

**Global Research journal of Natural Science
& Technology (GRJNST)**

Volume: 04 - Issue 2 (2026), 2075

ISSN P: [2790-7643](https://doi.org/10.53762/grjnst.04.02.26) ISSN E: [2790-7651](https://doi.org/10.53762/grjnst.04.02.26)

www.grjnst.net

<https://doi.org/10.53762/grjnst.04.02.26>

Quality and Nutritional Evaluation of Oat Cupcakes Enriched with Carrot Pomace

Received: 23 January 2025. Accepted: 5 March 2026. Published: 26 April 2026

Hira Jabeen

Faculty of Food Science and home nutrition
Muhammad Nawaz Sharif University of Agriculture, Multan, Pakistan
(heerajabin@gmail.com)

Shabbir Ahmad

Faculty of Food Science and home nutrition
Muhammad Nawaz Sharif University of Agriculture, Multan, Pakistan
Corresponding Author: (Shabbir.ahmad@mnsuam.edu.pk)

Hafiza Mamoonah Ahmad

Faculty of Food Science and home nutrition
Muhammad Nawaz Sharif University of Agriculture, Multan, Pakistan
(monaahmadmsfstoi@gmail.com)

Sadaf Yaqoob

Department of Food Science and Technology
Bahauddin Zakriya University, Multan, Pakistan
(sadafchi69@gmail.com)

Umair Raza

Faculty of Food Science and home nutrition
Muhammad Nawaz Sharif University of Agriculture, Multan, Pakistan
(umairraza5588@gmail.com)

Saba Kanwal

National Institute of Food Science and Technology (NIFSAT)
University of Agriculture Faisalabad
(dietitiansabakanwal@gmail.com)

Afshan Tehseen Asghar

Institute of Home Sciences (IHS)
University of Agriculture Faisalabad
(dietianafshantehseenasghar@gmail.com)

Abstract: Carrot pomace is the by-product of juice that is rich in fiber. Carrot pomace contains fiber and provides nutritional benefits for humans. Oat (*Avena sativa* L.) is the member of member of the Poaceae family and the fourth most significant cereal crop in the world. The basic purpose of this research was to utilize the carrot pomace in oat cupcakes in order to enhance value chain of oat (neglected cereal) and carrot pomace (by product). In this research carrot pomace powder was prepared by using the hot air oven. After that proximate analysis (moisture, fat, fiber, ash and protein) of raw material was performed. Then the cupcakes were prepared by two different methods one by using 5%, 10% and 15% carrot pomace (CP) and secondly by using 5%, 10% and 15% of carrot pomace powder (CPP) with 45%, 40% and 30% oat flour. Density and pH of batter was observed in range of 1.03 ± 0.05 to 0.89 ± 0.04 and 6.23 ± 0.29 to 7.02 ± 0.24 . Moisture, protein, fiber and ash were increased among treatments in both CP and CPP while on the basis of sensory analysis (overall acceptability) of prepared cupcakes was analyzed that T2 (10% CP) and T5 (10% CP) was more accepted. It was concluded that cupcakes 10% CP and CPP can be utilized with oat flour for preparation of fiber rich cupcakes.

Keywords: fiber, carrot pomace powder, oat flour, cupcak

I. Introduction

Vegetable by-products are high in fiber and other nutrients. Additionally, they are easily available and reasonably priced. *Daucus carota*, a common root vegetable, is frequently used to manufacture juice. Around 60–70% of the carrots are processed into juice, with the remainder being lost as pomace (Majzoobi et al., 2016). Carrot pomace is a mineral-rich byproduct of the juice-making industries (Afsharian et al., 2021). Different drying methods are available to remove moisture out of food. The procedure used should provide a dried good of the highest possible quality, with little suitable content, acceptable sensory properties, high nutritional value, and structural change. The ideal drying procedure must be used, as well as the ideal drying parameters, to produce such a dried product (Trilokia et al., 2022).

CPP is made by pressing the carrot juice, discarding the non-edible parts and rinsing the carrots in water from the tap. The leftover material (pomace) is then dried for 12 hours at 40°C. A grinding mill and sieves are used to produce CPP in various particulate sizes (Kohajdova et al., 2012). Carrot pomace powder has high dietary fiber, contains approximately 50% β -carotene and hydration properties. According to the chemical composition of CPP, TDF's content (55.70%) was lower than that of a number of other agricultural by-products, such as tomato fiber (65.9%) and asparagus by-products (62-77%) (Fuentes-Alventosa et al., 2009). This byproduct's incorporation into wheat dough increases dough development time, water absorption, and dough stability and decreases the mixing tolerance index, as well as bread volume and cambering. The judges liked bread with up to 3% carrot pomace powder best (Kohajdova et al., 2012).

Oats are the cereal that garners the most attention in this context due to their nutritious benefits. Its grain has a favorable fatty acid composition, is high in dietary fiber and protein contains (Czubaszek and Karolini-Skaradzinska, 2005). In temperate areas, a well-known annual crop is oats (*Avena sativa L.*). A member of the Poaceae family like all other grains, oats are referred to as "Jai" or "Javi" in India. The common oat is the most widely grown species of oat. Similar to wheat, it is an annual crop with a claimed Asian origin. It is an annual crop it benefits both people and animals. Because oats don't contain gluten, they are frequently served as flakes, breakfast cereals, or porridge prepared from crushed or rolled oats. Oatmeal or oat flour is used in a wide range of baked goods, including composite bread made with oats and wheat flour (Butt et al., 2008). Because oats are a significant source of proteins, minerals, fiber, lipids and vitamins including them in a gluten-free diet may help a celiac patient's nutritional condition. European rules required that the gluten-free substances included oats are required for celiac disease persons, but their safety for celiac sufferers to eat is still a big issue. According to some research, contamination from other cereal source is the main challenge faced by persons with this condition, and pure oats are acceptable for the majority of celiac patients (Comino et al., 2015).

The food industry is currently working hard to utilize oats more frequently in the creation of novel products. The creation of novel oat products may expand the market's selection of functional foods and help prevent

chronic diseases (Martinez-Villaluenga and Penas, 2017). Oats are frequently served as flakes, breakfast cereals, or porridge prepared from crushed or rolled oats. Oatmeal or oat flour is used in a wide range of baked goods, including composite bread made with oats and wheat flour (Butt et al., 2008). Oats are thought to provide a variety of health advantages, such as the capacity to reduce cholesterol and have anti-cancer characteristics. Oats were recently allowed in the diets of those with celiac disease (Rasane et al., 2015).

However, it is important to take into consideration that oats exist in a variety of forms, with varying amino acid sequences and immunological reactivity linked to harmful prolamins and carrot pomace are abundantly found with high nutritional value. Thus, the aim of this study is to utilize the carrot pomace(waste) with oat flour in baking product like cupcakes and increase their quality and nutritional value.

I. Materials and methods

I.1. Material procurement

Carrot and oats, wheat were being purchase from local market Multan Pakistan. All Chemicals that were use in research purpose was be obtain from BDH, Sigma Aldrich, Emplura, and Duksan Pure Chemicals.

I.2. Proximate analysis of raw materials

Carrot pomace, wheat and oat flour was tested for ash, crude fat, crude protein, crude fiber and moisture using the described method in AACC (2000).

I.3. Preparation of composite flour

Wheat and oats were milled by using the micro mill (Culatti

Type MFC) to form whole meal flour. For the removal of impurities, the samples for carrot pomace were washed in flowing water. Using a stainless-steel knife, unwanted parts were removed and then cut with the same instrument. Using a juice Mixer Grinder and a Food Processor, the juice was extracted. The collected carrot pomace will be dry by oven at $55 \pm 1^\circ\text{C}$ followed by (Kumar et al.2012) and then grinded with a laboratory grinder at cereal lab as shown in fig no. I.

After that composite flour was prepared according to treatment plant given in Table No. I.

Table No. I Treatment plan for preparation cupcakes with carrot pomace and carrot

Treatments	Wheat flour	Oat flour	Carrot pomace	Carrot pomace powder
T0	100%	----	----	----
T1	50%	45%	5%	
T2	50%	40%	10%	
T3	50%	35%	15%	



Fig no. 1

T4	50%	45%		5%
T5	50%	40%		10%
T6	50%	35%		15%

I.4. Rheological properties of composite flour

Rheological properties (water absorption, dough development time, and dough stability) of composite flour were analyzed by farinograph followed AACC (2000).

I.5. Preparation of batter

A control cupcake was made with 3/4 cup of sugar, 2 teaspoons of baking powder, 1/2 teaspoon of salt, 1/2 cup of oil, 2 eggs, 1 1/2 cups of flour, 1/2 cup of milk, and 1 teaspoon of vanilla extract. After adding the wet ingredients to the dry ones, the mixture was stirred until it was smooth and creamy. Preparation of batter for treatment dry ingredients contains composite flour according to the treatment plan.

I.6. Analysis of batter

A calibrated pH meter was used to determine the pH of the batter when it was heated to 20 degrees (Gomez et al 2011). The ratio of the weight of a standard container filled with batter to the weight of the same container filled with distilled water was used to calculate the density of the batter.

I.7. Baking of cupcakes

Before preparing cupcakes, an electric baking oven (Nan-e-Razavi Company, Iran) was preheated for 15 minutes at 180°C. Following steps followed in mixture preparation as shown in fig no 2. The cake mixture was poured into a baking mold and baked for 15-20 minutes at 180 °C. The cupcakes were then removed from the oven and allowed to cool down at room temperature for one hour. For further research, the cupcakes were placed in polyethylene bags and stored at room temperature.



Fig no. 2

I.8. Chemical analysis of Cupcakes

Cupcakes valuated for moisture, protein, ash, fat, fiber and NFE according to the method described in AACC (2000).

1.9. Texture analysis of cupcakes

According to Kirbas et al. (2019), the texture of the cake samples was analyzed using a texture analyzer (Force measurement IMADA Texture Analyzer, Model FTRS). In the analysis, a cylindrical compression prob with a 36 mm diameter was used. The cupcakes have been formed into rectangular shapes measuring 20mm×40mm×40 mm at the product's center. Standard equipment settings were used and the probe was moved at 2mm/s with a 30-second interval between the first and second compressions.

2.10. Evaluation of color of cupcakes

A colorimeter was used to get an accurate reading of both the surface color and the particle color of the cupcakes (CR-400 Konica Minolta Sensing Singapore) according to the method outlined by Konuk Takma et al. (2021). The L^* (lightness/darkness), a^* (redness/greenness), and b^* (yellowness/blueness) The color values were taken three times for each sample in order to provide an accurate picture of the changes in color that were caused by the various treatments.

2.11. Sensory analysis

As explained by Drabinska et al. (2018) a sensory evaluation of cupcakes was carried out by fifteen trained panelists. Using a nine-point hedonic scale, panelists evaluated the appearance, flavor, color, texture, aroma, taste, aroma and overall acceptability of the cupcakes (1=severely dislike, 5=fair, and 9=outstanding). Each sample was compared to a control sample. Cupcakes in the control sample were made from 100% wheat.

2.12. Statistical analysis

Triplicate analyses of all samples were performed to ensure the highest level of data reliability for the statistical evaluation. The significance of differences was determined using analysis of variance (ANOVA) in accordance with Montgomery (2017) guidelines. Statistics 8.1 was used for each of the resulting parameters, and the significance of the results was examined. A standard highly significant difference ($p<0.01$), significant differences ($p<0.05$), and non-significant difference ($p>0.05$) were established.

2. Results and discussions

2.1. Chemical composition of raw materials

In accordance AACC, (2000), wheat, oat, and carrot pomace powder were examined to determine their levels of moisture, ash, crude protein, crude fat, and crude fiber. Detailed results of raw material for proximate analysis are given in Table No. 2. It is found that oat and carrot pomace powder having high fiber and ash content while wheat flour having high protein. The current finding of wheat flour was in favor of David et al. (2015).

Table No. 2 Results of chemical composition for raw materials

Analysis	Moisture%	Ash%	Fat%	Fiber%	Protein%	NFE%
Wheat flour	11.52±0.42	0.89±0.01	1.35±0.04	1.45±0.05	12.98±0.60	70.81±0.97
Oat flour	11.02±0.36	2.04±0.02	7.99±0.37	13.75±0.63	12.34±0.18	12.03±0.18

Carrot pomace powder	5.04±0.22	5.26±0.16	1.38±0.06	16.05±0.69	12.03±0.18	59.24±1.37
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Mean values are given \pm Standard deviation T0=100% wheat flour; T1=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace 5%; T2=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace 10%; T3=Wheat Flour 50%, Oat Flour 35%, Carrot Pomace 15%; T4=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace powder 5%; T5=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace Powder 10%; T6=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace Powder 10%

2.2. Rheological properties of composite flour

Water absorption consistency (WAC)

According to the result, mean square of water absorption of composite flour showed highly significant difference ($p < 0.01$) among treatments. Table No. 3 WAC increased with increasing CPP amount from 60.67% (control sample) to 72.01% (sample with 10% CPP substitution). Tanska et al. (2007) observed similar effects on WA when dried carrot pomace and mango peels were mixed together into wheat dough. This effect is explained in part by the fact the large number of hydroxyl groups present in the fiber structure that interacts with the hydrogen bonds of water. Current findings are similar with Zaki and Hussien (2018). Who found the value of WA between 67.5 to 76.5% of composite flour prepared by oat and wheat flour with different percentage.

Dough development time (DDT)

CP and CPP addition of 5, 10, and 15% increased DDT from 6.34 to 7.82 min (Table No.3). During mixing, water hydrates, flour components, and dough form (Jurasova and Kukurová, 2011). Similar trends in DDT were observed by Ashoush and Gadallah (2011). The combination between fiber and gluten, which prevents protein from becoming hydrated, might be responsible for the increase in DDT (Gomez et al., 2011). The present findings are closely related with Kohajdova *et al.* (2021) who found the DDT between 6.83 to 7.91 min.

Dough stability (DS)

DS has been associated with the quality of the protein matrix, which can easily be damaged by the addition of additional ingredients. The addition of CP and CPP resulted in an increase of DS from 6.91 to 8.13 min (Table No.3). These observations were similar with Kohajdova *et al.* (2012) those obtained DS between 6.83 to 10.35 min.

Table No. 3 Results of rheological properties for composite flour

Treatments	T0	T1	T2	T3	T4	T5	T6
WAC%	56.21±0.90	68.84±0.89	68.37±0.96	68.04±0.20	72.03±0.22	72.64±0.14	73.14±1.02
DDT (min)	5.34±0.09	6.34±0.08	6.83±0.12	7.65±0.15	6.62±0.14	7.17±0.20	7.82±0.13
DS (min)	5.67±0.07	6.98±0.12	6.95±0.13	6.91±0.02	6.21±0.01	7.34±0.21	8.13±0.14

Mean values are given \pm Standard deviation T0=100% wheat flour; T1=Wheat Flour 50%, Oat Flour 45%,

Carrot Pomace 5%; T2=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace 10%; T3=Wheat Flour 50%, Oat Flour 35%, Carrot Pomace 15%; T4=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace powder 5%; T5=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace Powder 10%; T6=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace Powder 10%

2.3. Analysis of batter

pH of batter

Comparing the both CP and CPP, CPP imposed significant ($p < 0.05$) difference in pH value of batter of cupcakes. Mean values of pH content ranged from 6.23 ± 0.29 to 7.02 ± 0.24 (Table No. 4). The value of the pH of a solution indicates its acidity or alkalinity. 7 is considered neutral on this scale, which ranges from 0 to 14. A pH value below 7 means acidity, whereas a pH value above 7 means alkalinity. Recent findings are comparable to those of Majzoobi et al. (2016), whose range of batter pH is 6.93 to 6.77. The pH value of batter is decreasing by increasing the percentage of CP and CPP. This could be due to the CPP contains organic acids (such ascorbic acid and caffeic acid), proteins and amino acids (most notably glutamic acid), and other acidic components (Sharma et al., 2012).

Density of batter

According to the result, mean square of density content of cupcakes showed highly significant difference ($p < 0.01$) among treatments. Table No. 4 showed that highest value 1.03 ± 0.05 of density was observed in treatment in T6 (15% CPP) and lowest value 0.89 ± 0.04 was found in T1 (5% CP). According to Majzoobi et al. (2016), the density of batter ranges from 0.89-0.99 gcm⁻³. These results are comparable to those of the present study. Density increases with increasing the percentage of carrot pomace, carrot pomace powder and oat flour. The addition of lupine, buckwheat flour, and extruded broken bean flour to gluten-free batter or rice and wheat fodder and oat fiber to wheat flour batter produced comparable results Levent and Bilgicli (2017).

Table No. 4 Results of pH and density (gcm⁻³) of batter for cupcakes

Treatments	T0	T1	T2	T3	T4	T5	T6
Density	0.85 ± 0.05	0.89 ± 0.04	0.97 ± 0.03	1.02 ± 0.05	0.91 ± 0.03	0.97 ± 0.04	1.03 ± 0.05
pH	7.02 ± 0.34	6.69 ± 0.21	6.43 ± 0.28	6.36 ± 0.23	7.05 ± 0.32	6.96 ± 0.22	6.23 ± 0.29

Mean values are given \pm Standard deviation T0=100% wheat flour; T1=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace 5% ; T2=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace 10%; T3=Wheat Flour 50%, Oat Flour 35%, Carrot Pomace 15%; T4=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace powder 5%; T5=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace powder 10%; T6=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace powder 10%

2.4. Chemical composition of cupcakes

The analysis of variance of chemical composition of cupcakes presented in Table No. 5 showed highly significant difference ($p < 0.01$) among treatments, among control vs. others and among CP vs. CPP. The moisture, in this study is increasing among the treatments due to addition of both carrot pomace and carrot pomace powder as

described by Majzoobi *et al.* (2016) and due to addition of different cereals moisture is increased (Jabeen *et al.*, 2022). The fat content of cupcakes calculated in this study is similar to that reported by Mane and Kadam, (2021b), who found 20.02% to 23.13% fat content in Ragi supplemented cupcakes. Fat content in all treatments was decreased because both oat and CPP have low fat contents so increasing CPP decrease the fat value (Majzoobi *et al.*, 2016).

2.5. Color analysis of cupcakes

According to results in Table No.6, mean values of L^* in cupcakes found highest value (45.20 ± 1.73) and lowest value (31.99 ± 1.30) observed in "T6 (15% CPP) and T1(5%CP)". Highest value of a^* and b^* is shown in treatment in T1 with mean value 18.10 ± 0.95 and lowest in T6 (Table No. 6). The value of L^* is increasing while b^* and a^* is decreasing in both CP and CPP because of presence of coloring compound like anthocyanin in carrot. These findings are similar with Gadallah *et al.* 2017). The incorporation of CPP also revealed that the orange color of wheat roll crumbs is caused by carotenoids, notably β -carotene, which is principally responsible for the color of carrots (Kohajdova *et al.*, 2012).

2.6. Hardness of cupcakes

Mean value of hardness is described in Table. No.6 highest value of hardness for texture is shown in treatment in T3(15% CP) with mean value 7.57 ± 0.23 and lowest in T4 (5% CPP) with mean value of hardness is 4.63 ± 0.50 (control, T0 = 9.78 ± 0.42). Hardness of cupcakes depends upon the size of particle. As the CP has higher particle size that's why hardness is increase among as compare to CPP. Hardness of cupcakes reduced with reducing particle size (Kim and Shin, 2014). The texture analysis of cupcakes calculated in this study is similar to that reported by Ahmadi *et al.* (2022), who found 0 to 40 hardness in apricot kernel flour supplemented cupcakes.

Table No. 6 Mean value of color analysis (L^* , a^* and b^*) and hardness (N) of cupcakes prepared by composite flour

Analysis	T0	T1	T2	T3	T4	T5	T6
L^*	49.18 ± 1.82	31.99 ± 1.30	34.01 ± 1.94	34.19 ± 3.52	34.03 ± 2.03	37.89 ± 2.85	45.20 ± 1.73
a^*	9.78 ± 0.42	18.10 ± 0.95	14.63 ± 0.81	12.46 ± 0.84	13.26 ± 0.70	11.89 ± 1.19	6.63 ± 0.52
b^*	30.22 ± 1.09	42.17 ± 4.19	30.48 ± 2.01	28.39 ± 1.69	27.97 ± 1.71	27.86 ± 1.99	21.83 ± 1.77
Hardness (N)	7.33 ± 0.72	5.30 ± 0.17	6.50 ± 0.36	7.57 ± 0.23	4.63 ± 0.50	4.80 ± 0.26	7.43 ± 1.12

Mean values are given \pm Standard deviation T0=100% wheat flour; T1=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace 5%; T2=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace 10%; T3=Wheat Flour 50%,

Oat Flour 35%, Carrot Pomace 15%; T4=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace Powder 5%; T5=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace Powder 10%; T6=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace Powder 10%

2.7. Sensory evaluation of cupcakes

Evaluation of overall acceptability (Table 7) showed that acceptance of products with higher content of CP and CPP up to 10% acceptable above that was markedly decreased because it negatively affected taste, color, odor, and hardness of final products this is highly related to the study of Kohajdova *et al.* (2012). Generally, harder texture is expected for high density cake which was observed for both CP and CPP as early reported by Majzoobi *et al.* (2016), a sponge cake made by gluten free flour and different amount of CPP used.

Table No. 7 Results for sensory evaluation of cupcakes

Analysis	T0	T1	T2	T3	T4	T5	T6
Color	7.27±0.70	6.20±1.47	7.00±0.93	6.47±1.06	7.53±0.83	7.50±0.64	6.20±1.3 2
Appearance	7.27±0.88	6.33±1.29	6.20±1.26	6.33±1.11	7.87±0.64	7.80 ± 0.68	6.40±1.3 6
Texture	7.20±0.86	6.53±1.13	6.27±1.22	6.13±1.25	7.40±0.83	7.87±0.35	6.40±1.0 6
Aroma	6.80±1.15	6.87±0.92	6.07±0.96	6.60±0.74	7.27±0.88	7.60±0.83	6.67±0.8 2
Flavor	7.40±0.63	6.93±1.03	6.27±0.80	6.67±0.90	7.13±0.99	7.60±0.51	6.40±1.1 8
Taste	7.00±0.85	7.00±0.93	6.87±1.19	6.93±1.03	7.53±0.99	7.67±0.72	7.00±0.8 5
Overall Acceptability	7.40±0.63	6.13±0.83	6.47±1.36	6.40±0.99	7.67±0.62	7.93±0.26	6.27±1.1 6

Mean values are given ± Standard deviation T0=100% wheat flour; T1=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace 5%; T2=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace 10%; T3=Wheat Flour 50%, Oat Flour 35%, Carrot Pomace 15%; T4=Wheat Flour 50%, Oat Flour 45%, Carrot Pomace powder 5%; T5=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace Powder 10%; T6=Wheat Flour 50%, Oat Flour 40%, Carrot Pomace Powder 10%

3. Future Perspectives

Future studies should explore advanced formulation strategies to further optimize carrot pomace powder incorporation beyond 10% while preserving desirable sensory and textural properties. Novel ingredient engineering approaches, including hybrid protein systems and sustainable fortification matrices, may improve nutritional density and product functionality, as demonstrated in innovative protein blend research (Butt et al., 2025a; Butt et al., 2025b). Likewise, comparative product quality frameworks used in meat analogue and

processed food studies could be adapted to evaluate future bakery innovations for physicochemical, microbial, and consumer acceptability parameters (Butt et al., 2025c; Butt et al., 2024).

Further investigations may focus on the health-promoting potential of oat–carrot pomace cupcakes through probiotic enrichment, functional fermentation, and gut-health-oriented product design. Evidence from probiotic tempeh and functional yogurt studies suggests that incorporation of beneficial cultures may enhance metabolic wellness, digestive health, and consumer demand for preventive nutrition products (Ahmed et al., 2024; Rashid et al., 2026). In addition, the impact of such enriched cupcakes on obesity-related biomarkers, glycemic control, and epigenetic modulation should be assessed through dietary intervention trials, considering findings linking functional diets with insulin resistance and metabolic regulation (Butt et al., 2026b).

Since oats and carrot pomace contain antioxidant and micronutrient-rich compounds, future clinical studies may evaluate their protective role against oxidative stress, liver dysfunction, and exercise-related nutritional needs. Similar nutritional models have shown benefits of flaxseed oil, olive oil, and zinc supplementation in physiological health and growth regulation (Khan et al., 2024; Butt et al., 2026a). Such evidence supports the possibility of positioning these cupcakes as functional snacks for athletes, adolescents, and health-conscious populations.

From an agricultural sustainability perspective, future work may also integrate biofortified oats or carrots developed through modern breeding and genome editing tools. Advances in CRISPR-Cas mediated crop improvement for disease resistance, drought tolerance, and epigenome editing indicate strong potential for producing superior raw materials with higher resilience and nutrient quality for bakery applications (Jabeen et al., 2025; Fatima et al., 2026). This could strengthen the supply chain of climate-smart functional ingredients for food industries.

Industrial-scale commercialization should additionally assess digital optimization, consumer education, and ESG-based sustainable production systems. Artificial intelligence tools may support sensory prediction, process control, and market targeting, while broader sustainability frameworks can guide waste valorization and responsible manufacturing practices (Kamal et al., 2026; Khurshid et al., 2026). Finally, ergonomic and lifestyle research related to physical health and movement patterns may help tailor portion-controlled functional snacks for active consumers and rehabilitation populations (Mahmood et al., 2026). Overall, future progress lies in merging food waste utilization, functional nutrition, biotechnology, and smart sustainable manufacturing to transform carrot pomace cupcakes into next-generation health foods.

4. Conclusion

Food waste can also be used in term to increase the nutritional value of food products in term of direct use or by drying. Shortcomings of CP cupcakes are mostly related to their low volume, firm texture, and inferior sensory attributes then CPP. The results of this study revealed that CPP can be used more successfully than CP to reduce the food waste. The positive effects of CPP on physical and nutritional quality of the cupcake are mainly related to its high fiber, protein, and ash content. Increasing the percentage of CPP had significant positive effects on characteristics of batter and cupcake and sensory attributes of the cupcakes in terms of color, texture and overall acceptability. Therefore, addition of CP and CPP with up to 10% can be used to improve the quality of nutrition enrich cupcakes.

Conflict of interest

Authors declare that they have no conflicts of interest

Data Availability

Data will be available on demand.

Acknowledgement

Laboratory facilities provided by Department of Food Science and Technology, Faculty of Food and Home Sciences and Central Hi-Tech Laboratories, Muhammad Nawaz Sharif University of Agriculture Multan, Pakistan to execute the present work are duly acknowledged.

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Declaration: The current study was carried out in Department of Food Science and Technology, Muhammad Nawaz Sharif University of Agriculture Multan. The abovementioned titled manuscript has not been and will not be submitted to any other journal unless or until the final decision from the editor of Journal.

Funding: N/A

Conflict of Interest: There is no conflict of interest.

Ethics Approval: N/A

Consent to Participate: N/A

Consent for publication: N/A

Availability of Data and Material: It will be provided on demand

Code Availability: Yes, on demand