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Cooking Quality, Nutritional Composition and Textural Properties of Noodles Functionalised using *Rheum ribes* Plant Powder

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This research aimed to explore the potential of incorporating *Rheum ribes* L. plant as an ingredient in noodle production to enhance nutritional properties. *Rheum ribes* powder was added to noodle formulation at 6 different ratios (0%-control, 3%, 6%, 9%, 12% and 15%) according to the principle of replacing with wheat flour. While using *Rheum ribes* in the formulation reduced moisture amount of noodle, it increased ash, protein and fat contents. The inclusion of *Rheum ribes* resulted in elevated levels of total phenolic content and antioxidant activity in the noodles, accompanied by a decrease in their phytic acid contents. Depending on increase in the addition ratio of *Rheum ribes* powder, the cooking time, volume and weight increase values decreased, while the cooking loss and total organic matter values increased. The incorporation of *Rheum ribes* had a notable impact on the textural characteristics of the samples. As a result of the sensory analysis, the noodle sample with 12% *Rheum ribes* powder additive received the highest score in terms of overall acceptability, while the sample with 15% *Rheum ribes* powder additive received the lowest score. However, the panelists also stated that they could consume all the noodles prepared with *Rheum ribes* powder. All these findings showed that adding up to 12% *Rheum ribes* powder to the formulation can be used to improve most quality characteristics of noodles.

Keywords: Antioxidant, Medicinal plants, Noodle, *Rheum ribes*, Uşkun

Introduction

Noodles are a staple food that forms a significant part of the diet of most people, not only in Asian countries, but all over the world. Approximately 40% of the total flour produced in Asia is used in noodle production.[1] Noodles, which have been consumed in various ingredients, formulations and forms in many Asian countries since ancient times, are generally produced by mixing wheat flour, water and salt (NaCl) and/or alkaline salts. There are two common types of noodles, distinguished by the type of salt used: White salty noodles containing NaCl, and yellow alkaline noodles containing kansui, a blend of sodium and potassium carbonates.[2] Noodles are traditionally produced in Turkey much resemble of Asian noodles in terms of the production technique and raw materials used. Noodles continue to gain popularity owing to their straightforward preparation, affordability, quick and convenient cooking, sensory appeal, extended shelf life in dried form, diverse varieties, and nutritional value.

Due to consumers' increasing concerns about health and the perception that nutrition directly affects health, interest in functional food consumption and demand for these products have increased significantly in recent years. Functional foods are often defined as “natural health products” or “healthy foods”. These products could potentially offer physiological benefits and/or mitigate the risk of non-communicable diseases. Presently, the functional product sector is marked by dynamic growth and innovation, with a continuous stream of new product introductions.[3–5] Although noodles include approximately 75% carbohydrates, 11–15% protein and 0.6% fat, still they are deficient of various micronutrients and dietary fiber.[6] For this reason, it is thought that there is need for further enrichment of noodles.

Until now, studies have been conducted on the use of various materials to enrich and flavour noodles and the effects of these materials on the final product quality.[7–9] It has been reported that, to enrich noodles and similar products or provide them with functional properties, other cereal flours and legumes other than wheat flour can be used in noodle production.[10–12]

Rheum ribes L., a perennial plant from the Polygonacea family, native to Lebanon, Iran, Iraq, and eastern Turkey, is thus potentially benefit to enrich the noodles. In Turkey, this vegetable is known

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as ışgın, uşkun, and uçkun and is the only local Rheum species grows in the eastern regions, including Van, Erzurum, Bitlis, Tunceli, Sivas, Muş, Hakkari, and Kars. In Bitlis, the plant's stem is known to aid digestion, while its underground parts are used to treat hemorrhoids and diabetes. Young roots and stems of *Rheum ribes* plant are widely used in folk medicine as a preventive, gall remover, anti-diarrhea and antiemetic against measles and smallpox. Its roots also have an effect that repairs ulcers and stomach discomfort.[13,14] *Rheum ribes* is also a plant that is rich in vitamin C. Studies have determined that *Rheum ribes* plant has a high phenolic substance content and binds free radicals to a high extent, and it could be easily used as a functional food component due to its antioxidant properties.[15]

Despite these functional properties it has, there are very few studies on the use of *Rheum ribes* plant as a functional food component. The objective of this study was to develop a functional noodle that can benefit health by using *Rheum ribes* plant, which is a local plant spices rich in phenolic compounds and antioxidant substances, in the noodle formulation.

Materials and Methods

Materials

In noodle production, wheat flour obtained from the market was used. The *Rheum ribes* plant that was used in the trials was obtained from a local market within the Van province, Turkey. Additionally, refined table salt was used in noodle production. The *Rheum ribes* plant was firstly peeled and cut into small pieces and dried in the sun. The dried *Rheum ribes* was ground in a laboratory type hammer mill (Yücebaş Hammer Mill, with a sieve at 0.5 mm pore size, Turkey) and stored at +4°C in a refrigerator until used for analysis and noodle production.

Methods

Noodle Production

The dried and ground *Rheum ribes* (uşkun) was incorporated into the noodle formulation through substitution it with wheat flour at the ratios of 0-control, 3%, 6%, 9%, 12% and 15% on the basis of flour weight. The *Rheum ribes* plant powder ratios were determined with preliminary trials in a way to not disrupt the structural properties of the noodles. The noodle production method by Yuksel and Gurbuz[16] was used with modification in noodle production. For the control noodle, 200 g of flour, 4 g of salt, and 90 mL of water were used in the production process. To the noodle formulations prepared by adding *Rheum ribes* plant powder at different ratios, 2% table salt over the weight of the wheat flour- *Rheum ribes* plant powder mixture was added. The water amount required for obtaining the dough was determined in preliminary trials by looking at the dough processing characteristics for both noodles produced from 100% wheat flour (control) and those produced with *Rheum ribes* plant powder addition.

To prepare the noodle dough, the ingredients were kneaded in a KitchenAid brand mixer (KitchenAid Classic Model, 5KSM45, USA) for 8 min. After the obtained dough was divided into 3 parts and rounded, it rested for 15 min. The rested round dough masses were subjected to a preliminary thinning procedure without damaging them by passing over them with a rolling pin 3–4 times. To prevent the pre-thinned dough from sticking, each surface of the dough was rested in room conditions for 5 min to apply pre-drying. The rested dough was sliced into strips at a width of 5 mm and thickness of 2 mm in a noodle machine (Essenso Pasta Machine, Turkey). By cutting these strips at a length of 4 cm with the help of a knife, the final noodle shape was obtained. The noodles were left to dry in a way that they would not stick to each other under laboratory conditions (25°C and 30% relative humidity) for 18 ± 2 hours. A part of the produced noodles was allocated for the cooking analyses and sensory analysis, and the remaining part was ground homogenously in a spice mill (Arçelik brand K3104 model) and kept in glass jars in the refrigerator at +4°C until analysed.

Chemical Analyses

Using AACC methods (44–19 for moisture, 08–01 for ash, 46–12 for protein, and 30–25 for fat), the moisture, ash, protein, and fat contents of wheat flour, *Rheum ribes* plant powder, and dry noodle samples were determined.[17] Carbohydrate content was calculated by subtracting the sum of moisture, protein, fat and ash from 100%.

Nutritional Properties

Phytic acid: Analysis of phytic acid was conducted in the flour, *Rheum ribes* plant powder, and dry noodles by using of Haugh and Lantzsch's[18] colorimetric method.

Total Phenolic Content (TPC): Total phenolic content (TPC) of flour, *Rheum ribes* plant powder and dry noodles was analyzed according to Gutfinger.[19]

Samples were extracted with 80% methanol. TPC values were determined by applying an equation derived from a standard graph correlating absorbance with gallic acid concentrations. Results were expressed in milligrams of gallic acid equivalent (GAE) per gram of sample.

Antioxidant Activity: The analysis of flour, *Rheum ribes* plant powder, and dry noodles was conducted using a modified version of the method described by Yu *et al.*[20] The method relies on spectrophotometric analysis to track the decline in color intensity associated with the breakdown of the stable pink-colored compound, DPPH (2, 2-diphenyl-1-picrylhydrazyl), indicative of antioxidant potential. The percentage inhibition rate of the DPPH radical was calculated using Eq. 1, thereby quantifying the results.

$$\text{DPPH inhibition (\%)} = \frac{A_{Blank} - A_{Sample}}{A_{Blank}} \times 100 \quad \ldots (1)$$

where, A_{Blank} = Absorbance of blank; A_{Sample} = Absorbance of sample

Color Analyses

A HunterLab MiniScan EZ model color measurement device (Reston, Virginia, USA) was utilized to perform color analysis on the flour, Rheum ribes plant powder, and dry noodles. Results were calibrated according to the CIALAB measurement system integrated into the device, with L* (brightness), a* (redness), and b* (yellowness) values recorded under daylight conditions (D65/10°).

Noodle Cooking Tests

The optimal cooking time for the noodles was established following the AACC method (method 66–50).[17] Weight increase (WI), volume increase (VI), and cooking loss (CL) values were determined in accordance with the procedure outlined by Aktaş *et al.*[12] A 10-gram portion of noodles underwent cooking in 300 mL of distilled water for a duration of 18 minutes. Pre- and post-cooking weights of the noodles were recorded to calculate the weight increase using Eq. 2. For volume increase (VI) determination, both uncooked and cooked noodle samples were immersed in a volumetric cylinder containing a specified volume of distilled water, and the subsequent change in water volume was gauged. VI was subsequently calculated using Eq. 3. For cooking loss (CL), the cooking water was evaporated to constant weight at 100°C and the residue remaining in the cooking vessel was weighed to determine CL, i.e., weight of total solids in %.

$$WI\ (\%) = 100 \times \frac{\text{Cooked noodle weight} - \text{Raw noodle weight}}{\text{Raw noodle weight}} \quad \ldots (2)$$

$$VI\ (\%) = 100 \times \frac{\text{Cooked noodle volume} - \text{Raw noodle volume}}{\text{Raw noodle volume}} \quad \ldots (3)$$

Total organic matter (TOM): In determining the TOM amount in noodles, the method reported by D'Egidio *et al.*[21] was utilized. The method entails rinsing the cooked noodle sample with a predetermined volume of water, allowing any organic matter present on the sample surface to leach into the water. The amount of organic matter present in the washing water is subsequently assessed employing a chemical method.

Textural Properties

Textural characteristics of both dry and cooked noodles were evaluated utilizing the TA-XT2i texture analyzer (Stable Micro Systems Ltd., Godalming, Surrey, UK). The fracture strength (brittleness) of the dry noodles was assessed according to AACC method No.: 74–09.01.(17) A three-point bending test was employed for this purpose, with the following parameters: pre-test speed of 1 mm/s, test speed of 1 mm/s, post-test speed of 10 mm/s, test distance of 5 mm, and trigger value of 5 g. A 5 cm long cut noodle piece was placed between two vertical aluminum barriers spaced 2 cm apart. Then, force was applied to the midpoint of the noodle at a speed of 1 mm/s. The maximum force at the breaking point was recorded in Newtons (N). In the texture profile analysis (TPA) of cooked noodles, we followed the procedure outlined by Kong *et al.*[22] was used by some modifications. For the analysis, a 10 g noodle sample (cut to a length of 5 cm) was cooked in 200 mL of distilled water for a consistent duration of 8 minutes. After cooking, the noodles were slowly filtered using a Büchner funnel, followed by a 5-minute cooling period. Excess water was then removed using drying paper. Three noodle strips prepared in this manner were placed adjacent to each other on the device tray, and the analysis commenced. TPA was performed utilizing a P/36R cylinder probe, employing the following settings: Pre-test speed of 4 mm/s, test speed of 1 mm/s, post-test speed of 1 mm/s, test distance of 1.5 mm, trigger type set to Auto (Force) with a trigger force of 5 g (automatically detected), tare mode set to Auto, and advanced options enabled. From the resulting force-time curve, parameters including hardness, cohesiveness, gumminess, chewiness, and springiness were determined.

Sensory Analyses

The sensory analyses followed a method similar to that outlined by Inglett *et al.*[23] with minor modification. To prepare the noodle samples for sensory analysis, 100 grams of sample was cooked in 500 milliliters of water for 10 minutes, followed by draining excess water for 20 seconds. The sensory evaluation was conducted by 10 semi-trained participants aged between 30 and 55. Panelists were instructed to rate various attributes, including color, brightness, hardness, stickiness, taste-aroma, and overall acceptability, using a 5-point scale ranging from 1 (very bad) to 5 (very good).

Statistical Analyses

The study findings, conducted with two replicates, underwent statistical analysis using JMP software (version JMP 11 for Windows). Group distinctions were assessed utilizing the LSD test with a 5% confidence interval, employing the One-way statistical model.

Results and Discussion

Raw Material Properties

The general quality of noodles greatly depends on the properties of the raw materials. Data on the chemical, functional, and color properties of the wheat flour and *Rheum ribes* plant powder used as raw materials in noodle production are presented in Table 1. The moisture, ash, protein, fat, and phytic acid contents of the wheat flour on a dry weight basis were found to be 12.41%, 0.66%, 12.81%, 1.07%, and 2.70 mg/g, respectively.

Aktaş and Türker[24] reported the ash, protein, fat, and phytic acid contents of the wheat flour used in noodle production as 0.50%, 10.50%, 0.62%, and 2.40 mg/g, respectively. *Rheum ribes* plant powder was found to have higher ash and protein contents but lower fat and phytic acid contents than wheat flour. Doğan's[25] dissertation study reported that Rheum ribes plant powder contained 90.55% moisture, 8.64% ash, and 21.04% protein.

Considering the total phenolic content (TPC) and antioxidant activity values described as functional properties, it is seen that the *Rheum ribes* plant powder has much higher values than wheat flour (Table 1). TPC of the *Rheum ribes* plant powder was found to be 1248.95 mgGAE/100g, while its antioxidant activity value was 92.92%. A previous study reported the TPC of *Rheum ribes* plant powder as 236 mgGAE/100g and its antioxidant activity value as 91.00%.(14) It is believed that the difference in the TPC in comparison to the results in the literature originated from the differences in the ecological conditions in which the *Rheum ribes* plants were grown and the peeling, slicing and drying processes. Compared to wheat flour, *Rheum ribes* plant powder was found to have lower L* (brightness) values, and higher a* (redness) and b* (yellowness) values (Table 1). A dissertation study reported the L, a and b values of the *Rheum ribes* plant powder as 88.88, 0.67 and 33.51 respectively.[26] For the wheat flour, the L* value was 99.49, a* value was 0.43, and b* value was 10.50. These color values for wheat flour are consistent with those reported in the literature.[12]

Chemical Properties

The values of some chemical properties of the noodle samples produced with varying ratios of *Rheum ribes* plant powder are provided in Table 2. As the *Rheum ribes* plant powder addition ratio increased (0–15%), the ash, protein and fat contents

Table 1 — Chemical, nutritional and color properties of wheat flour and *Rheum ribes* plant powder used in noodle production

Properties	Wheat flour	*Rheum ribes* plant powder
Moisture (%)	12.41 ± 0.15^a	12.69 ± 0.81^a
Ash (%)§	0.66 ± 0.05^b	5.61 ± 0.09^a
Protein (%)§	12.81 ± 0.26^b	18.55 ± 0.67^a
Total fat (%)§	1.07 ± 0.00^a	0.98 ± 0.01^a
Carbohydrate (%)	73.06 ± 0.06^a	62.18 ± 1.37^b
TPC (mg/kg)	1348.60 ± 12.22^b	12489.50 ± 5.14^a
Antioxidantaktivity (% inhibition)	12.92 ± 0.88^b	92.92 ± 0.35^a
Phyticacid (mg/g)§	2.70 ± 0.13^a	0.09 ± 0.01^b
L*	99.49 ± 0.05^a	76.15 ± 0.01^b
a*	0.43 ± 0.01^b	5.67 ± 0.03^a
b*	10.50 ± 0.06^b	25.49 ± 0.37^a

In the table, the values marked with different letters are statistically different when the lines are examined from left to right. ($p \leq 0.05$); §Calculated on dry matter basis

Table 2 — Chemical properties of noodle samples

Rheum ribes plant powder ratio (%)	Ash (%)*	Protein (%)*	Total fat (%)*	Carbohydrate (%)
0	0.90 ± 0.00^{f}	13.36 ± 0.02^{f}	0.80 ± 0.01^{d}	75.27 ± 0.48^{a}
3	1.40 ± 0.02^{e}	13.86 ± 0.01^{e}	0.82 ± 0.01^{c}	74.05 ± 0.04^{b}
6	2.05 ± 0.01^{d}	13.94 ± 0.00^{d}	0.80 ± 0.00^{d}	73.67 ± 0.01^{bc}
9	2.28 ± 0.01^{c}	14.15 ± 0.04^{c}	0.82 ± 0.01^{c}	73.56 ± 0.10^{c}
12	2.40 ± 0.03^{b}	14.46 ± 0.04^{b}	0.83 ± 0.01^{b}	73.54 ± 0.06^{cd}
15	2.54 ± 0.01^{a}	14.86 ± 0.00^{a}	0.84 ± 0.00^{a}	73.10 ± 0.06^{d}

In the table, the values marked with different letters are statistically different when the columns are examined from top to bottom ($p \leq 0.05$); *Calculated on dry matter basis

of the noodle samples significantly increased ($p \leq 0.05$). The ash, protein and fat contents of the noodle sample containing the highest ratio of *Rheum ribes* plant powder were found to be 2.54%, 14.86% and 0.84% respectively. The obtained results were found as a consequence of the rich chemical composition of the *Rheum ribes* plant (Table 1) as expected. Similar results were reported in studies conducted by different researchers on noodles with additives.[8,10]

In comparison to control noodle, the amount of carbohydrates in the *Rheum ribes* plant powder-added noodles regularly decreased with the increasing *Rheum ribes* plant powder concentration ($p \leq 0.05$). The reason for this was the proportional changes in the other nutritional components (ash, protein and fat) in the *Rheum ribes* plant powder and wheat flour. Additionally, changes in the moisture content also caused difference in the carbohydrate contents. The carbohydrate content of the samples ranged from 73.10% to 75.27%. These results were consistent with those reported in the literature.[8,9,27]

Nutritional and Color Properties of Noodles

Total phenolic content (TPC), antioxidant activity and phytic acid values of control noodle and *Rheum ribes* plant powder-added noodles are presented in Table 3. TPC of all *Rheum ribes* plant powder-added noodles increased significantly by the increase in the *Rheum ribes* plant powder addition ratio of $p \leq 0.05$. The total phenolic content, antioxidant activity, and phytic acid values of control noodle and those with added *Rheum ribes* plant powder are presented in Table 3. The TPC of all noodles with *Rheum ribes* plant powder significantly increased as the addition ratio of *Rheum ribes* plant powder increased ($p \leq 0.05$). The lowest TPC was 1560.00 mg/kg in control noodle, while highest was 2650.90 mg/kg in noodle containing 15% *Rheum ribes* plant powder. The antioxidant activity values of the noodles with *Rheum ribes* plant powder were higher than those of control noodle. The addition of *Rheum ribes* plant powder significantly enhanced the antioxidant potential of the noodles ($p \leq 0.05$). The increases in bioactive compounds originated from the increase in the concentration of the *Rheum ribes* plant, which is phytochemically rich. Similar results were reported in a study where beetroot (*Beta vulgaris* L.) was used as a functional component in noodle production.[8]

Looking at the phytic acid amounts shown in Table 3, it was seen that the phytic acid values in the samples decreased in parallel with the increased in the *Rheum ribes* plant powder addition ratio. The highest phytic acid amount (1.70 mg/g) was in the control sample, while this value decreased to 0.11 mg/g in the 15% *Rheum ribes* plant powder-added noodle sample. Despite its important functions in plants, phytic acid can have detrimental effects on human health due to its ability to bind phosphorus as phytate phosphorus and interact with certain amino acids.[28] Phytic acid is accepted as an antinutrient as it can directly or indirectly bind minerals, proteins and starch. Therefore, it negatively affects the bioavailability or digestibility of these nutrients. On the other hand, numerous researchers have reported on the potential health benefits of phytic acid, including its antioxidant and anticarcinogenic properties. However, the extent of its beneficial effects remains unclear due to limited dosage information available for human consumption.[29]

Color values of the noodle samples are given in Table 3. The natural pigmentation of *Rheum ribes* plant powder significantly affected the color values of the noodles ($p \leq 0.05$). It was observed that the L* values of the *Rheum ribes* plant powder-added noodle samples varied between 89.50 and 92.91, and the values decreased in relation to the increase in the *Rheum ribes* plant powder addition ratio. The lowest L* value was in the 15% *Rheum ribes* plant powder-

Table 3 — Nutritional and color properties of noodle samples

Rheum ribes plant powder ratio (%)	TPC (mg/kg)	Antioxidant activity (% inhibition)	Phytic acid (mg/g)[§]	L*	a*	b*
0	156.00 ± 9.32^{d}	15.59 ± 0.01^{f}	1.70 ± 0.04^{a}	96.22 ± 0.57^{a}	0.97 ± 0.04^{d}	12.17 ± 0.22^{ab}
3	163.27 ± 3.22^{d}	18.45 ± 0.47^{e}	1.61 ± 0.06^{a}	92.91 ± 0.47^{b}	1.59 ± 0.11^{c}	9.67 ± 0.42^{c}
6	198.95 ± 3.54^{c}	24.84 ± 0.41^{d}	0.63 ± 0.04^{b}	92.44 ± 0.11^{b}	1.80 ± 0.09^{c}	10.73 ± 0.37^{bc}
9	243.50 ± 7.07^{b}	25.90 ± 0.25^{c}	0.45 ± 0.02^{c}	90.94 ± 0.75^{c}	2.37 ± 0.21^{b}	12.24 ± 1.12^{a}
12	256.45 ± 9.63^{a}	32.48 ± 0.38^{b}	0.17 ± 0.03^{d}	90.30 ± 0.35^{cd}	2.77 ± 0.06^{a}	12.69 ± 0.74^{a}
15	265.09 ± 6.62^{a}	33.73 ± 0.65^{a}	0.11 ± 0.01^{d}	89.50 ± 0.08^{d}	2.96 ± 0.05^{a}	13.20 ± 0.50^{a}

In the table, the values marked with different letters are statistically different when the columns are examined from top to bottom ($p \leq 0.05$); [§]Calculated on dry matter basis

Table 4 — Cooking properties of noodle samples

Rheum ribes plant powder ratio (%)	Cook in time (min)	Weight increase (%)	Volume increase (%)	Cooking loss (%)[*]	TOM (%)[*]
0	9.08 ± 0.00^{a}	181.82 ± 8.93^{a}	12.32 ± 0.23^{a}	6.98 ± 0.30^{f}	0.88 ± 0.05^{e}
3	8.80 ± 0.00^{b}	162.27 ± 3.45^{b}	11.45 ± 0.12^{b}	8.41 ± 0.18^{e}	1.02 ± 0.05^{de}
6	8.45 ± 0.00^{c}	151.08 ± 0.83^{c}	9.17 ± 0.02^{c}	10.22 ± 0.19^{d}	1.12 ± 0.10^{cd}
9	7.40 ± 0.00^{d}	144.89 ± 1.62^{cd}	8.99 ± 0.23^{c}	12.16 ± 0.45^{c}	1.33 ± 0.00^{c}
12	5.30 ± 0.00^{e}	137.07 ± 3.25^{de}	8.58 ± 0.57^{c}	14.25 ± 0.34^{b}	1.79 ± 0.15^{b}
15	5.08 ± 0.00^{f}	128.11 ± 2.57^{e}	7.39 ± 0.23^{d}	16.37 ± 0.84^{a}	2.24 ± 0.10^{a}

In the table, the values marked with different letters are statistically different when the columns are examined from top to bottom ($p \leq 0.05$); [*]Calculated on dry matter basis

added sample. The decrease in L* values caused the noodles to have a less bright and darker appearance. As can be seen from Table 3, the a* and b* values of the *Rheum ribes* plant powder-added noodle samples increased in line with the increase in the *Rheum ribes* plant powder addition ratio. The highest a* value was found as 2.96 in the 15% *Rheum ribes* plant powder-added sample, while the lowest value was 0.97 in the control sample. The *Rheum ribes* plant powder-added noodles were found to be yellower and redder than the control sample.

The observed colour variations in the noodle samples are directly linked to the colour attributes of the *Rheum ribes* plant powder incorporated into the noodle formulation. Numerous studies investigating the colour properties of noodles have consistently found that the final product's colour values shift in accordance with the colour properties of the raw material utilized for enrichment. Similar results were obtained in the colour values of noodles produced by addition of beet root[5], corncob fiber[30], lupinflour[31], rosehip flour[32] and parsley.[4]

Cooking Properties of Noodles

Cooking quality, defined by attributes such as cooking time, weight increase, volume increase, and cooking loss, is crucial for assessing noodle quality from a consumer perspective. High-quality noodles should have a short cooking time and low cooking loss. Additionally, weight increase, which reflects the quality of water absorption during cooking, is an important aspect of noodle cooking quality.[33] The cooking time, weight increase, volume increase, cooking loss, and total organic matter (TOM) values of noodles with added *Rheum ribes* powder are shown in Table 4.

The results showed that the control noodle had a longer cooking time than the *Rheum ribes* plant powder-added noodles. The cooking time decreased by increasing the *Rheum ribes* plant powder addition ratio. Ingredients other than wheat flour such as dried-ground *Rheum ribes* plant powder can cause faster moisture penetration by causing discontinuity in the gluten network, and therefore, result in shortening the optimum cooking time.[27] Studies that used increasing ratios of black carrot[9] and jamun seeds[27] in noodle formulations reported that the cooking time was shortened.

Rheum ribes plant powder addition significantly affected the weight increase and volume increase values of the noodle samples ($p \leq 0.05$). As the addition ratio of *Rheum ribes* plant powder increased, the weight and volume increase values decreased. The control sample exhibited the highest weight increase, while the 15% *Rheum ribes* plant powder added-sample had the lowest. The decrease in the weight increase was caused by less water absorption as the gluten density decreased. The volume increase values

Table 5 — Textural properties of noodle samples

Rheum ribes plant powder ratio (%)	Fracturability (N)	Hardness (N)	Cohesiveness	Gumminess	Chewiness	Springiness
0	6.21 ± 0.92^{ab}	51.88 ± 0.52^{a}	0.76 ± 0.03^{a}	38.17 ± 1.11^{a}	38.74 ± 1.24^{a}	0.98 ± 0.01^{a}
3	7.47 ± 1.64^{a}	44.43 ± 1.16^{b}	0.74 ± 0.00^{a}	32.89 ± 2.89^{b}	31.87 ± 2.60^{b}	0.99 ± 0.01^{a}
6	6.81 ± 0.88^{b}	42.58 ± 1.85^{bc}	0.73 ± 0.00^{a}	30.48 ± 1.67^{bc}	28.87 ± 0.06^{bc}	0.96 ± 0.01^{ab}
9	5.52 ± 0.47^{ab}	40.69 ± 0.69^{c}	0.69 ± 0.03^{b}	28.71 ± 0.07^{cd}	27.35 ± 0.86^{cd}	0.96 ± 0.01^{ab}
12	3.93 ± 0.40^{bc}	39.95 ± 0.76^{cd}	0.67 ± 0.02^{bc}	27.64 ± 0.51^{cd}	26.50 ± 1.41^{cd}	0.98 ± 0.02^{b}
15	2.61 ± 0.83^{c}	37.57 ± 1.33^{d}	0.64 ± 0.01^{c}	26.05 ± 0.54^{d}	24.10 ± 0.11^{d}	0.99 ± 0.01^{b}

In the table, the values marked with different letters are statistically different when the columns are examined from top to bottom ($p \leq 0.05$)

of *Rheum ribes* plant powder-added noodle samples were found to be significantly lower than that of the control noodle ($p \leq 0.05$). The volume increase values of cooked noodles varied from 7.39% to 12.32%, and the lowest volume increase was in the 15% *Rheum ribes* plant powder-added noodle sample. This decrease in volume increase may be due to the significantly higher cooking loss in noodles with *Rheum ribes* plant powder. The volume increase during boiling was influenced by starch gelatinization and protein hydration related to starch size.[34]

Cooking loss, which occurs as gelatinized starch and other water-soluble substances dissolve from the noodle surface into the cooking water, provides insight into the structural integrity of the noodles.[5] As cooking loss is an indicator of the resistance of noodles against cooking, it is desired to be at low levels.[27] As the addition ratio of *Rheum ribes* plant powder increased in the noodle formulation, cooking loss values rose from 6.98% to 16.37% (Table 5). Due to dilution of gluten by addition of *Rheum ribes* plant powder into the formulation, the cooking loss value was found high. Because the weak or discontinuous protein-starch network caused by gluten dilution allows more solids to pass into the water during cooking.[9] Singh *et al.*[6] used black carrot in noodle production and determined that this addition significantly increase cooking loss. In another study, addition of oyster mushrooms increased cooking loss in noodles from 3.6% to 4.3%.(35)

Total Organic Matter (TOM) analysis is based on determination of starch and other organic compounds on the surface of cooked noodles. A high correlation was determined between conventional organoleptic assessment and TOM content. This method was recommended as a valid and objective alternative to taste panel testing in pasta. Furthermore, it was reported that TOM values can also be used in classification of pasta. TOM value of below 1.4% is an indicator that the pasta is very high-quality. This classification was made for pasta made out of durum wheat semolina.[21] Total Organic Matter analysis was applied on the noodle samples in the present study. Total organic matter expressed as a function of starch is shown in Table 4 for all examined formulations. The TOM values of the *Rheum ribes* plant powder-added noodle samples varied between 1.02% and 2.24%, and were higher than control sample. An increase was observed in the TOM values in relation to the increase in the *Rheum ribes* plant powder addition ratio. The highest TOM value among the noodles was found as 2.24% in the 15% *Rheum ribes* plant powder-added sample, while the lowest was in the control sample as 0.88%. In their study on the effects of oat flour addition on spaghetti quality, Pilli *et al.*[36] found that TOM values increased in parallel with an increase in the oat flour addition ratio. Similar results on TOM values were also reported in the study conducted by Larrosa *et al.*[37]

Textural Properties of Noodles

The values on the fracturability and Textural Profile Analysis (TPA) results of the noodle samples are presented in Table 5. *Rheum ribes* plant powder addition significantly affected all textural properties of the noodles except for springiness ($p \leq 0.05$).

The hardness values of the noodles ranged from 37.57 N to 51.88 N, with all *Rheum ribes* plant powder-added noodles exhibiting lower hardness values compared to the control noodle. Increasing the *Rheum ribes* plant powder addition ratios resulted in decreased hardness values. There was a significant difference between the control and *Rheum ribes* plant powder-added noodles in terms of the cohesiveness values. With the increase in the *Rheum ribes* plant powder addition ratio, there was a decreasing trend in the cohesiveness values of the noodles. The *Rheum ribes* plant powder added into the noodle significantly

Table 6 — Sensory properties of noodle samples

Rheum ribes plant powder ratio (%)	Color	Brightness	Firmness	Stickiness	Taste-aroma	Overall acceptability
0	4.90 ± 0.14^{a}	4.90 ± 0.14^{a}	3.40 ± 0.00^{a}	3.95 ± 0.21^{a}	4.60 ± 0.00^{a}	4.35 ± 0.07^{a}
3	4.70 ± 0.00^{ab}	4.10 ± 0.42^{ab}	3.30 ± 0.14^{ab}	3.90 ± 0.14^{a}	3.90 ± 0.14^{c}	3.95 ± 0.07^{b}
6	4.60 ± 0.28^{ab}	4.10 ± 0.71^{ab}	3.15 ± 0.07^{bc}	3.70 ± 0.14^{a}	3.95 ± 0.35^{c}	4.05 ± 0.07^{b}
9	4.40 ± 0.14^{ab}	3.95 ± 0.21^{bc}	3.05 ± 0.07^{cd}	3.70 ± 0.14^{a}	4.10 ± 0.14^{bc}	4.10 ± 0.14^{b}
12	4.30 ± 0.42^{b}	3.85 ± 0.35^{bc}	2.95 ± 0.07^{d}	3.30 ± 0.14^{b}	4.50 ± 0.14^{ab}	4.45 ± 0.07^{a}
15	4.20 ± 0.00^{b}	3.20 ± 0.28^{c}	2.60 ± 0.00^{e}	3.10 ± 0.14^{b}	3.30 ± 0.14^{d}	3.50 ± 0.14^{c}

In the table, the values marked with different letters are statistically different when the columns are examined from top to bottom ($p \leq 0.05$)

decreased the gumminess value from 38.17 to 26.05 ($p \leq 0.05$). When the chewiness values were examined, a decrease was observed in the values in parallel with the increasing *Rheum ribes* plant powder addition ratio. The chewiness values of the *Rheum ribes* plant powder-added samples were found to be lower than control sample. While the lowest springiness value (0.96) was in the 6% and 9% *Rheum ribes* plant powder-added samples, the highest value (0.98) was in the 3% and 15% *Rheum ribes* plant powder-added samples. In general, no significant change occurred in the springiness values. The textural properties of noodles are primarily influenced by the matrix structural network of starches, glutens, proteins, fibers, and other added components, which can either weaken or strengthen the formation of hydrogen bonds within the noodle's structural network.[22] It is desired that dry noodles have a texture resistant against breaking during storage. In this study, significant decreases were recorded in the breaking strength of the *Rheum ribes* plant powder-added noodles in comparison to the control noodle ($p \leq 0.05$) (Table 5). The textural results obtained in this study were consistent with those reported in previous studies.[11,22]

Sensory Properties of Noodles

The results presented in Table 6 showed that the best color and brightness, hardness, stickiness during chewing and taste-aroma were the best in control sample. The *Rheum ribes* plant powder-containing samples' colour scores were 4.20–4.70, brightness scores were 3.20–4.10, hardness scores were 2.60–3.30, stickiness scores were 3.10–3.90, taste-aroma scores were 3.30–3.90, and overall acceptability scores were 3.50–4.45.

The lowest score in terms of the colour properties was in the 15% *Rheum ribes* plant powder-added noodle sample. As the *Rheum ribes* plant powder ratio increased, the brightness values significantly decreased ($p \leq 0.05$). In general, it is desired that noodles are soft (but not too soft). In the sensory analyses, while the control sample had the highest hardness score (3.40), the 15% *Rheum ribes* plant powder-added noodle sample had the lowest score (2.60). This showed that the noodles got a softer structure with addition of *Rheum ribes* plant powder. It was observed that, as the *Rheum ribes* plant powder addition ratio increased, the stickiness values of the noodles decreased.

Among the *Rheum ribes* plant powder-added cooked noodle samples, the highest taste-aroma score was in the 12% *Rheum ribes* plant powder-added noodle sample. The panelists liked the 12% *Rheum ribes* plant powder-added sample to which they gave a mean score of 4.45 most, and this was found to be statistically similar to the control sample. *Rheum ribes* plant powder addition generally caused a decrease in the sensory scores of the cooked noodles. Nevertheless, the panelists stated that they could consume all noodles prepared with *Rheum ribes* plant powder. According to the assessments, it was concluded that the use of *Rheum ribes* plant powder up to the ratio of 12% in noodle formulation provided satisfactory results in terms of acceptability.

Conclusions

In this study, noodles were produced by using *Rheum ribes* (uşkun) plant powder at different ratios, and *Rheum ribes* plant powder was utilized as a functional component for this purpose. The use of *Rheum ribes* plant powder on different ratios in the noodle formulation increased the noodles' ash, protein and fat contents. Additionally, using *Rheum ribes* plant powder increased the total phenolic content and antioxidant activity of noodles and reduced their phytic acid contents. Especially considering the results of the chemical and functional (ash, protein, fat, antioxidant activity, total phenolics, phytic acid, etc.) analyses, it was concluded that the *Rheum ribes* plant could be used in noodle formulations by up to the ratio of 12%. Moreover, it is thought that *Rheum ribes* plant can be used as a functional food component in other studies to be conducted in the future for enriching different foods.

Conflicts of Interest

The authors declare no conflict of interest.

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