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Research Article

Quality assessment of value-added Indian recipe *papad* prepared from dehydrated carrot pomace powder

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Abstract
Fruit and vegetable processing byproducts have a high concentration of biologically useful components and nutritional fibre, though they are frequently discarded as manufacturing waste. The purpose of this study was to improve the nutritional value of the Indian recipe *papad*, a low-moisture dish with a thin, crisp, wafer-like texture, by utilizing the beneficial properties of dehydrated carrot pomace powder (CPP), which is usually discarded as a food industry bio-waste. Carrot pomace powder was prepared and examined for nutritional and functional properties (10, 20, and 30%), and the developed samples were coded as P_0 (control, 100% black gram flour), P_1 (black gram flour: carrot pomace powder; 90:10), P_2 (black gram flour: carrot pomace powder; 80:20), and P_3 (black gram flour: carrot pomace powder; 70:30). The physical, sensory, and storage properties of the developed value-added *papads* were evaluated. Adding CPP to the flour mix increased the moisture, ash, and crude fiber content while decreasing the protein and carbohydrate content. Based on sensory evaluation, sample P_1 was found to be the most acceptable by the sensory panel. The product's microbiological studies showed that, up to a 30-day storage period, the product was well within safe limits. Based on the water activity (at 36.7ºC/ 83% RH) and overall acceptability scores, triple-laminated aluminum bags were considered an appropriate packaging material for storing the value-added *papads*. This study has established the incorporation of CPP as a healthier alternative to produce an inexpensive, fiber-rich, value-added *papads.*

Keywords: Carrot pomace powder, Functional properties, Microbiological stability, Nutrient composition, Sensory evaluation, Value-added *papad*

INTRODUCTION

The agricultural and food processing industries produce a significant amount of waste annually. Because of the problems associated with waste disposal, the accumulation of these industrial products has a detrimental effect on the environment. Food waste is collected at various stages throughout the supply chain, including harvesting, grading, sorting, and processing. Since these agricultural wastes are an inexpensive source of dietary fibre, protein, and bioactive compounds like phenolic compounds, antioxidants, minerals, and vitamins, valorizing them into food products is necessary (Dey *et al*., 2021). Globally, the fruit and vegetable processing industries have expanded significantly due to the need to minimize postharvest losses and create revenue. However, the processed food sector still accounts for 25% of wastage in the form of organic waste such as stems, seeds, peel, core, and pomace from juice extraction. Fruit processing plant byproducts have unexplored potential for manufacturing low-cost natural bio-components with food uses. As a result, there is an urgent need to focus on utilizing the tonnes of pomace generated to address ecological problems while also creating new revenue streams (Surbhi *et al*., 2018).

The root vegetable carrot (*Daucus carota L*.) belongs to the *Apiaceae* family. It is a key source of bioactive substances and other functional groups. β-carotene, minerals (calcium, copper, magnesium, potassium, phosphorus, and iron) and vitamins are some of the most significant bioactive substances (Surbhi *et al*., 2018; Luca *et al*., 2022). Wet carrot shavings produced during the extraction of carrot juice are referred to as carrot pomace. However, this pomace is high in beneficial elements like carotenoids, uronic acids, neutral sugars, and dietary fiber (Adeleye *et al*., 2016). Pectin (3.88%), cellulose (51.6%), lignin (32.1%), and hemicellulose (12.3%) make up the majority of the fibre in carrot pomace (Nawirska & Kwaśniewska, 2005). Following juice extraction, the byproduct becomes a prospective source of phytochemicals with numerous health advantages that could be considered when developing ingredients for the food sector and dietary supplements (Schieber *et al*., 2001). Byproduct value-addition aids in lowering the cost of the primary product, which generates a direct gain for producers and consumers. Due to the high moisture content of pomace, drying or dehydration is employed to extend the shelf life for future use (Alam *et al*., 2013). Carrot pomace has been reported to substitute for up to 5% wheat flour in wheat-based bread while maintaining the highest quality parameters (Tańska *et al*., 2007). Kırbaş *et al*. (2019) created a gluten-free cake with increased fibre content by incorporating carrot pomace powder at 5, 10, and 15%. It was reported that the sensory properties were significantly affected by the increase in pomace concentration.

Papad (*appalam/papadam*) has been a prominent and delightful food item in Indian dietary science since time immemorial. *Papad*, a low-moisture dish with a thin, wafer-like texture, is consumed after frying or roasting or as an accompaniment to vegetable soups and curries (Kumari *et al*., 2020). It is frequently developed using a dough consisting of pulse flour, cereal flour, edible starch flour, carbonates, spices, water, and edible vegetable oil (Venipriyadharshini and Archana, 2019). Akshatha *et al*. (2019) supplemented foxtail millet *papad* with basil leaves at different levels (10, 15, and 20 g) and assessed them for organoleptic attributes, functional properties, and shelf-life. Compared to other variations, *papad* containing 15 g basil leaves was the most acceptable. Chemical analyses revealed that the incorporation of basil leaves substantially increased the nutritional parameters of the product (protein: 19 g/100 g, ash: 7.2 g/100 g, fiber: 4 g/100 g, and fat: 4 g/100 g). It was determined that this value addition resulted in a product with a shelf life of one month.

Owing to the vast quantities of pomace generated through the carrot processing industries, a crucial demand exists for incorporating carrot pomace in foods to boost the nutritional value by supplying more nutrient-dense components than traditional flour blends. In recent years, substantial studies have been conducted on the utilization of carrot pomace in foods such as bread (Ohsawa *et al*., 1994), functional drinks (Henn & Kunz, 1996), fibre-rich cookies (Bellur- Nagarajaiah & Prakash, 2015; Sahni & Shere, 2017; Priyanka & Shukla, 2021), cakes, gluten-free batter (Majzoobi *et al*., 2017), and ready-to-eat high-fibre expanded snacks made from barley flour (Lotfi Shirazi *et al*., 2020). However, barely any attempt has been made to date to analyze the concurrent change in papad's physicochemical and sensory parameters that was supplemented with different levels of dehydrated carrot pomace powder. Therefore, the present study was undertaken to find out the effects of partial substitution of black gram flour with carrot pomace powder at varying levels (10, 20, and 30%) on the nutritional, sensory, and microbiological parameters of Indian recipe *papad*. Additionally, an effort was made to determine the product's shelf life following storage in different packaging materials over two months.

MATERIALS AND METHODS

Procurement of materials

The raw materials like black gram flour, fresh carrots, and other spices required to prepare *papad* were procured from the Dwarka Sector-10 local market in Delhi. All the other chemicals used were of analytical grade and were commercially accessible (Sigma-Aldrich).

Preparation of carrot pomace

The carrots (variety: Pusa kesar) were washed to remove any dirt, dust, or foreign materials stuck to the surface. These were de-headed and cut into cubes (0.3 cm) with a vegetable knife. The carrot juice was extracted using a food processor (Morphy Richards Icon DLX). The remaining post-juice extraction remains and carrot shreds were collected and blanched at 80 ºC/ 3 min. The obtained pomace was dried in a tray drier at 65 ± 2 ºC for 5 hours, with a drying bed thickness of 0.5 cm. These were then ground to powder form with a lab grinder, screened through a 40-mesh sieve, and stored in airtight jars at 4 ºC until use (Sharma *et al*., 2012). Fig. 1 depicts the process flow diagram for carrot pomace powder (CPP) preparation.

Standardization of the formula for the preparation of carrot pomace powder incorporated *papad* (ingredients in g/100 g)

Papads were standardized by incorporating CPP at 10, 20, and 30%, along with other ingredients, such as black gram flour used in different variations to determine the suitable ratio (Table 1). The best formulation was used for further utilization.

Preparation of value-added *papad*

All the dry ingredients were mixed into the black gram flour. The dough was kneaded for 5 minutes with lukewarm water. While kneading, mustard oil was used to prevent the dough from sticking to the hands. The dough was kept for proofing (30 min.) before being divided into small balls of 25-30 g each. Each ball was rolled out on a rolling board with the help of rolling pins in a circular path to give a *papad* of flat circular shape having 0.6-0.8 mm thickness and 15-20 cm diameter. The *papad* was then dried using an open sun drying method for 6-8 hours before being packaged into polyethylene bags (Garg & Sabharwal, 2015).

Based on the incorporation levels of carrot pomace into the dough for the preparation of value-added *papad*, these were coded as P_0 (control; 100 % black gram flour without CPP), sample P_1 (black gram flour: CPP; 90: 10), sample P_2 (black gram flour: CPP; 80: 20), and sample P_3 (black gram flour: CPP; 70: 30). The *papads* were subjected to deep-fat frying treatment at 180 ºC for 4-5 sec. The developed value-added *papads* were then stored in airtight containers for further chemical, microbial and shelf-life analysis. Fig. 2 depicts the process flow diagram for the preparation of value-added *papad*.

$$\text{Moisture content on a dry basis (M.C)}_{db} = \frac{\text{Sample wt. at time } \theta \text{ (g)} - \text{dry matter}}{\text{Dry matter of sample (g)}} \times 100 \quad \text{(Eq. 1)}$$

$$DR = \frac{\text{Initial weight of sample} - \text{Weight of sample after the time (t)}}{\text{Time interval (min.)} \times \text{dry matter of sample}} \quad \text{(Eq. 2)}$$

$$\text{Dehydration ratio} = \frac{\text{Initial weight of the product (before drying)}}{\text{Weight of the dehydrated product}} \quad \text{(Eq. 3)}$$

Drying characteristics of carrot pomace powder

The sample's moisture content was assessed using the dry matter of the sample at various times during the experiments. The sample's rate of drying was established using the following formula given below (Suman *et al.*, 2020):

Where, DR = Drying rate at time (t), g water/ g. min.

Dehydration ratio

The following equation was used to determine the dehydration ratio (Sharma & Bhat, 2018).

Rehydration ratio

A rehydration test was used to examine the rehydration quality of dried carrot pomace powder (More & Tayade, 2019). The data were expressed as RR and calculated using the following formula:

$$RR = \frac{\text{wt. (g) of rehydrated sample}}{\text{wt. (g) of dehydrated samples taken for the test}} \quad \text{(Eq. 4)}$$

Where, RR = Rehydration ratio

Functional properties of dehydrated carrot pomace powder

The procedures used by Robertson *et al.* (2000) and Raghavendra *et al*. (2006) were used to determine functional properties such as water-holding capacity (WHC), water retention capacity (WRC), oil-absorbing capacity (OAC), and swelling capacity (SC) of the carrot pomace powder.

Bulk and tapped density

The bulk and tapped density were calculated using the method described by Sahni and Shere (2017).

Physical characteristics of the developed value-added *papads*

A ruler was used to measure the diameter of five *papads* randomly selected from each lot, and the average was reported and expressed as a centimeter. A screw gauge was used to measure the thickness at 5 distinct points, and the average was determined in millimeters. An electronic balance was used to measure the weight (Kumari *et al*., 2020).

Frying characteristics

Oil uptake

The oil uptake by the *papad* was determined using the procedure given by Beniwal *et al*. (2015). The initial weight of the *papad* and the final weight after frying were noted. The difference was used to estimate the oil uptake by the *papad*.

Diametrical expansion

The diametrical expansion (%) of fried *papads* was evaluated using the procedure given by Beniwal *et al*. (2015).

$$\text{Diametric expansion (\%)} = \frac{D - F}{R} \times 100 \quad \text{(Eq. 5)}$$

Where, D = diameter of fried *papad*,

R = diameter of *papad* before frying (raw *papad*)

Chemical analysis

Proximate sample analysis was determined as per the AOAC (2012) standard techniques. The amount of carbohydrates was determined using the difference method (Hossain *et al*., 2015).

Sensory analysis

The fried *papads* were coded for identification before being presented to the panel for sensory analysis. The developed samples were scored for appearance, color, crispness, taste, flavor, aftertaste, and overall acceptability by a 10-member trained and semi-trained sensory panellist comprised of males and females from the Department of Food Technology, Bhaskaracharya College of Applied Sciences (BCAS), University of Delhi. Using a 9-point hedonic scale, the degree of acceptance, preference, or likeness was stated, with 1 signifying extreme dislike and 9 denoting extreme likenesses. The product with the highest sensory score was chosen and evaluated for further microbiological analysis and shelf-life study.

$$CFU/g = \frac{(\text{No. of colonies counted} \times \text{dilution factor})}{\text{mL of sample plated}} \qquad \text{(Eq. 6)}$$

Microbial stability

The best-accepted sensory sample was evaluated in triplicate for microbiological stability after 30 days (0-7-15-30) of room-temperature storage. Standard plate count (SPC) for yeast, mold, and coliform tests was performed according to the method described by Thambekar *et al.* (2009). Based on the average count of the triplicate set, colony-forming units (CFU)/g or CFU/ml were calculated.

Accelerated shelf life analysis

For a storage period of two months ((0th-15th-30th-45th-60th), accelerated shelf life studies in three different packaging materials were performed using an environmental chamber. The temperature-dependent water activity (a_w at 36.7ºC/ 83% RH) and moisture content were measured during this interval, and the overall acceptability scores were based on the suitability of packaging materials to maintain the developed value-added *papad* safe and wholesome without any detrimental changes.

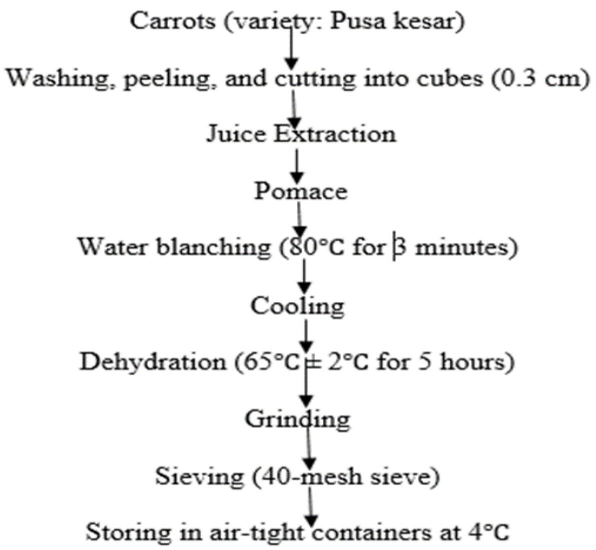

Fig. 1. *Process flow diagram for carrot pomace powder (CPP) preparation*

Statistical analysis

All statistical procedures were performed using SPSS software for Microsoft (IBM SPSS Statistics 20), $p<0.05$ All measurements were made in triplicate, and the results were recorded as the mean ± the standard deviation (SD).

RESULTS AND DISCUSSION

The physicochemical analysis and sensory properties were assessed to determine the quality aspects of CPP and the developed product, to which value-addition was done by incorporating carrot pomace powder. From all the variations, i.e., sample P_1 (black gram flour: carrot pomace powder; 90: 10), sample P_2 (black gram flour: carrot pomace powder; 80: 20), and sample P_3 (black gram flour: carrot pomace powder; 70: 30), sample P_1 recorded the highest values for all sensory attributes and thus had the highest overall acceptability. As a result, microbiological testing and accelerated shelf-life studies were performed on variation P_1.

Drying characteristics of carrot pomace powder

The moisture content of the carrot pomace powder decreased with time in the tray dryer. The initial moisture content was found to be 433.72% (dry basis). The drying rate at 65ºC was reported to be 1.399 g water/g dry matter-min. The drying air temperature was the most important element impacting the drying rate. The reduced drying time was a direct outcome of the higher drying rate caused by the warmer air temperature. This is due to the enhanced heat transfer between the drying air and the carrot pomace powder. Similar findings have been reported by Ross *et al*. (2020) who examined the drying kinetics and bioactive quality parameters of fermented Merlot grape, cranberry, highbush blueberry, and wild lowbush blueberry pomace in a cabinet convection air dryer at two loading densities (kg/m^2) at 50, 60, and 70°C. The results revealed that within each pomace type, material with lower load densities or thickness levels dried faster due to the decreased distance the moisture required to travel and the greater surface area exposed for the given volume of material. The influence of temperature on drying time was predicted since higher temperatures increase the energy of water molecules and cause evaporation to occur more quickly. According to Luca *et al*. (2021), the kinetics of the rehydration process are critical for the quality of dehydrated food since it is usually consumed following rehydration. The level of structural degradation and cell disintegration directly impact the

Mixing all dry ingredients (spices, dehydrated CPP) into the black gram flour

↓

Formulation of dough with lukewarm water and mustard oil

↓

Proofing of dough (30 minutes)

↓

Dividing the dough into small round balls

↓

Rolling the balls into a flat circular shape (thickness: 0.6-0.8 mm, diameter: 15-20 cm)

↓

Sun drying (6-8 hours)

↓

Storing in polythene bags for further analysis

Fig. 2. *Process flow diagram for the development of value-added papad*

Table 1. Formulation of *papads* (ingredients in g/100 g) with the incorporation of carrot pomace powder (CPP)

Ingredients	Control (P_0)	P_1	P_2	P_3
Black gram flour (g)	100	90	80	20
Carrot pomace (g)	-	10	20	30
Black pepper powder (g)	0.5	0.5	0.5	0.5
Edible common salt (g)	0.6	0.6	0.6	0.6
Asafoetida (g)	0.5	0.5	0.5	0.5
Red chili powder (g)	0.5	0.5	0.5	0.5
Papadkhar (g)	2	2	2	2
Mustard Oil (ml)	15	15	15	15
Water (ml)	30	30	30	30

P_0 (control; 100 percent black gram flour without carrot pomace powder), sample P_1 (black gram flour: carrot pomace powder; 90: 10), sample P_2 (black gram flour: carrot pomace powder; 80: 20), and sample P_3 (black gram flour: carrot pomace powder; 70: 30)

rehydration process. Fig. 3 depicts the change in moisture content of CPP with drying time at a drying temperature of 65ºC and an air velocity of 2 m/s.

Functional properties of dehydrated carrot pomace powder

The functional properties of carrot pomace powder (CPP) are given in Table 2. Water holding capacity (WHC), water retention capacity (WRC), and swelling capacity (SC) provide useful information about fiber's hydration capacity as well as insights into its behavior during gut transit and food processing. The observed values for WHC, WRC, SC, and OAC, were reported as 5.52 g/g, 4.31 g/g, 11.56 g/ml, and 2.48 g/g, respectively. The hydration properties of CPP were comparable to those reported by Sahni & Shere (2017), who studied the comparative analysis of physicochemical and functional characteristics of apple, carrot, and beetroot pomace powders.

Bulk and tapped density

The bulk and tapped density of carrot pomace powder were reported as 0.511 and 0.390 g/cm^3, respectively (Table 3).

Physical and frying characteristics of the developed value-added *papads*

Dimensional parameters are key quality criteria in the manufacturing of *papads*. Table 4 shows that the increased proportion of CPP in *papad* resulted in a progressive decrease in the diameter, whereas an increase in the thickness values was reported. The diameter ranged between 15.37 and 16.25 cm, with the highest value reported in the control sample (16.25 cm) and the lowest in the sample P_3. The *papad* developed with the incorporation of 30% CPP, i.e., sample P_3 exhibited a maximum thickness of 0.71 mm, while the control sample had the lowest thickness (0.64). With an increase in the level of CPP supplementation, the weight of the *papads* increased progressively from 16.24 g to 18.71 g. The increase in weight could be attributed to the water-binding capacity exhibited by carrot pomace powder. Similar findings were reported by Sahni and Shere (2017), who developed fiber-rich cookies (C_C- 0% CPP, C_1- 5% CPP, C_2- 10% CPP, C_3- 15% CPP, C_4- 20% CPP, C_5- 25% CPP) by partial substitution of refined wheat flour with carrot pomace powder (CPP) at 5%, 10%, 15%, 20%, and 25%. The study discovered that with the increase in CPP in flour blend, the weight and thickness of cookies increased, while a decline in diameter was observed.

The reported weight, diameter, and thickness of the present study were as per the requirements specified by the Bureau of Indian Standards (BIS, 1984). Among the variations developed, the expansion percentage of the control sample (P_0) was significantly higher (32.84%), followed by samples P_1 (25.40%), P_2 (18.16%), and P_3 (18.11%). The diameter of the *papad*

Table 2. Functional properties of dehydrated carrot pomace powder (CPP)

Parameters	Carrot pomace powder (CPP)
Water holding capacity (g/g)	5.52 ± 0.02
Water retention capacity (g/g)	4.31 ±0.04
Swelling capacity (ml/g)	11.56 ±0.05
Oil absorption capacity (g/g)	2.48 ± 0.07

Table 3. Physical properties of dehydrated carrot pomace powder (CPP)

Parameters	Carrot pomace powder (CPP)
Bulk Density (g/cm^3)	0.5110 ± 0.001
Tap Density (g/ cm^3)	0.390 ± 0.006
Water activity (a_w)	0.3043 ± 0.30 [at 24.91ºC

Values are presented as the mean ± SD of three independent assessments

is determined by the quantity and quality of gelatinized starch contained in the sample. The starch in the *papad* gets expanded during the frying. The main determinants of the starch's ability to expand are the combination of amylose and amylopectin in the starch's structure and any sudden changes that occur during frying (Chavan *et al*., 2015).

The control sample (P_0) had the highest level of oil uptake (15.41%), whereas sample P_3 had the lowest (13.89%). The amount of oil uptake is a key quality criterion for fried foods. Though there was no pronounced variation in the oil uptake, it was discovered that increasing the concentration of CPP in *papad* resulted in a decrease in the oil uptake (%). The root cause of variation in oil uptake by different papads might be their diversity in moisture content and the microstructure of the product (Gazmuri and Bouchon, 2009).

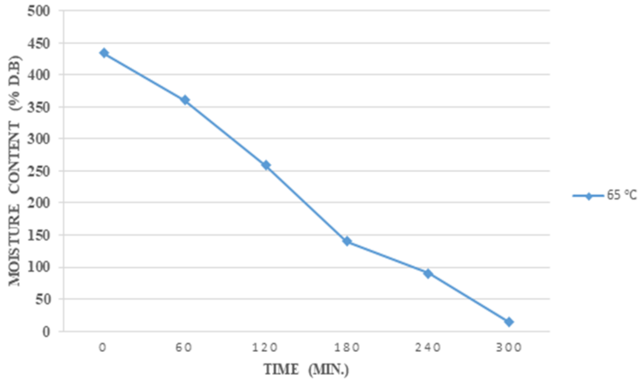

Fig. 3. *Changes in moisture content (% dry basis) of carrot pomace powder with time (min.)*

Chemical analysis

The proximate chemical analysis of carrot pomace powder revealed the following values: moisture: 8.55%, protein: 6.20%, crude fiber: 14.62%, crude fat: 3.21%, carbohydrates: 62.40%, and ash: 5.02% (Table 5; Fig. 4). The obtained values were consistent with prior findings reported by various researchers (Bellur- Nagarajaiah and Prakash, 2015; Sahni and Shere, 2017). Ta-

Table 4. Physical and frying characteristics of the developed value-added *papads*

Samples	Average weight (g)	Thickness (mm)	Diameter (cm)	Diametrical expansion (%)	Oil uptake (%)	Water activity (a_w) at 25.25ºC
P_0	16.24±0.08	0.64±0.03	16.25±0.07	32.84±0.99	15.41±0.07	0.3721±0.04
P_1	18.33±0.73	0.67±0.09	15.90±0.04	25.40±0.75	15.14±0.04	0.3822±0.08
P_2	18.47±0.69	0.68±0.08	15.41 ±0.03	18.16±0.45	14.55±0.03	0.3853±0.06
P_3	18.71±0.77	0.71±0.07	15.37 ±0.01	18.11±0.66	13.89±0.01	0.3902±0.08

Values are presented as the mean ± SD of three independent assessments; P_0 (control; 100 percent black gram flour without carrot pomace powder), P_1 (black gram flour: carrot pomace powder; 90: 10), P_2 (black gram flour: carrot pomace powder; 80: 20), and P_3 (black gram flour: carrot pomace powder; 70: 30)

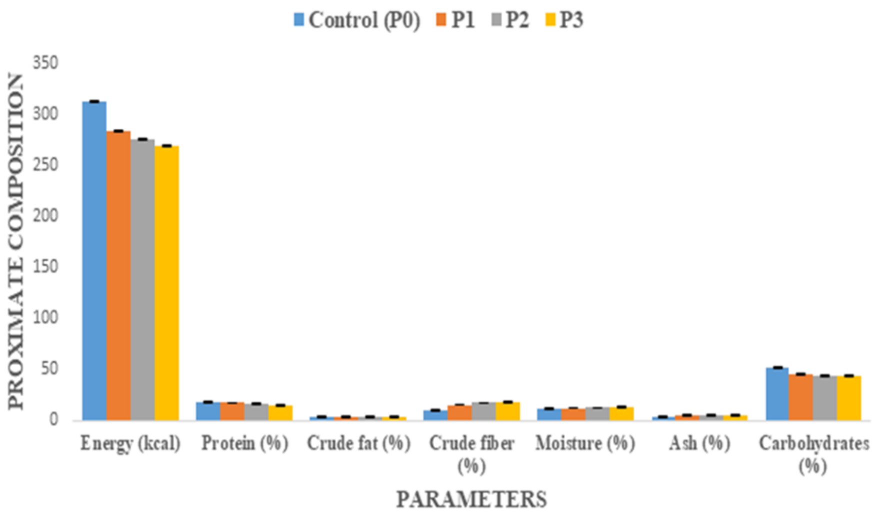

Fig. 4. *Bar chart showing the mean proximate chemical composition of carrot pomace powder*

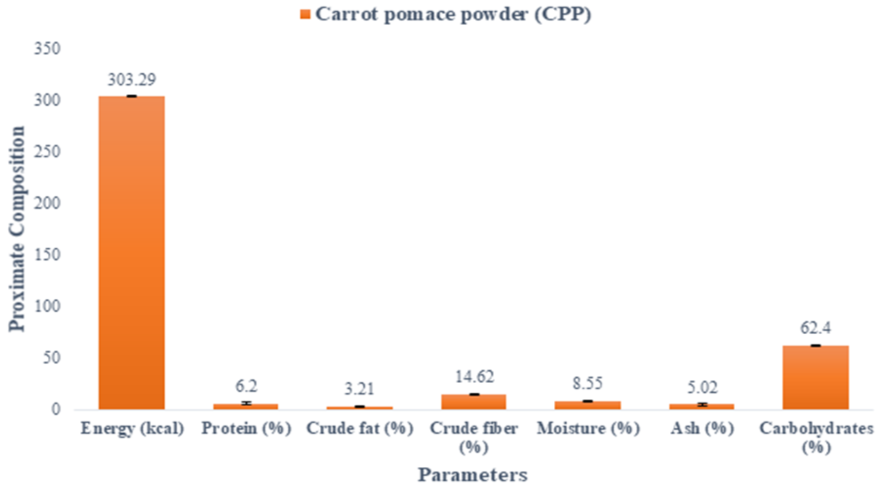

Fig. 5. *Bar chart showing the mean proximate chemical composition of control and developed value-added papads; Where, P_0 (control; 100 percent black gram flour without carrot pomace powder), P_1 (black gram flour: carrot pomace powder; 90: 10), P_2 (black gram flour: carrot pomace powder; 80: 20), and P_3 (black gram flour: carrot pomace powder; 70: 30)*

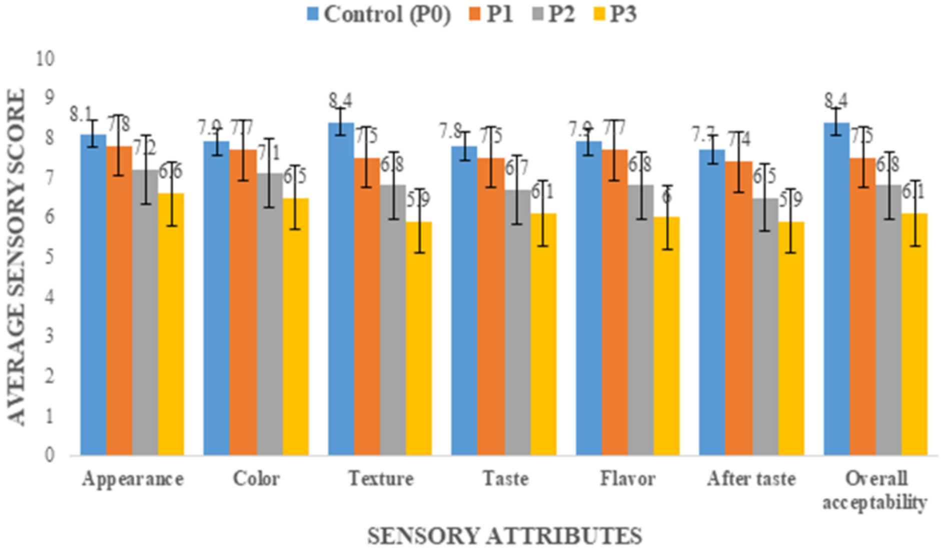

Fig. 6. *Average sensory score of different parameters in control and developed value-added papads; Where, P_0 (control; 100 percent black gram flour without carrot pomace powder), P_1 (black gram flour: carrot pomace powder; 90: 10), P_2 (black gram flour: carrot pomace powder; 80: 20), and P_3 (black gram flour: carrot pomace powder; 70: 30)*

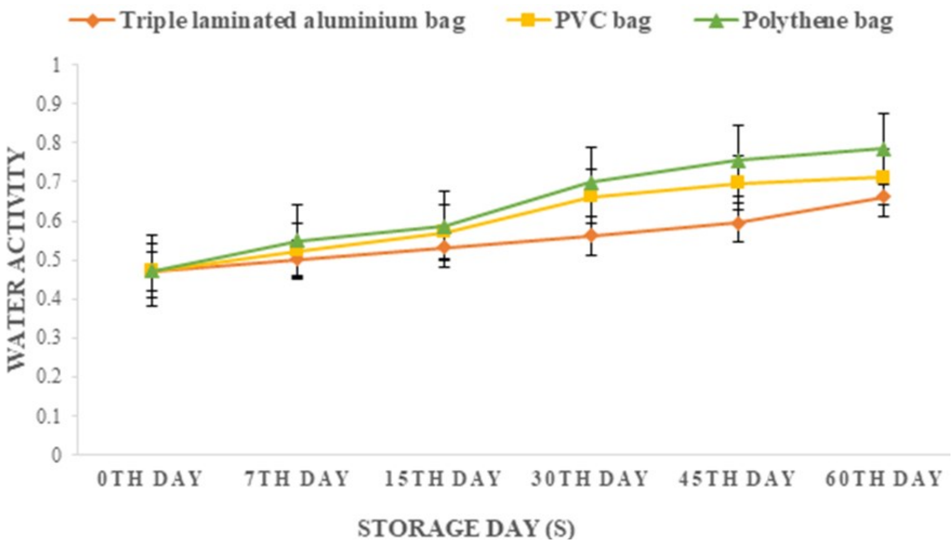

Fig. 7. *Variation of water activity (a_w) of value-added papads during storage in different packaging materials*

Table 5. Proximate composition analysis of carrot pomace powder

Parameters	Carrot pomace powder (CPP)
Energy (kcal)	303.29±0.30
Protein (%)	6.20±0.08
Crude fat (%)	3.21±0.66
Crude fiber (%)	14.62±0.02
Total carbohydrates (%)	62.40±0.85
Moisture (%)	8.55±0.32
Ash (%)	5.02±0.33

Values are presented as the mean ± SD of three independent assessments

ble 6 indicates the nutritional composition of carrot pomace powder-incorporated *papad*. The moisture content varied between 12.12% and 13.01%. The present findings of moisture content complied with the standards set by the Bureau of Indian Standards (12-15%) (BIS, 1984). The control sample had the lowest moisture content (12.12%), whereas the sample containing 30% CPP (P_3) had the highest moisture content, followed by samples containing 20% (P_2) and 10% (P_1) CPP (Fig. 5). The increase in moisture content was caused by the water-holding capacity of CPP, which increased the water content of the dough (Sahni and Shere, 2017).

There was no pronounced variation in the crude fat content of the developed value-added *papads*, which is attributed to the low-fat content of CPP. Protein and carbohydrate content in *papads* dropped linearly as CPP increased. Since black gram flour contains more protein than CPP, replacing black gram flour with CPP led to low protein levels in the *papads*. The carbohydrate content ranged from 44.46% to 51.55%, with the highest value observed in the control sample and the lowest in-sample P_3. The crude fiber content increased from 10.25% in the control sample to 18.12% (P_3) at various levels of incorporation (0% – 30%). The high crude fiber and ash content of CPP caused a significant increase in the fiber and ash content of the developed value-added *papads*.

Sensory evaluation

Table 7 demonstrates the average and standard deviation of sensory scores against various parameters. The control sample, P_0 (100% black gram flour), scored the highest in all attributes, followed by sample P_1. The sensory analysis of the product and control sample is depicted in Fig. 6. In terms of appearance, sample P_0 (8.1) obtained the highest mean score among the developed *papad* samples, followed by samples P_1 (7.8), P_2 (7.2), and P_3 (6.6). It is evident that the incorporation of CPP at higher concentrations (i.e., 20% and 30%) caused the average score for color to drop from 7.9 (P_0) to 6.5 (P_3). The higher degree of incorporation of CPP had a negative impact on the taste and texture. This could be a result of the high fiber content of carrot pomace powder, which tends to make the final product rough. The addition of carrot pomace powder greatly affected the overall acceptance of the *papad*. Although

Table 6. Proximate composition analysis of control and developed value-added *papad*

Parameters	Control (P_0)	P_1	P_2	P_3
Energy (kcal)	311.89±0.45	284.19±0.36	275.93±0.70	269.58±0.66
Protein (%)	18.21±0.18	17.41±0.15	16.68±0.24	15.51±0.36
Crude fat (%)	3.65±0.45	3.51±0.40	3.45±0.55	3.30±0.36
Crude fiber (%)	10.25±0.06	15.67±0.07	17.37±0.63	18.12±0.62
Carbohydrates (%)	51.55±0.77	45.74±0.65	44.54±0.60	44.46±0.55
Moisture (%)	12.12±0.45	12.45±0.40	12.5±0.50	13.01±0.55
Ash (%)	4.22±0.24	5.22±0.45	5.45±0.40	5.60±0.36

Values are presented as the mean ± SD of three independent assessments; P_0 (control; 100 percent black gram flour without carrot pomace powder), P_1 (black gram flour: carrot pomace powder; 90: 10), P_2 (black gram flour: carrot pomace powder; 80: 20), and P_3 (black gram flour: carrot pomace powder; 70: 30)

Table 7. Average and standard deviation of sensory scores against different parameters

Sensory attributes	Control (P_0)	P_1	P_2	P_3
Appearance	8.1± 0.33	7.8±0.26	7.2± 0.26	6.6 ±0.79
Color	7.9± 0.21	7.7± 0.76	7.1 ± 0.28	6.5 ±0.25
Texture	8.4± 0.20	7.5± 0.29	6.8 ± 0.26	5.9 ±0.76
Taste	7.8 ± 0.28	7.5± 0.33	6.7 ± 0.25	6.1 ±0.26
Flavor	7.9 ± 0.35	7.7± 0.39	6.8 ± 0.35	6.0 ±0.81
After taste	7.7 ± 0.31	7.4± 0.33	6.5 ± 0.74	5.9 ±0.23
Overall acceptability	8.4 ± 0.29	7.5± 0.67	6.8 ± 0.86	6.1 ±0.41

Values are presented as the mean ± SD of three independent assessments; P_0 (control; 100 percent black gram flour without carrot pomace powder), P_1 (black gram flour: carrot pomace powder; 90: 10), P_2 (black gram flour: carrot pomace powder; 80: 20), and P_3 (black gram flour: carrot pomace powder; 70: 30)

Table 8. Microbial analysis on the 0th, 7th, 15th, and 30th day at 28ºC

Parameters	Storage day (s)	Control (P_0) (10 CFU/g)	Sample (P_1) (10 CFU/g)
Standard plate count	0th	0	0
	7th	20	15
	15th	70	55
	30th	85	77
Yeast and mold count	0th	0	0
	7th	1.9	1.5
	15th	6.6	5.8
	30th	10.5	10.2
Coliform count	0th	Absent	Absent
	7th	Absent	Absent
	15th	Absent	Absent
	30th	Absent	Absent

P_0 (control; 100 percent black gram flour without carrot pomace powder), and sample P_1 (black gram flour: carrot pomace powder; 90: 10)

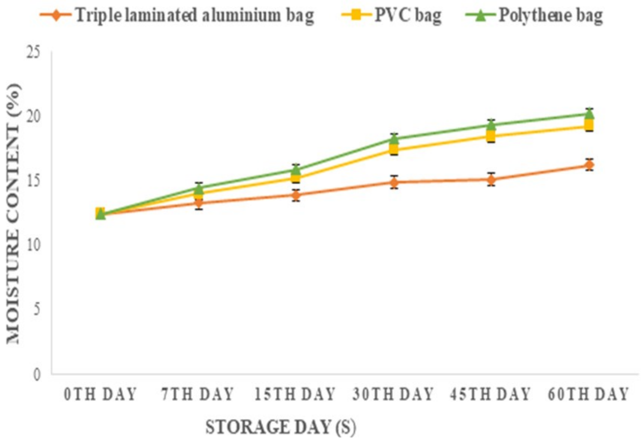

Fig. 8. *Variation of moisture content (%) of value-added papads during storage in different packaging materials*

the goal of fiber enrichment was achieved mainly, it affected the sensory properties of the *papad*, particularly the color, texture, and flavor, and disintegrated the paste's structural integrity. It rendered the product with a pronounced red color and a sweet flavor that was difficult to mask. Higher amounts of salt and other spices were added to counteract the sweetness, resulting in an unacceptable aftertaste. Therefore, *papads* developed with a 10% level of CPP were observed to be the most acceptable, with an overall acceptability score of 7.5 when compared to the other variations tested.

The results obtained are in agreement with those presented in Kultys and Moczkowska-Wyrwisz (2022); Sahni and Shere (2017). Kultys and Moczkowska-Wyrwisz (2022) evaluated the influence of carrot (C) and beetroot-apple (BA) pomace on the physicochemical and sensory qualities of pasta. In the consumer acceptability tests, pasta containing 10% carrot pomace received the highest rating, equivalent to the control pasta. Every parameter (appearance, color, fragrance, taste, flexibility, adhesiveness, hardness, and overall acceptability) was rated as higher or very similar to durum wheat pasta. Overall acceptability scores for the developed value-added cookies increased up to 10% CPP (C- 10%, BA- 10%), followed by a decline.

Microbiological stability

Table 8 demonstrates that *papads* were safe to consume with no microbial growth during the initial period. Microbial growth was discovered to be more prevalent in the control sample than in sample P_1. After 15 days of storage at room temperature, the yeast and mold count in sample P_1 was 5.8 x 10 CFU/g, but the count increased to 10.2 x 10 CFU/g on the 30th day. Similarly, the bacterial growth in the control and sample P_1 on the 30th day was 85 x 10 CFU/g and 77 x 10 CFU/g, respectively. The increased bacterial and fungal development could be attributed to product contamination during storage and the use of packaging material with poor gauge capacity. Water activity has a significant impact on various chemical reactions in food as well as the rate of microbial growth. The rise in microbial load with an increase in storage time might be attributed to increased moisture content during storage (Garg *et al.,* 2023).

Accelerated shelf life study

Table 9 contains data on the water activity and overall acceptability of value-added *papad* in three different packaging materials at various time intervals after storage. The control over moisture content and water activity aids in regulating microbial development, hence improving the product's shelf stability. The water activity (a_w) of products stored in a triple laminated aluminium bag, a transparent polyvinyl chloride (PVC) bag, and a polythene bag ranged from 0.4720-0.6621, 0.4720-0.7123, and 0.4720-0.7856, respectively (Fig. 7). Aluminum-based packaging material offers numerous advantages, such as recyclability, formability, and physical protection, making it the most commonly used metal-based material for packaging. The barrier func-

Table 9. Accelerated shelf life studies and overall acceptability of value-added *papads* during storage in different packaging materials

Water activity (a_w) [Environmental chamber - 36.7ºC/ 83% RH]						
Samples	**0th day**	**7th day**	**15th day**	**30th day**	**45th day**	**60th day**
Triple laminated aluminium	0.4720±0.00	0.5021±0.04	0.5326±0.04	0.5624±±0.02	0.5941±0.05	0.6621±0.04
PVC bag	0.4720±0.01	0.5244±0.03	0.5721±0.02	0.6621±0.03	0.6971±0.07	0.7123±0.07
Polythene bag	0.4720±0.00	0.5494±0.01	0.5869±0.00	0.6994±±0.02	0.7543±0.09	0.7856±0.08
Moisture content (%)						
Triple laminated aluminium	12.45±0.45	13.29±0.03	13.88±0.28	14.89±0.36	15.11±0.04	16.25±0.01
PVC bag	12.45±0.40	14.01±0.09	15.23±0.20	17.41±0.42	18.46±0.07	19.24±0.05
Polythene bag	12.45±0.33	14.45±0.02	15.89±0.26	18.26±0.36	19.34±0.05	20.26±0.08
Overall acceptability						
Triple laminated aluminium	7.6±0.01	7.1±0.01	6.8±0.26	6.5±0.36	6.0±0.55	5.8±0.01
PVC bag	7.6±0.01	6.9 ±0.03	6.5±0.29	6.1±0.34	5.9±0.45	5.5±0.04
Polythene bag	7.6±0.00	6.5 ±0.01	5.7±0.30	5.5±0.40	5.1±0.36	4.7±0.07

Values are presented as the mean ± SD of three independent assessments

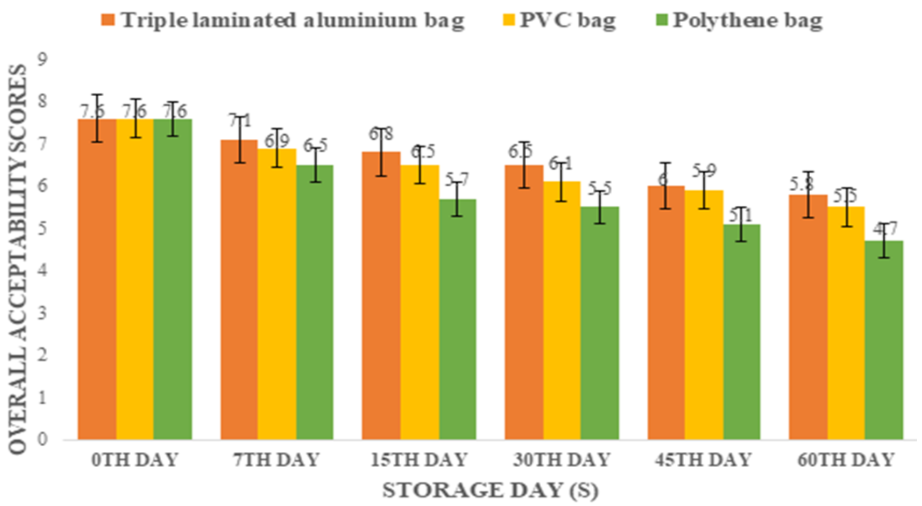

Fig. 9. *Overall acceptability of developed value-added papads during storage in different packaging materials*

tion of these laminated aluminium bags is often higher than any plastic laminate material, protecting the migration of moisture, oxygen, other gases, aromatic volatiles, and light (Ibrahim *et al*., 2022). As evident from Fig. 8, the triple laminated bag exhibited higher barrier properties against moisture content (12.45% to 16.25%) during the storage period from 0 to 60 days and consequently scored well in terms of overall acceptance (Fig. 9). The greatest increase in moisture content was recorded in the sample stored in polythene packaging material, i.e., from 12.45% to 20.26% due to its comparatively lower moisture barrier properties. After one month, the overall acceptability scores of all samples held in various packaging materials declined substantially, suggesting higher microbiological activity due to increased moisture content and water activity. This suggested that the *papad* made with the incorporation of CPP was acceptable for up to one month. Since consumer acceptance is greatly influenced by the product's organoleptic characteristics, which in this case were affected by the increased levels of CPP incorporation, considerable effort is required to optimize the concentration of CPP used to develop such traditional food recipes.

Conclusion

Carrot pomace is produced in vast quantities in the fruit and vegetable processing industries, posing major environmental concerns. Therefore, a modest attempt was made to utilize the carrot pomace powder (CPP) byproduct to develop a fiber-rich product that every household could potentially consume. The developed value-added *papad* was examined for its proximate composition, sensory attributes, and microbiological quality. The shelf life of the developed value-added *papad* (sample P_1) was found to be 30 days (from the microbiological study). *Papads* supplemented with CPP had reduced diametrical expansion and oil uptake (%) compared to the control group. Based on the present findings, P_1 (black gram flour: carrot pomace; 90: 10) was determined to be the most acceptable in terms of all sensory attributes, with nutritional values of carbohydrates, protein, ash, fat, and crude fiber as 45.74, 17.41, 5.22, 3.51, and 15.67%, respectively. The incorporation of CPP significantly improved the fiber content of developed Indian recipe *papads;* however, it had a detrimental impact on the textural quality due to increased hardness. Thus, being a less expensive fiber-rich food source, it will aid in the low-cost valorization of food items and the utilization of industrial waste. Further research may include an in-depth examination of the nutritional constituents of the developed value-added *papad*. Moreover, the study could be exploited to analyze the impact of CPP incorporation at varying levels on the rheological and textural properties of such developed *papads*.

Conflict of Interests

The authors declare that they have no conflict of interest.

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