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Research Article
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Production of pomegranate snacks as affected by different pre-treatments

Farklı ön işlemlerin atıştırmalık nar çerezi üretimine etkileri

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ABSTRACT

Objective: In this research, the production and quality characteristics of new healthy pomegranate snacks (*Punica granatum* L.) obtained by drying after different pre-treatments were investigated.

Material and Methods: Besides control group, three different pre-treatments were applied to the pomegranate seeds before drying. Pomegranate seeds without any pre-treatment were grouped as “control” samples (C) and other group was boiled in 80 °C water for 2 minutes “boiled” (B). Samples treated with sucrose and glucose (60 °Brix) solutions (18 hours at 40 °C) for osmotic dehydration were grouped as "sucrose” (S) and “glucose" (G) group. Samples in all groups were dried at 65 °C in a tray dryer at an air velocity of 1.6 m/s until the moisture content reached 6%.

Results: According to physical and chemical analysis results, the total sugar content was between 87.96-97.50 g/100 g; the amount of invert sugar 46.23-62.75 g/100 g; the total amount of phenolic substance 255.6-407.6 mg/100 g; antioxidant capacity values ranged from 40.2% to 49.6%. Total loss of phenolic substance according to raw material was found to be the lowest in boiled samples. According to sensory tests in terms of all sensory properties (color, texture, flavour and preference), boiling pre-treatment applied sample was determined as the most preferred sample.

Conclusion: When all results are analysed, to obtain a healthy snack product using pomegranate fruit, it is thought that applying the boiling pre-treatment before drying to the pomegranate may be appropriate for preserving nutrients and obtaining a preferred snack pomegranate.

ÖZ

Amaç: Bu araştırmada, farklı ön işlemlerden sonra kurutularak elde edilen yeni, sağlıklı nar çerezlerinin (*Punica granatum* L.) üretim ve kalite özellikleri araştırılmıştır.

Materyal ve Yöntem: Örneklere kurutma işlemi öncesi kontrol grubunun yanı sıra üç farklı ön işlem uygulanmıştır. Herhangi bir ön işleme tabi tutulmamış örnekler "kontrol" (C) örnekleri, 80 °C'de 2 dakika su içinde haşlama işlemi uygulanan örnekler ise, "haşlama" (B) olarak gruplandırılmıştır. Ozmotik dehidrasyon için sakaroz ve glikoz (60 °Brix) çözeltileri (40 °C'de 18 saat) ile işlenmiş örnekler "sakaroz" (S) ve "glikoz" (G) grubu olarak gruplandırılmıştır. Tüm örnek grupları nem içeriği %6'ya ulaşıncaya kadar tepsili kurutucuda 65 °C'de 1.6 m/s hava hızında kurutulmuştur.

Araştırma Bulguları: Fiziksel ve kimyasal analiz sonuçlarına göre toplam şeker içeriği 87.96-97.50 g/100 g; invert şeker miktarı 46.23-62.75 g/100 g; toplam fenolik madde miktarı 255.6-407.6 mg/100 g; antioksidan kapasite değerlerinin ise %40.2 ile 49.6 arasında değiştiği saptanmıştır. Hammaddeye göre toplam fenolik madde kaybı, haşlanmış örneklerde en düşük olarak bulunmuştur. Tüm duyusal özellikler (renk, doku, lezzet ve tercih) açısından uygulanan duyusal analiz sonuçlarına göre, ön işlem olarak 80 °C'de 2 dakika haşlama işlemi uygulanan örnek en çok tercih edilen örnek olarak belirlenmiştir.

Sonuç: Tüm sonuçlar analiz edildiğinde, nar meyvesi kullanılarak sağlıklı bir atıştırmalık ürün elde etmek için nar tanelerine ön işlem olarak haşlama işlemi uygulamasının, besin maddelerinin korunmuş ve duyusal olarak tercih edilen bir atıştırmalık nar üretimi için uygun olduğu düşünülmektedir.

INTRODUCTION

Snack foods are generally considered as foods that can easily be consumed outside of three meals during a normal diet but which cause malnutrition and one-way nutrition. However, in recent years, various snack foods with high nutritional value have been produced for different purposes such as meeting the special nutritional needs of individuals like athletes, children and patient nutrition. Such foods may have a high energy content, such as athlete nutrition, or maybe for a low-calorie diet capable of fulfilling medical purposes, like in people with diabetes or geriatric nutrition needs. It is understood from the products on the shelves that snacks prepared especially for children consist of snacks rich in fat, carbohydrates and minerals and thus have high-calorie value. Today, there are many studies in the literature on the production of healthy snack foods from many fruits and vegetables such as carrots, pineapples, apples (Domel et al., 1996; Potter et al., 2013; Chen et al., 2018; Yadav and Singh, 2014; Mphahlele et al., 2014).

Snack foods obtained from fruits and vegetables are usually produced by osmotic dehydration after various pre-treatments and then by drying. In the osmotic dehydration process, sliced fruits or vegetables are dipped into the osmotic dehydration solution. As a result of the concentration difference between the food and the osmotic solution, the solute passes from solution to food, increasing the dry matter content of the food. This ensures that there is minimal damage to the food during the drying process and that an acceptable quality product can be obtained. Osmotic dehydration can be easily carried out at low temperatures, such as room temperature, and the dehydration rate and the throughput of the material can be increased with the increasing temperature.

Polyphenolic compounds are commonly found in both edible and inedible plants (Aktaş and Malayoğlu, 2019). Pomegranate (*Punica granatum*, L.), one of the oldest known fruits, has rich antioxidant activity and polyphenol content due to its high nutritional content, antimicrobial and anticarcinogenic effects (Tehranifar et al. 2010; Karadeniz et al., 2005; Seeram et al., 2008). Karimi et al., 2017). In this research, to improve a healthy snack pomegranate product, the effects of different pre-treatments on the physicochemical and sensory properties of dried pomegranate seeds were investigated.

MATERIAL and METHODS

Material

Whole fresh pomegranate (*Punica granatum* L.), were purchased from a local supermarket in İzmir, Turkey, and were stored in cold storage at 4±1 °C until treatments.

Methods

Pre-treatments and drying

Besides control group three different pre-treatments were applied to the pomegranate seeds before drying. The first group of pomegranate seeds (C) was coded as the control group and no pre-treatment was applied. The second group (B) was boiled in 80 °C water for 2 minutes and quickly cooled to room temperature. The third (S) and fourth group (G) pomegranate seeds were immersed in a 1:4 (w:v) (pomegranate : osmotic solution) of sucrose and glucose (both at 60 °Brix) at 40 °C for 18 hours. After pre-treatment application, all samples were dried at 65 °C in a tray dryer (Weintek, Turkey) with 1.6 m/s airspeed.

Physicochemical analysis

Total dry matter: Total dry matter contents of untreated fresh and dried pomegranate samples were determined at 65 °C in a vacuum oven (EV Core 018, Turkey) (Anon, 2005).

Bulk Density: The sample was filled into a 250 ml measuring cylinder and shaken gently until the lowest volume was achieved. The sample was allowed to fit well into the measuring cylinder, then weighed using an analytical balance with a sensitivity of 0.0001 g. Measurements were performed in 8 replicates (Calin-Sanchez et al., 2012). The bulk density of the dried pomegranate samples was calculated using the following formula.

$$d_b = m/V_b \qquad \text{Eq. 1}$$

Where, d_b is bulk density, m is mass of bulk and Vb is the volume of bulk.

Color Values: The color values (L*, a* and b*) of the samples were measured in ten replicates by Hunter colorimeter (Hunter Lab Color Flex Management Company, USA). The means and standard deviations of the measured color values were calculated using Chroma (C*), Hue angle (h*) and Total Color Difference (∆E*) equations 2, 3 and 4 (Patras et al., 2011, Pathare et al., 2013).

Chroma	$C^* = \sqrt{a^{*2} + b^{*2}}$	*Eq. 2*
Hue	$h^* = tan^{-1}(\frac{b^*}{a^*})$	*Eq. 3*
Total Colour Difference	$\Delta E^* = \sqrt{\Delta a^{*2} + \Delta b^{*2} + \Delta L^{*2}}$	*Eq. 4*

Water Activity Measurement: The water activity (a_w) values of the samples were measured using the Testo 400 water activity meter.

Titratable acidity: Pomegranate juice obtained by crushing pomegranate was titrated with 0.1N adjusted NaOH solution and the results were calculated as citric acid as determined in Anon, 2000.

Total and Invert Sugar Determination: Total and invert sugar amounts of raw materials and dry samples were determined using Lane-Eynon Method (Pearson, 1973).

Total Phenolic Analysis: Total phenolic content of raw materials and dried samples was determined by Folin Ciocalteu reagent as indicated by Spanos and Wrolstad (1990). The method is based on the principle of colorimetric measurement of the color blue at 760 nm by reducing the Folin Ciocalteu reagent in the basic medium by phenolic substances. In the analysis according to this method, samples diluted at a certain dilution rate (100-fold) were homogenized with 1.2 N HCl and then filtered through Whatman No. 1 filter paper. Then 0.5 mL of clear filtrate was transferred to glass tubes, 2.5 mL of dilute Folin & Ciocalteu reagent (1:10) was added. 2 mL of Na_2CO_3 was added to the tubes which were kept in the dark for 4 minutes, vortexed and stirred at 50 °C for a further 5 minutes in the dark. The absorbance of the blue color resulting from the redox reaction was measured colorimetically. The measured absorbance values were calculated from the equation of the standard graph prepared in gallic acid and the amount of phenolic material was expressed in mg gallic acid/100g.

Determination of Antioxidant Capacity: As described in Blois (1958), 0.1 mL of sample extracts and standard solutions were allowed to stand in the dark for 30 minutes by mixing with 2.9 mL of DPPH solution dissolved in 0.1 mM ethanol. The absorbance of the mixture was then read at 517 nm against ethanol, and results were expressed as percentage of inhibition (%).

Sensory analysis: Sensory ranking test was applied to the samples as indicated in Altuğ and Elmacı (2011). For this purpose, 20 semi-trained panelists consisting of 12 female and 8 male aged between 26-55 years were used and the panelists were asked to rank the samples from the best to the worst in terms of color, texture and taste, and the place of the samples in the ranking was evaluated as points. The ranking scores of the panelists for each sample were evaluated by Rank analysis at $p < 0.05$ significance level.

Statistical Analysis: The results obtained after the analyzes were evaluated statistically by using one-way analysis of variance (ANOVA) using SPSS Statistics 25 software (IBM, USA) and for significant differences, $p < 0.05$ significance level was evaluated statistically by Duncan test.

RESULTS and DISCUSSION

Raw materials

The total dry matter content of the pomegranate seeds used in the study was 19.6%, the water-soluble dry matter (°Brix) content was 14.5 °Brix, the pH value was 3.5 and the titration acidity was found to be 1.23% in citric acid and these values were found to be consistent with the values reported in the literature (Al-Maiman and Ahmad, 2002; Al-Said et al., 2009; Poyrazoglu et al., 2002; Tehranifar et al., 2010).

Effect of pre-treatments on dry matter and water activity

Dry matter values for pre-treated pomegranate seeds after drying was determined as 95.20%, 94.40%, 93.67% respectively. Accordingly, the fact that the dry matter value, which is about 20% in the raw material, increases to 94% in the processed samples shows that a sufficient drying process is applied (Table 1).

Table 1. Total dry matter contents of snack pomegranate samples
Çizelge 1. *Atıştırmalık nar örneklerinin toplam kuru madde içerikleri*

Sample		Total dry matter (%)
Raw material	(R)	19,67±0,05[a]
Control	(C)	93,09±0,18[b]
Boiling	(B)	95,20±0,96[c]
Sucrose	(S)	94,40±0,21[c]
Glucose	(G)	93,66±0,63[b]

* Different letters in the same column indicate a significant difference (α=0.05)

The pre-treated (B, S, G) samples were dried in about 5 hours and the control group (C) dried in about 7 hours. The boiling and osmotic dehydration processes were shorten the drying time of pomegranate seeds compared to the control group. In general, the amount or rate of water loss in the osmotic dehydration process increases with the difference between the osmotic solution and the food concentration. Factors such as temperature, processing time, osmotic solution / food ratio and surface area of food are also reported to affect the amount and rate of water loss (Lerici et al., 1985). As a matter of fact, after applying osmotic dehydration process, 21.0% (S) and 18.7% (G) weight loss were determined. This suggesteds that pomegranate seeds are susceptible to dehydration since they have a thin membrane structure as well as forming a large surface area.

The dry pomegranate samples water activity values were found as 0.41 for control, 0.31 for boiled and 0.31 for sucrose, 0.3 for glucose. All samples were considered to be microbiologically safe.

Bulk density:

The bulk densities of dry pomegranate samples obtained by pre-treatment were determined as (B) 501 kg/m^3, (S) 573 kg/m^3, (G) 571 kg/m^3 and (C) 588 kg/m^3. There was no statistically significant difference between the samples ($p<0.05$). When the control sample and the osmotically dehydrated samples were compared, it was found that the dehydrated samples had approximately equal bulk density values. The boiled sample showed a relatively lower bulk density and a more bulky appearance.

Color Analysis:

The color values (C*, h*, ΔE*) calculated by the L*, a* and b* color values of the samples obtained in the study are given in Table 2.

There was a statistically significant difference between the L*, a* and b* values of the dried pomegranate samples and the colors of the pre-treated samples were darkened according to the total color difference values of ΔE* starting from the boiled samples. The highest color change was observed in the osmotically pre-treated sample with glucose. The total color difference indicates the magnitude of the color difference between the processed and control samples (Patras et al., 2011). This difference in color values is thought to be due to pre-treatment. Similarly, as it is seen in the studies on processed fruits, it is accepted as the most sensitive parameter in measuring color differentiation. (Patras et al., 2011).

Total and Invert Sugar Analysis

Total sugar amounts of dried pomegranate samples are given in Table 4 and no statistically significant difference was found between the results ($p> 0.05$) (Table 3).

Table 2. Hunter L*, a*, b* color values of snack pomegranate samples
***Çizelge 2**. Atıştırmalık nar örneklerinin Hunter L*, a*, b* renk değerleri*

Sample	L*	a*	b*	C*	h*	ΔE* by raw material	ΔE* by control sample
Raw material (R)	21.87±0.23[a]	23.57±0.22[a]	11.38±0.15[a]	26.17 ±0.22[a]	25.78±0.29[a]	-	-
Control (C)	21.05±0.10[b]	19.08±0.05[b]	7.54±0.98[b]	20.51±0.512[b]	21.57±0.26[b]	5.97	-
Boiling (B)	18.49±0.12[d]	15.19±0.15[e]	5.50±0.21[c]	19.72±0.11[e]	19.71±0.26[c]	6.90	1.13
Sucrose (S)	21.52±0.08[c]	18.57±0.11[d]	6.65±0.09[d]	16.93±0.16[d]	19.57±0.49[c]	9.56	3.65
Glucose (G)	21.01±0.08[b]	15.95±0.14[c]	5.67±0.16[c]	16.16±0.17[c]	19.89±0.63[c]	10.77	5.07

* Different letters in the same column indicate a significant difference (α=0.05)

Table 3. Total and Invert sugar values of snack pomegranate samples
***Çizelge 3**. Atıştırmalık nar örneklerinin toplam ve invert şeker değerleri*

Sample		Invert Sugar (g/100 g DM)	Total Sugar (g/100 g DM)
Raw material	(R)	32.59 ±1.10[c]	65.89 ±2.57[a]
Control	(C)	62.75 ±0.83[a]	87.96 ±3.13[b]
Boiling	(B)	46.22 ±4.05[b]	90.90 ±3.00[b]
Sucrose	(S)	60.97 ±6.96[a]	90.06 ±6.03[b]
Glucose	(G)	64.27 ±7.29[a]	97.50 ±0.63[c]

* Different letters in the same column indicate a significant difference (α=0.05)

According to sugar analysis results, total sugar amount of raw material is approximately 66 and invert sugar amount is 33 g/100g (DM). It is observed that the total amount of sugar increased from the samples obtained as a result of the processes applied to the raw material to the glucose sample starting from the control sample. The sample with the highest total sugar content was detected in the sample treated with glucose. This is thought to be because the molecular weight and structure of glucose are lower and different than that of sucrose.

When the invert sugar values are analyzed, it is seen that the lowest invert sugar is in the boiled sample and the highest invert sugar is in the glucose treated sample. This can be explained by the fact that boiling as a pre-treatment causes loss of dry matter in the sample. However, when the dry matter values obtained in the study are taken into consideration (Table 1), the boiled sample shows the highest dry matter value and thus the relatively high level of total sugar content.

Total phenolic content:

The total phenolic contents of fresh and dried pomegranate samples were given in Table 4 in terms of gallic acid equivalent (GAE). The phenolic content closest to the raw material in these samples was determined in the boiled sample (407.6 mg/100 g sample). In the control (C) sample, the phenolic content was significantly lower than the other samples ($p < 0.05$). This can be explained by the degradation of phenolic substances for the control sample. However, no significant difference was found between pomegranate samples treated with osmotic dehydration ($p < 0.05$).

Table 4. Total phenolic content of snack pomegranate samples
***Çizelge 4.** Atıştırmalık nar örneklerinin toplam fenolik içerikleri*

Sample		Total Phenolic Content (mg/100 g DM sample)
Raw material	(R)	410.6±0.6[a]
Control	(C)	255.6±8.4[c]
Boiling	(B)	407.6±5.2[a]
Sucrose	(S)	314.6±14.0[b]
Glucose	(G)	318.7±9.7[b]

* Different letters in the same column indicate a significant difference (α=0.05)

Table 4 indicates that the processes applied to pomegranate fruit decrease the total phenolic content of the final product. This is consistent with the findings that food processing practices reduce the amount of phenolic substances.

Antioxidant Capacity (DPPH)

Antioxidant capacities of fresh and snack pomegranate samples are shown in Table 5. Antioxidant capacity values of the samples ranged between 40.2% and 62.8%. When the antioxidant capacity values of the samples were examined, it was found that similar to the changes in phenolic content (Figure 1), it was found to be high in the raw material and decreased depending on the processes applied. Differences in the antioxidant capacity of the samples were also statistically significant ($p < 0.05$).

Table 5. Antioxidant capacity of snack pomegranate samples

Çizelge 5. *Atıştırmalık nar örneklerinin antioksidan kapasiteleri*

Sample		Antioxidant capacity (%)
Raw material	(R)	62.8 ± 0.23[a]
Control	(C)	49.6 ± 0.02[b]
Boiling	(B)	45.3 ± 0.01[c]
Sucrose	(S)	40.8 ± 0.06[e]
Glucose	(G)	40.2 ± 0.03[d]

* Different letters in the same column indicate a significant difference (α=0.05)

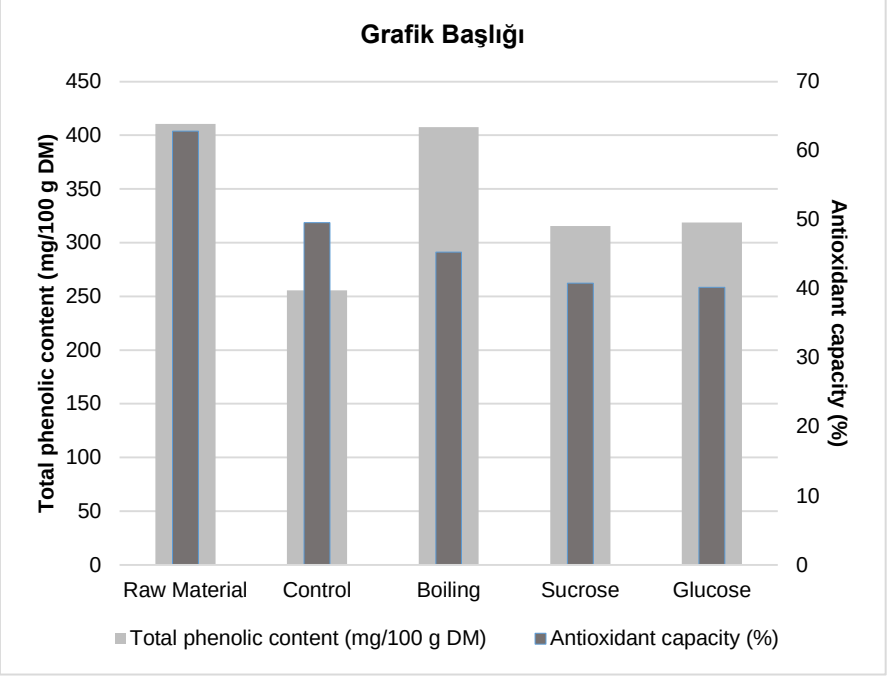

Figure 1. Antioxidant capacity and total phenolic content of snack pomegranate samples.

Şekil 1*. Atıştırmalık nar örneklerinin antioksidan kapasite ve toplam fenolik değerleri.*

According to Piluzza and Bullitta (2011), there are linear correlations between phenolic concentration and antioxidant capacity, and phenolic content could be used as an indicator of antioxidant properties of their examined plant species. It is known that phenolic substances have an important role in antioxidant activity values of foods (Turgut and Seydim, 2013). The different relationships between the antioxidant activity and the total phenolic content can be due to many factors; in fact, the total phenolic content does not incorporate all the antioxidants.

Besides, the synergies between antioxidants in the mixture, which perform antioxidant activity, are not only concentration-dependent. It should be noted that it also depends on the structure and interactions between antioxidants (Piluzza and Bullitta, 2011).

Sensory Analysis

When the color, texture, taste and preference order test results were examined (Table 6), boiled samples with the highest score values and osmotic treatment with sucrose were determined as the superior samples ($p < 0.05$). However, the boiled sample was found to be higher and more preferred than sucrose.

Table 6. Table of total points of sensory analysis of snack pomegranate samples

Tablo 6. *Atıştırmalık nar örneklerinin duyusal analiz toplam puan tablosu*

Sample		Scores			
		Colour	Texture	Taste	Preference
Control	(C)	26	27	32	27
Boiling	(B)	76	75	68	76
Sucrose	(S)	64	61	66	62
Glucose	(G)	34	37	34	35

CONCLUSIONS

In this research, high antioxidant content pomegranate fruit was used as a raw material in snack production. The effects of pre-treatments (boiling, osmotic dehydration with sucrose and glucose) on the physical properties, total phenolic content, antioxidant capacity and sensory properties of the dried snack pomegranate were investigated. The highest loss of color values (L *, a *, b *) was observed in dried pomegranate samples pre-treated by boiling. However, the total phenolic content and antioxidant capacity of pomegranate snacks, which were boiled as a pre-treatment, were found to be higher than the pomegranate snacks dried with osmotic dehydration pre-treatment. Besides, although there was no statistically significant difference in terms of the phenolic content of samples treated with osmotic dehydration pre-treatment with sucrose and glucose, it was found that samples treated with sucrose solution gave higher results in terms of antioxidant capacity. According to sensory analysis results, dried snack pomegranate sample after boiling pre-treatment was determined as the superior samples. Consequently, for improving a healthy snack food product using pomegranate fruit, it is concluded that applying the boiling pre-treatment before drying to the pomegranate arils is the best pre-treatment for preserving nutrients and obtaining a sensorily preferred dried pomegranate.

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