Hindawi
Journal of Food Quality
Volume 2022, Article ID 5881459, 8 pages
https://doi.org/10.1155/2022/5881459

Research Article

Response Surface Methodology and Textural Profile Analysis for Optimization of Fruit Peel-Based Extruded Snack (Elbow Macaroni)

Pragya Mishra[1] **Ena Gupta**[2] **and Karishma Gupta**[3]

[1]*Food Processing and Management, DDU Kaushal Kendra RGSC, Banaras Hindu University, Varanasi-221005, Uttar Pradesh, India*
[2]*Department of Home Science, University of Allahabad, Prayagraj-211002, Uttar Pradesh, India*
[3]*Center of Food Technology, Institute of Professional Studies, University of Allahabad, Allahabad-211002, Uttar Pradesh, India*

Correspondence should be addressed to Ena Gupta; enaravish@gmail.com

Received 13 August 2021; Revised 11 January 2022; Accepted 7 March 2022; Published 16 April 2022

Academic Editor: Jridi Mourad

Fruit peel (papaya and banana peel) waste, an agricultural by-product of the fruit processing industry, has abundant phytonutrients and is utilized as a new raw ingredient to develop extruded snack products (macaroni). In our study, macaroni was formulated by response surface methodology (RSM) and textural profile analysis (TPA) using a texture analyzer. The three critical ingredients A = FPB (i.e., papaya and banana peel blend mixed in the ratio of 5 : 2), B= finger millet, and C= semolina were selected to optimize macaroni with balanced nutrition and wholesomeness. Individual 3D plots of the different quality response variables were superimposed, and the maximum sensory scores in terms of texture, colour and appearance (C&A), and overall acceptability (OA) were 5.9, 6.6, and 6.1, respectively. The optimized critical, independent parameters (A = 30.66 g, B = 26.67 g, and C = 12.66 g) were observed for nutritional parameter as energy = 318.3 kcal, protein = 9.6 g/100 g, fiber= 2.7 mg/100 g, and calcium = 26.4 mg/100 g and textural profile (25.1 g force, 0.8 (dimensionless), 22.64 N, 0.91 mm, 20.66 N/mm for hardness/firmness, cohesiveness, gumminess springiness, chewiness, respectively). The proximate composition of optimized fruit peel macaroni was reported to have 5.06, 9.7, 2.7, 1.33, 1.42, and 79.79 percent of moisture, protein, fibre, fat, ash, and carbohydrate, respectively. Thus, instead of disposing and causing environmental hazards, the fruit peels act as promising sources for food supplementation and can be utilized for the nutritional enrichment of snack foods. The present work proposes an alternative method of utilizing food processing wastes (fruit peel) to develop useful value-added extruded food products. Such a replacement in innovative snacks may help in combating malnutrition and reduce the risk of obesity due to overconsumption of snack products.

1. Introduction

Worldwide, India is the second largest food producer with the prospects of attaining the first rank if all the emerging problems are appropriately addressed. India is also the second largest consumer and producer of fruits, with a buffer stock of over 60 million tons of wheat and rice. However, there is a significant gap between gross production and the net availability to the consumer due to high postharvest losses and poor handling of the produce. A massive quantity of by-products and waste material such as fruit peels from food processing plants emerged as a significant disposal problem for the industry. Such by-products are considered low value at the postharvest stage, accounting for 14 percent of food loss and waste worldwide [1]. However, they still contain many nutrients and can be promising sources for food supplementation [2]. In India, there is only 7 percent value addition to raw food material, whereas it is 23, 45, and 188 percent in China, Philippines, and the UK, respectively [3]. To promote the utilization of the by-products and tackle their environmental impacts, Dey et al. (2021) reported that the extrusion technology has been suggested as excellent avenue in terms of developing value-added food products from the inedible waste of fruits and vegetables [4].

Macaroni (dry narrow tube-shaped pasta) could be made with durum wheat, cut in a curved shape known as elbow macaroni, and made on a large scale through extrusion. Around the globe, macaroni is highly consumed because of its long shelf life, convenience, palatability, and low cost than other bakery products. Nowadays, it is becoming popular in Indian delicacy [5]. In today's generation, macaroni is liked by all age groups but mostly in demand by children because of its taste, simple preparation, and inexpensiveness.

Macaroni is an ideal foundation for satisfying healthy and nutritious meals when eaten with nutrient-dense partners. Durum wheat (*Triticum durum*), one of the hardest wheat types, is traditionally used in the preparation of macaroni as it provides firm texture, more elasticity, low sodium levels, and good eating and cooking quality. The extensive range of macaroni makes it a trendy food, acceptable among numerous population groups, including fitness enthusiasts. Interests of food manufacturers and researchers have shifted to develop nutritious macaroni rich in minerals, vitamins, and fibre content as the demand for healthy foods is growing in number, especially among health-conscious people. The Food and Drug Administration (FDA) and World Health Organization (WHO) considered macaroni as the best vehicle for the incorporation of nutrition supplements [6]. Value addition of traditional macaroni with finger millet (*Eleusine coracana*), one of the most nutritious cereals, adds a good source of carbohydrate, protein, iron, calcium, and other essential nutrients, keeping premature ageing malnutrition degenerative diseases at bay. At present, the food industry is constantly searching for value-added ingredients derived from the wastes.

The conversion of agricultural products into processed food yields numerous by-products or waste, of which fruit and vegetable peels constitute a significant portion [4]. Fruit peels represent a significant source of biologically active constituents that can be utilized as a promising functional food ingredient for value addition, especially nutraceuticals and food additives [7]. Thus, fruit peels have been recommended as a functional ingredient for developing healthy foods to prevent nutritional issues and diet-related diseases. Peels of some widely consumed fruits like banana (*Musa paradisiaca* L.) and papaya (*Carica papaya*) are rich in vitamins, minerals, fibre, polyphenol, and antioxidants and hence represent a tremendous therapeutic potential to the consumers. These fruit peels are utilized for multiple purposes as they are full of nutrients with great significance in improving the well-being of citizens and economy, reducing pollution, and protecting the environment. Currently, the food industry is constantly working to introduce functional food products enriched with bioactive components and nutrients [8]. Therefore, highly nutritious macaroni can be developed by incorporating finger millet, banana, and papaya peels with traditional semolina, providing additional health benefits to consumers. Thus, a scientific effort was undertaken to produce ready-to-cook, extruded, and value-added snacks by utilizing the by-products of food industries. The present work is framed with the objective to optimize the ingredients for the development of macaroni by using response surface methodology based on sensory and nutritional parameters. The developed macaroni was further analyzed for its textural property as palatability is the primary concern for snack foods. The proposed workprovides a new combination of ingredients utilizing the extrusion method for exploitation of food processing wastes into developing nutritionally enriched extruded food products, which may find its craving prevalence among children.

2. Material and Methods

2.1. Raw Materials. Ingredients like finger millet, semolina, and salt were purchased from the local market of Prayagraj, UP, India. In addition, analytical grade chemicals were purchased from Sigma-Aldrich (Seelze, Germany) and Lab-Scan (Dublin, Ireland) available in the local market.

2.2. Preparation of Fruit Peel Powder Blend (FPB). The fruit peels of papaya and banana were collected from a local fruit market in Prayagraj, India. The samples were cleaned to remove dirt, cut into small pieces, blanched, and then dried at $60 \pm 5^{\circ}C$ for 12 h in a hot air oven (relative humidity maintained at 0.70 to 0.75%). The dried peel ground to fine powder, sieved (60 mesh size), and stored in airtight bags under refrigerated conditions for further use.

2.3. Nutritional Analysis of Fruit Peel. The proximate composition includes moisture, ash, protein, fat, and fibre of papaya and banana, and the optimized macaroni was determined by AOAC (2012) [9]. The percentage of carbohydrates was determined by the difference method. Caloric values were computed using the Atwater general factor system. The mineral content in terms of calcium, phosphorous, iron, and ascorbic acid was also analyzed by AOAC methods. All the determinations were undertaken in triplicate and expressed as a percentage of dried matter (DM).

2.4. Modelling of Experimental Design by Response Surface Methodology (RSM). For the development of fruit peel macaroni, 23 factorial experiences were constructed to optimize the levels of independent variables, including semolina as the base material, fruit peel blend (FPB), and finger millet, to investigate their effect on the sensory parameters (texture, colour and appearance (C&A), overall acceptability (OA)) and nutritional competency (energy, protein, fibre, and calcium (Ca)). After a series of screening experiments through the trial and test method, the higher and lower limits of all three independent variables were set: semolina = 30–60%, fruit peel blend (FPB) = 10–30%, and finger millet = 10–30%. Coded and actual levels of the experimental design are given in Supplementary Table S1. The interactive effect of multiple parameters on response variables was analyzed by the central composite design (CCD) or Box–Behnken design of response surface methodology (RSM) using Design Expert (version 7.0.0) software (Stat-Ease Design Expert, the USA). The design consisted of 20 runs (8 factorial runs, 6 center points, and 4 star points), as shown in Supplementary Table S2. The optimized values of selected variables were obtained by solving the multiple regression equation below:

$$\begin{aligned}
\text{Texture} &= +6.65 + 0.47^{*}A + 0.077^{*}B - 0.096^{*}C - 6.25^{*}A^{*}B - 0.094^{*}A^{*}C + 0.084^{*}B^{*}C - 0.20^{*}A2 \\
&\quad + 0.045^{*}B2 - 0.29^{*}C2, \\
\text{Colour and appearance}\,(C\&A) &= +7.40 + 0.69^{*}A + 0.20^{*}B - 0.15^{*}C + 0.035^{*}A^{*}B - 0.060^{*}A^{*}C - 0.077^{*}B^{*}C - 0.22^{*}A2 \\
&\quad + 0.036^{*}B2 - 0.31^{*}C2, \\
\text{Overall Acceptability}\,(OA) &= +5.6 + 0.29^{*}A - 0.010^{*}B - 0.72^{*}C + 0.14^{*}A^{*}B - 0.26^{*}A^{*}C - 0.28^{*}B^{*}C + 0.29^{*}A2 \\
&\quad + 0.091^{*}B2 + 0.19^{*}C2, \\
\text{Energy} &= +327.56 + 8.62^{*}A + 0.42^{*}B + 2.22^{*}C + 0.44^{*}A^{*}B + 0.86^{*}A^{*}C - 0.21^{*}B^{*}C \\
&\quad + 0.46^{*}A2 - 0.28^{*}B2 - 1.13^{*}C2, \\
\text{Protein} &= +10.66 + 0.80^{*}A - 0.062^{*}B + 0.21^{*}C + 0.010^{*}A^{*}B - 0.055^{*}A^{*}CC \\
&\quad + 0.045^{*}B^{*}C - 0.059^{*}A2 + 0.043^{*}B2 + 0.025^{*}C2, \\
\text{Fiber} &= +3.10 + 0.27^{*}A + 0.054^{*}B + 0.099^{*}C + 0.064^{*}A^{*}B - 0.011^{*}A^{*}C + 0.051^{*}B^{*}C - 0.058^{*}A2 \\
&\quad + 0.018^{*}B2 + 0.016^{*}C2, \\
\text{Calcium}\,(\text{Ca}) &= +27.53 + 0.43^{*}A + 0.24^{*}B + 0.69^{*}C + 0.16^{*}A^{*}B - 0.084^{*}A^{*}C - 0.10^{*}B^{*}C - 0.37^{*}A2 \\
&\quad + 0.18^{*}B2 + 4.641^{*}C2,
\end{aligned} \tag{1}$$

where A, B, and C are the independent variables

2.5. Preparation of Extruded Snack (Elbow Macaroni). Fruit peel-based elbow macaroni was developed by mixing a blend of stabilized papaya and banana peel (5 : 2) with finger millet flour and semolina (all 20 runs suggested by response surface design accordingly) along with salt and warm (40 ± 2°C) distilled water for uniform distribution of salt and water to form the dough. In the next step, it was subjected to a single screw laboratory cold-extrusion machine (La Monferrina, Castell'Alfero, Asti, Italy), and the dough was extruded (40 ± 2°C) through a die to obtain the elbow-shaped macaroni. Finally, in a tray dryer, the extruded macaroni sample was dried at 75°C for 5 h (Supplementary Figure S1).

2.6. Sensory Analysis. The organoleptic sensorial property such as texture, colour and appearance (C&A), flavour, taste, and overall acceptability (OA) of fruit peel macaroni was evaluated by 15 semitrained panel members for all 20 run samples on a nine-point hedonic scale.

2.7. Texture Profile Analysis (TPA). The texture profile, including the parameters such as hardness, cohesiveness, springiness, chewiness, and gumminess, of the developed fruit peel macaroni was determined by the resulting curve obtained by compressing the sample in a texture analyzer (model TA-XT2i; Stable Microsystems, the UK) using a 3-point bending rig and 5 kg load cell. The distance between the two beams was 40 mm. Another identical beam fell from above at a pretest speed of 1.0 mm/s, test speed of 3.0 mm/s, and post-test speed of 12.0 mm/s with trigger force 0.05 N [10].

3. Result and Discussion

Macaroni is shaped like dry pasta narrow tubes, made up of durum wheat by utilizing cold-extrusion technology as a compounding tool rather than a cooking tool, and is eaten as snacks most preferably by children. The idea of producing fruit peel macaroni with an excellent sensory profile along with outstanding nutritional value will help in novel upgradation in food processing, fabrication of the product, and by-product utilization. It may also help pave a way that demands zero wastage [11].

3.1. Nutritional Composition of Papaya and Banana Peels. The main objective of the present part of the research work is to reutilize fruit peels as they represent the significant bulk of food waste and create profitable value-added products such as nutraceutical foods [12]. The nutritional and functional properties of four types of fruit peels and related data have already been published in one of our recent articles [13]. It is evident from the results depicted in Supplementary Figure S2 that there is an insignificant difference in the mean score of moisture content (88.6 ± 0.72 and 87.9 ± 0.52%), fat (6.2 ± 0.015 and 6.43 ± 0.07%), protein (7.27 ± 0.05 and 8.6 ± 0.7%), and ash content (11.5 ± 0.3 and 12.3 ± 0.15%) between papaya and banana peels, respectively. However, a significantly lower value of energy (164.9 ± 26.3 and 274.3 ± 25.02 kcal), carbohydrate (23.9 ± 0.39 and 45.6 ± 1.58%), and fibre was observed in papaya peel compared with banana peel, respectively. The experimental analysis for mineral estimation (Supplementary Figure S3) indicates an insignificant difference in the mean value of calcium (15.5 ± 0.3 and 17.7 ± 0.59 mg/100 g) between papaya and banana peels, respectively; also, there is a significantly lower value of iron concentration (23.8 ± 0.35 and

33.4 ± 0.2 mg/100 g). Still, a higher value of phosphorus (20.4 ± 0.25 and 10.13 ± 0.3 mg/100 g) and ascorbic acid (8.3 ± 0.15 and 3.3 ± 0.15 mg/100 g) was observed in papaya peel compared with banana peel, respectively [13]. Results related to proximate composition analysis were inconsistent with the similar work reported by Feumba et al. [14]. Our previous study suggests that antioxidants [15], naturally present in the fruit peels, potentially increase the functionality and nutrition of any food product when added. Betsy (2011) studied the total dietary fibre (TDF) content and storage stability of antioxidant activity of nutraceutical mango products and gluten-free cookies, which play an essential role in health benefits [12]. Another study also reported the health-protective potential of fruit peels for their utilization in pharmaceutical, nutraceutical, and food preparation [16].

3.2. Optimization of Ingredients for the Development of Fruit Peel Macaroni. The utilization of fruit peel and finger millet for macaroni preparation may prove as ideal ingredients due to their higher dietary fiber and essential mineral content [17]. A previous study reported that the textural properties and colour of formed snack products were affected by the addition of fruit waste [17]. Therefore, to make a balanced blend of fruit peel powder, banana and papaya peels are mixed in the ratio of 5 : 2 with a slightly sweet and bland taste and appealing colour and appearance and other ingredients. Fruit peel macaroni was developed using the blend of papaya and banana peels and other ingredients by applying response surface methodology (RSM). Yağci and Göğüş (2009) also developed extruded snacks from food by-products through response surface analysis [17]. Based on a series of preliminary experimental trials, fruit peel blend (FPB), finger millet, and semolina were selected as critical, independent parameters for the formulation of fruit peel macaroni. Sensory attributes are the most desirable characteristics to determine the product quality as the first perception by the consumer acceptability. On the other hand, the nutritional value is of concern as snack food like macaroni is most popular among children who seek taste besides essential nutrition. The results are depicted in Table 1, derived from the RSM design (Supplementary Table S1) to optimize ingredients (A = semolina, B = FPB, and C = finger millet) by the ANOVA. The ANOVA results); optimized based on the quality response variable which was analyzed in terms of sensorial [texture = 5.9, colour & appearance (C&A) = 6.6 and overall acceptability (OA) = 6.1] as well as nutritional parameters such as energy = 318.3 kcal, protein = 9.6 g/100 g, fiber = 2.7 mg/100 g, and calcium = 26.4 mg/100 g.. The sensory evaluation of such products should be addressed as mandatory steps because consumer acceptability is crucial for the commercialization of value-added products [4].

The analysis of variance (ANOVA) revealed that the p values of all regression models were less than 0.05. Model F values (ratio of mean square regression to mean square residual) of texture, C&A, OA, protein, energy, fibre, and Ca were 9.73, 9.39, 11.31 (on the 9-point hedonic scale), 9.47 g/100 g, 1116.13 kcal, 1.30 mg/100 g, and 12.81 mg/100 g, respectively, indicating the significance of models for all the critical response variables. The coefficient of determination (R2) values of the responses taken for this study, such as sensory and nutritional parameters, were found to be ranged from 0.77 to 0.99, as presented in Table 1. The coefficient of determination for all sensory and nutritional responses was satisfactory, higher than 89 percent, reflecting the fitness of polynomial models used to describe the effect of variables on the responses. The software suggested that the cubic model describes the significant effect of factors on all the responses . The lack of fit for all analyzed parameters is insignificant implies that it is not significant relative to the pure error. Nonsignificant lack of fit is good, suggesting models developed were highly adequate. A negative Pred R-squared value was also observed in the case of C&A and OA (−0.075 and −0.76, respectively) of the product, which implies that the overall mean is a better predictor of our response than the current model. While in the case of other sensory and nutritional parameters (except fibre), the Pred R-squared was not as close to the Adj R-squared as it might be normally expected. This difference may indicate a significant block effect or a possible problem with our model and data. Only in the case of fibre, the Pred R-squared of 0.9418 is in reasonable agreement with the Adj R-squared of 0.9854. Adeq precision measures the signal-to-noise ratio, and a ratio greater than four is desirable. In our study, the Adeq precision was observed to be greater than 4 for all the experimental parameters, indicating an adequate signal. Hence, the entire parameters under the sensory and nutritional response model can navigate the design space. The preciseness and reliability of the model are denoted by the low coefficient of variation (CV%), which was observed as 3.81, 5.50, 9.52, 1.70, 0.66, 1.03, and 1.41 for texture, C&A, OA, protein, energy, fibre, and Ca, respectively.

The three-dimensional response surface plots visualize the individual cumulative effects of the independent variables (A = semolina, B= FPB, and C= finger millet) on the response variables for sensorial parameters (texture, colour and appearance (C&A), overall acceptability (OA)) of fruit peel macaroni, as depicted in Figures 1(a), 1(b), and 1(c), respectively, and for its nutritional competency (energy, protein, fibre, and calcium (Ca)), as depicted in Figures 2(a)–2(d), respectively. Henceforth, the interaction among all the response variables was analyzed using the 3D graph for all possible combinations of factors and keeping one-factor constant at a time. ANOVA results showed that the fruit peel blend and finger millet were the limiting ingredients. A slight variation of these ingredients produces a significant ($p < 0.05$) effect on sensorial competency for linear and quadratic models. Therefore, in our study, fruit peel blend and finger millet positively affect the nutritional value. Similar to the current study, Kaur et al. (2019) [18] indicated the maximum positive effect of mango peel powder addition compared with seed followed by pulp on the vitamin content. Furthermore, the previous report showed that utilization of apple and papaya peels helped to make value-added snacks like energy bars and their oxidative stability was also evaluated [19].

Table 1: Regression coefficients of the quadratic model and ANOVA for different attributes of fruit peel macaroni.

Model term	Responses						
	Texture	C&A	OA	Protein	Energy	Fibre	Ca
F value	9.73	9.39	11.31	9.47	1116.13	1.30	12.81
Mean value	6.35	7.07	6.00	10.67	327.30	3.08	27.40
Standard deviation	0.24	0.39	0.57	0.18	2.15	0.032	0.39
CV%	3.81	5.50	9.52	1.70	0.66	1.03	1.41
R2 value	0.89	0.86	0.77	0.96	0.96	0.99	0.89
Adj R-squared	0.80	0.0.73	0.57	0.93	0.92	0.98	0.80
Pred R-squared	0.21	−0.075	−0.76	0.74	0.69	0.94	0.16
Adeq precision	9.525	9.036	7.27	20.96	19.07	51.23	10.79
Lack of fit	0.12	0.30	0.05	0.065	9.23	0.01	0.30
Model	Significant	Significant	Significant	Significant	Significant	Significant	Significant

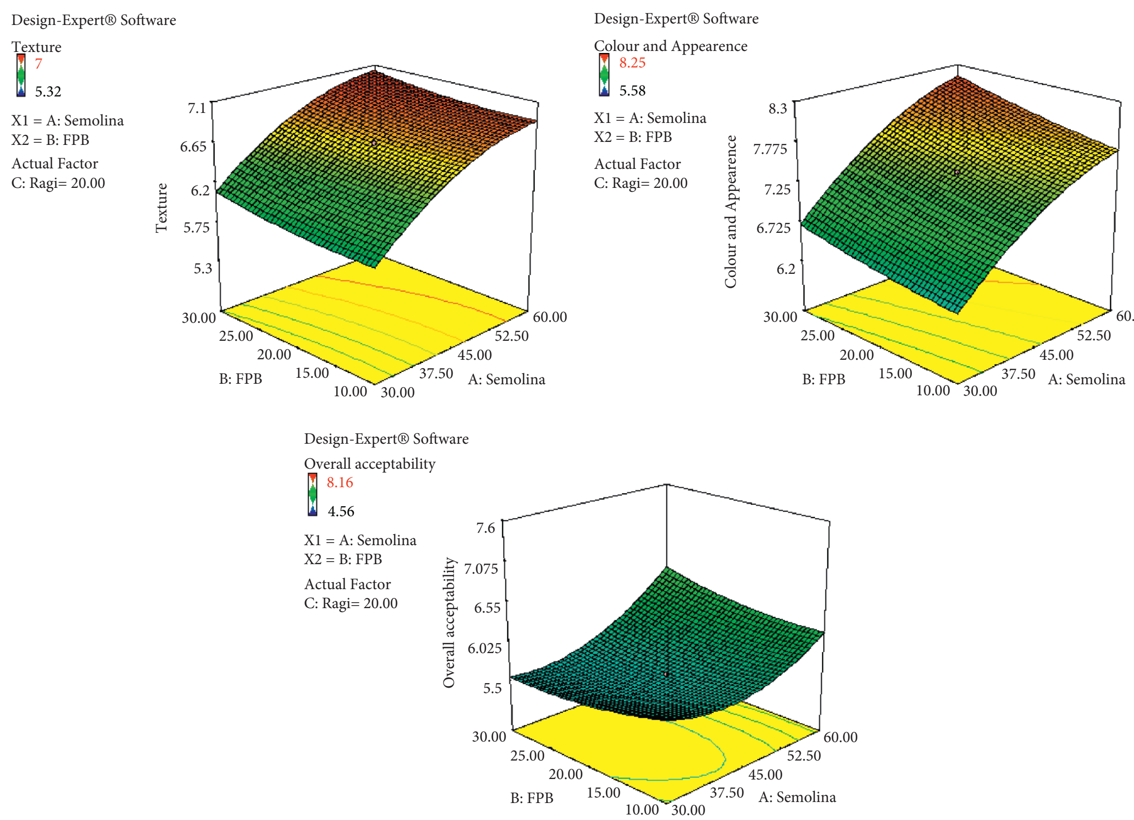

Figure 1: Three-dimensional (3D) surface plot indicating cumulative effects of the independent variables (A = semolina, B = FPB, and C = finger millet) on the response variables, viz, sensory parameters such as texture (a), colour and appearance (b), and overall acceptability (c) of fruit peel macaroni.

3.3. Texture Profile Analysis (TPA) of Fruit Peel Macaroni. The texture is an essential quality characteristic to accurately predict the textural attributes, having significance in the overall quality and acceptance of food products [20]. The TPA test consists of compressing bite-size pieces of food two times in a motion that simulates the action of the jaw and extracting several textural parameters from the resulting force-time curve. The results of TPA revealed that the textural parameters such as hardness, cohesiveness, gumminess, springiness, and chewiness of all 20 samples of fruit peel macaroni varied from 23.53 ± 0.26 to 67.36 ± 0.18 (g force), 0.63 ± 0.02 to 1.23 ± 0.05 (dimensionless), 20.87 ± 1.36 to 59.25 ± 2.43 (N), 0.64 ± 0.01 to 1.6 ± 0.04 (mm), and 18.43 ± 3.04 to 85.29 ± 5.32 (N/mm), respectively. For illustrating the TPA for all 20 samples of fruit peel macaroni, a web diagram was constructed that clearly showed the textural diversity with a significant difference for all five considered texture parameters (Figure 3). The texture of fruit peel macaroni is primarily attributable to gelatinization finger millet with other ingredients. Earlier it was reported that the addition of banana peel flour to a gluten-free rissol has positively impacted its nutritional, textural, and colour values without affecting its typical characteristics [21].

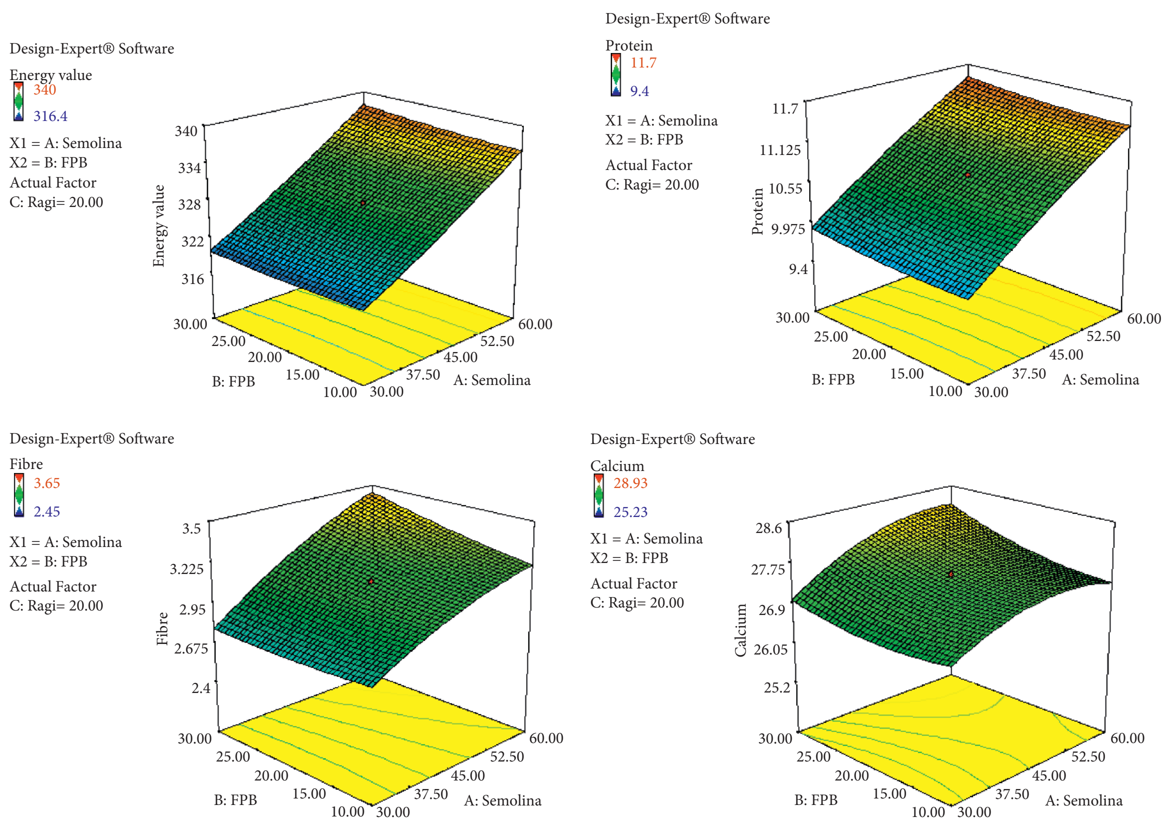

Figure 2: Three-dimensional (3D) surface plot indicating cumulative effects of the independent variables (A = semolina, B = FPB, and C = finger millet) on the response variables, viz, nutritional parameters such as energy (a), protein (b), fibre (c), and calcium (d) of fruit peel macaroni.

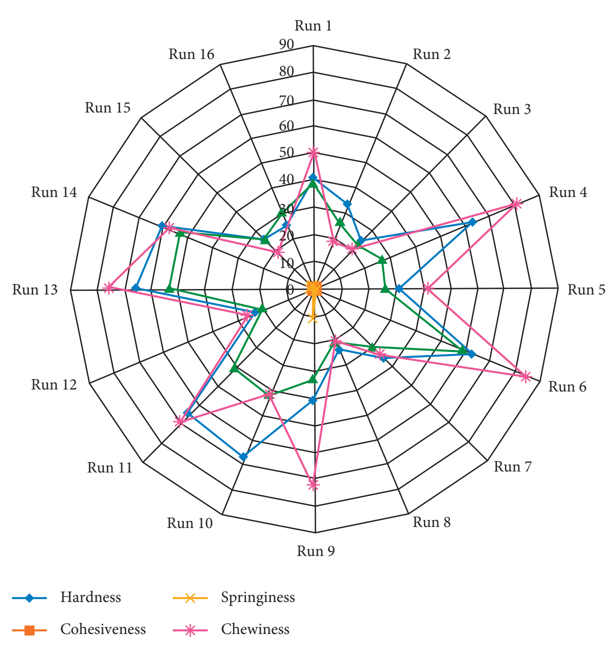

Figure 3: Web diagram representing the textural profile analysis (TPA) of all 20 sample runs of fruit peel macaroni obtained by RSM design.

3.4. Nutritional and Textural Analysis of Optimized Fruit Peel Elbow Macaroni. The results showed that the proximate composition of optimized fruit peel macaroni (A = 30.66 g, B = 26.67 g, and C = 12.66 g) has 5.06 ± 0.11, 9.7 ± 0.13, 2.7 ± 0.018, 1.33 ± 0.15, 1.42 ± 0.02, and 79.79 ± 4.54 percent of moisture, protein, fibre, fat, ash, and carbohydrate,

Table 2: Nutritional composition of optimized macaroni.

Sample	Moisture (%)	Protein (%)	Fibre (%)	Fat (%)	Ash (%)	Carbohydrate (%)	p value
Control	4.98 ± 0.11	8.12 ± 0.11	1.81 ± 0.11	1.21 ± 0.11	1.27 ± 0.11	82.61 ± 0.11	0.5
Optimized sample	5.06 ± 0.11	9.7 ± 0.13	2.7 ± 0.018	1.33 ± 0.15	1.42 ± 0.02	79.79 ± 4.54	

respectively (Table 2). Similar to the optimized product in the present study, Mendes et al. (2013) [19] also developed snack food (energy bars) by utilizing different ingredients along with apple and papaya peels and evaluated its oxidative stability. Fruit and vegetable by-products are reported to have a valuable amount of insoluble and soluble fibre, including polyphenols, antioxidants, and vitamins, which can affect the nutritional composition [4]. Dziki reported that enrichment of pasta or macaroni with fruits and vegetables, which are naturally rich in polyphenols and anthocyanins that are known for their antioxidant potential, consequently, increased the antioxidant activity (ABTS (2, 2′-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) assay) in these enriched products [22]. TPA was also carried out for the optimized fruit peel macaroni. The results of TPA revealed that the hardness/firmness, cohesiveness, gumminess, springiness, and chewiness of the optimized fruit peel macaroni were 25.1 g force, 0.8 (dimensionless), 22.64 N, 0.91 mm, and 20.66 N/mm, respectively. A good amount of protein concentration results in forming a solid protein network and prevents water penetration, consequently giving a firm texture to the extruded product [4]. The TPA profile of optimized macaroni is texturally firm enough with little cohesiveness and springiness and pleasing chewiness and moderate gumminess, which proves it has the potential to be accepted by consumers [23]. The firmness value corresponding to the mouthfeel may be because pectin molecules were forming hydrogen bonds and the resultant cross-links enhanced fruit peel macaroni's ability to show resistance against the deformation caused by the probe of texture analyzer [20]. However, an increased level of by-products addition generally increases the hardness of the extruded product [4]. The addition of fruit peel may improve the textural characteristics of the optimized elbow macaroni; earlier it was reported that banana peel flour slightly increased the hardness, springiness, and chewiness in a gluten-free rissol [21].

4. Conclusion

Recently, there has been a global trend for the development of healthy snacks. An attempt was made to formulate fruit peel macaroni by optimizing the three critical factors semolina, FPB, and finger millet for its scientific validation through statistical three-dimensional modelling using the response surface methodology (RSM) based on their sensory and nutritional attributes. Of all 20 sample runs, one sample is optimized with a combination of $A = 30.66$ g, $B = 26.67$ g, and $C = 12.66$ g, as well as other ingredients with maximum acceptability, for formulating fruit peel macaroni. The optimized snack product, elbow macaroni, has a balanced nutritional composition and a hard, chewy texture to draw the consumer's interest. Such innovative fruit peel macaroni would encourage the industrial utilization of fruit peel, a primary waste material from fruits, in food processing industries. This product can be used as an alternative for sustainable use of fruits peels. The functionality of fruit peel included in macaroni could enhance the immune system due to its additional nutritional and antioxidant benefits with improved organoleptic qualities, better texture, and palatability.

Data Availability

All data generated or analyzed during this study are included in this published article.

Conflicts of Interest

The authors declared there are no conflicts of interest.

Authors' Contributions

P. Mishra designed the study and interpreted the results. E. Gupta collected test data and drafted the manuscript. K. Gupta contributed to the design of the study.

Acknowledgments

The authors thank the Center of Food Technology, University of Allahabad, for providing the necessary laboratory facilities for their work's experimental investigations.

Supplementary Materials

Table S1: factors and levels for optimizing the ingredients for development of fruit peel macaroni. Table S2: the experimental design (factor and responses) for the optimization of ingredients in fruit peel macaroni. Figure S1: pictorial representation of the preparation of fruit peel macaroni. Figure S2: nutritional profile of papaya and banana peels. Figure S3: mineral profile of papaya and banana peels. (*Supplementary Materials*)

References

[1] FAO, "The state of food and agriculture 2019," *Moving Forward on Food Loss and Waste Reduction*, United Nations, New York, NY, USA, 2019.

[2] S. Korkerd, S. Wanlapa, C. Puttanlek, D. Uttapap, and V. Rungsardthong, "Expansion and functional properties of extruded snacks enriched with nutrition sources from food processing by-products," *Journal of Food Science and Technology*, vol. 53, no. 1, pp. 561–570, 2016.

[3] M. Wadhwa and M. P. S. Bakshi, "Utilization of fruit and vegetable wastes as livestock feed and as a substrate for generation of other value-added products," in *Food and*

Agriculture Organization of United Nations, H. P. S. Makkar, Ed., pp. 56–2013, FAO, Rome, Italy, 2013.

[4] D. Dey, J. K. Richter, P. Ek, B. Gul, and G. M. Ganjyal, "Utilization of food processing by-products in extrusion processing: a review," *Frontiers in sustainable food systems*, vol. 26, 2021.

[5] R. A. T. Nilusha, J. M. J. K. Jayasinghe, O. D. A. N. Perera, and P. I. P. Perera, "Development of pasta products with non-conventional ingredients and their effect on selected quality characteristics: a brief overview," *International Journal of Food Science*, vol. 2019, Article ID 6750726, 10 pages, 2019.

[6] S. Chillo, J. Laverse, P. M. Falcone, and M. A. Del Nobile, "Quality of spaghetti in base amaranthus wholemeal flour added with quinoa, broad bean and chick pea," *Journal of Food Engineering*, vol. 84, no. 1, pp. 101–107, 2008.

[7] E. Gupta and P. Mishra, "Functional food with some health benefits, so called superfood: a review," *Current Nutrition & Food Science*, vol. 17, no. 2, pp. 144–166, 2021.

[8] T. Oliviero and V. Fogliano, "Food design strategies to increase vegetable intake: the case of vegetable enriched pasta," *Trends in Food Science & Technology*, vol. 51, pp. 58–64, 2016.

[9] *AOAC Official Methods of Analysis*, Association of Official Analytical Chemists, Arlington, VA, USA, 17th ed. edition, 2012.

[10] N. Sozer and A. Kaya, "The effect of cooking water composition on textural and cooking properties of spaghetti," *International Journal of Food Properties*, vol. 11, no. 2, pp. 351–362, 2008.

[11] A. C. da Silva and N. Jorge, "Bioactive compounds of the lipid fractions of agro-industrial waste," *Food Research International*, vol. 66, pp. 493–500, 2014.

[12] N. G. Betsy, "Fiber content and storage stability of antioxidants activity of nutraceutical mango products and gluten-free cookies," in *Proceedings of the 2nd International Conference on Biotechnology and Food Science IIPCBEE*, IACSIT Press, Singapore, 2011.

[13] E. Gupta, A. Sheikh, K. Gupta, N. Mishra, P. Mishra, and P. Singh, "Fruit peels: a strong natural source of antioxidant and prebiotics," *Carpathian Journal of Food Science and Technology*, vol. 12, no. 5, pp. 134–143, 2020.

[14] D. R. Feumba, R. P. Ashwini, and R. S. Manohar, "Chemical composition of some selected fruit peels," *European Journal Food Science Technology*, vol. 4, pp. 12–21, 2016.

[15] P. P. Bhalerao, N. S. Chaudhari, A. B. Muley, M. I. Talib, V. R. Parate, and D. C. Kudake, "Fortification of wheat flour with ragi flour: effect on physical, nutritional, antioxidant and sensory profile of noodles," *Current Research in Nutrition and Food Science Journal*, vol. 6, no. 1, pp. 165–173, 2018.

[16] R. Kalpna, K. Mital, and C. Sumitra, "Vegetable and fruit peels as a novel source of antioxidants," *Journal of Medicinal Plants Research*, vol. 5, no. 1, pp. 63–71, 2011.

[17] S. Yağci and F. Göğüş, "Development of extruded snack from food by-products: a response surface analysis," *Journal of Food Process Engineering*, vol. 32, pp. 565–586, 2009.

[18] P. Kaur, N. Kaushal, A. Singh, S. Gupta, and G. Kaur, "A blended approach of mango seed, peel and pulp through statistical modelling for development of mango bar," *Acta Scientific Nutritional Health*, vol. 3, pp. 61–67, 2019.

[19] N. D. S. R. Mendes, C. R. Gomes-Ruffi, M. E. Lage et al., "Oxidative stability of cereal bars made with fruit peels and Baru nuts packaged in different types of packaging," *Food Science and Technology*, vol. 33, no. 4, pp. 730–736, 2013.

[20] M. C. Bourne, "Basic principles of food texture measurement," in *Dough Rheology and Baked Product Texture*, H. faridi and J. M. Faubion, Eds., pp. 331–341, AVI Van Nostrand Reinhold, New York, NY, USA, 1990.

[21] S. Gomes, B. Vieira, C. Barbosa, and R. Pinheiro, "Evaluation of mature banana peel flour on physical, chemical, and texture properties of a gluten-free Rissol," *Journal of Food Processing and Preservation*, vol. 107, pp. 1–6, 2020.

[22] D. Dziki, "Current trends in enrichment of wheat pasta: quality, nutritional value and antioxidant properties," *Processes*, vol. 9, no. 8, p. 1280, 2021.

[23] X. Huang and F. H. Hsieh, "Physical properties, sensory attributes, and consumer preference of pear fruit leather," *Journal of Food Science*, vol. 70, pp. 177–186, 2005.