatinization which leads to longer duration of cooking. Results further showed that addition of xanthan gum @ 2% in multigrain pasta blends increased the cooking time of pasta in comparison to the pasta prepared without xanthan gum. This shows that xanthan gum aids in development of system network which supports and binds starch and other ingredients firmly which therefore increased the cooking time in the treatment samples as seen in the present study unlike for control pasta (5.46±0.29 min). Cooking time revealed that the time taken for control was least followed by T_1, T_2 and T_3 and which gradually increased in T_4, T_5.

Cooking loss revealed a highly significant difference between control and all other treatments as shown in Table 2. There was a gradual increase in cooking loss in all the treatments as the level of RFW declined. With the inclusion of other starchy and fibre rich ingredients, the cooking loss of all treatments gradually increased. Progressive addition of finger millet and black bean flour to pasta lowered the wheat protein content which developed weaker gluten network. In addition, the increased fibre content from finger millet and black bean may have hindered the gluten network development. This may have resulted in increased susceptibility of starch and other constituents for solubilization in hot water during cooking. The total solid loss in gruel increased as the level of substitution increased as opined by Kamble et al. [23]. The increase in loss due to enrichment may be related to gluten dilution and the protein solubility fraction of wheat germ. The total solids loss in gruel increase as the level of substitution increased is in tandem to the observation of Joseph et al. [24]. The cooking loss was least for control and T_1. Similar values were obtained for T_2 and T_3 and a gradual increase for T_4 and T_5.

Swelling power is a measure of hydration capacity, being the measure of swollen starch granules and their occluded water. There was a highly significant difference between control and other treatments as shown in Table 2. The swelling index of the control pasta was lower when compared to other treatments. This might be due to water absorption during cooking. The starch and fibre rich grains used in processing are responsible for higher water absorption. As the level of substitution gradually increased in the treatments and due to the presence of starchy molecules, the swelling capacity also increased. The observation in the present study is in accordance to Kaur et al. [19], who reported that the volume expansion of pasta is linearly related with the water absorption. Water absorption trend was well reflected in the swelling power of the pasta due to amylose

Table 1. Sensory analysis of control and functionally enriched pasta prepared using sprouted finger millet flour and black bean flour (Mean ± SE) @

Treatments	Appearance and Colour	Body and Texture	Flavour	Overall acceptability
Control	8.22^{d} ±0.01	8.01^{c}±0.20	8.10^{d} ±0.20	8.11^{d}±0.12
T_1	7.82^{c} ±0.06	7.20^{b} ±0.20	7.60^{c} ±0.25	7.52^{c}±0.07
T_2	7.82^{c} ±0.06	7.20^{b} ±0.20	8.10^{d} ±0.00	7.66^{c}±0.04
T_3	8.81^{e} ±0.03	7.20^{b} ±0.20	8.64^{e} ±0.25	8.21^{e}±0.18
T_4	6.84^{b} ±0.00	6.00^{a} ±0.31	6.60^{b} ±0.25	6.43^{b}±0.08
T_5	6.05^{a} ±0.07	5.75^{a} ±0.25	6.00^{a} ±0.00	5.89^{a}±0.03
F-value	88.70**	58.02**	55.46**	112.99**

*@ Average of six trials, ** Statistically highly significant ($P \leq 0.01$)*
Means bearing various superscripts in the same column differs highly significantly ($P \leq 0.01$)
Control – RWF (100%): FMF (0%): BBF (0%), T_1 – RWF (80%): FMF (10%): BBF (10%)
T_2 – RWF (60%): FMF (20%): BBF (20%), T_3 – RWF (40%): FMF (30%): BBF (30%)
T_4 – RWF (20%): FMF (40%): BBF (40%), T_5 – RWF (0%): FMF (50%): BBF (50%)

Table 2. Cooking quality parameters of control and functionally enriched pasta prepared using sprouted finger millet flour and black bean flour (Mean ± SE) @

Treatments	Cooking time (min)	Cooking loss (%)	Swelling index (g/g)
Control	5.46^{a} ±0.29	6.06^{a} ±0.05	4.74^{a} ±0.02
T_1	7.87^{b} ±0.18	6.06^{a} ±0.003	4.76^{b} ±0.01
T_2	8.10^{b} ±0.37	6.07^{b} ±0.002	4.80^{c} ±0.03
T_3	9.00^{c} ±0.17	6.09^{b} ±0.012	4.82^{d} ±0.05
T_4	9.58^{d} ±0.20	6.17^{c} ±0.008	4.83^{e} ±0.01
T_5	10.16^{e} ±0.53	6.21^{d} ±0.04	4.94^{f} ±0.01
F-value	727.67**	172.00**	0.0450**

*@ Average of six trials, ** Statistically highly significant ($P \leq 0.01$)*
Means bearing various superscripts in the same column differs highly significant ($P \leq 0.01$) Control – RWF (100%): FMF (0%): BBF (0%), T_1 – RWF (80%): FMF (10%): BBF (10%)
T_2 – RWF (60%): FMF (20%): BBF (20%), T_3 – RWF (40%): FMF (30%): BBF (30%)
T_4 – RWF (20%): FMF (40%): BBF (40%), T_5 – RWF (0%): FMF (50%): BBF (50%)

content and the structure of amylopectin as observed by Joseph et al. [24]. From the values of swelling power it was observed that T_3 had values of 4.82±0.05 which increased in 4.83± 0.01 and 4.94±0.01 in T_4 and T_5 respectively. However, despite the increased swelling power the body ad shape of T_4 and T_5 was not firm.

Hence, from this table it was concluded that on comparison with T_2 although T_3 had higher cooking time (min) and similar cooking loss (%), the swelling power was more, which is a preferred trait in cold extruded product.

3.3 Physical Properties of Pasta

Water Solubility Index was found to increase with increase in substitution in all treatments as shown in Table 3. Highly significant difference was found in water solubility index of control and all treatments. The results are in agreement with Dhas et al. [25] who reported that the addition of millets and tapioca flour in pasta making, showed increased water solubility index. However, the findings differed from that of Verma et al. [26] who reported water solubility index of 7.3% in noodles due to the incorporation of chicken meat. From this table it was concluded that T_2 and T_3 had optimum water solubility index compared to T_4 and T_5.

Water Absorption Index was found to increase with increase in substitution in all treatments as shown in Table 3. Highly significant difference was found in water absorption index between control and other pasta treatments. This may be attributed to the presence of starch and fibre content in sprouted finger millet and black bean treated samples. These results were found to be in concurrence with Devaraju et al. [27], who showed increased water absorption index in finger millet, defatted soy/ whey protein concentrate and refined wheat flour incorporated enriched pasta. T_3 had WAI of 2.47±0.02 and it can be correlated with the optimum swelling index as observed in Table 2.

In the extruded and expanded products, bulk density plays an important factor, because it has an impact on products volume and consumer acceptability. There was a highly significant difference between control pasta and all the treatments. This difference may be due to the inclusion of functional ingredients in the product development. Highest bulk density was observed for control whereas lowest bulk density was observed for T_5 due to highest level of inclusion of functional ingredients. Bulk density gradually decreased in treatments due to inclusion of functional ingredients. Among the treatments T_1 had higher bulk density followed by T_2 and T_3. The findings were similar to the findings of Benhur et al. (2015), who reported that the bulk density ranged from 0.45 to 0.36 g/ml in varying levels of sorghum incorporated pasta.

From Table 1 it is concluded that T_3 scored a maximum overall acceptability of 8.66±0.18 followed by control, T_1 and T_2. On analysis of cooking quality parameters from Table 2 it was deduced that although T_1 and T_2 required minimum cooking time than T_3, the swelling power of T_3 was appreciable when compared to T_1 and T_2. T_1 had minimum cooking loss followed equally by T_2 and T_3. Table 3 also revealed similar values for WSI (%) for T_2 and T_3. However the WAI was higher for T_3 when compared to T_1 and T_2 which correlated with optimum swelling power as observed in Table 2. On summarizing the maximum inclusion level of SFM and BB flour in the development of functionally enriched pasta and keeping in view the sensory, cooking quality parameters and physical properties which are important benchmark for cold extruded product, it was concluded that T_3 with inclusion level of 30% each of SFM and BB flour to 40% RWF, was an ideal extruded product and was used for further analysis.

3.4 Color

The parameters such as lightness (L), redness (a*) and yellowness (b*) were assessed both in control and T_3 as shown in Table 8. Highly significant difference was observed between extrudates of control and T_3, due to the addition of FMF and BBF in the development of T_3 pasta. The change in lightness (L), redness (a*) and yellowness (b*) may be due to the raw ingredients incorporated. The incorporation of FM had contributed to the increased redness and the incorporation of RWF had contributed to the increased lightness (L) and yellowness (b*). This is in accordance to the work of Raghu *et al.* (2021) who also observed varied colour characteristics like lightness (L), redness (a*) and yellowness (b*) in the samples prepared with anthocyanins of *Hibiscus* and *Clitoria* for the development of naturally incorporated string hopper.

3.5 Texture

The textural profile such as hardness, springiness, resilience, cohesiveness, adhesiveness of control and T_3 shown in Table 5 is found to be a highly significant between the treatments. Textural attributes like hardness (kgf), adhesiveness (kg-sec), springiness (mm), cohesiveness (ratio), gumminess (kg), chewiness (N*mm) in raw sample were found higher in T_3 than control pasta. Hardness of T_3 may be due to the fibre and protein content, due to the incorporation of sprouted finger millet flour and black bean flour. From the table it was also observed that adhesiveness was more in T_3 which may be due to the xanthan and other ingredients and is in accordance to Jalgaonkar and Jha (2016) who found that springiness was more in the developed pasta prepared with wheat semolina and pearl millet. Similarly cohesiveness and resilience was significantly high in T_3 and is in accordance to Dahal et al. (2021) who reported higher values on using mixture of millet flour, eggs and xanthan gum to noodles.

3.6 Storage Stability Study

The peroxide value of control and functionally enriched pasta incorporated with sprouted finger millet flour and black bean flour during storage is shown in Table 6. During storage condition, the study of peroxide value is a significant one which it indicates the sensorial attributes. Oxidation process occurs when lipids present in processing products gets exposed to oxygen. Processing also reduces antioxidant mechanism. This oxidation affects the flavour, colour and appearance, taste and texture during storage. The peroxide value of control and standardized

Table 3. Physical properties of the control and functionally enriched pasta prepared using sprouted finger millet flour and black bean flour (Mean ± SE) @

Treatments	Water solubility index (%)	Water absorption index (g/g)	Bulk density (g/cm^3)
Control	3.24^{a} ±0.01	2.15^{a} ±0.07	0.48^{f}±0.07
T_1	3.35^{b} ±0.00	2.28^{b} ±0.00	0.45^{e}±0.04
T_2	3.62^{c} ±0.00	2.40^{c} ±0.00	0.43^{d}±0.06
T_3	3.72^{c} ±0.00	2.47^{d} ±0.02	0.42^{c}±0.08
T_4	4.35^{d} ±0.00	2.54^{e} ±0.02	0.40^{b}±0.02
T_5	5.36^{e} ±0.08	2.64^{f} ±0.02	0.39^{a}±0.01
F-value	1444.85**	77.25**	27.59**

*@ Average of six trials, ** Statistically highly significant ($P \leq 0.01$)*
Means bearing various superscripts in the same column differs highly significantly ($P \leq 0.01$) Control – RWF (100%): FMF (0%): BBF (0%), T_1 – RWF (80%): FMF (10%): BBF (10%),
T_2 – RWF (60%): FMF (20%): BBF (20%), T_3 – RWF (40%): FMF (30%): BBF (30%),
T_4 – RWF (20%): FMF (40%): BBF (40%) and T_5 – RWF (0%): FMF (50%): BBF (50%)

Table 4. Colour characteristics of control and functionally enriched pasta prepared using sprouted finger millet flour and black bean flour (Mean ± SE) @

Characteristics	Control	T_3	t-value
Lightness(L)	55.29±0.01	41.55±0.01	986.15**
Redness (a^*)	0.58±0.02	3.34±0.02	221.13**
Yellowness(b^*)	16.27±0.01	4.01±0.01	956.13**

*@ Average of six trials, ** Statistically highly significant ($P \leq 0.01$)*
Control – RWF (100%): FMF (0%): BBF (0%) and T_3 – RWF (40%): FMF (30%): BBF (30%)

Table 5. Textural characteristics of control and functionally enriched pasta prepared using sprouted finger millet flour and black bean flour (Mean ± SE) @

Texture analysis	Control	T_3	t-value
Hardness (kgf)	1.57±0.07	6.26±0.01	97.46**
Adhesiveness (kg-sec)	0.17±0.78	0.22±0.03	3.24**
Springiness (mm)	0.05±0.03	0.14±0.02	2.15**
Cohesiveness (ratio)	0.43±0.07	0.56±0.01	2.69**
Gumminess (kg)	1.86±0.02	3.21±0.05	11.75**
Chewiness (N*mm)	0.02±0.10	0.28±0.03	1.65**
Resilience	0.23±0.03	0.61±0.05	3.79**

*@ Average of six trials, ** Statistically highly significant ($P \leq 0.01$)*
Control – RWF (100%): FMF (0%): BBF (0%) and T_3 – RWF (40%): FMF (30%): BBF (30%)

Table 6. Physicochemical parameters of control and functionally enriched pasta prepared using sprouted finger millet flour and black bean flour during storage at ambient condition (Mean ± SE) @

Parameters	Storage days	Control	T_3	t-value
Peroxide Value (meq/kg)	0	2.19^{a}±0.07	2.24^{a}±0.08	74.37**
	30	2.56^{b}±0.09	2.63^{b}±0.03	103.71**
	60	2.87^{c}±0.05	2.96^{c}±0.04	145.62**
	90	3.05^{d}±0.02	3.13^{d}±0.06	84.56**
	F-value	1012.54**	1596.85**	
Free Fatty Acid (%)	0	0.45^{a}±0.01	0.51^{a}±0.08	39.42**
	30	0.57^{b}±0.05	0.63^{b}±0.05	61.75**
	60	0.69^{c}±0.07	0.78^{c}±0.03	49.46**
	90	0.80^{d}±0.03	0.89^{d}±0.07	93.12**
	F-value	95.86**	64.83**	

Parameters	Storage days	Control	T_3	t-value
Water activity (a_w)	0	$0.33^a \pm 0.02$	$0.39^a \pm 0.01$	0.26**
	30	$0.37^b \pm 0.01$	$0.43^b \pm 0.03$	0.35**
	60	$0.59^c \pm 0.03$	$0.71^c \pm 0.04$	0.29**
	90	$0.88^d \pm 0.01$	$0.93^d \pm 0.01$	0.41**
	F-value	2.41**	1.97**	

@ Average of six trials, *** Statistically highly significant ($P \leq 0.01$) and NS- Non Significant*
Control – RWF (100%): FMF (0%): BBF (0%) and *T_3 – RWF (40%): FMF (30%): BBF (30%)*

sample T_3 were of highly significant. The peroxide value was slight higher in standardized treatment T_3 and lower peroxide value were observed in control during the storage of 90 days. The results was in similar to Shoba *et al.* [28] who reported that lower peroxide values indicate lower lipid oxidation occurred and when the storage of products to 3 months, the lipid oxidation was increased by absorption of moisture which leads to increased peroxide value.

The storage stability study on effect of free fatty acid of control and T_3 is shown in Table 6. The oxidative deterioration of unsaturated fatty acids present in the pasta may be responsible for the free fatty acids. The results obtained showed a highly significant difference in free fatty acid of control and the standardized treatment T_3. And it is evident that the free fatty acid was found to increase during the storage period. The gradually increase in free fatty acids formation may be due to the addition of oil in all treatments. During the mixing of ingredients and mechanical process carried out during extrusion processing, it enabled the contact between enzyme lipase and the substrates. During the entire storage period, the free fatty acids was found to be in permissible limit. Yadav et al. [29] result was in congruence with this findings, who reported an increase in free fatty acids during entire storage period of the developed wheat-pearl millet composite pasta.

The control and standardized treatment T_3 revealed a highly significant difference in water activity as shown in Table 6. The higher value was found in control during storage of 90 days than standardized treatment T_3. The results were in concurrence with Kuen et al. [30-32] who shown that there was an increasing in trend of water activity from 0.243 to 0.396 in 6 months of storage in instant noodles [33-36].

4. CONCLUSION

The present investigation on the development of cold extruded pasta mainly focused on the utilization of underutilized raw materials incorporation in the product formulations with protein and dietary fibre enrichment. The basic composition was modified with different levels of ingredients incorporation like sprouted finger millet flour and black bean flour in different proportions as mentioned above. By carrying out sensory evaluation and based on the analysis of cooking quality parameters and physical properties the treatment were standardized. Among the five treatments, the best treatment was the pasta enriched with sprouted finger millet flour 30g/ 100g, black bean flour 30g/ 100g and refined wheat flour 40g/ 100g. The functionally enriched pasta was slightly darker in appearance due to the incorporation of sprouted finger millet flour. This maximum substituted enriched product has the highlights of improved nutritional characteristics, good cooking qualities, better sensory attributes and shelf stability. The enriched pasta could be stored for 90 days safely without excessive deterioration in quality. The developed product can be effectively utilized to reduce the risk of degenerative diseases due to bioactive components in it and good quality pasta to increase the grain and cereal consumption. By proper utilization of underutilized food components in new product development, the outcome will be a boon to the food processing industries by bringing up novel products to commercial markets.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Gopalakrishnan J, Menon R, Padmaja G, Sajeev MS, Moorthy SN. Nutritional and functional characteristics of protein-fortified pasta from sweet potato. Food and Nutrition Sciences. 2011;2(9):944-955.
2. Kowalski R J,Medina-Meza IG, Thapa BB, Murphy KM, Ganjyal GM. Extrusion processing characteristics of quinoa (Chenopodium quinoa Willd.) var. Cherry Vanilla. J. Cereal Sci. 2016;70:91-98.

3. Dalbhagat CG, Mishra HN. Effects of extrusion process conditions on system parameters; physicochemical properties and cooking characteristics of extruded fortified rice kernels. Journal of Cereal Science. 2019;89:102782.
4. Mishra A, Mishra HN, Srinivasa Rao P. Preparation of rice analogues using extrusion technology. International journal of food science & technology. 2012; 47(9):1789-1797.
5. Fuad T, Prabhasankar P. Role of ingredients in pasta product quality: A review on recent developments. Crit Rev Food Sci Nutr. 2010;50(8):787-798.
6. Shavikla GR, Olafsdottir A, Sveinsdotir K, Thorkelsson G, Rafipour. Quality characteristics and consumer acceptance of a high fish protein puffed corn fish snack. J. Food Sci. Technol. 2011; 48(6):668-676.
7. Majumdar TK, Premavalli KS, Bawa,AS. Effect of puffing on calcium and iron contents of ragi varieties and their utilization. J. Food Sci. Technol. 2006; 43(5):542-543.
8. Saravana M, Soam SK. Exploitation of minor millets genetic resources for poverty alleviation in India. In National Conference on Biodiversity, Development and Poverty Alleviation, Lucknow, India; 2010.
9. Singh N, Singh SP, Kumar M, Kanhiya K, Kumar A. Nutri cereal pearl millet: way forward. Int J Curr Microbiol App Sci. 2018; 7(6):578-581.
10. Aubukkani P, Nithyashree ML. Production and Consumption of Minor Millets in India-A Structural Break Analysis. Indian Journal of Agricultural Economics. 2016;71(3):419.
11. Parameswaran KP, Sadasivam S. Changes in the carbohydrates and nitrogenous components during germination of proso millet, Panicum milaceum. Plant foods for human nutrition. 1994;45(2):97-102.
12. Wadmare VB, Pawar VS, Shinde IN. A review of finger millet (Eleusine coracana (L.) its varieties, nutrient composition, cooking qualities and health benefits. J Pharm Innov. 2022;11:3223-3227.
13. Kulkarni SS, Desai AD, Ranveer RC, Sahoo AK. Development of nutrient rich noodles by supplementation with malted ragi flour. International Food Research Journal. 2012;19(1):309.
14. Verma V, Patel S. Value added products from nutri-cereals: Finger millet (Eleusine coracana). Emir J Food Agric. 2013; 169-176.
15. Mudryj AN, Yu N, Aukema HM. Nutritional and health benefits of pulses. Appl Physiol Nutr Metab. 2014;39(11):1197-1204.
16. Arribas CB, Cabellos C, Cuadrado, E, Guillamon, Podrona, MM. Cooking Effect on the Bioactive Compounds, Texture, and Color Properties of Cold-Extruded Rice/Bean-Based Pasta Supplemented with Whole Carob Fruit. Foods. 2020; 9(4):415.
17. Abdulrahman BO, Bala M, Bello OM. Bioactive compounds of black bean (Phaseolus vulgaris L.). Bioactive Compounds in Underutilized Vegetables and Legumes. 2020;1-20.
18. Raungrusmee S, Shrestha S, Sadiq MB, Anal AK. Influence of resistant starch, xanthan gum, inulin and defatted rice bran on the physicochemical, functional and sensory properties of low glycemic gluten-free noodles. LWT - Food Sci. Technol. 2020;126:109279.
19. Kaur H, Bobade H, Singh A, Singh B, Sharma S. Effect of formulations on functional properties and storage stability of nutritionally enriched multigrain pasta. Chemical Science International Journal. 2017;19(1):1-9.
20. AACC. Approved Methods of the American Association of Cereal Chemists, American Association of Cereal Chemists, St. Paul, MN; 2000.
21. Yagci S, Gogus F. Response surface methodology for evaluation of physical and functional properties of extruded snack food
22. Shukla K, Srivastava S. Evaluation of finger millet incorporated noodles for nutritive value and glycemic index. J. Food Sci. Technol. 2011;51(3):527-534.
23. Kamble DB, Singh R, Rani S, Upadhyay A, Kaur BP, Kumar N, Thangalakshmi S. Evaluation of structural, chemical and digestibility properties of multigrain pasta. J. Food Sci. Technol. 2020;58:1014-1026.
24. Joseph A, Balakrishnan A, Devika K, Kumar MS, Johnson S, Rajesh GK. Development and quality evaluation of nutrient rich pasta from composite flour (doctoral dissertation, department of processing and food engineering); 2022.
25. Dhas TA, Rao VA, Sharon MEM, Manoharan AP, Nithyalakshmi V. Development of fibre enriched ready-to-cook pasta with foxtail millet and tapioca

flour. J. Pharm. Innov. 2021;10(5): 1432-1435.

26. Verma AK, Pathak V, Umaraw P, Singh VP. Quality characteristics of refined wheat flour based noodles containing chicken meat stored at ambient temperature under aerobic conditions. Nutr. Food Sci. 2015;7(5):68-80.
27. Devaraju BJ, Mushtari Begum S, Shamshad Begum, Vidya K. Nutritional quality, sensory attributed and storage study of finger millet (Eleusine coracana) composite flour pasta. Paper presented at the 5th International Food Convention, Mysore, 5-8 December. 2003;116.
28. Shoba D, Vijayalakshmi D, Puttaramnaik, Asha KJ. Effect of maize based composite flour noodles on functional, sensory, nutritional and storage quality. J. Food Sci. Technol. 2015;52(12):8032-8040.
29. Yadav DN, Sharma, Chikara N, Anand T, Bansal S. Quality characteristics of vegetable-blended wheat-pearl millet composite pasta. Agricultural Research. 2014;3(3):263-270.
30. Kuen, NH, Hamid MA, Hasmadi M, Akanda JH, Ahmad F. Effect of Chickpea and Okara Composite Flours on The Quality of Instant Noodles. J. Adv. Soc. Sci. Humanit. 2018;112:180-191.
31. Ahmed ZS. Physico-chemical, structural and sensory quality of corn-based flaxsnack. Food/Nahrung. 1999;43(4): 253-258.
32. Akajiaku LO, Nwosu JN, Kabuo NO, Odimegwu EN, Umelo MC, Unegbu VC. Using sorghum flour as part substitute of wheat flour in noodles making. MOJ Food Process Technol. 2017;5(2): 250-257.
33. Shere PD, Devkatte AN, Pawar VN. Cooking and textural qualities of carrot incorporated instant noodles. J. pharmacogn. Phytochem. 2018;7(3): 3040-3045.
34. SK M, Sudha K. Functional and phytochemical properties of finger millet (Eleusine coracana L.) for health. International journal of pharmaceutical, chemical and biology sciences. 2012;2(4): 431-438.
35. Verma AK, Pathak V, Singh VP. Incorporation of chicken meat in rice flour based noodles and its effects on physicochemical and sensory qualities. Int. J. Current Res. 2012;4(12):461-466.
36. Xu F, Li XQ, Li, Chen J. The interaction between inulin and wheat starch and effects of inulin on frozen storage quality of noodles. Int. J. Food Sci. Technol. 2021; 56(5):2423-2431.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/110287