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EFFECT OF DIFFERENT DRYING TECHNIQUES ON THE BIOACTIVE, COLOR, ANTIBACTERIAL AND SENSORY FEATURES OF DATE PLUM FRUITS (*DIOSPYROS LOTUS* L.)

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ABSTRACT
In this study, the effects of hot air drying (HD), vacuum drying (VD) and freeze drying (FD) processes on total phenolic (TPC) and flavonoid contents (TFC), antioxidant capacity (AC), color and antibacterial properties and sensory evaluation of date plum (DP) fruit were determined. Total phenolic, total flavonoid and antioxidant capacity values of dried and fresh samples were determined as 13.86-7.45 mg GAE/g, 7.17-4.09 mg CE/g and 86.60-54.98%, respectively. The highest inhibition levels against *Bacillus cereus* (24.50 mm) and *Salmonella* Typhimurium (24.67 mm), *Yersinia enterocolitica* (25.75 mm) and *Staphylococcus aureus* (25.17 mm) were determined for HD and VD, respectively. In terms of sensory evaluation, FD drying was scored similarly to fresh samples (P>0.05). Overall, FD drying could be applied for longer preservation of DP fruits in terms of bioactive properties, color and sensory evaluation.
Keywords: Date plum, drying techniques, bioactive properties, antibacterial properties, sensory evaluation

FARKLI KURUTMA TEKNİKLERİNİN HURMA ERİĞİ MEYVELERİNİN (*DIOSPYROS LOTUS* L.) BİYOAKTİF, RENK, ANTİBAKTERİYEL VE DUYUSAL ÖZELLİKLERİ ÜZERİNE ETKİSİ

ÖZ
Bu çalışmada sıcak havayla kurutma, vakumla kurutma ve dondurarak kurutma işlemlerinin hurma eriği meyvesinin toplam fenolik ve flavonoid içerikleri, antioksidan kapasitesi, renk ve antibakteriyel özellikler üzerine etkileri ve duyusal değerlendirmesi belirlenmiştir. Kurutulmuş ve taze örneklerin toplam fenolik, toplam flavonoid ve antioksidan kapasitesi değerleri sırasıyla 13.86-7.45 mg GAE/g, 7.17-4.09 mg CE/g ve %86.60-54.98 olarak tespit edilmiştir. *Bacillus cereus* (24.50 mm) ve *Salmonella* Typhimurium (24.67 mm) için en yüksek inhibisyon seviyesi sıcak havayla kurutulmuş örneklerden elde edilen ekstraktlarda, *Yersinia enterocolitica* (25.75 mm) ve *Staphaylococcus aureus* (25.17 mm) için ise vakum kurutma ile kurutulmuş örneklerden elde edilen ekstraktlarda en yüksek inhibisyon seviyeleri belirlenmiştir. Duyusal değerlendirme açısından dondurarak kurutma taze numunelere benzer şekilde puanlanmıştır (P>0.05). Bu çalışmadan elde edilen bulgular biyoaktif özellikler, renk ve duyusal değerlendirme açısından hurma eriği meyvelerinin daha uzun süre korunması için dondurarak kurutmanın uygulanabileceğini göstermiştir.
Anahtar kelimeler: Hurma eriği, kurutma teknikleri, biyoaktif özellikler, antibakteriyel özellikler, duyusal değerlendirme

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INTRODUCTION

The date plum (*Diospyros lotus* L.), a member of the *Ebenaceae* family, is native to the Asian continent and is grown in various countries (Hassan et al., 2022). Ripe DP fruits are collected for their eatable, nourishing and therapeutic features (Hassan et al., 2022). DP fruits offer some useful effects on human health such as antidiabetic, antiseptic, antidiarrhea, dry cough suppressant and blood pressure regulator (Uddin et al., 2014). Also, in alternative Chinese medicine, DP fruits are used to as antifebrile and for becoming calming (Gao et al., 2014). The aforementioned healthy features of the DP are due to its phenolic substances including some hydroxybenzoic acids, hydroxycinnamic acids and flavanoids. (Gao et al., 2014; Ayaz et al., 1997). It is necessary to increase the storage time of DP fruits in order to offer stated health benefits by using preservation techniques.

Date plum is seasonal fruit and inherently exposed and quickly to biological, biochemical and microbiological alterations (Hassan et al., 2022). Therefore, the most basic method could be used to reduce the water content of the date plum in order to prevent stated alterations is the application of drying techniques. Different drying processes like hot air drying, vacuum drying and freeze drying have been applied for the preservation of fruits and vegetables (Kayacan et al., 2020; Goztepe et al., 2022; Argyropoulos et al., 2011). Each drying technique has its own advantages and disadvantages. For example; HD is the most preferred method for its low cost and simply uses, on the other hand, FD is not much choosed because it is a long and high cost method and not easy to apply (Wojdyło et al., 2016; Kayacan et al., 2020). Although HD may cause some undesired conditions such as corruption of secondary metabolites and loss of nutritional and sensorial characteristics, FD is considered the best drying process as it preserves the nutritional and visual features of foods (Wojdyło et al., 2016; Kayacan et al., 2020). Water in foods can be evaporated by VD at lower temperatures, and also it raises drying rate by speeding up water transfer (Başlar et al., 2015). However, if the food has a high water content, higher temperatures will be required for VD to dry the inner part (Tekin et al., 2017). Thus, the effects of varied drying processes on the bioactive and color features and sensory evaluation of foods should be determined, and drying technique alternatives specific to each food should be created.

In the last two decades, interest in drying methods has increased in order to improve the final product quality of seasonal and perishable products and to obtain longer shelf life (Petikirige et al., 2022). Studies about drying have substantially focused on drying kinetics, modelling, positive effect on health and physiochemical features of dried products. However, limited number of studies has been carried out to understand between sensory quality and different drying techniques (Petikirige et al., 2022). With this study, the effects of HD, VD and FD processes on the bioactive features, color properties and sensory evaluation of DP fruits were investigated. In addition, the antibacterial effects of the extracts obtained from different drying techniques on some pathogenic bacteria were determined.

MATERIALS AND METHODS

Materials

DP fruits were harvested from Erzurum, Turkey. For analysis and drying, DP fruits of similar elliptical or round shape (approximately 4-5 cm in size), ripe and of similar colour were selected and stored at 4 °C until different drying techniques were applied. For analyzes Merck (Darmstad, Germany) chemical products were used.

Applying Different Drying Techniques

Three different techniques, (HD, VD and FD), were applied to dry to DP fruits and results were compared to fresh DP fruits. Before drying, DP fruits were divided into two equal slices with a knife and approximately 9- 11 grams of fruits were placed in tared porcelain cups. HD (Mikrotest, MST-55, Turkey) and VD (JP Selecta, Vaciotem-T, Spain) were applied at 55 °C air temperatures. The evaporated water (%) for HD and VD drying techniques was calculated based on moisture loss (%) during drying process at 4-hour intervals with using the following formula.

The drying process was applied to DP fruit samples for HD and VD techniques until the total moisture content was reached at 20%, and total moisture content of the samples were determined by equation below. However, the FD was carried out according to the standard fruit drying program installed in the freeze dryer (Christ, Alpha 1-2 LDplus, Germany) at −55 °C and 0.054 mbar for 72 h and at the end of the drying program, DP fruits were weighed to determine the moisture content of samples. The weight of DP fruit samples was recorded by a precision balance (Mettler Toledo, Switzerland). The drying processes were carried out in 4 different repetitions, and drying graphs were created by expressing the results in terms of average (±) standard error.

Moisture content (%)= $(M_2-M_1)/(M_2-M_3)*100$
Evaporated water (%) = Total moisture content (%)-Moisture content (%) at 4-hour intervals
M_1:tare of drying container
M_2:fresh DP fruit+drying container
M_3:dried DP fruit+drying container

Extraction Process of DP Fruits
Five grams of fresh and dried DP fruits were mixed with solvent methanol:water (1:1, v/v) at a ratio of 1:9 (solid material to solvent) and homogenized for 2 minutes with hand blender. Then, the mixtures were extracted by magnetic stirrer for 2 hours at room temperature. To obtain a clear supernatant, extracts were centrifuged (Hitachi, CF15RN, Japan) at 14,200 rpm for 15 minutes at 4 °C, filtered by a 0.45 µm filter and stored -18 °C until analyzes.

Total Phenolic Content
TPC of the DP fruits was determined according to Singleton and Rossi (1965). DP fruits extracts, Folin Ciocelteau's phenol reagent and sodium carbonate (%7.5, w/v) were mixed at volume of 0.5, 2.5 and 2 mL, respectively. The mixtures were stood at ambient temperature for 30 minutes, absorbance values were recorded at 765 nm (Genesys 10S UV-Vis, Thermo Scientific, USA). The results were presented in milligrams of gallic acid equivalent per/g (mg GAE/g).

Antioxidant Activity
A method was adopted described by Singh et al. (2002) to determine antioxidant activity of DP fruits. Briefly, 0.1 mM DPPH solution was prepared by methanol and 200 µL extract was mixed with 1.6 mL DPPH solution. After incubated for 20 min at ambient temperature in darkness place, absorbance values were recorded at 517 nm. Using following equation % antioxidant activity of DP fruits were determined:
% Antioxidant Activity = $(A_{blank}-A_{sample})/A_{blank}*100$
A_{blank}: Absorbance value of methanolic DPPH solution
A_{sample}: Absorbance value of DP fruit extracts

Total Flavonoid Content
TFC of DP fruits were determined by defined Zhishen et al. (1999) with some modifications. Briefly, 0.25 mL DP fruits extracts were mixed with 1.25 mL pure water, 0.075 mL sodium nitrite (%5), 0.150 mL aluminum chloride (%10) and 0.5 mL sodium hydroxide (1M) and 0.275 mL pure water added to mixture. Finally, absorbance values of the extracts were recorded at 415 nm. Results were given in mg catechin equivalent per/g (mg CE/g).

Color Parameters
Color parameters L* (brigthness), a* (red (+) to green (-)), b* (yellow (+) to blue (-)), C* (Chroma) and h° (hue angle) of DP fruits were determined with colorimeter (3nh NR200, Shenzhen, China). For color measurement, 4 different fresh and dried fruit samples were selected and measurements were carried out two different points of the outer shell of the samples. Results are given in mean (±) standard deviation.

Antibacterial Activity
Antibacterial activity of fresh and dried DP fruits on some pathogenic bacteria was determined according to the method described by Goktas et al. (2021). Firstly, DP fruit extracts were filtered by 0.22 µm to sterilize. Overnight bacteria of *Bacillus cereus* BC 6830, *Salmonella* Typhimurium RSSK 95091, *Staphylococcus aureus* ATC 25923 and *Yersinia enterocolitica* ATCC 27729 were inoculated in nutrient agar at 1% ratio and agars containing

pathogenic bacteria were poured into petri dishes. Then, agars were perforated using the number 2 cork borer and 150 µL of extract was placed in the holes. A methanol:water mixture was used as the control group. Finally, petri dishes were incubated for 24 h at 37°C and inhibition zones were measured. Antibacterial activity analysis was performed as three parallels of two replications for each pathogen, and the zones formed were expressed in mm.

Sensory Evaluation

Sensorial evaluation of dried DP fruits was actualized with 10 panelists who were informed about study (aim of the study, applied drying techniques were used, etc.) and requested to compared with fresh DP fruit. A 5-scale hedonic scale was prepared and the panelists were asked to evaluate the samples according to the parameters of color and appearance, odor, taste, chewiness (tissue crispness) and general acceptability. At last, scoring was done from 1 to 5 (very liked=5, liked=4, not bad=3, bad=2, very bad=1) (Mahjoorian et al., 2017). Sensorial evaluation protocol was reviewed and approved by the Istinye University Food Technology Department.

Statistical Analysis

Statistical differences between the samples were determined by using statistical programme of JMP software. Results were expressed as mean plus standard deviation of the replicates. Student't t test at 95% importance level was carried out to estimate the effect of varied drying processes and compared to fresh samples.

RESULTS AND DISCUSSION

Relationship Between Drying Technique, Moisture Content and Drying Time

The primary aim of drying techniques is to prevent of microbial growth and eliminate enzymatic changes by means of a decreasing in the moisture content and water activity and so to preserve the products for a long time (Alp and Bulantekin, 2021). For this, the total dry matter content of fresh date plums was determined for an effective drying. Total dry matter of fresh date plum products was calculated by taking the average of 5 independent parallels and it was determined that has an average of 51.27% dry matter. The drying processes (HD and VD) were applied until the total moisture content of the fresh date plum samples was reduced to approximately 20% (20.46±1.11 and 21.24±2.21 for HD and VD, respectively) and the results are shown in Figure 1. To obtain the expressed moisture content, 28 hours of drying time was applied for both HD and VD drying, but to obtain the desired moisture content for FD standard freeze drying procedure was applied until 72 h, and at the completion of the standard freeze-drying procedure, the moisture content reached a total of 20.74±2.04%. Different drying times have been reported for different fruits in the literature. Kayacan et al. (2020) reported that drying time for persimmon fruits as 4, 5 and 12 h for hot air drying (HAD), ultrasound assisted vacuum drying (UAVD) and infrared drying (IR), respectively. Also, for pomegranate arils these times were reported for HAD, VD and UAVD as 15.8, 10.8 and 8.5 h (Ozay-Arancioglu et al., 2021). However, compared to literature drying times, in our study, for HD and VD were similar. The difference in the required times for drying of fruits could be explained by differences in the water content or the amount of soluble substances of the fruits.

TPC, TFC, AC of DP Fruits

Total phenolic and flavonoid contents of the DP fruits are shown in the Figure 2. The TPC values were found 7.45±0.06, 10.09±0.12, 11.67±0.03 and 13.85±0.02 mg GAE/g for fresh, HD, VD and FD drying, respectively. The maximum TPC value was recorded for FD drying, followed by VD drying, but the lowest TPC value was detected in fresh samples. Drying methods affected the TPC results of the samples and increased compared to the fresh samples. Among the drying processes applied, the lowest TPC values were determined for HD drying. In addition, the statistical difference between TPC values of samples was found to be significant ($P \leq 0.05$). Similar findings have been cited in many studies on drying, and it has been stated that FD is the best drying method (Goztepe et al., 2022; Kayacan et al., 2020; Ozay-Arancioglu et al., 2021; Turkmen et al., 2020).

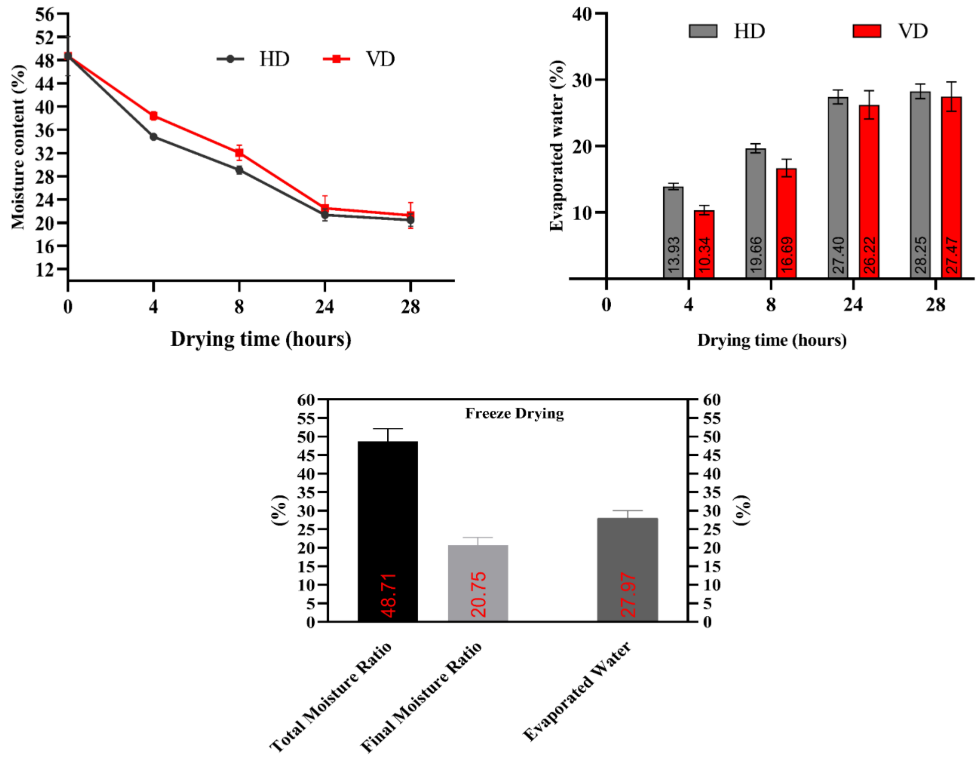
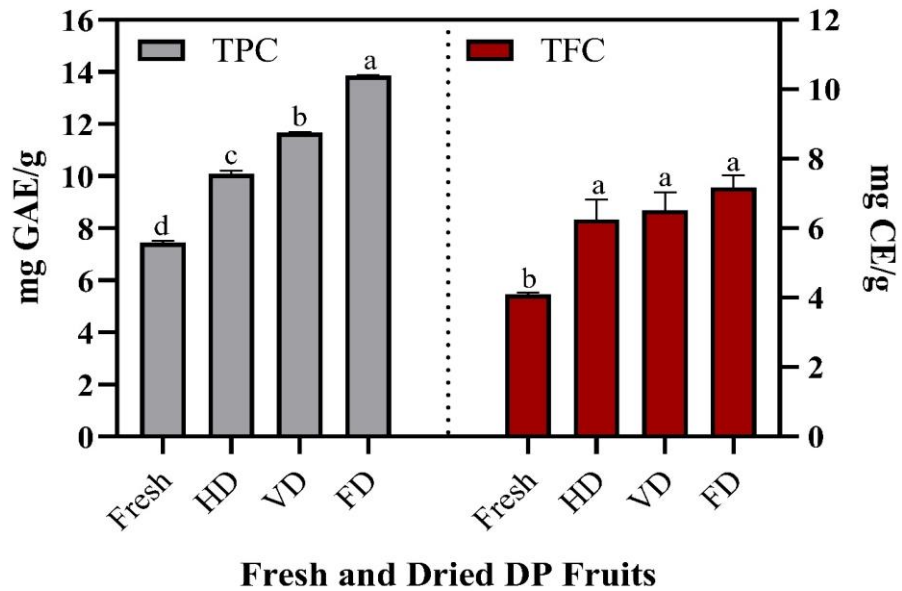


Figure 1. Total moisture content and evaporated water amount of dried DP fruits with different drying techniques

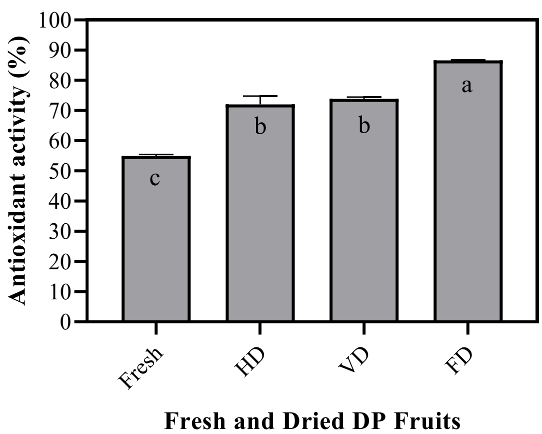


HD: Hot air drying, VD: Vacuum drying, FD: Freeze drying. Different letters show statistical difference ($P \leq 0.05$).

Figure 2. Total phenolic and flavonoid content of fresh and dried DP fruits

Similar results were found in TFC and these values of dried samples were greater than fresh DP fruit. Although the TFC findings of the dried samples were statistically different from the fresh sample ($P \leq 0.05$), there was no significant difference between the different drying techniques ($P > 0.05$).

The antioxidant capacity (AC, %) of the DP fruits were determined with DPPH radical scavenging ability and result were shown in the Figure 3. The AC values of fresh and dried DP fruits showed a similar tendency with TPC and TFC values. At the end of the drying treatment, the AC values increased compared to the fresh samples. The highest and lowest AC values were found for fresh and FD samples and were determined as 86.60±0.23 and 54.98±0.46, respectively. The AC values of the dried samples were significantly different compared to the control ($P \leq 0.05$), and FD significantly increased the AC value of the DP fruit. There was no statistical difference between AC values of HD and VD samples ($P > 0.05$).



HD: Hot air drying, VD: Vacuum drying, FD: Freeze drying. Different letters show statistical difference ($P \leq 0.05$).

Figure 3. Antioxidant activity (%) of fresh and dried DP fruits

Temperature is a crucial parameter affecting oxidation reactions. At freeze drying process, samples dried at low temperatures and vacuum conditions, however, during hot air drying and vacuum drying process samples dried at higher temperatures and times. As a result of the low temperature and vacuum application in FD, the samples are not exposed to thermal degradation and oxidation reactions, so phenolic compounds have been preserved and TPC values of the samples were found to be higher than other drying methods (Turkmen et al., 2020). Phenolic compounds are highly susceptible to heat and oxidation reactions (Kayacan et al., 2020). The lower TPC values detected in HD may be related to the degradation occurring in phenolic compounds.

Color Properties of DP Fruits

The color values of the DP fruits varied according to the applied drying techniques, and the results were given in the Table 1. L* values were indicated the brightness of the samples and values changed between 27.39±1.39 and 17.59±3.67. Applied drying tecniques decreased L* values of the DP fruits. L* values of the dried DP fruits, except dried FD fruits, found significantly important compared to fresh fruits ($P \leq 0.05$). However, no significant differences were found between the L* values of dried HD and VD fruits ($P > 0.05$). Consequently, DP fruits that were dried using HD and VD methods had a darker colour than fresh and FD dried fruits. Although HD and VD drying techniques decreased the a* and b* values of DP fruits, the FD drying technique increased the a* and b* values. The a* and b* values of the dried fruits were found to be significantly important compared to the control ($P \leq 0.05$). As a result, FD drying increased the redness and yellowness of the DP fruits, while HD and VD drying decreased it. Chroma indicates the density of color values and C* values of the DP fruits were changed between 1.39±0.37 and 6.12±3.54. Applying drying techniques increased C* values of the samples, but only the HD dried samples were found statistically important compared to fresh DP fruits ($P \leq 0.05$). However, applying drying techniques significantly decreased h° values of the samples compared to fresh DP fruits ($P \leq 0.05$). Additionally, changes in color values of DP fruits, for HD and VD drying, could potentially be linked to non-enzymatic browning reactions that transpire due to the influence of temperature. However, since browning reactions are absent in FD drying, color values may be similar or slightly different from fresh products. Parallel results to our study have been reported by many studies expressing the changes in the color values of fruits with different drying techniques (Kayacan et al., 2020; Goztepe et al., 2022; Guclu et al., 2022).

Table 1. Color properties of fresh and dried DP fruits

	L*	a*	b*	C*	h°
Fresh	27.39±1.84^{a}	-0.17±0.88^{b}	-0.94±0.58^{b}	1.39±0.37^{b}	273.39±57.90^{a}
HD	17.59±3.67^{b}	-5.27±3.03^{c}	-2.96±1.95^{c}	6.12±3.54^{a}	207.41±9.11^{b}
VD	20.83±0.43^{b}	-3.48±0.83^{c}	-1.44±0.16^{b,c}	3.97±0.86^{a,b}	191.51±23.89^{b}
FD	24.84±0.94^{a}	3.86±1.48^{a}	1.32±0.71^{a}	4.20±1.59^{a,b}	18.89±10.87^{c}

HD: Hot air drying, VD: Vacuum drying, FD: Freeze drying. Different letters in the same column show statistical difference ($P \leq 0.05$).

Antibacterial Activity of DP Fruits

Antibacterial effect of fresh and dried DP fruits methanolic extracts on some pathogenic bacteria, *B. cereus*, *S.* Typhimurium, *S. aureus* and *Y. enterocolitica*, was determined and the extracts inhibited growth of tested pathogenic bacteria at different rates (Table 2). Although *B. cereus* and *S.* Typhimurium were inhibited at the highest inhibition levels by HD methanolic extract, *Y. enterocolitica* and *S. aureus* were inhibited at the highest inhibition levels by VD methanolic extract. Moreover, for *B. cereus*, HD samples were found to be statistically different from VD, for *S.* Typhimurium, fresh samples were found to be statistically different from HD and VD samples. Fresh and FD samples were statistically different from VD and HD samples for *Y. enterocolitica*. Finally, for *S. aureus* fresh samples were statistically different from VD, and VD samples were statistically different from FD. And also, the inhibition levels of *B. cereus*, *S.* Typhimurium, *Y. enterocolitica* and *S. aureus* ranged between 22.75 and 24.5 mm, 23.08 and 24.67 mm, 22.67 and 25.75 mm, 23.00 and 25.17 mm, respectively. According to gram characteristics of the tested bacteria, the highest (25.75 mm) and the lowest (22.67 mm) inhibition levels were determined against *Y. enterocolitica*, gram-negative bacterium. However, between the Gram positive bacteria, the highest inhibition level was determined against *S. aureus*, while the lowest inhibition level was determined against *B. cereus*. Pathogens inhibition levels of methanolic extracts of dried DP fruits compared to control; for *B. cereus* no significant differences was found, for *S.* Typhimurium and *Y. enterocolitica* HD and VD extracts were found to be significantly differences, and for *S. aureus* only VD extract was found statistically important. This study showed that methanolic extracts of HD, VD and FD have potential to inhibit pathogens at a higher level compared to fresh DP fruits, although there is little differences or no significant differences in the level of inhibition of pathogens. Similarly to our study, Opara et al. (2009) reported that the antibacterial effects of fresh and dried pomegranate extracts on different pathogens are at different levels. Also, Thamburaj et al. (2022) found that antibacterial effect of *Ficus benghalensis* fruit fresh and dried extracts showed different inhibition zone against *S. typhi*. The antibacterial effect of methanolic extracts of fresh and dried fruits may be due to amount of phenolic compounds (Farahmandfar et al., 2019). In this study, different drying methods resulted in varying levels of inhibition against the tested bacteria. These results may be related to tested bacteria, phenolic profile of the fruit, and the antibacterial method applied.

Sensory Evaluation of DP Fruits

The sensorial evaluation of the dried products is the most important parameter in defining the success of a drying methods as it is related to the consumer perception (Petikirige et al., 2022). Fresh and dried DP fruits were assessed for sensory attributes including color and appearance, odor, taste, chewiness and overall acceptability (Figure 4). Color and appearance scores of the samples changed from 3.33 to 4.5, and although no statistically differences was found between the all samples, fresh DP fruit had the higher score.

Although there was a difference between the colour values of fresh and dried fruit in the colorimetric colour measurement, no statistical difference in colour and appearance was found between fresh and dried samples in the panelist evaluation. As colourimetry is more sensitive, panelists' ratings may vary from person to person. Similarly, it was determined that there were no differences in the panelist evaluation in terms of odor and taste.

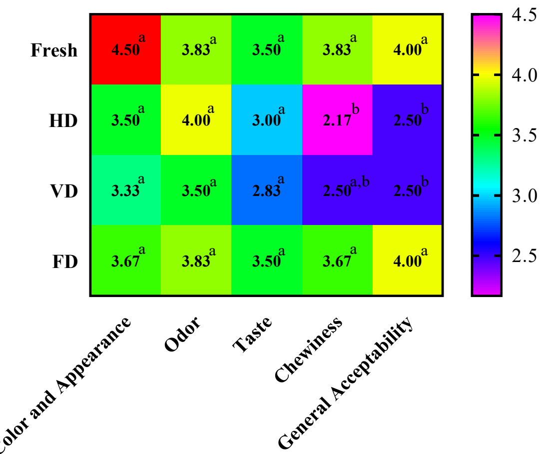
Table 2. Antibacterial effects of fresh and dried DP fruits methanolic extracts against some pathogenic bacteria represented as inhibition zone (mm)

	B. cereus	*S.* Typhimurium	*Y. enterocolitica*	*S. aureus*
Fresh	23.9±0.13[a,b]	23.08±0.07[b]	22.67±0.11[b]	23.00±0.08[b]
HD	24.5±0.10[a]	24.67±0.14[a]	25.50±0.07[a]	24.40±0.12[a,b]
VD	22.75±0.13[b]	24.60±0.10[a]	25.75±0.13[a]	25.17±0.14[a]
FD	23.3±0.12[a,b]	23.75±0.12[a,b]	22.92±0.16[b]	23.08±0.14[b]

HD: Hot air drying, VD: Vacuum drying, FD: Freeze drying. Different letters in the same column show statistical difference ($P \leq 0.05$).

Chewiness scores of the fresh and dried DP fruits ranged between 3.83 and 2.17 for all samples, and so the highest and the lowest scores were detected for fresh and HD samples, respectively. FD samples were scored similarly to fresh samples by the panelists according to the chewiness and statistical importance was not determined for fresh and FD fruits. However, the chewiness scores of HD and VD samples were statistically different from both fresh and FD samples. Drying of fresh DP fruits with HD and VD resulted in a harder finished product and lower scores of chewiness are related to hardness of the samples and HD and VD samples were not preferred by the panelists due to their harder structure.

General acceptability scores of fresh and dried DP fruits were changed between 2.5 and 4 and the mean values of the HD and VD samples and the mean values of the fresh and FD samples were the same and were scored by the panelists as 2.5 and 4, respectively. The general acceptability scores of the HD and VD samples were not statistically significant. Additionally, the overall acceptability scores of fresh and FD samples were not statistically significant. However, the overall acceptability scores of HD and VD samples were found to be statistically significant compared to fresh and FD samples. Similarly to our study, Piotrowski et al. (2021) and Wojdyło et al. (2016) were reported that FD drying is the best drying technique for the sensory evaluation of strawberry and jujube fruits, respectively. As a result, this study revealed that HD and VD drying were different compared to fresh samples, especially in terms of chewiness and general acceptability values, on the other hand, FD drying had similar scores with fresh samples and was more appreciated in terms of sensory evaluation compared to the other two drying techniques.



HD: Hot air drying, VD: Vacuum drying, FD: Freeze drying. Different letters show statistical difference ($P \leq 0.05$).

Figure 4. Sensory evaluation of fresh and dried DP fruits

CONCLUSION

At this work, the effects of some drying process on the quality parameters and sensory features of DP fruit were studied. In terms of sensory assessment, TPC, TFC, AC and color properties

FD was the best drying technique. Also, different drying techniques had the different antibacterial effect on selected pathogenic bacteria and generally inhibitory effect of the HD, VD and FD extracts were greater than fresh DP fruit extract. In conclusion, this study has shown that freeze-drying is the optimal method for maintaining the properties of DP fruits. Additionally, due to their high antioxidant content, DP fruits can find potential applications in the field of food technology.

CONFLICT OF INTEREST

The author inform no conflict of interest.

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