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Research Article

INFLUENCE OF CARROT POMACE FROM DIFFERENT VARIETIES ON COMMON AND DURUM WHEAT FLOUR MIXTURES PROPERTIES

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ABSTRACT

Common and durum wheat flour functionality and bioactive properties can be enhanced by incorporating carrot by-products. This paper aimed to evaluate the functional, color, and molecular properties as well as gluten content and quality, total polyphenols, and β-carotene of durum and common wheat flour as influenced by carrot pomace addition (3, 6, 9, and 12%) from different varieties. A decrease in gluten content, index deformation, and falling number was observed as the addition doses of carrot pomace increased. A proportional enhancement of total polyphenols and β-carotene content was obtained. Flour lightness decreased and the nuance of yellow and red rose as the addition dose was higher. FT-IR bands specific for β-carotene, fibers, and polyphenols were observed. The hydration, absorption, and retention capacities of common and durum wheat flours were enhanced depending on the addition dose. These results suggest that common and durum wheat–carrot pomace flour mixtures can be used in pasta production to obtain functional products with enhanced nutritional value.

1. Introduction

The incorporation of non-gluten ingredients into wheat flour significantly alters the functional properties, quantity, and quality of gluten, alpha-amylase activity, color, and chemical composition. These changes are primarily due to the chemical composition of the added ingredient - in the case of carrot pomace, its fiber, polyphenol, and pigment content - as well as interactions between the components of the pomace and those of the flour, especially starch, lipids, and gluten proteins.

Studies in the scientific literature have highlighted the impact of adding carrot by-products and powders on gluten quality, wheat flour properties, dough characteristics, and the final product. Tikhiy et al. (2022) observed a reduction in gluten content and deformation when 1.5 - 9.0% carrot powder was added to pretzels, likely due to a gluten dilution effect. Another study demonstrated that supplementing refined wheat flour with black carrot powder decreased gluten content in proportion to the dose, which consequently reduced bread volume (Pandey et al., 2024).

The functional properties of flour can be modified by adding fruit and vegetable by-products. Oil retention capacity depends on factors such as lignin content, its structure, surface characteristics, apparent density, thickness, hydrophobicity, and particle size, while water retention capacity is determined by the amount of available dietary fiber (Kausar et al., 2024). A higher content of soluble dietary fiber in the flour increases its water retention capacity. As carrot pomace contains significant amounts of soluble fiber with high water retention ability, this parameter of wheat flour improves proportionally with the dosage. Kohajdová et al. (2011) noted an increase in the water absorption capacity of wheat flour proportionate to the amount of lemon and orange fiber added, likely due to the large number of hydroxyl groups in the fiber structure, enabling more hydrogen bond interactions with water. Another study reported an increase in the swelling capacity of wheat flour mixtures with carrot pomace powder as concentration increased, likely due to its high fiber content, which led to greater water absorption (Bamal & Dhull, 2024).

The color of wheat flour depends on the presence of pigments, and adding fruit or vegetable pomace alters the color depending on the pigments in the added ingredient. Ahmad et al. (2016) reported decreased brightness, yellowness, and redness in flour blends and cookies with 10-20% carrot pomace powder compared to the control. Bamal and Dhull (2024) demonstrated that carrot pomace powder altered the crumb color of muffins to orange due to bioactive compounds such as β-carotene. The authors noted reduced brightness for muffin crumb and crust depending on the amount of carrot pomace powder and interactions between polyphenols and other constituents (Bamal & Dhull, 2024).

Carrot pomace is a source of vitamins and minerals that can enhance the nutritional value of products, depending on the amount added. Sule et al. (2019) found that introducing carrot powder into pasta significantly increased the content of B-group vitamins (B1, B3, B6), vitamin C, vitamin E, vitamin K, and β-carotene. The high carotenoid concentrations in carrots, particularly β-carotene, confer free radical inhibition capacity, antimutagenic effects, and immune system enhancement (Hussein et al., 2013). The polyphenol content and antioxidant activity of the final product can be improved by incorporating carrot pomace. Ahmad et al. (2016) demonstrated increased antioxidant activity in wheat flour blends and cookies with carrot pomace powder, depending on the dosage. Research by Pandey et al. (2024) showed increased total flavonoid and polyphenol content in bread as the concentration of black carrot powder increased. The enhanced antioxidant activity of bread with black carrot powder can be attributed to phenolic compounds, flavonoids, anthocyanins, and phenolic compound formation due to anthocyanin thermal degradation during baking (Pandey et al., 2024).

In this context, the research presented in this paper aimed to determine the effect of various doses of carrot pomace, obtained from different varieties cultivated in Romania, on the characteristics of raw materials for pasta - durum wheat and common wheat flour. The study analyzed protein, fat, ash, and carbohydrate content; the quantity of bioactive compounds (total polyphenols and β-carotene); as well as the functional and physical properties of the formulated mixtures (water absorption capacity, oil absorption capacity, swelling capacity, water retention capacity, foaming capacity, foam stability, and color parameters). Furthermore, the bio-molecular functional groups present in the flour mixtures for pasta were identified using FT-IR spectroscopic techniques.

2. Materials and methods

2.1. Materials

Four carrot varieties (Niagara, Belgrado, Sirkana, and Baltimore) were sourced from a farmer in Bacău, Romania. The carrot pomace was obtained by extracting carrot juice using a Bosch MES3500 juicer (Luca et al., 2022). The pomace was dried in a hot-air convection oven at 60°C for 24 hours, then it was ground and sieved at particle size < 200 µm. The carrot powders were stored in amber glass jars until analysis.

Durum wheat flour and type 650 common wheat flour were purchased from the market. Flour mixtures were prepared using durum wheat flour (F1) or common wheat flour (F2) blended with 3%, 6%, 9%, or 12% carrot pomace from the four varieties - Niagara (Ni), Belgrado (Be), Sirkana (Si), and Baltimore (Ba).

2.2. Methods

2.2.1. Wet gluten content, deformation index and falling number

The international method no. 38-12.02, approved by the American Association of Cereal Chemists (AACC), was used to determine the wet gluten content of the flour. For this purpose, the Glutomatic® 2200 device (Perten Instruments, Sweden) was employed. A dough was prepared using 10 g of flour, which was subsequently washed with a saline solution to extract the total wet gluten.

The deformation index of the gluten was determined by thermostating the gluten sphere on a glass slide covered with a funnel lined with wet parchment paper at 29 °C for 60 minutes. The diameter of the sphere was measured before and after thermostating, and the difference represented the deformation index, expressed in millimeters.

The falling number of the flour was determined according to ICC standard 107/1 using the Falling Number Perten model FN 1500 device (Perten Instruments, Sweden). This method involves the gelatinization of the flour suspension and the measurement of liquefaction caused by α-amylase activity.

These measurements were conducted in the laboratory of the SC Panifcom SA factory, Todireni, Botoșani County.

2.2.2. Color of the mixtures

Color parameters were measured by reflectance in the CIE Lab system using a Konica Minolta CR-400 device (Konica Minolta, Tokyo, Japan). Chroma and Hue angle were calculated (Eq. 1 and 2):

$$H = arctan\frac{b^*}{a^*} \tag{1}$$

$$C = \sqrt{a^{*2} + b^{*2}} \tag{2}$$

where a^* is the red-green intensity, and b^* is the yellow-blue intensity

2.2.3. Functional properties

The functional properties of flour mixtures were determined as previously described in our study (Luca et al., 2022).

The water hydration capacity was determined following the protocol proposed by Bordei et al. (2007), with modifications. A 2.5 g sample was mixed for 1h (every 10 min) with 15 mL of water and using a glass wand. The mix was centrifuged for 20 min at 3000 rpm, and then the solid residue was incubated at 50°C for 25 min, cooled, and weighed.

Water absorption capacity was evaluated as described by Oladiran and Emmambux (2018), with modifications. A 1 g sample was mixed with 10 mL of distilled water and incubated with stirring for 30 min at 30˚C. After centrifugation and supernatant discarding, the weight of the residue was recorded.

Oil absorption capacity was analysed following the instructions of Elkhalifa and Bernhardt (2018), with modifications. A 1 g sample of carrot pomace flour or wheat flour was mixed with 10 mL of sunflower oil and stirred every 10 min, for 30 min. Then, the residue that resulted after centrifugation was weighed.

The swelling capacity was evaluated following the method employed by Raghavendra et al. (2004), with modifications. The sample (1g) was put in a 50 mL graduated cylinder with 25 mL of water and covered with aluminum foil. After incubation at room temperature for 24 hours the volume of the sample was recorded.

Water retention capacity was evaluated as described by Raghavendra et al. (2004), with modifications. A 1 g sample of flour was mixed with 30 mL of distilled water; it was rested for 24 hours, then centrifuged and the residue was dried for 2 hours at 105°C in a convection oven.

Foaming capacity and foam stability were analyzed according to the methods presented by Elkhalifa and Bernhardt (2018). For this purpose, 2 g of flour was mixed with 100 mL of distilled water in a 500 mL beaker, then the content was transferred to a 250 mL graduated cylinder, and the volume of the foam was recorded. Foam stability was evaluated by registering the foam volume every 10 min for 1 hour.

Bulk density was evaluated according to Okaka and Potter (1977), with modifications. A 5 g sample of flour mixture was shaked in a 50 mL graduated cylinder 20-30 times. The apparent density was calculated as the weight per unit volume of the sample.

2.2.4. Bioactive compounds

The extract was prepared following the method described by Ziobro et al. (2022). A total of 6 g of sample flour was dissolved in 30 mL of 80% ethanol, and the mixture was stirred for 120 min using a shaker. After centrifugation for 15 min at 4500 rpm, the supernatant was collected and subsequently used for the analysis of phenolic compounds and antioxidant activity.

For total polyphenols content analysis, in a test tube, 0.2 mL of sample extract, 2 mL of Folin-Ciocalteu reagent, and 1.8 mL of 7.5% Na_2CO_3 were mixed. The mixture was kept in the dark at 20 °C for 30 min before measuring absorbance at 750 nm. A Shimadzu UV-VIS-NIR 3600 spectrophotometer (Tokyo, Japan) was used for the analysis. The calibration curve was generated using gallic acid (R^2 = 0.99).

For β-carotene extraction, 0.1 g of the sample was weighed and quantitatively transferred into a 10 mL volumetric flask, with the volume adjusted using $CHCl_3$. The mixture was sonicated for 15 min at 20 °C and then centrifuged at 1500 × g for 10 min. The extraction was repeated twice, and the combined supernatant was filtered through a sterile 0.45 nm syringe filter and diluted at a ratio of 3:10 mL. The absorbance was measured at 450 nm using a UV-Vis spectrophotometer (Jasco V630). A calibration curve was prepared using a β-carotene standard (R^2 = 0.99).

2.2.5. FT-IR molecular properties

The FT-IR spectra used for the molecular characterization of flour mixtures were collected in the range of 650 - 4000 cm^{-1}, using a Thermo Scientific Nicolet iS20 device (Waltham, MA, USA), at a resolution of 4 cm^{-1} and 32 scans. The spectra were processed using Omnic software. The interpretation of the peaks was performed according to the data presented in the scientific literature.

2.3. Statistics

All measurements were performed at least in duplicate. Statistical processing of the data was carried out using XLSTAT software for Excel 2024 (Addinsoft, New York, USA). One-way ANOVA with Tukey's test was applied to assess differences between samples, with a confidence level of 95%. Principal Component Analysis (PCA) was used to evaluate relationships between variables.

3. Results and discussions

3.1. Wet gluten content, deformation index and falling number

The introduction of non-gluten flours into wheat flour generates changes in rheological behavior due to their effects on gluten. Additionally, alpha-amylase activity is significantly influenced, with all these changes being dose-dependent.

The addition of carrot pomace resulted in a significant decrease in the falling number index of durum wheat flour (Table 1), and this decrease was proportional to the dosage. The carrot variety had a significant influence ($p < 0.05$) on this parameter.

Table 1. Gluten characteristics and falling number for durum wheat flour (F1) mixtures with carrot pomace from various varieties (Ba – Baltimore, Be – Belgrade, Ni – Niagara, Si – Sirkana)

Sample	Falling number (s)	Wet gluten content (%)	Deformation index (mm)
F1	592.50±2.50^{aA}	12.25±0.25^{aA}	2.50±0.00^{aA}
F1Ba3	435.00±2.00^{bBC}	12.25±0.25^{aA}	2.25±0.25^{aA}
F1Ba6	401.00±1.00^{cBC}	11.75±0.25^{abA}	2.25±0.25^{bA}
F1Ba9	378.00±2.00^{cdBC}	11.25±0.25^{b6A}	2.00±0.00^{bcA}
F1Ba12	356.50±2.50^{dBC}	10.75±0.25^{cA}	1.75±0.25^{cA}
F1Be3	456.00±4.00^{bB}	12.25±0.25^{aA}	2.50±0.00^{aA}
F1Be6	429.50±0.50^{cB}	12.00±0.00^{abA}	2.25±0.25^{bA}
F1Be9	416.50±1.50^{cdB}	11.50±0.50^{bA}	2.00±0.00^{bcA}
F1Be12	396.50±1.50^{dB}	11.25±0.25^{cA}	1.75±0.25^{cA}
F1Ni3	439.00±1.00^{bCD}	12.25±0.25^{aA}	2.50±0.00^{aA}
F1Ni6	390.00±0.00^{cCD}	12.00±0.00^{abA}	2.00±0.00^{bA}
F1Ni9	367.50±10.50^{cdCD}	11.75±0.25^{bA}	1.75±0.25^{bcA}
F1Ni12	355.50±14.50^{dCD}	11.25±0.25^{cA}	1.75±0.25^{cA}
F1Si3	402.00±3.00^{bD}	12.25±0.25^{aA}	2.25±0.25^{aA}
F1Si6	358.00±1.00^{cD}	12.00±0.00^{abA}	2.00±0.00^{bA}
F1Si9	337.50±2.50^{cdD}	11.75±0.25^{bA}	2.00±0.00^{bcA}
F1Si12	317.00±2.00^{dD}	11.25±0.25^{cA}	2.00±0.00^{cA}

The average values followed by different indices (a-e for different doses, A-C for different carrot varieties) in the same column are significantly different ($p < 0.05$).

The falling number index is inversely proportional to the alpha-amylase activity of the flour. Thus, an improvement in alpha-amylase activity was achieved with the addition of carrot pomace, which could be linked to the calcium content that stabilizes α-amylase (Mironeasa et al., 2012). A study by Lu et al. (2017) also observed a decrease in the falling number index of flour with the addition of apple pomace due to dietary fibers with strong water-binding capacity that improved the water absorption of wheat dough.

Table 2. Gluten characteristics and falling number for common wheat flour (F2) mixtures with carrot pomace from various varieties (Ba – Baltimore, Be – Belgrade, Ni – Niagara, Si – Sirkana)

Sample	Falling number (s)	Wet gluten content (%)	Deformation index (mm)
F2	354.50±5.50^{aA}	26.75±0.25^{aAB}	2.50±0.00^{aA}
F2Ba3	292.50±2.50^{bB}	26.50±0.50^{aAB}	2.25±0.25^{aAB}
F2Ba6	254.00±0.00^{cB}	26.25±0.25^{aAB}	2.00±0.00^{abAB}
F2Ba9	240.00±1.00^{dB}	25.75±0.75^{abAB}	2.00±0.00^{bcAB}
F2Ba12	230.50±0.50^{dB}	25.25±0.25^{bAB}	2.00±0.00^{cAB}
F2Be3	318.00±2.00^{bB}	26.25±0.25^{aBC}	2.25±0.25^{aAB}
F2Be6	305.00±4.00^{cB}	25.00±0.00^{aBC}	2.00±0.00^{abAB}
F2Be9	252.00±3.00^{dB}	24.25±0.25^{abBC}	2.00±0.00^{bcAB}
F2Be12	236.00±2.00^{dB}	23.25±0.25^{bBC}	1.75±0.25^{cAB}

F2Ni3	301.00±2.00^{bB}	26.75±0.25^{aAB}	2.50±0.00^{aAB}
F2Ni6	245.00±0.00^{cB}	26.50±0.50^{aAB}	2.50±0.00^{abAB}
F2Ni9	229.00±1.00^{dB}	26.25±0.25^{abAB}	2.00±0.00^{bcAB}
F2Ni12	249.00±1.00^{dB}	26.00±0.50^{bAB}	1.75±0.25^{cAB}
F2Si3	331.00±1.00^{bB}	25.50±0.50^{aC}	2.25±0.25^{aB}
F2Si6	282.00±2.00^{cB}	24.75±0.75^{aC}	2.00±0.00^{abB}
F2Si9	261.50±1.50^{dB}	24.00±0.00^{abC}	1.75±0.00^{bcB}
F2Si12	245.50±2.50^{dB}	20.00±0.00^{bC}	1.50±0.00^{cB}

The average values followed by different indices (a-e for different doses, A-C for different carrot varieties) in the same column are significantly different ($p < 0.05$).

For common wheat flour mixtures with carrot pomace, similar trends were observed to the results for durum wheat flour regarding the falling number, gluten content, and gluten deformation index: a progressive decrease in these parameters was noted as the dose increased. For gluten content, a significant influence ($p < 0.05$) of the carrot pomace variety was observed (Table 2). Bender et al. (2017) reported a decrease in the falling number of flour proportional to the dose of added grape skins, which was attributed to the reduction in flour proportion and increased enzyme availability. The decrease in falling number values observed by Sogi et al. (2002) with the addition of degreased tomato seed flour could be due to the dilution effect on the starch content of the dough, resulting in a decrease in viscosity. The modification of gluten content and quality may be due to interactions between the fibers in carrot pomace and gluten proteins. Two hypotheses explain these interactions: the first refers to the partial dehydration of gluten due to competition for water between dietary fibers and gluten, which leads to a modification of the gluten matrix structure and partial collapse of the polymer network; the second hypothesis refers to the dilution effect of gluten, where the gluten network is physically disrupted by the presence of fibers (Zhou et al., 2011).

In general, the durum wheat flour mixtures exhibited higher falling number values, while the gluten content was lower. The differences in gluten content and quality between different wheat flour genotypes may be attributed to variations in genetic traits, climatic conditions, and the region of origin (Punia et al., 2019a).

3.2. Color properties of flour mixtures

The color of the flour mixtures depends on the dose of carrot pomace and the variety added. The durum wheat flour mixtures with carrot pomace showed lower values of lightness (L^*) and hue angle (H) compared to the control sample, as well as more reddish and yellowish hues (Table 3).

Table 3. Color parameters of durum wheat flour (F1) mixtures with carrot pomace from different varieties (Ba – Baltimore, Be – Belgrado, Ni – Niagara, Si – Sirkana)

Sample	***L**** (adim.)	***a**** (adim.)	***b**** (adim.)	***C*** (adim.)	***H*** (adim.)
F1	88.46±0.07^{aA}	-1.24±0.03^{eC}	20.14±0.09^{cD}	20.18±0.09^{dD}	93.53±0.07^{aA}
F1Ba3	87.35±0.03^{bBC}	0.08±0.04^{dA}	21.53±0.07^{bB}	21.53±0.07^{cB}	89.78±0.10^{bB}
F1Ba6	86.37±0.05^{cBC}	0.95±0.11^{cA}	22.02±0.18^{abB}	22.04±0.18^{bcB}	87.52±0.29^{cB}
F1Ba9	85.43±0.35^{dBC}	1.93±0.26^{bA}	22.21±0.36^{aB}	22.29±0.38^{abB}	85.04±0.58^{dB}
F1Ba12	85.37±0.10^{dBC}	1.94±0.04^{aA}	22.77±0.08^{aB}	22.86±0.08^{aB}	85.14±0.08^{dB}
F1Be3	87.31±0.08^{bB}	-0.19±0.02^{dB}	20.88±0.10^{bC}	20.88±0.10^{cC}	90.53±0.06^{bB}
F1Be6	86.72±0.12^{cB}	0.45±0.07^{cB}	21.60±0.01^{abC}	21.60±0.01^{bcC}	88.81±0.18^{cB}

F1Be9	86.35±0.06^{dB}	0.98±0.04^{bB}	21.55±0.09^{aC}	21.58±0.09^{abC}	87.41±0.10^{dB}
F1Be12	86.09±0.06^{dB}	1.20±0.04^{aB}	21.86±0.09^{aC}	21.89±0.09^{aC}	86.86±0.13^{dB}
F1Ni3	86.90±0.08^{bC}	-0.10±0.04^{dA}	22.00±0.03^{bAB}	22.00±0.03^{cAB}	90.25±0.10^{bB}
F1Ni6	85.90±0.01^{cC}	0.72±0.07^{cA}	22.37±0.10^{abAB}	22.38±0.10^{bcAB}	88.16±0.17^{cB}
F1Ni9	85.16±0.05^{dC}	1.27±0.0^{bA}	22.85±0.06^{aAB}	22.88±0.06^{abAB}	86.82±0.21^{dB}
F1Ni12	84.52±0.03^{dC}	1.92±0.07^{aA}	23.36±0.13^{aAB}	23.44±0.13^{aAB}	85.30±0.14^{dB}
F1Si3	86.97±0.01^{bBC}	-0.04±0.09^{dA}	22.00±0.07^{bA}	22.00±0.07^{cA}	90.11±0.22^{bB}
F1Si6	85.74±0.04^{cBC}	0.83±0.05^{cA}	23.02±0.03^{abA}	23.03±0.03^{bcA}	87.94±0.13^{cB}
F1Si9	85.35±0.05^{dBC}	1.27±0.04^{bA}	23.41±0.04^{aA}	23.44±0.04^{abA}	86.90±0.10^{dB}
F1Si12	84.94±0.03^{dBC}	1.68±0.15^{aA}	23.79±0.12^{aA}	23.85±0.11^{aA}	85.97±0.38^{dB}

The average values followed by different indices (a-e for different doses, A-C for different carrot varieties) in the same column are significantly different ($p < 0.05$).

Chroma (*C*) recorded a lower value in the case of the control durum wheat flour compared to the mixtures. *L** and *H* decreased proportionally with the amount of carrot pomace added, while the values of *a**, *b**, and *C* increased. The variety of carrot pomace had a significant influence on some of the color parameters (*b**, *C*, *L**). The main pigments in orange carrot pomace are carotenoids and xanthophylls, which are responsible for the red and yellow color of the products (Ikram et al., 2024). β-carotene is one of the pigments that caused the color modification of the flour mixtures, and it is well-known that the four types of carrot pomace from different varieties are rich in β-carotene. The Sikrana variety showed the highest β-carotene content (7.34 mg/100g), which could explain the higher red and yellow hue values and the color intensity obtained for the flour mixtures. Kultys et al. (2022) also observed a decrease in lightness and an increase in the *a** parameter for fresh pasta, proportional to the increase in the dose of carrot pomace in durum wheat flour.

Table 4. Color parameters of common wheat flour (F2) mixtures with carrot pomace from different varieties (Ba – Baltimore, Be – Belgrado, Ni – Niagara, Si – Sirkana)

Sample	*L** (adim.)	*a** (adim.)	*b** (adim.)	*C* (adim.)	*H* (adim.)
F2	90.19±0.03^{aA}	-0.73±0.03^{dB}	12.45±0.07^{bB}	12.47±0.07^{bB}	93.37±0.15^{aA}
F2Ba3	88.14±1.80^{aA}	0.11±0.02^{cA}	14.33±0.04^{bB}	14.33±0.04^{bB}	89.58±0.06^{bB}
F2Ba6	89.09±0.57^{abA}	0.52±0.03^{cA}	14.91±0.06^{abB}	14.92±0.06^{abB}	87.99±0.11^{bB}
F2Ba9	87.84±0.03^{bcA}	0.98±0.04^{bA}	15.73±0.12^{abB}	15.76±0.11^{aB}	86.45±0.18^{cB}
F2Ba12	87.79±0.07^{cA}	0.88±0.03^{cA}	15.83±0.08^{aB}	15.85±0.08^{aB}	86.82±0.08^{dB}
F2Be3	89.34±0.04^{aA}	0.06±0.03^{cA}	13.74±0.04^{bB}	13.74±0.04^{bB}	89.75±0.11^{bB}
F2Be6	89.25±0.09^{abA}	0.11±0.04^{cA}	13.68±0.07^{abB}	13.68±0.07^{abB}	89.56±0.17^{bB}
F2Be9	88.50±0.09^{bcA}	0.92±0.03^{bA}	15.00±0.08^{abB}	15.03±0.08^{aB}	86.51±0.10^{cB}
F2Be12	87.71±0.06^{cA}	1.62±0.03^{aA}	15.97±0.05^{aB}	16.06±0.05^{aB}	84.20±0.09^{dB}
F2Ni3	89.83±0.03^{aB}	0.24±0.03^{cA}	13.92±0.09^{bA}	13.92±0.09^{bA}	89.02±0.14^{bB}
F2Ni6	85.90±0.01^{abB}	0.72±0.07^{cA}	22.37±0.10^{abA}	22.38±0.10^{abA}	88.16±0.17^{bB}
F2Ni9	85.16±0.05^{bcB}	1.27±0.09^{bA}	22.85±0.06^{abA}	22.88±0.06^{aA}	86.82±0.21^{cB}
F2Ni12	84.52±0.03^{cB}	1.92±0.07^{aA}	23.36±0.13^{aA}	23.44±0.13^{aA}	85.30±0.14^{dB}
F2Si3	89.37±0.16^{aA}	0.14±0.03^{cA}	13.64±0.07^{bB}	13.64±0.07^{bB}	89.43±0.13^{bB}
F2Si6	88.67±0.15^{abA}	0.54±0.01^{cA}	15.05±0.18^{abB}	15.06±0.18^{abB}	87.96±0.03^{bB}
F2Si9	88.33±0.12^{bA}	0.83±0.08^{bA}	15.31±0.07^{abB}	15.34±0.07^{aB}	86.91±0.27^{cB}

F2Si12	86.37±0.02[cA]	2.54±0.02[aA]	17.88±0.13[aB]	18.06±0.13[aB]	81.92±0.06[dB]

The average values followed by different indices (a-e for different doses, A-C for different carrot varieties) in the same column are significantly different ($p < 0.05$).

The common wheat flour showed higher lightness and hue angle, a greenish hue, a higher yellow color intensity, and lower Chroma compared to the mixtures with added carrot pomace (Table 4).

An increase in red hue (*a*), yellow hue (*b*), and color intensity (*C*) were observed with the increase in the addition dose, while *H* and *L** decreased proportionally (Table 4). The carrot pomace variety had a very slight influence on the color parameters of the common wheat flour mixtures. A similar reduction in *L** and increase in *a** and *b** parameters was reported by Ahmad et al. (2016) for wheat flour with the addition of carrot pomace powder in different concentrations (0-20%). The intensification of the yellow-red color of wheat flour mixtures with carrot pomace may be an advantage, as the final product – pasta – could be more attractive to consumers (Kultys et al., 2022).

Compared to common wheat flour, durum wheat flour showed lower *L** and a more pronounced yellow hue, likely due to the higher presence of pigments. The color difference between the two types of wheat flour may be attributed to the presence of lutein as the main carotenoid pigment in durum wheat (Ficco et al., 2014). Hidalgo et al. (2017) also reported lower values for *L** and *a** parameters and higher values for *b** in durum wheat compared to common wheat.

3.3. Functional properties

The addition of non-gluten flours has a major impact on the techno-functional properties of the mixture. Carrot pomace is a fiber-rich ingredient that can significantly affect the absorption and retention properties of liquids depending on the dose used. The durum wheat flour mixtures with carrot pomace showed significantly higher values ($p < 0.05$) than the control sample of durum wheat flour for hydration capacity (HC), while water absorption capacity (WAC), swelling capacity (SC), water retention capacity (WRC), and foaming capacity (FC) were all significantly higher (Table 5). The bulk density (BD) and foam stability (FS) were not influenced by the dose or the variety of carrot pomace. Increasing the addition dose resulted in a proportional increase in HC, OAC, WAC, SC, and WRC, while FC decreased. The carrot variety influenced OAC, WAC, and FC.

The presence of polysaccharides in the composition of carrot pomace may increase the HC, while a lower value might be due to a lower availability of polar amino acids in the flour (Gull et al., 2015). Rocha Parra et al. (2019) reported higher values for the water-binding capacity and the water or oil retention capacity of wheat flour, proportional to the dose of added apple pomace, due to the presence of cellulose, pectin, and hemicellulose. Carrot pomace is rich in fiber (Luca et al., 2022), which may support this hypothesis in the current case. According to data obtained by Kehinde et al. (2017), the water retention capacity of wheat flour mixtures with tiger nut by-products was significantly higher compared to the control sample and increased with the dose due to the presence of fibers. Similar to our results, the authors reported an increase in the swelling capacity of the wheat flour-tiger nut by-product mixtures, which could be correlated with the water absorption index during heating (Kehinde et al., 2017). Naseem et al. (2024) observed an increase in the foaming capacity of the wheat flour mixture with 5% carrot pomace compared to the control sample, while the foaming capacity and foam stability of the wheat flour mixtures with apple pomace decreased proportionally with the addition dose. It is well known that foaming and foam stability depend on the protein content, which forms a film around the air bubbles and stabilizes the foam by reducing the surface tension at the air-water interface (Naseem et al., 2024). Thus, the decrease in FC and FS may be due to the protein dilution effect with the addition of carrot pomace.

Table 5. Functional properties of durum wheat flour mixtures (F1) with carrot pomace from various varieties (Ba – Baltimore, Be – Belgrado, Ni – Niagara, Si – Sirkana)

Sample	HC (%)	OAC (%)	WAC (%)	SC (mL/g)	WRC (g/g)	FC (%)	FS (%)	BD (g/cm^3)
F1	49.58±0.20^{cB}	93.41±0.20^{aA}	97.93±0.05^{cC}	3.03±0.00^{dB}	0.65±0.03^{aC}	0.51±0.02^{bD}	98.53±0.00^{aA}	1.00±0.00^{aA}
F1Ba3	62.42±0.16^{dA}	71.59±0.20^{cB}	105.79±0.15^{cAB}	3.37±0.01^{cA}	0.85±0.04^{bAB}	1.51±0.02^{aC}	99.60±0.00^{aA}	1.00±0.01^{aA}
F1Ba6	79.80±0.14^{cA}	72.23±0.21^{bB}	114.52±0.17^{bAB}	3.55±0.01^{bA}	0.86±0.01^{bAB}	1.48±0.01^{aC}	99.70±0.00^{aA}	1.00±0.01^{aA}
F1Ba9	84.24±0.10^{bA}	74.28±0.28^{bB}	130.81±0.18^{aAB}	3.90±0.00^{aA}	1.07±0.02^{aAB}	1.49±0.00^{aC}	99.70±0.00^{aA}	1.00±0.01^{aA}
F1Ba12	90.82±0.14^{aA}	73.33±0.23^{bB}	153.34±0.26^{aAB}	3.93±0.01^{aA}	1.08±0.01^{aAB}	1.50±0.01^{aC}	99.70±0.00^{bA}	1.00±0.01^{aA}
F1Be3	69.96±0.11^{dA}	62.89±0.22^{cC}	99.86±0.12^{cBC}	3.41±0.01^{cA}	0.82±0.02^{bB}	1.48±0.01^{aBC}	99.60±0.00^{aA}	1.00±0.01^{aA}
F1Be6	75.67±0.13^{cA}	64.62±0.30^{bC}	112.28±0.07^{bBC}	3.38±0.00^{bA}	0.85±0.02^{bB}	1.50±0.01^{aBC}	99.60±0.00^{aA}	1.00±0.01^{aA}
F1Be9	82.42±0.15^{bA}	67.62±0.62^{bC}	127.12±0.07^{aBC}	3.62±0.01^{aA}	0.97±0.02^{aB}	1.51±0.02^{aBC}	99.60±0.00^{aA}	1.00±0.01^{aA}
F1Be12	90.03±0.09^{aA}	70.33±0.30^{bC}	118.38±0.06^{aBC}	3.80±0.00^{aA}	1.02±0.03^{aB}	1.61±0.01^{aBC}	99.70±0.00^{bA}	1.00±0.00^{aA}
F1Ni3	70.64±0.24^{dA}	64.28±0.28^{cC}	109.20±0.04^{cAB}	3.32±0.00^{cA}	0.84±0.02^{bB}	1.59±0.01^{aB}	99.70±0.00^{aA}	1.00±0.01^{aA}
F1Ni6	77.77±0.11^{cA}	69.40±0.17^{bC}	126.32±0.08^{bAB}	3.54±0.01^{bA}	0.84±0.04^{bB}	1.60±0.00^{aB}	99.70±0.00^{aA}	1.00±0.01^{aA}
F1Ni9	92.20±0.09^{bA}	68.59±0.27^{bC}	132.50±0.06^{aAB}	3.52±0.01^{aA}	0.95±0.03^{aB}	1.51±0.02^{aB}	99.60±0.00^{aA}	1.00±0.01^{aA}
F1Ni12	97.89±0.10^{aA}	72.23±0.17^{bC}	130.91±0.07^{aAB}	3.82±0.01^{aA}	0.93±0.03^{aB}	1.50±0.01^{aB}	0.00±0.00^{bA}	1.00±0.01^{aA}
F1Si3	67.38±0.19^{dA}	60.60±0.19^{cC}	117.68±0.12^{cA}	3.42±0.01^{cA}	0.85±0.02^{bA}	1.61±0.01^{aA}	99.60±0.00^{aA}	1.00±0.01^{aA}
F1Si6	82.19±0.13^{cA}	69.22±0.22^{bC}	135.85±0.13^{bA}	3.67±0.01^{bA}	0.95±0.02^{bA}	1.61±0.01^{aA}	99.60±0.00^{aA}	1.00±0.01^{aA}
F1Si9	98.45±0.21^{bA}	70.23±0.16^{bC}	145.57±0.08^{aA}	3.86±0.00^{aA}	1.18±0.03^{aA}	1.59±0.01^{aA}	99.60±0.00^{aA}	0.99±0.00^{aA}
F1Si12	101.94±0.16^{aA}	68.68±0.27^{bC}	131.66±0.12^{aA}	3.79±0.01^{aA}	1.19±0.03^{aA}	1.61±0.01^{aA}	99.60±0.00^{bA}	1.00±0.01^{aA}

The mean values followed by different indices (a-e for different doses, A-C for different carrot varieties) in the same column are significantly different ($p < 0.05$), HC – hydration capacity, WAC – water absorption capacity, OAC – oil absorption capacity, WRC – water retention capacity, FC – foaming capacity, FS – foam stability, SC – swelling capacity, BD – apparent density.

The functional properties of wheat flour mixtures with carrot pomace are presented in Table 6. Higher values of FC were observed for the control flour compared to the flour mixtures, while OAC, WRC, and FS were lower. Increasing the addition dose resulted in higher values of HC, OAC, WAC, SC, WRC, FC, and FS, but without significant changes in BD. The carrot variety significantly influenced OAC and FC. Vihishima et al. (2024) reported a significant increase in the water absorption capacity of wheat flour with the addition of mango seed flour and orange pomace. Proteins, fibers, and carbohydrates are the main components contributing to the modification of water absorption in flours due to the presence of hydrophilic groups in their structure (Vihishima et al., 2024). Thus, the contribution of proteins, fibers, and carbohydrates from carrot pomace can explain the proportional increase in WAC with the dose of addition. Similar to the results of this study, Vihishima et al. (2024) observed an increase in OAC with the introduction of mango and orange by-products, probably due to the modification of protein content, since OAC refers to the ability of lipids in the flour to bind with the non-polar chains of proteins. Ahmad et al. (2016) found higher values of WAC and OAC in wheat flour with carrot pomace compared to the control sample, with values increasing with the dose. The authors attributed these changes to the fiber content, which generates competition between the pomace and the wheat flour for water or oil absorption (Ahmad et al., 2016).

Table 6. Functional properties of common wheat flour mixtures (F2) with carrot pomace from various varieties (Ba – Baltimore, Be – Belgrado, Ni – Niagara, Si – Sirkana)

Sample	HC (%)	OAC (%)	WAC (%)	SC (mL/g)	WRC (g/g)	FC (%)	FS (%)	BD (g/cm^3)
F2	57.70 ± 0.15^{bcB}	72.76 ± 0.15^{cD}	109.33 ± 0.11^{abAB}	3.28 ± 0.01^{cdB}	0.86 ± 0.04^{cdA}	1.48 ± 0.02^{aA}	0.00 ± 0.00^{cC}	1.00 ± 0.00^{aA}
F2Ba3	59.92 ± 0.11^{cA}	86.51 ± 0.37^{bC}	96.37 ± 0.09^{cAB}	3.09 ± 0.00^{dAB}	0.90 ± 0.02^{dA}	0.51 ± 0.02^{dBC}	98.72 ± 0.00^{bB}	1.00 ± 0.01^{aA}
F2Ba6	71.43 ± 0.13^{bA}	90.23 ± 0.18^{aC}	107.24 ± 0.05^{bAB}	3.63 ± 0.00^{bcAB}	0.93 ± 0.01^{bcA}	0.98 ± 0.01^{cBC}	99.11 ± 0.00^{abB}	0.99 ± 0.00^{aA}
F2Ba9	80.32 ± 0.11^{abA}	87.59 ± 0.29^{aC}	117.40 ± 0.04^{abAB}	3.94 ± 0.00^{bAB}	1.04 ± 0.02^{bA}	0.98 ± 0.01^{bcBC}	99.11 ± 0.00^{aB}	0.99 ± 0.00^{aA}
F2Ba12	86.09 ± 0.07^{aA}	94.21 ± 0.23^{aC}	113.63 ± 0.08^{aAB}	4.03 ± 0.01^{aAB}	1.36 ± 0.02^{aA}	1.05 ± 0.01^{bBC}	99.16 ± 0.00^{aB}	1.00 ± 0.01^{aA}
F2Be3	56.23 ± 0.09^{cB}	84.75 ± 0.23^{bBC}	83.79 ± 0.10^{cB}	3.01 ± 0.00^{dAB}	0.86 ± 0.02^{dA}	0.48 ± 0.02^{dBC}	98.92 ± 0.00^{bAB}	1.00 ± 0.01^{aA}
F2Be6	62.66 ± 0.13^{bB}	95.48 ± 0.15^{aBC}	96.15 ± 0.06^{bB}	3.37 ± 0.01^{bcAB}	0.91 ± 0.02^{bcA}	0.99 ± 0.00^{cBC}	99.21 ± 0.00^{abAB}	1.00 ± 0.01^{aA}
F2Be9	66.39 ± 0.09^{abB}	96.49 ± 0.23^{aBC}	105.31 ± 0.07^{abB}	3.53 ± 0.00^{bAB}	1.00 ± 0.02^{bA}	0.98 ± 0.01^{bcBC}	99.11 ± 0.00^{aAB}	1.00 ± 0.01^{aA}
F2Be12	69.85 ± 0.06^{aB}	101.35 ± 0.16^{aBC}	114.79 ± 0.09^{aB}	3.68 ± 0.01^{aAB}	1.14 ± 0.01^{aA}	1.18 ± 0.01^{bBC}	99.31 ± 0.00^{aAB}	1.00 ± 0.00^{aA}
F2Ni3	49.17 ± 0.07^{cB}	87.93 ± 0.17^{bAB}	97.78 ± 0.12^{cA}	3.16 ± 0.01^{dAB}	0.83 ± 0.04^{dA}	0.50 ± 0.01^{dC}	99.01 ± 0.00^{bB}	1.00 ± 0.00^{aA}
F2Ni6	56.37 ± 0.09^{bB}	97.62 ± 0.16^{aAB}	112.91 ± 0.06^{bA}	3.57 ± 0.00^{bcAB}	0.95 ± 0.05^{bcA}	0.48 ± 0.01^{cC}	98.82 ± 0.00^{abB}	1.00 ± 0.00^{aA}
F2Ni9	59.15 ± 0.08^{abB}	100.74 ± 0.15^{aAB}	122.80 ± 0.08^{abA}	3.80 ± 0.00^{bAB}	0.99 ± 0.03^{bA}	0.98 ± 0.01^{bcC}	99.31 ± 0.00^{aB}	1.00 ± 0.00^{aA}
F2Ni12	65.43 ± 0.10^{aB}	99.13 ± 0.17^{aAB}	130.60 ± 0.09^{aA}	4.11 ± 0.01^{aAB}	1.09 ± 0.04^{aA}	0.99 ± 0.01^{bC}	99.21 ± 0.00^{aB}	0.99 ± 0.00^{aA}
F2Si3	52.87 ± 0.07^{cB}	98.74 ± 0.17^{bA}	105.53 ± 0.09^{cA}	3.25 ± 0.00^{dA}	0.77 ± 0.03^{dA}	1.01 ± 0.02^{dB}	99.21 ± 0.00^{bA}	0.99 ± 0.00^{aA}
F2Si6	59.13 ± 0.20^{bB}	98.77 ± 0.21^{aA}	109.74 ± 0.11^{bA}	3.80 ± 0.00^{bcA}	1.02 ± 0.04^{bcA}	1.01 ± 0.02^{cB}	99.31 ± 0.00^{abA}	0.99 ± 0.00^{aA}
F2Si9	64.29 ± 0.12^{abB}	100.74 ± 0.19^{aA}	111.48 ± 0.10^{abA}	3.88 ± 0.00^{bA}	1.05 ± 0.04^{bA}	1.17 ± 0.07^{bcB}	99.40 ± 0.00^{aA}	0.99 ± 0.00^{aA}
F2Si12	72.46 ± 0.06^{aB}	103.37 ± 0.19^{aA}	123.34 ± 0.10^{aA}	4.47 ± 0.00^{aA}	1.20 ± 0.04^{aA}	1.11 ± 0.02^{bB}	99.31 ± 0.00^{aA}	0.99 ± 0.00^{aA}

The mean values followed by different indices (a-e for different doses, A-C for different carrot varieties) in the same column are significantly different ($p < 0.05$), HC – hydration capacity, WAC – water absorption capacity, OAC – oil absorption capacity, WRC – water retention capacity, FC – foaming capacity, FS – foam stability, SC – swelling capacity, BD – apparent density.

SC is influenced by particle size, botanical origin of the flours, and processing methods. The increase in SC of wheat flour proportional to the dose of carrot pomace may be attributed to the improvement of the flour's ability to absorb water and swell, as this parameter suggests the extent of the associative forces in the starch granules (Godswill et al., 2019). Vihishima et al. (2024) reported a decrease in SC and FC with the introduction of mango seed flour and orange pomace into wheat flour as a result of the protein content, which aligns with the results of the current study. Foaming capacity and foam stability depend on the interfacial film formed by proteins, which keeps the air bubbles in suspension and slows down the coalescence rate (Cousminer, 2016). The foaming capacity and foam stability of wheat flour mixtures with carrot pomace decreased significantly with increasing the dose due to the dilution of the protein network by the fiber-rich ingredient, as suggested by Ahmad et al. (2016), whose results align with those obtained in this study. Negi et al. (2021) also reported higher values for WRC, OAC, and SC and lower values for FC and FS for the wheat flour mixture with 33% apple pomace compared to the control sample.

Compared to durum wheat flour, common wheat flour showed higher values for HC, SC, WAC, and WRC, while OAC, FS, and FC were lower. The higher protein content (Luca et al., 2022) in durum wheat flour compared to common wheat flour could explain the differences in functional properties, as Punia et al. (2019) demonstrated that WAC, OAC, FC, and FS increased with the rise in protein content in wheat flour and obtained significant positive correlations ($r > 0.73$, $p < 0.05$).

3.4. Bioactive compounds content

The content of total polyphenols (TPC) and β-carotene in the flour mixtures is represented in Figure 1. The increase in the dose of carrot pomace led to an increase in the amount of total polyphenols and β-carotene in the durum wheat or common wheat flour mixtures, as expected, due to the presence of these compounds in the added ingredient. TPC was not significantly influenced by the carrot variety, while the β-carotene content showed slight changes. Dalla Costa et al. (2016) observed a significant increase in the β-carotene content of uncooked pasta made from common wheat flour with the addition of carrot flour. Moreover, the β-carotene content in uncooked pasta with 10% carrot flour, without eggs, was higher after cooking (> 140%) than that of the control sample with eggs after cooking, indicating that the use of carrot pomace could fully replace eggs and could lead to improvements in the nutritional characteristics of the final product (Dalla Costa et al., 2016). Ćetković et al. (2022) reported an improvement in the β-carotene content of uncooked durum wheat pasta after the addition of encapsulated carrot pomace extract.

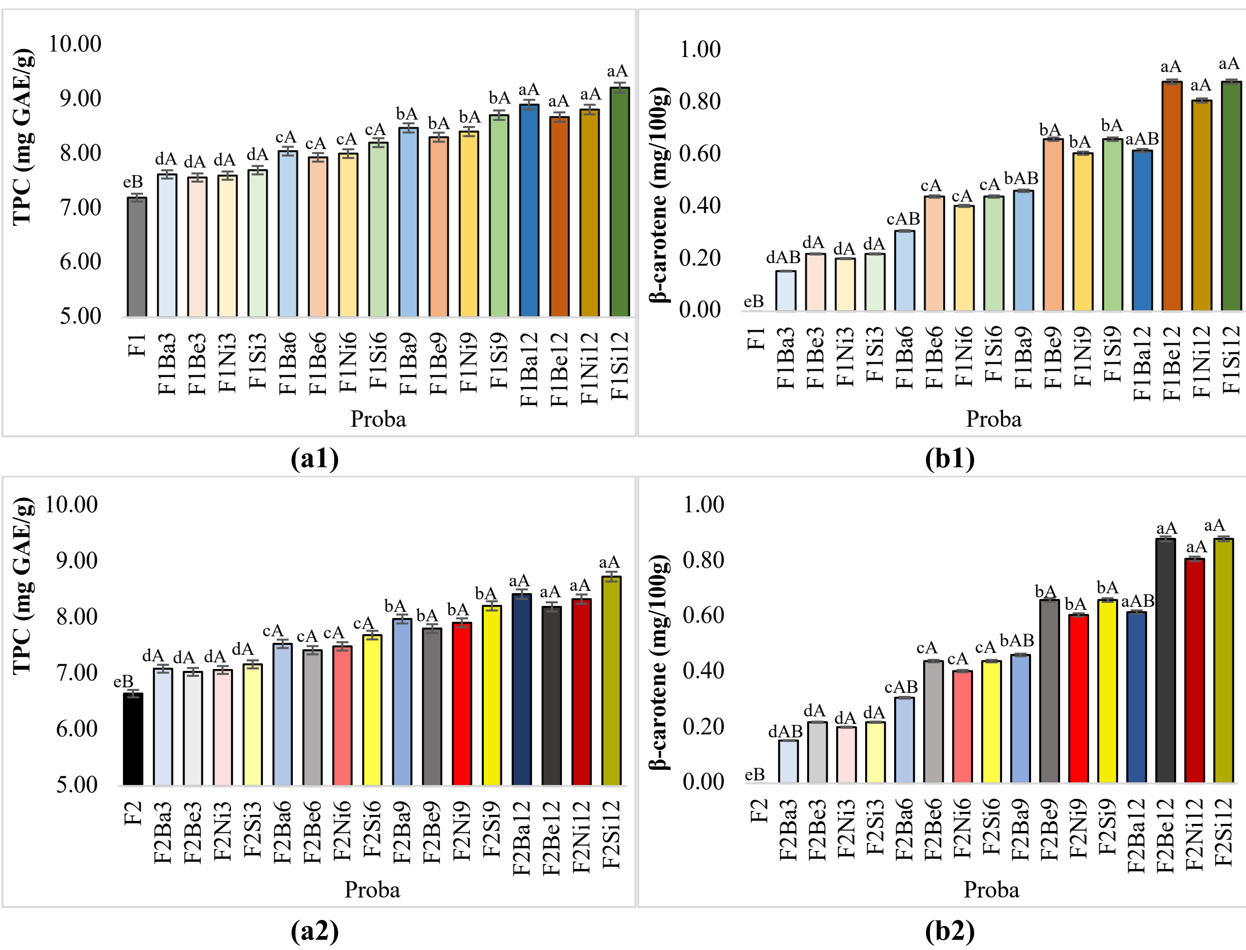
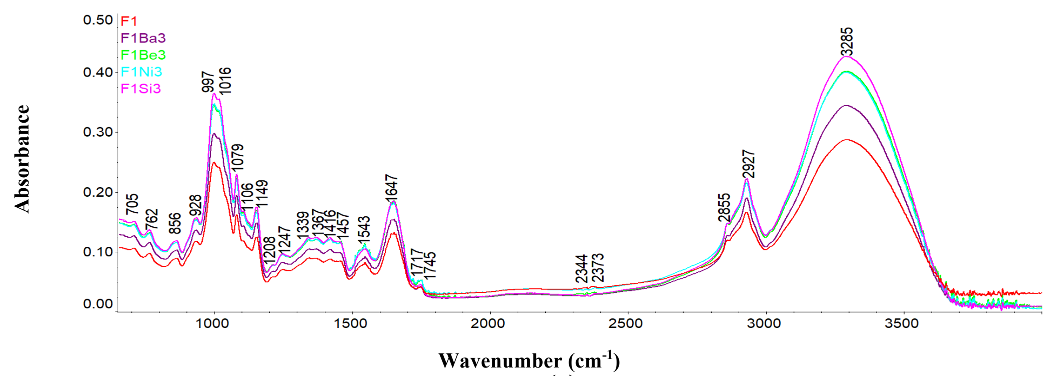


Figure 1. Total polyphenols content (TPC) (a) and β-carotene (b) of durum wheat flour (1) and common wheat flour (2) mixtures with carrot pomace from various varieties (Ba – Baltimore, Be – Belgrado, Ni – Niagara, Si – Sirkana); columns marked with different indices (a-e for different doses, A-C for different carrot varieties) indicate significant differences ($p < 0.05$).

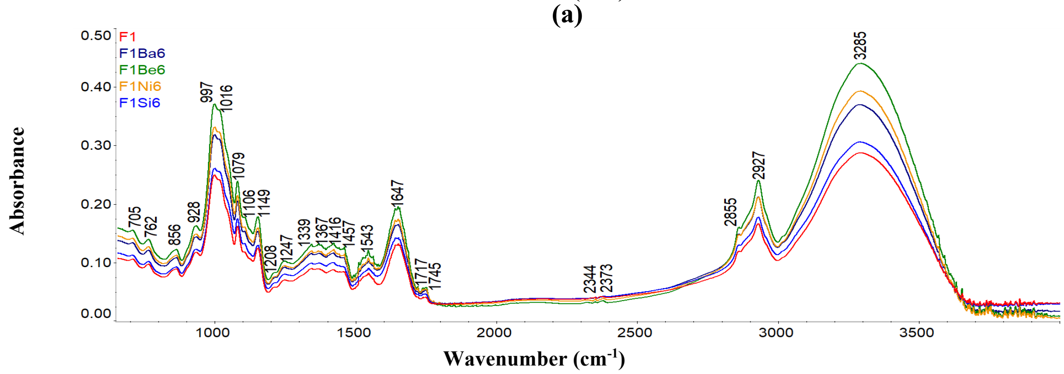
Konrade and Klava (2017) highlighted an increase in the total polyphenol content of the wheat and rice flour mixture proportional to the dose of carrot pomace added, similar to the trend observed in this study. According to data obtained by Bayrakcı and Bilgiçli (2024), a 6-fold increase in the total polyphenol content of gluten-free pasta was observed, depending on the dose of carrot pomace added, with a major contribution from carotenoids and flavonoids in the carrot pomace.

3.5. FT-IR molecular characteristics

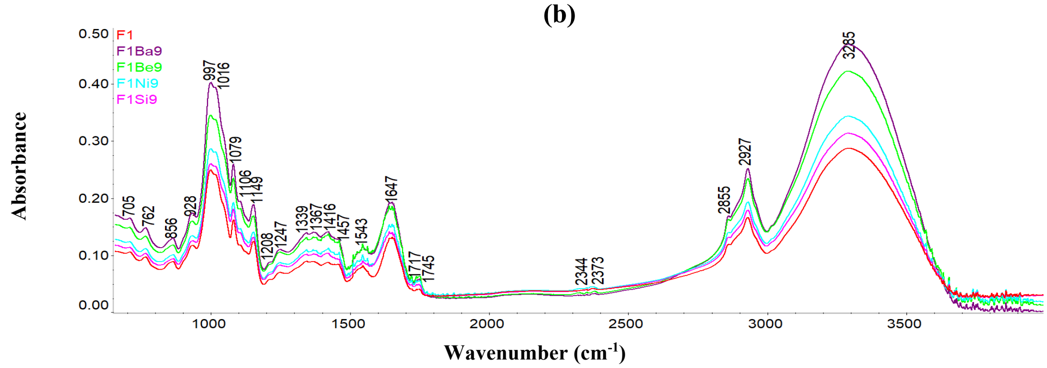
The molecular properties of the wheat flour and carrot pomace mixtures are shown in Figure 2. The control sample showed significantly lower absorption intensities compared to the mixtures, and the differences became more pronounced as the dose of the addition increased. The peak intensities were significantly different depending on the carrot variety, and the increase in the addition dose led to an increase in the absorption intensities of the peaks. The carrot variety had a significant influence on the intensity of the peaks.



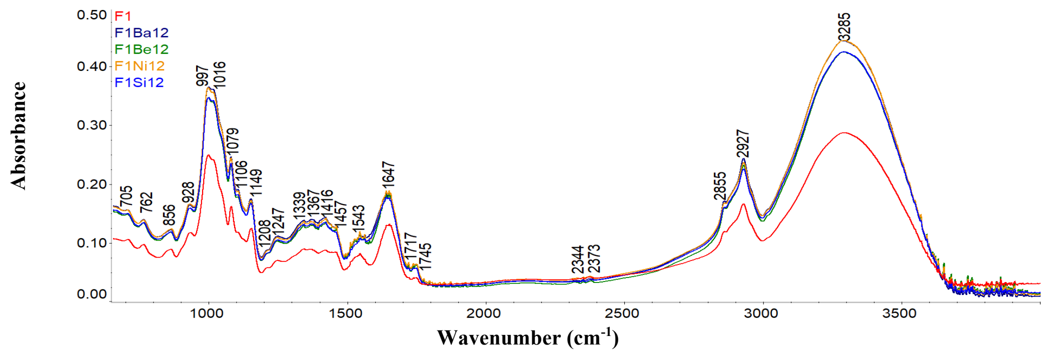
(a)



(b)



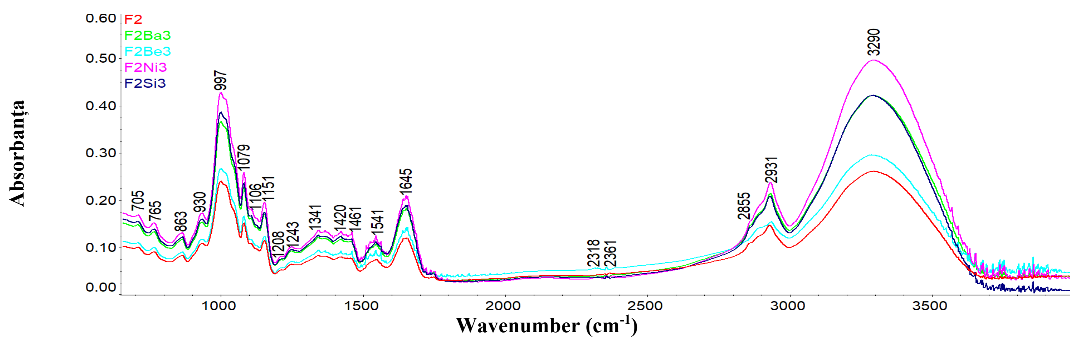
(c)



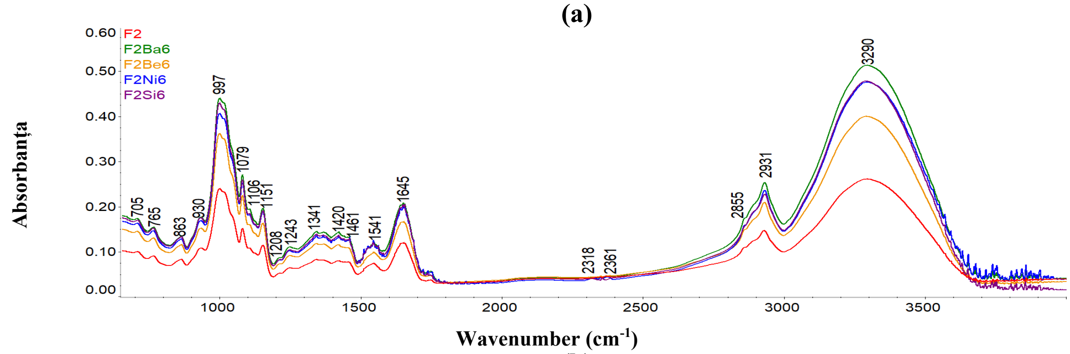
(d)

Figure 2. FT-IR spectra for durum wheat flour (F1) mixtures with carrot pomace from various varieties (Ba – Baltimore, Be – Belgrado, Ni – Niagara, Si – Sirkana): 3% (a), 6% (b), 9% (c), 12% (d)

The common wheat flour showed the lowest absorbance intensity values across the entire considered wavelength range, except for the region 2318-2361 cm⁻¹ for the samples with 3%, 6%, and 12% added doses (Figure 3). A prominent peak can be observed in all the analyzed samples at 3290 cm⁻¹, corresponding to the stretching vibrations of hydroxyl (-OH) groups in the structure of polysaccharides (especially hemicellulose and cellulose) or polyphenols (Rezvani and Goli, 2023). The peaks at 2931 cm⁻¹ and 2855 cm⁻¹ are generated by the stretching vibrations of the CH, CH_2, and CH_3 groups of the methyl esters of galacturonic acid, which is in line with previous studies (Güzel and Akpınar, 2019; Misra and Yadav, 2020). The peak observed at 1737 cm⁻¹, especially in the flour mixtures with a higher addition of carrot pomace (> 6%), indicates the presence of ester bonds in the carrot pomace (Sucheta et al., 2019).



(a)



(b)

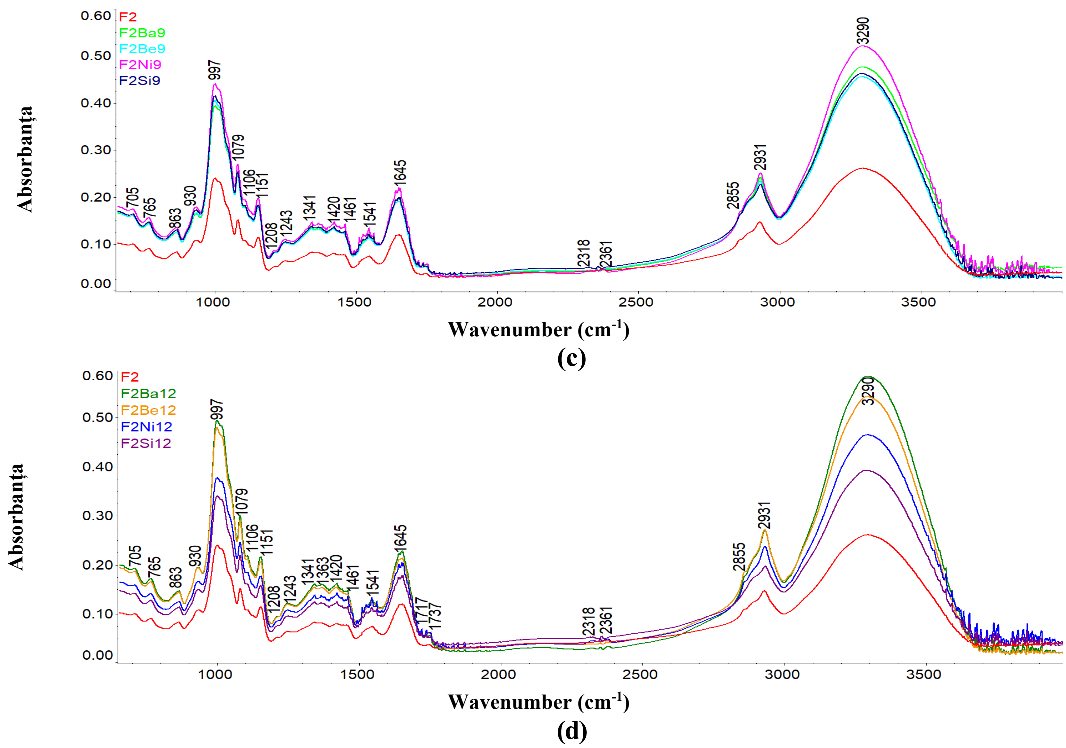


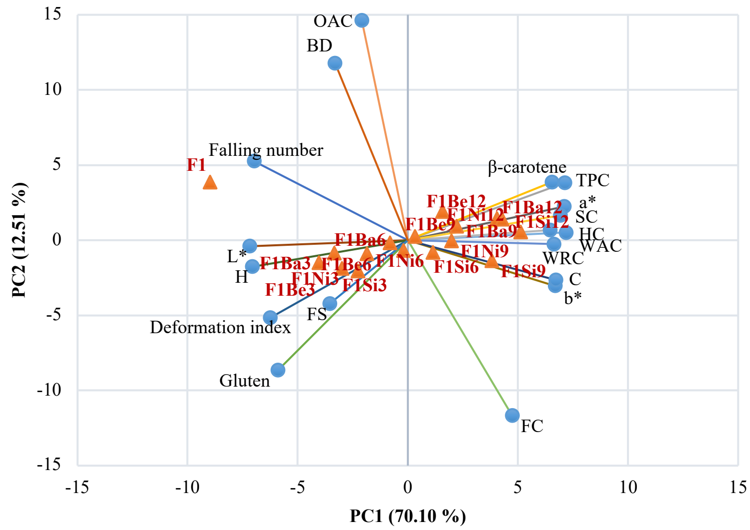
Figure 3. FT-IR spectra for common wheat flour (F2) mixtures with carrot pomace from various varieties (Ba – Baltimore, Be – Belgrado, Ni – Niagara, Si – Sirkana): 3% (a), 6% (b), 9% (c), 12% (d)

The C-O group can generate stretching vibrations, leading to the appearance of the peak at 1079 cm⁻¹ (Güzel and Akpınar, 2019). The higher intensity of the peak at 3290 cm⁻¹ (which suggests the presence of pectin) reflects strong hydrogen bonds for the different carrot pomace varieties depending on the addition dose, and could be attributed to the differentiated interaction with phenolic substances (Sucheta et al., 2020). The presence of β-carotene is suggested by the appearance of the peak at 1737 cm⁻¹, caused by the stretching vibrations of the C=O group (Kaur et al., 2019), and its intensity increased proportionally with the amount of carrot pomace added, which is consistent with the results presented in Figure 1 regarding the β-carotene content.

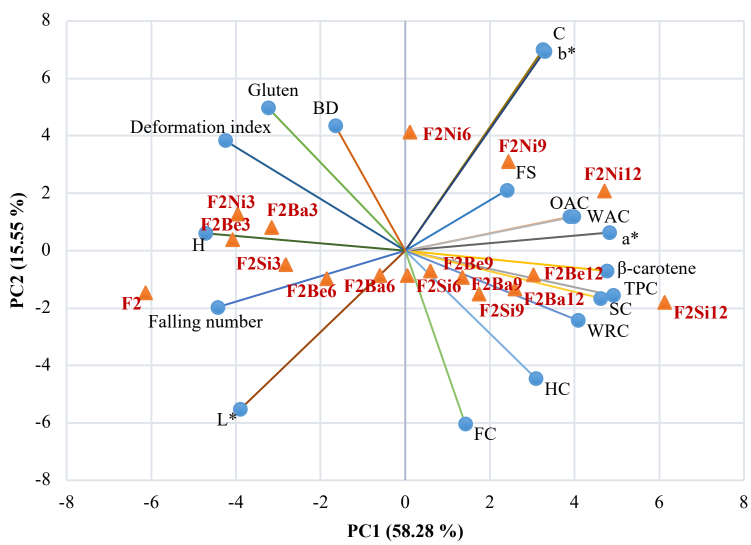
3.6. Relationships between variables

The relationships between the variables highlighted by the Principal Component Analysis are shown in Figure 7.

For the durum wheat flour mixtures (Figure 4a), the first component (PC1) explained 70.10% of the data variation, and the second component (PC2) explained 12.51% of the total variation. PC1 was associated with WRC, HC, OAC, SC polyphenol content, β-carotene, falling number, and color parameters, while PC2 was associated with BD, OAC, and FC. The control sample (F1) was distinguished from the other flour mixtures mainly by the falling number. A predominant grouping was observed on the right side of the graph for the mixtures with 9% and 12% carrot pomace, while those with lower doses of 6% were mostly grouped in the left quadrants.



(a)



(b)

Figure 4. Principal Component Analysis for the mixtures with durum wheat flour (F1) (a) and common wheat flour (F2) (b) with carrot pomace from different varieties (Ba – Baltimore, Be – Belgrado, Ni – Niagara, Si – Sirkana)

For the mixtures with common wheat flour, PC1 explained 58.28% of the data variation, and PC2 explained 15.55% of this variation (figure 4b). PC1 was associated with OAC, WAC, *a**, polyphenol content, β-carotene, SC, WRC, falling number, *H*, and gluten deformation index, while PC2 was associated with BD, *C*, *b**, *L**, FC, and HC. Similar to durum wheat flour, the control sample was distinguished mainly by the falling number. The samples of flour with carrot pomace from the Niagara variety were positioned in the upper quadrants. A distribution of mixtures with 3% and 6% carrot pomace was predominantly observed in the left part of the graph, while those with 9% and 12% additions were located in the right quadrants. The samples with 3% addition were differentiated from the other samples by the *H* parameter and the gluten deformation index, while those with 12% were differentiated by OAC, WAC, *a**, SC, WRC, TPC, and β-carotene.

4. Conclusions

Carrot pomace has significant effects on the techno-functional properties of common wheat and durum wheat flour mixtures due to its high content of fibers and polyphenols. A significant increase in alpha-amylase activity and a decrease in gluten content and deformation index were observed as the dose increased. Color parameters also underwent changes that became more pronounced as the content of carrot pomace increased, especially with the decrease in brightness and the intensification of yellow and red hues, depending on the variety used. The high fiber content of carrot pomace led to an increase in the hydration capacity of the flour, the oil absorption capacity, and the water absorption and retention capacities in proportion to the dose. Foam capacity of common wheat flour mixtures decreased compared to the control sample, but slightly increased as the dose of addition increased due to the protein content in the flour matrix. An enrichment of the total polyphenol and β-carotene content of the durum and common wheat flour mixtures was obtained in proportion to the increase in the added carrot pomace dose, regardless of the variety used. The molecular characteristics of the flour mixtures confirmed the presence of bioactive compounds such as polyphenols, fibers, and β-carotene in the mixtures.

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