Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 34, issue 4, 2024, pp. 127 - 140

EFFECT OF TRADITIONAL SUN DRYING ON PHENOLIC COMPOSITION AND ANTIOXIDANT ACTIVITY OF PEEL AND PULP FROM LIGHT AND DARK FIG (*FICUS CARICA* L.) VARIETIES

Leila MEZIANT[1,2], Yazid KHALED KHODJA[3*], Yaiche HASSINA[4], Aicha BENBOURICHE[4], Azzeddine CHENAFI[5], Mostapha BACHIR-BEY[6]

[1]Division Biotechnologie Alimentaire, Centre de Recherche en Biotechnologie, Constantine 25001, Algeria.
[2]Division Biotechnologie et Santé, Centre de Recherche en Biotechnologie, Constantine 25001, Algeria.
[3]Laboratory of Exploration and Valorization of Steppe Ecosystems, Faculty of Natural Sciences and Life, University of Djelfa, PO Box 3117, Djelfa 17000, Algeria
[4]Université de Bejaia, Faculté des Sciences de la Nature et de la Vie, 06000 Bejaia, Algérie.
[5]Research Laboratory of Applied Hydraulics and Environment, Faculty of Technology, University of Bejaia, 06000, Bejaia, Algeria
[6]University of Bejaia, Faculty of Natural and Life Sciences, Laboratory of Applied Biochemistry, 06000 Bejaia, Algeria

Abstract: Figs (*Ficus carica* L.) are widely consumed fruits known for their richness in phenolic compounds and antioxidant properties. This study aimed to evaluate the effect of traditional sun drying on the phenolic profile and antioxidant activity of peel and pulp from two Algerian fig varieties, a light-skinned (*Taamriwthe*) and a dark-skinned (*Azenjer*) cultivar. Both fresh and sun-dried figs were subsequently freeze-dried and analyzed separately for peel and pulp. Total phenolics, flavonoids, flavonols, and anthocyanins were quantified using spectrophotometric methods, while antioxidant activity was assessed by DPPH radical scavenging, reducing power, phosphomolybdenum assay, and hydrogen peroxide scavenging. Drying caused a marked reduction in fruit weight (~55%) and moisture content (from ~75% to ~30%), significantly affecting phenolic distribution. Total phenolic content increased significantly after drying, particularly in peels of the light (>250%) and dark (79%) varieties, while only slight changes were observed in pulps. In contrast, flavonoids and anthocyanins were highly sensitive to drying, with reductions of 40–60% and more than 75%, respectively, especially in dark figs. Antioxidant responses depended on tissue and assay: DPPH scavenging activity decreased markedly after drying (up to 80% in light fig pulp), while reducing power and phosphomolybdenum capacity were partially maintained or enhanced in dried peels. Principal component analysis (accounting for 83.3% of the total variability) clearly discriminated samples according to tissue, variety, and processing state. Overall, fig peel, particularly from dark fresh fruits, exhibited the highest antioxidant potential, while sun drying markedly altered phenolic composition and functionality.

Keywords: *Ficus carica*, peel, pulp, fresh, sun dried, phenolic compounds, antioxidant activity.

INTRODUCTION

Figs (*Ficus carica* L.) are among the oldest cultivated fruit trees. They are widely distributed throughout the Mediterranean basin and are valued for both their organoleptic qualities and potential health benefits (Rasool *et al.,* 2023). Figs not only represent a significant source of dietary fiber, vitamins, and minerals, but they are also rich in bioactive phenolic compounds, including phenolic acids, flavonoids, flavonols, and anthocyanins. These compounds are associated with antioxidant, anti-inflammatory, and cardioprotective effects (Bachir Bey *et al.,* 2015), contributing to the growing interest in figs as a functional food with potential roles in the prevention of oxidative stress-related chronic diseases (Ammar *et al.,* 2015).

The phenolic composition of figs is strongly influenced by genetic and morphological factors. Dark-skinned cultivars generally exhibit higher phenolic and flavonoid contents than light-skinned cultivars, and the peel typically contains greater concentrations of bioactive compounds than the pulp (Bachir Bey *et al.,* 2015; Ersoy *et al.,* 2015). These compounds not only contribute to antioxidant activity but also play a role in plant defense mechanisms against environmental stressors, such as ultraviolet radiation and oxidative damage (Zidi *et al.,* 2020). Therefore, distinguishing phenolic profiles between peel and pulp is essential for evaluating the nutritional and functional potential of figs; however, this tissue-specific perspective remains underexplored in many studies.

Drying represents the most commonly employed preservation method for figs due to its ability to reduce moisture content, limit spoilage, and extend shelf life (Bachir-Bey *et al.,* 2024). Traditional sun drying remains widely practiced in many fig-producing regions, particularly in North Africa and the Mediterranean,

***Correspondence**: Yazid Khaled Khodja, Laboratory of Exploration and Valorization of Steppe Ecosystems, Faculty of Natural Sciences and Life, University of Djelfa, PO Box 3117, Djelfa 17000, Algeria, email: y.khaled@univ-djelfa.dz*

owing to its low cost and simplicity (Henriques *et al.,* 2025). Nevertheless, the effects of sun drying on phenolic composition and antioxidant capacity are complex; while water loss may concentrate certain compounds, exposure to heat and light can lead to the degradation of sensitive molecules such as anthocyanins and certain flavonoids (Boukhalfa *et al.,* 2025). Recent studies have demonstrated that careful control of drying conditions can enhance the retention of key phenolic compounds (Bachir-Bey *et al.,* 2024; Henriques *et al.,* 2025), highlighting the need for comprehensive evaluations of drying effects.

Antioxidant activity encompasses multiple mechanisms, including free radical scavenging, reducing power, and total antioxidant capacity, each assessed using specific analytical assays (Molyneux 2004). The relationship between total phenolic content and antioxidant activity is not always linear, particularly following processing, making multivariate approaches, such as principal component analysis, highly relevant for revealing trends across tissues, varieties, and treatments.

This study assesses the impact of traditional sun drying on the phenolic composition, antioxidant activity, and physical properties of the peel and pulp of two fig varieties with contrasting skin colors, thereby providing a foundation for their strategic valorization in the food and nutraceutical sectors.

MATERIAL AND METHODS

Sampling

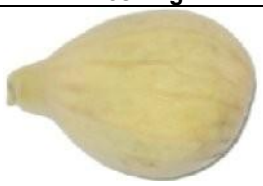
The study focused on two fig (*Ficus carica* L.) varieties highly produced and appreciated by consumers: a light-skinned variety locally known as "*Taamriwthe*" and a dark-skinned variety referred to as "*Azenjer*". Their main characteristics, along with representative photographs, are presented in Table 1.

Sampling was conducted by random selection from several fig trees located in the Beni Maouche region (Bejaia, Algeria), an area renowned for its high-quality fig production. For each variety, fully mature, healthy, and uninfected fresh figs were harvested and immediately transported to the laboratory. Approximately 3 kg of freshly picked figs were subjected to traditional sun-drying under ambient conditions until the desired texture, characterized by slight elasticity to the touch, was obtained.

A portion of each sample was used to determine the unit weight and moisture content. The remaining material was first frozen at –20°C for 24 h and then lyophilized (Alpha1-4 LD freeze dryer, Christ, Osterode, Germany). After freeze-drying, it was finely ground (A11 basic mill, IKA, Staufen, Germany), into a homogeneous powder and transferred into airtight containers, which were protected from light and stored at low temperature until further analyses.

Table 1.

Description and photographs of fresh and dried fig varieties used

Variety	Description	Fresh fig	Dried fig
Taamriwthe	Pyriform fruit with a slightly elongated neck; green skin and red pulp.		
Azenjer	Rounded fruit with a short neck; dark purple-dark skin with light hues and green around the ostiole; deep red pulp.		

Weight and moisture determination

For each variety, ten fresh and ten dried figs were randomly selected. Each fruit was weighed whole using an analytical balance (Radwag MA 50.R, Poland), then manually peeled, and the skin and pulp were weighed separately. For moisture determination, 4 g of each sample (skin or pulp) was placed in a ventilated oven (WTB Binder, 120 Tuttlingen, Germany) at 103°C for 24 hours. The samples were then cooled in a desiccator to room temperature before reweighing, and the moisture content was calculated and expressed as a percentage relative to the initial fresh weight (Zidi *et al.,* 2020).

Extraction and quantification of antioxidant compounds

The antioxidant compounds from the samples were extracted according to the procedure described by Bachir Bey *et al.,* (2013), with slight modifications. Briefly, 200 mg of the freeze-dried sample was mixed with 10 mL of 60% (v/v) acetone. The suspension was agitated using a magnetic stirrer (AM4, VELP Scientifica, Usmate, Italy) at 400 rpm for 2 hours at room temperature. The mixture was then centrifuged (NF 200, Nüve, Ankara, Turkey) at 5000 rpm for 10 minutes, and the resulting supernatant was carefully collected for subsequent antioxidant measurements.

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 34, issue 4, 2024, pp. 127 - 140

Total phenolic content

Total phenolic content (TPC) was estimated using the Folin-Ciocalteu method as described by Yahiaoui *et al.,* (2023). A volume of 200 µL extract was mixed with 750 µL Folin-Ciocalteu reagent, incubated for 3 minutes, then combined with 400 µL of 7.5% Na_2CO_3. After 90 minutes of dark incubation at room temperature, absorbance was measured at 720 nm with UviLine 9400 spectrophotometer (Secomam, Ales, France). Results were expressed as mg gallic acid equivalents per 100 g dry weight (mg GAE/100g DW).

Flavonoid content

The aluminum chloride ($AlCl_3$) colorimetric method was applied to determine the total flavonoid content, following the procedure described by Bachir Bey *et al.,* (2015). Briefly, 1 mL of the extract was mixed with 1 mL of a 2% (*w/v*) $AlCl_3$ solution prepared in methanol. The mixture was vortexed to ensure homogeneity and incubated for 30 minutes at room temperature in the dark to prevent photodegradation. The absorbance of the resulting flavonoid-aluminum complex was then measured at 430 nm using a spectrophotometer. Quantification was performed using a quercetin calibration curve, and the results were expressed as milligrams of quercetin equivalents per 100 g of dry weight (mg QE/100g DW).

Flavonol and anthocyanin contents

Flavonol and anthocyanin were quantified according to Djaoudene *et al.,* (2019). For flavonols, a volume of 900 µL extract was mixed with 900 µL of 0.1 N methanol-HCl. Absorbance was measured at 360 nm and quantified using the Beer-Lambert law referring to quercetin 3-glucoside (ε = 20,000 L/mol/cm). For anthocyanin, the same protocol as flavonols was applied, but absorbance was measured at 530 nm (ε = 38,000 L/mol/cm). Flavonol and anthocyanin contents were expressed as mg quercetin 3-glucoside equivalents per 100 g of dry weight (mg QGE/100g DW).

Antioxidant activity assays

DPPH radical scavenging

An aliquot of 100 µL of the extract was mixed with 1 mL of a freshly prepared DPPH radical solution (60 mM in methanol). The mixture was vortexed and allowed to react in the dark for 30 min. The decrease in absorbance was then measured at 517 nm (Mouhoubi-Tafinine *et al.,* 2024). Results were expressed as milligrams of gallic acid equivalents per 100 g of dry weight (mg GAE/100g DW).

Reducing power

One mL extract was mixed with 2.5 mL phosphate buffer (pH 6.6) and 2.5 mL of 1% $K_3[Fe(CN)_6]$, incubated at 50°C for 20 minutes, then combined with 2.5 mL of 10% trichloroacetic acid. After centrifugation, 1 mL of supernatant was mixed with 1 mL H_2O and 0.2 mL of 0.1% $FeCl_3$, and absorbance was measured at 700 nm (Khaled Khodja *et al.,* 2020). Results were expressed as milligrams of gallic acid equivalents per 100 g of dry weight (mg GAE/100g DW).

Phosphomolybdenum assay

An aliquot of 200 µL of the extract was mixed with 2 mL of freshly prepared phosphomolybdate reagent (0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate). The mixture was vortexed to ensure homogeneity, then incubated in a water bath at 95 °C for 90 minutes to allow the reduction of phosphate–Mo(VI) to Mo(V), leading to the formation of a stable green complex detectable by spectrophotometry. After cooling to room temperature, the absorbance was measured at 595 nm using a spectrophotometer (Djaoudene *et al.,* 2024). The total antioxidant capacity was calculated from a gallic acid calibration curve, and results were expressed as milligrams of gallic acid equivalents per 100 g of dry weight (mg GAE/100g DW).

Hydrogen peroxide scavenging

An aliquot of 150 µL of the extract was mixed with 1 mL of a 40 mM hydrogen peroxide (H_2O_2) solution prepared in phosphate buffer (pH 7.4). The mixture was gently vortexed and incubated for 10 minutes at room temperature to allow the scavenging reaction to occur. The residual concentration of H_2O_2 was determined by measuring the absorbance at 230 nm against a blank containing phosphate buffer instead of the extract (Bachir Bey *et al.,* 2015). The antioxidant activity was quantified using a gallic acid standard curve, and results were expressed as milligrams of gallic acid equivalents per 100 g of dry weight (mg GAE/100g DW).

Statistical analysis

All experiments were carried out in triplicate, and the results were expressed as mean values accompanied by their corresponding standard deviations (mean ± SD). Statistical analyses were performed using the STATISTICA software package (version 5.5, StatSoft Inc., Tulsa, OK, USA). Differences among means were assessed by analysis of variance (ANOVA) or multivariate analysis of variance (MANOVA), depending on the data set. Statistical significance was established at a probability level of $p \leq 0.05$. Graphical outputs were generated using OriginPro 2024 SR1.

RESULTS AND DISCUSSION

Analysis of physical parameters

Average fruit weight

Fruit weight is a physical parameter that provides an indication of fruit size. Fig. 1 shows the variation in average weight according to variety and sample state (fresh and dried). In the fresh state, the two varieties,

dark and light figs, had mean weights of 37.16 and 38.40 g, respectively. After drying, the fruit weight decreased to 13.43 g for dark figs and 12.96 g for light figs. This reduction is attributed to the evaporation of free water from the tissues under the effect of heat during the drying process. These findings are consistent with previous reports indicating that fig drying induces a 46–54% reduction in fruit weight (Bachir-Bey *et al.,* 2024). Similarly, the weights of fresh fig varieties from Turkey were reported to range between 44 and 64 g, whereas dried fruits weighed between 8 and 19 g (Teruel-Andreu *et al.,* 2023; Tikent *et al.,* 2023).

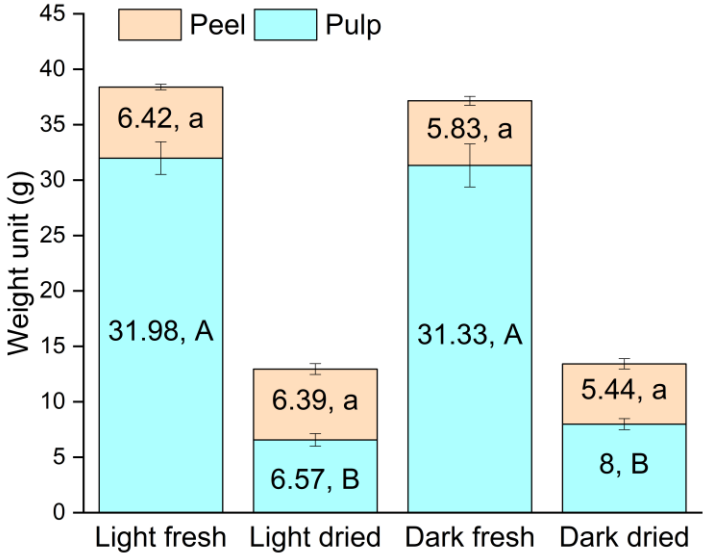


Fig. 1. Average weight of figs as influenced by variety and sample state (fresh and dried). *Vertical bars represent standard deviations. Values with uppercase letters (A, B) for pulp and lowercase letters (a, b) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05, a>b).*

The weight of the isolated peels from both varieties, in both fresh and dried states, showed no significant differences, ranging from 5.44 g for dried dark figs to 6.42 g for fresh light figs. In contrast, the pulp exhibited a significant decrease in weight from the fresh state (31.98 g for light figs and 31.32 g for dark figs) to the dried state (6.57 g for light figs and 7.99 g for dark figs). This observation suggests that drying affects the pulp more than the peel due to its higher water content. Moreover, the water evaporated from the peel is partially replaced by the migration of sugars from the pulp to the dried peel, which explains the relative stability of peel weight after drying.

Moisture and dry matter

Moisture content and dry matter are two complementary parameters that provide essential information on the water content of fruits and help estimate yield after drying. In addition, their determination facilitates the calculation of the concentrations of different constituents expressed on a dry weight basis.

Fig. 2 shows the moisture and dry matter percentages of the figs studied. In the fresh state, moisture content was approximately 75%, decreasing to about 29% after drying. In fresh samples, no significant differences were observed between the dark and light varieties, whether in the peel or the pulp. Once dried, moisture content decreased similarly in both varieties, without significant differences, leading to a proportional concentration of dry matter. Specifically, moisture content decreased by about 60% in the peel and 62% in the pulp.

The moisture percentage obtained in this study for dried figs is consistent with the findings of Vinson (1999), who reported a value of 30%. According to Guvenc *et al.,* (2009), fresh figs have a moisture content ranging from 77.5 to 86.8%, while dried figs contain about 23%. However, (Vinson *et al.,* 2005) reported 83% moisture in fresh figs and 11% after drying, values that differ from those found in the present work. Such variations may be attributed to geographical and climatic differences, the varieties analyzed, as well as drying conditions and duration. Overall, regardless of the drying method applied (Boukhalfa *et al.,* 2025) or the pre-treatment used prior to drying (Kaur *et al.,* 2025), the moisture content of dried figs generally remains around 20%.

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 34, issue 4, 2024, pp. 127 - 140

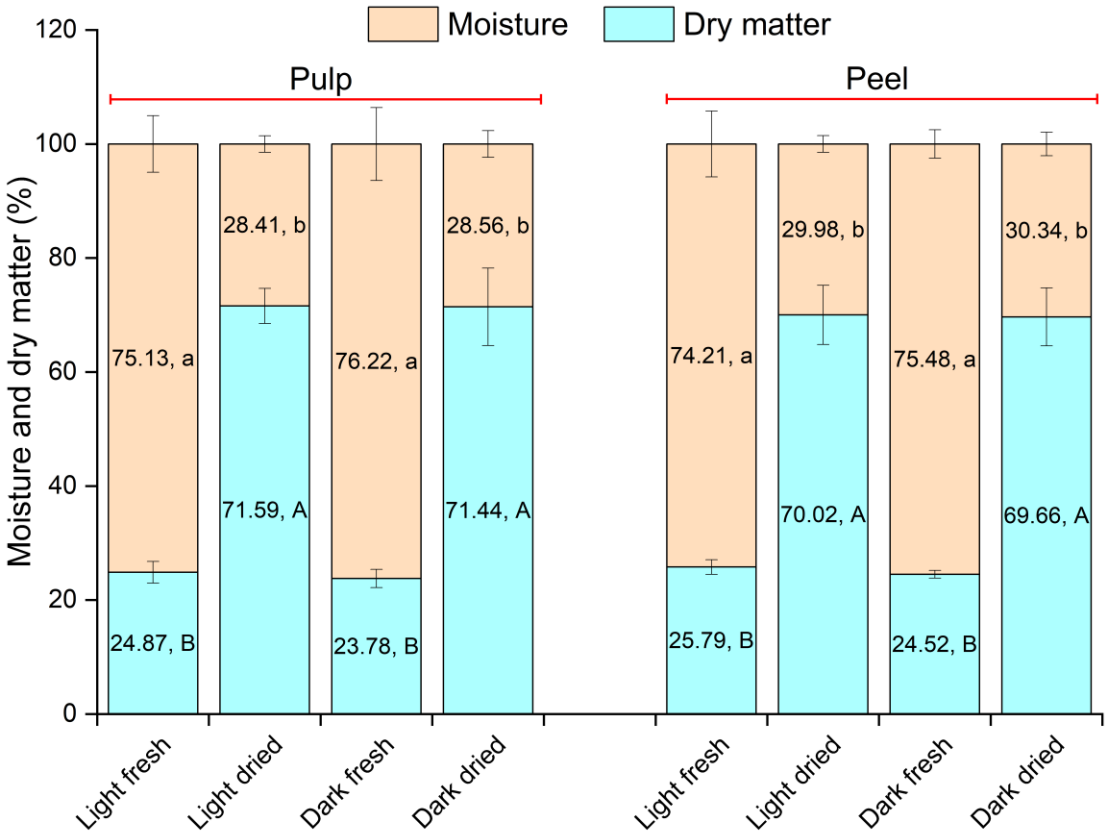


Fig. 2. Moisture and dry matter percentages of figs according to variety and sample state (fresh and dried). *Vertical bars represent standard deviations. Values of pulp or peel with uppercase letters (A>B) for dry matter and lowercase letters (a>b) for moisture indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

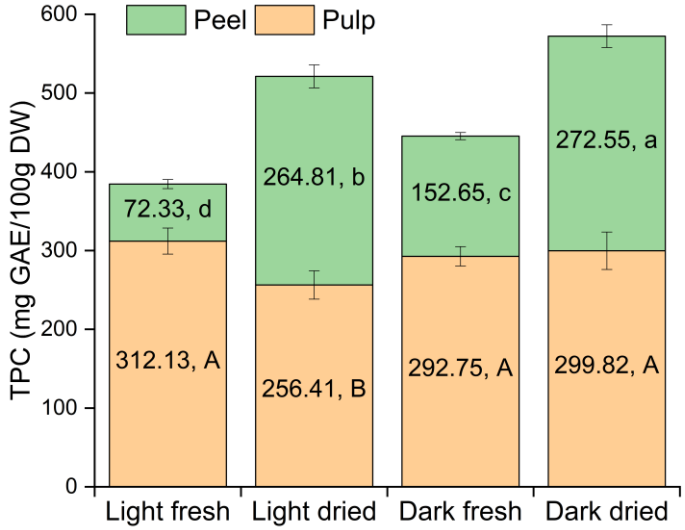


Fig. 3. Phenolic compound contents of the pulp and peel from fresh and dried light and dark figs. *Vertical bars represent standard deviations. Values with uppercase letters (A>B) for pulp and lowercase letters (a>b) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

Antioxidant content

Total phenolic compounds

Fig. 3 shows the total phenolic contents of the pulp and peel from fresh and dried fig varieties. The fresh and dried pulp of dark figs, as well as the fresh pulp of light figs, exhibited similar polyphenol concentrations of approximately 300 mg GAE/100g DW. The dried pulp of light figs contained a slightly lower concentration, at 256.41 mg GAE/100g DW. The peel fractions showed significant differences among all samples. The highest

polyphenol content was recorded for the dried peel of dark figs (272.55 mg GAE/100g DW), while the lowest value was observed for the fresh peel of light figs (72.33 mg GAE/100g DW).

Studies on the antioxidant composition of figs are generally based on the whole fruit. Vinson *et al.,* (2005) reported a decrease in polyphenols after drying, from 486 to 320 mg CEy/100g FW. Qusti *et al.,* (2010) showed that the content of these compounds in fresh figs is 29.26 mg GAE/g fresh matter and increases during drying to 486.18 mg GAE/g dry fig. In our case, drying caused a slight decrease in polyphenol content in the pulp, which may be due to oxidation of these compounds. However, their content in the peel increased after drying, with 366% for the light variety and 178% for the dark variety.

This increase can be explained by the hydrolysis of large phenolic compounds, such as proanthocyanidins, into smaller and more abundant molecules. The effect is particularly pronounced in the peel, which is the tissue most exposed to environmental factors during drying. On one hand, the peel directly absorbs solar radiation and heat, receiving the highest thermal load while acting as a barrier that limits heat transfer to the pulp. On the other hand, being the outermost tissue, it is also directly exposed to sunlight, which may stimulate the biosynthesis of phenolic compounds. Taken together, these factors contribute to the higher phenolic content observed in peels compared to inner tissues during sun drying.

Light enhances the biosynthesis of polyphenols in plants by amplifying the enzymatic activities, including phenylalanine ammonia-lyase (PAL) activity, which plays an important role in the conversion of phenylalanine (produced via the shikimate pathway) into coumaric acid, a precursor molecule involved in the synthesis of phenolic compounds in plants (Toor *et al.,* 2006; Liu *et al.,* 2023).

The study by Solomon *et al.,* (2006) on figs indicated that peels are richer in phenolics than pulps, with respective contents of 41.7–463 mg GAE/100g FW and 36.5–100.6 mg GAE/100g FW. This does not correspond to our results, where we found that pulps were richer in polyphenols than peels. This divergence may be due to the calculation basis for concentrations, considering varietal factors and the extraction protocol used. In the same study, it was found that dark varieties contain more polyphenols than lighter varieties, which is confirmed by our results.

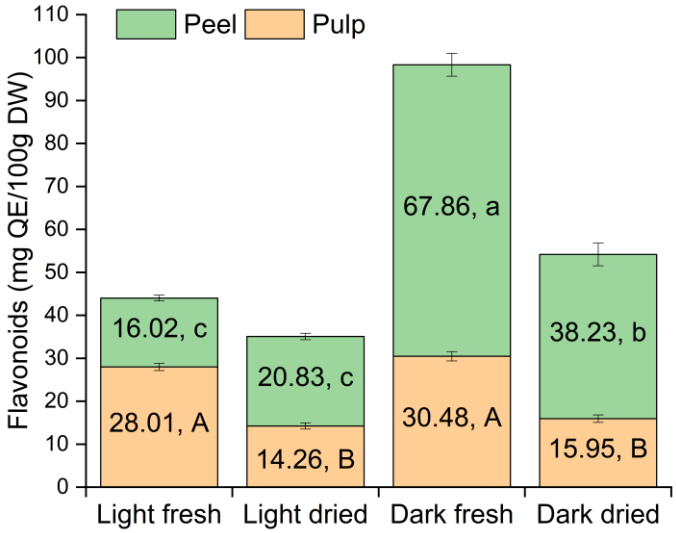


Fig. 4. Flavonoid contents of the pulp and peel from fresh and dried light and dark figs. *Vertical bars represent standard deviations. Values with uppercase letters (A>B) for pulp and lowercase letters (a>b>c) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

Flavonoids

The colored compounds of fruits are mainly represented by flavonoids. These molecules act as protective filters for cellular structures against UV radiation (Ferreyra *et al.,* 2021). Several flavonoids constitute the active principles of medicinal plants and exhibit protective and preventive effects for both consumers and the plants themselves (Jucá *et al.,* 2020).

The flavonoid contents of the different parts of figs are shown in Fig. 4. The peel of fresh dark figs exhibited the highest content of these compounds (67.86 mg QE/100g DW). After drying, this value decreased by almost half (38.23 mg QE/100g DW). The peel of fresh light figs contained only 16.02 mg QE/100g DW, with a slight change after drying. The pulp of both fresh varieties (light and dark) showed no significant difference, with respective flavonoid contents of 28.01 and 30.48 mg QE/100g DW. These values decreased significantly after drying, reaching 14.26 and 15.95 mg QE/100g DW, respectively. The reduction in flavonoids after drying can be attributed to the fact that some classes among these compounds, such as anthocyanins, are thermolabile.

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 34, issue 4, 2024, pp. 127 - 140

The study conducted by Solomon *et al.,* (2006) reported that dark varieties accumulate more total flavonoids than light varieties. The authors also found that these compounds are more concentrated in the peel (2.2–45.6 mg CE/100g FW) than in the pulp (1.6–5.7 mg CE/100g FW). The present results are in full agreement with this study. The most abundant flavonoids in figs, in particular dark ones, are anthocyanins (Meziant *et al.,* 2018), responsible for the brown coloration of the peel, where they accumulate to mitigate oxidative stress caused by external agents likely to damage the tissues most exposed to free radical attack.

Flavonols

Flavonols, mainly quercetin, are widely distributed in edible plants but occur at low concentrations, leading to modest dietary intakes (≈10–35 mg/day). Recent studies highlight their potential health benefits, including a reduced risk of several chronic diseases (Mahmud *et al.,* 2023; Oei *et al.,* 2023).

The flavonol content in the peel of fresh dark figs was the highest (57.96 mg QGE/100g DW), followed by dried dark fig peel (39.84 mg QGE/100g DW), and finally by the fresh and dried peel of light figs, which showed no significant difference (24.73 and 27.69 mg QGE/100g DW, respectively) (Fig. 5).

In the pulp, fresh light figs showed the lowest flavonol content (4.22 mg QGE/100g DW), significantly different from all other samples. The highest pulp content was recorded for dried dark figs (15.49 mg QGE/100g DW).

The study conducted by Del Caro *et al.,* (2008) reported flavonol contents of 145.1 and 69.7 mg RE/100g FW in the peels of dark and light figs, respectively. However, flavonols were not detected in the pulp of either variety. This higher accumulation of flavonols in the peel compared with the pulp is explained by the greater exposure of the peel to light, which stimulates their biosynthesis.

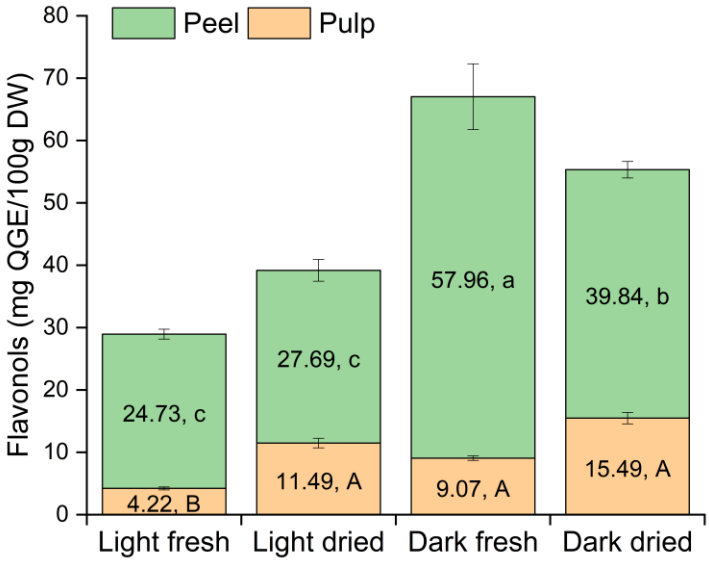


Fig. 5. Flavonol contents of the pulp and peel from fresh and dried light and dark figs. *Vertical bars represent standard deviations. Values with uppercase letters (A>B) for pulp and lowercase letters (a>b>c) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

Anthocyanins

Anthocyanins are among the most widely studied flavonoids, responsible for the red, blue, and purple pigmentation of many fruits and vegetables. They are commonly found in berries, grapes, and other deeply colored plant foods. Beyond their role as natural colorants, anthocyanins have attracted significant scientific interest for their potential health-promoting effects, including antioxidant, anti-inflammatory, and cardioprotective activities (Pereira 2022).

Fig. 6 shows the anthocyanin contents in figs. Fresh dark figs stand out as they exhibit the highest levels in both the peel and pulp, with 27.67 and 12.21 mg QGE/100 g DW, respectively. In contrast, fresh light figs contain only trace amounts in the peel (0.49 mg QGE/100 g DW), while the pulp contains 12.71 mg QGE/100 g DW. The total anthocyanin content (pulp + peel) is markedly higher in dark figs (39.88 mg QGE/100 g DW) compared to light figs (13.20 mg QGE/100 g DW).

During drying, anthocyanins in both peel and pulp showed significant degradation due to their high sensitivity to light and heat. In dried dark figs, the remaining anthocyanin amounts were very low, with reductions of 80% in the peel and 76% in the pulp. Similarly, in light figs, drying decreased anthocyanins drastically to 1.04 mg in the peel and 2.75 mg in the pulp, resulting in a total of 3.79 mg QGE/100 g DW.

Previous studies have reported that anthocyanin levels differ significantly between varieties and tissues, with dark figs generally exhibiting higher concentrations, especially in the peel (Toor *et al.,* 2006; Oei *et al.,* 2023). Environmental factors, particularly light exposure, play a crucial role in anthocyanin biosynthesis and accumulation, with both ripening and coloration being light-dependent processes (Sun 2019).

Recent research confirms that high temperature and oxygen exposure during drying promotes anthocyanin breakdown through oxidation and structural transformations. In other fruits, such as blood-flesh peach and blueberry, hot-air drying significantly reduces anthocyanin content, whereas lower-temperature or vacuum-assisted methods better preserve these pigments (Tan *et al.,* 2022; Zhang *et al.,* 2023).

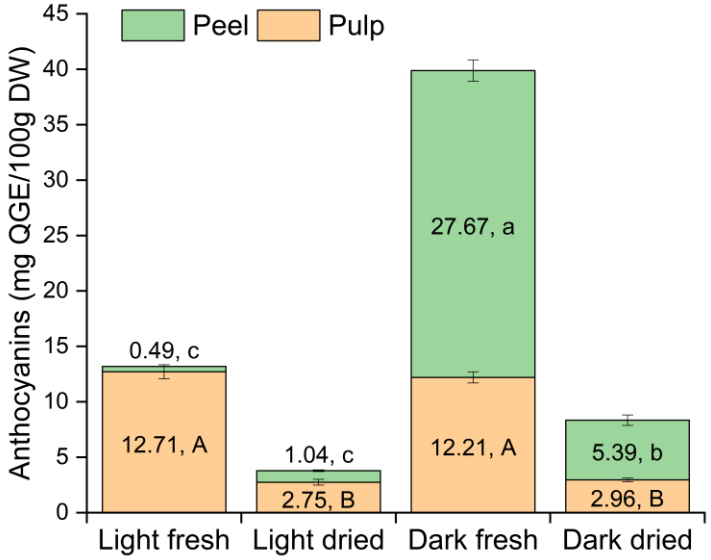


Fig. 6. Anthocyanin contents of the pulp and peel from fresh and dried light and dark figs. *Vertical bars represent standard deviations. Values with uppercase letters (A>B) for pulp and lowercase letters (a>b>c) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

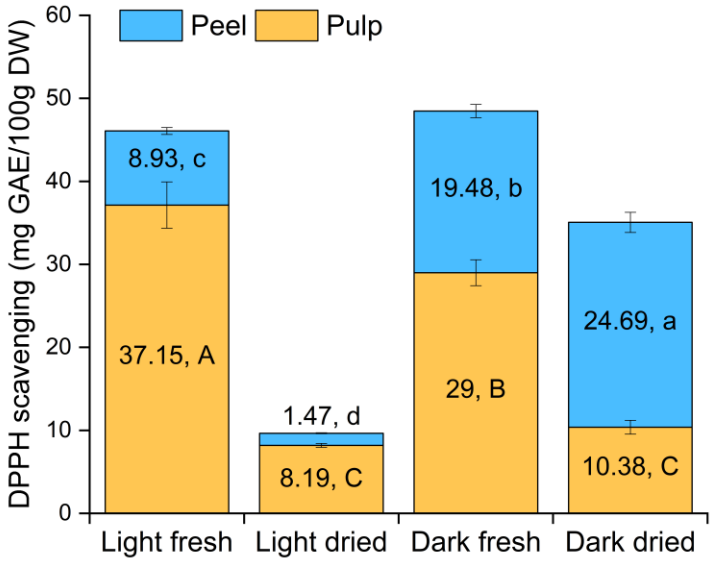


Fig. 7. DPPH radical scavenging activity of light and dark figs. *Vertical bars represent standard deviations. Values with uppercase letters (A>B>C) for pulp and lowercase letters (a>b>c) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

Determination of the antioxidant activity of figs

DPPH° radical reduction

DPPH is a stable radical that cannot dimerize due to steric hindrance around the nitrogen atom carrying the unpaired electron. It can, however, be reduced through hydrogen atom transfer from antioxidants present in the medium (Molyneux 2004).

Fig. 7 shows the DPPH radical scavenging activity of different fig parts. Overall, drying significantly altered radical scavenging activity. For the light variety, total

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 34, issue 4, 2024, pp. 127 - 140

activity (pulp + peel) decreased by 79%, from 46.08 to 9.66 mg GAE/100 g DW, whereas in the dark variety, the decrease was smaller (−28%, from 48.48 to 35.07 mg GAE/100 g DW). In the pulp, fresh figs showed the highest activity in light figs (37.15 mg GAE/100 g DW) and slightly lower in dark figs (29.00 mg GAE/100 g DW). Drying reduced pulp activity by 78% in light figs and by 64% in dark figs. In the peel, light figs exhibited a drastic reduction (−83.5%) from 8.93 to 1.47 mg GAE/100 g DW, whereas dark figs showed an increase from 19.48 to 24.69 mg GAE/100 g DW after drying, likely reflecting the release or concentration of bound antioxidants.

The decline in activity for light figs is mainly linked to the degradation of flavonoids, particularly anthocyanins, despite an increase in total phenolic content, highlighting the strong contribution of flavonoids to radical scavenging. Recent studies confirm that anthocyanin degradation during drying reduces free radical scavenging activity (Zhang *et al.,* 2023). In contrast, Qusti *et al.,* (2010) reported higher antioxidant activity in dried figs compared to fresh ones. Solomon *et al.,* (2006) also found that dark figs generally possess higher antioxidant activity than light figs, consistent with our findings for dried samples. The peel of light figs is rich in chlorophyll, which may contribute to antioxidant activity, but its degradation during drying further explains the observed decline.

Reducing power

Antioxidant activity can be assessed by measuring reducing power, which reflects the electron-donating capacity of polyphenols and is often correlated with other antioxidant properties (Gulcin *et al.,* 2025). The reduction of Fe(III) to Fe(II) is commonly used as an indicator of this activity.

Fig. 8 shows the reducing power of different parts of fig samples. Drying affected reducing power differently depending on variety and tissue. For the total (pulp + peel) of the light *Taamriwthe* variety, reducing power increased by approximately 41% after drying (from 65.46 to 92.05 mg GAE/100 g DW), whereas in the dark *Azenjer* variety, a slight increase of 4.5% was observed (from 97.12 to 101.61 mg GAE/100 g DW).

In the pulp, fresh dark figs exhibited the lowest reducing power (33.74 mg GAE/100 g DW), while other pulps ranged between 49 and 53 mg GAE/100 g DW. Drying slightly decreased pulp activity in light figs (−7%) but significantly increased it in dark figs (+51%). Peel reducing power differed markedly between varieties. Fresh dark peel showed the highest activity (63.38 mg GAE/100 g DW), which decreased by 20% after drying (50.58 mg GAE/100 g DW). Conversely, light peel exhibited a substantial increase (+248%) from 12.19 to 42.42 mg GAE/100 g DW.

These findings indicate that the impact of drying varies according to both fruit tissue and fig variety. The large increase in reducing power of light peel may be attributed to the concentration of bound polyphenols after water loss, whereas the decrease in dark peel likely reflects partial degradation of certain compounds. Overall, drying enhanced the total reducing power in light figs, while dark figs remained largely stable.

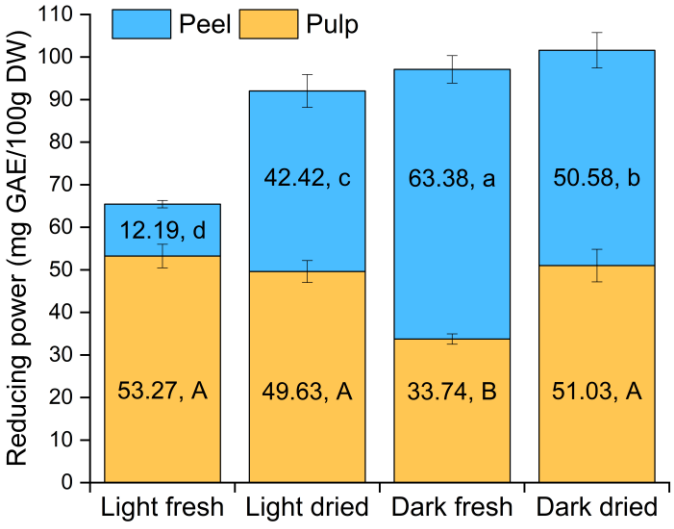


Fig. 8. Reducing power of the pulp and peel from fresh and dried light and dark figs. *Vertical bars represent standard deviations. Values with uppercase letters (A>B) for pulp and lowercase letters (a>b>c>d) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

Phosphomolybdate assay

The reduction of phosphomolybdate by antioxidants present in fig samples was measured using the phosphomolybdenum assay (Fig. 9). This method evaluates total antioxidant capacity (TAC) by the reduction of Mo(VI) to a green phosphate/Mo(V)

complex under acidic conditions. While it provides an overall estimate of antioxidant activity, it is non-specific and responds to a wide range of reducing agents, not solely phenolic compounds (Bachir bey Bey *et al.,* 2015; Bibi Sadeer *et al.,* 2020).

Overall, total phosphomolybdate activity (pulp + peel) was similar between light and dark fig varieties, around 5000 mg GAE/100 g DW, with only minor differences. In the pulp, fresh dark figs exhibited higher activity (4409.37 mg GAE/100 g DW) than light figs (4127.45 mg GAE/100 g DW). Drying decreased pulp activity in both varieties, to 2762.21 mg in dark figs (−37%) and 2238.02 mg in light figs (−46%). In the peel, fresh figs had lower and comparable activity. After drying, peel activity increased substantially, reaching 2196.53 mg in dark figs (+171%) and 2833.86 mg in light figs (+239%). Consequently, the contribution of the peel to total antioxidant capacity increased post-drying due to both concentration effects and the relative reduction in pulp mass. Fresh pulp remained the main contributor to TAC (≈83% of total activity), but after drying, the pulp accounted for only 55% of the total, with the peel representing 45%. This illustrates that the effect of drying on phosphomolybdate activity is tissue-dependent, enhancing peel activity while reducing pulp activity.

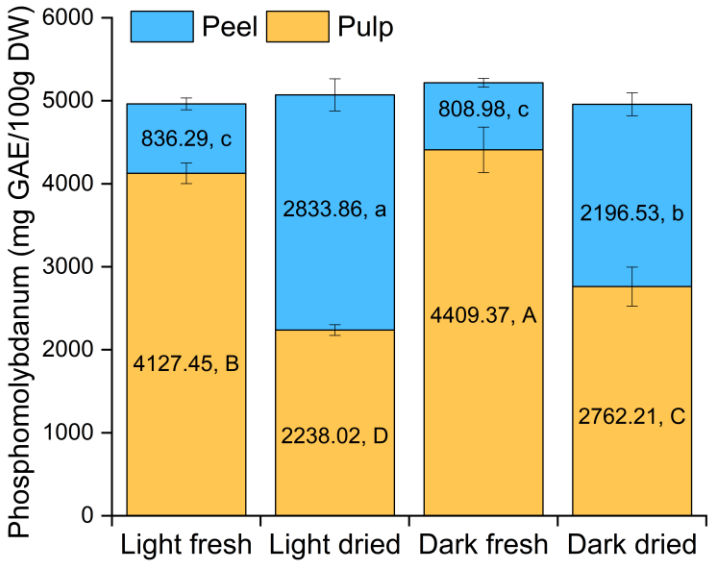


Fig. 9. Phosphomolybdate activity of light and dark figs. *Vertical bars represent standard deviations. Values with uppercase letters (A>B>C>D) for pulp and lowercase letters (a>b>c) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

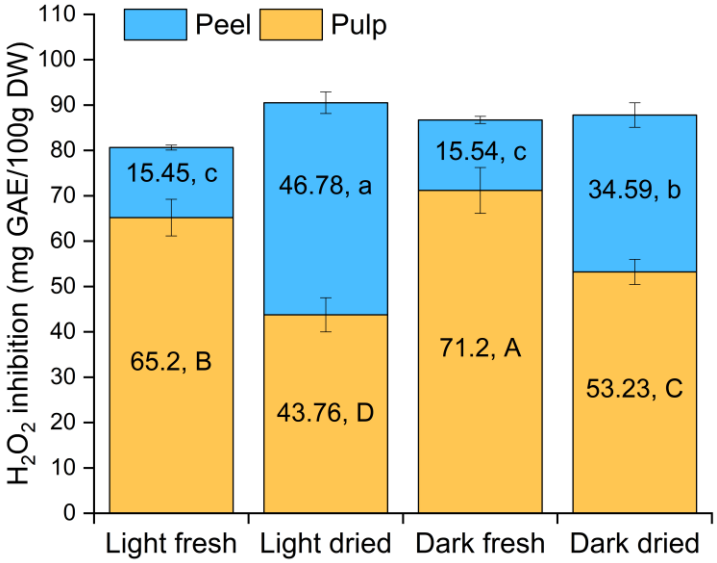


Fig. 10. Hydrogen peroxide inhibition in light and dark figs. *Vertical bars represent standard deviations. Values with uppercase letters (A>B>C>D) for pulp and lowercase letters (a>b>c) for peel indicate statistically significant differences (ANOVA-LSD test, p ≤ 0.05).*

Studia Universitatis "Vasile Goldiş", Seria Ştiinţele Vieţii
Vol. 34, issue 4, 2024, pp. 127 - 140

Hydrogen peroxide inhibition

Fig. 10 illustrates the hydrogen peroxide (H_2O_2) inhibitory activity of the fig varieties. Overall, this activity remained relatively stable between varieties when considering total activity (pulp + peel) before and after drying, with totals around 80–88 mg GAE/100 g DW. In the pulp, fresh dark figs showed higher H_2O_2 inhibitory activity (71.20 mg GAE/100 g DW) than light figs (65.20 mg GAE/100 g DW). Drying reduced pulp activity in both varieties, to 53.23 mg in dark figs (−25%) and 43.76 mg in light figs (−33%).

In the peel, fresh figs exhibited the lowest activity (≈15 mg GAE/100 g DW). After drying, peel activity increased substantially, reaching 46.78 mg in light figs (+203%) and 34.59 mg in dark figs (+122%). Consequently, the contribution of the peel to total H_2O_2 inhibition increased after drying, while the contribution of the pulp decreased. These changes closely follow the variations in dry matter content of each tissue: mass loss in the pulp is accompanied by a relative increase in peel mass, which affects both antioxidant concentration and activity.

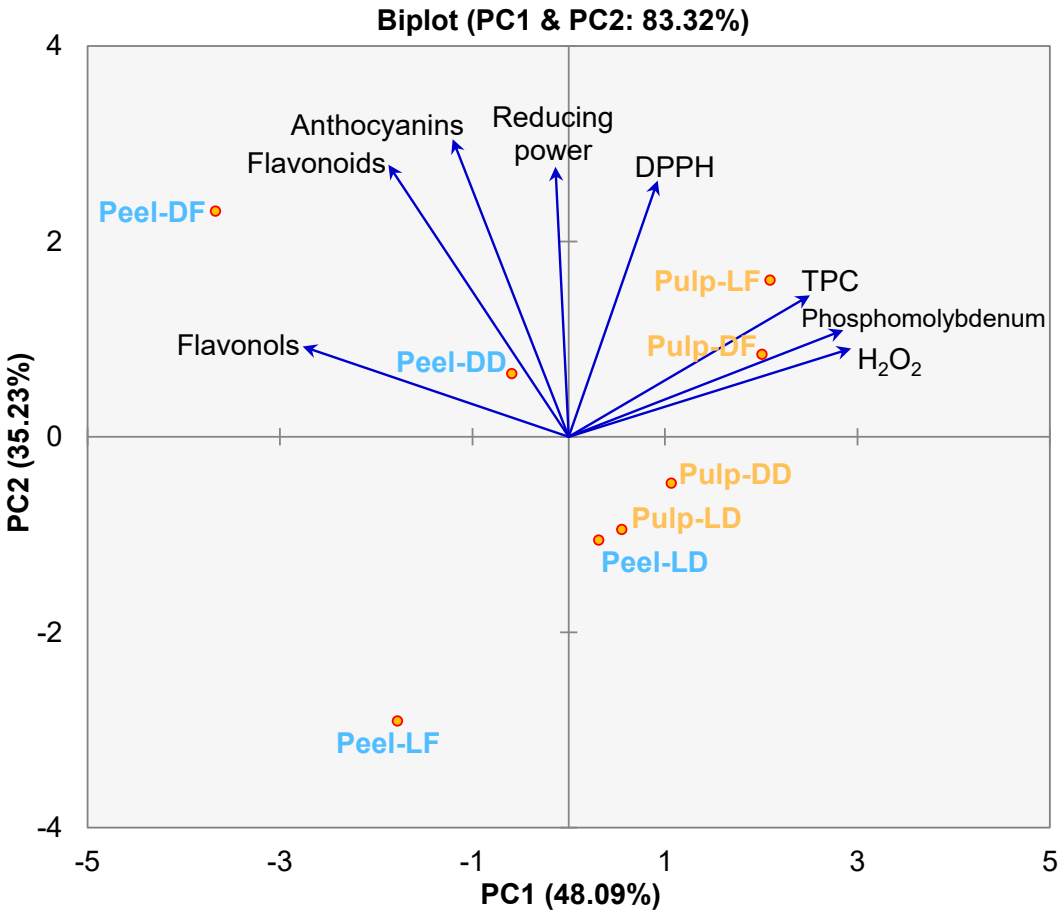


Fig. 11. PCA biplot illustrating the distribution of pulp and peel samples from fresh and dried fig varieties (light and dark) according to phenolic composition and antioxidant activities. *LF, Light fresh; LD, Light dried; DF, Dark fresh; and DD, Dark dried. Vectors represent the contribution and direction of phenolic compounds (TPC, flavonoids, flavonols, anthocyanins) and antioxidant activity assays (DPPH, reducing power, phosphomolybdenum, H_2O_2 scavenging activity), while points correspond to the individual pulp and peel samples.*

Multivariate analysis of antioxidant parameters

Principal Component Analysis (PCA) was performed to evaluate the relationships between phenolic compounds and antioxidant activities in pulp and peel of two fig varieties (light and dark), analyzed in fresh and dried states. The first two principal components (PC1 and PC2) accounted for 83.32% of the total variance, indicating that the PCA biplot provides a robust and meaningful representation of the dataset. PC1 explained 48.09% of the total variability, while PC2 accounted for 35.23%, reflecting a strong structuring of both compositional and functional antioxidant variables.

The first principal component (PC1) was mainly driven by four variables. High positive loadings were observed for H2O2 scavenging activity, phosphomolybdenum reducing capacity, and total phenolic content, all of which exhibited high squared cosines on PC1 ($\cos^2 \geq 0.66$), indicating their strong contribution to this axis. In contrast, flavonols showed strong negative loadings on PC1 ($\cos^2 = 0.81$). This

opposition suggests that PC1 represents a gradient separating samples dominated by high global phenolic content and redox activity from those characterized by specific flavonoid subclasses, particularly flavonols.

The second principal component (PC2) was mainly associated with radical scavenging activity, reducing power and pigment-related phenolics. Anthocyanins (r = 0.846), flavonoids (r = 0.774), reducing power (r = 0.767), and DPPH scavenging activity (r = 0.729) contributed strongly and positively to PC2, with high squared cosine values ($\cos^2 \geq 0.53$). These results indicate that PC2 reflects a dimension related to antioxidant efficiency mediated by flavonoid compounds and electron-donating capacity, rather than total phenolic concentration alone.

Correlation analysis supported these PCA patterns. Strong positive correlations were observed between flavonoids and anthocyanins (r = 0.907) and between flavonoids and flavonols (r = 0.767), highlighting the coordinated accumulation of these compounds. TPC was strongly correlated with phosphomolybdenum (r = 0.842) and H2O2 scavenging activity (r = 0.869), confirming that these assays primarily reflect total phenolic content. Conversely, flavonols showed strong negative correlations with phosphomolybdenum (r = −0.732) and H2O2 (r = −0.780), indicating that not all phenolic subclasses contribute equally to the same antioxidant mechanisms. The near-perfect correlation between phosphomolybdenum and H2O2 (r = 0.984) suggests that these two assays describe closely related redox processes.

The score distribution on the PCA biplot reveals clear discrimination among fig samples according to tissue type, variety, and processing state. Pulp samples, particularly Pulp-LF and Pulp-DF, were positioned on the positive side of PC1, closely associated with TPC, phosphomolybdenum, and H2O2, indicating a higher overall phenolic content and stronger total antioxidant capacity. In contrast, peel samples, especially Peel-DF, were located on the negative side of PC1 and positive side of PC2, strongly associated with flavonoids, and flavonols, anthocyanins reflecting their richness in bioactive pigments.

Drying also influenced sample distribution. Dried samples (LD and DD) tended to cluster closer to the origin, suggesting a partial reduction or transformation of phenolics and related antioxidant activities due to processing. Notably, Peel-LF was clearly separated from other samples, reflecting its low TPC and antioxidant activity values, as previously stated.

The PCA demonstrates that fig peel, particularly from dark fresh varieties, is characterized by high flavonoid and anthocyanin contents and strong radical scavenging capacity, whereas pulp samples are more closely associated with total phenolic content and redox-based antioxidant assays. These findings highlight the combined influence of variety, tissue, and drying process on the phenolic profile and antioxidant behavior of figs.

CONCLUSION

Traditional sun drying significantly affects the physical properties, phenolic composition, and antioxidant behavior of figs. Although drying concentrates dry matter and increases total phenolic content in the peel, it induces marked degradation of thermolabile flavonoids, particularly anthocyanins, resulting in reduced radical scavenging activity. The pulp remains the main contributor to total antioxidant capacity, while the peel is richer in flavonoids and pigments, especially in dark varieties. Multivariate analysis confirmed the strong influence of tissue type, variety, and processing on antioxidant profiles. These findings highlight the nutritional interest of fig peel and the need to optimize drying conditions to better preserve bioactive compounds.

ACKNOWLEDGMENTS

The authors sincerely thank the Algerian Ministry of Higher Education and Scientific Research, particularly the DGRSDT, for financial support that made this work possible.

AUTHOR CONTRIBUTIONS

Conceptualization, Data curation, Writing – original draft preparation: L.M. Methodology, Formal analysis, Writing – review & editing: Y.K.K.. Investigation, Data collection: Y.H. Validation, Supervision: A.B. Visualization, Resources: A.C. Supervision, Writing – review & editing, Project administration: M.B.

FUNDING

This research was funded by the Directorate General for Scientific Research and Technological Development (DGRSDT), Algeria.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest that could have influenced the results of this study.

ETHICAL APPROVAL

This study did not involve any experiments on human participants or animals.

REFERENCES

Ammar S, del Mar Contreras M, Belguith-Hadrich O, Bouaziz M, Segura-Carretero A. New insights into the qualitative phenolic profile of *Ficus carica* L. fruits and leaves from Tunisia using ultra-high-performance liquid chromatography coupled to quadrupole-time-of-flight mass spectrometry and their antioxidant activity. RSC Adv, 5, 20035-20050, 2015.

Bachir-Bey M, Khodja YK, Meziant L, Benbouriche A, Chikhoune A, Louaileche H. Impact of sun drying on the physicochemical characteristics and phytochemical contents of nine fig fruit varieties:

a comparative study. Ann Univ Dunarea Jos Galati Fascicle VI Food Technol, 48, 106-124, 2024.

Bachir bey Bey M, Louaileche H. A comparative study of phytochemical profile and in vitro antioxidant activities of dark and light dried fig (*Ficus carica* L.) varieties. The Journal of Phytopharmacology, 4, 41-48, 2015.

Bachir Bey M, Louaileche H. A comparative study of phytochemical profile and *in vitro* antioxidant activities of dark and light dried fig (*Ficus carica* L.) varieties. J Phytopharmacol, 4, 41-48, 2015.

Bachir Bey M, Louaileche H, Zemouri S. Optimization of phenolic compound recovery and antioxidant activity of light and dark dried fig (*Ficus carica* L.) varieties. Food Sci Biotechnol, 22, 1613-1619, 2013.

Bibi Sadeer N, Montesano D, Albrizio S, Zengin G, Mahomoodally MF. The Versatility of Antioxidant Assays in Food Science and Safety—Chemistry, Applications, Strengths, and Limitations. Antioxidants, 9, 709, 2020.

Boukhalfa F, Bachir-Bey M, Medouni S, Madani K. Effect of temperature and drying method on the phenolic profile of four varieties of figs (*Ficus carica*). J Food Meas Charact, 1-12, 2025.

Del Caro A, Piga A. Polyphenol composition of peel and pulp of two Italian fresh fig fruits cultivars (*Ficus carica* L.). Eur Food Res Technol, 226, 715-719, 2008.

Djaoudene O, Bachir-Bey M, Schisano C, Djebari S, Tenore GC, Romano A. A Sustainable Extraction Approach of Phytochemicals from Date (Phoenix dactylifera L.) Fruit Cultivars Using Ultrasound-Assisted Deep Eutectic Solvent: A Comprehensive Study on Bioactivity and Phenolic Variability. Antioxidants, 13, 181, 2024.

Djaoudene O, López V, Cásedas G, Les F, Schisano C, Bachir Bey M, Tenore GC. Phoenix dactylifera L. seeds: A by-product as a source of bioactive compounds with antioxidant and enzyme inhibitory properties. Food Funct, 10, 4953-4965, 2019.

Ersoy N, Gozlekci S, Gok V, Yilmaz S editors. V International Symposium on Fig 1173. 2015.

Ferreyra MLF, Serra P, Casati P. Recent advances on the roles of flavonoids as plant protective molecules after UV and high light exposure. Physiol Plant, 173, 736-749, 2021.

Gulcin İ, Alwasel SH. Fe3+ Reducing Power as the Most Common Assay for Understanding the Biological Functions of Antioxidants. Processes, 13, 1296, 2025.

Guvenc M, Tuzcu M, Yilmaz O. Analysis of fatty acid and some lipophilic vitamins found in the fruits of the *Ficus carica* variety picked from the Adiyaman District. Res J Biol Sci, 4, 320-323, 2009.

Henriques BR, Neves CM, Moumni M, Romanazzi G, Le Bourvellec C, Cardoso SM, Wessel DF. A comparative study of traditional sun drying and hybrid solar drying on quality, safety, and bioactive compounds in "Pingo de Mel" Fig. Antioxidants, 14, 362, 2025.

Jucá MM, Cysne Filho FMS, de Almeida JC, da Silva Mesquita D, de Moraes Barriga JR, Dias KCF, Barbosa TM, Vasconcelos LC, Leal L, Ribeiro JE. Flavonoids: Biological Activities and Therapeutic Potential. Nat Prod Res, 34, 692-705, 2020.

Kaur H, Kaur R, Kaur A, pal Singh R. Influence of pre-treatment on drying kinetics and chemical composition of pea processing waste. J Food Sci Technol, 62, 1250-1259, 2025.

Khaled Khodja Y, Dahmoune F, Madani K, Khettal B. Conventional method and microwave drying kinetics of Laurus nobilis leaves: Effects on phenolic compounds and antioxidant activity. Braz J Food Technol, 23, e2019214, 2020.

Liu Y, Singh SK, Pattanaik S, Wang H, Yuan L. Light regulation of the biosynthesis of phenolics, terpenoids, and alkaloids in plants. Commun Biol, 6, 1055, 2023.

Mahmud AR, Ema TI, Siddiquee MF. Natural flavonols: actions, mechanisms, and potential therapeutic utility for various diseases. Beni-Suef Univ J Basic Appl Sci, 12, 47, 2023.

Meziant L, Boutiche M, Bachir Bey M, Saci F, Louaileche H. Standardization of monomeric anthocyanins extraction from fig fruit peels (*Ficus carica* L.) using single factor methodology. J Food Meas Charact, 12, 2865-2873, 2018.

Molyneux P. The use of the stable free radical diphenylpicrylhydrazyl (DPPH) for estimating antioxidant activity. Songklanakarin J Sci Technol, 26, 211-219, 2004.

Mouhoubi-Tafinine Z, Khodja YK, Bachir-Bey M. Effect of Geographical Origin on the Quality and Antioxidant Activity of Honey in North Algeria. Taiwan J Agric Chem Food Sci, 62, 2024.

Oei S, Millar CL, Nguyen TN, Mukamal KJ. Higher intake of dietary flavonols, specifically dietary quercetin, is associated with lower odds of frailty onset over 12 years of follow-up among adults in the Framingham Heart Study. Am J Clin Nutr, 118, 2023.

Pereira L. Dietary Effects of Anthocyanins in Human Health: A Comprehensive Review. Pharmaceuticals, 14, 690, 2022.

Qusti SY, Abo-khatwa AN, Lahwa MB, Qusti S. Screening of antioxidant activity and phenolic content of selected food items cited in the Holly Quran. EJBS, 2, 40-51, 2010.

Rasool IFU, Aziz A, Khalid W, Koraqi H, Siddiquie SA, Al-Farga A, Lai WF, Ali A. Industrial application and health prospective of fig (*Ficus carica*) by-products. Molecules, 28, 960, 2023.

Solomon A, Golubowicz S, Yablowicz Z, Grossman S, Bergman M, Gottlieb HE, Altman A, Kerem Z, Flaishman MA. Antioxidant Activities and Anthocyanin Content in Various Fig (*Ficus carica* L.) Varieties. J Agric Food Chem, 54, 7717-7723, 2006.

Sun H. Differential color development and response to light deprivation of fig (*Ficus carica* L.) syconia peel and female flower tissues: transcriptome elucidation. BMC Plant Biol, 19, 217, 2019.

Tan S, Miao Y, Zhou C, Luo Y, Lin Z, Xie R, Li W. Effects of Hot Air Drying on Drying Kinetics and Anthocyanin Degradation of Blood-Flesh Peach. Foods, 11, 1596, 2022.

Teruel-Andreu C, Sendra E, Hernández F, Cano-Lamadrid M. Nutritional and functional compounds and antioxidant activity of edible and non-edible fruit part of brebas and figs (*Ficus carica* L.) among different varieties. Scientia Horticulturae, 318, 112069, 2023.

Tikent A, Laaraj S, Marhri A, Taibi M, Elbouzidi A, Khalid I, Bouhrim M, Elfazazi K, Elamrani A, Addi M. The Antioxidant and Antimicrobial Activities of Two Sun-Dried Fig Varieties (Ficus carica L.) Produced in Eastern Morocco and the Investigation of Pomological, Colorimetric, and Phytochemical Characteristics for Improved Valorization. 14, 845-863, 2023.

Toor RK, Savage GP, Lister CE. Seasonal variations in the antioxidant composition of greenhouse grown tomatoes. J Food Compos Anal, 19, 1-10, 2006.

Vinson JA. The functional food properties of figs. Cereal Foods World, 44, 82-87, 1999.

Vinson JA, Zubik L, Bose P, Samman N, Proch J. Dried fruits: excellent *in vitro* and *in vivo* antioxidants. J Am Coll Nutr, 24, 44-50, 2005.

Yahiaoui S, Kati DE, Chaalal M, Otmani A, Bettache N, Bachir-Bey M. Phenolic compounds of fig (*Ficus carica* L.) leaves: optimization of extraction by response surface methodology and UPLC-MS phytochemical characterization. Curr Bioact Compd, 19, 39-51, 2023.

Zhang L, Zhang C, Wei Z, Huang W, Yan Z, Luo Z, Beta T, Xu X. Effects of four drying methods on the quality, antioxidant activity and anthocyanin components of blueberry pomace. Food Prod Process Nutr, 5, 35, 2023.

Zidi K, Kati DE, Benchikh Y, Bachir Bey M, Ouandjeli D, Yahiaoui S. The use of modified atmosphere packaging as mean of bioactive compounds and antioxidant activities preservation of fresh figs (*Ficus carica* L.) from rare cultivars. Ann Univ Dunarea Jos Galati Fascicle VI Food Technol, 44, 149-164, 2020.