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Research Article

SOME PHYSICOCHEMICAL, COLOR, COOKING, BIOACTIVE AND SENSORY PROPERTIES OF TURKISH NOODLES: ENRICHED WITH ARONIA POWDER (*ARONIA MELANOCARPA*)

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ABSTRACT

Aronia (*Aronia melanocarpa*) is a fruit with a high polyphenol content, and its use is increasing due to its potential health effects with increased polyphenol content. The widespread consumption of Turkish noodles and similar products in society is important for increasing their nutritional quality. The aim of this study was to evaluate the physicochemical, color, bioactive, and sensory properties of noodle samples to which aronia powder was added at different concentrations of 2%, 4%, 6%, 8%, and 10%, respectively. Total Polyphenol Content (TPC), Total Antioxidant Capacity (TAC), and Total Flavonoid Content (TFC) amounts were found to be significantly increased (p<0.05). In addition, significant increases were found in the antioxidant activity (ABTS$^{\bullet+}$, DPPH and FRAP) of the samples. According to the sensory evaluations, the noodles with 8% aronia had a high level of general acceptability, while the group with 10% aronia had a lower level. Consequently, we observed that adding aronia could yield an acceptable noodle enriched in bioactive components.

1.Introduction

Aronia berries belong to the genus Aronia of the family Rosaceae, subfamily Maloideae. Aronia is commonly known as chokeberry and there are two types of fruit that are consumed. These two species are Aronia melanocarpa (Michx.) Ell. (black chokeberry) and Aronia arbutifolia (L.) Pers. (red chokeberry). The fruit of A. melanocarpa is remarkable for the bioactive compounds it contains (Kulling & Rawel, 2008). Aronia melanocarpa fruit was found to have a high content of anthocyanin (Cyanidin 3-O-arabinoside, Cyanidin 3-O-galactoside, Cyanidin 3-O-glucoside, Cyanidin 3-O-xyloside, and Pelargonidin 3-O-arabinoside), flavonol (Quercetin 3-O-galactoside, Quercetin 3-O-glucoside) from flavonoids, and hydroxycinnamic acids (Caffeic acid) from phenolic acids (Neveu et al., 2010). In addition to polyphenols, Aronia melanocarpa fruits contain over 60% dietary fiber, over 60% insoluble fiber (lignin, cellulose and hemicellulose), B vitamins, carotenoids, tocopherols, vitamin C and vitamin K. Aronia fruits and berries are rich in K, Ca, P, Mg, Na, Fe and Zn, with high mineral content (Sidor & Gramza-Michałowska, 2019).

A diet rich in polyphenols has beneficial effects on human health. It is therefore becoming increasingly important to consume foods rich in polyphenols, such as fruit, vegetables, cereals, pulses, chocolate, tea, coffee and wine (Han et al., 2007). Enhancing the consumption of polyphenols has significant health benefits and can aid in the prevention of chronic illnesses, as well as the maintenance and enhancement of current health conditions (Scalbert et al., 2005). Aronia consumption has been shown to be effective on cardiovascular diseases (Rahmani et al., 2019), diabetes mellitus (Mu et al., 2020), cancer (Yu et al., 2021), and neurodegenerative diseases (Zdunić et al., 2020). Although aronia is not consumed directly as fruit due to its sour taste, it can be used in fruit juice, canned food, tea, wine, jam, alcoholic beverages (Kapci et al., 2013), and in the development of new products (Esatbeyoglu et al., 2023). Moreover, food coloring and functional food development can utilize aronia (Jakobek et al., 2007).

Traditional Turkish noodles are made by kneading a mixture of wheat flour, salt, and water, then rolling out, cutting into thin slices and finally drying. Consumers prefer noodles, pasta, and similar products due to their short preparation times, long storage conditions, and low cost (Özkaya et al., 2001). Furthermore, these products, derived from cereals, play a crucial role in fulfilling the daily energy and protein needs of individuals. According to TBSA (2019) data, in Turkey, 33.4% of adult (19-64 years) men consume pasta/noodles and couscous 2-3 days a week, 36.4% consume it once a week, 38.8% of adult (19-64 years) women consume it once a week, and 30.2% consume it 2-3 days a week. The addition of different nutrients and different raw materials (legumes, buckwheat flour, etc.) is used to increase the nutritional and functional value of noodles (Aktaş et al., 2015). Moreover, researchers use various nutrients to boost the phenolic content of noodle samples, including molokhia (Corchorus olitorius) powder (Olcay et al., 2022) and grape, pomegranate, and rosehip seed flours (Koca et al., 2018). Aronia contains higher amounts of polyphenols and anthocyanins compared to other red fruits (blackberry, red raspberry, and strawberry) and can be an alternative functional food source in the food development industry (Jakobek et al., 2007), with the addition of noodles, which are widely consumed in Turkish society.

This study aims to develop a novel functional food by enriching Turkish noodle samples with aronia powder in specific ratios. The physicochemical, color, bioactive, and sensory properties of the prepared noodle samples were analyzed. It is also to develop a food product with a high polyphenol content that enhances health benefits when included in the diet.

2. Materials and methods

2.1. Materials

In this study, the noodle formulations were prepared as six different design (Table 1). Wheat flour (Sinangil Co.) and aronia powder (Mor Aronya- Freeze Dried 100% Natural Aronia Fruit Powder by Freeze Dried Method) were used as the basic ingredients in noodle making. The wheat flour and salt used in dough manufacturing were purchased from regional markets, while the aronia powder was provided by a private company that manufactures aronia products.

2.1.1. Noodle Preparation

Table 1 shows the components of both the control group (C) and the noodles with aronia added. In the noodle formulation, different concentrations of aronia powder: 2% (N1), 4% (N2), 6% (N3), 8% (N4), and 10% (N5) were used instead of wheat flour (Figure 1). Firstly, the ingredients for the noodles are mixed in a bowl, and the dough is kneaded until it reaches a homogenous consistency (about 10 min). The dough was divided into approximately 100 g pieces, rolled by hand, and left to rest in plastic wrap at room temperature (25.0 °C±2.0) for 30 minutes. The rested dough pieces were thinned to 1.5 mm thickness with a noodle and pasta making machine (Celik, Turkey). After that, the thinned dough was passed through the cutting rollers of the noodle machine and cut into noodle strips (20 cm strips). The noodles were laid on sheets with 2 mm hole spacing to ensure equal drying on both sides and left to dry for 24.0±2.0 hours under laboratory conditions (25.0±2.0 °C and 35% relative humidity). The dried noodles were placed in zip-lock refrigerator storage bags and stored in the refrigerator at +4 °C until analyses were performed. The samples were pulverized with waring commensal blender grinder and then analyzed.

2.1.2. Physicochemical Analyses

According to AOAC (2000), the dry matter, protein, oil, water activity (a_w), and ash contents of the noodle samples were analyzed. The dry matter contents were determined by drying in an oven at 130 °C. The ash contents of the samples were determined by incineration in a muffle furnace (Protherm Furnace ECO, 110/9, Ankara, Turkey) at 550 °C for 5 hours after the pre-combustion process was completed. The protein contents of the sample were determined using a Kjeldahl nitrogen analyzer. The oil contents of the samples were determined by extraction with petroleum ether using a Soxhlet apparatus (5±0.5 g of dehumidified sample, 5 h extraction with the addition of 150 mL petroleum ether). The water activity (a_w) values were determined by using an automatic water activity analyzer (WA-60A Landtek water activity meter). The color properties of the samples (L*, a* and b*) were determined using a Lovibond color meter (The Tintometer Limited, UK). The total carbohydrate contents of the samples were calculated using the following formula (Sayaslan et al., 2016);

$$\%CHO=100-(\%Moisture+\%Prt+\%Oil+\%Ash) \quad (1)$$

The total energy content of the samples was calculated based on the following energy conversion factors: 4.0 kcal/g for protein, 9.0 kcal/g for oil, and 4.0 kcal/g for carbohydrates (Maclean et al.,2003).

2.1.3. Bioactive Analysis

Total Polyphenol Content (TPC), Total Antioxidant Capacity (TAC), and Total Flavonoid Content (TFC) were determined in noodle samples. The ability to scavenge DPPH free radicals and ABTS cation radicals, FRAP ferric (Fe^{+3}) ions, and ferrous (Fe^{+2}) reduction of antioxidants were evaluated. Extraction was performed using an ultrasonic bath (3 L, 320 W Bandelin Ultrasonic Bath) for TPC, TAC, and TFC evaluation. To 10 g of the samples, 50 mL of 80% ac. Methanol (MeOH) was added, and ultrasound-assisted extraction was performed at 40 °C (1 h) and filtered using filter paper, and this filtrate was used for all bioactive analysis (Dranca & Oroian, 2016).

2.1.3.1. Total Phenolic Content Assays

Kasangana et al. (2015) were taken as references and analyzed for TPC by the Folin-Ciocalteu spectrophotometric method. For analysis, 100 µL of the extract was taken, 5 mL of deionized water, 100 µL of Folin-Ciocalteu reagent, and 300 µL of a 2% Na_2CO_3 solution were added. The mixture was vortexed and kept at room temperature for 1 hour. The absorbance values of the solution were measured using a UV-vis spectrophotometer. TPC was expressed as milligrams of gallic acid equivalent per kilogram (mg GAE/kg) using the gallic acid calibration curve.

2.1.3.2. Total Flavonoids Content Assays

The TFC of the samples was mixed with 3200 µL methanol (30% v/v), 150 µL 0.5 M sodium nitrite solution, and 150 µL 0.5 M sodium nitrite solution to prepare a 500 µL extract prepared previously using the Kasangana method. After 5 minutes, 1 mL of 1 M NaOH solution was added and vortexed the mixture once more. The absorbance values of the incubated samples were recorded using a UV-vis spectrophotometer at 506 nm. The TFC of the samples was calculated as mg QE/kg using the calibration curve with catechin solution (dissolved in ethanol) (Kasangana et al., 2015).

2.1.3.3. Total Antioxidant Capacity Assays

The phosphomolybdenum method was used to determine the TAC of the extracts of the samples. 500 µL of extract was mixed with 2500 µL deionized water and 1000 µL molybdate reagent and vortexed. Test tubes covered with aluminum foil were incubated at 95 °C for 90 min. After incubation, the samples were allowed to reach room temperature. The absorbance of the samples was measured at 765 nm, and antioxidant activity was calculated as mg AAE/kg using an ascorbic acid calibration curve (Kasangana et al., 2015).

2.1.3.4. 2,2-Diphenyl-1-picrylhydrazyl (DPPH) for Antioxidant Activity

The DPPH radical scavenging activity of methanol extracts was analyzed using the Sanchez-Moreno method (Sagdic et al., 2011) as a reference. 100 µL of sample was mixed with 3000 µL of DPPH solution (0.1 mM in methanol) by vortex. The samples were incubated for 30 minutes, and the absorbance values were measured using a UV-vis spectrophotometer at 517 nm. The results are given as mg AA eq./g, and % free radical removal and DPPH radical scavenging activity were calculated as in Equation 2.

$$\%\text{Antioxidant activity} = ((Ac - As)/Ac)x100 \quad (2)$$

Where Ac represents the absorbance of the control, while as signifies the absorbance of the sample.

2.1.3.5. ABTS•+ Cation Radicals for Antioxidant Activity

The ability of antioxidants to neutralize the ABTS (2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) radical was determined using. 150 µL of methanol blank and 150 µL of standard (ascorbic acid) were taken, and the resulting solution was read at an absorbance value of 734 nm in a spectrophotometer. The content of ABTS cation removal activity in the samples were calculated (Eq. 3). Antioxidant activity was given as mg AA eq./g and % free radical removal using an ascorbic acid calibration curve (Ahmed et al., 2015).

$$\%\text{Antioxidant activity} = ((Ac - As)/Ac)x100 \quad (3)$$

2.1.3.6. FRAP for Antioxidant Activity

FRAP analysis was performed with reference to Ahmed et al. (2015). The FRAP reagent was prepared with 2.5 mL of tripyridyltetrazolium chloride (TPTZ), 2.5 mL of iron (III) chloride ($FeCl_2$), and 25 mL of acetic acid. 500 µL of distilled water blank was used, and a total of 250 µL of standards were taken, and the same procedures were performed. The mixture was incubated in the dark for 30 minutes, and the absorbance was measured by a UV-Vis spectrophotometer. FRAP amounts were determined as total iron-reducing capacity in µg ascorbic acid equivalent (AAE) per mL.

2.1.4. Cooking Analysis of Noodles

Noodle samples of 25 g were used to determine the optimum cooking times of the samples. The noodles were then cooked in 250 mL of boiling distilled water and checked every 30 seconds. The time when the white dots in the center of the noodles disappeared was recorded as the cooking time (Singh et al., 1989). Özkaya et al. (1984) were taken as references, and the amount of substance cooking loss water was calculated. The noodles (25 g) cooked at the optimum cooking time were drained and washed by adding 90 mL of water and stirring. Water was added to all washing and cooking water to reach 350 mL. Then 50 mL of this water was taken, evaporated in a water bath, dried in an oven at 98 °C until it reached, and it reached a constant weight, and calculated according to Eq. 4:

$$\%\ \text{Amount of cooking loss} = (G\times 28/100-W)\times 100 \quad (4)$$

Where G is Residue content and W is Noodle moisture (%)

The amount of volume increase was determined by dropping the same amount of uncooked 150 mL water into a 250 mL measuring cylinder. The same procedure was applied to the cooked and drained noodles. The amount of water overflowed by the noodles was determined as % (Rabetafika, 2011), and the volume increase was calculated according to Eq. 5:

$$\% \text{ Noodle volume increase} = ((V_2 - V_1)/V_1) \times 100 \quad (5)$$

Where V_1 is volume of the noodles before cooking and V_2 is volume of the noodles after cooking.

The water absorption value was calculated using the same amount (25 g) of uncooked (G_1) and cooked and drained noodle weights (G_2) (Yuksel et al., 2018) (Eq. 6)

$$\% \text{ Noodle water absorption value} = ((G_2 - G_1)/G_1) \times 100 \quad (6)$$

2.1.5. Sensory Analysis

Control and Aronia enriched noodles consisted of 30 panelist (employees and students of Nigde Ömer Halisdemir University Department of Nutrition and Dietetics) aged between 18 and 30 years. Noodle samples were presented to panelists with randomly coded three-digit numbers and rated on a 9-point hedonic scale. The analysis is a linear evaluation where 1 = unsatisfactory and 9 = satisfactory and includes color, hardness, taste/smell, and overall acceptability (Yuksel et al., 2022).

3.Results and discussions

The composition and physicochemical properties of noodles enriched with aronia are given in Table 1. It was observed that the content of dry matter and ash increased with the increase in the amount of aronia. While the ash content was 2.02% in the control group, it was 2.19% in the 6th sample, and the increase was found to be significant ($p<0.05$). Cacak-Pietrzak et al. (2023), found that the increase in ash content between the highest aronia-enriched bread samples (0.974%) and the control group (0.928%) was significant. While the addition of aronia did not affect the oil content of the samples, it was observed that the protein content decreased in the N5 sample compared to the others. Similarly, increasing the addition of aronia to bread resulted in a decrease in the protein content. It was also observed that the prepared products had similar energy content.

Color affects the consumption of a food and the choice of consumers. The color properties of the noodles with the addition of aronia (L*, a*, b*) are given in Table 2. The addition of aronia powder significantly decreased the lightness/darkness (L*) values of the noodle samples ($p<0.05$). The darker color of aronia may be related to its effectiveness in the L* values of the samples. While the L* value was 78.02 in the control sample, it was 54.07 in the noodles with 10% Aronia added. In the studies conducted, it was observed that the addition of aronia increased the color content of a similar selection (Cacak-Pietrzak et al., 2023; Petković et al., 2021). It was observed that the noodle samples had a more reddish (a*) color with the addition of aronia ($p<0.05$). Wheat bread enriched with Black Chokeberry (Aronia melanocarpa L.) Pomace had a similarly significant increase in a* content (Cacak-Pietrzak et al., 2023). Yoon et al. (2014) also found that the a* value increased with each increase in Aronia powder in bread samples with aronia addition ($p<0.05$). The yellow blue (b*) color change of the noodle samples significantly decreased, but there was no difference between N4 and N5. There was no difference in b* value between 4% and 5% or between 5% and 6% bread with Aronia added (Cacak-Pietrzak et al., 2023). However, in the other study, the b* value of the samples decreased significantly as the addition of aronia increased (Yoon et al., 2014). In the results of the study, there was no difference in the b* value between 6% and 8% samples, while an increase in b* content was observed with increasing concentration (10%).

Cooking analyses of noodle samples enriched with aronia powder are presented in Table 3. The increase in fiber in the noodle samples with the addition of aronia may cause an increase in cooking time. It was observed that there was no significant change in volume increase and water absorption rates with the addition of aronia powder. Xu et al. (2020) demonstrated that the water absorption ability of noodle samples containing the greatest proportion of apple pomace (20%) was superior. In addition, the cooking loss of noodles to which aronia powder was added was found to be 7.44- 8.51- 11.69- 14.52- 18.98 and 19.28, respectively, and it was observed that the cooking loss increased significantly. Similarly, it was observed that cooking losses increased in pasta samples with black carrot powder compared to the control group. It was also observed that cooking losses increased with higher additions in freeze dried samples (Ozer et al., 2024). The use of freeze-dried aronia powder in this study also supports the increased cooking loss.

Figure 2 shows the TAC, TPC and TFC of the noodle samples after adding aronia. Aronia fruit is among the richest sources of polyphenols such as anthocyanins (ACNs), proanthocyanidins (PACNs), and hydroxycinnamic acid. Additionally, there are trace levels of flavan-3-ols (epicatechin) and flavanols (quercetin glycosides) (Denev et al., 2012). Polyphenols have been found to have an effect on chronic diseases in numerous in vitro and in vivo studies (Del Bo et al., 2019). The positive effects of polyphenols on human health increase the importance of polyphenol-enriched foods and their importance in nutrient development research (Adebooye et al., 2018). Aronia polyphenol content was found to be higher when compared with fruits such as blackberries, red raspberries, and strawberries (Jakobek et al., 2007). The TPC value of the noodles without aronia added was 50.00 GAE mg/100 g, and the TPC value of the noodles with 10% aronia added was 139.43 GAE mg/100 g. The TPC values significantly increased when aronia powder was added to the samples. ($p<0.05$). When 1% and 6% aronia were added to bread samples, TPC in the aronia-treated samples doubled and increased by around 4.5 times compared to the control (Cacak-Pietrzak et al., 2023). In the present study, adding 10% aronia powder also caused an increase that was three times greater. There was a similar content of total flavonoid in noodle samples C (1.62) and N1 (4.22). However, there was a significant rise of 9.55- 24.65- 30.46, and 74.37 mg KAE/100 g in the N2, N3, N4, and N5 samples (Figure 2).

Polyphenols are the primary constituents accountable for the antioxidant action in plants. The level of antioxidant activity rises in direct correlation with the concentration of polyphenols (Denev et al., 2018). $ABTS^{\bullet}$+ reduction, $DPPH^{\bullet}$ reduction, FRAP, Cupric Reducing Antioxidant Capacity (CUPRAC), Oxygen Radical Absorbance Capacity (ORAC), and Chemiluminescence (CL) assays are among the commonly used methods for the evaluation of total antioxidant activity (Sadowska-Bartosz & Bartosz, 2022). Adding aronia powder to noodles is anticipated to enhance antioxidant activity due to the elevated levels of polyphenol components. The antioxidant capacity of noodles was evaluated using $ABTS^{\bullet+}$ reduction mgAAE/100 g, $DPPH^{\bullet}$ reduction mgAAE/100 g, and FRAP mg $FeSO_4$/100 g (Figure 3). The reduction of $DPPH^{\bullet}$ considerably increased from C to N5 at the following values: 3.14- 16.11- 38.65- 57.94- 82.23, and 99.03, respectively. Similarly, the FRAP values also showed a significant rise from C to N5 at the following values: 2.74- 44.43- 80.78- 122.30- 198.91, and 252.64 ($p<0.05$), respectively. $ABTS^{\bullet+}$ increased from C (71.29) to N4 (162.60), while N4 (162.60) and N5 (164.39) showed similar $ABTS^{\bullet+}$ activity. In samples of bread with aronia added, the levels of $ABTS^{\bullet+}$ and $DPPH^{\bullet}$ (Cacak-Pietrzak et al., 2023) increased, whereas in samples of cookies, the levels of $ABTS^{\bullet+}$ and ORAC increased (Raczkowska et al., 2022).

The color, smell, hardness, taste, and overall acceptability of the noodle samples were evaluated by 30 panelist with hedonic scale scores between 1 and 9. Significant differences were found, and N4 had higher color, smell, taste, hardness and overall acceptability ($p<0.05$, Figure 4). Although noodles containing 8% aronia powder were generally well-liked, the group that received 10% aronia had a decline in acceptance. According to the sensory analysis of the noodle samples, the color values were recorded as 5.40 for the control, while N1 had the lowest score with 3.73 and N4 had the highest score with 6.17. With the addition of aronia powder, low color changes caused consumers to dislike it, while more intense color changes were found to be effective. The highest scores for acceptability in terms of appearance, rising, and flavor were given to the control group compared to the breads to which aronia powder was added. Higher additions of aronia powder resulted in a compact and hard structure in the bread, which resulted in a lower level of appreciation (Cacak-Pietrzak et al., 2023). In cake a sample to which aronia was added, the acceptability of the control group was similarly high and decreased with the addition of aronia (Jang et al., 2018). The addition of 3% aronia to bread products resulted in superior ratings for look, color, and overall acceptability. The increase in the quantity of powder, due to the addition of aronia, was shown to have an impact on the quality attributes of the food, specifically its color, flavor, and taste. These effects were subject to varying evaluations by the panelists (Yoon et al., 2014). It was noticed that the general appreciation scores increased when aronia powder was added to the noodle samples, in comparison to the cake and bread samples. This is because the noodle samples lacked a rising feature and had minimal impact on the cooking qualities. However, the addition of 10% aronia powder is not recommended in higher quantities as it adversely affects flavor and acceptability.

The correlation matrix between the physicochemical properties and phenolic content of the prepared noodle samples was used (Figure 5). Protein content and dry matter of noodles and TFC were significantly negatively correlated, while TPC, TAC, and TPC were significantly positively correlated with ash content. In the study investigating the effect of anthocyanin levels on bread quality parameters, anthocyanin levels were found to be negatively correlated with moisture content (Pandey et al., 2024). The reduction in the number of cereals with the addition of aronia leads to a reduction in the content of protein (Cacak-Pietrzak et al., 2023). In addition, the addition of a fruit rich in bioactive compounds supports the decreasing protein and increasing polyphenol content in the product. Increasing polyphenol content is expected to increase antioxidant activity (Denev et al., 2018). A significant positive correlation was found between the TAC, TPC, and TFC and the ABTS, DPPH, and FRAP assays.

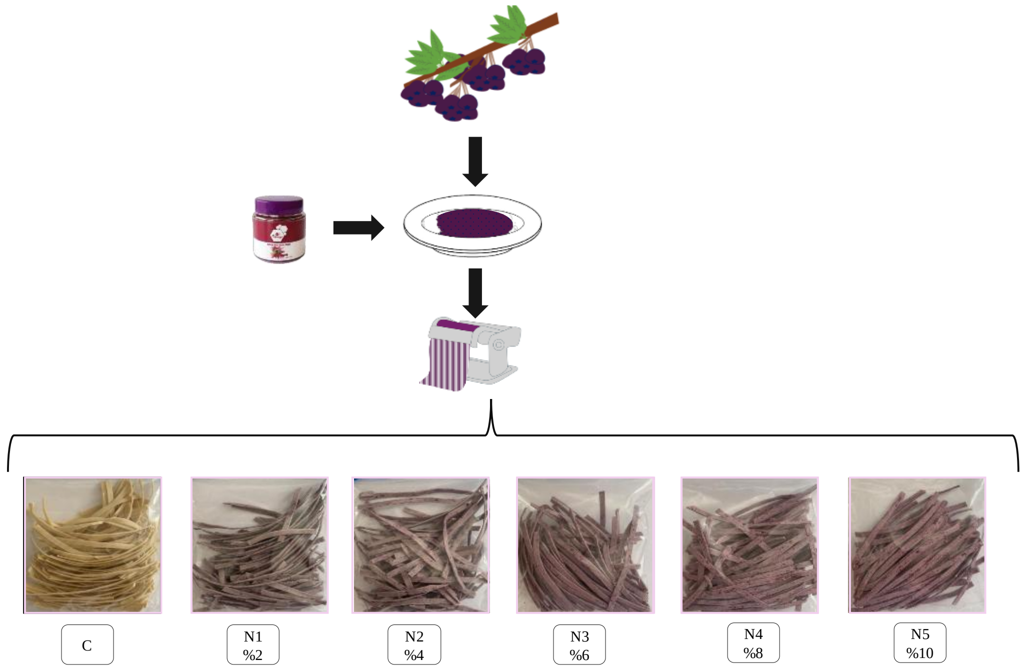

Figure 1. The noodle production flow chart

Table 1. Composition and physicochemical properties of noodle samples

Sample	Component ratios		Physicochemical properties						
	Wheat flour %	Aronia powder %	Dry matter (g/100g)	Ash (g/100g)	Water activity (a_w)	Oil (g/100g)	Protein (g/100g)	CHO (g/100g)	Total energy (kcal/100g)
C	100	0	91.59 ± 0.02^{a}	2.02 ± 0.02^{c}	0.40 ± 0.01^{b}	1.29 ± 0.52^{a}	10.64 ± 0.12^{a}	77.60 ±0.63^{a}	364.72±2.82^{a}
N1	98	2	90.28 ± 0.15^{c}	2.04 ± 0.01^{c}	0.41 ± 0.00 ^{b}	1.45 ± 0.65^{a}	10.75 ± 0.07^{a}	76.05±0.91^{bc}	360.21±2.63^{a}
N2	96	4	90.17 ± 0.12^{c}	2.07 ± 0.05^{bc}	0.41 ± 0.02^{b}	1.61 ± 0.19^{a}	10.70 ± 0.06^{a}	75.83±0.06^{bc}	360.47±1.66^{a}
N3	94	6	89.94 ± 0.04^{d}	2.10 ± 0.00^{b}	0.44 ± 0.01^{a}	1.93 ± 0.14^{a}	10.74 ± 0.12^{a}	75.18±0.25^{c}	361.01±0.53^{a}
N4	92	8	90.22 ± 0.02^{c}	2.12 ± 0.03^{b}	0.45 ± 0.00^{a}	1.75 ± 0.36^{a}	10.69 ± 0.12^{a}	75.79±0.22^{bc}	361.15±1.77^{a}
N5	90	10	90.57 ± 0.01^{b}	2.19 ± 0.01^{a}	0.44 ± 0.01^{a}	1.54 ± 0.04^{a}	10.37 ± 0.09^{b}	76.47±0.08^{ab}	361.23±0.21^{a}

Table 2. Color parameters of the noodle samples

Sample	L*	a*	b*
C	78.02 ± 2.05^{a}	2.87 ± 0.34^{f}	19.17 ± 0.86^{a}
N1	61.02 ± 1.49^{b}	5.13 ± 0.10^{e}	2.92 ± 0.05^{b}
N2	59.31 ± 1.28^{bc}	6.60 ± 0.23^{d}	-0.53 ± 0.16^{c}
N3	56.41 ± 0.76^{d}	8.57 ± 0.13^{c}	-1.63 ± 0.17^{d}
N4	57.51 ± 0.98^{dc}	9.78 ± 0.14^{b}	-2.09 ± 0.13^{d}
N5	54.07 ± 0.71^{e}	11.75 ± 0.15^{a}	-2.71 ± 0.07^{e}

Table 3. Cooking analyses of noodles samples

Sample	Cooking Time	Water Absorption	Volume Increase	Cooking loss
C	11.24 ± 0.23^{c}	155.06 ± 21.12^{a}	126.50 ± 4.95^{a}	7.44 ± 0.44^{c}
N1	12.82 ± 0.66^{b}	115.55 ± 18.76^{a}	128.89 ± 69.14^{a}	8.51 ± 0.69 ^{c}
N2	13.82 ± 0.42^{a}	117.27 ± 23.16^{a}	151.39 ± 37.32^{a}	11.69 ± 0.28^{bc}

N3	14.32 ± 0.21[a]	136.67 ± 5.66[a]	150.00 ± 14.14[a]	14.52 ± 0.07[ab]
N4	14.45 ± 0.06[a]	138.71 ± 0.57[a]	174.44 ± 20.43[a]	18.98 ± 2.13[a]
N5	14.66 ± 0.50[a]	135.48 ± 3.20[a]	165.00 ± 7.07[a]	19.28 ± 4.66[a]

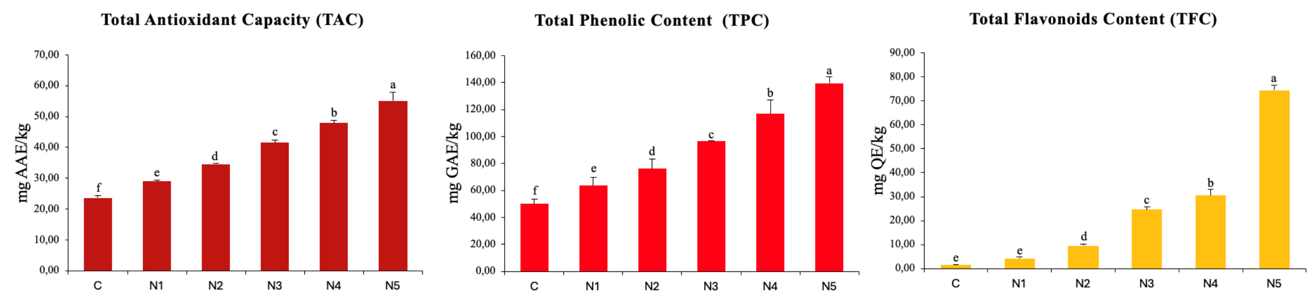

Figure 2. Analysis of variance of total phenolic, flavonoid and total antioxidant values of noodle samples. Mean values indicated with different letters (a-e) are significantly different at the significance level (p<0.05)

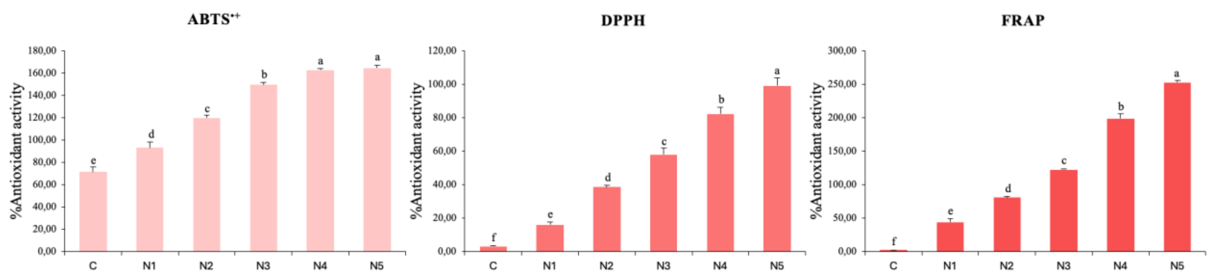

Figure 3. Analysis of variance of ABTS, DPPH and FRAP values for antioxidant analysis of noodle samples. Mean values indicated with different letters (a-e) are significantly different at the significance level (p<0.05)

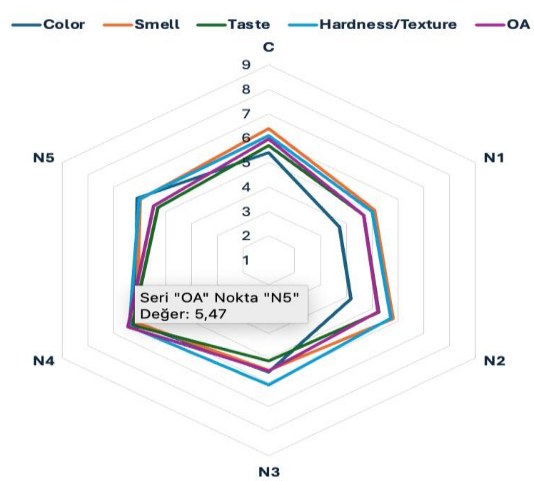

Figure 4. Sensory analyses of noodle samples evaluated using a hedonic scale scored from 1 to 9 (n=30)

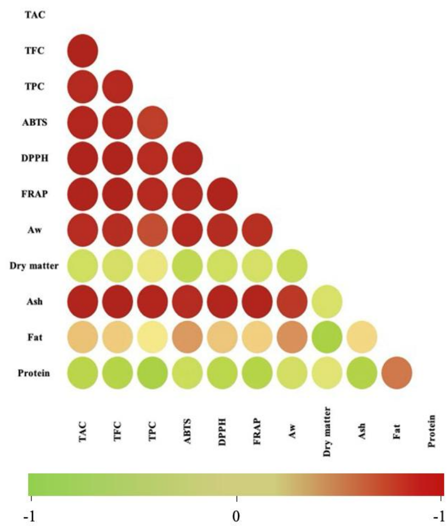

Figure 5. Correlation between physicochemical properties and phenolic content of noodle sample

4. Conclusion

As a result, the noodles were enriched with the aronia powder to develop a healthy food product. The addition of aronia powder into the noodle increased the bioactive properties of the resultant product. Higher sensory scores were given for the enriched noodles by the panelists at the process formulation: 8.0% of aronia powder. The noodle enriched with aronia powder may find opportunity to be commercialized as healthy food products.

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