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Development of Functional Muffins from Wheat Flour-Carrot Pomace Powder using Fenugreek Gum as Fat Replacer

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Abstract

Carrot stands out as one of the globally consumed vegetables, and its juice production yields significant quantities of valuable by-products, notably pomace. To mitigate environment impacts and enhance production cost efficiency, incorporating carrot pomace as an ingredient in diverse food items become a viable strategy. This study investigated the potential of carrot pomace powder (CPP) as dietary fiber source and fenugreek gum (FG) as fat-replacer in preparation of muffins. The flour samples i.e. wheat flour (WF) and CPP were analyzed for their physico-chemical, functional and pasting properties. CPP contained crude fiber (27.6 %), moisture (8.75 %), protein (4.25 %), fat (0.2 %), and ash (1.2 %), indicating higher amounts of ash, and fiber contents than WF. Further, WF was replaced with CPP at different levels (5 %, 10 %, 15 % and 20 %), and FG was added at 0.1, 0.2, 0.3 and 0.4 g levels to analyze their effects on different attributes of muffin. The results showed that muffin fortified with CPP showed an increase in crude fiber content, the highest observed for MF4 of 1.19 %. The water and oil absorption capabilities of WF (143 % and 151 %) were lower than CPP (181 % and 163 %) blends. Addition of CPP and FG increased the flour paste viscosity and specific volume (SV). Moreover, sensory analysis showed the firmness, taste and appearance of muffins were improved by the addition of CPP. The most popular muffins were those made with 10 % CPP and 0.2 g FG. In conclusion, CPP and FG can be effectively utilized to produce fiber-enriched low-fat muffins with improved nutritional profiles and acceptable sensory characteristics.

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Physico-Chemical Properties;
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Introduction

A wide variety of baked products are consumed worldwide due to their affordability and ease of preparation. Muffin is a baked product made of sugar, salt, wheat flour (WF), fat, water, baking powder, eggs, and milk that is used as an evening snack, a

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spongy breakfast, and sweets.[1,2] Furthermore, lacto-vegetarians can eat eggless muffins in countries such as India having vegetarians as a larger percentage of the population. Fat plays a major role in the sensory properties of baked goods. The selection of fats in the production of bakery products is crucial, not only in terms of nutritional value for consumers but also in terms of the rheological properties.[1,3] However, high amounts of saturated fats can have adverse effects on human health. The health food industry has grown as a result of increased awareness of the diet-health association. In order to successfully replace saturated fats in baked products, complex carbohydrates like gums are needed. They can bind water and form gels, provide lubrication and flow properties, mimic the viscosity and texture of fats in food systems, and can be used as fat substitutes.[4] Fenugreek gum (FG) is a natural polysaccharide obtained from the endosperm of fenugreek (*Trigonella foenum-graecum*) seeds.[5] It is a form of galactomannan composed of linear poly (1 - 4) – D - mannan backbone, with 1- 6 - glycosidic linkages, with an average ratio of galactose to mannose of 1:1.11.[6] The FG exhibits a high molecular weight, is abundant in hydroxyl groups, and easily forms hydrogen bonds with water, leading to the formation of a viscous solution.[7] Gum is demonstrated to enhance the taste of muffins and cakes by enhancing the viscosity of dough.[8,9]

Carrot (*Daucus carota*) pomace is a byproduct recovered after extraction of juice and generally discarded as waste. The pomace from carrots contains good amounts of dietary fiber and bioactive compounds like β-carotene.[10] An ascorbic acid and carotene content of 13.53 - 22.95 mg and 9.87 - 11.57 mg/ 100 g, respectively, has been reported for dried carrot pomace.[11] The insoluble fibers, cellulose, and hemicelluloses make up a large portion of total dietary fiber (50–92 %), with a minor quantity of lignin (4 %). High phytochemical content, anthocyanins, phenols, and high dietary fiber intake are linked to several significant physiological benefits in humans, including lowering the risk of chronic heart diseases and diabetes.[5,12] Therefore, the incorporation of fiber-rich foods into the diet is crucial for maintaining good health in humans. Carrot pomace has higher water retention and swelling capacity than other agricultural by-products such as orange, apple, and pear pomace.[13] Due to its widespread availability and lower cost worldwide, CPP has the potential to replace WF in various nutritional food product formulations. Determining the appropriate level of CPP flour consumption is crucial for the formulation and development of new food products.[12]

Traditionally, bakery items are prepared using WF, which may lack essential nutrients. By substituting WF with alternative flours derived from vegetables, fruits, and gums, such as carrot pomace and FG, it is possible to enhance the nutritional value of the product. Additionally, limited studies have comprehensively assessed the impact of fat replacers on both nutritional composition and sensory attributes of muffins, particularly using novel ingredients like CPP and FG.

This study presents the first work investigating the combined use of FG and CPP as fat replacers and dietary fiber enrichers, respectively, in muffins. Through a detailed analysis of functional properties, proximate composition, texture profile, and sensory evaluation, this study provides a comprehensive understanding of the incorporation of CPP and FG. Our findings offer valuable insights into optimizing muffin formulations for improved nutritional profiles and consumer acceptance. The utilization of carrot pomace as a functional ingredient in the preparation of cereal-based products can not only decrease the environmental impact but is deemed valuable. It has been used in a variety of food products like noodles, bread, biscuits, cookies, and cakes.[14]

Material and Methods

Raw Materials

Fresh carrots, wheat flour (WF), and other ingredients used in the preparation of muffins (Table 1) were purchased from a local market in Sirsa, Haryana, India. FG was isolated from fully matured and dried fenugreek seeds (variety HM-57) purchased from CCSHAU, Hisar, Haryana, India. The chemicals and reagents used were of analytical grades.

Extraction of Fenugreek Gum

The method described by Brummer *et al*. with some modifications as described by Dhull *et al*. was used to extract FG from the fenugreek seeds.[15,5] The extraction of FG from defatted seed flour involved cold water (10°C) solubilization with continuous stirring for 3 h using a magnetic stirrer (REMI 5 MLH Plus, Mumbai, India). Subsequently, the gum solution was filtered, and ethanol was used to precipitate the gum. The resulting precipitate was then filtered, re-dissolved in water at 50°C, subjected to oven drying (NSW-143, New Delhi, India), ground into a fine powder, and stored for further analysis.

Carrot Pomace Powder (CPP) Preparation

The washing, peeling, and juicing of fresh carrots using a juicer (the JX 5 mixer juicer grinder from Bajaj Electricals, Mumbai, India) was carried out the same as the method described by Hussain *et al*. with slight modifications.[16] The resulting pomace after juice extraction was collected and subsequently subjected to hot air oven drying for 12 h at 60°C. The dried carrot pomace was then finely ground and sieved through a 250 mm mesh sieve. The resulting CPP was stored in airtight pouches for further use.

Bulk Density and Functional Properties of Flour

The bulk density (BD) of the flour samples was analyzed using the method described by Makinde and Ladipo.[17] In the process, the sample was filled in a measuring cylinder of 100 ml capacity and tapped gently until there was no further volume reduction. Cylinders were again weighed, and BD was calculated in ml/ g. The method of Al-Janabi and Yasen was used for water absorption capacity (WAC) of flour samples with slight modifications, while the method described by Adeleke and Odedeji was used for oil absorption capacity (OAC).[18,19] To determine the WAC, 100 mg of flour sample was added with 1 ml of distilled water. Further, the mixture was mixed for 1 min and subsequently centrifuged (2000 rpm, [20] min) using a centrifuge (Eltek, TC 8100F, Mumbai, Maharashtra, India). After centrifugation, the tubes were drained and reweighed. In OAC, 100 mg of samples were mixed with 1 ml of soybean oil. After 30 min of incubation at ambient temperature, the mixtures were centrifuged for 10 min at 3000 rpm. The tubes were reweighed after decanting the oil layer. Water absorbed/ g and oil absorbed/ g of sample material were calculated as WAC and OAC, respectively.

Pasting Properties of WF and CPP

The pasting properties of WF and composite flour samples (WF replaced with 5 %, 10 %, 15 %, and 20 % CPP) were studied using the method of Dhull and Sandhu, with minor adjustments and by using a compact rheometer (MCR52, Anton Paar, Austria), prepared with a (ST 24-2D/2 V/2 V-30) stirrer probe, and a starch cell (C-ETD 160).[20] In the starch cell, 1.2 g flour samples, and 13.8 ml water were added and mixed thoroughly with the help of a glass road to avoid the formation of lumps. The suspension underwent a heating process, with an initial hold at 50°C for 1 min, followed by a gradual increase in temperature from 50°C to 95°C at a rate of 6°C/min. Subsequently, it was maintained for 5 min at 95°C before undergoing a cooling phase from 95°C back to 50°C at a rate of 6°C/ min, and a final hold at 50°C for 2 min in the pasting analysis. The parameters recorded were BV (break-down viscosity), FV (final viscosity), PV (peak viscosity), and PT (pasting temperature).

Chemical Composition and Dietary Fiber Analysis

The moisture, ash, fat, crude fiber, and protein compositions of WF and CPP were determined using methods of AACC as described below.[21]

The sample was weighed and then placed in hot air oven for 24 h at 105 °C to determine the moisture content of WF and CPP using method 44-15 A described in AACC.[21] After 24 h, the sample was weighed again. The sample was then placed back in the oven to obtain a constant weight. 3g of dried samples were heated on a flame until smokeless, to determine ash content.[21] After placing the crucible in the muffle furnace at 550 °C for 4 h, grayish white residues were formed. A desiccator was used to cool the sample and weigh it. As described in AACC, fat was determined using method no. 30-25.[21] Fat content was determined using the soxhlet apparatus. In a flask with excess hexane residue, a 5 g flour sample was dissolved in hexane at a condensation rate of 2-3 drops per second for 16 h, followed by drying at 100 °C for 30 min until a constant weight was obtained. A crude fiber content analysis of the flour samples was performed by following method no. 32-10, as described in AACC.[21] 2 g of defatted flour sample was taken in 500 ml beaker and 200 ml of 1.25 % sulphuric acid was added to it and the level was marked. After the content was filtered, it was washed with hot water three times until it was acid-free. After transferring the residues to a 500 ml beaker again, 200 ml of 1.25 % NaOH was added. Again, the content was boiled for 30 min, filtered, and washed with hot water 3 times to remove alkali. We dried the residues at 100 °C for 3-4 h until they reached a constant weight in a china dish. Until smoke stopped coming out of the sample, the content was heated on flame. An ash grayish material was obtained by heating the sample to 550°C for 4 h, then cooling in a desiccator and weighing it. As described in AACC, method no. 46-10, nitrogen in flour samples was determined using the Kjeldhal method.[21] Using 2 g of flour, 5 g of digestion mixture and 30 ml of conc. sulphuric acid were added to a digestion flask. After that, the sample was heated and digested for 2-3 h until light green color was achieved. In the Kjeldhal apparatus, 10 ml of distal water was taken from dilution and 10 ml of NaOH was added to the mixture in 250 ml flasks. After adding 10 ml of boric acid to a beaker, we added 1-2 drops of methyl red indicator. As a result, steam was provided and ammonia gas was trapped in boric acid. As the color of the boric acid changed from red to golden, this process was continued for 2 min. A solution of 0.1 N sulphuric acid was added to boric acid until a light golden yellow color was achieved. The determination of total dietary fiber (TDF), soluble dietary fiber (SDF), and insoluble dietary fiber (IDF) content in both WF and CPP was carried out following the enzymatic-gravimetric method as specified in the AACC standard method 32-05.[22] The analysis was conducted in triplicate.

Preparation of Muffins

The muffin was prepared according to Punia *et al*. with some minor adjustments.[1] Table 1 shows the recipe for muffins made with WF and CPP using FG as a fat replacer. FG was incorporated into muffins at different levels (0, 0.1, 0.2, 0.3, and 0.4 g) with reducing the fat content simultaneously. The WF was replaced with CPP at replacement levels of 0 %, 5 %, 10 %, 15 %, and 20 %. The WF, salt, sugar, water, fat, and baking powder were mixed thoroughly by using a pin mixer (National Manufacturing Company, Lincoln, NE, USA). Using a muffin cup, the batter was filled and baked in an oven (preheated) at 200-220°C for 25-30 min. After cooling to 25°C and within a period of 3 h (Figure 2), sensory analysis was performed to maintain consistency.

Table 1: Formulation of WF and CPP incorporated muffins at different levels with FG

Muffin	WF (g)	Sugar (g)	Baking powder (g)	Salt (g)	CPP (g)	FG (g)	Fat (g)
MF0	100	65	5	1	0	0	40
MF1	95	65	5	1	5	0.1	35
MF2	90	65	5	1	10	0.2	30
MF3	85	65	5	1	15	0.3	25
MF4	80	65	5	1	20	0.4	20

Here, WF- wheat flour; CPP- carrot pomace powder; FG- fenugreek gum; MF0- 100 % WF; MF1- 95 g WF+5 g CPP+0.1 g FG; MF2- 90 g WF+10 g CPP+0.2 g FG; MF3- 85 g WF+15 g CPP+0.3 g FG; MF4- 80 g WF+20 g CPP+0.4 g FG

Proximate Composition of Muffin

The Proximate composition of the muffin includes moisture, fat, protein and ash were determined by the method of AACC as described above.[21]

Muffin Characteristics

In this study, muffin characteristics (crust color, crumb, volume, texture, and height) were measured after 24 h of baking.[23] A Hunter Colorimeter (Model D 25 Optical Sensor, Hunter Associates Laboratory Inc., Reston, VA, USA) was used to measure the color attributes of both the muffin crumb and crust. In this measurement, L * represents the degree of darkness or lightness, (L * = 100 indicating white, and L * = 0 indicating black). The parameter a* indicates the hue along a red (+a *) to green (a *) axis, while b * indicates the hue along a yellow (+b *) to blue (-b *) axis. Additionally, to measure the height of the muffins a caliper was used. In order to determine the volume and specific volume (ml/ g) of muffins, the millet-seed displacement method was used. Texture profile analysis (TPA) was conducted on crumb cubes measuring 12.5 mm^3, extracted from each muffin center. A texture analyzer equipped with a 5 Kg load cell (TA/TX2 Plus, Stable Micro Systems, Surrey, UK) was used for TPA. As discussed by

Shevkani and Singh, using a 75 mm diameter flat aluminum probe (P/75), crumbs were placed on a heavy-duty platform (HD P/90) and compressed (50 %) at a 1 mm/ s test speed.[24] Different texture characteristics such as cohesiveness, gumminess, springiness, firmness, and hardness of muffins were estimated as of the TPA force-time curves.[1]

Sensory Analysis of Muffins

Muffins were subjected to sensory evaluation for attributes such as crumb color, taste, texture, appearance, and overall acceptability by following the method described by Rafique *et al.*[25] A panel of 20 semi-trained panelists used a 9-point hedonic scale for their evaluations, and muffins were assigned random 3-digit numbers to maintain anonymity. The evaluations took place at room temperature (35°C), and to minimize residual effects, after each analysis, panelists were instructed to rinse their mouths with water.

Statistical Analysis

The data presented in the tables were analyzed in triplicate, and the experimental data were analyzed by single-factor (ANOVA) analysis of variance. The significant differences between the data were determined with Duncan's multiple range tests (DMRT) using SPSS 20 (IBM Analytics, USA).

Table 2: Physico-chemical composition of WF, CPP and muffins

	Parameters			**Raw materials**		**Muffins**	
	WF	**CPP**	**MF0**	**MF1**	**MF2**	**MF3**	**MF4**
Moisture (%)	11.2 ± 0.23^{b}	8.75 ± 0.22^{a}	16.8 ± 0.2^{p}	17.7 ± 0.1^{q}	19.2 ± 0.5^{r}	20.1 ± 0.6^{s}	21.5 ± 0.1^{t}
Ash (%)	0.8 ± 0.03^{a}	1.2 ± 0.02^{b}	1.42 ± 0.04^{p}	1.50 ± 0.08^{q}	1.58 ± 0.03^{r}	1.61 ± 0.02^{s}	1.65 ± 0.05^{t}
Fat (%)	2.6 ± 0.02^{b}	0.2 ± 0.02^{a}	33.1 ± 0.2^{t}	28.9 ± 0.1^{s}	21.6 ± 0.3^{r}	13.5 ± 0.0^{q}	6.75 ± 0.1^{p}
Crude fiber (%)	2.9 ± 0.01^{a}	27.6 ± 0.09^{b}	0.5 ± 0.03^{p}	0.9 ± 0.07^{q}	1.11 ± 0.06^{r}	1.15 ± 0.08^{s}	1.19 ± 0.02^{t}
Protein (%)	12.2 ± 0.67^{b}	4.25 ± 0.01^{a}	-	-	-	-	-
Total dietary fiber (%)	7.9 ± 1.20^{a}	68.8 ± 1.6^{b}	-	-	-	-	-
Soluble fiber (%)	2.4 ± 0.01^{a}	20.7 ± 1.4^{b}	-	-	-	-	-
Insoluble fiber (%)	5.5 ± 0.01^{a}	48.1 ± 1.2^{b}	-	-	-	-	-

Here, WF- wheat flour; CPP- carrot pomace powder; MF0- 100 % WF; MF1- 95 g WF+5 g CPP+0.1 g FG; MF2- 90 g WF+10 g CPP+0.2 g FG; MF3- 85 g WF+15 g CPP+0.3 g FG; MF4- 80 g WF+20 g CPP+0.4 g FG. Values expressed are mean ± standard deviation of triplicates. The values followed by different superscripts (a-b for raw materials; p-t for muffins) in a row differ significantly ($p < 0.05$).

Results and Discussion

Chemical Composition of Wheat Flour (WF) and Carrot Pomace Powder (CPP)

The flour sample i.e. WF and CPP differed significantly ($p < 0.05$) for their proximate composition, as shown in the results present in Table 2. WF and CPP both had moisture content (11.2 % and 8.75 %, respectively) that was within acceptable limits for safe storage. Tiwari and Sarkar found that fresh carrots contained 87.02 % moisture, while dry carrot flour contained 4.2 %.[26] The ash and fat content (1.2 % and 0.2 %, respectively) of CPP were significantly ($p < 0.05$) different than WF (0.8 % and 2.6 %, respectively). A high value of crude dietary fiber (27.6 %) was observed in CPP suggesting it rich source of fibers. Bellur Nagarajaiah and Prakash also reported that carrot pomace contains both soluble and insoluble fiber (14.75 %, and 30 %, respectively).[27] The protein content of CPP was found lesser (4.25 %) as compared to that of WF (12.2 %). Ahmad *et al*. also found very low protein content (0.21 %) in CPP.[28] The total dietary fiber (TDF, 68.8 %), soluble dietary fiber (SDF, 20.7 %), and insoluble dietary fiber (IDF, 48.1 %) of CPP were significantly ($p < 0.05$) higher than WF (7.9 %, 2.4 % and 5.5 %, respectively). However, Kirbas *et al*. reported a much higher TDF content of 83.91 g/ 100 g in CPP as compared to our results.[29] In another study, the fiber contents of cake rusks exhibited a sequential increase with the rising concentration of sweet potato flour. This phenomenon is likely attributed to the higher presence of dietary fibers in sweet potato flour.[25] Dietary fiber has no calorific value as it cannot be absorbed by the human body, but extends several health benefits such as prevention of constipation, protecting against cardiovascular problems, regulating blood sugar, maintaining blood cholesterol, and preventing some forms of cancers.[14] Owing to health-promoting attributes of dietary fiber, CPP can be integrated with different foods to create healthy food products on an industrial scale.[30]

Bulk Density (BD) and Functional Properties of WF and CPP

The bulk density (BD) and functional properties of flour samples are presented in Table 3. The BD depicted by WF and CPP-WF blends ranged between 0.40 to 0.61 g/ ml, the highest was observed for 20 % CPP blend. BD is generally influenced by the particle size of the flour and it determines flour expansion as well as the amount of porosity in food products.[31] The WAC of WF and blends varied significantly ($p < 0.05$), ranging from 143 % to 181 %, the highest was observed in blend containing 20 % CPP, while the lowest WAC was found for 100 % WF (control). Singh *et al*. found WHC (19.6 %) for the control sample and (241.3 %) was found for 20 % formulated black carrot powder in noodles.[32] This increase in WAC with higher CPP content can be due to hydroxyl groups abundantly present in dietary fibers, facilitating water interaction through hydrogen bonding, as described by Nouri *et al*. WAC of flour is an important property considered during product formulation.[14] Usually, the flour with good WAC is considered better for bakery products as they improve the handling properties of dough and also helps in enhancing the freshness of the baked goods. WHC mainly depends upon the chemical and physical structure of fibers as well as the processing of fibers.[33,34] OAC of WF and CPP blends ranged from 151 % to 163 %, the lowest and the highest values observed in F0 and F4, respectively. OAC helps in the improvement of mouth feel and the retention of flavor.[20] The swelling capacity (SC) of flour is related to its starch, fiber, and protein content. The WF showed a significantly ($p < 0.05$) lower SC (1.52 ml) compared to CPP blends. The SC of the flour blend increased with increasing concentration of CPP which may be attributed to its high fiber contents resulting in more water absorption and more swelling of blends. Foaming capacity (FC) refers to the ability of flour to form foam on whipping. FC of WF and CPP blends ranged from 12 % to 48 % and exhibited a decreasing trend as the proportion of CPP in the blend increased. This decrease in FC may be attributed to dilution of wheat protein (gluten) with increasing the proportion of CPP in blends.

Table 3: Bulk density and functional properties of WF and CPP blends

Blends	BD (g/ml)	WAC (%)	OAC (%)	SC (ml)	FC (%)
F0	0.40 ± 0.01^{a}	143 ± 1.7^{a}	151 ± 2.1^{a}	1.52 ± 0.05^{a}	48.5 ± 0.4^{d}
F1	0.48 ± 0.03^{b}	155 ± 1.5^{b}	157 ± 1.9^{b}	1.59 ± 0.03^{b}	12.2 ± 0.7^{a}
F2	0.53 ± 0.05^{c}	164 ± 1.2^{c}	159 ± 1.5^{c}	1.63 ± 1.01^{c}	14.4 ± 0.3^{c}
F3	0.57 ± 0.03^{d}	173 ± 1.1^{d}	161 ± 1.2^{d}	1.65 ± 0.01^{d}	13.7 ± 0.1^{b}
F4	0.61 ± 0.02^{e}	181 ± 1.6^{e}	163 ± 1.6^{e}	1.68 ± 0.02^{e}	14.9 ± 0.5^{c}

Here, WF- wheat flour; CPP- carrot pomace powder; FG-fenugreek gum; F0- 100 % WF; F1- 95 g WF+5 g CPP+0.1 g FG; F2- 90 g WF+10 g CPP+0.2 g FG; F3- 85 g WF+15 g CPP+0.3 g FG; F4- 80 g WF+20 g CPP+0.4 g FG. Values expressed are mean ± standard deviation of triplicates. The values followed by different superscripts (a-e) in a column differed significantly ($p < 0.05$).

Pasting Profile of Flour Samples

The pasting profile analysis of flour samples provides information on how their paste viscosity changes with temperature, which is influenced by flour composition, starch, and protein properties.[20] Figure 1 shows the pasting profile of different flour samples. A significant ($p < 0.05$) difference was observed in the values of the peak viscosity (PV) and final viscosity (FV) of WF and CPP blends, varying from 522 - 684 mPa.s and 490 - 774 mPa.s, respectively. WF showed the highest PV, which might be due to the higher water holding and swelling capacity of starch.[35] A blend containing 20 % CPP had the lowest PV, because of CPP's small particle size and decreased content of starch, when CPP was added. A similar result was observed for FV and SV of different flour samples. It was observed that the control (774 mPa.s) had the highest FV (ability to form a viscous paste). CPP blends have a lower FV as a result of their weaker resistance to heating and shear mixing, resulting in decreased viscosity.[36] When flour pastes are cooled, the SV measures their tendency to retrograde or syneresis. The SV decreased as the proportion of CPP was increased (5 to 20 % CPP blends), varied from 314 - 467 mPa.s. The BV is a measure of granules' disintegration caused by continuous shear and stress at elevated temperatures.[37,38] The BV values ranged from 139 to 438 mPa.s. for CPP blends. In blends containing 20 % CPP, the lowest BV was observed owing to the CPP small particle size, and the dilution of starch. TV measures the amount of paste that can withstand BV during cooling, which ranged from 176 to 383 mPa.s.[39] The temperature and time of pasting were also affected by CPP levels. According to these parameters, flour must be cooked at the right temperature for a certain period of time.[28]

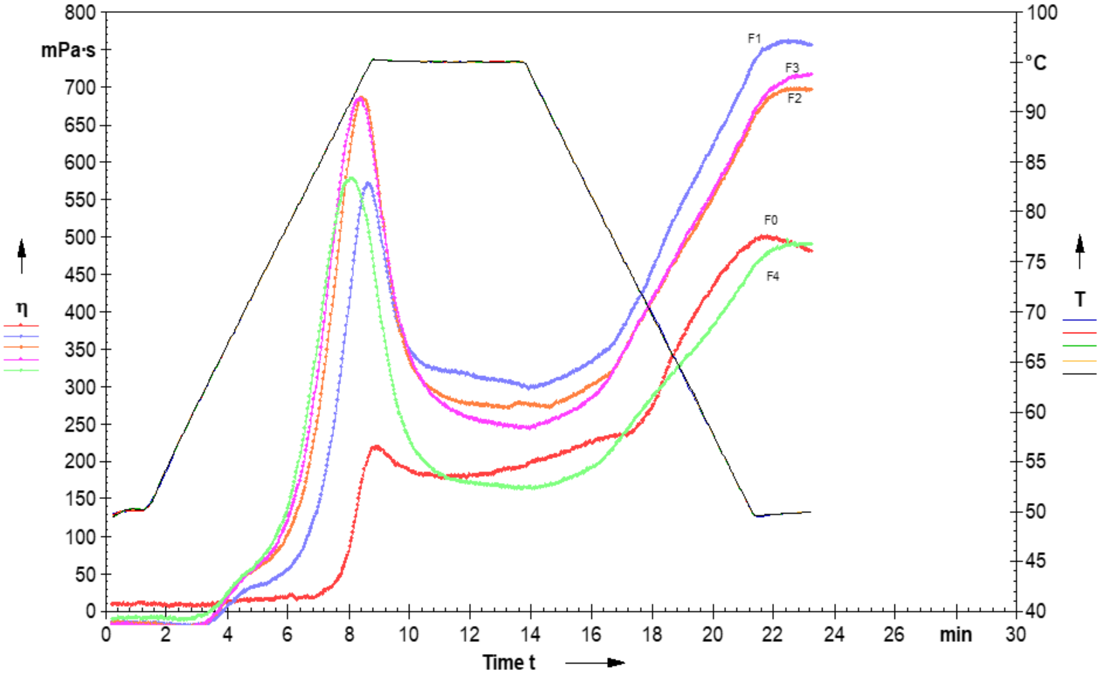

Fig.1: Pasting properties of WF and CPP blends: F0- 100 % WF; F1- 95 % WF+5 % CPP; F2- 90 % WF+10 % CPP; F3- 85 % WF+15 % CPP; F4- 80 % WF+20 % CPP

Proximate Composition of Muffins

The results for the proximate composition of muffins, prepared using WF without FG (control) and CPP blends with FG as fat replacer are presented in (Table 2). The moisture content of different muffins ranged from 16.8 % to 21.5 % and showed an increasing trend with increasing CPP and FG concentrations. This rise in moisture content can be attributed to the increasing level of fibers, which tend to absorb and retain more moisture. The ash and fiber content in control was 1.42 % and 0.5 %, respectively. Hussain *et al*. found contents of ash and fiber in control were 1.89 % and 0.43 %, respectively.[34] Muffins also showed a slightly increasing value for ash content with increasing CPP and FG incorporation, varying from 1.42 % to 1.65 %. Fortified muffins with higher ash content might provide a better mineral source.[40] The CPP blend muffins with FG as a fat replacer showed a significantly lower fat content value as compared to the control sample (33.1 %). Also, the fat content value decreased further with the increasing CPP and

FG level, the lowest value showed by sample MF4 (6.75%). This can be due to a lesser amount of fat used in the preparation of muffins with FG at different levels. The muffins fortified with CPP showed an increase in crude fiber content, the highest observed for MF4 of 1.19 %. This increase might be due to higher crude fiber in CPP than in WF.

Specific Volume (SV) and Height of Muffins

The results for SV and height of different muffins are presented in Table 4. The SV of muffins increased after the addition of FG in different formulations, the values varied from 1.60 ml/ g to 1.72 ml/ g (Figure 2). However, at a higher level of FG addition i.e. 0.4 g in MF4, SV increased slightly as compared to MF3. Several authors have suggested that the increased viscosity of the batter may be related to gum addition.[8,41] As a result, after gum addition, Gomez *et al*. found that muffins' volume increased for a longer period of time before the batter changed from a liquid (aerated emulsion) to a solid (porous structure).[41] It was reported by Lu *et al*. and Rupasinghe *et al*. that the volume of cake and muffin decreased after the addition of green tea and apple pomace, respectively.[42,43] A positive correlation has been found between the volume and height of cakes and air (trapped during mixing), CO_2 (from baking powder), water vapor generated during baking, temperature, and structural changes caused by protein denaturation and starch gelatinization.[44] A gradual increase in the concentration of CPP and FG led to an increase in the height of muffins. According to Table 4, the height of muffins prepared using WF without FG (control) and CPP blends with FG as fat substitute varied between (30.4 % to 33.5 %), with the highest observed for MF4. According to Singh *et al*., XG increased muffin height, possibly because hydrocolloids contribute to proper rising.[8] In eggless yellow cake height increased with the addition of XG.[45]

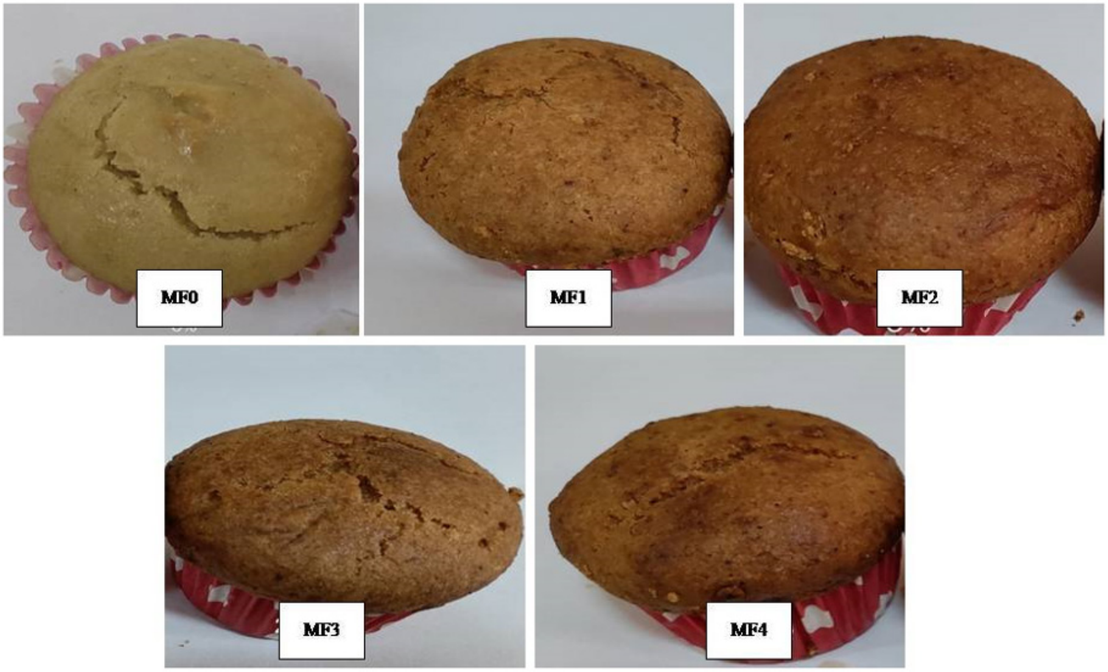

Fig. 2: Prepared muffins of WF and CPP blends using FG as a fat replacer

Textural Properties

The textural properties of muffins are presented in Table 4. The firmness of muffins was determined by the maximum force required to smash its crumb. The firmness of muffins was increased with increasing the concentration of CPP and FG formulation, the values varied from 1.1 to 1.8 N (Table 4). The effects of FG on firmness were greater than those of CPP incorporation due to its water binding and swelling capacity which might be because starch and FG interact and affect retro-gradation.[41] Several factors influence textural properties, including moisture content, volume, and interactions between components.[46] Baked goods are generally considered to have good textural properties due to their cohesiveness, which measures the internal resistance and sticking ability of the food.[47] The cohesiveness of muffins, varied from (0.38 to 0.64 N), the highest value observed in MF4 (0.64 N), and the lowest was observed in control (0.38 N). Cohesive products exhibit a higher degree of resistance to packaging and delivery stresses, ensuring they are delivered to consumers in expected quality.[48] The degree of springiness in muffins, as measured by the degree of recovery after the second compression (elasticity), was closely associated with the freshness of aerated products.[49] The springiness of muffins decreased with values varied from 0.80 to 0.86 mm, while the gumminess increased (ranging from 0.53 to 0.91 N) with the increasing level of CPP and FG. Walker *et al*. reported that increasing the amount of wine grape pomace (WGP) in muffins, enhanced the firmness of muffins and a reduction in springiness.[50] In another study by Singh *et al*. springiness increased initially with a 3 % black carrot fiber (BCF) formulation but reduced with the addition of 6 and 7 % BCF.[8] The gumminess decreased with the addition of BCF, up to a 6 % level with or without the formulation of XG, but it increased with the incorporation of a 9 % level of BCF with XG.[8]

Table 4: Some physical and textural properties of WF and CPP-formulated muffins with FG

Muffins	SV (ml/g)	Height (mm)	Textural properties of muffins			
			Firmness (N)	Cohesiveness (N)	Springiness (mm)	Gumminess (N)
MF0	1.60 ± 0.1^{a}	30.4 ± 0.3^{a}	1.1 ± 0.04^{a}	0.38 ± 0.05^{a}	0.86 ± 0.05^{d}	0.53 ± 0.02^{a}
MF1	1.62 ± 0.2^{a}	31.6 ± 0.2^{b}	1.3 ± 0.00^{b}	0.49 ± 0.03^{b}	0.84 ± 0.03^{c}	0.56 ± 0.01^{ab}
MF2	1.65 ± 0.2^{b}	32.3 ± 0.3^{c}	1.5 ± 0.07^{c}	0.57 ± 0.06^{c}	0.82 ± 0.01^{b}	0.63 ± 0.00^{b}
MF3	1.69 ± 0.1^{bc}	32.1 ± 0.3^{c}	1.8 ± 0.03^{d}	0.60 ± 0.02^{cd}	0.80 ± 0.03^{a}	0.82 ± 0.03^{c}
MF4	1.72 ± 0.3^{c}	33.5 ± 0.1^{d}	1.8 ± 0.01^{d}	0.64 ± 0.04^{d}	0.80 ± 0.02^{a}	0.91 ± 0.01^{d}

Here, WF- wheat flour; CPP- carrot pomace powder; FG- fenugreek gum; SV, Specific volume. Values expressed are mean ± standard deviation of triplicates. The values followed by different superscripts (a-e) in a column differed significantly ($p < 0.05$).

Color Characteristics

Color variation was observed in muffins, prepared with WF without FG (control) and CPP blends with FG (Table 5). The lightness value (L *) for both crust and crumb in the control muffin sample was significantly ($p < 0.05$) higher than those in CPP-fortified muffin samples. The presence of CPP blends in muffins with FG as a fat replacer changes the crumb creamy color into orange due to the presence of bioactive compounds (β - carotene with orange color pigments in CPP).[51a,b] CPP fortified muffins showed increasing a * values of crusts and crumbs, compared to the control sample. However, the b * values were reduced (yellowness) with increasing the concentration of CPP and FG in muffins. Singh *et al*. also reported similar results with the addition of BCF to gluten-free cakes.[48] The study reported that the lightest color observed in samples containing 0 % CPP with hydrocolloids can be attributed to the lack of CPP and its expanded structure.

Several factors contribute to the color of a baked good; including its ingredients and their interactions.[50] According to Walker *et al*. dark muffins are healthier than light muffins.[50] Fortified muffins had a darker color owing to the presence of β - carotene (color pigment) in our study. The β - carotene led to a darkening of the muffins, and a decrease in the L * value of both crumbs and crusts. This darkening effect was influenced by the amount of CPP addition and interactions between polyphenols and other constituents.[52]

In an earlier study, both crumbs and crusts a * value initially decreased upon the addition of 6 % BCF, followed by a subsequent increase when the BCF content reached 9 %. A decrease in yellowness (b * value) was observed with increasing BCF incorporation.[8] Lu *et al*. reported similar results for cakes prepared without and with the addition of green tea.[42]

Table 5: Color characteristics of both crusts and crumbs of WF and CPP-fortified muffins with FG

Muffins	Crust			Crumb		
	L *	**a ***	**b ***	**L ***	**a ***	**b ***
MF0	61.2 ± 0.1^{e}	2.3 ± 0.1^{e}	29.5 ± 1.2^{e}	63.4 ± 0.5^{e}	1.4 ± 0.1^{c}	22.2 ± 0.2^{e}
MF1	44.3 ± 0.3^{d}	-4.1 ± 0.2^{a}	11.3 ± 0.1^{d}	59.3 ± 0.8^{d}	-3.4 ± 0.0^{a}	8.9 ± 0.1^{d}
MF2	38.5 ± 0.6^{c}	-3.5 ± 0.0^{b}	8.5 ± 0.4^{c}	52.7 ± 0.4^{c}	-3.2 ± 0.3^{ab}	7.2 ± 0.0^{c}
MF3	35.7 ± 0.4^{b}	-2.6 ± 0.3^{c}	7.6 ± 0.2^{b}	48.8 ± 1.2^{b}	-3.1 ± 0.2^{ab}	6.8 ± 0.4^{b}
MF4	29.9 ± 0.5^{a}	-2.1 ± 0.1^{d}	7.0 ± 0.2^{a}	46.0 ± 0.2^{a}	-3.0 ± 0.4^{b}	5.9 ± 0.1^{a}

Here, WF- wheat flour; CPP- carrot pomace powder; FG- fenugreek gum; Values expressed are mean ± standard deviation of triplicates. The values followed by different superscripts (a-e) in a column differed significantly ($p < 0.05$).

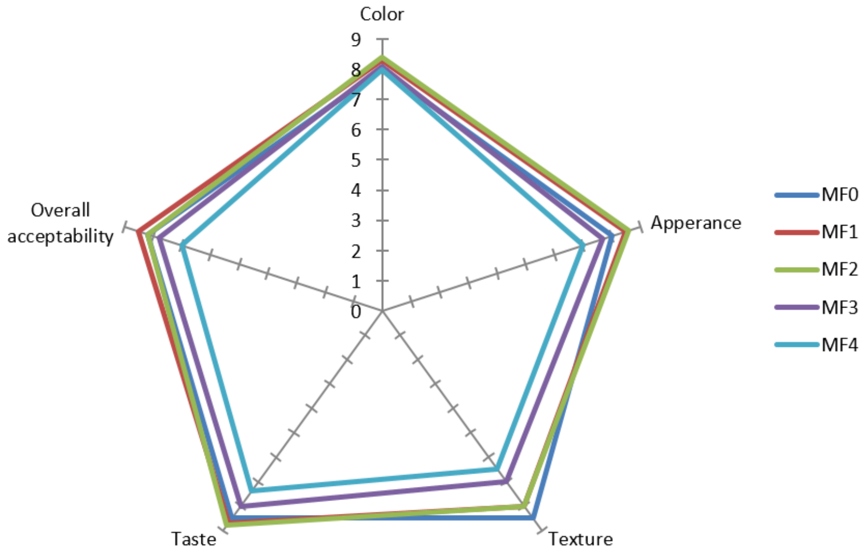

Fig. 3: Sensory characteristics of WF and CPP incorporated muffins using FG as a fat replacer

Sensory Characteristics of Muffins

There were numerous sensory attributes measured for the control and fortified muffins, including crumb color, texture, taste, aroma, appearance, and overall acceptability (Table 7). The sensory characteristics of control and fortified muffins differed significantly ($p < 0.05$). Due to its inferior texture and mouthfeel, control muffins scored lower than MF1 and MF2 in terms of color, appearance, taste, and overall acceptability (Figure 3). When CPP blends (up to 10 %) with FG as a fat replacement (up to 0.2 g) were added to the fortified muffins, the taste improved significantly ($p < 0.05$). Further addition of CPP and FG resulted in lower scores in MF3 and MF4. During the baking process, maillard and caramelization reactions occurred on the muffin surfaces, resulting in a golden brown crust color.[8] In addition, β-carotene, which is the natural pigment in CPP, contributes to the dark color of the muffin crust.[51a,b] The muffins changed color from pale to orange/red after adding CPP because it contains a high amount of β - carotene. A fortified muffin (up to MF2) represented a higher volume (low density), and the crumb and crust texture were preferred by panelists. By adding CPP, maillard and caramelization reactions were enhanced, leading to an improved taste. According to the panelists, all muffins were good; the most significant sensory scores could be made with MF2 (prepared with 10 % CPP blend with 0.2 g FG as a fat replacer). In a prior research study, Singh *et al*. observed no significant difference between the gluten-free muffins containing 0, 3, 6, and 9 % BCF.[48] On the other hand, Sudha *et al*. found that increasing the amount of apple pomace led to a reduction in cake sensory attributes.[53]

Conclusion

The residue remaining after extracting carrot juice, when transformed into powder, has demonstrated to be an outstanding provider of nutrition components. The purpose of this study was to prepare low-fat muffins using FG as a fat replacer along with CPP, which contains a high fiber content. Based on the results of chemical composition analysis of CPP, it is a good source of nutrients, including dietary fibre and β-carotenoids. In muffins, increasing FG and CPP content resulted in increased SV (1.72 ml/ g) and firmness (1.8 N). Moreover, sensory analysis showed that adding 10 % CPP with 0.2 g FG improved consumer acceptance of muffins. Therefore, it can be concluded that a low-fat fiber enriched muffins with desired sensory properties can be successfully achieved by utilizing CPP upto 10% and FG (0.2 g) simultaneously. The incorporation of CPP and FG can improve the functionality of different foods such as muffins, biscuits, cakes, bread, rusks, noodles, and more. Further, a better utilization of CPP can be achieved through a better understanding of its composition and properties in relation with other compounds such as gums. Implementation of effective and efficient waste handling technologies could be utilized to generate by products from waste streams of carrot juice processing.

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Conflict of Interest

Authors have no conflict of interest pertaining to this study whatsoever.

Author's Contribution

Pooja Bamal: Conceptualization, Data Curation, Writing-Original Draft preparation, Formal analysis, Investigation, Methodology. Sanju Bala Dhull: Supervision, Project Administration, visualization, Software, Review and Editing, Resources, Validation.

Data Availability

Not applicable

Ethics Approval

Not applicable

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