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Effect of rice, chickpea flour, and mango peel powder on functional, nutritional, structural, and sensory characteristics of gluten-free pasta

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Abstract

The present work investigated the effect of rice, chickpea flour, mango peel powder, and guar gum addition on nutritional and functional properties of gluten-free pasta. Experiments were conducted to formulate protein-fortified gluten-free pasta using rice and chickpea flour at different proportions (90:10, 80:20, and 70:30) as base flour ingredients. This mixture was incorporated with mango peel powder to enhance the phytonutrients, and guar gum as a binding agent. The three best pasta samples were selected based on the cooking qualities, colour, and overall acceptability of 27 formulations. The optimised proportions of ingredients were estimated to be 80:20 of base flour and mango peel powder, and guar gum to be 10 and 4.5% of base flour. The optimised sample was found to possess 11.36 ± 0.42% protein content, 1.04 ± 0.01% ash content, 154.17 ± 2.42 mg GAE/100 g total phenolic content, 72.53 ± 0.84% radical scavenging activity, and a sensory score of 8.33 ± 0.65 as overall acceptability. The microstructural and FTIR analyses of the novel pasta exhibited a composite starch-protein matrix due to the incorporation of mango peel powder. Therefore, this novel pasta with low-cost ingredients could be commercially viable, and used as a dietetic alternative for people with celiac disease.

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Introduction

Pasta is the world’s most popular food item among the products prepared from cereals. Pasta has also become more popular as a result of its low cost, simplicity in preparation, variety of uses, long storage life, and sensory properties (Teterycz *et al.*, 2019). Italy has always been the world's leading producer and consumer of pasta. The world’s hardest wheat is durum wheat (*Triticum durum* Desf.), historically used to prepare pasta because it has gluten, which gives good sensory and textural quality to pasta. Gluten is a complex protein in grains such as wheat, rye, barley, and triticale, made up of glutenin and prolamins, responsible for wheat's capacity to make dough (Diez-Sampedro *et al.*, 2019). Gluten protein in durum wheat semolina provides key properties such as low solid loss, excellent texture, minimal surface adhesiveness, and resistance to surface destruction (Nilusha *et al.*, 2019).

Celiac disease is a multisystem-resistant issue caused by gluten intake, which affects the small intestine lining, and prevents nutrients from being absorbed (Aronsson *et al.*, 2016). The only medically approved therapy for celiac disease is a gluten-free diet. Aljada *et al.* (2021) concluded that celiac disease patients who consume less than 10 mg of gluten per day are unlikely to develop histological abnormalities. According to Codex Alimentarius (2008), 20 ppm of gluten is the limit for "gluten-free" products. Gluten-free eating is commonly associated with celiac disease, but those with gluten sensitivity should avoid this type of grain as well (Chandralekha *et al.*, 2017). Rice, potato, maize, amaranth, quinoa,

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buckwheat, flaxseed, and millet flours are some of the gluten-free alternatives that are safe for consumption by celiac patients (Fradinho *et al.*, 2020).

Some chemicals need to be utilised to create a cohesive network that can compensate for the lack of gluten. In this aspect, hydrocolloids and dairy proteins may imitate the viscoelastic characteristics of gluten, resulting in enhanced gluten-free pasta structure, mouthfeel, acceptance, and shelf life (Deora *et al.*, 2015). Hydrocolloids, often known as gums, have the ability to change the overall quality of the food items. Guar gum is obtained from the seeds of the drought-tolerant Leguminosae plant guar (*Cyamopsis tetragonoloba* (L.) Taub.). It is a carbohydrate that has mannose and galactose in the ratio of 2:1. When exposed to cold water, it expands, and is commonly used as a binding agent and volume enhancer. It is often used as a new food ingredient, emulsifier, and fibre source (Chauhan *et al.*, 2017).

Rice (*Oryza sativa* L.) is suggested as a gluten-free diet for celiac patients because it contains no gluten, and may be used to make pasta. However, due to the lack of gluten, various technological issues may occur during the manufacture of rice pasta. Whenever rice flour is used as the primary ingredient in pasta production, additives or specific processing techniques are necessary to adjust the properties of macromolecular components (starches and proteins), which are important for the final product's structure (Fernandes *et al.*, 2013). Rice is also considered one of the most ideal cereal grains for making gluten-free foods, either alone or in combination with other gluten-free cereals (Martínez *et al.*, 2017). Rice bran is an essential source of dietary fibre, and has been extensively researched to aid in the development of gluten-free foods that can help avoid various health concerns (Wang *et al.*, 2018).

Chickpea (*Cicer arietinum* L.) is a legume that is high in gluten-free protein. As a result, chickpeas can be used as the major component to replace gluten in gluten-free pasta recipes. Legumes, such as chickpeas, have a high resistant starch (RS) concentration in their carbohydrate. RS is already related to a slower digestion process, and as a result, a delayed glucose delivery into the bloodstream following legume ingestion. Increased RS content in legume-based meals leads to lower glycaemic and insulinemic postprandial responses than diets based on cereal grains or potatoes (Flores-Silva *et al.*, 2014). Study on the use of beans added to pasta to improve nutritious value have been published (Rajiv *et al.*, 2015). Dieticians suggested incorporating pulses like chickpea into the diet since they provide several nutritional advantages. Chickpea seed is high in protein digestibility, minerals, and vitamins, and low in glycaemic index and anti-nutritional elements. Customers are becoming more health-conscious, and while many acknowledge that pulses are healthy for them, many are unsure how to include them in their diet (Kaur and Prasad, 2021).

In order to increase the nutritional value of pasta, it has been enriched with beta-carotene, inulin, and different protein levels. Mango (*Mangifera indica* L.) is a popular seasonal fruit, and its peel generates a significant amount of by-product. Mango peel is high in bioactive components such as polyphenols, carotenoids, vitamins, enzymes, and dietary fibres (Ajila *et al.*, 2010).

Since a gluten-free diet is essential for treating celiac disease as well as other gluten-related medical problems, we may choose rice flour as a raw material in the manufacturing of gluten-free foods due to its bland flavour, high digestibility, and hypoallergenic characteristics (Phongthai *et al.*, 2017). Keeping in view of the high dietary fibre of chickpea and the phytochemical properties of mango peel powder, the present work was undertaken firstly to standardise the proportion of ingredients to prepare gluten-free functional pasta, and secondly, to compare the quality characteristics of selected newly-formulated pastas against that prepared from durum wheat, in line with the sustainable and healthy food trends.

Materials and methods

Raw materials

The rice flour, chickpea flour, mango (Totapuri variety) peel powder, and guar gum were used in the preparation of gluten-free pasta. Rice (Annapurna variety) flour and chickpea (Bharati) flour were purchased from the local market in Bhubaneswar, India. Mango peel powder was prepared in the laboratory. Blends of rice flour, chickpea flour, mango peel, and guar gum (Hi-media IP043) were kept for 24 h in a hot air oven at 100°C for determination of the moisture content of the blends.

Mangos were purchased to prepare the mango peel powder. Mango peel was collected from these mangoes by separation from mango pulp and kernel. Then, the peel was cleaned with cold water, and blanched in hot water for 2 min. After blanching, mango peels were dried in a tray dryer at 60°C for 3 h, and then ground to make powder using a centrifugal mill (RETSCH ZM1). Powder was sieved (mesh size 0.5 µm) and packed in polypropylene pouches until further analyses.

Preparation of gluten-free functional pasta

Gluten-free pasta *(tagliatelle* shape) was formulated with different percentages of base flour consisting of rice flour (90, 80, and 70%) with corresponding proportions of chickpea flour (10, 20, and 30%). Then, mango peel (0, 5, and 10%) with guar gum (2.5, 3.5, and 4.5%) as a binder were added. These percentages of mango peel and guar gum were based on the total amount of flour. Full factorial design was used, and 27 numbers of experimental samples were generated for testing.

All the ingredients for each experimental combination based on the experimental design were mixed for 2 min manually. Then, the required amount of water (75 ± 5%, v/w) was slowly added. The dough was mixed for 10 min until it attained the required consistency. The prepared dough was covered with a polyethylene sheet, and kept for 30 min for tempering. Then, the dough was moulded with a home pasta maker (Kresal, China) with a die for long pasta of *tagliatelle* type using cold extrusion principle. Moulded pasta was dried in a tray dryer at 40°C for 3 h, and packed in polyethylene pouches until further analyses. Control sample was prepared with 100% durum wheat flour with 30 mL of water to simulate the commercially available pasta, and dried in the same condition as gluten-free pasta.

Proximate analysis of gluten-free functional pasta

The moisture content of the sample was evaluated following the method of AOAC (1990). Briefly, the sample was placed in a hot air oven at 105 ± 1°C for 24 h until a constant mass was achieved. The crude protein content was determined by Kjeldahl method (AOAC, 2005), and the ash content was determined according to Sadasivam and Manickam (2008).

Cooking quality of gluten-free functional pasta

The optimum cooking time for gluten-free pasta was calculated according to Marti *et al.* (2010). Briefly, the cooking continued up to the white core of gluten-free pasta disappeared, while the pasta was pressed between two glass plates. The cooking loss of the sample was calculated following the AACC 16-50 (AACC, 2000) method. The water absorption index and water solubility index were determined according to Anderson *et al.* (1970).

Colour measurement of gluten-free functional pasta

The colour measurements of the samples were done using a colour reader CR-20 (Konica Minolta, Inc. Japan). Briefly, samples were taken on a flat surface, and measurements were taken thrice for each sample; average of those three measurements was considered the final value. In colour reader, 'L' represents the lightness (100 equal to white, and 0 equal to black), 'a' represents greenness (-a equal to redness, and +a to greenness), and 'b' represents blueness (-b equal to yellowness, and +b to blueness). The ΔE was calculated using Eq. 1:

$$\Delta \mathrm{E} = [(\mathrm{L} - \mathrm{L}^{*})^{2}(a - \mathrm{a}^{*})^{2}(b - \mathrm{b}^{*})^{2}]^{\frac{1}{2}} \qquad \text{(Eq. 1)}$$

where, superscript (*) = value associated with the prepared gluten-free pasta.

Sensory quality of gluten-free functional pasta

The sensory evaluation of control and gluten-free pasta samples (both selected and optimised) was conducted using the nine-point hedonic scale method described by Gull *et al.* (2015). The samples were selected and optimised based on the optimum cooking time (OCT) and cooking loss (CL). Samples were cooked in boiling water without adding salt and oil, and panellists were asked to rate and write the feedback based on their colour, flavour, taste, and texture. Subjective measurement of overall acceptance of the selected samples was carried out by ten semi-trained panellists of different gender and age groups, using composite scoring of a 9-point hedonic scale. The sensory evaluation included colour, flavour, texture, and taste on a 9-point scale, where the parameters were scored from 'like extremely' as 9 to 'dislike extremely' as 1. The overall acceptability was estimated through composite scoring by allotting the attributes a weight factor in percentage, so that the summation of these factors was equal to hundred. The panellists were provided with a sample, and requested to assign scores based on colour, flavour, taste, and texture using the 9-point scale. Each panellist tasted the samples presented in a random order. For this, the help of semi-trained panellists who were aware of the scope and procedure of the experiment, and familiar with different classes of foods, was solicited. They were further trained thoroughly for the particular food under study so that they were able to discriminate and communicate the differences effectively.

Phytonutrients analysis of gluten-free functional pasta

The total phenolic content of the samples was determined according to Sadasivam and Manickam (2008), and the antioxidant activities of gluten-free pasta samples were determined according to procedure described by Demir and Bilgicli (2021). Briefly, 1 g of the sample was ground using a mortar and pestle, and taken in test tubes with 10 times volume of 80% methanol to be kept overnight. Then test tubes containing samples were centrifuged at 10,000 rpm for 20 min, and the supernatant was filtered. Next, 2 mL of pasta sample extract with 4 mL of DPPH solution and 2 mL of methanol were used for the standard sample, added to test tubes, and kept in dark place for 45 min. Absorbance values of samples were taken at wavelength of 514 nm using a spectrophotometer, and antioxidant activity values were calculated using Eq. 2.

$$\text{Antioxidant activity}(\%) = \left(1 - \frac{\text{Xs}}{\text{Xc}}\right) \times 100 \quad \text{(Eq. 2)}$$

where, Xc = absorbance of the control/blank sample, and Xs = absorbance of the extract solution

Gluten content of gluten-free functional pasta

The gluten content of control and optimised pasta samples was determined according to Greenaway and Watson (1975). Briefly, 25 g of flour was taken and treated with water to form a dough ball of required smoothness, and then the dough ball was placed in distilled water for an hour. After an hour, the dough ball was squeezed continuously below the tapping water until the water became clear (starch gets separated), and wet gluten was obtained. Wet gluten was placed in a hot air oven at 104°C for 24 h for drying, and then the weight of dry gluten was measured and the percentage presence was calculated.

SEM of gluten-free functional pasta

The scanning electron microscopy analysis of the sample was carried out by generating micrographs using scanning electron microscope (Model: S-3400N). The dried samples were cut into small slices, and placed on stainless steel specimen stubs coated with gold. Then, pasta samples were observed with accelerating voltage of 20 KV at 1,000× magnification.

Textural quality of gluten-free functional pasta

The textural quality of gluten-free and control pasta was analysed using a texture analyser (TA.XT. Plus, Stable Micro Systems) fitted with a cylindrical probe (with compression to 75% strain) with a diameter of 35 mm for determination of hardness, springiness, and adhesiveness, and 5-Bladed Kramer Shear Cell (HDP/KS5) for firmness and shearing force. The samples were cooked for optimum cooking time, and kept in the beaker containing water for 5 min so that the temperature was reduced. Samples were kept for a few minutes in front of a fan before the measurements. The samples were put on the testing platform, and texture analysis was performed at 2 mm/s speed. To achieve the best results, each sample's measurement was performed three times.

FTIR analysis of gluten-free functional pasta

Fourier-transform infrared spectroscopy (FTIR) analysis is a helpful technique for identifying unknown compounds, detecting impurities in a substance, locating additives, and determining chemical bonds present in samples (Titus *et al.*, 2019). This analysis was conducted to find the peak values of several functional groups. Selected samples were put separately into a spectrophotometer to obtain the FTIR spectrum of each sample. The pasta samples were analysed using Perkin-Elmer spectrum Version 10.4.3, having wave numbers in a range of 4000 - 400 cm^{-1}. LiTa03 detector origin software was used for the peak determination. This instrument was connected to a Perkin-Elmer professional computer equipped with its related Infrared Data System software (NIOS2 Main 00.02.0100). Spectra were taken with thin layer of sample pressed between two KBr plates. Each spectrum resulted from averaging eight scans taken at a resolution of 4.

Statistical analysis

Measures of central tendency and analysis of variance (ANOVA) with Tukey's pairwise comparison was used to standardise the proportion of ingredients to prepare gluten-free functional pastas, and to compare the quality characteristics of developed pastas with those of control pasta samples. The statistical software MINITAB 17 (trial version) was used for the analysis.

Results and discussion

Effect of ingredients proportion on cooking properties of gluten-free functional pasta

The details of cooking attributes of samples concerning their ingredient proportion specified through codes are given in Table 1. As per the level of each factor, 27 sets of pasta were expected to be formulated using full factorial design. However, the sample containing 10% mango peel could not be formulated using guar gum at 2.5%. Development of cracks was observed with a high percentage of mango peel powder and a low level of guar gum. Therefore, overall, 24 numbers of samples could be prepared and were subjected to cooking tests. From Table 1, it was observed that the optimum cooking time (OCT) varied from 4.25 ± 0.25 to 10.00 ± 0.25 min. The minimum and maximum cooking loss (CL) of samples obtained were 7.20 ± 0.20% for (R70/C30/G4.5), and 11.60 ± 0.60% for (R80/C20/M10/G3.5), respectively.

Careful examination of data indicated that the control sample had OCT of 9.20 ± 0.20 min, and CL of 6.49 ± 0.42%. It was observed that OCT increased but CL decreased with an increase in both chickpea and guar gum proportion in gluten-free pasta samples. This could be attributed to the formation of a complex matrix between amylose fractions of rice flour, protein, and guar gum, which inhibited the solubilisation of starch during cooking. Similar findings have been reported by Padalino *et al.* (2014) and Chauhan *et al.* (2017) in durum wheat spaghetti and gluten-free pasta, respectively.

Table 1. Effect of ingredients' proportion and binding agent on cooking and colour properties of control and gluten-free pastas.

Sample no.	Sample code	Proportion of ingredient				Optimum cooking time (min)	Cooking loss (%)	ΔE
		RF	CF	MP	G			
1	R90/C10/G2.5	90	10	0	2.5	4.25 ± 0.25^{i}	10.20 ± 0.20^{abcde}	9.49 ± 0.03^{j}
2	R90/C10/G3.5	90	10	0	3.5	5.25 ± 0.25^{ghi}	9.76 ± 0.48^{bcdef}	6.72 ± 0.06^{k}
3	R90/C10/G4.5	90	10	0	4.5	5.33 ± 0.28^{fghi}	9.30 ± 0.60^{defgh}	6.92 ± 0.25^{k}
4	R80/C20/G2.5	80	20	0	2.5	5.00 ± 0.50^{hi}	9.88 ± 0.12^{bcdef}	14.46 ± 0.18^{i}
5	R80/C20/G3.5	80	20	0	3.5	6.00 ± 0.25^{efgh}	8.00 ± 1.00^{ghijk}	4.84 ± 0.05^{l}
6	R80/C20/G4.5	80	20	0	4.5	6.00 ± 0.25^{efg}	7.93 ± 0.07^{hijk}	3.48 ± 0.11^{m}
7	R70/C30/G2.5	70	30	0	2.5	5.25 ± 0.25^{ghi}	9.00 ± 0.24^{efghi}	8.59 ± 0.16^{j}
8	R70/C30/G3.5	70	30	0	3.5	7.00 ± .025^{cde}	7.56 ± 0.32^{jk}	6.28 ± 0.34^{k}
9	R70/C30/G4.5	70	30	0	4.5	8.00 ± 0.75^{bc}	7.20 ± 0.20^{k}	3.08 ± 0.02^{m}
10	R90/C10/M5/G2.5	90	10	5	2.5	5.25 ± 0.25^{ghi}	10.45 ± 0.05^{abcd}	18.62 ± 0.23^{ef}
11	R90/C10/M5/G3.5	90	10	5	3.5	5.48 ± 0.25^{fghi}	9.96 ± 0.06^{bcdef}	20.41 ± 0.08^{cd}
12	R90/C10/M5/G4.5	90	10	5	4.5	6.00 ± .0.25^{efgh}	8.60 ± 0.40^{fghijk}	21.21 ± 0.21^{bc}
13	R80/C20/M5/G2.5	80	20	5	2.5	5.50 ± 0.50^{fgh}	11.00 ± 0.05^{ab}	17.05 ± 0.21^{gh}
14	R80/C20/M5/G3.5	80	20	5	3.5	6.00 ± 0.25^{efgh}	10.80 ± 0.30^{abc}	14.53 ± 0.27^{i}
15	R80/C20/M5/G4.5	80	20	5	4.5	6.50 ± 0.50^{def}	9.60 ± 0.20^{bcdefg}	16.52 ± 0.10^{h}
16	R70/C30/M5/G2.5	70	30	5	2.5	5.50 ± 0.50^{fgh}	8.86 ± 0.16^{efghij}	16.20 ± 0.08^{h}
17	R70/C30/M5/G3.5	70	30	5	3.5	8.00 ± 0.50^{bc}	8.25 ± 0.25^{ghijk}	17.18 ± 0.08^{gh}
18	R70/C30/M5/G4.5	70	30	5	4.5	8.83 ± 0.52^{ab}	7.68 ± 0.38^{ijk}	18.91 ± 0.06^{ef}
19	R90/C10/M10/G3.5	90	10	10	3.5	6.25 ± 0.25^{efg}	10.52 ± 0.27^{abcd}	21.52 ± 0.22^{bc}
20	R90/C10/M10/G4.5	90	10	10	4.5	7.00 ± 0.50^{cde}	9.92 ± 0.16^{bcdef}	21.97 ± 0.11^{b}
21	R80/C20/M10/G3.5	80	20	10	3.5	7.00 ± 0.50^{cde}	11.60 ± 0.60^{a}	14.53 ± 0.27^{i}
22	R80/C20/M10/G4.5	80	20	10	4.5	7.50 ± 50^{cd}	7.94 ± 0.68^{hijk}	17.88 ± 1.72^{fg}
23	R70/C30/M10/G3.5	70	30	10	3.5	9.00 ± 0.25^{ab}	9.58 ± 0.84^{cdefg}	19.49 ± 0.24^{de}
24	R70/C30/M10/G4.5	70	30	10	4.5	10.00 ± 0.25^{a}	8.89 ± 0.89^{efghij}	26.59 ± 0.19^{a}
Control	Control					9.20 ± 0.20	6.49 ± 0.42	

R: rice flour; C: chickpea flour; M: mango peel powder; and G: guar gum. Values are mean ± S.D. Means in the same column followed by similar lowercase superscripts are not significantly different ($p < 0.05$).

On the contrary, it was also revealed from Table 1 that with the increase in mango peel proportion, CL also increased. This could have been due to the weakening of bonding of base ingredients during the incorporation of mango peel having high fibre content. OCT also increased with an increase in peel proportion due to the lack of uniformity in the transparent texture of the pasta samples. Our results were in agreement with earlier findings, where an increase in CL was observed with an increase in almond flour (Martínez *et al.*, 2017), rice bran fibre (Wang *et al.*, 2018), and quinoa flour (Demir and Bilgicli, 2021). The increase in the quantity of mango peel and guar gum took more time to be cooked, and to be as soft as desirable.

Screening of samples for optimisation

Since a large number of samples were prepared, it was decided to select the most acceptable pasta samples by eliminating the rest set of samples based on cooking properties, such as OCT and CL. Therefore, the cut-off values of CL being the most important cooking parameter were decided as per the report of Hummel (1996), who graded the quality of pasta to be poor for more than 10% of CL, medium for 6 to 8%, and high quality up to 6% of CL. Further, the objective measurement of colour also revealed that there was a significant difference in colour attributes (L*, a*, and b*) due to the addition of chickpea powder, and particularly mango peel powder. Therefore, to eliminate the biasness in selection procedure, the whole range of products was divided into three groups: mango peel 0% (sample numbers 1 to 9), 5% (sample 10 to 18), and 10% (sample 19 to 24). Accordingly, the CL between 8 - 10% with minimum cooking time and minimum colour change (ΔE) within the same category was analysed to bring in balance with all these properties. ΔE was calculated from L*, a*, and b* values of individual sample, considering L*, a*, and b* values of control sample as the base values.

After conducting the statistical analysis of OCT, CL, and ΔE values of all the samples, the selection of acceptable samples was made from each category. Thus, the selected sample were R80/C20/G3.5, R80/C20/G4.5, R70/C30/G3.5, and R70/C30/G4.5 from category 1 (without mango peel), R70/C30/M5/G2.5, R70/C30/M5/G3.5, and R70/C30/M5/G4.5 from category 2 (with 5% mango peel), and R80/C20/M10/G4.5 from category 3 (with 10% mango peel), which could satisfy the cut-off levels (Table 1) and the results of analysis of variance (ANOVA) at 5% level of significance. As the objective of the present work was to select one sample from each category, these eight selected samples were subjected to sensory evaluation as presented in Table 2. Since consumer acceptability is considered to be the foremost factor for the marketability of any product, it was given more weightage in the final selection procedure. The outcome of this procedure was the selection of one sample from each category as highlighted in Table 2. These selected samples were R80/C20/G3.5, R70/C30/M5/G2.5, and R80/C20/M10/G4.5, which were subjected to detailed quality analysis, and compared against the control pasta sample in the forthcoming section.

Table 2. Change in colour and overall acceptability of selected samples.

Sample	ΔE	Overall acceptability
R80/C20/G3.5	4.84 ± 0.05^{f}	7.94 ± 0.25^{ab}
R80/C20/G4.5	3.48 ± 0.11^{g}	7.34 ± 0.03^{c}
R70/C30/G3.5	6.28 ± 0.34^{e}	7.41 ± 0.29^{c}
R70/C30/G4.5	3.08 ± 0.02^{g}	7.16 ± 0.38^{c}
R70/C30/M5/G2.5	16.20 ± 0.08^{d}	8.05 ± 0.43^{a}
R70/C30/M5/G3.5	17.18 ± 0.08^{cd}	7.36 ± 0.17^{c}
R70/C30/M5/G4.5	18.91 ± 0.06^{ab}	7.39 ± 0.27^{c}
R80/C20/M10/G4.5	17.88 ± 1.72^{bc}	8.33 ± 0.65^{a}

R: rice flour; C: chickpea flour; M: mango peel powder; and G: guar gum. Values are mean ± S.D. Means in the same column followed by similar lowercase superscripts are not significantly different ($p < 0.05$).

Comparative evaluations of quality characteristics of selected and control pastas

The control pasta was made up of refined wheat flour (RWF). To maintain the uniformity in preparation procedure, this pasta was also prepared using the same pasta maker. The gluten content of this control pasta sample was found to be 7.5%, whereas the rest of the samples possessed no gluten at all. The ingredients used for the preparation of gluten-free pasta were evaluated for quality analysis. Rice flour (R), chickpea flour (C), mango peel powder (M), and guar gum (G) contained protein (7.8, 21.2, 10, and 3.6%, respectively), ash (0.39, 0.55, 2.8, and 2.6%, respectively), total phenolic content (51, 108, 280, and 90 mg GAE/100 gm, respectively), and antioxidant activity (43, 65, 90, and 70.5%, respectively). However, during the cold extrusion of pasta making followed by drying, there was an overall change in the composition of the formulated product which is discussed in the following sub-sections.

Functional properties

The cooking and functional properties of the sample are given in Table 3. No significant difference was found in the water absorption index (WAI) of all samples, except the mango peel incorporated samples showing higher values. This was probably attributed to the higher pectin and fibre content of peel absorbing more water. However, WSI was significantly ($p < 0.05$) higher in sample R70/C30/M5/G2.5, with R80/C20/M10/G4.5 having higher mango peel content.

Proximate composition and phytonutrients

The proximate composition and phytonutrients are given in Table 3. The protein content was higher in samples with higher content of chickpea flour, and ranged between 10.36 ± 0.30 to 13.79 ± 0.27%. Sample R70/C30/M5/G2.5 had the highest protein content of 13.79 ± 0.27% among all. However, out of 10.36 ± 0.30% of the protein of control sample, 7.50% was gluten, whereas the rest of the pasta samples were free of gluten. Therefore, the net useful protein available in the control pasta sample was less. Similarly, all the gluten-free pasta samples were found to contain significantly higher ($p < 0.05$) amount of ash content (0.85 to 1.04%) than the control sample (0.40 ± 0.01%). Total phenolic and antioxidants (% radical scavenging activity) followed the same pattern. This could have been due to the addition of increasing content of mango peel and chickpea powder. However, all the samples were significantly different from each other at a 5% level of significance. The sample R80/C20/M10/G4.5 contained the highest amount of phytonutrients and ash content. It was further observed from Table 3 that the samples R70/C30/M5/G2.5 and R80/C20/G3.5 followed this trend regarding bio-nutrients. Similar findings have been reported by Ajila *et al.* (2008) and Demir and Bilgicli (2021) who demonstrated that the incorporation of mango peel powder and quinoa flour enhanced the product quality attributes.

Textural properties

The textural properties play a vital role in supplementing the results of sensory evaluation by the consumers. Table 3 presents the textural properties of cooked pastas in terms of hardness, adhesiveness, and total shearing force. The hardness and adhesiveness of the sample (R80/C20/M10/G4.5) were very close to the control sample.

Sample R80/C20/M10/G4.5 had the highest hardness (18.81 ± 0.14) and adhesiveness (0.28 ± 0.00), which might have been due to the addition of a higher percentage of guar gum, leading to the formation of a strong network between rice starch and gum. However, it showed the minimum value of shear force, which might have been possible due to the incorporation of mango peel powder containing

Table 3. Comparison of different properties of control and gluten-free functional pastas.

Parameter	Sample			
	Control	**R80/C20/G3.5**	**R70/C30/M5/G2.5**	**R80/C20/M10/G4.5**
Moisture content (%)	4.20 ± 0.20^{b}	4.5 ± 0.60^{b}	4.4 ± 0.40^{b}	5.1 ± 0.08^{a}
Optimum cooking time (min)	9.20 ± 0.20^{a}	6.00 ± 0.25^{c}	5.50 ± 0.50^{c}	7.50 ± 0.50^{b}
Cooking loss (%)	6.49 ± 0.42^{c}	8.00 ± 1.00^{b}	8.86 ± 0.16^{a}	7.94 ± 0.68^{b}
WAI (g/g)	2.85 ± 0.25^{ab}	2.47 ± 0.08^{b}	2.55 ± 0.05^{b}	3.07 ± 0.17^{a}
WSI (%)	3.20 ± 0.10^{b}	2.80 ± 0.20^{b}	6.80 ± 0.30^{a}	7.13 ± 0.30^{a}
Total phenolic content (mg GAE/100 g)	40.39 ± 0.91^{d}	94.14 ± 2.70^{c}	105.46 ± 1.89^{b}	154.17 ± 2.43^{a}
Antioxidants (%)	34.24 ± 1.84^{d}	58.140 ± 0.95^{c}	64.00 ± 0.27^{b}	72.53 ± 0.84^{a}
Protein content (%)	10.36 ± 0.30^{c}	10.67 ± 0.47^{bc}	13.79 ± 0.27^{a}	11.36 ± 0.42^{b}
Ash content (%)	0.40 ± 0.015^{d}	0.85 ± 0.010^{c}	1.15 ± 0.050^{a}	1.04 ± 0.005^{b}
Hardness (N)	17.99 ± 0.12^{b}	15.23 ± 0.41^{c}	13.05 ± 0.27^{d}	18.81 ± 0.14^{a}
Adhesiveness (N-s)	0.28 ± 0.01^{a}	0.24 ± 0.01^{b}	0.25 ± 0.002^{b}	0.28 ± 0.00^{a}
Total shearing force (N-s)	467.64 ± 0.08^{b}	537.89 ± 0.19^{a}	467.78 ± 0.16^{b}	326.95 ± 0.07^{d}

R: rice flour; C: chickpea flour; M: mango peel powder; and G: guar gum. Values are mean ± S.D. Means in the same column followed by similar lowercase superscripts are not significantly different ($p < 0.05$).

high fibre content. On the contrary, gluten-free pasta samples R80/C20/G3.5 and R70/C30/M5/G2.5 showed lesser hardness and adhesiveness, indicating desirable preference in pasta samples. However, these two samples were shown to have relatively higher shearing force. These agreed with Chauhan *et al.* (2017).

Sensory evaluation

The sensory score of all the gluten-free pastas had already been discussed previously. The overall acceptability (OA) of all the samples was determined using composite scoring of a 9-point hedonic scale based on scores obtained for organoleptic attributes such as colour, flavour, taste, and texture. As presented in Figure 1, the OA of gluten-free pasta was better than control pasta due to the presence of chickpea flour and mango peel powder. The panellists preferred the additional taste of chickpea flour in pasta along with mango peel flavour. The order of samples in terms of descending score of OA was R80/C20/M10/G4.5, R70/C30/M5/G2.5, R80/C20/G3.5, and control sample (Figure 1). However, no significant difference ($p > 0.05$) was visible in colour values of control, R70/C30/M5/G2.5, and R80/C20/M10/G4.5 samples. This could have been due to the change in colour from extreme light for the control sample, to the brownish (combination of redness and yellowness) colour of other samples. Interestingly, the off-white colour of sample R80/C20/G3.5 was preferred by panellists, and obtained the highest colour score of 8.2 ± 0.4.

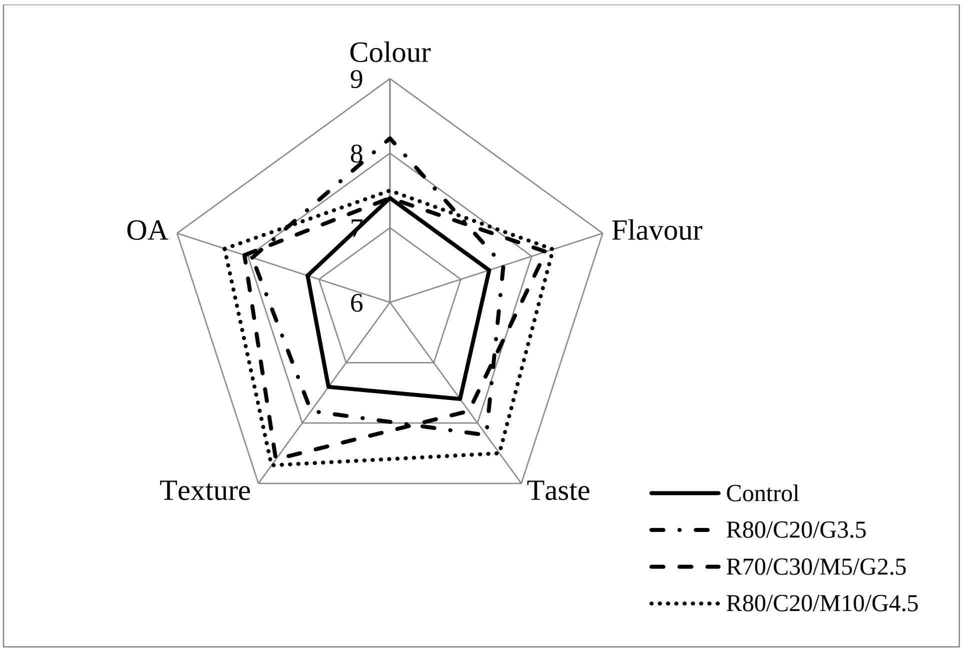


Figure 1. Effect of ingredients on sensory attribute of control and gluten-free pastas.

Microstructural characteristics of selected pasta

Scanning electron microscopy was conducted to verify the structural network of control and selected gluten-free pastas. Figure 2 depicts the photomicrographs at 1,000× magnification. Careful examination of photomicrographs revealed clearly that the control sample made up of only refined wheat flour had regular starch granules of different sizes (Figure 2a). The particles were connected to each other under the influence of gluten during different stages of pasta formation such as dough mixing, tempering, cold extrusion, and drying. On the contrary, micrographs of gluten-free pasta samples exhibited a composite structural view which might have been due to the embedded starch-protein matrix with the help of the binding action of guar gum. With the increase in guar gum proportion, the starch particles were less visible which was evident from particle sizes. Further, with the incorporation of mango peel powder in samples R70/C30/M5/G2.5 and R80/C20/M10/G4.5, cleavage in patches could be seen, which might have been due to the weakening of bonds because of the high fibre content of mango peel powder (Figures 2c and 2d). Similar results were reported by Sudha and Leelavathi (2012) and Chauhan *et al.* (2017).

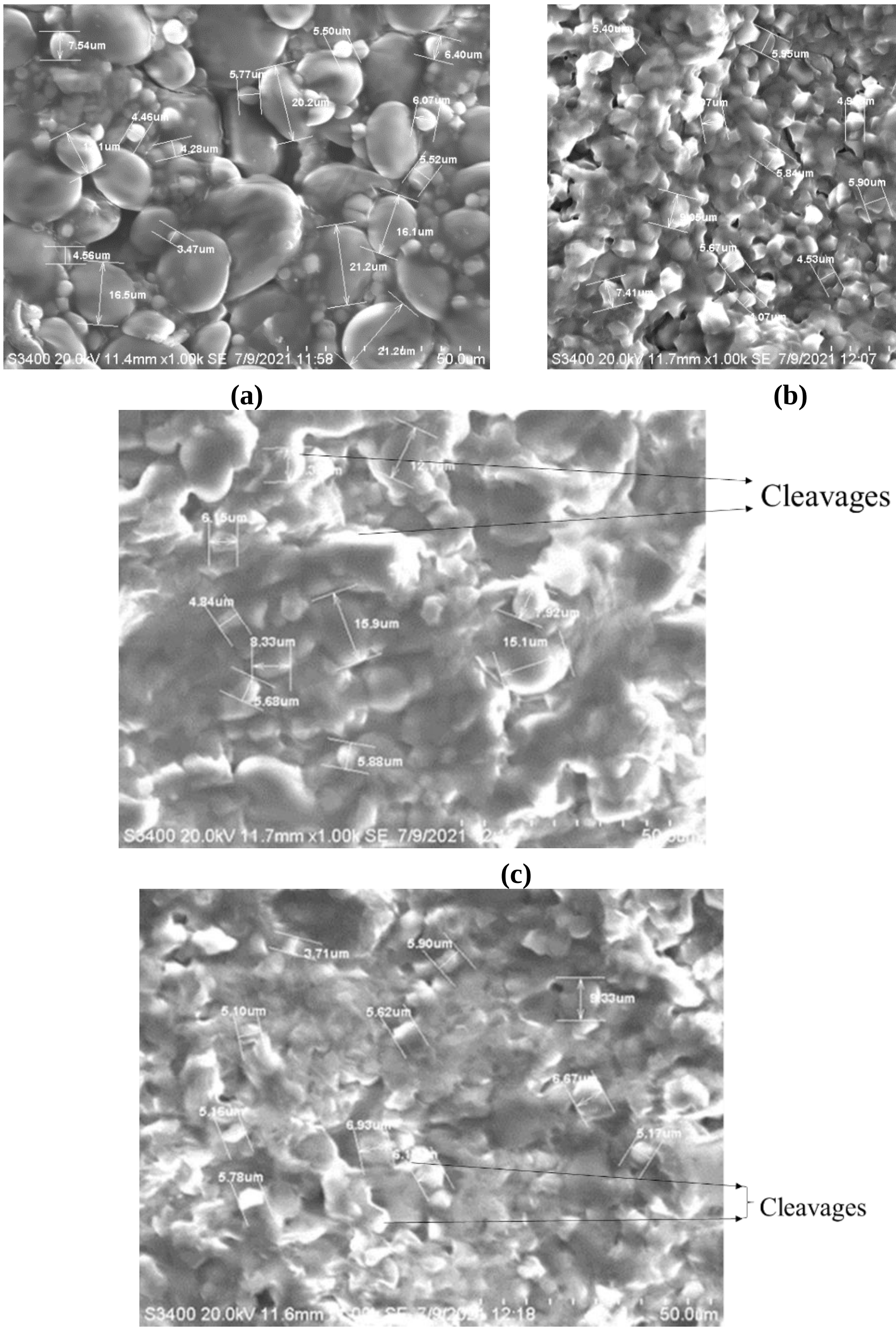


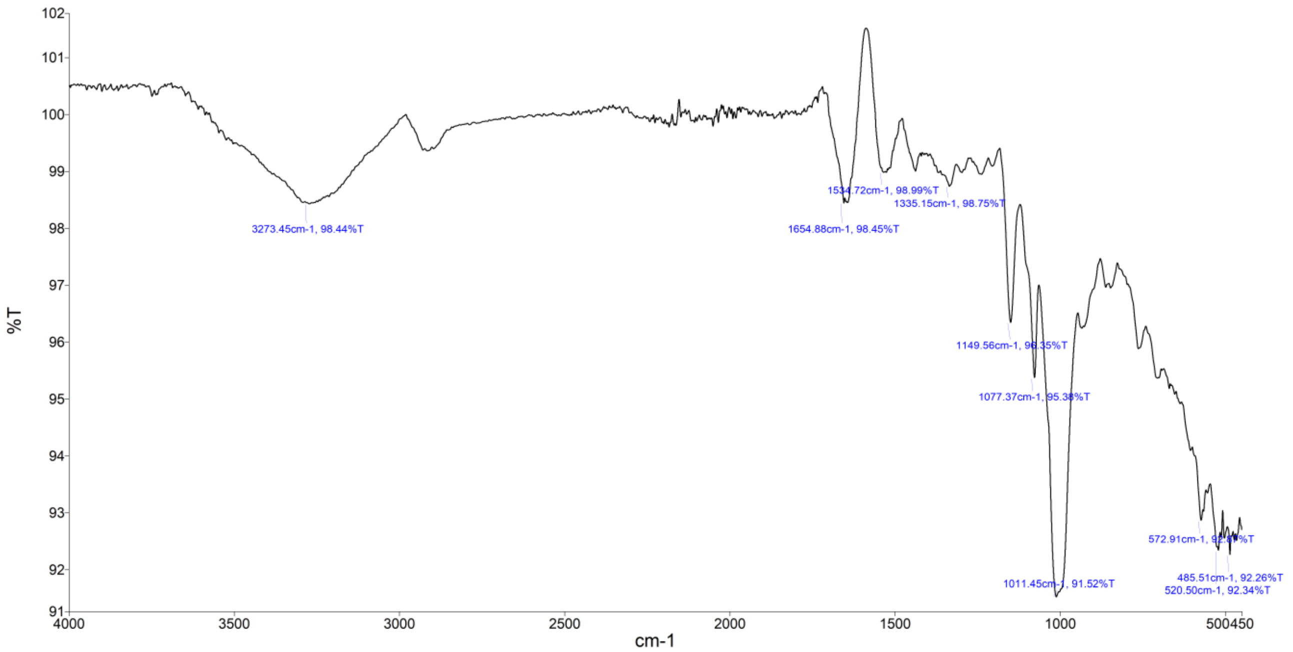
Figure 2. Photo micrographs of **(a)** control, **(b)** R80/C20/G3.5, **(c)** R70/C30/M5/G2.5, and **(d)** R80/C20/M10/G4.5 pastas at 1,000× magnification.

FTIR analysis of selected and control pasta samples

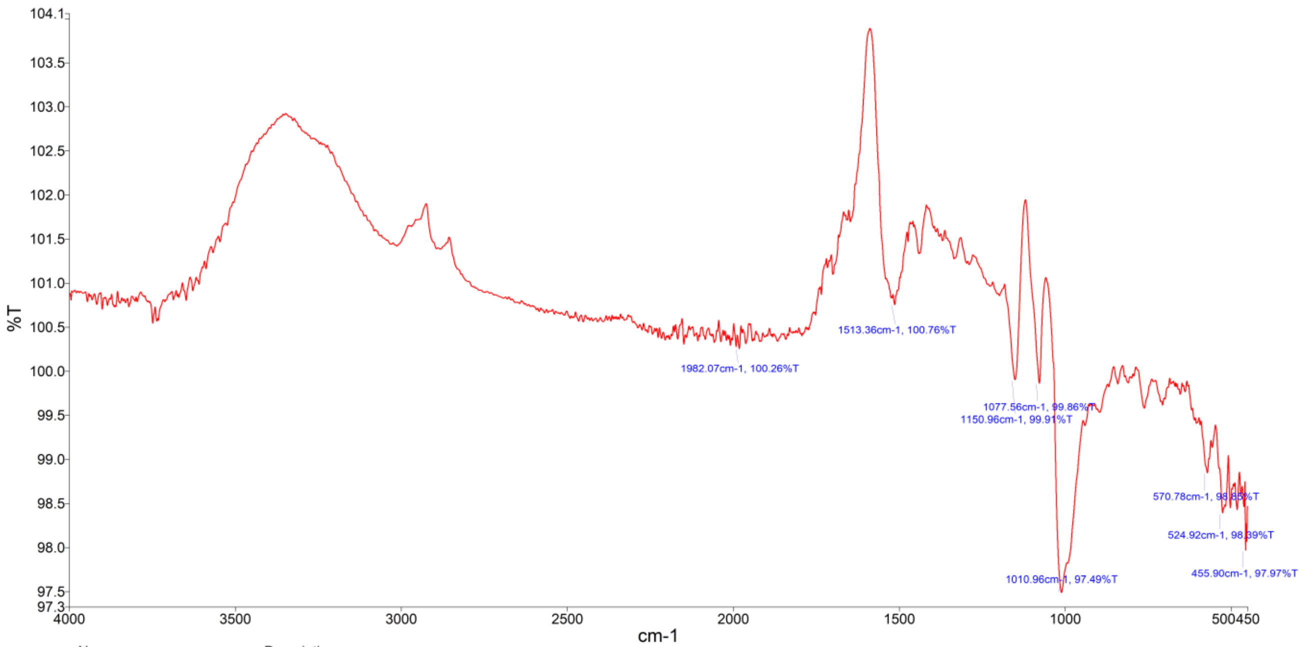
FTIR spectra of selected uncooked pasta samples (control, R80/C20/G3.5, R70/C30/M5/G2.5, and R80/C20/M10/G4.5) are illustrated in Figure 3 (3a to 3d). The control sample made up of refined wheat flour only showed a maximum number of peaks at different wave numbers ranging from 485.51 to 3273.45 cm^{-1} (Figure 3a). The other three samples exhibited similar characteristic peaks despite the variations in intensity from each other.

The absorption bands between 3000 and 3300 cm^{-1} are attributed to the alkynes bonds, and the peak at 2900 cm^{-1} is attributed to the symmetric deformation of alkanes and alkyls. Typical spectral peaks at 1650 and 1540 cm^{-1} are attributed to the occurrence of the stretching vibration of C-C bonding

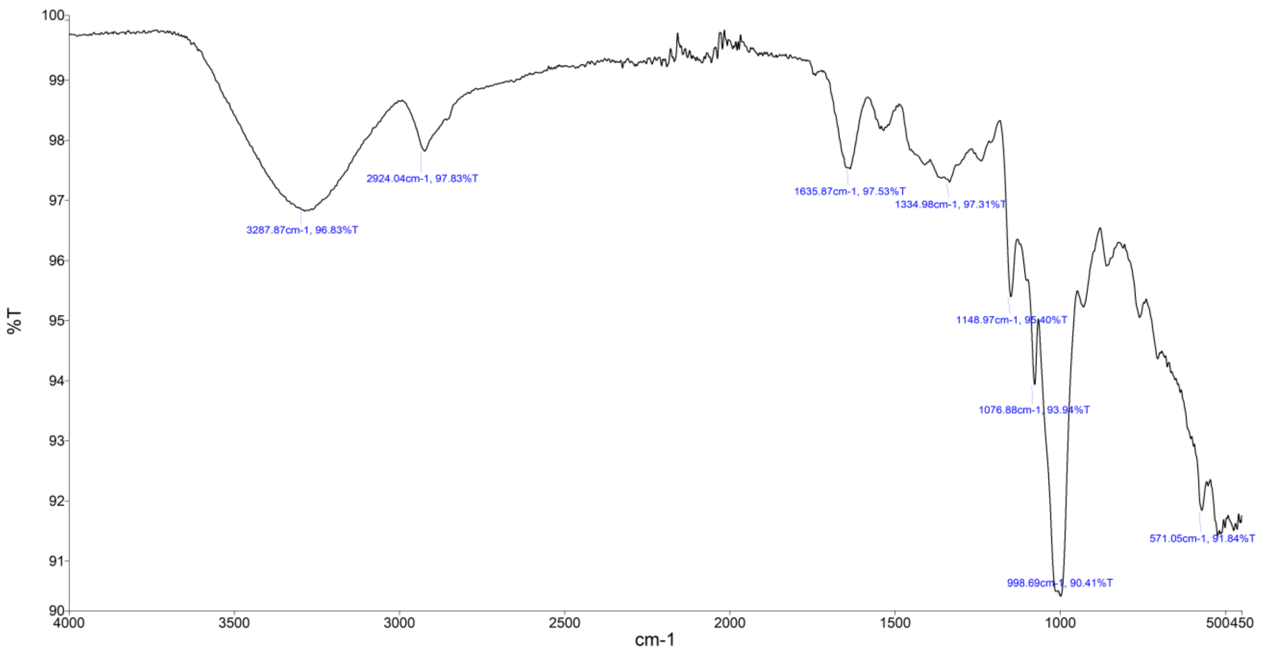
(a)


%T
cm-1
4000
3500
3000
2500
2000
1500
1000
500450
3273.45cm-1, 98.44%T
1654.88cm-1, 98.45%T
1534.72cm-1, 98.99%T
1335.15cm-1, 98.75%T
1149.56cm-1, 96.35%T
1077.37cm-1, 95.38%T
1011.45cm-1, 91.52%T
485.51cm-1, 92.26%T
520.50cm-1, 92.34%T

(b)


%T
cm-1
4000
3500
3000
2500
2000
1500
1000
500450
1982.07cm-1, 100.26%T
1513.36cm-1, 100.76%T
1077.56cm-1, 99.86%T
1150.96cm-1, 99.91%T
1010.96cm-1, 97.49%T
524.92cm-1, 98.39%T
455.90cm-1, 97.97%T

(c)



(d)

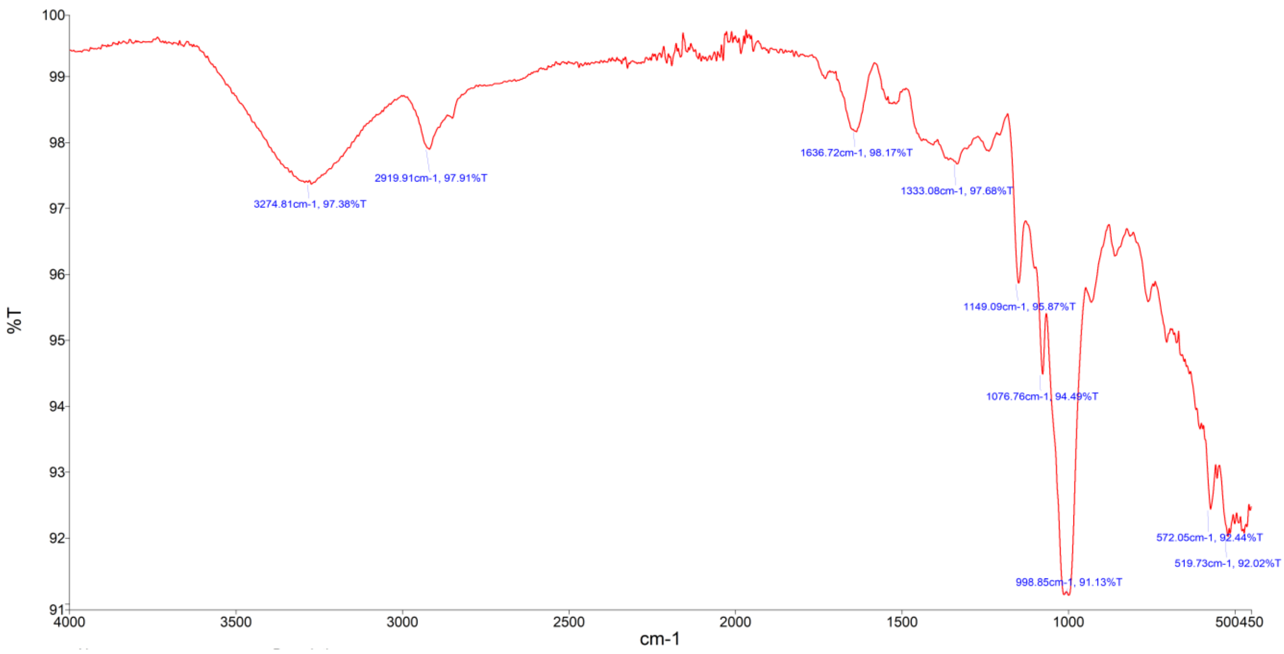


Figure 3. FT-IR spectra of pasta samples: **(a)** control, **(b)** R80/C20/G3.5, **(c)** R70/C30/M5/G2.5, and **(d)** R80/C20/M10/G4.5.

alkene and amide I bonds (gluten). The dominant peak centres at 1635 cm^{-1} (in sample R70/C30/M5/G2.5 and R80/C20/M10/G4.5) suggested the presence of a secondary structure of chickpea flour proteins in the presence of gum as studied by Jia *et al.* (2019). Raungrusmee and Anal (2019) depicted an interval (800 - 1000 cm^{-1}) in a typical FTIR spectrum corresponding to the carbohydrates (starch) fingerprint spectral region. Peaks at 1100 to 1150 cm^{-1} may be due to ether (C-O-C). Major peaks at around 3280 and 2920 cm^{-1} indicated the involvement of functional groups ascribed to mango peel component as shown by Ul Haq *et al.* (2019). Among all the samples, the blended samples revealed many other broader and more intense peaks indicating the modified starch-protein matrix along with the presence of mango peel.

Based on the overall analyses of functional, phytochemical, nutritional, and sensory properties, it is recommended to prepare gluten-free pasta with an ingredient proportion of 80% rice flour, 20% chickpea flour, 10% mango peel powder, and 4.5% guar gum to obtain protein-rich functional pasta with phytonutrients and other desirable qualities. However, in the absence of mango peel powder, 80% rice flour, 20% chickpea flour, and 3.5% guar gum can also be produced for commercial application. A protein-enriched pasta variant of 70% rice flour, 30% chickpea flour, 5% mango peel powder, and 2.5% guar gum can also be prepared with slight compromise on solid loss.

Conclusion

The overall acceptability of gluten-free pasta in sensory evaluation was better than control pasta due to addition of chickpea flour and mango peel powder. Based on the overall results of functional, phytochemical, nutritional, and sensory analyses, the best parameters to prepare gluten-free pasta with an ingredient proportion of the base flour were 80% rice flour, 20% chickpea flour, 10% mango peel powder, and 4.5% guar gum. This yielded 11.36 ± 0.42% protein content, 1.04 ± 0.005% ash content, 154.17 ± 2.42 mg GAE/100 g total phenolic content, 72.53 ± 0.84% radical scavenging activity, with a sensory score of 8.33 ± 0.65. However, in the absence of mango peel powder, 3.5% guar gum of the same base flour can also be produced for commercial application.

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