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Investigation of the effects of changes in formulation and cooking times on the quality parameters in the production of goji berry leather

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Goji berry (*Lycium barbarum* L.) is described as a food with several health benefits. This valuable fruit has been processed into fruit leather, which is one of the important traditional products. This study allowed us to determine the effect of changing formulations (starch and flour) and cooking times (10, 15, and 20 min) on quality criteria during goji berry leather production. The goji berry leather samples exhibited the following characteristics: pH values ranging from 4.96 to 4.99, titration acidity values spanning from 2.97% to 3.23%, dry matter content within the range of 84.78% to 87.69%, ash content between 3.12%, and 4.27%, water activity (a_w) values ranging from 0.37 to 0.38, protein content between 14.71%, and 15.66%, HMF content varying from 17.33 mg/kg to 34.51 mg/kg, total phenolic content ranging from 7.14 µg GAE/g to 7.89 µg GAE/g, total sugar content falling between 61.18%, and 63.89%, reducing sugar content within the range of 60.13% to 61.89%, sucrose content ranging from 0.91% to 2.25%, thickness values ranging from 0.74 mm to 0.89 mm, hardness values varying between 17.09, and 33.27, stickiness values within the range of 4.10 to 23.34, cohesiveness values from 0.85 to 1.00, elasticity values ranging from 0.88 to 0.97, chewability values spanning from 12.85 to 30.85, L^* values ranging from 27.27 to 32.66, a^* values between 8.62, and 10.32, b^*values varying from 7.06 to 8.59, C^* values within the range of 11.15 to 12.81, and H° values falling between 39.31, and 41.13. Following the sensory evaluation of leather samples, it was determined that the color score ranged from 3.80 to 4.27, the smell score fell between 3.53 and 4.00, the taste score varied from 2.93 to 4.00, the mouthfeel score ranged from 2.93 to 3.93, and the general acceptability score was found to be within the range of 3.27 to 4.20. It was determined that cooking time and additional additives affect some quality values of the goji berry leather.

Keywords: Cooking time, Goji berry, Goji berry leather, Ingredient, *Lycium barbarum* L.

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People have needs that must be met in order to survive. In addition to needs such as air and water, the need for nutrition has a very important place in human life[1]. It is known that there is a positive correlation between nutrition and health. All foods of herbal origin (fruit, vegetable, cereals, etc.) and animal origin (meat, milk, etc.) are important in this sense. However, among all these foods, fruits containing antioxidants are of particular importance. Fruits are processed into many products, such as molasses, jam, and fruit leather, and are presented for consumption in different ways.

Fruit leather is a nutritious, delicious, and dehydrated product that can be obtained from many types of fruit, such as grape, mulberry, strawberry, and mango. Fruit leather is rich in vitamins and minerals[2]. Considering all this, fruit leather is a dense food that is high in nutrients and beneficial for health[3]. The fruit leather has a soft and chewable texture with a sharp and sweet taste. Different ingredients can be added to fruit pulp to improve the physicochemical and sensory qualities of the product[4]. Many fruit leathers are prepared directly by mixing fruit puree or additives such as sugar, pectin, acid, glucose syrup, and potassium metabisulfite and then dehydrating under special conditions[5].

Goji berry is a significant fruit known for its abundant nutrients and health advantages[6]. Through this research, goji berry, a fruit renowned for its rich nutritional value, was utilized in the production of fruit leather, which holds a significant place among traditional products. The effect of different formulations (starch and flour) and cooking time on quality criteria in goji berry leather production was investigated. The preferred cooking time and ingredients in the production of fruit leathers are important because the cooking time and the ingredients affect some nutritional components of the

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product. In addition, there is no study on goji berry leather in the literature. For this reason, it is thought that this study will contribute to the literature.

Materials and Methods

Materials

Dried goji berry (*Lycium barbarum* L.), fresh lemon juice, wheat starch, and wheat flour were used as materials in this study.

Methods

Preparing of goji berry leather

The dried goji berry was weighed at 1500 g and washed with 2 liters of water. Since the fruit was dry, it absorbed 400 mL of water. Considering the water absorbed by the fruit, 2600 mL of water was added to the fruit. After this process, the fruit and water mixture was passed through a blender. However, since the fruit has large amounts of small seeds, it was filtered with a sieve in order to be more homogeneous. Thus, the beans remained in the sieve and were removed. 700 g of residuum was removed and 3090 mL of pulp was obtained. In this way, pulp was obtained by keeping the recipe amount under control. The total pulp was divided into 6 equal amounts, each being 515 mL. 70 mL of the 515 mL pulps were separated to be mixed with starch (10 g) and flour (10 g). In addition to starch and flour to the pulp, 20 mL more water was added. Later, 1 mL of lemon juice was added to 445 mL pulps. After this stage, fruit leather samples coded as G1, G2, G3, G4, G5, and G6 were produced using 2 different ingredients (starch and flour) and 3 different cooking times (10, 15 and 20 min), as shown in Table 1. After all these processes, herle was laid on wax papers of 37 cm × 37 cm size. Herle was dried in an oven at 50°C for 10 h. After drying, fruit leather samples were packaged in a locked bag. The production flow chart of the goji berry leather is shown in Figure 1, and the production visuals are shown in Figure 2.

Determination of pH and titration acidity value

The pH measurement was conducted utilizing a pH meter that had been calibrated with a pH 7.0 buffer solution. Titratable acidity was determined potentiometrically by titrating the sample with 0.1 M NaOH until the pH reached 8.1, and the results were expressed as grams of anhydrous citric acid per 100 g[7].

Determination of dry matter and ash content

The dry matter content was assessed by subjecting it to an air oven at 104°C, and the obtained dry matter content was computed employing the following formula[7]. Formula 1 is used below for calculation.

$$\text{Dry matter (\%)} = \frac{\text{Final weight} - \text{Tare weight}}{\text{Weight of sample}} \times 100 \quad \text{... (1)}$$

To determine the ash content, the samples were incinerated in an ash furnace at 550°C until they turned into white ash. The resulting ash content was then calculated using the formula provided in Formula 2 below[7].

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times 100 \quad \text{... (2)}$$

Table 1 — Description of goji berry leather samples

Sample codes	Ingredient	Cooking time (min)
G1		10
G2	Starch	15
G3		20
G4		10
G5	Flour	15
G6		20

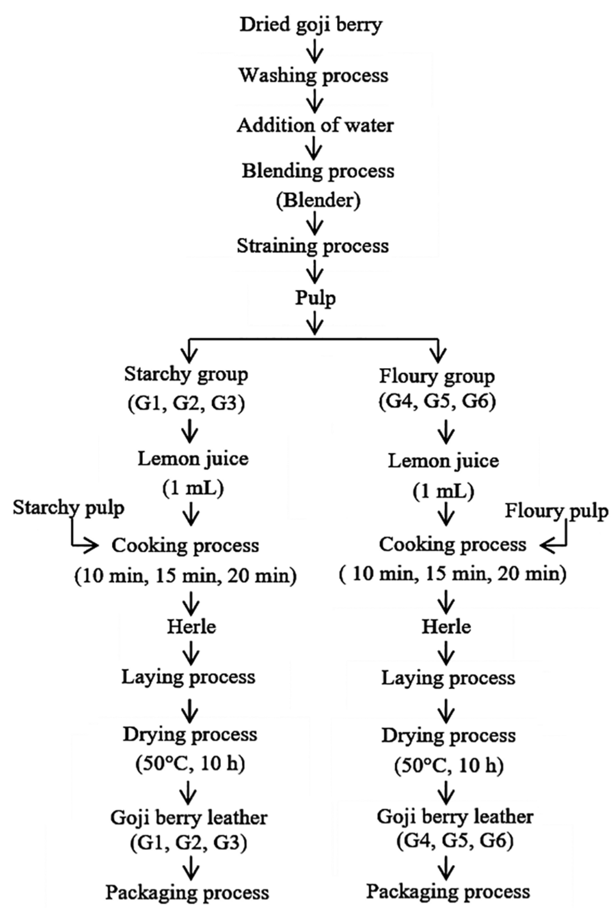

Fig. 1 — Goji berry leather production flow chart

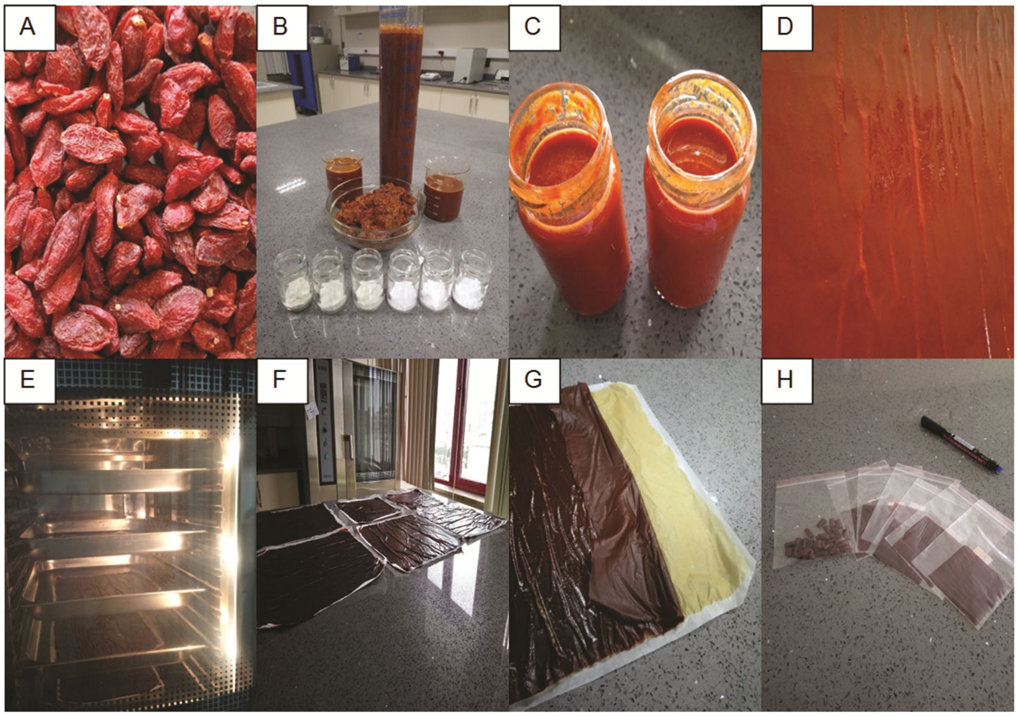

Fig. 2 — Images of goji berry leather production; (A) dried goji berry, (B) pulp, starch, flour and residuum, (C) starchy and floury pulp to be used in the formation of herle, (D) herle laid on wax paper (E) oven drying process, (F) fruit leather samples, (G) the process of removing the fruit leather from wax paper, (H) the packaged fruit leather samples

Determination of water activity (a_w) value

Water activity was assessed for each treatment through three measurements using a Novasina Labmaster water activity meter.

Determination of protein content

The protein content was determined using the Kjeldahl method, and the resulting protein quantity was computed with the application of Formula 3 provided below[7].

$$\% \text{ Protein} = \% \text{ Total nitrogen} \times 6.25 \quad \text{... (3)}$$

Determination of HMF content

Hydroxymethylfurfural (HMF) was detected by assessing the change in absorbance of the samples through a spectrophotometer, using barbituric acid and p-toluidine[8].

Determination of total phenolic content

The phenolic content was assessed using the Folin-Ciocalteu method[9].

Determination of total sugar, reducing sugar and sucrose content

The Lane-Eynon method was employed to analyze the total sugar, reducing sugar, and sucrose contents[10]. This method relies on the fundamental principle of reducing copper^{2+} oxide in the Fehling solution, using invert sugar, into water-insoluble copper^{1+} oxide.

Thickness analysis

The thickness of the fruit leather was determined using calipers.

Texture profile analysis (TPA)

The texture of the fruit leather samples was determined using a texture analyzer (TA-XTplus, Stable Micro Systems, Godalming, Surrey, UK). Texture profile analysis was performed using a 35 mm probe in the fruit leather samples cut into circles with a diameter of 25 mm and the hardness, adhesiveness, cohesiveness, elasticity and chewability values were calculated from the obtained two-stage compression graphic[11].

Determination of colour (L^*, a^*, b^*, C^* and H°) values

The color parameters (L^*, a^*, and b^*) of the samples were determined using the Minolta Reflectance Chroma Meter CR-300. By employing the L^*, a^*, and b^*values, color density (C^*) and hue angle (H°) were computed using the formulas provided in Formula 4 and Formula 5 below[12].

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad \text{... (4)}$$

$$H° = \tan^{-1} b^*/a^* \quad \text{... (5)}$$

Sensory analysis

Sensory evaluation of goji berry leather samples was carried out by 15 panelists. Sensory evaluation criteria were limited because texture profile analysis was also performed on the fruit leather samples. The panelists evaluated the samples on a 5-point scale only based on color, odor, taste, mouth feeling, and general acceptability criteria.

Statistical analysis

The data obtained from the analyses were statistically analyzed using the SPSS program through variance analysis. Variation sources that were significantly different as a result of variance analysis were evaluated with Duncan Multiple Comparison Test at 95% reliability level.

Result and Discussion

Titration acidity value

Titration acidity value of goji berry leather was determined as 2.97-3.23% (Table 2). The highest titratable acidity value of the starchy goji berry leather group was determined in sample G3 with 20 min cooking time. The highest titratable acidity value in the floury goji berry leather group was determined in sample G6 with a 20 min of cooking time. It is clear from the data in Table 2 that the maximum 3.23 titration acidity was noticed in sample G6. The sample G1 showed the minimum level of the titration acidity (2.97). The titration acidity level of the goji berry leather increased with increase in the time of the cooking. Boz *et al.*[13] reported that the titratable acidity value of mulberry leather was affected by 10 and 20 min of cooking time.

pH value

As shown in Table 2, the pH value of goji berry leather ranged from 4.96-4.99. It has been determined that the pH value decreases with the increase in the cooking time in both starchy and floury goji berry leather groups. The highest pH value of the starchy goji berry leather group was determined in sample G1 with 10 min of cooking time. The highest pH value in the floury goji berry leather group was determined in sample G4 with a 10 min cooking time. It is clear from the data in Table 2 that the maximum 4.99 pH value was noticed in samples G1 and G4. The sample G3 showed the minimum level of the pH value (4.96). The pH level of the goji berry leather decreased with an increase in the time of the cooking. Boz *et al.*[13] reported that the pH value of mulberry

Table 2 — The averages of some physicochemical properties of goji berry leather samples.

Code	Ingredient	C. T (min)	TA (%)	pH	Dry Matter (%)	Ash (%)
G1		10	2.97 ± 0.03^{Bd}	4.99 ± 0.00^{Aa}	86.03 ± 0.37^{Bc}	3.12 ± 0.06^{Bc}
G2	Starch	15	3.18 ± 0.02^{Aab}	4.97 ± 0.00^{Bc}	86.78 ± 0.57^{ABb}	3.83 ± 0.59^{Aab}
G3		20	3.20 ± 0.07^{Aa}	4.96 ± 0.00^{Cd}	86.89 ± 0.22^{Ab}	4.27 ± 0.10^{Aa}
G4		10	3.07 ± 0.07^{Bc}	4.99 ± 0.00^{Aa}	84.78 ± 0.38^{Cd}	3.70 ± 0.17^{Bb}
G5	Flour	15	3.10 ± 0.03^{Bbc}	4.98 ± 0.00^{Bb}	86.67 ± 0.20^{Bbc}	3.91 ± 0.25^{ABab}
G6		20	3.23 ± 0.04^{Aa}	4.97 ± 0.00^{Cc}	87.69 ± 0.35^{Aa}	4.13 ± 0.12^{Aab}
Code	Ingredient	C. T (min)	Water Activity (a_w)	Protein (%)	HMF (mg/kg)	TPS (µg GAE/g)
G1		10	0.38 ± 0.00	14.72 ± 0.04^{Ab}	17.33 ± 0.80^{Ce}	7.78 ± 0.21^{Aa}
G2	Starch	15	0.37 ± 0.01	14.71 ± 0.05^{Ab}	24.42 ± 0.76^{Bd}	7.74 ± 0.31^{Aa}
G3		20	0.37 ± 0.01	14.72 ± 0.04^{Ab}	31.23 ± 3.43^{Ab}	7.36 ± 0.20^{Aab}
G4		10	0.37 ± 0.01	15.66 ± 0.02^{Aa}	22.48 ± 0.09^{Cd}	7.89 ± 0.47^{Aa}
G5	Flour	15	0.37 ± 0.00	15.63 ± 0.10^{Aa}	28.59 ± 0.12^{Bc}	7.77 ± 0.19^{ABa}
G6		20	0.37 ± 0.01	15.58 ± 0.02^{Aa}	34.51 ± 0.48^{Aa}	7.14 ± 0.26^{Bb}
Code	Ingredient	C. T (min)	Total Sugar (%)	Reducing Sugar (%)	Sucrose (%)	Thickness (mm)
G1		10	63.89 ± 0.16^{Aa}	61.64 ± 0.17^{Aa}	2.25 ± 0.14^{Aa}	0.78 ± 0.03
G2	Starch	15	62.51 ± 0.84^{Bb}	60.82 ± 0.44^{ABbc}	1.68 ± 0.42^{Ab}	0.86 ± 0.28
G3		20	61.18 ± 0.84^{Bc}	60.13 ± 0.56^{Bc}	1.05 ± 0.28^{Bc}	0.89 ± 0.02
G4		10	63.69 ± 0.89^{Aa}	61.53 ± 0.59^{Aab}	2.16 ± 0.30^{Aab}	0.74 ± 0.01
G5	Flour	15	63.80 ± 0.14^{Aa}	61.89 ± 0.17^{Aa}	1.91 ± 0.26^{Aab}	0.80 ± 0.12
G6		20	62.28 ± 0.17^{Bb}	61.37 ± 0.17^{Aab}	0.91 ± 0.15^{Bc}	0.83 ± 0.03

*C. T= Cooking Time, TA= Titration Acidity, TPS= Total Phenolic Substance

*The averages shown with the same capital letter in the same column and in the same ingredient group are not statistically different from each other.

*The averages shown in the same column with the same lowercase letter are not statistically different from each other.

leather was affected by 10 and 20 min of cooking time. Torres *et al.*[14] reported the pH values of apple leather and quince leather as 4.05 and 3.5, respectively. Goji berry leather appears to have lower acidity than apple leather and quince leather.

Dry matter content

The dry matter content of goji berry leather varies between 84.78% and 87.69% (Table 2). It has been determined that the dry matter content increased with the increase in the cooking time in both starchy and floury goji berry leather groups. The highest dry matter content of the starchy goji berry leather group was determined in sample G3 with 20 min of cooking time. The highest dry matter content in the floury goji berry leather group was determined in sample G6 with a 20 min cooking time. It is clear from the data in Table 2 that the maximum 87.69% dry matter content was noticed in sample G6. The sample G4 showed the minimum level of the dry matter content (84.78%). It was observed that the cooking time affected the dry matter content of the fruit leather. Yıldız[15] and Nakilcioğlu Taş *et al.*[16] reported the dry matter content of mulberry leather as 90.22% and 87.71-89.04%, respectively. Suna *et al.*[17] reported the dry matter content of apricot leather samples as 85.61-86.88%. Our result is between these values. Torres *et al.*[14] reported the dry matter content of apple leather and quince leather as 84.1% and 82.8%, respectively. Concha-Meyer *et al.*[18] reported the dry matter content of strawberry leather and kiwi leather as 79% and 79.87%, respectively. It seems that the dry matter content observed in our research surpasses the findings reported by Torres *et al.*[14] and Concha-Meyer *et al.*[18]

Ash content

The ash content is the total content of minerals present in the sample. In our study, the ash content of goji berry leather was determined as 3.12-4.27% (Table 2). It has been determined that the ash content increased with the increase in the cooking time in both starchy and floury goji berry leather groups. The highest ash content of the starchy goji berry leather group was determined in sample G3 with 20 min of cooking time. The highest ash content in the floury goji berry leather group was determined in sample G6 with a 20 min cooking time. It is clear from the data in Table 2 that the maximum 4.27% ash content was noticed in sample G3. The sample G1 showed the minimum level of the ash content (3.12%). The ash content of goji berry leather appears to increase with increasing cooking time. There are studies in the literature that support these results. Lopes *et al.*[19] and Arkoub-Djermoune *et al.*[20] reported that the ash content of the cooked samples was higher than the uncooked ones. Concha-Meyer *et al.*[18] reported the ash content of strawberry leather and kiwi leather as 2.2% and 2.6%, respectively. Sarma *et al.*[3] also reported the ash content of banana leather as 5.31%.

Water activity (a_w) value

Water, one of the basic components in the structure of foods, is extremely effective on the quality characteristics and general acceptability of the food[21]. As shown in Table 2, the water activity value of goji berry leather ranged from 0.37-0.38 (Table 2). The water activity of the goji berry appears to be unaffected by the cooking time and the addition of flour and starch. In similar results, the value of water activity in pear leather was 0.36-0.48 by Huang and Hsieh[22], in apple-currant leather was 0.269-0.477 by Diamante *et al.*[23], and in mango leather was found to be the value of water activity 0.43-0.49 by Nurhadi *et al.*[24]

Protein content

In our research, the protein content of goji berry leather was found to be 14.71-15.66% (Table 2). It is clear from the data in Table 2 that the maximum 15.66% protein content was noticed in sample G4. Sample G2 showed the minimum level of the protein content (14.71%). It is clearly understood that cooking time has no effect on protein content in goji berry leather groups. The protein content of goji berry leather appears to increase with flour addition. It is observed that the flour addition causes a higher increase in the protein content of the goji berry leather compared to the starch additive. This result is due to the protein content of flour. Yıldız[15] and Nakilcioğlu Taş *et al.*[16] reported the protein content of mulberry leather as 4.34% and 1.23-1.86%, respectively. Concha-Meyer *et al.*[18] reported the protein content of strawberry leather and kiwi leather as 3.1% and 2.8%, respectively. Sarma *et al.*[3] also reported the protein content of banana leather as 6.23%. It appears that the protein content of goji berry leather is higher than that of mulberry, strawberry, kiwi leather, and banana leather. This difference is due to fruit and other additives used in production.

HMF content

HMF content of the product is affected by many parameters such as cooking time, drying temperature, and drying time. Cooking time is among the most important factors affecting HMF formation. In general, HMF formation increases with increasing cooking time[13]. In our research, the HMF content of goji berry leather was determined as 17.33-34.51 mg/kg (Table 2). HMF content of goji berry leather appears to increase with increasing cooking time. In addition, it is observed that flour and starch additives affect the HMF content of fruit leather. The highest HMF content of the starchy goji berry leather group was determined in sample G3 with 20 min of cooking time. The highest HMF content in the floury goji berry leather group was determined in sample G6 with a 20 min cooking time. It is clear from the data in Table 2 that the maximum 34.51 mg/kg HMF content was noticed in sample G6. The sample G1 showed the minimum level of the HMF content (17.33 mg/kg). Our results are similar to those reported by Yıldız[15] and Suna *et al.*[17] who reported the HMF content of leather as 27.94 mg/kg and 13.62-45.64 mg/kg, respectively.

Total phenolic content

Fruits are described as a potential source of natural phenolics in the food industry[25]. But cooking factors can affect the level of phytochemicals in cooked foods[26]. The total phenolic content of goji berry leather ranges from 7.14 to 7.89 µg GAE/g (Table 2). The highest total phenolic content of the starchy goji berry leather group was determined in sample G1 with 10 min of cooking time. The highest total phenolic content in the floury goji berry leather group was determined in sample G4 with a 10 min cooking time. It is clear from the data in Table 2 that the maximum 7.89 µg GAE/g total phenolic content was noticed in sample G4. The sample G6 showed the minimum level of the total phenolic content (7.14 µg GAE/g).

Total sugar, reducing sugar and sucrose content

As shown in Table 2, the total sugar, reducing sugar, and sucrose content of goji berry leather ranged from 61.18-63.89%, 60.13-61.89%, and 0.91-2.25%, respectively. The highest total sugar, reducing sugar, and sucrose content of the starchy goji berry leather group were determined in sample G1 with 10 min of cooking time. In the floury goji berry leather, the highest total sugar and reducing sugar content were determined in sample G5 with a 15 min cooking time, while sucrose content was determined in sample G4 with a 10 min cooking time. From the data in Table 2, it is clear that the maximum content of total sugar, reducing sugar, and sucrose were noticed at 63.89%, 61.89%, and 2.25% in the samples G1, G5, and G1, respectively. Samples G3, G3, and G6 showed the minimum level of total sugar (61.18%), reducing sugar (60.13%), and sucrose content (0.91%), respectively. It is understood that cooking time in goji berry leather has an effect on total sugar and sucrose content. It is understood that the addition of starch and flour in goji berry leather has an effect on total sugar and reducing sugar. Boz *et al.*[13] reported that the cooking time of mulberry leather has no effect on the total sugar content it increases the content of reducing sugar and decreases the content of sucrose. Arkoub-Djermoune *et al.*[20] reported that cooking processes led to a significant increase in total sugar content. Suna *et al.*[17] reported the sugar content of apricot leather as 51.32-61.40%. Nurhadi *et al.*[24] also reported the total sugar content of mango leather as 53.60-63.89%.

Thickness value

The thickness value of goji berry leather was determined as 0.74-0.89 mm (Table 2). It has been understood that cooking time, flour, and starch additives have no effect on the thickness value of goji berry leathers. Yıldız and Boyracı[27] reported the thickness value of sugar beet leather as 0.92-1.12 mm. Nakilcioğlu Taş *et al.*[16] reported the thickness value of mulberry leather as 0.91-1.02 mm. Our result is between these values.

Textural values

The fruit leather should be foldable and flexible. Because moisture loss will be inevitable during the shelf life of the fruit leather, a high hardness value is not sought[28]. The values for hardness, stickiness, cohesiveness, elasticity, and chewability value of goji berry leather obtained in the present investigation ranged from 17.09-33.27 N, 4.10-23.34 N.s, 0.85-1.00, 0.88-0.97 and 12.85-30.85, respectively (Table 3). The highest hardness, stickiness, cohesiveness, elasticity, and chewability value of the starchy goji berry leather group were determined in sample G3 with 20 min of cooking time. In the floury goji berry leather, the highest hardness, stickiness, cohesiveness, and chewability value were determined in sample G6 with a 20 min cooking time. From the

Table 3 — The averages of texture, color and sensory properties of goji berry leather samples

Code	Ingredient	C. T (min)	Hardness (N)	Stickiness (N.s)	Texture Values Cohesiveness	Elasticity	Chewability
G1		10	17.17±3.59^{Ac}	5.97±0.45^{Bcd}	0.99±0.01^{Aab}	0.96±0.00	16.38±3.21^{Ac}
G2	Starch	15	17.09±0.47^{Ac}	11.24±3.63^{ABbc}	1.00±0.00^{Aa}	0.93±0.03	15.82±0.88^{Ac}
G3		20	25.76±1.66^{Ab}	16.22±3.98^{Ab}	1.00±0.00^{Aa}	0.96±0.00	24.49±1.12^{Ab}
G4		10	17.29±0.52^{Bc}	4.10±1.51^{Cd}	0.85±0.01^{Bc}	0.88±0.11	12.85±1.35^{Cc}
G5	Flour	15	20.38±1.49^{Bbc}	9.77±1.42^{Bc}	0.96±0.04^{Ab}	0.97±0.00	19.08±0.73^{Bbc}
G6		20	33.27±2.58^{Aa}	23.34±4.09^{Aa}	1.00±0.00^{Aa}	0.93±0.01	30.85±1.93^{Aa}
					Color Values		
Code	Ingredient	C. T (min)	L^*	a^*	b^*	C^*	H°
G1		10	32.66±0.38^{Aa}	8.62±0.18^{Ab}	7.06±0.38^{Bc}	11.15±0.33	39.31±1.35
G2	Starch	15	31.03±1.06^{ABab}	8.95±0.22^{Ab}	7.65±0.07^{ABbc}	11.77±0.16	40.52±0.83
G3		20	27.27±3.31^{Bc}	9.66±1.04^{Aab}	8.36±0.91^{Aab}	12.81±0.71	40.91±5.23
G4		10	30.60±0.48^{Aab}	9.12±0.46^{Aab}	7.96±0.43^{Aab}	12.11±0.62	41.13±0.50
G5	Flour	15	31.55±0.74^{Aab}	9.37±0.05^{Aab}	8.16±0.08^{Aab}	12.43±0.09	41.05±0.14
G6		20	29.05±0.64^{Bbc}	10.32±1.14^{Aa}	8.59±0.34^{Aa}	12.01±2.68	39.87±2.02
					Sensory Scores		
Code	Ingredient	C. T (min)	Color	Smell	Taste	Mouthfeel	General Acceptability
G1		10	4.13±0.74	3.93±0.70	3.80±0.68^{Aab}	3.87±0.74^{Aa}	3.87±0.74^{Aab}
G2	Starch	15	4.07±0.70	3.80±0.68	3.53±0.64^{Aab}	3.20±0.56^{Bb}	3.40±0.63^{ABbc}
G3		20	3.87±0.83	3.80±0.68	2.93±0.88^{Bc}	2.93±0.80^{Bb}	3.27±0.80^{Bc}
G4		10	4.27±0.59	4.00±0.76	4.00±0.85^{Aa}	3.93±0.80^{Aa}	4.20±0.78^{Aa}
G5	Flour	15	3.93±0.59	3.73±0.59	3.27±0.70^{Bbc}	3.27±0.70^{Bb}	3.40±0.74^{Bbc}
G6		20	3.80±1.08	3.53± 0.64	3.20±0.86^{Bbc}	3.00±1.07^{Bb}	3.33±0.62^{Bbc}

*The averages shown with the same capital letter in the same column and in the same ingredient group are not statistically different from each other.
*The averages shown in the same column with the same lowercase letter are not statistically different from each other.

data in Table 3, it is clear that the maximum value of hardness, stickiness, and chewability were noticed at 33.27 N, 23.34 N.s and 30.85 in the samples G6, G6 and G6, respectively. Samples G2, G4, G4 and G4 showed the minimum level of hardness (17.09 N), stickiness (4.10 N.s), cohesiveness (0.85) and chewability (12.85), respectively. The hardness, stickiness, and chewiness values of the goji berry leather were affected by the cooking time. The hardness, stickiness, cohesiveness, and chewiness values of the goji berry leather were affected by the addition of flour and starch.

Color (L^*, a^*, b^*, C^* and H) values

Color is one of the quality parameters of fruit leather because customer acceptance is affected by color[29]. As shown in Table 3, L^*,a^*, and b^* values of goji berry leather ranged from 27.27-32.66, 8.62-10.32, and 7.06-8.59, respectively. The highest L^*,a^*, and b^* values of the starchy goji berry leather group were determined in sample G1 with 10 min cooking time, G3 with 20 min of cooking time and G3 with 20 min cooking time, respectively. In the floury goji berry leather, the highest L^*,a^*, and b^* values were determined in sample G5 with 15 min of cooking time, G6 with 20 min of cooking time, and G6 with 20 min of cooking time, respectively. From the data in Table 3, it is clear that the maximum value of L^*, a^*, and b^* values were noticed at 32.66, 10.32, and 8.59 in the samples G1, G6, and G6, respectively. Samples G3, G1, and G1 showed the minimum level of L^*(27.27), a^*(8.62), and b^*(7.06) values, respectively. $L^*$and b^* values of the goji berry leather were affected by the cooking time.

Sensory scores

The acceptability of the fruit leather product is influenced by the choice of fruit, the addition of ingredients, and the thermal processing methods employed. The sensory scores in terms of taste, mouthfeel, and general acceptability of goji berry leather were ranged from 2.93-4.00, 2.93-3.93, and 3.27-4.20, respectively (Table 3). The highest taste, mouthfeel, and general acceptability scores of the starchy goji berry leather group were determined in sample G1 with 10 min of cooking time. In the floury goji berry leather taste, mouthfeel, and general acceptability scores were determined in sample G1 with 10 min of cooking time. From the data in Table 3, it is clear that the maximum taste, mouthfeel, and general acceptability values were determined in the G4 samples as 4.00, 3.93, and 4.20, respectively. Sample G3 showed the minimum level of taste (2.93), mouthfeel (2.93), and general acceptability (3.27), respectively. It can be concluded from the present investigation the taste, mouthfeel, and general acceptability of goji berry leather increased as the cooking time were decreased. Though the starchy goji berry leather and floury goji berry leather were not significantly different, the sensory scores showed that the floury leather (G4) was more preferred. Consequently, the factor affecting the sensory character of goji berry leather is the cooking time. It is suggested that a shorter cooking time may be preferred for goji berry leather.

Conclusion

Various processes applied in the production of fruit leather (cooking time, ingredients, etc.) affect some quality parameters of the product. It has been determined that goji berry leather contains high protein. In addition, it was determined that the cooking time did not affect the protein content, while the protein content of the flour-added leathers was found to be higher than the starch-added leathers. The HMF content of the fruit leather increased with the increase in cooking time.

Based on the sensory assessment, it was established that the goji berry leather samples were generally well-received. Goji berry leather is an alternative to confectionery varieties with its rich nutritional content. From this perspective, goji berry leather can be considered as a healthy snack.

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Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

RTM wrote the main manuscript text and UE reviewed the manuscript.

References

1 Talay R & Erdoğan U, Nutritional and sensory quality in organic and conventional foods, *Turkish J Agric Food Sci Technol*, 7 (5) (2019) 774-782.
2 Talay R & Erdoğan U, The Effect of hydrocolloids on texture of fruit leathers, *3rd International Conference on Advanced Engineering Technologies*, 19-21 September, 2019, (Bayburt University, Bayburt), p. 516-519.
3 Sarma O, Kundlia M, Chutia H & Mahanta C L, Processing of encapsulated flaxseed oil-rich banana-based (*dwarf cavendish*) functional fruit leather, *J Food Process Eng*, 46 (4) (2023).
4 Phimpharian C, Jangchud A, Jangchud K, Therdthai N, Prinyawiwatkul W, *et al.*, Physicochemical characteristics and sensory optimisation of pineapple leather snack as affected by glucose syrup and pectin concentrations, *Int J Food Sci Technol*, 46 (5) (2011) 972-981.
5 Diamante L M, Bai X & Busch J, Fruit leathers: method of preparation and effect of different conditions on qualities, *Int J Food Sci*, 2014 (2014), Article ID 139890. http://dx.doi.org/10.1155/2014/139890.
6 Talay R, Erdoğan U & Turan M, Physico-chemical properties, mineral matter, organic acid, amino acid, and plant hormones content of goji berry (*Lycium barbarum* L.) grown in Turkey, *Turkish J Agric Food Sci Technol*, 9 (10) (2021) 1889-1894.
7 AOAC, Association of official analytical chemists, Official and tentative methods of the AOAC international, AOAC International Gaithersburg, (1997).
8 Winkler O, Beitrag zum Nachweis und zur Bestimmung von Oxymethylfurfurol in Honig und Kunsthonig, *Zeitsch Lebensm Unters Forsch*, 102 (3) (1955) 161-167.
9 Gulçin İ, Oktay M, Kufrevioğlu O I & Aslan A, Determination of antioxidant activity of lichen *Cetraria islandica* (L) Ach, *J Ethnopharmacol*, 79 (3) (2002) 325-329.
10 Lane J H & Eynon L, Determination of reducing sugars by Fehling's solution with methylene blue indicator, N. Rodger, (1934), University of Wisconsin - Madison.
11 Karaoğlu M M, Kotancilar H G & Gerçekaslan K E, The effect of par-baking and frozen storage time on the quality of cup cake, *Int J Food Sci Technol*, 43 (10) (2008) 1778-1785.
12 Pathare P B, Opara U L & Al-Said F A J, Colour measurement and analysis in fresh and processed foods: a review, *Food Bioprocess Technol*, 6 (1) (2013) 36-60.
13 Boz H, Karaoğlu M & Kaban G, The effects of cooking time and sugar on total phenols, hydroxymethylfurfural and acrylamide content of mulberry leather (pestil), *Qual Assur Saf Cro Food*, 8 (4) (2016) 493-500.
14 Torres C A, Romero L A & Diaz R I, Quality and sensory attributes of apple and quince leathers made without preservatives and with enhanced antioxidant activity, *LWT-Food Sci Technol*, 62 (2) (2015) 996-1003.
15 Yıldız O, Physicochemical and sensory properties of mulberry products: Gumuşhane pestil and kome, *Turkish J Agric For*, 37 (6) (2013) 762-771.
16 Nakilcioğlu Taş E, Cakaloğlu B & Otleş S, The determination of some physical, chemical and sensory properties of pestil containing carob flour at different ratio, *Turkish J Agric Food Sci Technol*, 6 (8) (2018) 945-952.
17 Suna S, Tamer C E, Incedayı B, Sinir G O & Copur O U, Impact of drying methods on physicochemical and sensory properties of apricot pestil, *Indian J Tradit Know*, 13 (1) (2014) 47-55.

18 Concha-Meyer A A, D'Ignoti V, Saez B, Diaz R I & Torres C A, Effect of storage on the physico-chemical and antioxidant properties of strawberry and kiwi leathers, *J Food Sci*, 81 (3) (2016) C569-C577.

19 Lopes A F, Alfaia C M, Partidario A M, Lemos J P & Prates J A, Influence of household cooking methods on amino acids and minerals of Barrosa-PDO veal, *Meat Sci*, 99 (2015) 38-43.

20 Arkoub-Djermoune L, Bellili S, Khenouce L, Benmeziane F, Madani K, *et al.,* Effect of domestic cooking on physicochemical parameters, phytochemicals and antioxidant properties of Algerian tomato (*Solanum lycopersicum* L. var. Marmande), *J Food Technol Res*, 6 (1) (2019) 1-17.

21 Yıldırım A, Duran M & Koç M, The effect of water activity and different drying systems on the stability of bioactive compounds, *Foods*, 43 (3) (2018) 512-522.

22 Huang X & Hsieh F H, Physical properties, sensory attributes, and consumer preference of pear fruit leather, *J Food Sci*, 70 (3) (2005) E177-E186.

23 Diamante L M, Li S, Xu Q & Busch J, Effects of apple juice concentrate, blackcurrant concentrate and pectin levels on selected qualities of apple-black currant fruit leather, *Foods*, 2 (3) (2013) 430-443.

24 Nurhadi B, Sari I P, Mahani, Deliana Y & Hariadi H, Influence of type and concentration of plasticizers on the properties of harumanis mango dregs fruit leather, *Int J Fruit Sci*, 23 (1) (2023) 116-134.

25 Saeed A, Marwat M S, Shah A H, Naz R, Abidin S Z U, *et al.,* Assessment of total phenolic and flavonoid contents of selected fruits and vegetables, *Indian J Tradit Know*, 18 (4) (2019) 686-693.

26 Abacan S, Hurtada W & Devanadera M, Effects of cooking time, temperature, and salt concentration on the phenolic content and antioxidant activity of selected edible mushrooms, *Int Food Res J*, 24 (5) (2017) 2028-2032.

27 Yıldız O & Boyracı G M, Production and some quality parameters of sugar beet sweets (pestil and köme), *Sugar Tech*, 22 (2020) 842-852.

28 Karaoğlu M M, Bedir Y & Boz H, Effect of whole grain flours on the overall quality characteristics of mulberry pestil. *Qual Assur Saf Cro Food*, 12 (1) (2020) 67-75.

29 Maskan A, Kaya S & Maskan M, Effect of concentration and drying processes on color change of grape juice and leather (pestil), *J Food Engg*, 54 (1) (2002) 75-80.