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EFFECTS OF VACUUM IMPREGNATION WITH HONEY AND ROSEHIP SOLUTIONS ON THE FORTIFICATION AND ENZYMATIC BROWNING OF QUINCE (*CYDONIA OBLONGA* M.)

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ABSTRACT
This study aimed to determine the effects of the vacuum impregnation process and different drying techniques (hot-air, microwave, and osmotic) on the enrichment of quince and limiting enzymatic browning. Some physicochemical changes and sensory properties of the obtained samples were determined. According to the results, the total phenolic content of the control sample, calculated as 25.10 mg/100g, increased with the vacuum impregnation. Similarly, the control samples' ascorbic acid content also increased with vacuum impregnation. Antioxidant activity was determined as 1.90±0.08 g/mg DPPH in control samples, increased to 1.67±0.05g/mg DPPH on average with vacuum impregnation and drying techniques. Enzymatic browning was limited by the vacuum impregnation. According to the sensory analysis results, vacuum-impregnated quince fruits scored higher in all categories than fresh quince fruits. In addition, it was found that all drying methods had a statistically significant (p<0.01) effect on the physicochemical properties of vacuum impregnated quince samples.
Keywords: Vacuum impregnation, fortification, enzymatic browning, microwave drying, honey solution

BAL VE KUŞBURNU ÇÖZELTİLERİ İLE VAKUM İMPREGNASYONUN AYVA (*CYDONIA OBLONGA* M.)'NIN ZENGİNLEŞTİRİLMESİ VE ENZİMATİK ESMERLEŞMESİ ÜZERİNE ETKİLERİ

ÖZ
Bu çalışmada, vakum impregnasyon işleminin ve farklı kurutma tekniklerinin (sıcak hava, mikrodalga ve ozmotik) ayvanın zenginleştirilmesi ve enzimatik esmerleşmesinin sınırlandırılması üzerine etkilerinin belirlenmesi amaçlanmıştır. Elde edilen örneklerde bazı fizikokimyasal değişimler ve

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duyusal özellikler belirlenmiştir. Elde edilen sonuçlara göre, 25.10 mg/100g olarak hesaplanan kontrol örneğinin toplam fenolik madde içeriği vakum impregnasyon ile artmıştır. Benzer şekilde, kontrol örneklerinin askorbik asit içeriğinin de vakum impregnasyon ile arttığı gözlenmiştir. Antioksidan aktivite kontrol örneklerinde 1.90±0.08 g/mg DPPH olarak belirlenmiş olup, vakum impregnasyon ve kurutma teknikleri ile ortalama 1.67±0.05g/mg DPPH değerine yükselmiştir. Enzimatik esmerleşme vakum impregnasyon ile sınırlandırılmıştır. Duyusal analiz sonuçlarına göre, vakum impregnasyon uygulanmış ayva meyveleri taze ayva meyvelerine göre tüm kategorilerde daha yüksek puan almıştır. Ayrıca, vakum impregnasyon uygulanmış ayva örneklerinin fizikokimyasal özellikleri üzerinde tüm kurutma yöntemlerinin istatistiksel olarak anlamlı (p<0.01) bir etkiye sahip olduğu bulunmuştur.

Anahtar kelimeler: Vakum impregnasyon, zenginleştirme, enzimatik esmerleşme, mikrodalga kurutma, bal solüsyonu

INTRODUCTION

In recent years, the health benefits of foods have been one of the specific issues in the food industry. So, food companies have fronted to functional foods that meet consumer demands for a healthy lifestyle. Functional foods have been identified as providing additional benefits in preventing disease or supporting human health (Hironaka et al., 2015; Menrad, 2003). One of the options for developing new food products, in other words, functional foods, is the use of vacuum impregnation treatment that depends on immersing the samples in a solution, indicating the exchange of internal gas in the pores of the samples for an external liquid. It is an application based on low pressure to a solid-liquid system followed by the return of atmospheric pressure. Vacuum impregnation treatment causes important changes in the physicochemical properties of food samples that affect demeanour in drying treatments in highly porous foods, especially fruits, and vegetables, such as apple, pineapple, mushroom, and carrot (González-Fésler et al., 2008; Martín-Esparza et al., 2006; Matusek et al., 2008). It has been used in a wide range of practical applications such as the salting process (Chiralt et al., 2001), enrichment in some nutritional compounds (Blanda et al., 2008; Hironaka et al., 2011; Hironaka et al., 2015; Park et al., 2005), osmotic dehydration (Adsare et al., 2016; Bellary et al., 2011), enrichment with probiotic microorganisms (Betoret et al., 2003), calcium fortification (Gras et al., 2003; Moraga et al., 2009) and pH reduction (Derossi et al., 2010, 2013). It provides the removal of oxygen from the food pores, and this is effective in preventing the fading of fruit by enzymatic browning without using antioxidants. Vacuum impregnation treatment also contributes to quality improvement in foods and extends shelf life by hindering enzymatic and oxidative browning (Jeon and Zhao, 2005; Perez-Cabrera et al., 2011).

Enzymatic browning is an undesirable case that occurs during food transportation, storage, and processing. Enzymatic browning often impairs the sensory properties of foods, and this situation reduces consumers' appetite for that food. In addition to all these, as foods' colour, taste, and textural properties deteriorate with enzymatic browning, the nutritional value also decreases (Uenal et al., 2010).

Quince fruit (*Cydonia oblonga* Miller) belongs to the pome fruit family known as the Maloideae subfamily of the Rosaceae family, which includes some fruits such as apples and pears. The main constituents of quince fruit are water (84%) and carbohydrates (15%), and it is also known as a good source of fibre, potassium, and vitamin C (Moreira et al., 2008). Quince has many essential health benefits such as expectorant, carminative, anticancer (Duke, 2002), anti-ulcer, antimicrobial, anti-allergic, and anti-inflammatory, and it is also used in the treatment of colds, flu, migraine (Hilgert, 2001) and conjunctivitis (Siddiqui et al., 2002). It has a hypoglycemic effect and supports the heart and brain (Szychowski et al., 2014). Because of its acidity, hardness, and astringency, quince fruit is difficult to be consumed as fresh; nevertheless, it is often consumed as jam, jelly, liqueur, and marmalade (Wojdylo et al., 2013). In addition to being difficult to consume without processing, quince is also very prone to enzymatic browning due to the polyphenol oxidase enzyme (Yildiz et al., 2020).

This study aims to solve these problems of quince fruit with a vacuum impregnation technique. For this purpose, quince was vacuum-impregnated with two different solutions (honey and rosehip solutions), and some physicochemical and sensory analyses were carried out on the obtained products.

MATERIAL AND METHODS

Material

The quince fruits, honey, rosehip, and hibiscus used in the present study were purchased from a local market in Antalya, Turkey. All chemicals used in analyses were procured from Sigma (Taufkirchen, Germany) and Merck (Darmstadt, Germany) in analytical and chromatographic purity by their quality.

Methods

Preparation of Vacuum Impregnation Solutions

In the present study, honey and rosehip solutions were prepared for vacuum impregnation of quince samples. Both solutions were prepared in distilled water at 5, 10 and 20% concentrations. While honey was used directly, rosehip fruit was pureed with the help of a Waring blender (7011HS, CT, USA), and the solution was prepared with the puree. Hibiscus at the rate of 1.5% was added into both solutions for an acceptable colour.

Vacuum Impregnation Treatment and Drying of the Samples

A vacuum pump (Heidolph, Rotavac, Schwabach, Germany) was connected to the rotary evaporator (Heidolph, Laborota 4000, Schwabach, Germany), and the system was reinforced by an ultrasonic bath (Bandelin Electronic, RK 100 H, Berlin, Germany). Ultrasonic bath operating conditions were determined as 320 W ultrasonic peak power, 80 W nominal ultrasonic power, 35 kHz ultrasonic frequency, and 25C° room temperature. The temperature was controlled during the process and kept constant at 25C° with cold water supplement. Quince samples (approximately 20-25 pieces) sliced in a square shape with a thickness of 6 mm were placed in a flask, and vacuum impregnation solutions (about 100-150 mL) were added to it. A 75 mmHg vacuum pressure was applied to the system for 20 minutes. After vacuum treatment, the system was restored to atmospheric pressure for 10 min. After vacuum impregnation treatment, the quince slices were drained, and the excess solution was removed with the help of a paper tissue. Then, the samples were dried by three different methods:

-They were dried in the oven at 50°C for 5 hours.

-They were dried in a microwave oven at 180 W power for 15 minutes.

-After keeping the samples in 60% sugar solution for one day, they were dried at 25°C for five days.

For control sample, fresh quince fruits were kept in impregnation solutions for the same time (30 min), but the vacuum impregnation treatment was not applied them. All samples were stored at -18 °C until analyses. The experimental procedure design is given in Figure 1.

Moisture Content, Water Activity and pH

The moisture content and the water activity values of the samples were determined via a moisture analyser (Kern DBS, Balingen, Germany) at 105°C, as gravimetrically and a water activity meter (Aqualab 4TE: Decagon Devices, Pullman, WA) at room temperature, respectively. pH values of the samples were determined using a pH meter (S20 SevenEasy, Mettler Toledo, Columbus, OH, USA) by homogenizing 2 g of quince sample in 18 mL distilled water (Tontul and Topuz, 2017; Eroglu et al., 2018).

Extraction and Sample Preparation

Extracts of vacuum impregnated quince samples and control samples were prepared for each analysis. Details of the extraction and sample preparation procedures are given below.

Antioxidant activity, total phenolic content, and ascorbic acid content: Extracts of quince samples were obtained by solid–liquid extraction with distilled water. First, quince samples were ground until they became puree with the help of a household blender. Then, they were mixed with

distilled water at a ratio of 1:20 (w/w). This mixture was kept in a shaking water bath at 99°C for 15 minutes. The extracts were quickly cooled with cold water and filtered through filter paper. Finally, the extracts were stored in bottles at -18°C (Sahin et al., 2009; Topuz et al., 2014).
5-hydroxymethylfurfural (HMF): 500 mg of pureed sample was taken and suspended with 5 mL of deionized water in a 10 mL centrifuge tube. The centrifuge tube was vortexed for 1 min and 0.25 mL of Carrez I and 0.25 mL of Carrez II solutions were added to clarify. The mixture was centrifuged at 4500 g for 10 min. The supernatant was collected in a 10 mL volumetric flask and 2 more extractions were performed with 2 mL of deionized water. The volume was then completed to 10 mL with deionized water. The mixture was analyzed by passing through a 0.45 mm filter paper for HMF analysis (Gunel et al, 2018).

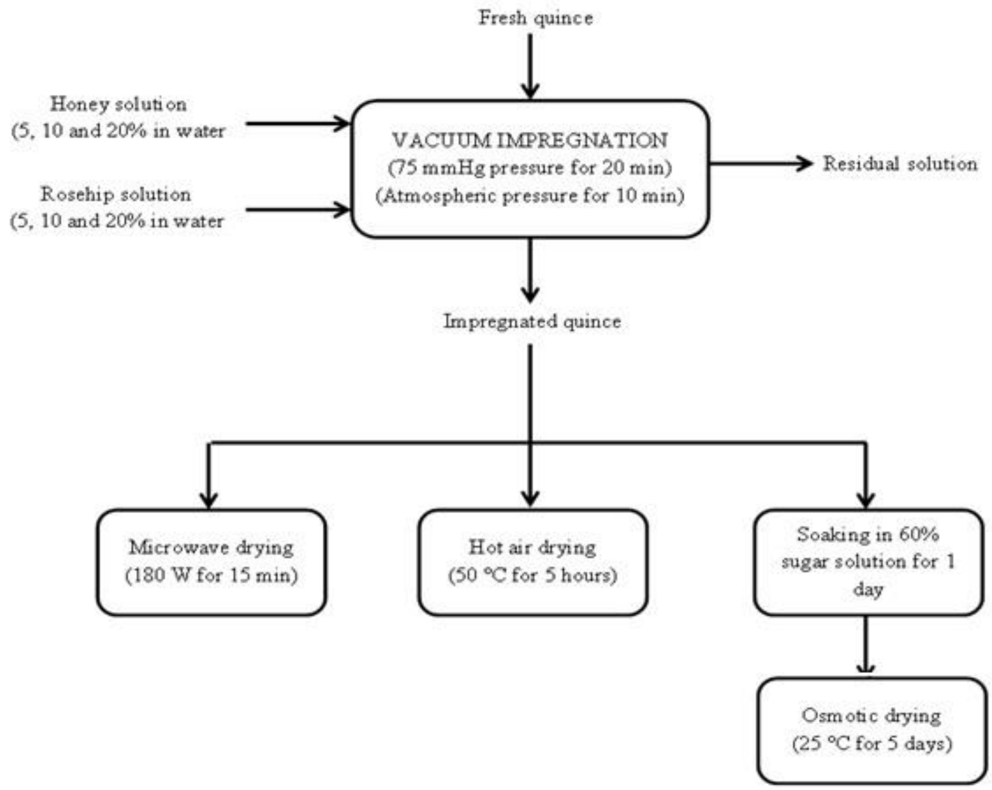

Figure 1. Experimental procedure design

Antioxidant Activity (AA)
The stable radical DPPH (2,2-diphenyl-1-picryhydrazyl radical) was used for determining the free radical-scavenging activity of the vacuum impregnation solutions and the quince samples by using the DPPH method (Topuz et al., 2014). The sample extract providing 50% inhibition (IC_{50}) of the DPPH radical was calculated from the plot of concentration versus percent inhibition. The IC_{50} value of Trolox solution was also determined to compare the antioxidant activity of the samples by using the same procedure.

Total Phenolic Content (TPC)
The TPC of samples was determined using the Folin-Ciocalteu method (Sahin et al., 2009). According to this method, 100 µL of diluted sample was mixed with 900 µL of ultra-pure water, 5 mL of 0.2 N Folin-Ciocalteu reagent, and 4 mL of Na_2CO_3 (7.5% in water, w/w). The final

mixture was incubated at room temperature for one hour in a dark place. Absorption was measured at 765 nm with Shimadzu Spectrophotometer UV-1800 (Nakagyō-ku, Kyoto, Japan). The TPC was expressed as gallic acid equivalents (GAE) in mg/100 g dry matter.

5-hydroxymethylfurfural (HMF) Content

HMF contents of the vacuum impregnation solutions and the quince samples were determined using LC (Gunel et al., 2018). HMF amounts were calculated using external standards. Chromatographic separation was carried out on a solvent delivery system (20AD, Shimadzu, Japan) with an autosampler (SIL-20A Prominence, Shimadzu, Japan), column (C18 column, five µm, 25 × 0.4 cm), maintained at 32°C in a column oven (CTO-20AC, Shimadzu, Japan). SPD-M20A Diode Array Detector (Shimadzu, Japan) was used to detect individual peaks. Acetonitrile in water (5% v/v, isocratic) was used as a mobile phase at a 1 mL/min flow rate. Sample aliquots of 20 µL were injected into the column, and the separated peaks were monitored at 280 nm.

The limit of detection (LOD), the limit of quantification (LOQ), the calibration curve, and the coefficients of regression (R^2) values of the HMF were calculated as 0.44, 1.35, y=180222x+21000 and 0.9999, respectively.

Ascorbic Acid Content (AAC)

The ascorbic acid content of the vacuum impregnation solutions and the quince samples was determined chromatographically after the dissolution of the samples in a 4.5% meta-phosphoric acid solution (Tontul et al., 2018). Then, 0.45 µm Nylon filters (Sartorius, Goettingen, Germany) were used to filter the mix, and 20 µl of supernatant was injected into the HPLC system (Shimadzu, Japan). The flow rate of the mobile phase ultra-pure water acidified to pH 2.2 with H_2SO_4 was 0.8 ml/min. ALiChroSpher column (250 mm × 4.6 mm, 5 µm) was used for separation at 40°C. A diode array detector was used for detection at 245 nm for 15 minutes. Ascorbic acid content was calculated using external standards. The ascorbic acid content of the vacuum impregnation solutions and quince samples were calculated as g/kg dry matter.

Colour Analysis (Hunter Lab)

Colour values of the samples were determined by using Chroma Meter CR-400 (Konica-Minolta Sensing Inc., Osaka, Japan) and expressed as Hunter *L* [(0) dark - (100) light], *a* [(+) red – (-) green] and *b* [(+) yellow – (-) blue] (Gunel et al., 2018).

Browning Index (BI)

Browning index values of the samples were determined according to the literature method (Gunel et al., 2018). For this purpose, the quince samples were homogenized in distilled water (1:20). Absorbance was measured at 420 nm by using a Shimadzu Spectrophotometer UV-1800 (Nakagyō-ku, Kyoto, Japan), chromatographically.

Sensory Analysis

The quince samples (vacuum-impregnated and control samples) were evaluated by 15 panellists previously informed about the sensory panel, quince, vacuum impregnation, and solutions. The samples were presented on a white plate and scored in terms of their sensory properties (colour, appearance, acidity, sweetness, flavour, texture, and global preference) on a hedonic scale, including points from 1 (very bad) to 9 (very good) (Barat et al., 2002).

Before the sensory analysis started, the samples dried with different drying methods (hot air, microwave, and osmotic) were tasted by the same panellists, and preliminary sensory analysis was performed. The sample that the panellists liked most in all criteria was the sample dried with microwave. Then, sensory analysis was made again and tried to determine the most preferred solution (honey or rosehip) and concentration (5, 10 or 20%) in microwave drying. Therefore, the results to be discussed under the sensory analysis title will be given for microwave-dried samples. In addition, both control and microwave-dried samples were served to panellists immediately after production to prevent possible browning that could change the panellists' minds.

Statistical Analysis

The vacuum impregnation experiments were conducted in two replicates and analyses were performed in duplicate. Results obtained in the present study and the main sources of variation were subjected to variance analysis and Duncan Multiple Comparison Test (SAS system for Windows V7, SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

Moisture Content, Water Activity and pH

According to moisture content analysis results (Table 1), the moisture content of quince fruit, having approx. 82% initial moisture content, was reduced by vacuum impregnation and drying treatments. Impregnation solutions, both honey and rosehip, affected significantly (p<0.01) the moisture content of the quince fruit. Similarly, drying processes affected the samples' moisture content significantly (p<0.05). According to the results, the moisture content of the quince samples applied with vacuum impregnation decreased to approximately 15% in all drying methods.

Table 1. Effects of drying type and impregnation solutions on the moisture content, a_w and pH values of the samples

Drying type	Moisture content (%)	a_w	pH
Microwave	$16.02^a \pm 0.52$	$0.5055^a \pm 0.0002$	$3.50^a \pm 0.04$
Hot air	$14.60^c \pm 1.09$	$0.4722^c \pm 0.0010$	$3.01^b \pm 0.11$
Osmotic	$15.08^b \pm 0.74$	$0.4964^b \pm 0.0007$	$3.46^a \pm 0.02$
Significance level	*	*	*
Impregnation solutions			
5% Honey	$80.09^a \pm 2.16$	$0.9610^a \pm 0.0004$	$3.63^a \pm 0.00$
10% Honey	$72.06^b \pm 1.17$	$0.9554^a \pm 0.0000$	$3.99^a \pm 0.02$
20% Honey	$65.48^c \pm 1.26$	$0.9412^a \pm 0.0003$	$4.03^a \pm 0.04$
Significance level	**	-	-
5% Rosehip	$81.56^a \pm 1.52$	$0.9651^a \pm 0.0001$	$3.56^a \pm 0.04$
10% Rosehip	$76.02^b \pm 1.21$	$0.9581^a \pm 0.0002$	$3.62^a \pm 0.02$
20% Rosehip	$70.23^c \pm 1.04$	$0.9512^a \pm 0.0008$	$3.73^a \pm 0.03$
Significance level	**	-	-
Control (Fresh)	82.13 ± 2.35	0.9691 ± 0.0006	3.52 ± 0.02
Control (SI)	81.09 ± 1.29	0.9685 ± 0.0002	3.67 ± 0.07

** P<0.01; *P<0.05 BI: Browning index, SI: Simple immersed

Since the initial moisture contents of the honey (approx. 15%) and rosehip (approx. 45%) used in the present study were lower than the quince fruit (approx. 82%), it is thought that the moisture content of the samples decreased with vacuum impregnation treatment. It is also believed that the moisture content decreased proportionally with the air exchange in the fruit pores by vacuum impregnation. The literature has already stated that vacuum impregnation is a pre-treatment used before the final drying stage to achieve two critical goals. These goals are stated as reducing the moisture content before final drying for energy saving and increasing the physicochemical properties of the final product with impregnation solutions (Zhao and Xie, 2004; Barat et al., 2001). In the present study, these goals stated in the literature were achieved, and the moisture content of the product was reduced before the final drying.

A slight decrease in the pH values of the samples was observed at all drying types. Drying processes affected the samples' pH values significantly

($p<0.05$). The lowest pH value (3.01±0.11) was determined by hot air drying, while the highest pH value (3.50±0.04) was determined by microwave drying. Some acidic chemical compounds formed during drying as a result of the Maillard reaction may have caused a decrease in the pH values of the samples (Gunel et al., 2018).

Antioxidant Activity

In the present study, the antioxidant activity of the control samples increased both vacuum impregnation treatment and drying processes. Impregnation solutions and drying methods affected significantly ($p<0.01$) the antioxidant activity of the control samples (Table 2). Antioxidant activity values of 1.90±0.08 g/mg DPPH in control samples increased to 1.67±0.05g/mg DPPH on average with vacuum impregnation and drying processes. The quinces' uptake of honey and rosehip solutions and their antioxidant compounds (e.g., flavonoids, citric acid) may account for this result.

Table 2. Effects of drying type and impregnation solutions on some chemical properties of quince fruit

Drying type	TPC (mg/100 g)	AA (g/mg DPPH)	HMF (mg/kg)	AAC (mg/100 g)
Microwave	56.52[c] ± 0.52	1.72[a] ± 0.02	1.26[b]± 0.02	55.56[b] ± 1.56
Hot air	77.64[a] ± 2.49	1.52[c] ± 0.02	16.56[a]± 1.14	32.51[c] ± 1.13
Osmotic	61.48[b] ± 2.74	1.64[b] ± 0.07	3.56[b]± 0.08	40.49[a] ± 1.98
Significance level	**	**	*	**
Impregnation solutions				
5% Honey	53.09[c] ± 2.13	1.76[a] ± 0.97	11.13[c] ± 0.59	30.13[c] ± 0.99
10% Honey	59.56[b] ± 1.19	1.69[b]± 0.03	15.56[b] ± 1.02	38.56[b] ± 0.17
20% Honey	69.48[a] ± 1.11	1.60[c] ± 0.05	19.26[a] ± 1.06	43.49[a]± 1.19
Significance level	**	**	**	**
5% Rosehip	50.42[c] ± 0.92	1.78[a] ± 0.01	<LOD[b]	49.56[c] ± 1.98
10% Rosehip	58.02[b] ± 1.33	1.71[b] ± 0.05	<LOD[b]	52.59[b] ± 1.75
20% Rosehip	63.22[a] ± 1.14	1.62[c] ± 0.08	1.43[a]± 0.03	60.63[a] ± 2.02
Significance level	**	**	*	**
Control (Fresh)	25.10± 0.15	1.98 ± 0.06	<LOD	17.80 ± 1.12
Control (SI)	27.02 ± 0.29	1.82 ± 0.02	<LOD	19.13 ± 1.15

** $P<0.01$; *$P<0.05$ TPC: Total phenolic content, AA: Antioxidant activity, AAC: Ascorbic acid content, SI: Simple immersed, LOD: Limit of Detection

Similar studies in the literature emphasized that the antioxidant activities of control samples were increased with vacuum impregnation. In one of these studies, it was reported that the antioxidant activity of the chokeberry fruit enriched with apple-pear juice increased by vacuum impregnation compared to its fresh state (Nawirska-Olszańska et al., 2020). In another study, it was reported that apple fruit was enriched with blueberry juice, and the final product's antioxidant activity was higher than the control sample (Castagnini et al., 2015).

Total Phenolic Content

The total phenolic contents of the samples were approximately doubled by both impregnation and drying processes (Table 2). The total phenolic content value, determined as 25.10±0.15 mg/100g in the control sample, was measured as 27.02±0.29 mg/100g in the samples kept in impregnation solutions without impregnation. The total phenolic content of the impregnated samples was determined as 58.96±11.13 g/100g on average. The highest values of the total phenolic content were calculated as 77.64±2.49g/100g for hot air drying. The lowest value of the total phenolic content was determined as 56.52±0.52g/100g for microwave drying. Both impregnation solutions and drying processes significantly (p<0.01) affected the total phenolic content of the samples.

Many studies have reported that phenolic compounds are reduced due to leakage into the impregnation solution (Blanda et al., 2008; Radziejewska-Kubzdela et al., 2014). It has been reported that reducing phenolic content in vacuum impregnation treatment may result from osmotic dehydration of the plant tissue. In the literature, researchers have reported that another method, such as drying and/or ultrasound reinforcement, should be applied to reduce or stop this loss (Radziejewska-Kubzdela et al., 2014). However, in the present study, it was observed that the total phenolic content of quince samples increased with vacuum impregnation treatment. An increase in total phenolic content may result from the vacuum impregnation setup reinforced by an ultrasonic bath. In addition, it was also thought that since the vacuum-impregnated samples were dried, the total phenolic content of the samples increased.

In similar studies in the literature, it was reported that the phenolic content of the samples increased with vacuum impregnation reinforced by an ultrasonic bath. A study reported that the vacuum impregnation technique increased the total phenolic content of the mango fruit impregnated with grape residues. The same study stated that the vacuum impregnation setup was reinforced by an ultrasonic bath (de Medeiros et al., 2019).

In another study, black carrot concentrates were impregnated into apple samples. It was noted that there was a significant decrease in the total phenolic contents of the samples impregnated with a solution that were not contain black carrot concentrate. However, the researchers reported that as the concentration of black carrot concentrate in the impregnation solution increased, the total phenolic contents of the samples increased (Yılmaz and Ersus Bilek, 2017).

5-hydroxymethylfurfural (HMF) Content

HMF, one of the Maillard reaction products, causes non-enzymatic colour changes in the final product depending on the pH, type of reactants, water activity, and temperature. HMF is a primary Maillard reaction product (Gunel et al., 2019). HMF measurement is used to evaluate the quality of honey. HMF is not usually found in fresh honey and increases during storage. HMF is formed during the acid-catalyzed dehydration of hexoses. The amount of HMF in honey is linked to its chemical properties, such as pH, total acidity, and mineral content (Zappala et al., 2005).

HMF amount of the honey sample used in the present study was calculated as 23.12±1.06 mg/kg on average. According to the Turkish Food Codex Honey Communiqué, it was stated that the HMF amount in honey should be at most 40 mg/kg, and honey above this value should not be consumed (Can et al., 2015). According to Honey Communiqué, it was observed that there was no harm in the consumption of honey used in the present study.

According to HMF analysis results (Table 2), it was determined that there was no HMF in control samples, both fresh and simple immersed. In both samples, the amount of HMF was calculated below the LOD value. Like the control samples, the amount of HMF in rosehip solutions (5 and 10%) was calculated below the LOD value. However, HMF amounts of quince samples impregnated with honey solutions increased depending on the honey concentration and were calculated as 15.32±3.56 mg/kg, on average. Honey concentrations in impregnation solution affected significantly (p<0.01) the HMF content of the quince samples. In addition, drying also affected significantly (p<0.05) HMF content. As expected, the highest HMF amount was determined as 16.56±1.14 mg/kg for hot air drying, while the lowest HMF amount (1.26±0.02 mg/kg) was determined for microwave drying.

In foods, HMF can be formed in different ways, such as dehydration of hexoses or caramelization. Previous studies have shown that HMF can easily be formed in foods with high sugar, like honey (Durmaz and Gökmen, 2010).

In the literature, no study was found to determine the amount of HMF content of the final products after vacuum impregnation treatment. The only research similar to the present study was carried out by Jeon and Zhao (2005). In the study, fresh-cut apple slices were vacuum-impregnated with a honey solution. However, HMF amounts of honey samples were determined while HMF analysis was not performed in impregnated apple samples. Therefore, according to the results of the present study, it was determined that the amount of HMF can increase with the vacuum impregnation process depending on whether the impregnation solution and/or control sample contains HMF. In this case, HMF can also be transferred from the impregnation solution to the sample with the vacuum impregnation process.

Ascorbic Acid Content

Ascorbic acid (Vitamin C), as is known, protects phenolic compounds from oxidation. It even reduces quinone to phenols (Zeraatgar et al., 2008; Zhang et al., 2019). Ascorbic acid is a nutrient and important antioxidant component in quince fruits and is known as a reducing and chelating agent to scavenge free radicals. The ascorbic acid content of the quince fruit used in the present study was calculated as 18.50±0.98 mg/100g, which is compatible with the previous studies (Ahmad et al., 2008; Sharma et al., 2011). In addition, the ascorbic acid content of honey and rosehip used in the present study was calculated as 5.39±2.02 and 65.56±3.85 mg/100g, respectively.

According to the results, the ascorbic acid content of the fresh quince sample increased with vacuum impregnation treatment (Table 2). Impregnation solutions, both honey and rosehip, affected significantly ($p<0.01$) the ascorbic acid content of the control samples. Drying type also affected significantly ($p<0.01$) the vitamin C content of the control samples.

Since the initial ascorbic acid content of the rosehip solution was high, the vitamin C content of the quince samples impregnated with the rosehip solution was higher than that of the honey solution. Besides, while the highest ascorbic acid amount was determined in microwave drying, the lowest ascorbic acid amount was determined in hot air drying as expected. Ascorbic acid degradation by hot air drying has also been reported in the literature (Nicoleti et al., 2007). The decrease in ascorbic acid content in osmotic drying is also thought to be due to the transition of ascorbic acid to the osmotic solution. As a matter of fact, it has been reported in the literature that osmotic pre-treatment can reduce the amount of ascorbic acid (Marfil et al., 2008).

In a study in the literature in which potato tubers were impregnated with an ascorbic acid solution, it was reported that the ascorbic acid content of the control samples increased, similar to the results of the present study (Hironaka et al., 2011). Obtained results from the present study indicated that vacuum impregnation treatment could reduce oxidation and effectively inhibit the decomposition of quince's ascorbic acid. It was determined that the vacuum impregnation process could increase the ascorbic acid content of quince, and browning could be slowed down/stopped indirectly.

Colour Properties and Browning Index (BI)

In the present study, to determine the effect of the vacuum impregnation process on the colour change in quince fruit accurately, vacuum-impregnated quince slices and quince slices without any treatment were kept for the same time (30 min) and under the same conditions (25 °C). Colour measurement results were taken in the 1st and 30th minutes.

According to the results, impregnation solutions affected significantly ($p<0.01$) Hunter L values of quince samples (Table 3). Drying type affected also significantly ($p<0.05$) Hunter L values of the samples. According to the measurements taken in the 1st minute, the L value determined as 66.06±2.19 in the control sample seems to have decreased with the vacuum impregnation process. Still, the decrease in the L value in the control sample after 30 minutes was more than in the impregnated samples. The decrease in L value in the control sample at the end of 30 minutes was approximately 40.76%, while it was about 0.76% in the vacuum-impregnated samples. Hence, it has been observed that honey with high antioxidant content effectively prevents the browning of quince's colour. As a matter of fact, Chen et al. (2000) stated that the effectiveness of honey in reducing browning is due to its antioxidant content. Likewise, Jeon and Zhao (2005) noted that honey prevents discolouration in apples due to its high antioxidant activity. The reason why rosehip solutions preserved the colour of quince samples was thought to be that rosehip has high ascorbic acid and antioxidant activity (PaunoviĆ et al., 2019).

Although keeping the control sample in honey and rosehip solutions by simple immersion partially prevented the browning of colour, it was predicted that darkening may continue after a long waiting period (Table 3). The vacuum impregnation process helps induce honey and rosehip into the pores of the fruit tissue and is more effective than simple immersion in preventing browning. A similar result was reported by Jeon and Zhao (2005), and it was noted that vacuum impregnation was more effective in preventing apple fruit colour than simple immersion in a honey solution.

Table 3. Colour properties of quince samples

	1st minute			
Drying type	Hunter *L*	Hunter *a*	Hunter *b*	BI
Microwave	63.52^{a} ± 1.82	10.02^{a} ± 0.12	16.36^{a} ± 1.22	21.01^{c} ± 1.02
Hot air	41.44^{b} ± 2.09	23.54^{c} ± 0.19	8.56^{b} ± 1.03	29.46^{a} ± 0.07
Osmotic	61.26^{a} ± 1.14	11.04^{b} ± 0.03	15.42^{a} ± 1.08	26.40^{b} ± 0.98
Significance level	*	**	*	**
Impregnation solutions				
5% Honey	60.56^{a} ± 2.22	-1.46^{c} ± 0.03	16.53^{a} ± 0.29	21.09^{a} ± 0.19
10% Honey	52.58^{b} ± 2.19	-1.00^{b} ± 0.00	12.41^{b} ± 1.00	24.42^{b} ± 0.78
20% Honey	47.08^{c} ± 1.17	0.02^{a} ± 0.00	9.01^{c} ± 0.07	28.69^{c} ± 0.99
Significance level	**	**	**	**
5% Rosehip	62.56^{a} ± 2.14	11.08^{c} ± 0.51	19.56^{a} ± 1.11	24.03^{a} ± 1.18
10% Rosehip	57.12^{b} ± 0.33	18.01^{b} ± 0.49	20.21^{a} ± 0.98	26.41^{b} ± 0.75
20% Rosehip	51.03^{c} ± 2.04	22.44^{a} ± 1.18	19.99^{a} ± 0.23	28.76^{c} ± 1.02
Significance level	**	**	-	**
Control (Fresh)	66.06 ± 2.19	-4.03 ± 0.00	20.06 ± 0.88	16.80 ± 1.12
Control (SI)	61.52 ± 1.17	-2.12 ± 0.01	18.52 ± 0.72	19.13 ± 1.15
	30th minutes			
Drying type	Hunter *L*	Hunter *a*	Hunter *b*	BI
Microwave	60.42^{a} ± 1.02	12.14^{a} ± 0.02	15.06^{a} ± 0.29	23.04^{c} ± 1.00
Hot air	39.38^{b} ± 1.49	24.41^{c} ± 0.11	7.99^{b} ± 0.04	31.03^{a} ± 0.02
Osmotic	58.22^{a} ± 1.01	13.06^{b} ± 0.11	14.92^{a} ± 0.13	28.40^{b} ± 0.98
Significance level	*	**	*	**
Impregnation solutions				
5% Honey	60.42^{a} ± 1.21	-0.06^{c} ± 0.00	15.03^{a} ± 0.17	22.00^{a} ± 0.11
10% Honey	51.50^{b} ± 2.03	0.14^{b} ± 0.01	11.06^{b} ± 0.00	25.56^{b} ± 0.21
20% Honey	46.12^{c} ± 0.17	1.16^{a} ± 0.03	8.04^{c} ± 0.02	29.06^{c} ± 0.09

Significance level	**	**	**	**
5% Rosehip	60.96[a] ± 0.14	13.00[c] ± 0.05	18.22[a] ± 0.11	25.13[a] ± 1.02
10% Rosehip	55.02[b] ± 1.30	19.13[b] ± 0.11	19.91[a] ± 0.09	27.99[b] ± 0.05
20% Rosehip	49.09[c] ± 1.14	23.04[a] ± 0.18	18.96[a] ± 0.04	30.13[c] ± 1.00
Significance level	**	**	-	**
Control (Fresh)	39.13 ± 1.21	-2.01 ± 0.02	19.56 ± 0.21	35.66 ± 1.10
Control (SI)	44.58 ± 0.17	-0.14 ± 0.00	16.52 ± 0.02	32.33 ± 0.15

** $P<0.01$; *$P<0.05$ BI: Browning index, SI: Simple immersed

Browning is mainly caused by the reaction of polyphenol oxidase and polyphenols and is known as a key quality attribute for consumer acceptance of fresh-cut quince slices. It generally resulted in the formation of melanins (brown colour) (Lin et al., 2006; Rößle et al., 2011). The browning index value is known as an indicator of browning formation in the final stage of the browning reaction (Şahin et al., 2009; Gunel et al., 2018). In the present study, BI values of the quince fruit were significantly ($p<0.01$) influenced by both impregnation solutions and drying type (Table 3). At the end of the 30th minute, it was observed that the BI values of the samples were also significantly ($p<0.01$) affected by both impregnation solutions and drying types.

Similar to the *L* values of the samples, according to the measurements taken in the 1st minute, the BI value of the control sample seems to have increased with the vacuum impregnation process, but the increase in the BI value in the control sample after 30 minutes was more than the impregnated samples. The increase in BI value in the control sample at the end of 30 minutes was approximately 112.26%, while it was about 4.31% in the vacuum-impregnated samples. The results showed that vacuum impregnation with honey and rosehip solutions slowed/stopped the browning index of quince. Many researchers have reported similar results (Lin et al., 2006; Rößle et al., 2011). It has been reported in the literature that phenolic compounds in honey inactivate reactive oxygen. Therefore, it has its own antioxidant activity. It has also been reported that the enzymes in honey act as antioxidants by promoting the removal of oxygen (Lin et al., 2006).

It was observed that vacuum impregnation was more effective than the simple immersion method in the samples' BI and Hunter *L* values. Lin et al., (2006) and Rößle et al., (2011) reported similar results for BI values of fresh-cut apples. The porous microstructure of food can be impregnated with honey or other nutraceuticals using vacuum impregnation. Thus, the air is removed from the pores of the fruit by vacuum impregnation, and the impregnation of honey is promoted into the pores. Finally, impregnating honey into the pores of quince slices is more preventive for browning than simple immersion.

Sensory Properties

Sensory evaluation is one of the most critical stages of product development. Few studies in the literature evaluated the sensory qualities of quince-developed physicochemical and sensory properties with different technologies.

Sensory properties of the vacuum-impregnated and microwave-dried quince fruit are given in Figure 2. According to the results, the sensorial properties of the quince fruit were significantly ($p<0.01$) influenced by impregnation solutions. In addition, all vacuum-impregnated quince fruits had significantly higher ($p<0.05$) consumer acceptability ratings on appearance, colour, acidity, flavour, texture, odour, and global preference than the control samples.

The average appearance points of the control samples were calculated as 7.00±0.50. Appearance points of the samples impregnated with honey solution increased, while those impregnated with rosehip solution decreased. The sample impregnated with 20% honey solution got the maximum appearance point at 9 points.

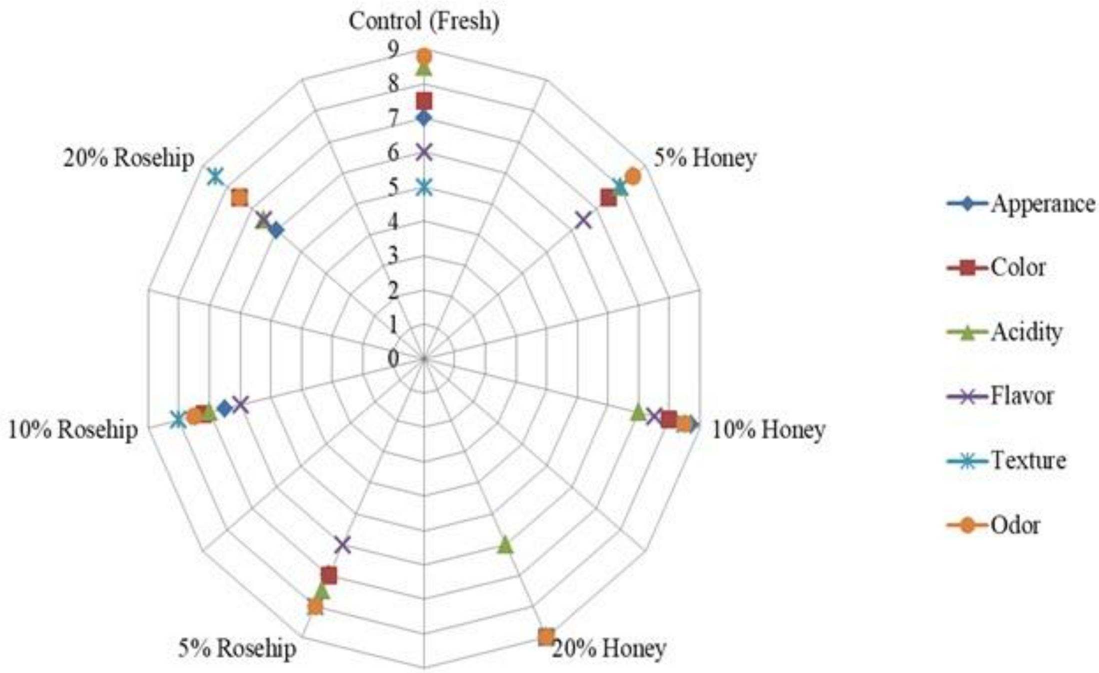

Figure 2. Sensorial properties of the vacuum impregnated quince fruit

According to the colour properties, the control sample got 7.50±0.00 points for colour, while the sample impregnated with 20% honey solution scored 9.00±0.00 points (the maximum) for colour. In addition, it was observed that the use of rosehip solution in vacuum impregnation reduced the colour values of the samples. The colour values of the samples impregnated with rosehip solution decreased to 6 points.

The acidity points of the control sample were calculated as 8.50±0.50 on average. In contrast, the acidity points of the samples impregnated with honey and rosehip solutions decreased compared to the control sample. The sample impregnated with 20% honey solution got the minimum acidity point. Due to the sweetness of the honey solution, it was thought that the specific sourness/acidity of the quince fruit was suppressed. Thus, the panellists' favourite sample in terms of acidity was the sample impregnated with 20% honey solution.

According to the taste scores, the control sample got approx. 6.00±0.50 points from panellists. While vacuum impregnation with honey solution increased the taste points of the samples, impregnation with rosehip solution did not affect the taste points of the samples. The taste scores of the samples impregnated with rosehip solution were calculated like the control sample. The sample impregnated with 20% honey solution had the highest taste points.

Textural properties of the control sample got 5.00±0.50 points from panellists, while those of impregnated samples with both honey and rosehip solution had higher texture points than the control sample. All panellists stated that the impregnated samples had better mouth feel and chewiness than the control sample. The maximum point was calculated for the sample impregnated with 20% honey solution.

According to the odour scores, the control sample had 8.70±0.30 odour points. Samples impregnated with honey solution got almost the same score as the control sample, while samples impregnated with rosehip solution got lower odour scores than the control sample. The highest odour score was determined for the sample impregnated with 20% honey solution.

The panellists were asked to indicate their global preference for the samples. According to the global preference results, the control sample received the lowest score, samples impregnated with rosehip solution ranked second, and samples impregnated with honey solution ranked first. When asked which product they would prefer to buy, all 15 panellists stated the sample impregnated with 20% honey solution. The same sample was preferred in both repetitions of sensory analyses.

Studies on the subject have reported that vacuum impregnation technique increases the sensory properties of fruits and vegetables (Radziejewska-Kubzdela et al., 2014). In a study where fresh-cut apples were vacuum-impregnated with different solutions, it was reported that the sensory properties of the impregnated samples compared to the control sample were improved. It was also stated that the impregnated samples received consumer acceptance (Park et al., 2005). In another study made with apple fruit, it was reported that the vacuum impregnation technique improved the sensory properties of apples, and the impregnated apple was liked by consumers (Joshi et al., 2010).

In a study in which fresh-cut pear fruit was impregnated with honey solution, sensory analyses were carried out on the obtained products, and a comparison was made with control samples. According to the analysis results, the impregnated samples got higher scores than the control samples in all sensory properties. In addition, panellists gave their maximum global preference points for impregnated samples rather than the control sample (Lin et al., 2006).

In a study examining the sensory properties of pineapple fruits impregnated with sucrose solution by vacuum impregnation process, it was stated that vacuum impregnation improved the sensory properties of pineapple fruit. According to the sensory analysis results, the impregnated samples got the maximum global preference points from the panellists (Barat et al., 2002).

CONCLUSION

Due to its physicochemical properties, quince fruit, which is exposed to enzymatic browning quickly, has been vacuum-impregnated with honey and rosehip solutions. Also, quince consumption is limited due to its hardness, acidity, and astringency. The vacuum impregnation technique to process quince fruit limits enzymatic browning while increasing total phenolic content, antioxidant activity, and ascorbic acid content. It has been also observed that the sensory properties and consumer liking of the quince increase with the vacuum impregnation technique. Considering the consumer liking, drying the vacuum-impregnated quince with microwave has been deemed appropriate. It has been observed that microwave drying both shortens the process time and limits the formation of HMF. When the properties of the quince fruit impregnated by vacuum are examined, it can be observed that impregnation of quince with honey solution, rather than rosehip solution, increases its sensory properties as well as its physicochemical properties. Moreover, it has been observed that the enzymatic browning of the quince fruit impregnated with honey solution is limited. As a result, the vacuum impregnation technique can eliminate some problems that limit quince fruit consumption and processing.

DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest.

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