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Efficacy of freeze-dried carrot pomace powder in improving the quality of wheat bread

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Abstract

The application of carrot pomace powder (CPP) in various foods can ensure the utilization of by-products produced from carrot processing industries as well as improve the nutritional quality of the formulated product. The quality of several composite pieces of bread was assessed using physical, chemical, microbiological, and sensory methods. The crude fibre content (13.09%), ash content (6.71%), water holding capacity (5.93 g/g), water retention capacity (4.67 g/g) and swelling capacity (11.50 mL/g) of CPP were significantly higher (p<0.05) than wheat flour whereas, oil absorption capacity (2.03 mL/g) and bulk density (0.23 g/mL) of CPP stayed lower than wheat flour. Besides, antioxidant (52.23%), β-carotene (1.17 mg/100 g) and phenolic content (0.48 mg GAE/g) were found more in bread incorporated with 10% CPP than in other formulated breads (5%, 15% and 20%) and control sample (0%). The addition of carrot pomace powder with wheat flour in composite bread enhances better nutritional value and look of the bread by giving it a more appealing hue as well as a better taste and flavor but reduces the specific volume and springiness. The bread containing 10% CPP had a higher overall acceptance, good physical properties with better nutritional quality compared to other formulations and was equivalent to the control sample. These findings support the use of low-cost by-products like CPP as a useful functional additive for enhancing the nutritional value of composite bread and it can be commercially exploited.

1. Introduction

The Umbelliferae family includes the carrot (*Daucus carota* L.), a popular vegetable among humans and animals which may be planted all over the world for its consumable roots (Ahmad *et al.,* 2019). It is viewed as one of the ten utmost valued crops in terms of commercial worth, and it is an extensively consumed item (Ergun and Susluoglu, 2018). It was also graded 6 out of 22 widespread vegetables in relation of per-person ingesting (Zhang and Hamauzu, 2004). Carrot pomace is a by-product generated during the manufacture of carrot juice. It is utilized as a possible animal feed (Balat, 2011; Yu *et al.,* 2013). The pomace is perishable and in turn affects the environment (Hernandez-Ortega *et al.,* 2013). Drying or dehydrating perishable foods extends their shelf life and allows them to be used again (Alam *et al.,* 2013). Dried carrot pomace, on the other hand, also contains carotene and ascorbic acid (Goyal, 2004). Dehydrated carrot pomace extract is high in antioxidants and a usual source of α and β carotene, all of which have powerful well-being benefits (Kumar *et al.,* 2010). Carrot pomace extracts also contain pectin, hemicellulose, cellulose, and lignin (Nawirska and Kwasniewska, 2005). This fibre-rich substance plays a significant role as a non-caloric bulking agent and a cost-effective substitute for flour, fat, and sugar (Elleuch *et al.,* 2011). They have the ability to improve emulsion or oxidative stability by increasing water and oil retention (Elleuch *et al.,* 2011). Because of its capacity to retain water, dietary fibre additives in bakery goods, such as bread, have been demonstrated to be helpful. A rich fibre content and a drop in calorific value are one of the primary factors that prolong freshness (Elleuch *et al.,* 2011; Kohajdová *et al.,* 2011). Dietary fibre serves a variety of purposes in the human body. It binds water and bile acid, absorbs metals, slows the passage of chyme through the intestines, decreases blood glucose and cholesterol levels, and enhances face bulk (Gorecka *et al.,* 2002; Kahlon and Woodruff, 2003). As fibre-rich pomace is readily available during juice production, the

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carrot insoluble fibre-rich fractions might be used as a prospective hypocholesterolemia component to meet the growing need for functional ingredients in the development of fibre-rich food items. The cellulose and insoluble fibre-rich fractions in a fibre-free diet lowered blood total fat level by 17.3% and 33.5%, respectively (Hsu *et al.,* 2006). The by-product of carrot juice extraction provides a viable source of bioactive chemicals that might be investigated for use in the production of food components and nutritional supplements (Moure *et al.,* 2001; Schieber *et al.,* 2001). A large number of people in Bangladesh now work in production-related and income-generating jobs. People are busy and unable to prepare their own meals and they turn to eating fast food. Furthermore, people's eating habits have changed, and they increasingly seek good, nutritious meals that not only provide a balanced nutritional intake but also provide additional health benefits, i.e., functional benefits (Bech-Larsen and Scholderer, 2007). Typically, wheat flour is used as the raw material for producing bread, but carrot pomace powder can considerably improve the texture, quantity of biologically active compounds, and functional properties of bread. As a result, it is critical to consider carrot pomace powder's suitability as a bread-making ingredient. This study aimed to investigate the efficacy of freeze-dried carrot pomace powder in improving the quality of wheat bread.

2. Materials and methods

2.1 Collection of samples

Carrot (seasonal local variety), wheat flour, milk powder, sugar, butter, salt and yeast were obtained from the local market of Tangail, Bangladesh. All the analytical chemicals were procured from Merck (Merck KGaA, Darmstadt, Germany) and Sigma-Aldrich (Sigma -Aldrich Tokyo, Japan).

2.2 Sample preparation

The fresh carrot was washed thoroughly with plenty of water to remove all the adhering dust and dirt particles. Excess water was drained out and the carrot was cut and sliced into tiny pieces. Carrot juice was extracted using a blender and carrot pomace was collected after complete juice extraction. Then carrot pomace was overnight freeze-dried (vacuum) and pulverized to powder using a crusher. Carrot pomace powder was sieved by 42 mash screens to obtain uniform particle size. Then powder was stored in a Ziploc bag for future use.

2.3 Biochemical determination of raw ingredients and end products

The moisture, ash, fat, protein, and crude fibre content of freeze-dried carrot pomace powder, wheat flour, and produced bread samples and the total carbohydrate content of the samples was measured using analytical methodologies established by the Association of Official Analytical Chemists (AOAC) method (AOAC, 2010).

2.4 Percentage of wet gluten and dry gluten determination

With minor modifications, the amount of wet and dry gluten in carrot pomace powder and wheat flour was determined by means of the technique defined by Kaushik *et al.* (2015). In the case of wet gluten, about 25 g wheat flour was combined with 15 mL tap water and permitted to rest at room temperature for 20 mins. The dough was hand-washed with tap water until all of the starch was removed (iodine test). To eliminate extra water, gluten was centrifuged at 6000 rpm for 60 s. The difference in 5 g wet gluten weight before and after 60 min of incubation at 30°C and 85% relative humidity was used to quantify gluten amount (RH).

$$\%\ \text{of gluten (wet weight basis)} = \frac{\text{Weight of the wet gluten residue}}{\text{Weight of the sample}} \times 100$$

Wet gluten was dried in a freeze dryer for 24 hrs to determine the dry gluten content of carrot pomace powder and wheat flour.

$$\%\ \text{of gluten (dry weight basis)} = \frac{100 \times \text{Weight of dry gluten}}{\text{Weight of sample}}$$

2.5 Particle size distribution

About 25 g of sample (pomace powder and wheat flour) were placed into a laboratory electric sieve shaker containing varied sieve diameters and shaken for 30 mins to determine the particle size distribution. The mass of the sample retained by each filter was weighed using an electronic weighing scale (Sahni and Sher, 2017).

2.6 Determination of antioxidant activity

About 1 mL of methanol bread extracts were added to 3 mL of DPPH methanol solution. A UV/Vis spectrophotometer (Jenway 6405, Cole-Parmer, Stone, United Kingdom) was used to determine the absorbance of the reaction mixture at 515 nm. The out-of-a-hundred inhibition of the sample was calculated using the equation below (Miliauskas *et al.,* 2004).

$$\text{DPPH Scavenged (\%)} = \frac{\text{Absorbance of DPPH solution} - \text{Absorbance in the presence of sample extract}}{\text{Absorbance of DPPH solution}} \times 100$$

2.7 Determination of phenolic compounds

The total phenolic content was analyzed by means of

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the Folin-Ciocalteu reagent. In this scenario, about 0.5 mL bread extract was shared with 5 mL Folin-Ciocalteo substance and neutralized with 4 mL-soaked sodium carbonates (75 g/L). The absorbance at 765 nm was measured using a Jenway 6405 UV/V spectrophotometer after 120 mins in the dark. Gallic acid equivalents were used to calculate the total phenolic content (mg GAE/g dry weight) (Miliauskas *et al.,* 2004).

2.8 Determination of vitamin C content

The AOAC (2005) technique was used to assess vitamin C content. About 5 g sample was homogenized and filtered with 3% metaphosphoric acids. After centrifuging the filtered solution, the supernatant was titrated with a 2,6 dichlorophenol indo phenol solution. The amount of vitamin C present in the extract was evaluated by comparing the titration result of a standard vitamin C solution with the amount of vitamin C contained in the extract.

2.9 Determination of beta carotene content

The AOAC technique was used to determine the beta carotene content (AOAC, 1980). A representative piece of this sample (5 g) was carefully weighed in a glass test tube before extraction. The extracting solvent n-hexane was then added to the tube, which was kept for 15 mins with periodic shaking and vortexed for 10 mins at high speed. The mixture was then allowed to stand before the supernatant was separated into a 25 mL volumetric flask and the bottom layer was transferred to a test tube for n-hexane re-extraction. Both supernatants were combined and filtered using a Jenway 6405 UV/V spectrophotometer at a wavelength of 480 nm. The Lambert-Bear rule, which stipulates that the absorbance (A) is proportionate to the pigment concentration (C), was used to compute the concentration of beta-carotene. For beta carotene measurement, a 2592 absorptivity coefficient was used (Rodriguez-Amaya, 1989).

$$\text{Concentration of the pigment} = \frac{\text{Absorbance}}{2592 \times \text{Thickness of cuvette}}$$

2.10 Determination of water holding capacity

A weight of 1 g of sample and 30 mL of water was graduated into a test tube. After that, it was hydrated for 18 hrs. The supernatant was removed by passing it through a sintered glass crucible a under vacuum. The weight of the hydrated trash was recorded, and the residual dry weight was acquired by drying it for 2 hrs at 105°C (Raghavendra *et al.,* 2004).

$$\text{Water holding capacity}(\text{g/g}) = \frac{\text{Residue hydrated weigh} - \text{Residue dry weight}}{\text{Residue dry weight}}$$

2.11 Determination of water retention capacity

About 1 g sample was taken in a graduated test tube and 30 mL of water was added. Then it was hydrated for 18 hrs. After hydration, it was centrifuged at 3000 rpm for 20 mins. Then supernatant solution was removed by passing it through a sintered glass crucible under an applied vacuum. The hydrated residue weight was recorded and then sample was dried at 105°C for 2 hrs to obtain its dry weight (Raghavendra *et al.,* 2004).

$$\text{Water retention capacity (g/g)} = \frac{\text{Residue hydrated weight after centrifugation} - \text{Residue dry weight}}{\text{Residue dry weight}}$$

2.12 Determination of oil absorption capacity

About 1 g sample was combined with 10 mL refined soybean oil, left at room temperature for 30 mins, and then centrifuged at 2000 rpm for 10 mins. After centrifugation, the supernatant was separated and measured. The percentage of oil bound per gram of sample was used to calculate the oil absorption capacity (Sosulski *et al.,* 1976).

$$\text{Oil absorption capacity (mL/g)} = \frac{\text{mL of oil added to the sample} - \text{mL of supernatant oil}}{\text{Weight of sample}}$$

2.13 Determination of swelling capacity

In a graduated test tube, about 0.2 g of sample was inserted, and 10 mL of water was added. It was then hydrated for 18 hrs. The fibre ultimate volume was measured after 18 hrs (Raghavendra *et al.,* 2004).

$$\text{Swelling capacity (mL/g)} = \frac{\text{Volume occupied by sample}}{\text{Original sample weight}}$$

2.14 Determination of bulk density

About 50 g sample was placed in a 100 mL graduated cylinder and tapped 20-30 times. After that, the sample volume was calculated. The bulk density of each sample was calculated as weight per unit volume (Okaka and Potter, 1979).

$$\text{Bulk density (g/mL)} = \frac{\text{Weight of the sample}}{\text{Volume occupied by the sample}}$$

2.15 Preparation of carrot pomace incorporated breads

Carrot pomace was used to replace 5, 10, 15, and 20% of wheat flour in the creation of composite flour loaves. As a control, a sample of 100% wheat flour was made. Carrot pomace, wheat flour, and the other bread-making components (sugar, butter, salt, and yeast) were all weighed separately and then manually combined together. To avoid moisture loss, the dough was rounded and left to rest at 40°C for 90 mins before being wrapped with wet muslin cloth. The dough was then split into dough-size parts and proofed on a baking pan at roughly 40°C for 30 mins. The leavened dough was then baked for 25-35 mins at 230°C in a preheated oven. After baking breads were reserved for further investigation.

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2.16 Dough expansion analysis

All of the ingredients were combined and carrot pomace was added in various proportions (5, 10, 15, and 20%). After that, all of the dough samples were precisely measured to ensure that they were all the same weight. The dough was then transferred to a 250 mL measuring cylinder at 37°C and the expansion of the dough was watched over time (Begum *et al.,* 2011).

2.17 Physical analysis of breads

Mass, volume, specific volume, and density measurements of five samples of the composite bread were analyzed using the method described by Begum *et al.* (2019) where specific volume was measured as the volume/mass ratio (Begum *et al.,* 2019).

2.18 Sensory analysis

The sensory evaluation included ten students, staff, and faculty members from the Department of FTNS, MBSTU, Santosh, Tangail, Bangladesh. Each evaluator was given five randomly numbered bread samples and asked to rate them on a nine-point hedonic scale, 9=like extremely, 8=like very much, 7=like moderately, 6=like slightly, 5=neither like nor dislike, 4=dislike slightly, 3=dislike moderately, 2=dislike very much, 1=dislike extremely. Panelists evaluated the samples in a sensory testing room, and they were instructed to rinse their mouths with water during the process to eliminate cross-residual effects (Lim *et al.,* 2011).

2.19 Texture profile analysis

FRTS Food Texture Analyzer (Imada, Japan) was used for instrumental texture profile analysis on the basis of hardness, springiness, chewiness, and gumminess of bread crumb according to the standard method (Ziobro *et al.,* 2016). The loaves were kept in Ziploc bags at a temperature of 22±2°C and a humidity of 64% for the following days' analysis. Bread slices from each sample were compressed to 50% of their original height at the rate of 5 mm. S-1 by a P/2 cylindrical probe (2 cm diameter). The sample was compressed twice with a 5 s delay time.

2.20 Free fatty acids and acid value

In a flask, around 10 g of pulverized sample was inserted. After that, 50 mL of benzene was added, and free fatty acids were removed from the solution using filter paper after 30 mins. A flask containing about 5 mL extract, 5 mL benzene, 10 mL alcohol, and 2 mL phenolphthalein as an indicator was used and titrated against 0.02N KOH considering 30 s persistence of pink color as endpoint. Using the following equation, the percentages of free fatty acids in most samples were determined as oleic acid. To convert the percentage of free fatty acids (as oleic) to acid value, multiply the percentage of free fatty acids by 1.99 (AOAC, 2001).

$$\text{Free fatty acid as oleic acid \%} = \frac{(\text{Titrant volume} - \text{blank volume}) \times \text{normality of alkali} \times 28.2}{\text{Sample weight}}$$

2.21 Microbiological analysis

Harringan and McCance's (1976) approach was used to calculate total viable bacterial count and total fungal count. About 1 g of bread sample was diluted with 9 mL distilled water and whirled on a horizontal shaker for 30 mins to achieve a tenfold dilution. About 0.1 mL of the solution was injected on the surface of nutrient agar plates to identify bacteria, and potato dextrose agar to determine microscopic fungus. For bacteria, plates were incubated at 37°C for 24 hrs, while for microscopic fungi, plates were incubated at 28°C for 24 hrs.

Dividing the number of colonies by the amount of specimen provided to liquid agar and multiplied by the dilution factor the number of bacteria or fungus per mL or g of sample was calculated.

$$\text{Number of bacteria or fungi (CFU/g)} = \frac{\text{Number of colonies} \times \text{Dillution factor}}{\text{Amount of sample plated}}$$

2.22 Statistical analysis

All measurements were made in triplicate and evaluated using the Statistical Package for Social Science (SPSS). One-way analysis of variance (ANOVA) was used to determine the variation among the sample at a significance level of $P<0.05$.

3. Results and discussion

3.1 Physicochemical properties

The proximate analysis, gluten, and bioactive characteristics of wheat flour and carrot pomace powder are shown in Table 1. As presented in Table 1, carrot pomace powder is an excellent source of crude fibre (13.09%) and ash (6.71%). The higher ash content in carrot pomace powder contributed to its high mineral content and higher crude fibre content justifying its suitability to be used as a functional ingredient. Moreover, among these important nutritive compounds, carrot pomace powder contains higher amounts of β-carotene (11.83 mg/100 g) and vitamin C (1.53 mg/100 g). The current findings on proximate analysis, gluten, and bioactive characteristics of wheat flour and carrot pomace powder were quite similar to those reported previously by other researchers (Kohajdová *et al.,* 2012; Gull *et al.,* 2015). Data on β-carotene and vitamin C content are in agreement with the values found by other research findings (Upadhyay *et al.,* 2008; Adeleye *et al.,* 2016). Regarding gluten content, carrot pomace powder did not have the structural gluten-forming protein but

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Table 1. Physicochemical properties of wheat flour and carrot pomace powder.

Parameters	Wheat flour (%)	Carrot pomace powder (%)
Proximate composition		
Moisture	11.91±0.06[a]	9.06±0.00[b]
Ash	1.14±0.25[b]	6.71±0.03[a]
Crude Fat	1.25±0.05[a]	1.19±0.15[a]
Crude Fibre	3.28±0.03[b]	13.09±0.09[a]
Crude Carbohydrates	65.30±0.16[a]	63.50±0.29[b]
Crude Protein	17.12±0.45[a]	6.46±0.56[b]
Gluten content		
Wet basis	35.77±0.17	0.00±0.00
Dry Basis	13.09±0.28	0.00±0.00
Bioactive properties		
Beta Carotene (mg/100 g)	0.26±0.07[b]	11.83±0.11[a]
Vitamin C (mg/100 g)	0.00±0.00	1.53±0.08

Values are presented as mean±SD of three replicates. Values with different superscripts within the same row are statistically significantly differences at $P<0.05$.

was found in wheat flour.

3.2 Functional properties of raw materials

Carrot pomace powder showed significantly higher water holding capacity (WHC), water retention capacity (WRC) and swelling capacity compared to wheat flour because of its high fibre content and large particle size (Sahni and Sher, 2017) but carrot pomace powder showed lower oil absorption capacity in relation to wheat flour and the difference between them is not statistically significant (Table 2). This can be justified on the basis of particle size as oil absorption capacity increases with a decrease in particle size (Raghavendra *et al.,* 2006). It was also revealed that wheat flour had a higher bulk density compared to carrot pomace due to the presence of smaller particles (Sahni and Sher, 2017). In this study, the high WHC, WRC and low oil absorption capacity of carrot pomace powder indicated its potential application in food manufacturing as a functional ingredient (Table 2).

3.3 Rheological property of dough

Figure 1 shows that wheat flour dough grew far more quickly than any other combination. As the gluten content of the dough is reduced when carrot pomace powder is added, the rate of expansion of the dough is reduced. As a consequence, composite bread retains less gas than control bread (Begum *et al.,* 2013). Carrot pomace powder was a rich source of fibre which promoted a physical disruption of gluten protein matrix

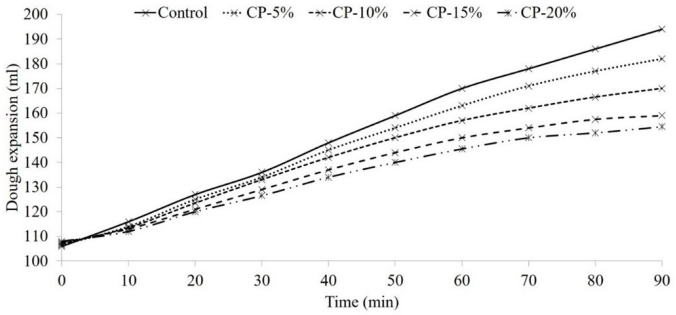

Figure 1. Expansion of dough containing various levels of carrot pomace (CP) powder.

Table 2. Functional properties of wheat flour and carrot pomace powder.

Parameter	Wheat flour	Carrot pomace powder
Water holding capacity (g/g)	2.86±0.05[b]	5.93±0.07[a]
Water retention capacity (g/g)	2.43±0.08[b]	4.67±0.10[a]
Oil absorption capacity (mL/g)	2.17±0.25[a]	2.03±0.23[a]
Swelling capacity (mL/g)	4.33±0.29[b]	11.50±0.05[a]
Bulk density (g/mL)	0.64±0.01[a]	0.23±0.005[b]
Particle size distribution (%)		
180 µm	3.17	14.97
150 µm	26.62	32.86
<150 µm	70.21	52.17

Values are presented as mean±SD of three replicates. Values with different superscripts within the same row are statistically significantly differences at $P<0.05$.

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to dough another reason of less expansion rate of carrot pomace powder incorporated dough (Gan *et al.,* 1989).

3.4 Physical analysis of breads

Figure 2 shows the physical characteristics of carrot pomace and wheat flour breads. Control bread had the lowest density compared to the other bread samples (highest volume). The inclusion of carrot pomace powder considerably enhanced the density of the bread compared to the control bread due to fibre weaning or crippling dough structure and reduced CO_2 gas retention (Hussein *et al.,* 2013). Furthermore, significant amounts of water may have bonded to the additional fibre during the baking process, leaving less water available for the creation of the starch-gluten network, resulting in an underdeveloped gluten network and lower loaf volume (Hryshchenko *et al.,* 2019). Specific volumes of the bread with carrot pomace powder were found less compared to the control sample (Hryshchenko *et al.,* 2019). Figure 2 also revealed that the density of bread samples gradually increased whereas the specific volume gradually decreased with storage time due to the reduction of the gluten framework ability to retain gas.

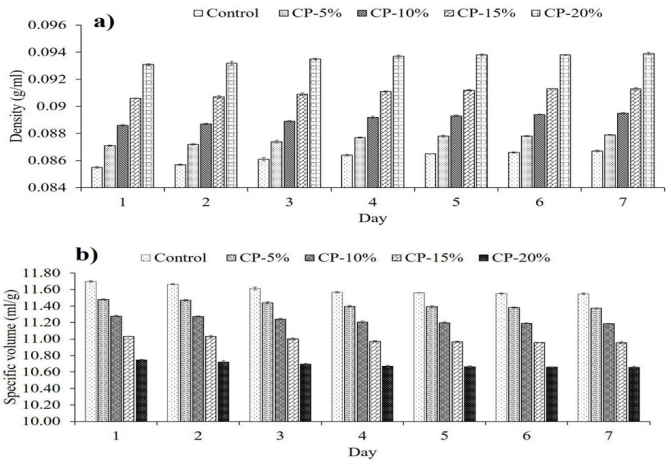

Figure 2. (a) Density and (b) specific volume of control and carrot pomace (CP) powder incorporated breads.

3.5 Sensory evaluation

The effects of carrot pomace powder inclusion on the sensory features of wheat bread are shown in Table 3. Except for the integration of carrot pomace powder up to 10%, sensory ratings for appearance, fragrance, crust and crumb color, taste, texture, and overall acceptability of bread fell as the proportion of carrot pomace powder in the formulation increased. In terms of appearance, color, flavor, texture, and general acceptability, the loaves made by substituting refined wheat flour with up to 10% carrot pomace powder were more or less comparable to the control bread. Increased amounts of carrot pomace powder integration of 15% or more resulted in a worse grade for sensory quality parameters. Thus, substituting up to 10% carrot pomace powder for refined wheat flour resulted in healthy fibre-rich loaves with acceptable overall acceptability.

3.6 Texture profile analysis of breads during storage

The result of the texture profile analysis of bread revealed that the assimilation of carrot pomace powder significantly *(P*<0.05) increases the hardness of bread. The harder texture might be attributed to the dilution of gluten upon the addition of carrot pomace powder (Mildner-Szkudlarz *et al.,* 2016). From Figure 3(b) it was discovered that the springiness of the bread samples was significantly *(P*<0.05) reduced by the addition of carrot pomace powder in their formulation.

Chewiness is the amount of energy and time needed to masticate a food for swallowing. From Figure 3(c) it was observed that control bread had the lowest chewiness, while carrot pomace powder-enriched bread had significantly (*P*<0.05) higher values for chewiness. The increase in chewiness may be a result of an increase in fibrous material upon the incorporation of carrot pomace powder (Tiwari *et al.,* 2013). Gumminess is the energy requirement to disintegrate the bread for easy swallowing. From Figure 3(d), it was observed that the gumminess of the bread samples was significantly (*P*<0.05) increased by the addition of carrot pomace powder in their formulation. Higher gumminess can be attributed to the gluten-weakening effect of carrot pomace powder components which leads to a more compact dough network (Wronkowska *et al.,* 2015). Figure 3 also revealed that the hardness, chewiness and gumminess of all types of bread gradually increased while the springiness of all types of bread gradually decreased as a function of storage time due to the reduction of the specific volume of all types of bread with time (Sammalisto *et al.,* 2021).

Table 3. Sensory evaluation score.

Bread Sample	Appearance	Aroma	Crust color	Crumb color	Taste	Texture	Overall acceptability
Control	7.2±0.63	7.1±0.32	7.3±0.48	7.1±0.32	6.6±0.51	7.1±0.31	7.4±0.52
CP-5%	6.3±0.67	6.4±0.52	6.3±0.67	6.2±0.42	6.3±0.48	6.2±0.42	7.1±0.31
CP-10%	6.8±0.42	6.6±0.70	6.7±0.52	6.3±0.48	6.8±0.42	6.5±0.52	7.3±0.48
CP-15%	5.9±0.31	6.8±0.42	6.1±0.56	5.8±0.42	5.9±0.31	5.9±0.74	6.7±0.67
CP-20%	4.8±1.13	5.1±1.28	4.9±1.20	4.5±0.85	5.1±0.73	4.7±1.05	5.8±0.79

Values are presented as mean±SD.

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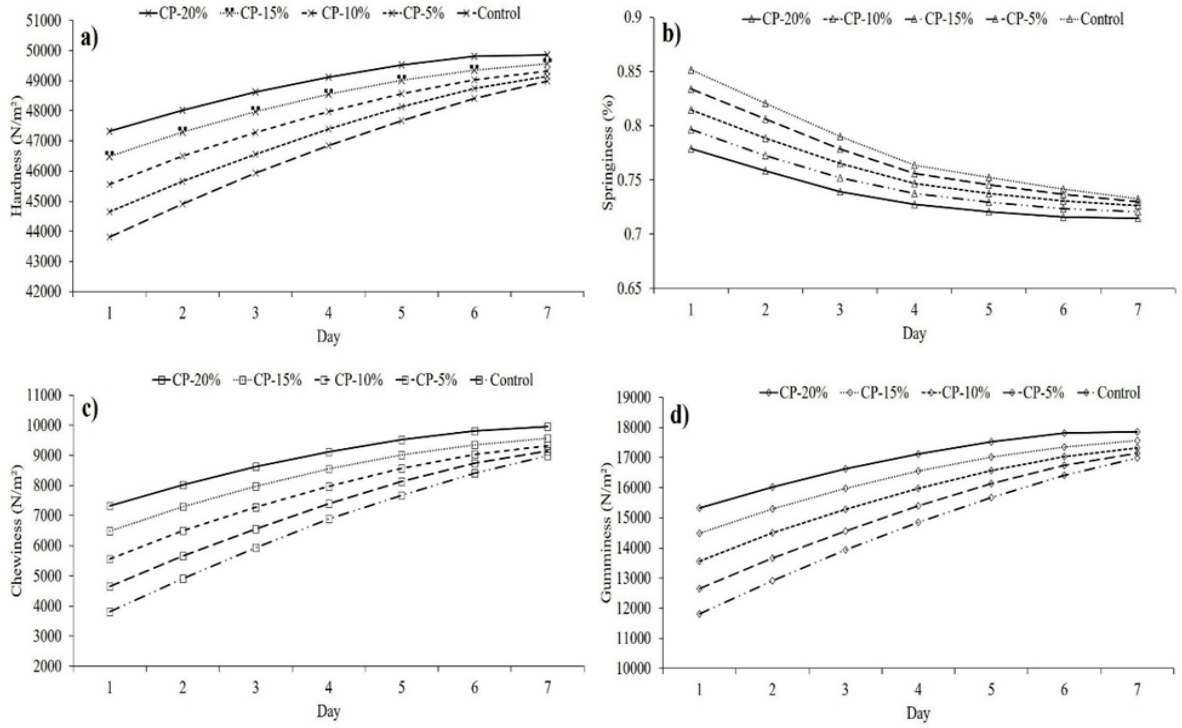

Figure 3. Evolution of hardness (a), springiness (b), chewiness (c) and gumminess (d) of control and carrot pomace (CP) powder incorporated breads during storage.

3.7 Acid value and free fatty acid analysis of breads

The acid value is a measure of the amount of free fatty acids, which were produced by the oxidation of double bonds of unsaturated fatty acid esters due to the action of oxidative enzymes, and by hydrolysis from triacylglycerols due to the action of lipolytic enzymes. The acid value of bread decreased progressively upon the additional increase of carrot pomace powder in the bread formulation (Figure 4a). A decrease in acid value may be as a result of an increase in antioxidant activity upon the incorporation of carrot pomace powder (He and Lu, 2015). Figure 4(a) also revealed that the acid value for each of the breads increases with storage time. This might be due to the deterioration of oil in bread (He and Lu, 2015). From Figure 4(b) it was discovered that the percentage of free fatty acids in bread decreased with the addition of carrot pomace powder in the bread. This may be due to the lower amount of fat in the carrot pomace powder bread and its raw materials (Pandey *et al.,* 2016). These findings are in agreement with Hryshchenko *et al.* (2019) who reported that additions of carrot pomace powder can improve the shelf life of the bread. Figure 4 (b) also revealed that free fatty acids of all types of bread gradually increased with the increase of storage time. The increase in FFA content could be caused by an increase in the rate of triacylglycerol hydrolysis when the moisture content of the product and air inside the container react with the absorbed oil of the product (Nagarajaiah and Prakash, 2015). From Figure 4 it was observed that the rate of increase of free fatty acid and acid value of carrot pomace powder incorporated breads with storage time was slower compared to control bread because of its high antioxidant content (He and Lu, 2015).

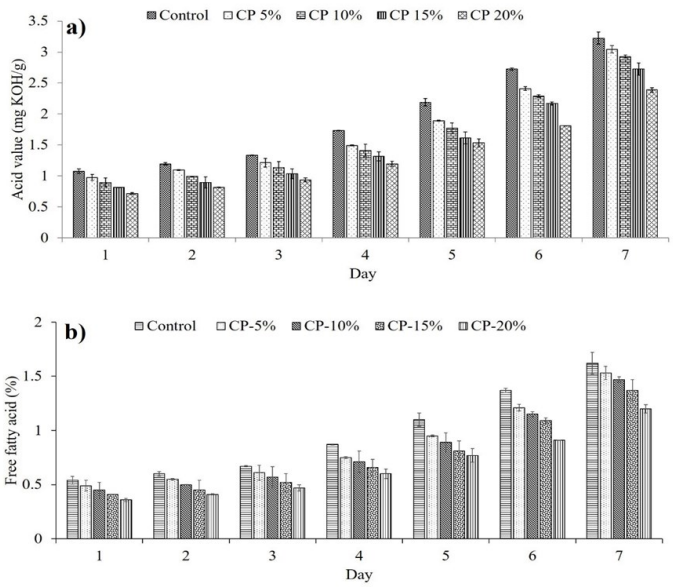

Figure 4. (a) Acid value and (b) free fatty acids (%FFA) of control and carrot pomace (CP) powder incorporated breads during storage period.

3.8 Microbiological analysis of breads

Total viable bacterial counts are used as an acceptability index for food products because of the role of bacteria in spoilage (Durmuş *et al.,* 2014). The values for bread during the storage period are presented in Table 4. On the day of production, the level of bacterial growth was almost the same for each type of bread while fungal growth was absent. From the very next day of

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Table 4. Microbial growth on breads during storage.

Total viable bacterial count (CFU/g)					
Day	Control	CP-5%	CP-10%	CP-15%	CP-20%
Day -1	2.5×10^4	2.4×10^4	2.4×10^4	2.2×10^4	2.1×10^4
Day -2	5.6×10^4	4.9×10^4	4.2×10^4	3.6×10^4	2.7×10^4
Day -3	3.0×10^5	2.1×10^5	1.7×10^5	1.5×10^5	1.1×10^5
Day -4	4.3×10^5	3.7×10^5	3.2×10^5	3.1×10^5	2.6×10^5
Day -5	6.0×10^5	5.7×10^5	5.6×10^5	5.4×10^5	4.1×10^5
Day -6	3.1×10^6	2.2×10^6	1.3×10^6	1.2×10^6	9.3×10^5
Day -7	1.8×10^7	9.2×10^6	9.1×10^6	8.9×10^6	2.1×10^6
Total fungal count (CFU/g)					
Day -1	NG	NG	NG	NG	NG
Day -2	1×10^4	1×10^4	1×10^4	1×10^4	1×10^4
Day -3	5×10^4	2×10^4	2×10^4	2×10^4	2×10^4
Day -4	1.2×10^5	4×10^4	4×10^4	4×10^4	3×10^4
Day -5	6.7×10^5	1.5×10^5	1.5×10^5	1.5×10^5	1.4×10^5
Day -6	1.8×10^6	6.8×10^5	6.2×10^5	6.2×10^5	5.7×10^5
Day -7	9×10^7	3.8×10^6	2.7×10^6	2.1×10^6	1.6×10^6

NG: No growth

production, the number of microbial colonies increases in a progressive manner with the storage period. On the 4th day of storage, the control bread exhibited a higher level of microbial colony than the other breads, which was beyond the accepted level. According to the World Health Organization (WHO) Standard (1994), the acceptable range of total viable bacterial count and total fungal count was 4×10^5 CFU/g and 1×10^5 CFU/g respectively. Results also revealed that the total viable bacterial count and total fungal count of bread samples were decreased with increased levels of supplementation of carrot pomace powder. This may be attributed to the fact that wheat flour has a higher moisture content, carbohydrates and other nutrients necessary for microbial growth than carrot pomace powder; thus, bread prepared with carrot pomace powder contained the minimum number of bacteria and fungus (Hryshchenko *et al.,* 2019).

3.9 Physicochemical properties

The mean value of proximate composition, bioactive properties and energy value of control and carrot pomace powder incorporated bread with 10% are given in Table 5. The data revealed that the incorporation of 10% carrot pomace powder in wheat flour bread increased ash (1.98%) and crude fibre (4.87%) of bread (Watzke, 1988). Higher ash contents reflect possibly more minerals in bread, which may have a positive role in health and high-fiber diets are associated with the prevention, reduction and treatment of some diseases, such as diverticular and coronary heart diseases (Figuerola *et al.,* 2005). However, such supplementation

Table 5. Physicochemical properties of control and carrot pomace powder incorporated breads.

Parameters	Control (%)	CP-10 (%)
Moisture	22.48 ± 0.11^a	22.41 ± 0.03^a
Ash	1.04 ± 0.09^b	1.98 ± 0.06^a
Crude Fat	8.16 ± 0.04^a	8.03 ± 0.10^a
Crude Fiber	3.53 ± 0.05^b	4.87 ± 0.05^a
Crude Carbohydrates	50.45 ± 0.22^a	49.56 ± 0.26^b
Crude Protein	14.33 ± 0.29^a	13.15 ± 0.12^b
Total energy (kcal/100 g)	332.6	323.11
Bioactive properties		
Beta Carotene (mg/100 g)	0.31 ± 0.07^b	1.17 ± 0.13^a
Vitamin C (mg/100 g)	0.00±0.00	0.00±0.00
Antioxidant activity (%)	37.42 ± 0.27^b	52.23 ± 0.16^a
Total phenolic content (mg GAE/ g)	0.25 ± 0.06^b	0.48 ± 0.02^a

Values are presented as mean±SD of three replicates. Values with different superscripts within the same row are statistically significantly differences at $P<0.05$.

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decreased the energy value (323.11 kcal/100 g) of bread. The findings were in agreement with earlier stated outcomes. Regarding bioactive properties carrot pomace powder incorporated bread show a significantly higher amount of β-Carotene (1.17 mg/100 g), antioxidant activity (52.23%) and total phenolic content (0.48mg GAE/ g). Such data are in good accordance with the findings (Yilmaz and Pekmez, 2005). In the case of vitamin C, bread with and without the incorporation of carrot pomace powder did not contain any vitamin C. This might be due to excessive heating temperature during baking (Igwemmar *et al.,* 2013).

4. Conclusion

The present study found that adding carrot pomace powder to bread increased fibre content while simultaneously lowering the calorie load. In terms of functional qualities, carrot pomace powder outperforms wheat flour in terms of water holding capacity, water retention capacity, and swelling capacity. The use of carrot pomace powder instead of wheat flour enhanced the look of the bread by giving it a more appealing hue as well as a better taste and flavor. Overall, the bread made with 10% carrot pomace powder in wheat flour was deemed to be satisfactory, and they were equivalent to the control wheat flour bread. The physical features of bread made from a combination of wheat flour and carrot pomace powder were discovered in the study, which demonstrated that the specific volume of the composite bread reduces as carrot pomace powder proportions grow, while the density of the composite bread increases. In a comparison of control and carrot pomace powder integrated bread, the degradation was reduced in the bread with carrot pomace powder inclusions. Breads made with 10% carrot pomace powder in wheat flour were shown to be rich sources of nutrients and phytochemicals, indicating that carrot pomace powder is a viable component for bread formation. The antioxidant activities of carrot pomace powder including bread were discovered to be much greater than control, and they were determined to be adequate without impacting the overall bread quality or sensory qualities such as scent and flavor. These findings support the use of low-cost by -products like carrot pomace powder as a useful functional additive for enhancing the nutritional value of food items with lower gluten content. The use of 10% carrot pomace residue in bread was shown to be the most satisfactory method. As a result, more research may be done to see if this carrot pomace powder can be used to manufacture a variety of goods.

Conflict of interest

There are no conflicts of interest declared by the authors.

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