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EXPLORING THE NUTRITIONAL BENEFITS OF USING CARROT POMACE POWDER IN FONDANT CANDY PRODUCTION

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Abstract

Carrots, or Daucus carota L., are a type of root food that are known for being very healthy. Carrot pomace is a useful by-product abundant in dietary fiber and carotenoids that can be economically beneficial for enhancing culinary products, showing this waste's diversity and potential uses. his research examined the effect of carrot pomace (CP) powder at different concentrations (5% and 7%) on the improvement of fondant candies quality. This study aimed to assess the impact of these elements on the physicochemical and phytochemical characteristics, color, and sensory attractiveness of the fondant candies. Our study's results indicate that adding CP powder greatly improves the nutritional composition by increasing the fiber content and providing advantageous antioxidants. An analysis of sensory evaluations revealed that fondant candies containing up to 7% CP were favored for their taste and texture without any noticeable negative impact on consumer acceptance. The research findings indicate that carrot pomace powder is a feasible natural component for manufacturing nutritionally superior fondant candies with enhanced health advantages. This ingredient achieves a harmonious combination of increased nutritional content and preserving favorable sensory characteristics.

Key words*: antioxidants, carotenoids, carrot pomace, fondant candies, food applications, phytochemical characterisation.*

INTRODUCTION

As seen by introducing new goods on the market, supplemented with components that provide health benefits to consumers, the food sector is continuously evolving. Integrating different by-products into food can offer a practical economic solution by exploiting their potential while providing significant health benefits through their nutritional and functional properties (Surbhi et al., 2018).

A substantial quantity of by-products is generated in the food business, and their proper disposal is essential to minimize environmental contamination. Conversely, these remaining constituents present substantial amounts of polysaccharides, polyphenols, carotenoids, and other useful components that can be recovered and thereafter repurposed in the manufacturing of functional foods (Di Donato et al., 2014).

Carrots (*Daucus carota* L.) are a highly consumed crop from the *Apiaceae* family, extensively cultivated globally annually for culinary use. Carotenoids and flavonoids are polyphenolic compounds present in the roots of carrots, responsible for their coloration and antioxidant characteristics (Ahmad et al., 2019).

Carrots, which are rich in phytochemicals such as carotenoids, phenolics, ascorbic acid, and polyacetylenes, have been linked to a decreased mortality risk for cardiovascular disease and cancer (Ahmad et al., 2019). Up to 50% of the ingredients used in carrot juice processing are either thrown as waste or diverted into animal feed. However, this pomace has significant amounts of very healthy substances including carotenoids, dietary fibers, uronic acids, and neutral sugars (Sharma et al., 2021). An estimated 175,000 tons of carrot pomace waste are generated globally each year. Historically, attempts to convert carrot waste mostly concentrated on extracting nutraceuticals such as carotenoids and dietary fiber (Surjadinata et al., 2017). It has a high residual content of all the vitamins, minerals, dietary fiber, and bioactive compounds, including β-carotene, a precursor of vitamin A (Kumar et al., 2012).

In their study, Nawirska & Kwasniewska (2005) identified pectin (3.88%), cellulose (51.6%), hemicellulose (12.3%), and lignin (32.1%) as the primary fiber types present in carrot pomace. Hence, the residual product of extracting juice from carrots yields a highly promising reservoir of phytochemicals that offer numerous health advantages. This resource holds the potential for advancing plant-based components in the food sector and developing dietary supplements (Schieber et al., 2001).

Integrating carrot pomace powder into foods offers a sustainable waste reduction approach that enhances health advantages. Incorporating value into by-products reduces the price of the primary product, generating a direct profit for both processors and consumers.

The literature studies have shown the potential to employ several methods to value carrot pomace. The study conducted by Tańska et al. (2007) showed that carrot pomace can be used as a substitute for wheat flour in wheat bread up to a maximum of 5%, where the resulting product exhibited the highest quality characteristics.

Another study carried out by Kirbaş et al. (2019) achieved gluten-free cake with increased fiber content by including carrot pomace, resulting in a final product that exhibited satisfactory sensory attributes.

Typically, fondants are prepared by dissolving sugar in water and glucose syrup and then boiling the resulting syrup to intensify its concentration. Once cooled, the syrup is vigorously pounded to promote crystallization. The fondant is often allowed to undergo a one-day maturation period. The crystalline fondant can be applied either into a molding system, starch or starchless and enrobed, or used as a filling (Edwards, 2009).

Fondant, a well-known confectionery item renowned for its smooth consistency and visual attractiveness, is composed of sugar, water, and glucose syrup. Although fondant is renowned for its adaptability in the field of sweets, it provides only modest nutritional advantages. In response to the rising consumer desire for better food choices, there is a rising interest in improving the nutritional composition of confectionery goods while maintaining their sensory qualities (Ozcan et al., 2019).

As the demand and acceptability of confectionery products increases, they can be used as matrices for fortification and creation of nutritional quality. Confectionery products such as cakes are high in starch, fat, and energy but low in fibre (Singh, 2016).

The objective of this work is to investigate the feasibility of using CP powder as a functional component in fondant candies, by analysing its impact on both nutritional composition and sensory characteristics.

Additionally, the effects of CP supplementation on the physicochemical content, phytochemical composition and colour qualities of the fondant candies were also examined.

MATERIALS AND METHODS

Materials and chemicals

Hexane, acetone, methanol, gallic acid, Folin-Ciocalteu reagent, [2,20 azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt] (ABTS), ethanol, 6-hydroxy 2,5,7,8 tetramethylchromane-2-carboxylic acid (Trolox), sodium carbonate, sodium hydroxide, and aluminium chloride were purchased from Sigma Aldrich Steinheim (Darmstadt, Germany). Market-purchased (Galați, Romania) fresh carrots (*Daucus carota*) were peeled, rinsed, and then subjected to juice extraction using a juicer.

A CHRIST Alpha 1-4 LD plus lyophilizer (Germany) was used to freeze and then dry the carrot pomace for 52 hours at –44°C with a pressure of 10 Pa. The dried pomace was ground into a fine powder using a laboratory grinder and subsequently stored in airtight containers under refrigerated at 4ºC until required. Fondant candies are made from the following ingredients: fondant mass, walnut, starch, and water were all purchased from a supermarket in Galați, Romania.

*Ultrasound-Assisted Extraction of specific bioactive compounds from CP powde*r

This study employed the ultrasound-assisted extraction technique to extract phytochemicals from carrot pomace powder, following the methods described by Umair et al. (2021) with minor modifications. For the extraction of specific bioactive compounds (total carotenoid, flavonoids, and polyphenols) the carrot pomace extraction solution consisted of a mixture of hexane:acetone, 3:1 (*v/v*). The extraction using ultrasounds with a temperature of 30°C, a frequency of 40 kHz, and a plant-to-solvent ratio of 1:10 (w/v) was performed for 35 minutes. The extracted materials were centrifuged at 6500 rpm for 10 minutes at 4°C. The supernatant obtained was subsequently analyzed to identify the phytochemicals present in CP powder.

Determination of total carotenoid, β-carotene, and lycopene contents

The total carotenoid content, β-carotene, and lycopene contents were determined using the Rațu et al. (2024) method.

Accordingly, 0.2 mL of the extract was dissolved in a mixture of extraction solvent (hexane: acetone, 3:1) and then added to the UV quartz cuvette. The absorbance at three wavelengths was measured using the Libra S22 UV-VIS spectrophotometer (Biochrom, Cambridge, UK): 450 nm for total carotenoids, 470 nm for β-carotene, and 503 nm for lycopene. The quantitative data were presented as the dry weight (dw) in milligrams per gram (mg/100g). Concentrations were determined using Equation 1.

$$\text{Contents (mg/100 g)} = \frac{A \ x \ Mw \ x \ Df \ x \ Vd}{\text{m x L x Ma}} \qquad (1)$$

where: *Ma* is the molar absorptivity, which is 2500 L mol^{-1} cm^{-1} for total carotenoids, 2590 L mol^{-1} cm^{-1} for β-carotene, and 3450 L mol^{-1} cm^{-1} for lycopene; *A* is the sample absorbance; *Mw* is the molecular weight (536.873 g mol^{-1}); *Df* is the sample dilution rate; *Vd* is the solution volume; *m* is the mass/weight of the concentrated extract; *L* is the length of the cuvette's optical path (1 cm).

Determination of total flavonoid content

The total flavonoids in the samples were quantified using the Stoica et al. (2024) method with minor adjustments. 250 µL of plant extract was combined with 1.25 mL deionized water and 0.075 mL of a 5% sodium nitrate water solution. Immediately after 5 minutes of darkness, 0.15 mL of a 10% $AlCl_3$ solution was introduced. After a 6-minute dark period, 0.5 mL of a 1M sodium hydroxide solution and 0.775 mL of deionized water were introduced into the reaction mixture. Absorbance was measured at a wavelength of 510 nm using a UV–Vis spectrophotometer Libra 22 model (Biochrom; Holliston, MA, USA). The results quantified as catechin equivalents in milligrams per gram of dry weight (mg CE/g dw), were determined using the catechin standard curve, which had an R^2 value of 0.997.

Determination of total polyphenol content

The Folin-Ciocâlteu colorimetric technique was employed to quantify the total polyphenols (Stoica et al., 2024).

200 µL of the extract, 15.8 mL of pure water, and 1 mL of the Folin-Ciocalteu reactive were mixed together in this experiment. Following 10 minutes, 3 mL of a 20% sodium carbonate solution was added to the final mix. After allowing the solution to stand at room temperature for 60 minutes, the absorbance at 765 nm was evaluated (Biochrom; Libra 22; Holliston, MA, USA). The concentration of polyphenolic compounds was measured in milligrams of gallic acid equivalents (GAE) per gram of dry weight (dw) using an equation obtained from the standard calibration curve of Gallic acid with a coefficient of determination (R^2) of 0.9837.

Determination of antioxidant activity

The ABTS (2,20 azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt) radical scavenging method was used to determine the antioxidant activity of carrot powder and fondant candies samples (Gheonea et al., 2020).

Accordingly, 0.02 mL of extract and 1.98 mL of ABTS solution were prepared. The mixture was left at room temperature and not exposed to light for 2 hours. The Libra 22 UV/Visible spectrophotometer was used to quantify the reduction in absorbance of the mixture at a 734 nm excitation wavelength. The findings regarding inhibition percentage and µM Trolox Equivalent /g dw were reported. The percentage inhibition of antioxidant activity was determined using the provided formula (2):

$$\text{ABTS scavenging activity (\%)} = \frac{\text{Absorbance Control} - \text{Absorbance Sample}}{\text{Absorbance Control}} \text{ x } 100 \qquad (2)$$

Preparation of Supplemented fondant candy samples

The supplemented fondant candies contain the following ingredients, % (g/g): fondant (72.46%), walnut (24.15%), starch (0.97%), water (2.42%), and carrot pomace powder (F1 - 5% and F2 - 7%).

Fondant mass is obtained with 1000 g of sugar, 250 g of water, and 250 g of glucose syrup. Water and sugar were placed in a pot on a low flame, foamed, and wiped the edges of the pot permanently to stop the crystallization of the syrup, then boiled until the composition thickened. After the heat was turned off, 250 g of glucose syrup was added and refrigerated for 24 h. Then, with the help of a stainless-steel spatula, spread the composition on a stainless steel surface until it turns white, after which it was placed in a grinder and finished in a powder with a pleasant colour by keeping it in the refrigerator at 4ºC until it is used.

The technology for fondant samples consists of a combination of ingredients, with carrot powder being included as an ingredient and suitable proportioned to the quantity of fondant. For the processing of the fondant mass, the fondant mass was homogenized with walnut, starch, and carrot powder in different concentrations (5 and 7%), and the obtained composition was left to dry for 24 h.

To finish the fondant candy products, the remaining fondant mass is melted with a little water with the help of a utensil and each piece of fondant candies is glazed separately.

For ease of comparison, a control sample (C) was also prepared using the same processing, but without carrot powder.

Proximate and phytochemical composition

Analysis of moisture, crude protein, crude fibre, lipids, carbohydrates, and ash content in CP and fondant candies was conducted following the guidelines of AOAC (2005).

The aforementioned techniques were used to assess the overall carotenoid, phenolic, flavonoid, and antioxidant activities of the fondant candies enriched with CP powder.

Color evaluation of CPP-supplemented fondant candies

The color of the CP powder and fondant candies sample was assessed in terms of L*, a*, and b* values by using a Minolta Chroma meter CR 410 (Konica Minolta, Inc. Osaka, Japan).

The Chroma or color intensity, the hue angle, and the total color difference (ΔE) were determined with the following formula (Nistor et al., 2022).

The Chroma =$\sqrt{(a^*)^2 + (b^*)^2}$)

Hue angle = arctan(b*/a*) for quadrant I (+a*, +b*)

ΔE= ($\sqrt{(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2}$).

Sensory evaluation of CPP-supplemented fondant candies

A nine-point hedonic scale was used, running from 1 (dislike extremely) to 9 (like extremely). Water was supplied for mouth rinsing between the assessments.

A group of 15 members, including students and staff members from the Faculty of Food Science and Engineering ("Dunarea de Jos" University of Galati), evaluated the external appearance, sectional appearance, consistency, color, taste, odor, aroma, aftertaste, and overall acceptability of the products.

The panelists were given comprehensive information about the primary objective of the study, as well as the requisite protocols for managing personal data.

Statistical analysis of data. The data are expressed as mean values ± standard deviation.

Mean values, standard deviation, and analysis of variance (ANOVA) were calculated using a commercial statistical software tool (Minitab Software for Windows, Version 19.1). Means were analysed using Tukey's test at a 5% significance level ($p < 0.05$).

RESULTS AND DISCUSSIONS

CP powder characterization

The current work utilized an ultrasound-assisted technique to produce a bioactive-enriched CP extract with total carotenoids of 179.91 ±4.99 mg /100 g dw, total flavonoids of 61.69 ±0.63 mg CE/100 g dw, and a total polyphenolic content of 175.62 ±1.77 mg GAE/100 g dw (Table 1). The extract exhibited an ABTS radical scavenging capability of 1049.99±18.73 µM TE/g dw, with 70.98 ±1.22% inhibition of ABTS radical.

Table 1. Phytochemical and physico-chemical characteristics of CP extract

Parameters	CP powder
Total Carotenoids (mg/100 g dw)	179.91 ±4.99
β-caroten (mg/100 g dw)	149.51 ±2.14
Lycopen (mg/100 g dw)	29.77±0.56
Total flavonoids (mg CE/100 g dw)	61.69 ±0.63
Total polyphenols (mg GAE/100 g dw)	175.62 ±1.77
ABTS (μM TE/g dw)	1049.99±18.73
Inhibition (ABTS) %	70.98 ±1.22
Ash, %	9.87±0.03
Moisture, %	10.03±0.05
Crude protein, %	9.95±0.08
Crude Fat, %	0.25±0.03
Carbohydrates, %	26.30±0.41
Total dietary fiber, %	43.60±0.03
L*	71.06±0.55
a*	10.11±0.27
b*	30.22±0.17
Hue angle	1.25±0.03
Chroma	31.87±0.23

A research by Upadhyay et al. (2008) indicates that the β-carotene content in dry carrot pomace varies from 13.53 to 22.95 mg/100 g. Table 1 exhibits the chemical composition of CP powder. The dried CP powder has the following contents: 10.03, 9.87, 9.95, 0.25, 43.60, and 26.30% for moisture, ash, protein, fat, fiber, and carbohydrates, respectively.

The chemical composition analysis of CP revealed their importance as a source of fiber and carbs and contributions to protein consumption. Existing literature indicates that CP typically contains a protein content ranging from 4% to 5% and total dietary fiber ranging from 37% to 48%. These findings align with the results found in the current study.

The observed variances may be attributed to the phytochemical diversity of the source material and the specific solvent combination used during the extraction procedure.

Based on the color parameters, the estimated values for L*, a*, and b* were 71.06, 10.11, and 30.22, respectively. The b* parameter, which quantifies the intensity of the blue-to-yellow spectrum, suggests a tendency towards yellow hues in CP powder due to its high carotenoid concentration. By analyzing the color indices, it was concluded that the CP powder fell into quadrant I (+a*, +b*). The primary cause of the orange hue in CP is carotenes, which undergo partial conversion into vitamin A (Bao & Chang, 1994). The results shown here are in agreement with those of Alam et al. (2013) for untreated carrot pomace that was convectively dried: L*= 65.00, a*= 8.60, and b*= 20.60.

Characterization of phytochemicals of CPP-supplemented fondant candies

One of the byproducts of carrot juice extraction, CP, has the ability to provide bioactive compounds that might be used in the production of food additives, dietary supplements, and other uses (Ikram et al., 2024).

Table 2 indicates that the supplemented fondant candies variations including CP exhibited elevated levels of carotenoids, flavonoids, and polyphenols, which were further corroborated by the antioxidant activity values.

Table 2. Phytochemical characteristics of supplemented fondant candies (C - fondant candies without added CP powder, F1 and F2 - fondant candies with the addition of 5 and 7% (w/w) CP)

Parameters	Fondant candies samples		
	C	F1 (5%)	F2 (7%)
Total carotenoids (mg/100 g d.w.)	-	22.49±0.18^{b}	31.42±0.22^{a}
Total flavonoids (mg CE/100 g d.w.)	1.28±0.06^{c}	12.51±0.12^{b}	17.89±0.17^{a}
Total polyphenols (mg GAE/100 g d.w.)	3.56±0.10^{c}	25.60±0.19^{b}	36.21±0.27^{a}
Antioxidant activity % Inhibition ABTS	8.79±0.13^{c}	67.44±0.17^{b}	95.23±0.19^{a}

Variations in letters for the same parameter (per line) indicate statistically significant variations in means ($p < 0.05$).

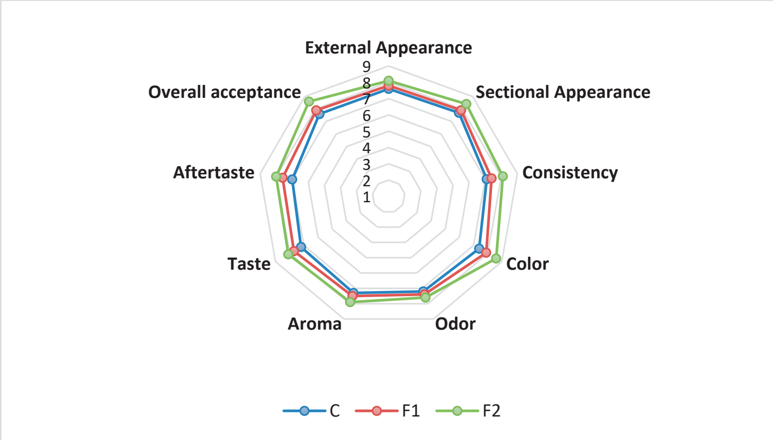

Figure 1. Comparative diagram of the sensory attributes specific to fondant candies: C - fondant candies without the addition of CP; F1 and F2 - fondant candies with 5 and 7% of CP

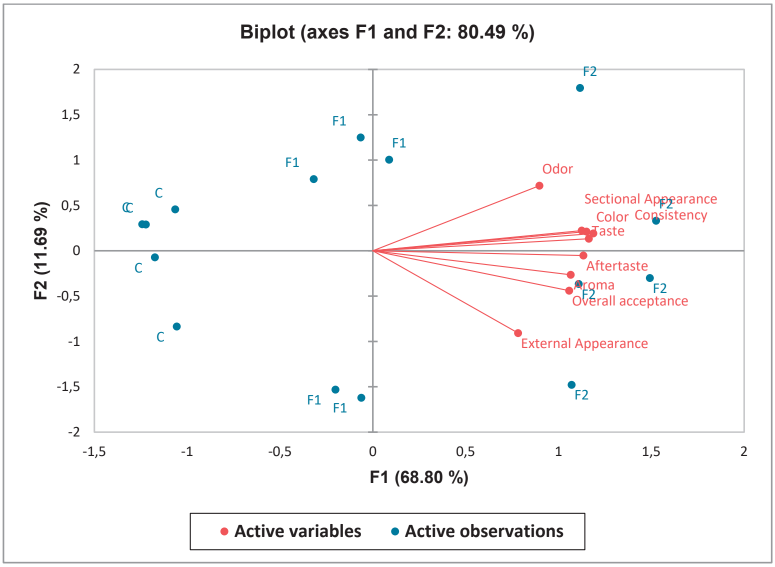

Figure 2. Depiction of correlations among sensory qualities utilising Principal Component Analysis (PCA)

Table 3. Physicochemical characteristics of supplemented fondant candies (C - fondant candies without added CP, F1 and F2 - fondant candies with the addition of 5 and 7% (w/w) CP)

Physical-Chemical Characteristics	Fondant candies samples		
	C	F1 (5%)	F2 (7%)
Protein, g/100 g	4.9±0.12[b]	5.4±0.17[a]	5.6±0.19[a]
Lipids, g/100 g	5.5±0.13[b]	5.6±0.18[a]	5.7±0.20[a]
Carbohydrates, g/100 g	77.4±0.28[b]	77.5±0.29[b]	77.8±0.30[a]
Insoluble fibers, g/100 g	-	2.1±0.13[b]	3.0±0.15[a]
Humidity, g/100 g	10.1±0.21[a]	8.9±0.16[b]	8.1±0.14[c]
Ash, g/100 g	2.1±0.18[c]	2.6±0.20[b]	2.8±0.22[a]
Energetic value, % Kcal/100 g kJ/100 g	 378.7±0.21[c] 1582.97±0.21[c]	 386.20±0.23[b] 1614.32±0.23[b]	 390.9±0.28[a] 1633.96±0.28[a]

Means with the same letter in each row are not significantly different ($p > 0.05$).

Table 4. Colorimetric parameters of the supplemented fondant candies: C- fondant candies without the addition of CP, F1 and F2 - fondant candies with the addition of 5 and 7% (w/w) CP

Parameters	Fondant candies samples		
	C	F1 (5%)	F2 (7%)
L*	91.11±0.28[a]	77.08±0.23[b]	60.39±0.21[c]
a*	1.02±0.11[c]	4.68±0.14[b]	8.36±0.16[a]
b*	10.53±0.15[c]	20.47±0.17[b]	32.14±0.19[a]
Chroma	10.58±0.14[c]	20.99±0.18[b]	33.21±0.20[a]
Hue angle	1.47±0.07[a]	1.35±0.06[b]	1.32±0.05[b]
ΔE	-	17.58±0.19[b]	38.27±0.22[a]

Different letters on the column for the same analyzed parameter show significant differences between means ($p < 0.05$).

The experimental candies had carotenoids contents ranging from 22.49±0.18 to 31.42±0.22 mg/100 g d.w. As anticipated, there is a notable rise in the concentration of carotenoids and antioxidant activity as the quantity of additional CP powder rises ($p < 0.05$).

A study conducted by Kamiloglu et al. (2017) demonstrated that carrot pomace enhanced the nutritional profile of cake by increasing polyphenolic levels, and antioxidant activity. In a study by Nagarajaiah & Prakash (2015) carrot pomace was incorporated cookies at levels of 4%, 8%, and 12%. In cookies containing 4% carrot, the initial β-carotene level was 126 μg/100 g; for 8%, it was 215 μg/100 g; and for 12%, it was 333 μg/100 g.

The incorporation of carrot powder occurs in proportions ranging from 0% to 30% in the creation of fiber-rich sponge cake. The cake with 30% carrot powder displays increased concentrations of β-carotene, ash, complex carbohydrates, and moisture (Salehi et al., 2016). Table 2 demonstrates the enhanced value of fondant candies with carrot powder, as evidenced by the increased levels of total carotenoids and antioxidant activity.

The results presented in Table 2 provide evidence for the improved nutritional quality of fondant candies, including pumpkin pomace powder.

Physicochemical characterization of CP powder-supplemented fondant candies

The supplemented fondant candies were analysed from a physicochemical point of view; the results being presented in Table 3. The proximate composition of the fondant candies with CP demonstrated a significant variation ($p < 0.05$) among the samples.

The humidity content of the control sample was 10.1 g/100 g, and with the greater integration of pomace, the moisture content reduced; specifically, at F2, the fondant candies exhibited 8.1±0.14 g/100 g. The lipid content increases with the increase in CP powder content, thus F1 having 5.7±0.20 g/100 g.

A minor increase in protein content is noted with the addition of carrot powder. The concentration of insoluble fibers rose with the increasing proportion of CP, reaching 3.0± 0.15 g/100 g in the product containing 7% CP. Moreover, carrot powder enhanced the fiber content and water absorption of the candies.

Regarding the carbohydrate content, the highest content was observed for sample F2 with 7% CP powder (77.8±0.30 g/100 g).

The control sample exhibited the lowest ash amount at 2.1 g/100 g, whereas the greatest ash content was recorded for F2 at 1.45 g/100 g.

The enhancement of the nutritious attributes of cookies with the addition of carrot pomace was noted in the research conducted by Nagarajaiah & Prakash (2015). Notably, the insoluble fiber content was 5.64% for the product with 12% CP powder.

Color evaluation of CP powder - supplemented fondant candies

The results of the colour attributes (L*, a*, b*, Chroma, Hue angle, ΔE) after obtaining of the value-added fondant candies samples are revealed in Table 4. The brightness of candy containing carrot pomace significantly diminished compared to the control, whereas a* and b* values concurrently increased, indicating a more pronounced browning effect in the CP-containing candies. This may result not only from the incorporation of a substance with a colour distinct from that of conventional fondant but also from the presence of glucose and fructose, which serve as reactants in the Maillard process.

A cake with 10% carrot powder exhibited a deeper, reddish, and more yellowish crumb colour, rendering it one of the preferred options. The pigments and compounds, such as carotenoids, in carrots, account for the variation in crumb colour, like the orange hue in the sample with 10% carrot powder. The addition of carrot powder to baked products can impart a red and yellow tint to the crumb, attributed to carotenoids (Salehi et al., 2016; Jafari et al., 2017).

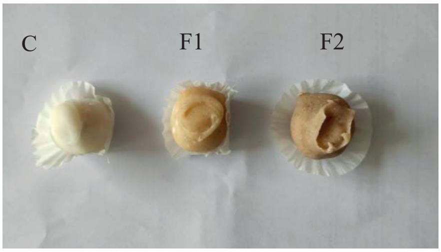

Figure 3. Images of the fondant candies without CP control (C); fondant candies with 5% CP (F1); fondant candies with 20% CP (F2)

The hue angle value was the highest in the control sample and the lowest in the sample with 7% CP addition (1.47±0.07). ΔE is the feature of total colour change ranging from 17.58 to 38.27 for the supplemented samples. The Chroma indicating the intensity and saturation of colour was highest in the F1 sample (33.21±0.20) and lowest in the control sample (10.58±0.14).

The results for the values of a* and b* indicated that all data were situated in the first quadrant (+a*, +b*), implying a propensity towards reddish and yellowish hues, indicative of carotenoids.

Sensory evaluation of CP powder - supplemented fondant candies

Figure 1 provides the sensory analysis of the control and CP-incorporated candies. Higher sensory scores for colour were associated with the concentration of CP powder in the candies.

Commercial viability for producing high-quality fondant candies with carrot powder is indicated by the mean overall acceptance scores above 7.5 for fondant candies samples containing up to 7% CP powder. The results of the taste sensory evaluation suggested that the enhanced candy had a significantly better flavor than the control sample. The use of CP at a concentration of 7% had a notable impact on the flavor qualities of the candies. Furthermore, there was a noticeable disparity in the ratings of the odor and flavor characteristics among the various types of candies.

The highest colour score was obtained for the colour of fondant candies samples with the addition of 7% powder (F2), highlighting its more intense and attractive dark yellow colour (Figure 3).

The overall result reveals that the flavor of fondant candies was acceptable when the level of incorporation of CP was increased up to 5%.

The quality of fondant candies candy was meticulously assessed through several fundamental indices that ensure a superior confectionery experience. Externally. fondant candies pieces was presented as whole, unmarred, and uniformly sized, reflecting a high level of production precision. The surface should remain dry, smooth, and glossy, absent of any cracks, visible spots, or asperities, which could indicate improper storage or handling. The sugar crystals coating must be uniformly thin, signaling expert craftsmanship and adequate cooling processes. Internally, the fondant candies revealed a homogeneous mass, indicating consistent ingredient integration and proper kneading. The color of the fondant candies was expected to be uniform and reflective of the flavors used (CP), indicating both quality ingredients and careful mixing. Taste and aroma are pivotal; they were pleasant and delicate, aligning with the product’s intended appearance and flavor profile, thus enhancing the consumer's sensory satisfaction. Finally, consistency is critical; fondant candies was soft yet slightly crumbly, maintaining a non-sticky texture that highlights its freshness and adherence to traditional preparation methods. These characteristics collectively create a fondant candies candy that was as pleasing in presentation as it is in flavor and mouthfeel.

In the study of Nagarajaiah & Prakash (2015), the overall acceptability demonstrated that panel members preferred the cookies with up to 8% additional carrot pomace in comparison to the control.

The biplot from the Principal Component Analysis (PCA) (Figure 2) offers a clear visualisation of the variances and relationships among the evaluated sensory qualities and the fondant candy samples. The attributes situated in the upper-right quadrant, namely colour, odor, sectional appearance, and consistency, were positively positioned within the same quadrant on the first axis (F1), signifying a positive connection. Additionally, external appearance, aftertaste, aroma, and overall acceptance positively influence axis F1. The placement of these sensory attributes suggests that F2 sample, located nearest to these characteristics and on the positive side of the Biplot, is favourably regarded by consumers regarding taste and overall evaluation. The two axes accounted for 80.49% of the total variation. The C was neutral as all sensory qualities were solely connected to the same axis (F1). An analysis of the PCA findings reveals that F2 has emerged as the leader in customer preferences.

CONCLUSIONS

The experiments revealed that carrot pomace is a highly abundant reservoir of fibers, carbs, and carotenoids, thereby indicating its potential to enhance the nutritional composition of food items in which it can be integrated. Supplementation of fondant candies with CP powders increased the dietary fiber and carotenoid content in fondant candies and improved the product colour. Analysis of the sensory perception indicated that the panelists valued the enhanced hue of the fondant candies. Overall, there was a notable appreciation for the value-added fondant candies. Upon examination, it was determined that the fondant candy sample (F2) containing 7% CP powder had the most optimal composition. Consequently, the potential of by-products derived from the industrial processing of carrots as a reservoir of antioxidants and an alternative for synthetic pigments can be explored.

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