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Research Article

Impact of carrot pomace powder (CPP) on the physicochemical and sensory properties of mayonnaise

Mohammad Noshad[1*], Mohammad Hojjati[1] and Bahareh Goodarzi Shamsabadi[1]

1. Department of Food Science and Technology, Faculty of Animal Science and Food Technology, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, Iran

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Abstract

This study examines the effects of incorporating carrot pomace powder (CPP) into mayonnaise. Utilizing agricultural by-products like CPP can enhance nutritional value, improve product stability, and promote sustainability. Mayonnaise samples containing 1.5%, 3%, and 4% CPP were analyzed for physicochemical properties, texture, color, total phenolic content, pH and acidity and sensory attributes. The results indicated that the highest phenolic content (13.85) was found in sample with 4% CPP, while the lowest phenolic content (4.57) was in the control sample without CPP (S0). The results demonstrated that CPP improved emulsion stability, texture, and antioxidant capacity. The 4% CPP sample exhibited the highest firmness and adhesiveness, while the 3% CPP sample achieved the most favorable sensory evaluations. Additionally, CPP enhanced the natural color of mayonnaise due to its carotenoid content, contributing to a more appealing product. Although higher concentrations of CPP improved structural properties, excessive amounts slightly reduced consumer acceptability due to changes in texture and taste. Overall, the 3% CPP formulation provided the best balance between physicochemical enhancements and sensory appeal, making it the most suitable option. The findings suggest that CPP can serve as an effective natural fat substitute, reducing reliance on synthetic additives while enhancing the health benefits of mayonnaise. This approach not only contributes to the development of healthier food products but also promotes the sustainable utilization of agricultural waste, thereby reducing environmental impact.

Keywords: Carrot Pomace, Mayonnaise, Textural Profile, Total Phenol

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***** Corresponding author: Noshad@asnrukh.ac.ir

1. Introduction

The incorporation of agricultural by-products into food production contributes to enhanced nutritional value, economic efficiency, and environmental sustainability, reflecting the food industry's growing commitment to sustainable practice. This approach reduces waste and production costs while enabling the development of functional foods enriched with bioactive compounds, thus supporting environmental sustainability and food system [1-3]. The incorporation of fruit and vegetable pomace into mayonnaise formulations presents a promising strategy to improve the nutritional value, functional characteristics, and sustainability of this popular condiment [4–6]. Vieira et al. (2023) successfully showed that fruit flours, particularly nectarine flour, can serve as effective clean-label ingredients in mayonnaise formulations. They not only enhance the product's nutritional and sensory properties but also contribute to environmental sustainability by valorizing agricultural by-products. Future research should focus on scaling up production and conducting long-term microbiological studies to further validate the preservative potential of fruit flours in clean-label food products [7]. Similarly, previous studies have identified apple pomace as a potent source of bioactive compounds and explored the effects of apple, orange, and carrot pomace powders on gluten-free cake formulations. Notably, a 5% substitution with orange pomace powder increased dietary fiber content while preserving sensory properties comparable to control samples. [8]. Prokopov et al. (2023) investigated the incorporation of onion processing waste (OPW) into sunflower oil-based mayonnaise. Onion waste powder (OWP) was added at varying levels (0, 1, 2, and 3%), and the resulting formulations were evaluated for their characteristics. The study found that a 2% addition of OWP significantly increased phenolic compounds, flavonoids, and antioxidant activity, while maintaining product quality and consumer acceptability [9]. Carrot pomace, a byproduct of carrot juice extraction, has gained considerable interest in recent research due to its potential applications in food production [10]. Rich in dietary fiber, vitamins, and bioactive compounds, carrot pomace provides a sustainable approach to reducing food waste while improving the nutritional quality of diverse food products [11]. Moreover, the high carotenoid content in carrot pomace contributes to the natural coloration of food products. Studies have demonstrated that incorporating carrot pomace powder into food formulations can impart a desirable color, reducing the need for artificial colorants. This natural pigmentation, coupled with the antioxidant properties of carotenoids, enhances both the visual appeal and nutritional value of the final product [12]. Processing methods play a vital role in optimizing the functional properties of carrot pomace. Techniques such as freeze-drying have been shown to improve the water-holding and fat-binding capacities of carrot pomace, making it a more effective ingredient in emulsified products like mayonnaise. These treatments not only enhance the textural attributes but also preserve the nutritional quality of the pomace [9].

Richards et al. (2024), examined the chemical, functional, chromatic, and molecular properties of carrot pomace powders from four varieties. The results showed that *Belgrado* had the highest fiber and ash content, while *Sirkana* had the most protein and the least carbohydrates. Functionally, *Baltimore* exhibited the highest water absorption and retention. All samples had high foaming stability (FS > 94%). Chromatic analysis showed that *Baltimore* had the highest luminosity, while *Niagara* had the most intense yellow and red hues. FT-IR confirmed the presence of beta-carotene, fibers, carbohydrates, lipids, and proteins. The study concluded that, due to its nutritional and functional benefits, carrot pomace powder is a valuable ingredient for food formulations and contributes to waste reduction in the food industry [13]. Florina Stoica et al. (2024) investigated the use of black carrot pomace (BCP) as a nutrient-rich ingredient in yogurt formulations. Black carrot (*Daucus carota L.*), a by-product of industrial juice extraction, is rich in bioactive compounds, dietary fiber, antioxidants, and anthocyanin pigments, offering notable health benefits. The study found that adding BCP powder improved the nutritional profile and enhanced the color of yogurt, resulting in a more visually appealing and health-promoting product. Additionally, BCP increased the phytochemical content and antioxidant activity in the final yogurt formulation. The researchers concluded that such products contribute to sustainable food production while offering consumers innovative and nutritionally enriched options [14]. The present study aims to assess the feasibility of incorporating freeze-dried carrot waste powder as a fat substitute in mayonnaise and to evaluate its impact on the physicochemical, rheological, and sensory properties of the final product. By leveraging the nutritional and functional benefits of carrot by-products, this research seeks to develop healthier, more sustainable, and consumer-acceptable mayonnaise formulations.

2. Materials and methods

2.1 Carrot pomace powder (CPP) preparation

Carrots were procured from a local market in Ahvaz, Iran. After washing, excess surface moisture was removed, and the carrots were juiced. The resulting pomace was freeze-dried at −42 °C under a pressure of 0.10 mbar for 48 hours. The dried pomace was then ground into a fine powder using a Moulinex grinder (AR11083, France) and passed through a 60-mesh sieve (250 µm) to ensure uniform particle size. The final powder was stored in a dark, dry environment at room temperature until further use.

2.2 Characterization of physicochemical properties

The physicochemical parameters of CPP, including moisture content, acidity level, pH, and water activity, were determined using AOAC methods [15].

2.3 Mayonnaise preparation

At this stage, carrot powder was gradually used to replace oil in the formulation. Four samples were prepared: one control and three experimental formulations containing 1.5%, 3%, and 4% CPP, respectively, replacing an equivalent amount of oil. The control formulation was prepared following the method described by Golchubi et al. (2014), with slight modifications. The control ingredients included: oil (61.5 g), egg yolk (10 g), vinegar (5 g), mustard powder (1 g), water (20.5 g), salt (1 g), and sugar (1 g) [16]. To prepare the mayonnaise, salt, sugar, mustard powder, vinegar, and water were first dissolved. Oil was then gradually added to the aqueous mixture, and the emulsion was formed using a Moulinex electric mixer (France) operated for 10–15 minutes. Carrot pomace powder (CPP) was subsequently added at concentrations of 1.5%, 3%, and 4%, replacing an equivalent amount of oil in the formulation. Mixing continued until a uniform consistency was achieved. The resulting samples were coded as S1 (1.5% CPP), S2 (3% CPP), and S3 (4% CPP). A control sample was prepared following the same procedure without the addition of CPP. All samples were stored at 4 °C until further analysis.

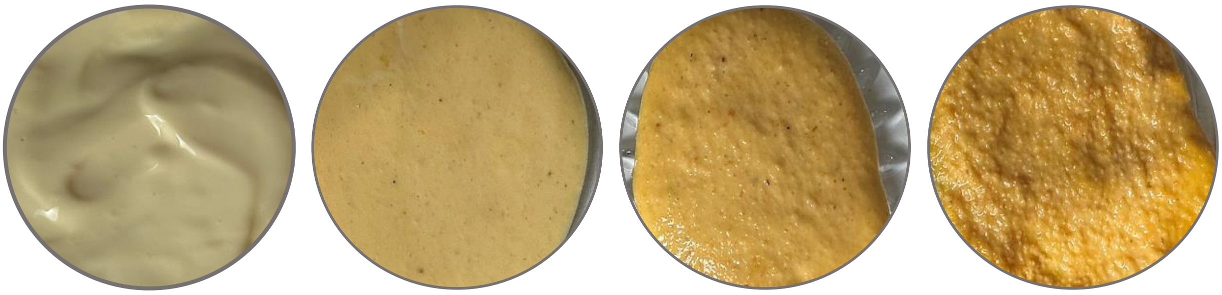

Fig 1. Images of the mayonnaise without CPP, control (S0); mayonnaise with 1.5% CPP (S1); mayonnaise with 3% CPP (S2); mayonnaise with 4% CPP (S3).

2.4 Color measurements

The color of mayonnaise samples was analyzed using a Minolta Colorimeter CR-400 (Osaka, Japan). In this test, the L* value represents lightness, a* indicates a tendency toward red and b* represents a tendency toward yellow [17].

2.5 Textural profile analysis

The textural characteristics of the mayonnaise samples were assessed using a Texture Analyzer (Model XT. PLUS, Stable Micro Systems, UK) using a back extrusion method. In this evaluation, a 5 kg load cell, a cylindrical probe, and a 35 mm compression disc were employed. Each sample was placed in a standard container with a diameter of 50 mm and a height of 75 mm. The probe was programmed to penetrate the sample at a speed of 1 mm/s to a depth of 50 mm. Key texture parameters—including firmness, chewiness, cohesiveness, and adhesiveness—were calculated from the resulting force–time curve. Each sample underwent three replicate measurements to ensure accuracy. Prior to testing, all samples were equilibrated at room temperature for two hours [18].

2.6 Physical stability

To evaluate the physical stability of the emulsion, 15 grams of each sample was accurately weighed into a

50 mL Falcon tube. The samples were centrifuged at 5000 rpm for 30 minutes to induce phase separation. After centrifugation, the weight of the sedimented phase was carefully measured to evaluate emulsion stability [19].

2.7 Determination of total phenol content

The total soluble phenolic compounds in the samples were quantified using the Folin–Ciocalteu assay. In this procedure, 15.8 mL of distilled water was first added to test tubes, followed by the addition of 1.0 mL of Folin–Ciocalteu reagent and 0.2 mL of the samples extract. The mixture was incubated for 10 minutes, after which 3 mL of 20% sodium carbonate (Na_2CO_3) solution was added to the reaction. The resulting solution was kept in the dark at room temperature for 60 minutes. After this incubation period, the absorbance was measured at 765 nm using ethanol as the blank. The total phenolic content was expressed as milligrams of gallic acid equivalents per gram of dry weight (mg GAE/g DW) [20].

2.8 pH and Acidity measurement of mayonnaise samples

To determine the pH of the mayonnaise samples, a 5% (w/v) solution was prepared. The pH was measured at 25°C using a calibrated pH meter, which was calibrated before each measurement to ensure accuracy and consistency. For acidity determination, 15 g of mayonnaise sample was diluted in 200 mL of distilled water to prepare a uniform solution. After adding an appropriate amount of phenolphthalein indicator, the solution was titrated with 0.1 N sodium hydroxide until a persistent color change signaled the endpoint. The acidity percentage, expressed as acetic acid, was calculated using Equation (1), where *s* represents the volume of sodium hydroxide consumed during titration, and *a* denotes the sample weight [21].

$$\text{Acidity}(\%) = \frac{\mathbf{0.006 \times S}}{\boldsymbol{A}} \times 100 \quad (1)$$

S = Volume of sodium hydroxide used in titration (mL)
A= Weight of the mayonnaise sample (g)

2.9 Determination of moisture content and fat in mayonnaise

The moisture content of mayonnaise was determined using the oven-drying method, following the AOAC official method [15]. Approximately 5 grams of the mayonnaise sample was accurately weighed. The sample was placed in a pre-weighed moisture dish and dried in a hot air oven at 105 ± 2°C for 3 to 4 hours until a constant weight was achieved. After drying, the sample was transferred to a desiccator to cool to room temperature before being weighed again. Moisture content was calculated using the following formula: (2).

$$\text{Moisture Content}(\%) = \frac{W1 - W2}{W1} \times 100 \quad (2)$$

W1 = Weight of the sample before drying (g)
W2= Weight of the sample after drying (g)

Fat content was determined using the Soxhlet extraction method (AOAC 963.15). A known weight of the mayonnaise sample was placed in a Soxhlet apparatus and extracted with hexane for 6 hours. After solvent evaporation, the extracted fat was dried at 105°C, cooled in a desiccator, and weighed to calculate the fat percentage [22].

2.10 Sensory analysis

The sensory characteristics (appearance, color, taste, texture, and overall acceptance) of mayonnaise samples were evaluated by a trained panel of 15 assessors, using the 9-point hedonic scale method. In this method, each attribute was rated on a scale from 1 (lowest satisfaction) to 9 (highest satisfaction). To ensure unbiased evaluation, the samples were randomly coded with serial numbers. Sensory evaluation was carried out one day after storing the samples at a temperature of 4°C, allowing adequate time for product stabilization prior to testing. This approach ensures a comprehensive and objective assessment of the mayonnaise samples based on the panelists' perceptions [23].

2.11 Statistical data

Statistical analysis was performed to evaluate the data, with mayonnaise samples prepared in two independent trials to ensure reproducibility. The study employed a completely randomized design to maintain objectivity and minimize bias. Data analysis was conducted using SPSS 19 for Windows (SPSS Inc., Chicago, IL, USA). One-way ANOVA was applied to determine statistically significant differences among groups at a 5% significance level. Mean comparisons were carried out using Duncan's multiple range test with a 95% confidence level. Graphs were generated using Microsoft Excel 2016.

3. Results and discussion

3.1. Characterization of Physicochemical Properties of CPP

The physicochemical analysis of carrot pomace powder (CPP) revealed several important characteristics relevant to its industrial applications. The moisture content was 4.24%, indicating good stability and an extended shelf life. The acidity was measured at 0.076% (as citric acid), while the pH was 4.845, reflecting a mildly acidic nature. Additionally, the ash content was 5.60%, suggesting a notable mineral presence that could contribute to enhancing the nutritional value of food products. Finally, the water activity (a_w) of the carrot pomace powder was measured at 0.48, indicating favorable microbiological stability that can help extend the product's shelf life. Carrot powder, derived from dehydrated carrots, serves as a functional ingredient providing a concentrated source of nutrients and bioactive compounds. Its physicochemical properties, which are influenced by processing methods, have important implications for its application in food products. Notably, carrot powder is rich in carbohydrates, dietary fiber, proteins, and essential minerals [24]. A study reported that carrot powder contains approximately 72.3% carbohydrates, 11.9% dietary fiber, 8.2% protein, and 4.8% ash [25]. In another study, the physicochemical properties of carrot pomace powder (CPP) were evaluated and compared its composition to that of fine wheat flour. The moisture content of CPP was reported as 9.13 ± 0.09%, which is slightly lower than that of fine wheat flour (10.72 ± 0.05%). Additionally, the ash content in CPP was significantly higher (1.39 ± 0.06%) compared to fine wheat flour (0.40 ± 0.02%), indicating a greater mineral content. These differences highlight the potential of CPP as a functional ingredient with unique compositional attributes [26].

3.2. Color measurement

The results showed that the color parameters (L*, a*, b*) exhibited significant differences across the various mayonnaise samples. Statistical analysis using one-way ANOVA demonstrated significant differences in all color parameters (L*, a*, and b*) among the samples ($p < 0.05$). The results are presented in Table 1.

Table 1. The color indices of the mayonnaise samples

Color Parameters	Mayonnaise Samples			
	S0	S1	S2	S3
L*	59.90 ± 2.78^{a}	54.44 ± 8.29^{a}	60.44 ± 6.65^{a}	42.42 ± 7.90^{a}
a*	-4.28 ± 0.26^{d}	-0.22 ± 0.11^{c}	0.67±0.12^{bc}	1.98±0.55^{a}
b*	18.40±0.86^{c}	21.9±2.40^{bc}	26.61±4.22^{b}	33.86±2.16a

Different letters indicate significant differences between samples.

The incorporation of natural colorants, such as carrot powder, into food products has been an area of increasing interest, particularly in the context of enhancing visual appeal while maintaining the product's natural and healthy image. In the present study, the color parameters (L*, a*, and b*) of mayonnaise samples were significantly altered by the addition of carrot powder, which is rich in carotenoids such as beta-carotene. The analysis of variance showed statistically significant differences in L* values among the mayonnaise samples. L* indicates the lightness of a product, ranging from 0 (black) to 100 (white). The significant variation indicates that the incorporation of carrot powder at different levels influenced the brightness of the mayonnaise. This may be attributed to the presence of natural pigments such as β-carotene, which can reduce lightness even at relatively low concentrations, especially when added to a light-colored product like mayonnaise. Similar findings have been reported in previous studies involving the use of natural colorants [24].

Significant differences were found in the a* values, with sample S3 exhibiting the highest value among the treatments. This result underscores the influence of carrot powder on the red-green color axis, indicating a clear shift toward the red spectrum. The increase in a* values correspond to the higher concentration of carotenoids—particularly β-carotene—present in the carrot powder, which imparts characteristic reddish-orange hues. As the level of carrot powder increased, the red tones became more visually prominent, reflecting the pigment's color-enhancing effect. The correlation between carotenoid content and the intensification of red coloration in food products has been well-documented in the literature [25], garnered increasing interest for enhancing visual appeal while maintaining a natural, health-conscious product profile. In the present study, the addition of carrot powder significantly influenced the color parameters (L*, a*, and b*) of mayonnaise samples, as confirmed by ANOVA results.

For the lightness parameter (L*), significant differences were observed among the treatments, with higher concentrations of carrot powder associated with lower L* values. This suggests that the addition of carrot powder led to a decrease in brightness, likely due to the presence of carotenoids such as β-carotene, which can impart darker tones even at relatively low concentrations. Given that mayonnaise is inherently light in color, the incorporation of pigmented compounds has a noticeable effect on its appearance. In terms of the red-green axis (a*), highly significant differences were found, with sample S3 exhibiting the highest a* value. This indicates a clear shift toward the red end of the spectrum as the concentration of carrot powder increased. Carrot powder is rich in reddish-orange carotenoids, particularly β-carotene, which intensifies the red hue of the product. The enhancement of a* values reflect the dose-dependent impact of carotenoids on color development, in agreement with previous studies on natural colorants [26].

Similarly, the b* values, which represent the blue-to-yellow color transition, also showed significant variation among samples, with sample S3 again recording the highest value. This indicates a pronounced shift toward a more intense yellow coloration. Carrots, naturally high in yellow-orange pigments, contribute to this effect through the effective dispersion of carotenoids in the mayonnaise matrix. These pigments likely interact with emulsifying agents to create a homogenous and visually vibrant yellow tone [22]. This observation aligns with prior research demonstrating that carotenoid-based colorants can significantly enhance the yellow intensity of food products, thereby improving their visual appeal. Overall, the shift in color parameters due to the addition of carrot powder not only reflects the functional role of natural pigments in product formulation but also supports growing consumer preferences for clean-label and naturally colored foods. The enhanced red and yellow tones in the treated samples could increase consumer acceptance, as bright and vibrant colors are often associated with freshness and quality [23].

3.3. Textural properties of mayonnaise

Table 2 presents the texture parameters (Firmness, Chewiness, Cohesiveness, and Adhesiveness) of mayonnaise samples (S0, S1, S2, and S3). Based on the obtained results, varying concentrations of cpp had a significant impact on the texture properties of mayonnaise. Among the different cpp concentrations, the 4% cpp sample showed the most prominent effects across various texture parameters, notably in terms of firmness, chewiness, and adhesiveness. This indicates that 4% cpp significantly improved the texture properties of the mayonnaise .This characteristic could contribute to improving the texture and increasing the quality of mayonnaise, especially in applications that require a soft and springy texture. Overall, the results indicate that using higher cpp concentrations, particularly 4%, has favorable effects on the texture properties of mayonnaise, enhancing its functionality and potential performance in diverse applications.

Table 2. Texture Parameters of Mayonnaise Samples

Texture parameter	Mayonnaise Samples			
	S0	**S1**	**S2**	**S3**
Firmness	0.472 ± 0.28^{b}	0.327 ± 0.28^{bc}	0.608 ± 0.1^{ab}	1.002 ± 0.76^{a}
Chewiness	0.423 ± 0.15^{b}	0.271 ± 0.12^{bc}	0.542 ± 0.29^{ab}	0.920 ± 0.16^{a}
Cohesiveness	0.913 ± 0.1^{a}	0.922 ± 0.3^{a}	0.927 ± 0.03^{a}	0.964 ± 0.17^{a}
Adhesiveness	-0.565 ± 0.07^{ab}	-0.280 ± 0.08^{b}	-0.490 ± 0.08^{ab}	-0.852 ± 0.14^{a}

Different letters indicate significant differences between samples.

Texture is a critical factor influencing consumer acceptance and the overall sensory appeal of food products. This study evaluated the effects of different concentrations of carrot pomace powder (CPP) on key textural parameters of mayonnaise, including firmness, chewiness, cohesiveness, and adhesiveness. The results showed that different concentrations of CPP had a significant impact on the texture properties, with the 4% CPP formulation exhibiting the most notable changes across various parameters. Firmness is a measure of the resistance of a product to deformation when a force is applied. The data shows a marked increase in firmness from the control sample (S0) to the 4% CPP sample (S3). Specifically, the firmness value for S3 (1.002 ± 0.76) was significantly higher than the values observed for the other samples (S0, S1, and S2), indicating that the addition of 4% CPP enhanced the firmness of the mayonnaise. This increase in firmness could be attributed to the structural contribution of the CPP, which may have strengthened the network of the emulsion, making the product firmer. Higher concentrations of natural fibers, like those found in carrot pomace, are known to enhance the structural properties of emulsions [28], which is consistent with the results found in this study. Chewiness also showed an increase with higher concentrations of CPP, with the 4% CPP sample (S3) exhibiting the highest value (0.920 ± 0.16). This suggests that the 4% CPP formulation not only increased the firmness but also contributed to a chewier texture, which is often desirable in mayonnaise products as it can provide a more satisfying mouthfeel. The increase in chewiness could be due to the improved structural integrity of the mayonnaise, allowing for more resistance to chewing [29].

Cohesiveness refers to the extent to which a product can maintain its integrity and resist breaking apart when a force is applied. The values for cohesiveness remained relatively consistent across all samples, with the 4% CPP sample (S3) showing a slightly higher cohesiveness (0.964 ± 0.17) compared to the other samples. Although the differences were not statistically significant, the trend suggests that the addition of higher concentrations of CPP slightly improved the cohesiveness of the mayonnaise. This may be because the natural fibers in CPP help to improve the emulsion stability and prevent the separation of phases, leading to a more cohesive product [30]. Adhesiveness measures the ability of a product to stick to surfaces. The results show that adhesiveness was significantly higher for the 4% CPP formulation (S3), with a value of -0.852 ± 0.14. This increase suggests that the addition of 4% CPP enhanced the adhesive properties of the mayonnaise, making it more likely to stick to surfaces such as bread or other food items. This is a desirable trait for mayonnaise, as it ensures that the product can adhere better to food, enhancing the sensory experience for consumers. The clear improvements in firmness, chewiness, adhesiveness, and cohesiveness observed with the 4% CPP formulation suggest that higher concentrations of carrot pomace powder could be used to enhance the texture properties of mayonnaise. This could have several practical applications in the food industry, as these texture improvements may lead to better product performance in both sensory and functional terms [24]. For example, the enhanced adhesiveness could improve the spread ability of mayonnaise, while increased firmness and chewiness might appeal to consumers who prefer a thicker and more substantial product [31]. Moreover, the addition of CPP, a natural by-product of carrot processing, offers an opportunity to create a more sustainable product by utilizing food waste. The use of CPP not only improves the texture but also adds fiber to the product, which aligns with the increasing consumer demand for healthier and more natural food ingredients [23].

3.4. Physicochemical properties of mayonnaise samples

The physicochemical properties of different mayonnaise samples (S0, S1, S2, and S3) are presented in Table 3. The evaluated parameters include physical stability, fat content, pH, moisture, and acidity. The results indicate that the addition of CPP influenced these properties, with an increase in CPP levels leading to improved physical stability in the formulated samples. Furthermore, variations in fat content and pH suggest potential effects of CPP on the structural and chemical characteristics of the product. Additionally, changes in acidity could impact the stability and sensory acceptance of the final product. Overall, the findings highlight the role of different CPP formulations in modifying the physicochemical properties of mayonnaise.

Table 3 .Physicochemical Properties of Mayonnaise Samples

Parameters	**Mayonnaise Samples**			
	S0	S1	S2	S3
Physical Stability	81.16 ± 0.51^{d}	82.90 ± 0.14^{c}	85.2 ± 0.28^{b}	89.26 ± 0.09^{a}
Fat	59.50 ± 0.7^{a}	57.67 ± 0.15^{b}	55.03 ± 0.98^{a}	53.22 ± 0.18^{b}
pH	1.7 ± 0.014^{c}	2.34± 0.01^{a}	2.11 ± 0.01^{b}	2.15 ± 0.007^{b}
Moisture	31.67 ± 0.63^{ab}	32.66 ± 0.021^{a}	30.92 ± 0.37^{b}	31.25 ± 0.21^{ab}
Acidity	0.35 ± 0.014^{a}	0.18 ± 0.007^{c}	0.24 ± 0.007^{b}	0.23 ± 0.01^{b}

Different letters indicate significant differences between samples.

The results demonstrate the effects of CPP addition on these properties, with varying concentrations of CPP showing significant influence on the texture and stability of the mayonnaise formulations. Physical stability is a critical factor in ensuring that the mayonnaise maintains its texture and structure over time [20]. The results presented in Table 3 indicate that the addition of CPP led to an improvement in the physical stability of the mayonnaise samples. Specifically, the physical stability values increased from 81.16 ± 0.51 for the control sample (S0) to 89.26 ± 0.09 for the sample containing 4% CPP (S3). This suggests that higher concentrations of CPP contribute to a more stable emulsion, likely due to the reinforcing effect of the natural fibers present in the carrot pomace. The increase in stability with higher CPP concentrations may prevent phase separation and improve the shelf life of the product [32]. Fat content is a significant component of mayonnaise, influencing both its texture and taste. The results show slight variations in fat content across the different samples. The control sample (S0) had the highest fat content (59.50 ± 0.7), while the samples with CPP (S1, S2, and S3) exhibited lower fat contents, ranging from 55.22 ± 0.18 to 58.03 ± 0.98. The results showed that the fat content decreased proportionally with the increased levels of carrot pomace powder (CPP) in the formulation, reflecting the intentional replacement of fat with CPP. This targeted reduction aligns with the study's design and supports the potential for developing healthier mayonnaise formulations without significantly compromising texture or flavor [27]. The pH values of the mayonnaise samples varied slightly, with the control sample (S0) showing the lowest pH (1.7 ± 0.014), and the samples containing CPP showing higher pH values. These changes in pH suggest that the addition of CPP may affect the acidic environment of the mayonnaise, potentially altering the behavior of the emulsifiers and other ingredients. Such shifts in pH can influence the stability of the emulsion and affect the sensory characteristics of the product, including its taste [29]. Reduction in acidity could be due to the buffering capacity of the carrot pomace powder, which might neutralize some of the acids present in the mayonnaise. Lower acidity levels would improve the overall taste and sensory acceptance, potentially making the product more palatable [33]. Moisture content is another critical physicochemical property, impacting the texture and stability of mayonnaise. In the present study, the moisture content remained relatively stable across all samples, ranging from 30.92 ± 0.37 for sample S2 to 32.66 ± 0.021 for sample S1. The addition of CPP did not result in significant changes in moisture content, suggesting that the incorporation of carrot pomace powder does not significantly affect the water content in the mayonnaise. This consistency in moisture may be advantageous in maintaining the overall texture and sensory properties of the product [34].

3.5 Total phenol content

In this part of the research, the Folin-Ciocalteu method was used to evaluate the effect of adding carrot waste powder on the total phenolic content of the samples. The results show that the highest phenolic content was found in sample 3 with 4% CPP (13.85), while the lowest phenolic content (4.57) was in the control sample without CPP (S0). This indicates that adding carrot waste powder led to a clear increase in the phenolic compounds in these samples, with sample 4 showing the most significant enrichment (Figure 2).

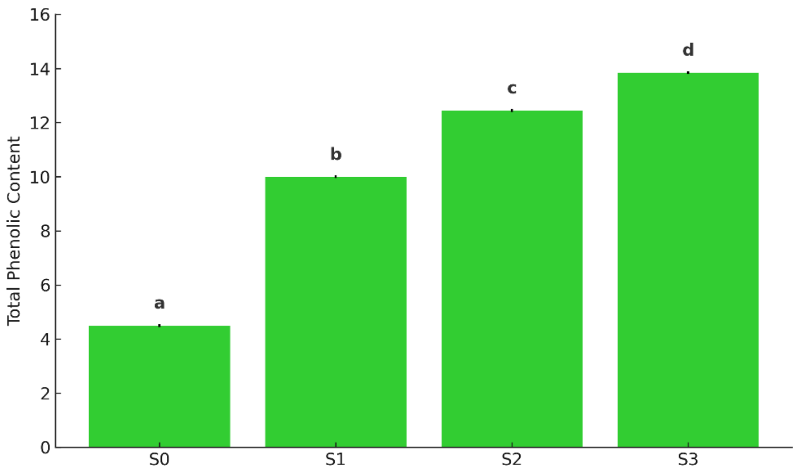

Fig 2. Total phenol content of Mayonnaise Samples

The total phenolic content in mayonnaise samples suggest that the incorporation of carrot pomace powder, which is rich in phenolic compounds, contributes to an increase in the antioxidant capacity of the mayonnaise. This enrichment could provide additional health benefits, such as reducing oxidative stress, and improve the nutritional profile of the product [35].

3.6. Sensory analysis

The sensory evaluation of mayonnaise samples (S0, S1, S2, S3) was conducted based on four different parameters: flavor, texture, color, smell, and general acceptance. In the flavor parameter, sample S2 with a score of 8.65 ± 0.7 received the highest rating, while sample S3 with a score of 6.25 ± 0.35 scored the lowest. For texture, sample S2 with a score of 7.83 ± 0.42 showed the best performance, while sample S3 with a score of 5.47 ± 0.35 had the lowest score. In the color parameter, sample S2 with a score of 8.04 ± 0.63 received the highest score, while sample S3 with a score of 7.06 ± 0.84 had the lowest. In terms of smell, sample S2 with a score of 8.03 ± 0.42 achieved the highest rating, while sample S3 with a score of 7.22 ± 0.32 received the lowest score. Finally, for general acceptance, sample S2 with a score of 8.77 ± 0.11 showed the highest acceptance, while sample S3 with a score of 6.5 ± 0.71 received the lowest. The results, shown in Figure 3, indicate that sample S2 generally outperforms the other samples in sensory attributes, while sample S3 received the lowest ratings in most parameters. These findings may assist in optimizing the formulation and optimizing the sensory characteristics of mayonnaise.

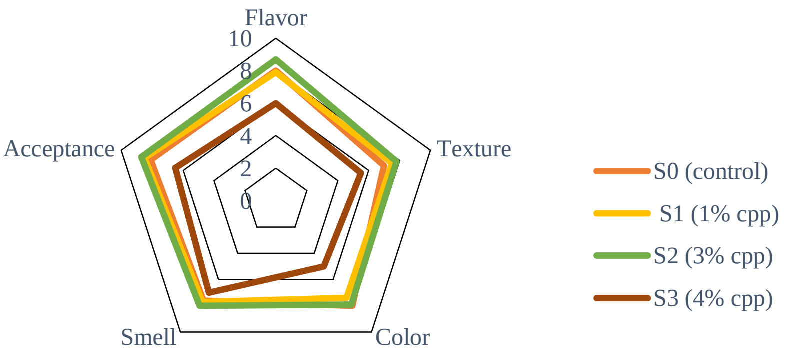

Fig 3: Radar chart comparing the sensory attributes of mayonnaise samples

The study by Talebi et al. (2019) investigated the effect of Carrot Pomace Powder (0-30%), on the physicochemical, textural, and sensory properties of gluten-free bread made with chickpea flour, rice flour, and corn starch. The results showed that CPP significantly increased moisture content, water activity, ash, fiber, protein, and antioxidant capacity, while reducing carbohydrate, calorie content, fat, specific volume, and L value. In terms of texture, increasing CPP led to higher cohesiveness but lower firmness, gumminess, chewiness, and resilience. Sensory evaluation revealed that up to 30% CPP substitution improved overall acceptance, making it a suitable ingredient for enhancing the nutritional value of gluten-free bread [36]. Derakhshideh et al., (2021) studied the effect of Carrot Pomace Powder (CPP) and stevia on tomato sauce quality. CPP (0-30%) increased pH, viscosity, and consistency, while reducing moisture, syneresis, and microbial growth. Color changes included a decrease in L, a, and TCS, and an increase in b*. Stevia had no significant impact on quality, and caloric reduction was minimal. Sensory evaluation recommended using less than 10% CPP with stevia for optimal product quality[37]. In another study, investigated the effect of adding carrot powder on the nutritional, antioxidant, and microbial properties of probiotic soft cheese. In this research, carrot powder was incorporated at levels of 0.2%, 0.4%, and 0.6% into probiotic soft cheese made from buffalo milk. The results showed that this addition led to a reduction in total bacterial count, an increase in probiotic bacteria such as *Bifidobacterium longum*, and changes in the moisture and salt content of the product. These findings suggest that carrot powder can enhance the quality and functional properties of probiotic cheeses [24]. Catana et al. (2022) investigated the effects of fortifying biscuits with carrot pomace powder. Their findings demonstrated improvements in nutritional value, antioxidant capacity, and sensory properties. The fortified biscuits contained significant amounts of protein, fiber, minerals (potassium, calcium, magnesium, iron, zinc), and bioactive compounds such as polyphenols and β-carotene. Additionally, differential scanning calorimetry analysis indicated that the fortification enhanced the biscuits' shelf life and microbiological stability [38].

4. Conclusions

The effect of using carrot pomace powder as a substitute ingredient in mayonnaise formulation demonstrated that the addition of this powder had a positive impact on the physicochemical properties of the final product. The increased levels of phenolic compounds in samples containing CPP indicated an improvement in functional properties and an enhancement in the nutritional value of mayonnaise.
Moreover, the evaluation of sensory properties showed that incorporating this ingredient had an acceptable effect on texture, color, and overall product acceptance. Specifically, samples with optimal percentages of CPP not only exhibited better emulsion stability but were also well-received in terms of taste and appearance. This study suggests that utilizing plant-based by-products, such as carrot powder, can be a sustainable approach to reducing food waste while improving the quality of food products. However, further research on product shelf life, ingredient interactions, and the commercialization potential of this formulation is recommended.

5. Ethical statement

This article does not involve any human or animal subjects.

6. Declaration of competing interest

This article: The authors declared no conflict of interest in this research.

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مقاله پژوهشی

بررسی تاثیر پودر تفاله هویج (CPP) بر خواص فیزیکوشیمیایی و حسی سس مایونز

محمد نوشاد [1]*، محمد حجتی [1] و بهاره گودرزی شمس‌آبادی [1]

۱. گروه علوم و صنایع غذایی، دانشکده علوم دامی و صنایع غذایی، دانشگاه علوم کشاورزی و منابع طبیعی خوزستان، ملاثانی، ایران

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چکیده

پژوهش حاضر به بررسی کاربرد پودر تفاله هویج (CPP) ، در فرمولاسیون سس مایونز پرداخته است. بهره‌گیری از محصولات جانبی کشاورزی مانند CPP می‌تواند منجر به ارتقاء ارزش غذایی، بهبود پایداری فیزیکی و افزایش ماندگاری محصول شود. در این مطالعه، خصوصیات فیزیکوشیمیایی، بافت، رنگ، محتوای فنلی کل، pH، اسیدیته و ویژگی‌های حسی سس مایونز حاوی ۱/۵٪، ۳٪ و ۴٪ پودر تفاله هویج مورد ارزیابی قرار گرفت. نتایج نشان داد که بیشترین میزان ترکیبات فنولی مربوط به نمونه حاوی ۴٪ CPP (۱۳٫۸۵ میلی‌گرم معادل گالیک اسید بر گرم) و کمترین مقدار در نمونه شاهد بدون CPP (۴/۵۷ میلی‌گرم معادل گالیک اسید بر گرم) مشاهده شد. همچنین استفاده از CPP در فرمولاسیون، موجب بهبود پایداری امولسیون، بافت و ظرفیت آنتی‌اکسیدانی نمونه‌ها شد. آزمون‌های بافت‌سنجی نیز نشان داد که نمونه دارای CPP ۴٪ بالاترین میزان سفتی و چسبندگی را دارا است، در حالی که نمونه حاوی CPP ۳٪ از نظر ارزیابی‌های حسی بالاترین امتیاز را کسب کرد. افزون بر این، به دلیل وجود کاروتنوئیدها، افزودن CPP به بهبود رنگ طبیعی سس مایونز کمک کرد. با وجود بهبود ویژگی‌های ساختاری در غلظت‌های بالاتر CPP ، افزایش بیش از حد آن می‌تواند با تغییر در طعم و بافت، از مقبولیت مصرف‌کننده بکاهد. به‌طور کلی، فرمولاسیون حاوی CPP ۳٪ تعادلی مطلوب میان ویژگی‌های فیزیکوشیمیایی و حسی ایجاد کرد. همچنین یافته‌ها نشان داد که CPP می‌تواند به‌عنوان جایگزینی طبیعی برای چربی عمل کند، وابستگی به افزودنی‌های مصنوعی را کاهش دهد و در عین حال، فواید سلامت‌محور سس مایونز را افزایش دهد. این رویکرد نه‌تنها به توسعه محصولات غذایی سالم‌تر کمک می‌کند، بلکه استفاده پایدار از ضایعات کشاورزی را نیز ترویج داده و اثرات زیست‌محیطی را کاهش می‌دهد.

***کلیدواژه‌ها:* تفاله هویج، سس مایونز، بافت‌سنجی، فنل کل**

* نویسنده مسئول: Noshad@asnrukh.ac.ir