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Determination of physical, chemical and antioxidant properties of pomegranate sauces sold in Turkish markets

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Abstract

This study aimed to determine the physical, chemical and antioxidant properties of pomegranate sauces sold in the Turkish markets. A total of eighteen pomegranate sauces, seventeen of which were purchased from the market, and one produced in a rotary evaporator, were analyzed with respect to antioxidant activity, titratable acidity, brix, hydroxymethylfurfural (HMF), pH, color, and sugar. The antioxidant activities of the samples were analyzed by six different methods, including DPPH (2,2-diphenyl-1-picrylhydrazil) radical scavenging activity, ferric reducing antioxidant power (FRAP), $ABTS^{\bullet+}$ radical scavenging capacity, total antioxidant capacity assay (TAC), total phenolic content (TPC), and total flavonoid content (TFC) methods. The highest and lowest antioxidant activity values were as follows, respectively: 5.23 and 822.69 mg AA/kg for the DPPH method, 57.94 and 2380.94 mg $FeSO_4$/kg for the FRAP method, 660.47 and 3690.83 mg AA/kg for the TAC method, 23.06 and 11680.71 mg QEE/kg for the TFC method, and 123.54 and 9566.95 mg GAE/kg for the TPC method. In addition, HMF contents of the most samples were below the permissible limit value (50 mg/kg), while some of them showed a heterogeneous distribution between 4.58 and 103.68 mg/kg. Such a heterogeneous distribution of the HMF contents may be due to the factors such as raw materials and additives used in production, applied heat treatments, production processes, and storage conditions. As a result, HMF content in pomegranate sauce can be reduced below the permissible limit if the production conditions comply with the standards.

Keywords: Antioxidant activity, hidroxymethylfurfural (HMF), physicochemical analysis, pomegranate sauces

1. Introduction

Pomegranate is an ancient fruit that has always been valuable throughout human history [1] and has a high cultural value as well as commercial value. [2]. There is evidence that the plant was cultivated in Egypt after the discovery of agriculture about ten thousand years ago [1]. The pomegranate plant (*Punica granatum* L) in the Punicaceae family is a deciduous shrub and monoecious, it is also grown up to 7 m [3,4]. The flowering time of the plant is usually between March-April and July-August and the flowering time lengthens out up to 10 – 12 weeks [5]. The native of the plant is Iran, which is one of the world's largest commercial producers and exporters of pomegranate fruit [6,7]. Besides Iran, the Southern Caucasus, Afghanistan, Southern Asia, Western Asia, Anatolia, and the Mediterranean are the native of the species [8]. In addition, it is cultivated in countries such as Türkiye, Iraq, Iran, Syria, USA, Italy, Spain, Tunisia, Morocco, Afghanistan, Palestine, Israel, Egypt, Saudi Arabia, India, China, and Thailand [9,10]. As stated, Türkiye is among the countries that are the native of the pomegranate plant and it is naturally spreads in the provinces of Türkiye such as Siirt, Şırnak, Adıyaman, Antalya, Artvin, Aydın and Samsun [11]. The production of pomegranate fruits in Türkiye is carried out in high quantities in the Mediterranean, Southeastern Anatolia, and Aegean regions [12]. Pomegranate fruit has many positive effects on human health with its bioactive components such as phenolic substances, antioxidants, organic acids, vitamins, polysaccharides, sugars, and minerals [13–15]. It shows biological activity and is a particularly good antioxidant [16,17], also has antiproliferative, antiviral, anti-aging, antimicrobial properties [17]. Because of all these properties, pomegranate fruit has gained common popularity as a functional food and nutraceutical source. Promising results have been obtained from human clinical trials on diabetes, cardiovascular disease, and prostate cancer [18]. Due to these positive effects of

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pomegranate on human health, there is an increase in demand for the product in the world [19]. While pomegranate is mostly consumed by people as a fresh fruit, it is also frequently consumed as pomegranate juice, pomegranate jam, pomegranate wine, dried pomegranate seeds, pomegranate molasses, pomegranate syrup or pomegranate sauce. Pomegranate sour is traditionally used in Turkish kitchens for give a sour-sweet taste to some dishes and salads [9]. In recent years, pomegranate sauce is also commercially available. Pomegranate sour is obtained by pressing the pomegranate fruit, and then clarifying and concentrating it in open air or under a vacuum in suitable conditions [20]. Pomegranate sauces are used in salads and many dishes in Türkiye. Therefore, it is important to add sufficient quantities of appropriate sauce ingredients to the pomegranate sour. Although traditional and small-scale companies are contributed to the production, pomegranate sauces are mostly produced by large-scale companies [21]. People show a high demand for pomegranate and pomegranate products because of their positive effects on health. However, incorrect practices in the manufacture of this product may occur food safety problems and this situation gives rise to health problems instead of positive health expectations for this product.

Although there are a few studies to determine the physical and chemical properties of pomegranate sauces produced in Türkiye [21–22]. Numbers of analyzed pomegranate sauce sample and physicochemical properties were limited in these studies unlike the current study. This study aimed to determine and evaluate the physical, chemical and antioxidant properties of pomegranate sauces sold in the Turkish market and to produce a standard quality product.

2. Material and methods

2.1. Sampling and preparation

A total of eighteen pomegranate sauces, seventeen (different brand products coded in the range of S1 – S17) of which were purchased ready-made from the market and one (coded as S18, the control sample) produced in the laboratory (Gümüşhane University, Faculty of Engineering and Natural Sciences, Department of Food Engineering) with the help of a rotary evaporator, were studied. First, the peels of the pomegranate fruits were removed, then the pomegranate juice was obtained by squeezing the fruit. The juice was evaporated to 70% Brix in the vacuum evaporator and, finally, pomegranate sauce was prepared by using starch, sugar, and lemon.

Each analysis was repeated at least three times and the results are presented as "mean ± standard deviation". Pomegranate sauces were stored at room temperature in the laboratory until the analysis studies were completed.

2.2. Chemicals and Instrumentation

The chemicals and solvents (analytical or HPLC purity) were purchased from Merck (Darmstadt, Germany) and Sigma-Aldrich (St. Louis., Missouri., USA). The following systems were used for the analyte measurements: Agilent 1200 series HPLC system for the sugar and HMF analysis, Shimadzu UV-1800 spectrophotometer for the antioxidant activity, the Ohaus Starter 3000 Bench pH Meter (Ohaus Corporation, Parsippany, NJ, USA) for the pH measurements, A Anton Paar MCR 102 rheometer (Thermo Scientific, Germany) for the rheological analysis, a Minolta CR-300 colorimeter (Minolta Camera Co., Osaka, Japan) for color analysis (values of L*, a*, b*), an ABBE refractometer (Optic IvymenSystem, Spain) for the water soluble dry matter contents (Brix%), A Heildoph rotary evaporator (Schwabach, Germany) for removing solvents from the solutions, A Shimadzu analytical scales with 0.1 mg sensitivity for weighing the samples.

2.3. Analysis

2.3.1. Physicochemical analysis

Water-soluble dry matter contents (Brix%) of the pomegranate sauce samples were determined with a refractometer device. Sample was placed to between two prisms and set to 20 °C and optical refractive index of the pomegranate sauce was read and recorded [23].

For determination of titratable acidity of the samples, the pomegranate sauce samples were homogenized and weighed 10 g. Then 75 mL of distilled water was added. While the suspension was stirred with a magnetic stirrer, at the same time the 0.1 N sodium hydroxide solution was titrated until the pH value reached 8.3 for a maximum of 60 seconds. Titratable acidity was calculated according to the Formula 1.

$$Titratable\ acidity\ (\%) = \frac{V \times N \times 0.064 \times 100}{m} \qquad (1)$$

V: Volume of the standard NaOH solution (mL)
N: Normality of the standard NaOH solution
m: Sample mass (g)
0.064: Equivalent factor used to impart the acidity as citric acid

pH measurements were made according to TS 1728 ISO 1842 (fruit and vegetable products - pH determination) [24] with the desktop pH meter.

Color analysis (L*, a*, b* values) of the samples were performed using a colorimeter device. L*, a*, b* values represent the colors on the food as red-green,

blue-yellow (Among b* values, -b denotes yellow and +b denotes blue), black to white lightness between 0 and 100, respectively. The measured color values were determined according to Quek [25].

The quantitative determination of HMF was carried out according to TS 6178 - ISO 7466 standard [26] and modified by Baltacı et al [27] and, Baltacı and Akşit [28]. In this method, 2.5 g of each pomegranate sauce samples were weighed and transferred to a 50 mL flask and then 25 mL of distilled water was added to extract the sample at the room temperature. To precipitate the protein, 0.25 mL Carrez I and 0.25 mL Carrez II solutions were added to the mixture for 10 min. Then the volume of the mixture was made up to 100 mL with distilled water and the mixture was filtered through a 0.45 µm injection filter. After that, the prepared extracts were transferred into vials and injected into the conditioned HPLC system. To generate the calibration plot, a series of HMF standard solutions were prepared, injected into the HPLC system and the peak areas were recorded. The HMF concentrations of the samples were determined quantitatively with the help of the standard calibration graph (the HMF concentrations versus the peak areas). The HMF concentrations calculated as mg/L with the calibration equation were converted to mg/kg with the following Formula 2:

$$HMF\ (mg/kg) = \frac{V_1}{M} \times \frac{1}{V_2} \times \frac{(y-b)}{m} \qquad (2)$$

V_1: Final volume (mL)
V_2: Initial sample volume injected into the HPLC system (mL)
M: Sample mass (g)
y: Device signal (pick area value)
b: The intercept value of the calibration equation
m: Slope value of the calibration equation

For sugar analysis, first, approximately 2.5 g of the pomegranate sauce was weighed into a beaker and treated with 40 mL of distilled water. Then, the beaker content was mixed well, transferred to a volumetric flask containing 25 mL of methanol, and the mixture transferred to vials after filtering through a 0.45 µm injection filter. A set of standard calibration solutions were prepared at sequential concentrations from glucose, fructose, and sucrose standards. After the peak areas of all standard and sample solutions were read in HPLC, the total sugar concentrations (µg/mL) in the samples were determined with the help of the linear calibration graph [29]. Finally, glucose sucrose and fructose contents of the samples were calculated separately according to the Formula 3 and thus, the % total sugar content was determined.

$$\begin{matrix} Glucose, \\ fructose, \\ sucrose\ (\%) \end{matrix} = \frac{V_1}{M} \times \frac{1}{V_2} \times \frac{100}{1000} \times \frac{(y-b)}{m} \qquad (3)$$

In order to identify the artificial food colors, first, approximately 40 g of the pomegranate sauce was treated with distilled water, and then, filtered. Then, a few drops of concentrated HCl were added to the filtrate and an oil-free sheep wool thread was plunged into the beaker. It was kept in a water bath for one hour and washed with running tap water. It was checked whether the wool thread was dyed or not. If the dye has not been removed from the wool thread by washing, it is placed in a beaker and distilled water and a few drops of NH_3 (%5) are added and boiled for evaporating NH_3 in a water bath for half an hour. As a result of this application, if the dye in the wool thread has passed into the solution, it is concluded that the dye in the product is artificial, and if not, it is natural [30].

A rheometer device was used to determine the viscosities of the pomegranate sauce samples at different temperatures. The samples were placed on the rheometer at a constant temperature (15, 25 and 35 °C) to plot flow behavior graphs. The graphs were obtained by measuring shear stress in the range of 0 – 100 s^{-1} shear velocity. The apparent viscosity values of the samples were determined at a shear rate of 50 s^{-1} based on measured values and plotted graph.

2.3.2. Antioxidant activity

2.3.2.1. DPPH radical scavenging activity:

The principle of this method is based on the ability of antioxidant compounds to reduce the intensity of the purple color of the DPPH radical. DPPH radical gives a strong absorption pick at 517 nm [31]. First, 3.0 mL of a methanolic DPPH solution was added to 0.1 mL of the aqueous extract of the pomegranate sauce extract, and the mixture was vortexed. After standing for 30 min, the absorbance of the mixture was read at 517 nm in a UV-Vis spectrophotometer. The same procedure was repeated for the standard ascorbic acid and trolox [32]. The standard calibration curve was plotted to determine the DPPH free radical scavenging activity.

2.3.2.2. Ferric reducing antioxidant power (FRAP):

According to the FRAP method developed by Benzie and Strain [33], first, 0.25 mL of the aqueous extract of each sample was transferred into a test tube and then 2.75 mL of FRAP solution was added to the tube. The mixture was incubated for 30 min after vortexing and finally the absorbance was read at 593 nm. The same procedure was repeated for the standard $FeSO_4$ solutions to obtain the standard calibration curve. The total iron

reduction antioxidant capacity was expressed as mg of $FeSO_4$ equivalent per kg [32].

2.3.2.3. ABTS•+ radical scavenging capacity:
2.85 mL of the ABTS•+ solution was added to 0.15 mL of the pomegranate sauce extract in a test tube. Then the mixture was kept for 120 min after vortexed. The same procedures were performed for the standard ascorbic acid and Trolox to obtain the standard calibration curve. All absorbance of the samples and standards were read at 734 nm [32]. Radical scavenging capacity of ABTS•+ was calculated as Trolox equivalent and the results is expressed as the trolox equivalent antioxidant capacity (TEAC).

2.3.2.4. Determination of total antioxidant capacity (TAC):
0.5 mL of the sample extract was transferred into a test tube and 2.5 mL of distilled water was added. Then, 1.0 mL of the molybdate reagent solution was added to the mixture. The mixture was incubated for 90 min in a water bath at 95 °C after vortexing for 10 min. The absorbance of the mixtures was read at 695 nm [34]. The standard calibration graph was obtained using ascorbic acid (AA) standards. The total antioxidant capacity values were determined as mg AA by comparing with the antioxidant ascorbic acid standard.

2.3.2.5. Total phenolic content (TPC):
Phenolic contents of the pomegranate sauce samples were analyzed using the Folin-Ciocalteu's reagent [35]. First, 3.4 mL of distilled water was added to 0.3 mL of the pomegranate sauce extract. Then, 0.5 mL of methanol and 0.2 mL of the Folin-Ciocalteu's reagent were added to the mixture, and the mixture was incubated for 10 min at room temperature after vortexing. After that, 0.6 mL of 10% Na_2CO_3 solution was added to the mixture, and the mixture was incubated again in the dark for 120 min at the room temperature. At the end of the incubation period, the absorbance of the mixture was read at 760 nm in the UV-vis spectrophotometer. The results were given as gallic acid equivalents (GAE) using the standard calibration curve.

2.3.2.6. Total flavonoid content (TFC):
First, 3.2 mL of methanol (30% v/v) was added to the pomegranate sauce extract, 0.5 mL of which was pipetted into a test tube, and then the mixture was vortexed. 150 µL of 0.5 M sodium nitrite solution and 150 µL of 0.3 M aluminum chloride solution were added to the mixture. 1.0 mL of 1.0 M NaOH solution was added to the mixture after incubating for 5 min at room temperature. the absorbance of the final mixture was read in the device at 506 nm [34]. The same procedure was repeated for the standard ascorbic acid and Trolox to plot the calibration graph using the catechin solutions at sequential concentrations ranging from 25 to 400 mg/mL. Total flavonoid quantities were given as mg catechin equivalents/L.

2.4. Statistical evaluations
The results obtained from all analyzes were statistically evaluated and interpreted by the Duncan test and principal component analysis (PCA) using the XLSTAT (2010) package program.

3. Results and discussion

3.1. Physicochemical analysis results
All results from the analysis of the samples are presented in Table 1. Water-soluble dry matter is an important parameter in the quality assessment of fruit, juice, and concentrates because of affecting the taste (especially sweetness) of the fruit and it directly affects the willingness to buy the product [36,37]. The highest water-soluble dry matter (Brix%) content obtained from the analysis of the samples was 76.70% in the S12 coded sample, and the lowest 70% was in the N18 coded sample. The Brix values of all samples were found to be close to each other. Similarly, Yıldız et al. [22] reported that the brix values of nine pomegranate sauces varied between 69.50% and 73.30%. In general, Brix values of fruit concentrates produced by thermal evaporation of some of the water vary between 25% and 60% [38]. Therefore, the Brix values of pomegranate sauces can be greatly affected by the heat treatment applied during production and as a result, differences can be observed between the products.

Titratable acidity, a better indicator than pH for determining the effect of acids on flavor, was determined in terms of citric acid equivalent in all samples. As seen in Table 1, the highest and lowest titratable acidity values belong to the samples coded S16 with 7.58% and S15 with 2.65%, respectively. Titratable acidity values of S5, S8, S9, S14, S16, and S18 coded samples are higher than other samples. This situation can be associated with the raw materials and additives used in the production of pomegranate sauces. Karabiyikli and Kisla [39] reported that titration acidity (as citric acid equivalent) values of traditional pomegranate sauces varied from 8.60 to 9.30%. In another study, it was determined that the acidity values of pomegranate sauces were in the range of 4.30 – 7.97 g/100 g [22]. The results obtained from this study are similar to those in the literature.

pH values of the samples varied between 1.66 (S12) and 2.88 (S18). pH is a decisive factor in processes in all foods, such as color (pigment), texture, water holding capacity, enzymatic, gelation, denaturation, growth, and

inhibition of microorganisms, germination or death of bacterial spores, and some chemical reactions (Maillard reaction) [40]. There is no standard guideline value in Türkiye for the pH values of pomegranate sauces. However, in some studies in the literature, it has been reported that the pH values of pomegranate sauces are in the range of 2.33 – 2.68 [39] and 2.64 – 2.91 [22], close to those in the present study.

As a result of HMF analysis of the pomegranate sauce samples, the lowest and highest values were found as 4.58 mg/kg (S18) and 103.68 mg/kg (S3), respectively. Daily intakes of HMF per person vary between 4 and 30 mg. However, when prune drinks are consumed, up to 350 mg of HMF can be taken into the body daily [41]. It has been found to be responsible for harmful effects such as mutagenic, genotoxic, cytotoxic and enzyme inhibition effects on human health when consumed in high doses [42].

As a result of the total sugar analysis, the highest content was found in the S8 coded sample with 28.70%, and the lowest in the S3 coded sample with 14.84%. Similar results have been reported in the literature. While Kışla and Karabıyıklı [43] reported that the total sugar content of pomegranate sauces ranged from 12.24% to 29.11%, another study reported that the values ranged between 21.89% and 53.44% [22].

From the Table 1, the highest glucose, fructose, and sucrose contents of the samples are 15.40% (S17), 16.41% (S6) and 24.61% (S15), respectively, while the lowest values are <LOQ for glucose and fructose, and 1.93% (S17) for sucrose. Total sugar, glucose, fructose, and sucrose contents of the sample S18 are determined as 26.05%, 8.59%, 12.10%, and 5.36%, respectively.

While glucose could be detected in S8, S9, S10, S11, S12, S14, S16, S17 and S18 coded samples, it could not be detected in other samples. Also, fructose could not be detected in the glucose-free samples except S1, S6 and S13 coded samples. On the other hand, sucrose was determined quantitatively in all samples. On the contrary, as glucose and fructose levels of the pomegranate sauces decreased, sucrose levels increased. The reason for the differences in glucose, fructose and sucrose levels may be attributed to the raw materials and additives.

Color is one of the most important sensory properties of foods. Therefore, minimizing the pigment losses during the processing and storage is an important to maintain the quality [44]. The red color of pomegranate juice is due to the formation of pelargonidin, cyanidin and delphinidin [45]. The highest values of L*, a*, b* and ΔE was determined as 31.31 (S11), 26.48 (S16), 17.58 (S11) and 27.37 (S11), while the lowest values were measured as 15.84 (S18), 9.03 (S12), -4.58 (S4) and 0.00 (S18), respectively (Table 2). Mokrzycki and Tatol [46] reported that a standard observer sense color differences between results as shown below: "0 < ΔE < 1 -the observer does not notice the difference, 1 < ΔE < 2 -only the experienced observer can notice the difference, 2 < ΔE < 3.5 -the inexperienced observer also notices the difference, 3.5 < ΔE < 5 -clear color difference is noticeable, 5 < observer ΔE -observer notices two different colors."

In addition to the color values of the samples, no artificial food colors were detected in any of the pomegranate sauce samples during the analysis.

Knowing the viscosity of the product in food processing is an important criterion to define the product

Table 1. Analysis results of Brix, titratable acidity (as citric acid equivalent), pH, HMF, fructose, glucose, sucrose, and total sugar of the pomegranate sauce samples

Sample	Water soluble dry matter %	Titratable acidity (as citric acid) %	pH	HMF mg/kg	Fructose % (m/m)	Glucose % (m/m)	Sucrose % (m/m)	Total sugar % (m/m)
S1	74.85 ± 1.85^{bcd*}	3.77 ± 0.19^{ef}	1.69 ± 0.06^{i}	26.67 ± 1.90^{ef}	4.78 ± 4.79^{def}	<LOQ	17.00 ± 0.10^{bc}	21.78 ± 4.89^{cde}
S2	76.70 ± 0.02^{a}	3.27 ± 0.17^{h}	2.30 ± 0.02^{d}	12.07 ± 1.35^{gh}	<LOQ**	<LOQ	23.49 ± 2.65a	23.49 ± 2.65^{bcd}
S3	76.40 ± 0.30^{a}	3.37 ± 0.23^{gh}	2.25 ± 0.01^{d}	103.68 ± 1.53^{a}	<LOQ	<LOQ	14.84 ± 3.30^{cd}	14.84 ± 3.30^{g}
S4	76.60 ± 0.80^{a}	3.34 ± 0.4^{gh}	2.03 ± 0.06^{f}	36.84 ± 0.94^{d}	<LOQ	<LOQ	17.65 ± 0.78^{bc}	17.65 ± 0.78^{efg}
S5	74.70 ± 0.004^{bcd}	5.66 ± 0.05^{c}	1.91 ± 0.03^{h}	24.18 ± 5.54^{f}	<LOQ	<LOQ	14.96 ± 0.83^{cd}	14.96 ± 0.83^{fg}
S6	75.10 ± 0.30^{bc}	3.65 ± 0.004^{f}	1.96 ± 0.02^{g}	14.52 ± 0.50^{g}	16.41 ± 5.30^{a}	<LOQ	10.78 ± 0.69^{ef}	27.19 ± 6.00^{ab}
S7	76.45 ± 0.05^{a}	3.37 ± 0.09^{gh}	2.18 ± 0.03^{e}	8.60 ± 0.39^{e}	<LOQ	<LOQ	18.15 ± 1.39^{b}	18.15 ± 1.39^{efg}
S8	73.65 ± 0.45^{ef}	6.70 ± 0.10^{b}	1.70 ± 0.04^{i}	43.40 ± 1.96^{c}	6.72 ± 1.61^{cd}	14.61 ± 0.24^{a}	7.38 ± 1.39^{gh}	28.70 ± 0.02^{a}
S9	72.50 ± 0.40^{g}	6.66 ± 0.14^{b}	2.27 ± 0.01^{d}	16.09 ± 1.01^{g}	2.75 ± 0.24^{efg}	2.90 ± 0.42^{f}	19.41 ± 4.01^{b}	25.06 ± 3.35^{abc}
S10	75.40 ± 0.003^{b}	3.55 ± 0.08^{fg}	2.14 ± 0.02^{e}	24.50 ± 1.03^{f}	5.42 ± 0.003^{cde}	4.05 ± 0.42^{e}	18.18 ± 1.31^{b}	27.64 ± 0.89^{ab}
S11	73.00 ± 0.003^{fg}	4.46 ± 0.09^{d}	2.03 ± 0.06^{f}	67.02 ± 1.83^{b}	8.19 ± 0.41^{c}	8.21 ± 1.48^{c}	5.55 ± 0.48^{h}	21.95 ± 2.36^{cde}
S12	73.90 ± 0.003^{def}	3.93 ± 0.17^{e}	1.66 ± 0.02^{i}	16.07 ± 1.96^{g}	6.01 ± 0.13^{cd}	4.22 ± 0.17^{e}	7.95 ± 0.73^{gh}	18.18 ± 0.77^{efg}
S13	70.15 ± 0.65^{h}	3.25 ± 0.12^{h}	2.06 ± 0.01^{f}	23.44 ± 0.56^{f}	13.30 ± 0.21^{b}	0.00 ± 0.00^{g}	12.77 ± 0.56^{de}	26.07 ± 0.36^{abc}
S14	70.30 ± 0.10^{h}	7.42 ± 0.20^{a}	2.52 ± 0.02^{b}	22.14 ± 1.55^{f}	4.75 ± 0.05d^{ef}	10.16 ± 1.13^{b}	10.82 ± 0.28^{ef}	25.73 ± 0.91^{abc}
S15	73.00 ± 0.30^{fg}	2.65 ± 0.11^{i}	1.90 ± 0.02^{h}	24.54 ± 1.49^{f}	<LOQ	<LOQ	24.61 ± 0.96^{a}	24.61 ± 0.96^{abc}
S16	74.30 ± 0.10^{cde}	7.58 ± 0.16^{a}	2.38 ± 0.01^{c}	44.19 ± 5.70^{c}	4.52 ± 0.25^{def}	6.93 ± 0.84^{d}	8.74 ± 0.90fg	20.20 ± 0.18^{de}
S17	74.30 ± 0.10^{cde}	3.73 ± 0.11^{ef}	1.91 ± 0.02^{h}	29.33 ± 4.31^{e}	1.98 ± 0.07^{fg}	15.40 ± 0.40^{a}	1.93 ± 0.00^{i}	19.31 ± 0.48^{def}
S18***	70.00 ± 0.004^{h}	5.58 ± 0.08^{c}	2.88 ± 0.03^{a}	4.58 ± 0.18^{i}	12.10 ± 0.28^{b}	8.59 ± 0.20^{c}	5.36 ± 0.69^{h}	26.05 ± 0.22^{abc}

*The different letters in the same column mean that the difference between the results is statistically significant at $p < 0.05$ according to the Duncan test.

**The values of LOQ: % 0.10 for fructose, 0.15 for glucose, 0.5 for sucrose; The values of LOD: % 0.03 for fructose, 0.05 for glucose, 0.17 for sucrose

***Control sample

Table 2. Color analysis results of the pomegranate sauce samples

Sample	L	a	b*	ΔE
S1	16.68 ± 0.68^{ghi*}	12.45 ± 1.35^{hi}	-3.38 ± 0.43^{fgh}	1.39 ± 0.93^{ij}
S2	23.56 ± 0.51^{bc}	17.83 ± 0.36^{cd}	7.33 ± 1.18^{c}	14.89 ± 1.30^{c}
S3	18.61 ± 2.74^{efgh}	9.47 ± 1.44^{j}	-3.55 ± 0.66^{fgh}	4.09 ± 2.83^{ghi}
S4	16.12 ± 0.11^{hi}	9.35 ± 0.10^{j}	-4.58 ± 0.06^{h}	2.93 ± 0.22^{ghij}
S5	16.46 ± 0.66^{ghi}	11.75 ± 3.02^{hi}	-4.21 ± 0.21h	2.24 ± 1.09^{ghij}
S6	16.67 ± 0.87^{ghi}	10.85 ± 0.59^{ij}	-3.71 ± 0.80^{gh}	2.06 ± 0.29^{hij}
S7	17.28 ± 0.76^{fghi}	13.32 ± 0.88^{hg}	-2.35 ± 0.58^{fg}	2.63 ± 1.35^{ghij}
S8	25.11 ± 0.33^{b}	22.97 ± 0.31^{b}	9.99 ± 0.51^{b}	20.01 ± 0.56^{b}
S9	18.91 ± 0.70^{efg}	18.80 ± 1.31^{c}	-0.60 ± 0.58^{e}	8.10 ± 0.99^{d}
S10	20.06 ± 3.22^{de}	9.38 ± 1.19^{j}	-3.32 ± 0.72^{fgh}	5.26 ± 3.27^{efg}
S11	31.31 ± 0.95^{a}	18.53 ± 0.26^{c}	17.58 ± 1.17^{a}	27.37 ± 1.38^{a}
S12	21.97 ± 2.16^{cd}	9.03 ± 2.15^{j}	-2.42 ± 0.24^{fg}	7.21 ± 2.70^{def}
S13	17.37 ± 0.17^{fghi}	13.88 ± 0.68^{fgh}	-2.58 ± 0.37^{fg}	2.77 ± 0.71^{ghij}
S14	17.28 ± 0.15^{fghi}	15.93 ± 0.50^{def}	-2.17 ± 0.23^{f}	4.45 ± 0.63^{fgh}
S15	19.65 ± 1.43^{ef}	16.21 ± 1.10^{de}	1.26 ± 0.55^{d}	7.81 ± 0.75^{de}
S16	22.80 ± 1.40^{c}	26.48 ± 1.56^{a}	7.35 ± 1.94^{c}	19.59 ± 2.77^{b}
S17	17.73 ± 0.54^{efghi}	15.29 ± 0.80^{efg}	-0.76 ± 0.83^{e}	4.95 ± 1.02^{fgh}
S18**	15.84 ± 0.20^{i}	12.21 ± 0.41^{hi}	-4.09 ± 0.23^{h}	0.00 ± 0.00^{j}

*The different letters in the same column mean that the difference between the results is statistically significant at $p < 0.05$ according to the Duncan test

** Control sample

Table 3. Rheology values of the pomegranate sauce samples

Sample	Shear rate (1/s)	Viscosity (mPa.s)	Shear stress (Pa)
S1	50	2086.57 ± 58.28^{f}	104.33 ± 2.91^{def}
S2	50	2131.60 ± 25.24^{e}	106.58 ± 1.26^{de}
S3	50	2464.13 ± 162.83^{c}	123.21 ± 8.14^{c}
S4	50	2864.93 ± 118.94^{b}	143.24 ± 5.94^{b}
S5	50	1519.10 ± 115.44^{hi}	75.96 ± 5.77^{fgh}
S6	50	1852.20 ± 51.22^{gh}	92.61 ± 2.56^{ef}
S7	50	3311.63 ± 177.60^{a}	165.58 ± 8.88^{a}
S8	50	722.54 ± 24.49^{j}	36.13 ± 1.22^{hi}
S9	50	793.93 ± 24.74^{ij}	39.70 ± 1.24^{gh}
S10	50	2263.80 ± 95.26^{d}	113.19 ± 4.76^{cd}
S11	50	889.30 ± 18.34^{i}	44.46 ± 0.92^{g}
S12	50	2178.70 ± 60.79^{ef}	108.94 ± 3.04^{d}
S13	50	760.39 ± 6.52^{ij}	38.02 ± 0.33^{h}
S14	50	574.29 ± 30.58^{k}	28.71 ± 1.53^{ij}
S15	50	1565.07 ± 24.66^{h}	78.25 ± 1.23^{fg}
S16	50	1861.00 ± 25.72^{g}	93.05 ± 1.28^{e}
S17	50	1710.17 ± 9.26^{ghi}	85.51 ± 0.46^{f}
S18 **	50	586.93 ± 115.05^{j}	29.35 ± 5.75^{i}

* The different letters in the same column mean that the difference

**Control sample

quality, that is, the texture of the product is based on viscosity [47].

Viscosity and shear stress values obtained from the rheology analysis of the samples are given in Table 3. From the table, the viscosity values at 50 shear rates are the highest in the sample S7 with 3311.63 value (mPa.s), and the lowest in the sample S14 with 574.29 (mPa.s). There is a direct proportionality between shear stress and viscosity (Table 3). The samples with the highest viscosity values also have high Brix and sucrose values. Brix and sucrose values were decisive for viscosity in the pomegranate sauces. Hidayanto et al [47] reported that viscosity increased with the increase of the sucrose concentration in the solution.

3.2. Antioxidant activity results

Antioxidants, one of the important components of the body defense system, protect organisms against the harmful effects of free radicals. Therefore, interest in natural foods, especially plants, which contain high amounts of antioxidants, has been increasing recently [48]. Analysis results of DPPH, FRAP, ABTS, TAC, TPC, TFC of the pomegranate sauce are given in Table 4. As a result of all antioxidant analysis methods applied, all results of the N18 coded sample produced in the laboratory were found to be the highest compared to the others. The highest antioxidant activity values of the pomegranate sauce samples were determined as 2822.69 ± 3.01 mg AA/kg for DPPH, %92.58 for DPPH (% inhibition), 2380.94 mg $FeSO_4$/kg for FRAP, 719.42 mg AA/kg for ABTS, %98.71for ABTS % inhibition, 3690.83 mg AA/kg for TAC, 9566.95 mg GAE/kg for TPC, 11680.71 mg QEE/kg for TFC.

The activity values measured in the sample N18 are considerably higher than the others. For example, the lowest TFC value determined was 23.06 mg QEE/kg in the N17 coded sample, while it was 11680.71 mg QEE/kg in the N18 coded sample, that is, N18 is approximately 500 times higher than N17. Tehranifar et al. [7] reported that pomegranate fruit shows high antioxidant activity due to the phenolic content. Therefore, the more pomegranate juice is added to the pomegranate sauce, the higher the antioxidant activity.

Principal component analysis (PCA) was performed to evaluate the relationship between 18 pomegranate sauces according to their physical and chemical properties. PCA can be described as the most popular method for determining correlations between both variables and observations. In this method, the considering data and all variables can be analyzed on a line chart simultaneously. Principal component analysis (PCA) was applied to all results obtained from the analysis of the pomegranate sauce samples using the XLSTAT (2010) package statistical program, and the resulting graph is shown in Fig. 1.

It is seen that F1 and F2 plots explains 65.97% of the. While the F1 variation explains 43.74%, the F2 variation explains 22.24%. According to the results, the pomegranate sauce samples formed four different groups. The samples S8, S9, S14, S11, and S16 formed one separate group because their antioxidant contents are higher than the other samples except S18. However, the sample S18 is in a separate group alone because it has a very high antioxidant content compared to all other samples. Except for the samples in these two groups, all other samples are grouped together because they have similar results.

Table 4. Analysis results of DPPH, FRAP, ABTS, TAC, TPC, TFC of the pomegranate sauce samples

Sample	DPPH mg AA/kg	DPPH % Inhibition	FRAP mg $FeSO_4$/kg	ABTS mg AA/kg	ABTS % Inhibition	TAC mg AA/kg	TPC mg GAE/kg	TFC mg QEE/kg
S1	304.73 ± 106.94^{g}	10.19 ± 3.58^{g}	556.90 ± 6.58^{cd}	69.99 ± 7.76^{ef}	9.79 ± 1.08^{ef}	742.93 ± 10.72^{ghi}	210.07 ± 0.95^{fgh*}	235.71 ± 18.73^{hi}
S2	5.23 ± 2.62^{k}	0.17 ± 0.09^{k}	608.77 ± 5.33^{b}	24.05 ± 6.28^{ef}	3.30 ± 0.86^{f}	660.47 ± 11.06^{i}	123.54 ± 10.83^{h}	251.68 ± 66.23^{hi}
S3	49.74 ± 22.82^{jk}	1.63 ± 0.75^{jk}	606.91 ± 8.47^{b}	27.22 ± 9.99^{ef}	3.73 ± 1.36^{ef}	714.39 ± 14.39^{hi}	175.41 ± 23.01^{fgh}	196.74 ± 50.65^{hi}
S4	147.01 ± 62.28^{hi}	4.85 ± 2.05^{hi}	609.96 ± 3.56^{b}	16.95 ± 4.19^{f}	2.34 ± 0.58^{f}	782.23 ± 5.69^{ghi}	202.79 ± 21.55^{fgh}	797.44 ± 37.94^{efg}
S5	265.91 ± 18.25^{g}	8.73 ± 0.60^{g}	544.24 ± 28.70^{d}	98.02 ± 33.84^{e}	13.47 ± 4.65^{e}	917.47 ± 31.48^{fg}	207.14 ± 26.25^{fgh}	361.04 ± 38.13^{ghi}
S6	24.00 ± 7.42^{k}	0.80 ± 0.25^{k}	580.12 ± 30.54^{bc}	45.60 ± 36.00^{ef}	6.35 ± 5.02^{ef}	776.60 ± 12.82^{ghi}	233.01 ± 17.44^{fg}	573.23 ± 32.57^{fgh}
S7	107.33 ± 9.75^{ij}	3.57 ± 0.33^{ij}	580.87 ± 7.43^{bc}	46.02 ± 8.77^{ef}	6.40 ± 1.22^{ef}	708.82 ± 6.29^{hi}	163.75 ± 1.66^{gh}	378.49 ± 32.63^{ghi}
S8	1740.02 ± 22.24^{c}	56.96 ± 0.73^{c}	57.94 ± 9.35^{h}	631.85 ± 59.28^{b}	86.53 ± 8.12^{b}	2411.09 ± 429.39^{b}	717.61 ± 56.43^{c}	638.24 ± 19.12^{fgh}
S9	1484.24 ± 58.32^{d}	48.34 ± 1.90^{d}	88.56 ± 6.96^{gh}	571.27 ± 129.60^{b}	77.84 ± 17.66^{b}	1211.40 ± 14.41^{e}	774.87 ± 114.03^{c}	1218.59 ± 33.30^{e}
S10	190.52 ± 57.58^{h}	6.22 ± 1.88^{h}	555.05 ± 4.90^{cd}	89.49 ± 5.77^{ef}	12.23 ± 0.79^{ef}	1033.62 ± 13.27^{f}	270.80 ± 19.58^{def}	971.94 ± 69.13^{ef}
S11	752.57 ± 40.82^{e}	24.66 ± 1.33^{e}	380.02 ± 26.67^{f}	293.36 ± 31.45^{c}	40.21 ± 4.31^{c}	2247.56 ± 31.54^{bc}	351.80 ± 97.30^{d}	858.37 ± 76.44^{ef}
S12	440.32 ± 61.95^{f}	14.33 ± 2.02^{f}	477.31 ± 16.59^{e}	183.84 ± 19.56^{d}	25.02 ± 2.66^{d}	782.07 ± 6.43^{ghi}	255.97 ± 4.27^{efg}	953.26 ± 57.73^{ef}
S13	459.94 ± 9.48^{f}	14.98 ± 0.31^{f}	491.30 ± 27.81^{e}	166.45 ± 32.78^{d}	22.68 ± 4.47^{d}	904.31 ± 13.30^{fgh}	247.20 ± 23.11^{efg}	2394.72 ± 19.22^{d}
S14	1869.84 ± 29.91^{b}	62.04 ± 0.99^{b}	86.06 ± 8.35^{hg}	627.18 ± 15.11^{b}	87.06 ± 2.10^{b}	1877.48 ± 70.19^{d}	1526.21 ± 80.78^{b}	3636.59 ± 75.48^{b}
S15	500.18 ± 32.73^{d}	16.47 ± 1.08^{f}	378.20 ± 24.43^{f}	291.96 ± 28.80^{c}	40.21 ± 3.97^{c}	763.70 ± 37.55^{ghi}	338.95 ± 18.07^{de}	338.19 ± 211.78^{ghi}
S16	1744.37 ± 38.01^{c}	57.25 ± 1.25^{c}	96.45 ± 4.37^{g}	616.01 ± 21.50^{b}	84.57 ± 2.95^{b}	2142.69 ± 16.51^{c}	1448.38 ± 49.34^{b}	3070.88 ± 212.44^{c}
S17	320.58 ± 13.14^{g}	10.45 ± 0.43^{g}	609.78 ± 9.02^{b}	26.63 ± 10.63^{ef}	3.63 ± 1.45^{ef}	684.45 ± 13.29^{i}	124.17 ± 19.02^{h}	23.06 ± 5.36^{i}
S18**	2822.69 ± 3.01^{a}	92.58 ± 0.10^{a}	2380.94 ± 46.69^{a}	719.42 ± 0.00^{a}	98.71 ± 0.01^{a}	3690.83 ± 41.00^{a}	9566.95 ± 108.09^{a}	11680.71 ± 1042.63^{a}

* The different letters in the same column mean that the difference between the results is statistically significant at $p < 0.05$ according to the Duncan test

** Control sample

Principal component analysis (PCA) was performed to evaluate the relationship between 18 pomegranate sauces according to their physical and chemical properties. PCA can be described as the most popular method for determining correlations between both variables and observations. In this method, the considering data and all variables can be analyzed on a line chart simultaneously. Principal component analysis (PCA) was applied to all results obtained from the analysis of the pomegranate sauce samples using the XLSTAT (2010) package statistical program, and the resulting graph is shown in Fig. 1. It is seen that F1 and F2 plots explains 65.97% of the. While the F1 variation explains 43.74%, the F2 variation explains 22.24%. According to the results, the pomegranate sauce samples formed four different groups. The samples S8, S9, S14, S11, and S16 formed one separate group because their antioxidant contents are higher than the other samples except S18. However, the sample S18 is in a separate group alone because it has a very high antioxidant content compared to all other samples. Except for the

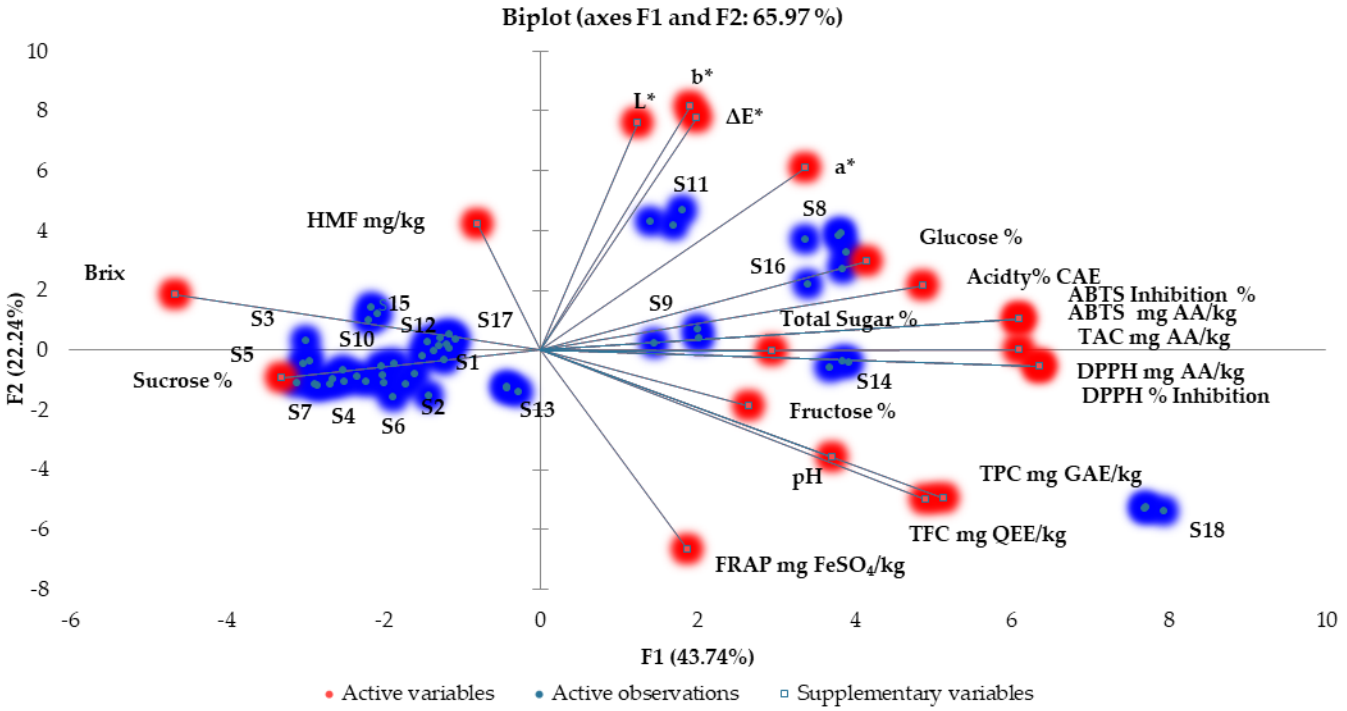

Figure 1. Results of the principal component analysis (PCA) for the pomegranate sauces

samples in these two groups, all other samples are grouped together because they have similar results.

4. Conclusions

This study was carried out to determine the some physicochemical and antioxidant properties of the pomegranate sauces. In terms of many parameters, the analysis results of the samples were different from each other due to raw materials, additional additives, applied heat treatments, and production process. The antioxidant content of the sample N18 (produced in the laboratory) is very high compared to all other samples as it is obtained from fresh pomegranate juice, and contains no additives except starch, sugar, and lemon. Because of the positive effects of pomegranate and pomegranate products on human health, its consumption should be increased. However, antioxidant activity and HMF contents are important in the production of pomegranate products.

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