



RESEARCH ARTICLE

Development and quality evaluation of minor millet-based pasta

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Abstract

India is the largest producer of millet with 9.71 million hectares under cultivation and 12.49 million tonnes of production. Millet has the potential to minimise the problems like hidden hunger. Globally food habits are changing rapidly and people are getting more health conscious, creating demand for wholesome alternative. Keeping this in view, a study was undertaken to develop ready to cook minor millet-based pasta using kodo flour (KF), lentil flour (LF) and semolina (S). Fifteen formulations were prepared using response surface methodology (RSM), with semolina maintained at 60 % and lentil flour at varying levels (5–35%). The study investigated the influence of kodo millet flour (5–25 %), CMC (1–7 g) and drying temperature (50–70 %) on proximate composition using central composite rotatable design (CCRD). The results indicated that the optimum value of blend ratio (BR) 60:20:20 (S: KF: LF), 55 °C drying temperature (DT) and 5.5 g of carboxy methyl cellulose (CMC) are suggested by the software for the preparation of the pasta. The optimum value of proximate composition for minor millet pasta is obtained as 11.97 % protein, 0.49 % fat, 1.92 % ash, 10.5 % moisture content and 75.12 % carbohydrate content. The results further demonstrated that the kodo millet and CMC incorporation reduced the fat content of the pasta, whereas lentil flour primarily contributed to increasing the protein content. The results further demonstrated that kodo millet and CMC incorporation reduced fat content, whereas lentil flour significantly increased protein content.

Keywords: carboxy methyl cellulose; central composite rotatable design; kodo millet; millet; pasta, proximate composition; response surface methodology

Introduction

Millet is an important food and fodder crops in arid and semiarid regions. Based on grain size, millets are classified into two main groups: major millets and minor or small millets. The classification is appropriate to the present study since it focus on minor millets especially the kodo millet which are nutritionally rich but underutilised compared to major cereals hence justifying their selection for value-added product development. As per the FAO reports, global millet production in 2020 was 30.46 million tonnes while India contributed about 12.49 million tonnes (1). India is the largest producer of millet followed by Niger, China and Nigeria. Millet can serve as an alternative nutritive food to meet the demand of growing population. Therefore, value addition of these crops is essential to provide healthy and nutritious millet-based food products.

Millets are tough C4 plants that belong to the family Poaceae. They are known for their high photosynthetic efficiency associated with C4 metabolism and ability to withstand abiotic stressors. These plants can survive in poor soils, low moisture and high temperatures because their root systems are well-developed, their life cycle is short and their bodies have adapted to these conditions (2, 3). Their plant structure, which includes the ability to tiller, compact panicles and upright leaves, helps them use resources well. Millet plants are often grown in areas that get rain and these

traits make them very important for making sure that farming can continue in the face of climate change. In recent years, millets have gained renewed attention due to their nutritional value and their potential contribution to sustainable agricultural systems.

Kodo millet (*Paspalum scrobiculatum* L.), little millet (*Panicum sumatrense* Roth), foxtail millet (*Setaria italica* (L.) P.Beauv.), barnyard millet (*Echinochloa frumentacea* Link) and proso millet (*Panicum miliaceum*) are all examples of minor millets. These plant species are referred to as “nutri-cereals” because they contain more dietary fiber, essential amino acids, vitamins, minerals and antioxidant phytochemicals than some of the most important cereals (4).

The global interest in millet farming is also growing because these plants are good for the environment because they can handle climate change. Millet plants are great for conservation agriculture and low-carbon food systems because they use water well, have few pests and don't need as many synthetic fertilisers (5). The FAO has declared 2023 to be the International Year of Millets. These plant-based cereals are being recognised as crops that are smart for the future because they may help with nutritional insecurity and promote sustainable agro-ecosystems. Value addition to millet plant grains is becoming more popular in research, industrial processing and the creation of functional food products.

Pasta is a cereal-based ready-to-cook food product. Its ease of preparation, inexpensive price, versatility, sensory qualities and long shelf life have made it widely accepted worldwide (6). Pasta is prepared by extrusion process. In this process, the dough is subjected to significant shear stresses, which possibly weaken the protein structure (7), but simultaneous application of pressure (9–10 MPa) provides the product with high compactness, allowing it to withstand cooking (8).

Pasta is traditionally made from durum wheat semolina (*Triticum durum* Desf.), which contains gluten as a protein. Deficiency of essential micronutrients such as iron, zinc and certain B-complex vitamins or excess of toxic ions are a concern in wheat (9). Pasta, being a wheat-based product, is a good source of carbohydrate (74–77 %) (10) and proteins (11–15 %) but is deficient in lysine and threonine (11). Therefore, substitution of semolina-based pasta with micronutrient-rich minor millet and lentil was used for this research.

Kodo is a highly nutritious minor millet and a good substitute for rice or wheat (12, 13). The grain is composed of 66.6 g of carbohydrates, 8.3 g of protein, 3.6 g of fat, 2.6 g of minerals, 9 g of fibre and 353 kcal of energy per 100 g, which is comparable to other millets (12). Kodo millet is very easy to digest; it contains a high amount of lecithin and is excellent for strengthening the nervous system. Kodo millet is rich in B vitamins-especially niacin, B6 and folic acid-and minerals such as calcium, iron, potassium, magnesium and zinc (13).

Lentil is a rich source of protein, containing between 20.6 % and 31.4 % protein (14). Although low in methionine and cystine, lentil is an excellent source of protein and amino acids to complement cereal protein, particularly wheat (15).

Although previous research has studied the use of substitute grains and legumes in pasta, limited study has been conducted on the combined use of kodo millet and lentil flour together with optimisation of processing factors such as drying temperature and binding agents. This represents a substantial research gap in the creation of nutritionally enriched pasta products (17).

Nowadays, the population is becoming more health conscious and demands health-promoting food products. In view of this, the present study has been carried out to optimise the level of kodo flour and lentil flour for the development of nutritious pasta (16).

Considering the increased demand for healthier food products, the present study was attempted to produce and optimise minor millet-based pasta utilising kodo millet flour (KMF) and lentil flour (LF). The influence of ingredient composition and drying temperature on the proximate composition of pasta was investigated using response surface approach.

Material and Methods

Raw Materials

For development of minor millets pasta raw materials viz., kodo millet, lentil and semolina, refined oil and salt were procured from local market Jabalpur. Carboxymethyl cellulose (CMC) used as a binding agent, were also procured from local market Jabalpur Madhya Pradesh.

Preparation of flour

The kodo millet and lentil grains were cleaned manually to remove dust, undesirable broken grains and other impurities. The initial moisture content of cleaned grains was determined by using hot air oven methods. The cleaned grains were dried and milled using a domestic flour mill (Mili Domestic flour mill, Enesh trading company Jabalpur) to obtain fine flour. The flour was sieved to ensure uniform particle sized before being used in pasta formulation

Pasta preparation

Pasta is prepared by blending semolina, KMF and LF according to the combinations given by the experimental design. The CMC was added as a binding agent. The dough formed by mixing the ingredients with a necessary quantity of water to obtain a homogeneous consistency. The obtained dough was then processed using a pasta-making apparatus (A MACPAN MAC7, 1.1 kW single-screw pasta extruder, having an approximate screw diameter of 60 mm, operating at 30–45 rpm with a capacity of 8–20 kg/hr, was used.) employing a cold extrusion approach to generate pasta strands. The extruded pasta samples were dried at different temperatures as described in the experimental design.

Experimental design

For this study, response surface methodology (RSM) was adopted to design the experimental combination for the development of nutritious pasta. The designed variables and their corresponding responses are presented in Table 1.

Table 1. Designed variables for the development of pasta and their response

Sample no.	Independent variable				Response			
	Blend ratio (S: KMF: LF)	CMC (g/100 g)	Drying temp. (°C)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)	Moisture content
A1	60:20:20	5.5	55	12.01	0.5	1.91	75.38	10.2
A2	60:15:25	4	60	11.9	1.35	2.05	74.65	10.05
A3	60:10:30	5.5	65	13.45	0.96	2.12	75.32	8.12
A4	60:15:25	4	60	12.25	1.15	2.01	74.14	10.45
A5	60:20:20	2.5	65	11.9	1.25	2.04	77.61	7.2
A6	60:15:25	4	60	12.6	1.39	2.05	73.56	10.4
A7	60:15:25	1	60	12.25	1.65	2.22	74.88	9
A8	60:15:25	4	70	13.25	1.37	1.93	76.77	6.8
A9	60:15:25	4	60	12.07	1.29	2.08	74.55	10
A10	60:25:15	4	60	11.02	0.91	2.22	76.44	9.4
A11	60:15:25	4	50	12.95	0.59	1.97	72.89	11.6
A12	60:10:30	2.5	55	13.47	1.75	2.21	71.36	11.2
A13	60:15:25	7	60	13.3	0.48	2.15	75.51	8.56
A14	60:5:35	4	60	14.25	1.339	2.08	70.73	11.6
A15	60:15:25	4	60	12.42	1.01	2.16	76.00	8.4
Control	100:0:0	0	0	14.02	3.59	1.75	73.84	6.8

Statistical analysis

The statistical analysis method investigated the effect of composition of the pasta on proximate composition (Protein, Fat, Moisture content, Ash and carbohydrate). Experiments were set up with three independent factors at five levels using a central composite design.

Moisture content

Moisture content was determined by using hot air oven method. The ground sample was weighed and put in a pre-weighed petri plate. Then sample was allowed to dry in a hot air oven at temperature of 130 °C for 2 hr. The moisture content of sample on wet basis was calculated using given standard formula.

Protein content

The protein content of the pasta evaluated using the Kjeldahl method, which estimates the quantity of reduced nitrogen (NH₂ and NH) present in the sample. This approach has three fundamental steps: digestion, distillation and titration. Initially, 0.5 g of ground pasta samples were introduced into the digesting tubes alongside a 3 g catalyst mixture (1 g of copper sulphate and 5 g of potassium sulphate). Subsequently, 10 mL of concentrated H₂SO₄ was introduced into the tube for sample digestion. During digestion, nitrogenous compounds in the sample were transformed into ammonium sulphate, resulting in the appearance of a bluish-green colour at the endpoint. Additionally, the distillation of the obtained ammonium sulphate was performed utilising a 40 % sodium hydroxide and 4 % boric acid solution. In the distillation process, NaOH was introduced to ammonium sulphate to render it alkaline, resulting in the formation of ammonia gas, which was subsequently combined with boric acid to produce ammonium borate. The titration of ammonium borate with standard 0.1 N sulphuric or hydrochloric acid, utilising an appropriate indicator, determines the nitrogen level of the food sample. The protein content in the sample was determined based on the nitrogen concentration in the diet. The protein percent was computed by the multiplication of conversion factor (6.25) with the nitrogen percentage.

Fat content

Soxhlet apparatus was used to evaluate the fat content of developed pasta. About 5 g of uncooked and ground sample was placed in a thimble and covered with the cotton. Then, the thimble was inserted in the automatic Soxhlet flask and solvent petroleum ether was added into the flask. The flask was held in the heating mantle and extraction process takes place for 6 hr. The Soxhlet extractor contains 3 compartments: flask, extraction chamber and condenser. Once the flasks were heated, the solvent evaporated and transported to condenser and transformed into liquid. Then, the

liquid was collected in the extraction chamber containing the sample. When the solvent travels through the sample, it dissolves the lipids and carries with them into the flask. After extraction, the solvent was evaporated by drying in oven and the mass of fat / oil remaining in the flask is measured.

Ash content

The ash content of pasta was assessed using the AOAC technique (18). For this, 5 g of pasta product were preserved in the dried crucible and placed in the muffle furnace. The product was allowed to burn in furnace at 700 °C for 2 hr. Weight of ash is measured after burning.

Carbohydrate content

The carbohydrate in the product is determined by using the difference method i.e. by subtracting the sum of (per 100 g) protein, fat, moisture and ash from 100.

Chemical analysis

The proximate composition (protein, fat, moisture, ash and carbohydrate) of the kodo based pasta was analysed using AOAC (18). Protein content was analysed by using Kjeldahl method. Fat and ash content analysis was performed using the Soxhlet apparatus and muffle furnace respectively. Moisture content was estimated by hot air oven method.

Results and Discussion

The response surface plots illustrating the effects of kodo millet flour (KMF), carboxymethyl cellulose (CMC) and drying temperature on proximate composition are presented in Fig. 1 (a–j).

Effect on protein content

Protein content of pasta varied from 11.025 % to 14.25 % (Table 1). The control sample exhibited 14.02 % protein content, which is comparable to the formulating containing 5 % KMF and 35 % LF. Protein content of pasta decreases with increase in the proportion of KMF in the blend. It may occur due to increasing the KMF proportion in blend and decreases in the lentil flour proportion, which is specifically substituted in blend for protein enrichment in pasta. The effect of CMC and drying temperature on protein content were found to be statistically non-significant ($p > 0.05$), indicating that formulation variable had an excellent influence than processing condition (Table 2; Fig. 1 a and b). Similar findings have been reported by previous researchers (13), who observed increased protein content in millet based pasta with incorporation of legume flour (13). Similarly earlier researcher (17) observed that protein enrichment in pasta is significantly dependent on legume replacement.

Table 2. Analysis of variance of independent variables on responses of nutritious pasta

Particular	Protein (%)	Fat (%)	Ash content (%)	Moisture content (%)	Carbohydrate (%)
Model	0.003*	0.004*	0.04*	0.04*	0.02*
(A)-BR	0.0003*	0.07	0.12	0.13	0.005*
(B)-CMC	0.03*	0.001*	0.39	0.70	0.62
(C)-DT	0.65	0.006*	0.59	0.008*	0.02*
AB	0.66	0.08	0.52	0.54	0.31
AC	0.19	0.34	0.28	0.79	0.60
BC	0.76	0.14	0.009*	0.95	0.80
A2	0.15	0.34	0.14	0.47	0.23
B2	0.05*	0.06	0.05*	0.14	0.37
C2	0.01*	0.04*	0.03*	0.24	0.67
Lack of fit	0.80	0.98	0.60	0.45	0.53
CV, %	1.01	6.12	1.25	4.32	0.57
R2	0.97	0.96	0.90	0.89	0.92

Significance * $p \leq 0.05$

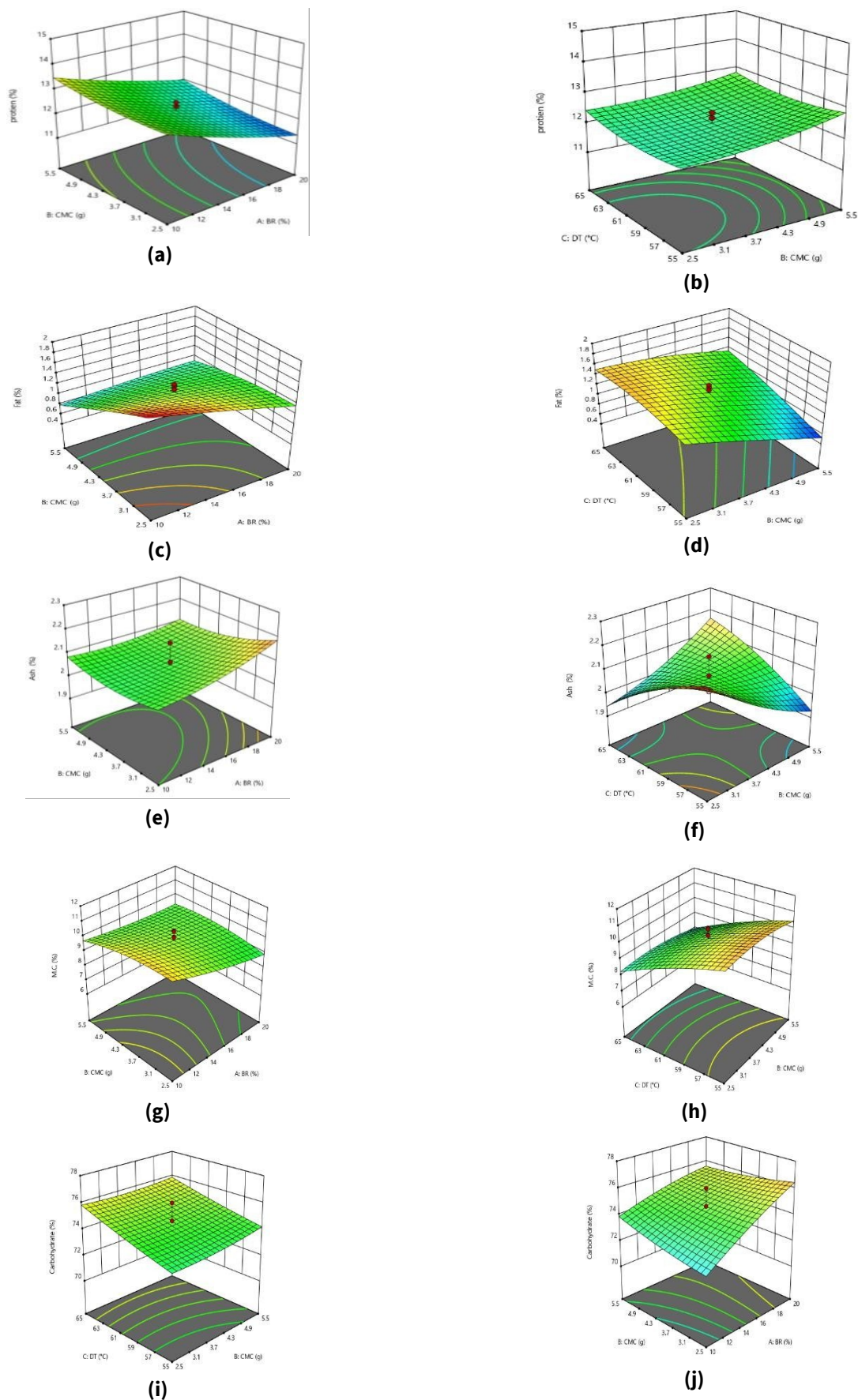


Fig. 1. Effect of kodo millet flour, carboxymethyl cellulose and drying temperature on proximate composition of the pasta. (a) Effect of kodo millet flour and carboxymethyl cellulose on protein; (b) Effect of drying temperature and carboxymethyl cellulose on protein; (c) Effect of kodo millet flour and carboxymethyl cellulose on fat; (d) Effect of drying temperature and carboxymethyl cellulose on fat; (e) Effect of kodo millet flour and carboxymethyl cellulose on ash content; (f) Effect of drying temperature and carboxymethyl cellulose on ash content; (g) Effect of kodo millet flour and carboxymethyl cellulose on moisture content; (h) Effect of drying temperature and carboxymethyl cellulose on moisture content; (i) Effect of kodo millet flour and carboxymethyl cellulose on carbohydrate; (j) Effect of drying temperature and carboxymethyl cellulose on carbohydrate.

Effect on fat content

Fat content of pasta ranged from 0.48 % to 1.75 % (Table 1). It was also found that fat content of kodo pasta is less than the control sample which has 3.59 % fat. With increase in a KMF % in blend results in decrease of fat content of pasta. Similarly, with increase in CMC, fat content rapidly decreases. It may be due to CMC is a fat replacer. CMC can form a thermo-gelation film and reduce oil absorption. Drying temperature showed a slight but statistically significant effect ($p < 0.05$) on fat content (Table 2; Fig. a c and d). These findings are in agreement with previous research where incorporating hydrocolloids reduced fat content in pasta products (6).

Effect on ash content

Ash content of pasta varied from 1.91 % to 2.22 % (Table 1). Higher ash content turned out in samples with increased amount of KMF and LF, which can be attributed to their higher mineral content compared to semolina. The interaction between variables showed a statistically significant effect ($p \leq 0.05$) on ash content, as supported by ANOVA results (Table 2; Fig. 1 e and f). Similar results have been reported by Kumar previously (12), indicating that minor millets are rich sources of minerals and greatly enhance ash content in value-added products.

Effect on moisture content

The maximum value of moisture content of pasta was found to be 11.6 %, where its minimum value was 6.8 % (Table 1). Control sample has less moisture content (6.12 %) due to less availability of fiber in semolina. In kodo pasta, CMC is also used as binding agent which has hydrophilic nature that help to bound the water molecules tightly in comparison to control pasta. Moisture content of pasta decreases with increment of the KMF in blend, CMC weight and drying temperature of pasta because process parameter also affects the moisture availability in pasta. On higher drying temperature, large moisture removal takes place (Table 2; Fig. g and h). These findings are consistent with findings of Previous researchers (8), who found that drying temperature play a key role in influencing moisture content and structural features of pasta.

Effect on carbohydrate content

The carbohydrate content of pasta varied from 70.73 to 77.61 % (Table 1). The carbohydrate content decreasing with increased level of kodo millets flour and lentil flour due to their higher protein, fibre and ash content compared to semolina. The interaction of blend ratio and drying temperature exhibited significant effect ($p < 0.05$) on carbohydrate content. The response surface plots (Fig. 1 i & j) demonstrate that increasing drying temperature slightly increased carbohydrate concentration due to moisture reduction. Similar effect were found in millets based pasta trials (13, 17)

Optimisation

The optimum solution was found at 20 % KMF proportion, 5.5 g CMC and 55 °C drying temperature. Following optimum values of proximate composition and cooking parameter are obtained from the above experiments for the kodo millet-based pasta. 11.97 % protein, 0.49 % fat, 1.92 % ash content, 10.5 % moisture content, 75.12 % carbohydrate. The high coefficient of determination ($R^2 > 0.90$) for all responses confirms the adequacy of the model in predicting the experimental outcomes. These results suggest that

response surface methodology is a useful tool for optimisation of functional food items, as was reported by previous researchers working on cereal-legume composite foods (17).

Conclusion

The present study indicated that partial substitution of semolina with kodo millet flour and lentil flour can greatly boost the nutritional quality of pasta. The adoption of response surface methodology permitted systematic optimisation of formulation factors, resulting in a balanced product with improved protein and mineral content and lowered fat levels. The optimised formulation (60:20:20; semolina:kodo millet flour:lentil flour, 5.5 g CMC, 55 °C drying temperature) (Table 3) showed excellent proximate composition and processing adaptability.

From a practical point of view, developed millet-based pasta provides potential as a functional food product that can contribute to better dietary diversity and nutrient intake, particularly in locations where millets are abundantly available. It may also promote the promotion of underused crops such as kodo millet in value-added food processing enterprises. However, the study is limited to proximate composition analysis and does not include sensory evaluation, cooking quality, or shelf-life assessment, which are crucial for consumer acceptance and commercial use. In addition, the findings are based on laboratory-size preparation and further validation at pilot or industrial scale is required.

Future research should focus on sensory features, textural aspects, glycaemic response and storage stability of the improved pasta. Exploration of different millet varieties and legume combinations may also bring greater applications in functional food production.

Table 3. Optimum values of nutritional formulation of pasta

Variable	Goal	Lower limit	Upper limit
KMF %	is in range	10	20
CMC g	is in range	2.5	5.5
DT °C	is in range	55	65
Protein (%)	maximize	3.32039	3.77492
Fat (%)	minimize	0.69282	1.32288
Ash (%)	is in range	1.38203	1.48997
Moisture content (%)	is in range	2.60768	3.40588
Carbohydrate (%)	is in range	8.41017	8.80965

KMF: Kodo millet flour; CMC: Carboxymethyl cellulose; DT: Drying temperature.

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Authors' contributions

SSM conducted the research work and prepared the manuscript. AKG supervised the study and assisted in research paper writing. MD carried out the chemical analysis of minor millet-based pasta. KCM assisted in data analysis and result writing. MS helped in correction and improvement of the manuscript. EKK contributed

to manuscript design. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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