

Optimization of Cold extruded pasta enriched with Functional and Non-conventional ingredients

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 with significant ingredients like Refined Wheat Flour (RWF), Sprouted Finger millet flour (F), Black bean flour (B) in different proportions as T₁- RWF: F: B - 80: 10: 10 and T₂- RWF: F: B- 60: 20: 20, T₃- 40: 30: 30, T₄- 20: 40: 40, T₅- 0: 50: 50 and control C- RWF: F: B- 100: 0: 0, along with xanthum 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 45°C. Before drying, steaming was done for 15 mins. The extruded pasta was tray dried at 70°C for 6 hours, cooled and then stored at room temperature. The optimization of the developed pasta was done using VETSTAT tool by assessing its functional and cooking quality parameters such as water absorption index, water solubility index, cooking time, cooking loss and swelling power. Proximate and sensory analysis was also carried out. Among the trials studied, T₃- RWF: F: B- 40:30:30 was preferred as the optimized treatment based on the functional, cooking parameters and higher sensory scores for color, texture and overall acceptability. Thus, this study proved that indigenous black bean and sprouted finger millet can be partially substituted for refined wheat flour in the preparation of enriched cold extruded like pasta. This developed novel product can satisfy the taste, satiety-oriented dieting and promote healthy aesthetic food habit of consumers

Keywords: Sprouted finger millet, black bean, pasta, extrusion, optimization, overall acceptability.

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 (Gopalakrishnan *et al.*, 2011). 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, macaroni, 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 (Kowalski *et al.*, 2016).

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 (Dalbhagat *et al.*, 2019).

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 (Mishra *et al.*, 2012). 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 (Fuad and Prabasankar, 2010). 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 (Shavikla *et al.*, 2011).

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.*, 2006). 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 (2010). 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 (Singh *et al.*, 2018).

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 (Aubukkani and Nithyashree, 2016), 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 (Parameswaran and Sadasivam, 1994).

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 (Wadmareet *et al.*, 2022).

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 (Kulkarniet *et al.*, 2012).

Verma and Patel (2013) 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. (Mathanghiet *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 glycaemic management and guard against hypercholesterolemia and type 2 diabetes (Mudryjet *et al.*, 2014).

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. *Phaseolus vulgaris L.* (Black beans) contains 24.28 g/100 g DW of protein, 1.60 g/100 g DW of total lipid (fat), 70.07 g/100 g DW of carbohydrate, 4.05 g/100 g DW of ash, 17 g/100 g DW of fibre. Among the pulses, beans are consumed worldwide and with the growing of vegetarianism and the demand in Western countries for non-wheat and non-soy proteins, dry beans are obtaining increased attention by consumers; nevertheless, they are underutilized by the food industry as an ingredient in novel foods. (Arribas *et al.*, 2020)

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 (Abdulrahman *et al.*, 2020).

Hydrocolloids like xanthan gums are added to the dough to stabilize the gluten-free network, increase intermolecular viscosity, and improve the texture of the pasta (Raungrusmeeet *al.*, 2020). Xanthan gum, due to its hydrocolloid nature shield the starch and other constituents of pasta from being soluble by forming strong and firm network (Kaur *et al.*, 2017).

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, 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 (T₁ to T₅), along with C as the control as outlined in list 1.

list 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%	
T ₁	80	10	10		

T ₂	60	20	20	8%
T ₃	40	30	30	
T ₄	20	40	40	
T ₅	0	50	50	

2.3 Pasta preparation

Refined wheat flour was substituted with varying levels of sprouted finger millet 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 Table 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 15- 20 min. Finally the steamed pasta was tray dried at 70°C 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

The developed extrudate cooking time was determined by AACC Method. Water Absorption index, Water Solubility index, Swelling power, 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 2000) method. Pasta samples were initially cooked in 200 ml boiling deionized 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 (AACC 2000). The optimum cooking time was the time required for complete disappearance of the white core, thereby indicating complete gelatinization of starch.

ii) Cooking Loss:

Cooking loss of pasta was estimated by standard methods (AACC 2000). 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.

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

Aliquot taken x Weight of raw sample

iii) Swelling power:

Swelling Index was calculated as per the method adopted by (AACC 2000). The swelling index was calculated as follows

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

iv) Water Absorption index and Water Solubility index:

Water solubility (WSI) and water absorption indices of extruded products were determined by the method followed by Yagci and Gogus (2008). 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 mins (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

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

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

2.5 Color

Using Hunter Lab colorimeter, the developed extrudate 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, texture, flavor, taste) by cooking and serving hot for sensory analysis by a panel of semi-trained judges (n=7).

2.8 Storage stability

Based on the functional properties, cooking quality parameters and organoleptic characters, one best sample was chosen to study the storage stability against the control sample (C). The optimized treatment T₃ was packed in polyethylene bags and stored at ambient room temperature (20-30°C) for further storage studies like cooking quality parameters, functional properties, water activity and peroxide value, 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 \pm 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

Table 1 Sensory analysis of the functionally enriched pasta using Finger millet and Black bean (Mean \pm SE) [@]

Treatments	Appearance and Colour	Body and Texture	Flavour	Overall acceptability
Control	8.81 \pm 0.03 ^d	8.80 \pm 0.20 ^c	8.64 \pm 0.25 ^e	8.83 \pm 0.20 ^e

T ₁	7.82±0.06 ^c	7.20±0.20 ^b	7.60±0.25 ^c	7.80±0.20 ^c
T ₂	7.82±0.06 ^c	7.20±0.20 ^b	8.10±0.00 ^d	8.00±0.00 ^c
T ₃	8.22±0.01 ^c	7.20±0.20 ^b	8.10±0.20 ^d	8.42±0.20 ^d
T ₄	6.84±0.00 ^b	6.00±0.31 ^a	6.60±0.25 ^b	6.80±0.20 ^b
T ₅	6.05±0.07 ^a	5.75±0.25 ^a	6.00±0.00 ^a	6.00±0.00 ^a
F-value	88.70**	58.02**	55.46**	109.69**

The sensory analysis of the functionally enriched pasta using sprouted finger millet and black bean was conducted by a panel of semi-trained judges (n=7), by cooking and serving hot for sensory analysis and the overall acceptability of the developed extrudate was evaluated based on the sensory attributes like (color and appearance, texture, flavor, taste). The control pasta made up of 100% refined wheat flour has topped the consumer acceptability and when comparison of control with other treatments, treatment T₃ has scored the maximum consumer satisfaction and acceptability and its results were provided by statistical analysis. The results of sensory assessment for control and functionally enriched pasta were presented in Table 1. Due to incorporation of sprouted finger millet flour and black bean flour, there was a highly significant difference on colour and appearance, and overall acceptability between control and functionally substituted pasta. And among that the optimized treatment T₃ also has highly significant difference when compared with control. The results obtained in this study are in accordance to the work of Shukla and Srivastava (2011), they reported that 30% finger millet flour incorporated noodles has optimum sensory quality with better functional properties.

3.2 Cooking quality parameters of pasta

Table 2 Cooking quality parameters of the functionally enriched pasta prepared from sprouted finger millet flour and black bean flour (Mean ± SE) [®]

Treatments	Cooking time (min)	Cooking loss (%)	Swelling power (g/g)

Control	5.46±0.02 ^a	6.06±0.01 ^a	4.74±0.02 ^a
T ₁	7.87±0.03 ^b	6.06±0.003 ^a	4.76±0.01 ^a
T ₂	8.10±0.01 ^b	6.06±0.002 ^a	4.77±0.03 ^a
T ₃	9.00±0.01 ^c	6.09±0.01 ^b	4.80±0.02 ^b
T ₄	9.58±0.03 ^c	6.17±0.001 ^c	4.83±0.01 ^b
T ₅	10.16±0.02 ^d	6.21±0.02 ^d	4.94±0.01 ^c
F-value	727.67**	172.00**	0.0450**

3.2.1 Cooking Time

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 mins for control to 10.16 mins for T₅ sample. The cooking time was found to be increased with increase in substitution. The results were found to be in correlation with the results of Kauret *et al.*, (2017), who stated that due to addition of fibre rich grains, an altered gluten matrix was developed thus making starch more exposed to heat treatment and hence rapid gelatinization occurs which leads to longer duration on cooking.

3.2.2 Cooking Loss

There was a highly significant difference between the pasta samples of control and all other treatments as shown in Table 2. There was a gradual increase in cooking loss with control and other treatments. With the inclusion of other starchy and fibre rich ingredients, the cooking loss of all treatments gradually increases. The results were in accordance with Kamble *et al.* (2021), progressive addition of multigrain in pasta lowered the wheat protein content like gluten which developed a weaker gluten network and leads to increased cooking loss with gradual substitution.

3.2.3 Swelling index

Swelling power is a measure of hydration capacity, because the determination is a weight measure of swollen starch granules and their occluded water. There was a highly significant difference between the pasta samples of control and the treatments as shown in Table 2. The swelling index of the control pasta was lower when compared with the 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 substitution is gradually increased in all treatments

and due to presence of starchy molecules the swelling capacity is increased. The results coincided with the findings of Akajiaku *et al.* (2017), who observed that the treatments varied significantly and this might be due to the raw materials composition present in different treatments.

3.3 Functional Properties of pasta

Table 3 Functional Properties of the enriched pasta prepared using sprouted finger millet flour and black bean flour (Mean \pm SE) [@]

Treatments	Water solubility index (%)	Water absorption index (g/g)
Control	3.24 \pm 0.01 ^a	2.15 \pm 0.03 ^a
T ₁	3.35 \pm 0.00 ^a	2.28 \pm 0.00 ^b
T ₂	3.62 \pm 0.00 ^b	2.40 \pm 0.00 ^c
T ₃	3.72 \pm 0.00 ^c	2.47 \pm 0.02 ^c
T ₄	4.35 \pm 0.00 ^d	2.54 \pm 0.02 ^d
T ₅	5.36 \pm 0.03 ^e	2.64 \pm 0.02 ^e
F-value	1444.85**	77.25**

3.3.1 Water Absorption index

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 of control and substituted pasta treatments. This may be attributed due 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.* (2003), who showed increased water absorption index in finger millet, defatted soy/ whey protein concentrate and refined wheat flour incorporated enriched pasta.

3.3.2 Water solubility index

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. Dhaset *al.* (2021) on his study reported that due to addition of millet and tapioca flour in pasta making, shown increased water solubility index.

3.4 Color

Table4 Colour characteristics of functionally enriched pasta during storage at ambient condition (Mean \pm SE)

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Characteristics	Storage days	Control	Optimized treatment (T ₃)	t-value
Lightness (L*)	0	55.29 \pm 0.01	41.55 \pm 0.01	986.15**
	90	53.06 \pm 0.03	40.03 \pm 0.03	322.71**
	t-value	234.37**	195.37**	175.51**
Redness(a*)	0	0.58 \pm 0.02	3.34 \pm 0.02	221.13**
	90	0.37 \pm 0.01	3.12 \pm 0.01	219.52**
	t-value	212.56**	223.15**	153.57**
Yellowness(b*)	0	16.27 \pm 0.01	4.01 \pm 0.01	956.13**
	90	15.99 \pm 0.02	3.97 \pm 0.03	432.18**
	t-value	312.15**	307.06**	213.15**

To assess the appearance of the product, colour is an important factor. Based on the usage of raw materials, the colour profile depends on it. With the increase of incorporation of raw ingredients into the product, the lightness (L*), redness (a*), and yellowness (b*) value increases. The Hunter lab colorimeter was used to carry out the colour analysis. The parameters such as lightness (L*), redness (a*), and yellowness (b*), were assessed both in control and the optimized treatment T₃ as shown in Table 4. The highly significant difference was observed between the extruded

products of control and optimized treatment T₃, due to the addition of sprouted finger millet flour and black bean flour for the development of extruded product. The higher values of lightness (L*) and yellowness (b*) was observed in control sample due to the presence of refined wheat flour in the extrudate. Whereas higher values of redness (a*) were observed in optimized treatment T₃ due to the incorporation of 30% finger millet flour and 30% black bean flour. The findings were in congruence with the study of Zahra S. Ahmed (1999), who reported that due to the inclusion of fiber-rich flax seed in the extrudate caused decreasing lightness, redness and yellowness value with more browning reactions due to the presence of pigments in flax flour.

3.5 Texture

Table 5 Textural characteristics of functionally enriched pasta during storage at ambient condition (Mean ± SE) @

Texture analysis	Control	Optimized treatment (T ₃)	t-value
Hardness (kgf)	1.60±7.90 ^a	8.29±0.02	1286.28**
Adhesiveness(kg-sec)	0.18±0.82 ^a	0.24±0.05	21.19**
Springiness(mm)	0.04±0.02 ^a	0.11±0.00	15.37**
Cohesiveness(ratio)	0.66±0.03 ^b	0.40±0.02	62.65**
Gumminess(kg)	1.48±0.01 ^a	2.65±0.02	315.45**
Chewiness(N*mm)	0.04±0.10 ^a	0.35±0.03	112.72**
Resilience	0.64±0.09 ^b	0.24±0.02	97.91**

The textural profile such as hardness, springiness, resilience, cohesiveness of control and optimized treatment T₃ was shown in Table 5 and found to have a highly significant difference between the treatments. Textural attributes like hardness(kgf), adhesiveness(kg-sec), springiness(mm), cohesiveness(ratio), gumminess(kg), chewiness (N*mm) were found higher in optimized treatment T₃ whereas lower levels were found in control pasta. This might be because the hardness of the sample is highly dependent on fibre and protein content. Fibre content also plays a role in texture profile of pasta, due to incorporation of raw ingredients like sprouted finger millet flour and black bean flour. Increase in addition of raw ingredients increases the fibre content and can affect the products textural properties. Similar results were reported with (Xu *et al.*, 2021) who stated that higher hardness value in all treatments when compared to control in the developed noodles. Hence the hardness value is a significant sensory characteristics of an extruded product.

3.6 Storage stability study

3.6.1 Cooking Quality parameters of the functionally enriched pasta during storage at ambient condition

Table 6 Effect of storage study on cooking quality parameters of the functionally enriched pasta prepared from sprouted finger millet flour and black bean flour (Mean \pm SE) [@]

Properties	Storage days	Control	Optimized treatment (T ₃)
Cooking time (min)	0	5.46 \pm 0.01	9.00 \pm 0.01
	30	5.46 \pm 0.02	9.10 \pm 0.01
	60	5.55 \pm 0.01	9.15 \pm 0.01
	90	5.59 \pm 0.01	9.20 \pm 0.02
	F-value	2.03 ^{NS}	3.17 ^{NS}
Cooking Loss (%)	0	6.06 \pm 0.02	6.09 \pm 0.01
	30	6.09 \pm 0.01	6.12 \pm 0.02
	60	6.11 \pm 0.01	6.15 \pm 0.01
	90	6.14 \pm 0.01	6.17 \pm 0.03
	F-value	2.10 ^{NS}	2.29 ^{NS}
Swelling power (g/g)	0	4.74 \pm 0.01	4.80 \pm 0.02
	30	4.71 \pm 0.03	4.77 \pm 0.01
	60	4.68 \pm 0.01	4.75 \pm 0.01
	90	4.65 \pm 0.01	4.75 \pm 0.01
	F-value	2.01 ^{NS}	2.17 ^{NS}

3.6.1.1 Cooking Time

The results indicated that there was a no significant difference in the cooking time between control and the optimized treatment T₃ as shown in table 6. The cooking time of pasta was 5.46 mins for control to 9.00 mins for T₃

sample. The cooking time was found to be increased with increase in substitution and on subsequent days of storage. The result were found to be in correlation with the results of Kaur *et al.*,(2017), who reported that due to addition of fibre rich grains, an altered gluten matrix was developed thus making starch more exposed to heat treatment and hence rapid gelatinization occurs which leads to longer duration on cooking and followed the same on subsequent storage days.

3.6.1.2 Cooking Loss

The results indicated that there was a no significant difference between the pasta samples of control and the optimized treatment T₃ as shown in table 6. There was a gradual increase in cooking loss with control and the optimized treatment T₃. With the inclusion of starchy and fibre rich ingredients, the cooking loss of optimized treatments gradually increased. The results were in accordance with Kamble *et al.* (2021), progressive addition of multigrain in pasta lowered the wheat protein content which developed weaker gluten network and lead to increased cooking loss, further on subsequent storage days.

3.6.1.3 Swelling index

The results indicated that there was a no significant difference between the pasta samples of control and the optimized treatment T₃ as shown in table 6. The swelling index of the control pasta was lower when compared with the optimized treatment T₃. This might be due to water absorption of starchy molecules present in the optimized treatment T₃ during cooking. The starch and fibre rich grains used in processing are responsible for higher water absorption. Further the low swelling power of starches on storage period might be attributed due to the presence of many crystallites formed by the association between long amylopectin chains. Crystallite formation increases granular stability, thereby reducing the extent of granular swelling. The swelling volume of starch was affected by amylose content and the structure of amylopectin (JOSEPH, A., *et al.*, 2022). The results coincided with the findings of Shere *et al.*, (2018) who observed that inclusion of carrot puree in instant noodles have significantly reduced the swelling capacity of the noodles on further storage period.

3.6.2 Functional properties of the functionally enriched pasta during storage at ambient condition

Table 7 Effect of storage study on functional properties of the functionally enriched pasta during storage at ambient condition (Mean \pm SE) [@]

Properties	Storage days	Control	Optimized treatment (T ₃)
WSI(%)	0	3.24 \pm 0.01	3.72 \pm 0.01
	30	3.23 \pm 0.02	3.71 \pm 0.01
	60	3.21 \pm 0.01	3.71 \pm 0.01
	90	3.20 \pm 0.01	3.69 \pm 0.01
	F-value	2.17 ^{NS}	2.39 ^{NS}
WAI (g/g)	0	2.15 \pm 0.02	2.47 \pm 0.01
	30	2.15 \pm 0.01	2.48 \pm 0.01
	60	2.16 \pm 0.01	2.49 \pm 0.02
	90	2.16 \pm 0.01	2.49 \pm 0.01
	F-value	2.87 ^{NS}	3.13 ^{NS}

3.6.2.1 Water solubility index

Water Solubility Index was found to decrease in subsequent storage period. No significant difference was found in water solubility index of control and optimized treatment T₃ as shown in table 7. There was a gradual decrease in water solubility index on subsequent storage period till 90th days. This is in agreement to the work of Verma et al (2015) who reported similar values of 7.3% in noodles incorporated with chicken meat on the 0th day to 7.0% on the 30th day of storage at ambient storage condition.

3.6.2.2 Water Absorption index

Water Absorption Index was found to increase in subsequent storage period. No significant difference was found in water absorption index of control and substituted pasta samples as shown in table 7. This may be attributed due to the presence of starch and fibre content in sprouted finger millet and black bean treated samples. Higher levels of water absorption capacity were found for treatments with higher incorporation levels of raw ingredients such as

optimized treatment T₃ whereas lower levels were found for control noodles. The findings of the present study coincided with the findings of Verma *et al.*(2012), who stated that the water absorption capacity increased due to increase in incorporation levels of chicken meat in noodles.

3.6.3 Physicochemical parameters of the functionally enriched pasta during storage at ambient condition

Table 8 Effect of storage study on physicochemical parameters of the functionally enriched pasta during storage at ambient condition (Mean ± SE) [@]

Parameters	Storage days	Control	Optimized treatment (T ₃)
Peroxide Value (meq/kg)	0	0.66±0.01	0.71±0.02
	30	0.67±0.01	0.71±0.01
	60	0.68±0.02	0.73±0.01
	90	0.70±0.01	0.74±0.01
	F-value	2.09 ^{NS}	3.01 ^{NS}
Free Fatty Acid (%)	0	0.37±0.01	0.41±0.01
	30	0.37±0.02	0.43±0.01
	60	0.38±0.01	0.43±0.02
	90	0.39±0.01	0.44±0.01
	F-value	1.87 ^{NS}	2.83 ^{NS}
Water activity (a_w)	0	0.33±0.02	0.32±0.01
	30	0.34±0.01	0.34±0.03
	60	0.36±0.03	0.36±0.01
	90	0.38±0.01	0.37±0.01
	F-value	2.41 ^{NS}	1.97 ^{NS}

3.6.3.1 Peroxide value (meq/kg)

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 8. 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 flavor, colour and appearance, taste and texture during storage. The peroxide value of control and optimized sample T₃ were of no significant. The peroxide value was slight higher in optimized treatment T₃ and lower peroxide value were observed in control during the storage of 90 days. The results was in similar to Shoba *et al.* (2015), 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.

3.6.3.2 Free Fatty Acid (%)

The storage stability study on effect of free fatty acid of control and optimized functionally enriched extrudate was shown in table 8. The oxidative deterioration of unsaturated fatty acids present in the pasta may be responsible for the free fatty acids. The results obtained shown a no significant difference in free fatty acid of the control and the optimized treatment T₃. 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 might 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.* (2014) 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..

3.6.3.3 Water activity (a_w)

The control and optimized treatment T₃ revealed a no significant difference in a_w as shown in table 8. The higher value was found with control during storage of 90 days than optimized treatment T₃. The results were in concurrence with Kuen *et al.* (2017), 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.

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 qualities and functional properties the treatment were optimized. Among the five treatments, the best treatment was the pasta product 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 in it. 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.

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