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Physicochemical Quality and Microbial Contamination of Solar-Dried Figs (*Ficus carica* L.)

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ABSTRACT

Fig (*Ficus carica* L.) is a nutrient-rich fruit with recognized therapeutic properties, but its soft texture and high sugar content make it highly perishable. Drying is therefore essential to extend its shelf life. This study aimed to evaluate the physicochemical and phytochemical characteristics of seven dried fig varieties and assessed their microbiological safety through fungal isolation and identification. Fully ripened fruits were solar-dried in a glasshouse under controlled conditions, with daily turning to ensure uniform dehydration. Significant inter-varietal differences were observed in nutritional, bioactive, and physicochemical traits. Moisture content remained below 26% in all samples, ensuring storage stability. Soluble sugars were predominant (41.71–78.67 g 100 g^{-1} DW), while protein content was relatively low (1.23–1.79 g 100 g^{-1} DW). Total phenolic content ranged from 164.88 to 340.55 mg GAE 100 g^{-1} DW, and flavonoids from 29.80 to 56.24 mg RE 100 g^{-1} DW. Mold counts varied between 2.29 and 4.48 log CFU g^{-1}, with *Aspergillus* species more prevalent than *Penicillium* and *Alternaria*, reflecting their higher ecological fitness under solar-drying conditions. Overall, these results demonstrated that glasshouse solar drying effectively reduced post-harvest deterioration of figs while preserving key nutritional and bioactive compounds, thus providing a sustainable alternative to conventional sun-drying that enhances product safety, stability, and market competitiveness.

Keywords: *Ficus carica*, Molds, Nutritional quality, Phenolic compounds, Solar drying.

INTRODUCTION

The common fig (*Ficus carica* L.), a member of the Moraceae family, is one of the earliest domesticated fruit trees and remains an integral part of the Mediterranean diet. It is widely cultivated in subtropical and tropical regions and, to a lesser extent, in temperate zones with moderate climates (Solomon *et al*., 2006). Figs are consumed both fresh and dried, and are

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highly valued for their richness in sugars, organic acids, essential minerals, vitamins, amino acids, and dietary fiber. They also contain phenolic compounds with antioxidant properties, which are associated with the prevention of chronic diseases such as cancer, cardiovascular disorders, and diabetes (Slatnar *et al*., 2011; Kamiloglu and Capanoglu, 2015). Dried figs are particularly appreciated for their extended shelf life, high energy value, and significant contribution to Mediterranean and Middle Eastern diets (Mat Desa *et al*., 2019). In recent years, the growing demand for minimally processed and organic foods has further increased global interest in dried figs (Aksoy, 2017; Sen, 2022).

However, fresh figs are highly perishable due to their delicate skin, high water content, and susceptibility to mechanical damage, which accelerate senescence and microbial decay (Crisosto *et al*., 2011). Drying remains the most effective preservation method, as it reduces water activity, enhances storage stability, and ensures year-round availability (Arvaniti *et al*., 2019). Traditional sun-drying, still the predominant practice worldwide, is often associated with heterogeneous product quality, postharvest losses, and contamination by dust, insects, and toxigenic fungi such as *Aspergillus*, *Fusarium*, *Alternaria*, and *Penicillium* (Galván *et al*., 2021; Maghoumi *et al*., 2022). Under favorable conditions, these fungi may produce mycotoxins, posing serious risks to human health and threatening the economic viability of the dried fig trade (Galván *et al*., 2022; Galván *et al*., 2023). To address these limitations, recent studies have explored improved drying technologies, such as solar tunnel and hybrid systems, as well as pretreatment methods, to enhance microbial safety while preserving nutritional and sensory quality (Lachtar *et al*., 2022; Henriques *et al*., 2025; Jafari *et al*., 2025).

Despite Tunisia's long-standing tradition of fig cultivation and its rich genetic diversity (Gaaliche *et al*., 2012), research on dried figs remains limited. The country has more than 2.5 million fig trees covering approximately 12,000 hectares, with annual production exceeding 26,000 metric tons (MARHP, 2024). While most of this production is consumed fresh, only a small portion is traditionally sun-dried, leaving Tunisian dried figs underutilized and underrepresented in international markets (Trad *et al*., 2014; Lachtar *et al*., 2022). Furthermore, their physicochemical, phytochemical, and microbiological characteristics are still poorly studied.

Therefore, this study aimed to (i) characterize the physicochemical and phytochemical properties of seven solar-dried fig varieties and (ii) isolate and identify contaminating molds to assess their microbiological safety. The findings are expected to provide novel insights into the

nutritional and functional potential of Tunisian dried figs and support efforts to enhance their quality, safety, and competitiveness within Mediterranean production systems.

MATERIALS AND METHODS

Fig sampling and drying process

Fig samples from seven local varieties were collected in August 2022 from four locations (Table 1) for physicochemical and phytochemical analyses. For each variety, 40 fruits were randomly harvested at full maturity from multiple trees within each orchard, ensuring they were free from physical damage and insect infestation. Drying began immediately after harvest using a glasshouse solar dryer, which consisted of a glass structure (8 m × 4.5 m × 3 m) with transparent panels designed to enhance solar radiation capture and increase internal air temperature. The system operated exclusively on solar energy through passive natural convection, without forced ventilation or auxiliary heating.

Fruits were arranged in a single layer on drying tables positioned 1 m above the ground, at a density of 60 fruits m^{-2}, with adequate spacing to facilitate airflow and minimize contamination risks. To promote uniform dehydration, fruits on each tray were turned daily, and trays were periodically repositioned within the glasshouse. Microclimatic conditions were monitored at multiple positions using calibrated digital thermo-hygrometers (ThermoPro TP49, USA), with average daily values of 39.2 ± 1 ºC and 51 ± 2% relative humidity throughout the drying period. Drying lasted approximately 10 days for all varieties. Figure 1 showed the external appearance of the different solar-dried fig varieties. After drying, all samples were ground using a meat mincer (JATA Electro Chopper PC123, Spain) and stored at 4 °C until analysis. For fungal growth assessment, three dried varieties (*Bouhouli*, *Saffouri*, and *Kahli*) and one commercial dried fig sample (used as a market reference) were selected based on availability, contrasting skin colors, and distinct drying behaviors. The *Kahli* variety was also processed with olive oil and salt, following a traditional preservation practice, to evaluate its effect on fungal development.

Table 1. Label and geographical origin of studied fig varieties.

Variety	Geographical origin	Skin color of fresh figs
Saffouri	Mornag (North-East)	Green-yellow
Gouti	Mornag (North-East)	Green-yellow
Zidi	Kelibia (North-East)	Black
Hemri	Bekalta (Center-East)	Purple
Kahli	Bekalta (Center-East)	Black
Bidhi	Bekalta (Center-East)	Green
Bouhouli	Djebba (North-West)	Black

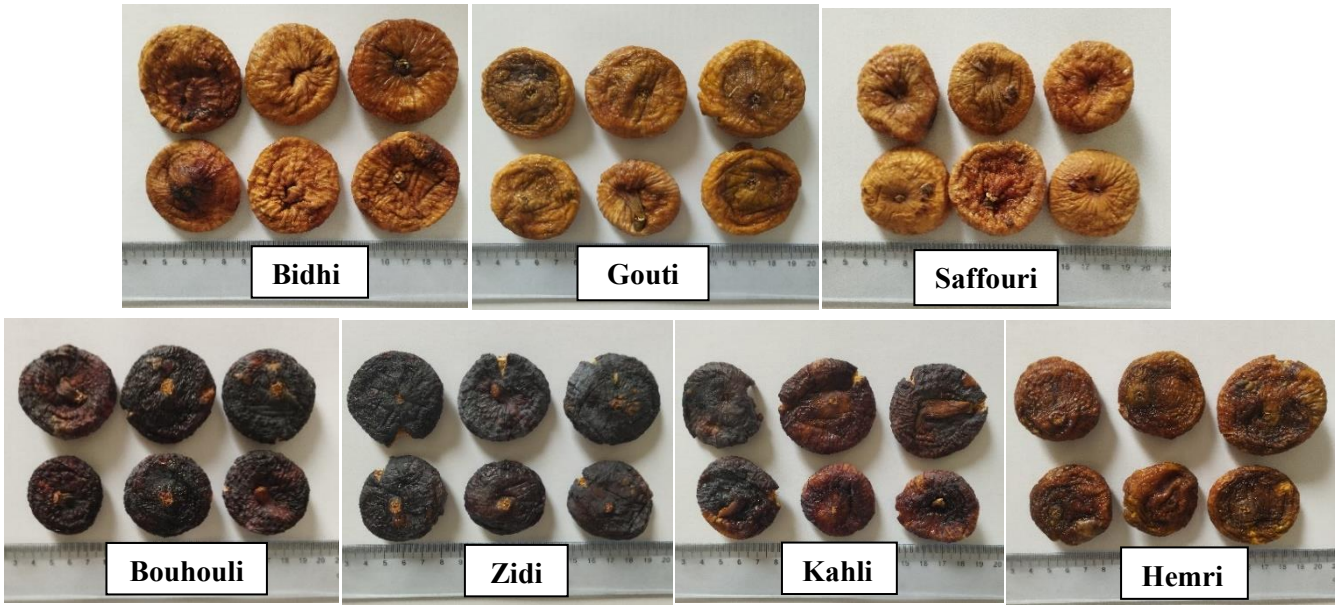

Figure 1. External appearance of the studied fig varieties after solar drying.

Physicochemical analysis

Physical measurements, including fruit weight and diameter, were performed on 30 dried figs per variety. Fruit weight (g) was measured using a digital balance (A&D FX-5000i, Japan; accuracy ± 0.01 g), and diameter (mm) was determined at the widest part using a digital caliper (Model 49-923, 150 mm; LINEAR Tools, UK; accuracy ± 0.02 mm), with careful handling to avoid fruit compression.

Moisture content was determined using the standard gravimetric method (AOAC, 1990). A 5-10 g sample of minced dried figs was oven-dried at 102 ± 2 °C for 24 h. Moisture content (%) was calculated as:

Moisture (%) = $([w_0 - w_f]/w_0) \times 100$, where, w_0 is the initial sample weight and w_f is the final weight after drying.

For pH, titratable acidity, and total soluble solids (TSS) determination, 5 g of dried figs were cut, homogenized with 50 mL of distilled water, and heated in a water bath at 70 °C for 1 h with occasional stirring, then ground in a mortar. The pH was measured using a benchtop pH meter (HI552, HANNA Instruments, Italy). Titratable acidity was determined by titration with 0.1 M NaOH to pH 8.1 and expressed as grams of citric acid (CA) per 100 g dry weight (g CA 100 g^{-1} DW). TSS (ºBrix) were measured at 20 °C using a digital refractometer (OPTECH GmbH, Munich, Germany).

Proteins were extracted following the method of Librandi *et al*. (2007). A 0.4 g sample was mixed with 10 mL of 70% ethanol. After 24 h, the mixture was centrifuged at 5000 rpm for 15

min, and the supernatant was collected to separate soluble proteins from insoluble residues. Protein content was quantified using the Bradford (1976) colorimetric method, with bovine serum albumin as the standard. Absorbance was measured at 595 nm, and results were expressed as g per 100 g dry weight (g 100 g^{-1} DW).

Sugar extraction was performed following Míguez Bernárdez *et al*. (2004), with minor modifications. A 0.1 g sample was homogenized in 10 ml of 80% ethanol and incubated at 95 ºC for 15 min. The mixture was centrifuged at 4500 rpm for 15 min, and the supernatant was collected. Total sugar content was determined using the phenol–sulfuric acid method (Dubois *et al*., 1956), and absorbance was recorded at 490 nm using a JASCO V-550 UV–visible spectrophotometer (JASCO Corporation, Tokyo, Japan). Results were expressed as g glucose equivalent per 100 g dry weight (g 100 g^{-1} DW).

The same physicochemical parameters, i.e. sugar content, moisture level, and pH, were measured in the samples selected for mycological analysis to assess their influence on fungal growth.

Phytochemical analysis

Extract preparation

Phenolic compounds were extracted using a modified protocol based on Fu *et al*. (2011) and Ouchemoukh *et al*. (2012). Briefly, 1 g of each sample was mixed with 10 ml of 80% ethanol and homogenized in a shaking water bath at room temperature for 40 min. The mixture was centrifuged at 1800 rpm for 30 min, and the supernatant was filtered through Whatman No. 1 paper before being evaporated to dryness under vacuum at 40 ºC. The dried extracts were stored in the dark at 4 ºC until analysis. Ethanol was chosen as the extraction solvent because of its food-grade safety, widespread use in food and nutraceutical research, and efficient extraction of phenolic compounds (Doğru *et al*., 2025; Henriques *et al*., 2025). Although solvents such as methanol or acetone may yield slightly higher recoveries, their toxicity limits their use in food applications.

Total phenolic content (TPC)

TPC was determined using the Folin-Ciocalteu colorimetric method, with modifications from Singleton *et al*. (1999). A 0.2 mL aliquot of each extract was mixed with 1 mL of 10% (v/v) Folin-Ciocalteu reagent and 0.8 mL of 7.5% (w/v) sodium carbonate solution. The mixture was incubated at 40 ºC for 10 min, and absorbance was measured at 720 nm using a JASCO V-550

UV–visible spectrophotometer. Results were calculated from a gallic acid standard curve and expressed as mg gallic acid equivalent per 100 g dry weight (mg GAE 100 g^{-1} DW).

Total flavonoid content (TFC)

TFC was measured using the aluminum chloride ($AlCl_3$) assay (Ouchemoukh *et al*., 2012). Briefly, 1 mL of extract was mixed with 1 mL of 2% (w/v) $AlCl_3$ solution and incubated at room temperature for 10 min. Absorbance was recorded at 410 nm and results were calculated from a rutin standard curve, expressed as mg rutin equivalent per 100 g dry weight (mg RE 100 g^{-1} DW).

Mycological analysis

Mold counts

Mold enumeration was performed according to the methodology described by Harrigan (1998). Three replicates of 10 g of samples were mixed with 90 mL of sterile peptone water, and serial 10-fold dilutions were prepared using 0.1% (w/v) peptone water. Aliquots of 0.1 mL were plated onto acidified potato dextrose agar (PDA) supplemented with streptomycin sulfate. Plates were incubated at 25 °C for 5 days, and mold colonies were counted. Results were expressed as log CFU g^{-1}.

Mold isolation

Mold colonies were differentiated based on their macroscopic characteristics, including colony color, texture, and morphology. Dominant colonies were randomly selected from the highest dilutions and transferred to PDA plates supplemented with streptomycin sulfate. The plates were incubated at 25 °C for 5-7 days until uniform colonies formed. Single-spore suspensions were prepared to establish monoclonal mold cultures as described by Choi *et al*. (1999). Pure fungal cultures were stored at 4 ºC until analysis.

Mold identification

Fungal isolates were identified to the species level by sequencing the ITS1–5.8S rDNA–ITS2 region using the primers ITS1 and ITS4 (White *et al*., 1990). Genomic DNA was extracted with the GF-1 Fungus DNA Extraction Kit according to the manufacturer's instructions. PCR products were visualized on 1.4% agarose gels using a 100 bp Plus Blue DNA Ladder (GeneON) as a reference. Species identity was determined by comparing the sequences with entries in the NCBI database. All sequences were deposited in GenBank with assigned accession numbers.

186 **Statistical analysis**

187 Data were analyzed using SPSS software (version 20.0; SPSS Inc., Chicago, IL, USA). A one-
188 way analysis of variance (ANOVA) was conducted to evaluate differences among fig varieties
189 for each parameter. Mean comparisons were performed using Duncan's Multiple Range Test
190 at a significance level of $P < 0.05$. Relationships between physicochemical and phytochemical
191 traits were examined using Pearson's correlation coefficients. All chemical analyses were
192 performed in triplicate, and the results are expressed as mean ± standard deviation.

193

194 **RESULTS AND DISCUSSION**

195 **Physicochemical traits**

196 Significant differences ($P < 0.01$) were observed among the studied varieties for all
197 physicochemical parameters (Table 2). Fruit weight ranged from 7.38 to 14.50 g, and diameter
198 from 28.33 to 41.19 mm, with the black-skinned variety *Kahli* exhibiting the highest values
199 (Table 2). Compared with previous findings, fruit weights were lower than those reported by
200 Konac *et al*. (2017) for light-colored dried figs (22.4–23.4 g), whereas diameters exceeded
201 those found by Pourghayoumi *et al*. (2012) for Iranian dried figs (21.29–23.64 mm). According
202 to UNECE Standard DDP-14 (2016), minimum diameter requirements are 18 mm for black-
203 and 22 mm for white-skinned dried figs; all studied varieties therefore comply with commercial
204 size standards, confirming their market suitability (Crisosto *et al*., 2011).
205 Moisture content ranged from 17.11 to 25.65%, remaining below the UNECE DDP-14
206 maximum threshold of 26% (Table 2). These results were consistent with Galván *et al*. (2023)
207 and Ait Haddou *et al*. (2014), who reported moisture ranges of 20.59–21.06% and 20.25–
208 24.30%, respectively.
209 The pH, a critical parameter for food stability, ranged from 4.49 in *Zidi* to 5.06 in *Bouhouli*
210 (Table 2), confirming the acidic nature of all varieties, which helps inhibit microbial growth
211 and enzymatic activity (Tikent *et al*., 2023). These results were consistent with Debib *et al*.
212 (2018) and Aljane and Ferchichi (2007), who reported similar pH ranges for Algerian and
213 Tunisian cultivars.
214 Acidity affects both the sensory properties and the preservation of quality in dried figs (Mat
215 Desa *et al*., 2019). Among the studied varieties, *Zidi* had the highest titratable acidity (1.14 g
216 CA 100 g^{-1}), while *Bidhi* had the lowest (0.87 g CA 100 g^{-1}). These values were comparable to
217 those reported by Bachir Bey *et al*. (2017) for Algerian dried figs (0.77–1.92 g CA 100 g^{-1}) and

by Konac *et al*. (2017) for Turkish cultivars (0.70–1.13 g CA 100 g^{-1}). Lachtar *et al*. (2022) reported a slightly higher titratable acidity of 1.54 g CA 100 g^{-1} in Tunisian *Bidhi* figs.

Total soluble solids (TSS) ranged from 45.00 to 52.66 °Brix, with *Bouhouli*, *Hemri,* and *Gouti* showed the highest values, without significant differences ($P < 0.05$) (Table 2). These levels were lower than those reported by Pourghayoumi *et al*. (2016) and Lachtar *et al*. (2022), who found ranges of 60.00–84.80 ºBrix and 56.56–71.13 ºBrix, respectively, while Konac *et al.* (2017) observed 66.50–71.50 °Brix in Turkish dried figs.

Protein content ranged from 1.23 g 100 g^{-1} DW in *Kahli* to 1.79 g 100 g^{-1} DW in *Hemri* (Table 2), which was lower than the values reported for Moroccan dried figs (4.17–7.23 g 100 g^{-1} DW) by Ait Haddou *et al*. (2014). In comparison, Alfaifi *et al*. (2013) reported a level of 2.80 g 100 g^{-1} DW, similar to those found in other dried fruits such as dates, apricots, raisins, and prunes, which ranged from 2.50 to 2.90 g 100 g^{-1} DW. Although plant-based proteins generally have a lower biological value than animal proteins, they contribute to enzymatic activity, nutrient transport, immune function, and may also trigger allergic reactions (Tikent *et al*., 2023).

Soluble sugar content (measured as glucose) varied significantly among varieties, ranging between 41.72 g 100 g^{-1} DW in *Hemri* and 78.67 g 100 g^{-1} DW in *Bouhouli* (Table 2). These levels were consistent with those reported by Bachir Bey *et al*. (2017) for Algerian dried figs (72.38–81.45 g 100 g^{-1} DW) and were higher than those observed by Faleh *et al*. (2015) for Tunisian dried figs (35.06 g 100 g^{-1} DW). The increase in sugar concentration can be mainly attributed to water loss during drying, as highlighted by Villalobos *et al*. (2019) and Lachtar *et al*. (2022). The high sugar content makes dried figs energy-dense and may contribute to both their sensory quality and storage stability (Aksoy, 2017; Sen, 2022).

Phytochemical traits

Total phenolic content (TPC)

Significant differences ($P < 0.01$) in TPC were observed among the dried fig varieties (Figure 2). *Bouhouli* and *Zidi* had the highest levels, exceeding 327 mg GAE 100 g^{-1} DW, whereas *Bidhi* had the lowest content (164.9 mg GAE 100 g^{-1} DW). These variations were likely due to genetic factors, geographical origin, and agro-ecological conditions. In addition, these results were consistent with previous studies on Tunisian dried figs (Faleh *et al*., 2015; Khadhraoui *et al*., 2019). TPC values in Tunisian dried figs were lower than those reported in Iranian figs (1120.0–2681.8 mg GAE 100 g^{-1} DW) by Pourghayoumi *et al*. (2016), but higher than those observed in Turkish figs (81.8–212.4 mg GAE 100 g^{-1} DW) by Nakilcioğlu and Hışıl (2013).

These discrepancies may result from genetic differences among cultivars, postharvest handling, drying methods, and variations in extraction and quantification protocols (Arvaniti *et al*., 2019). Fruit skin color also influenced TPC, with dark-skinned varieties generally exhibiting higher polyphenol levels than lighter-colored ones (Debib *et al*., 2014; Kamiloglu and Capanoglu, 2015). Regarding drying effects, some studies have reported that dried figs retain higher phenolic contents than fresh fruits (Slatnar *et al*., 2011; Hoxha and Kongoli, 2016; Konac *et al.,* 2017), whereas others observed a decline after drying (Bachir Bey *et al*., 2017). Phenolic compounds in dried figs exhibit antioxidant, anti-inflammatory, and cardioprotective activities, which may help reduce oxidative stress and the risk of chronic diseases (Arvaniti *et al*., 2019).

Total flavonoid content (TFC)

Significant differences ($P < 0.01$) in TFC were observed among the dried fig varieties (Figure 3). The dark-skinned varieties *Bouhouli* and *Zidi* had the highest concentrations, exceeding 52 mg RE 100 g^{-1} DW, whereas the green-skinned *Saffouri* showed the lowest (29.8 mg RE 100 g^{-1} DW). These results were consistent with those of Hoxha *et al*. (2015), who reported a range of 20.2–37.0 mg catechin equivalents 100 g^{-1} DW in Albanian dried fig cultivars, and Kehal *et al*. (2021), who found 17.5–31.4 mg quercetin equivalents (QE) 100 g^{-1} DW in Algerian varieties. In contrast, Khadhraoui *et al*. (2019) reported higher TFC values in Tunisian dried figs (58.0–112.3 mg QE 100 g^{-1} DW). Dried figs generally contain higher flavonoid levels than other dried fruits, such as raisins (28.2 mg QE 100 g^{-1} DW), apricots (30.1 mg QE 100 g^{-1} DW), and prunes (48.7 mg QE 100 g^{-1} DW) (Ouchemoukh *et al*., 2012). Our results also showed that dark-skinned fig varieties consistently contained higher flavonoid concentrations (37.3–56.2 mg RE 100 g^{-1} DW) than lighter-green varieties (29.8–47.0 mg RE 100 g^{-1} DW), confirming the results of Kamiloglu and Capanoglu, (2015) that skin color plays a decisive role in flavonoid accumulation.

277 **Table 2.** Mean values of physicochemical traits in the different dried fig varieties.

Varieties	Fruit weight (g)	Fruit diameter (mm)	Moisture (%)	pH	Titratable acidity (g CA 100 g^{-1} DW)	TSS (°Brix)	Protein content (g 100 g^{-1} DW)	Soluble sugars (g 100 g^{-1} DW)
Kahli	14.50±2.87 a	41.19±5.13 a	22.03±0.55 c	4.90±0.02 c	0.97±0.03 cd	45.59±1.15 cd	1.23±0.04 d	71.59±2.17 b
Hemri	8.01±1.21 d	33.40±2.03 c	23.47±1.05 bc	4.64±0.01 e	0.95±0.02 d	52.37±0.52 a	1.79±0.14 a	41.72±1.69 e
Bidhi	10.17±2.41 c	36.96±2.64 b	22.80±0.92 bc	4.74±0.02 d	0.87±0.03 e	45.00±2.65 d	1.34±0.09 cd	66.50±0.62 c
Zidi	7.38±1.70 d	28.33±2.15 d	24.26±0.48 ab	4.49±0.05 f	1.14±0.04 a	47.63±0.60 bc	1.30±0.15 cd	57.65±3.21 d
Bouhouli	12.30±1.89 b	36.15±2.35 b	25.65±1.27 a	5.06±0.04 a	1.01±0.01 bc	52.66±0.56 a	1.54±0.05 bc	78.67±1.31 a
Saffouri	9.05±1.38 cd	32.27±1.93 c	18.04±1.01 d	4.98±0.03 b	1.05±0.03 b	48.70±1.53 b	1.71±0.17 ab	64.42±1.79 c
Gouti	8.52±1.58 cd	31.10±2.42 c	17.11±0.95 d	5.03±0.06 ab	0.92±0.04 d	51.32±1.51 a	1.51±0.21 bc	58.79±0.57 d
F-value	17.46**	22.21**	35.29**	100.77**	26.15**	14.75**	7.29**	124.15**

278 Values are means ± standard deviation. Means followed by different letters within the same column indicate significant differences according to Duncan's multiple range test
279 at $P \leq 0.05$. **: highly significant ($P < 0.01$).
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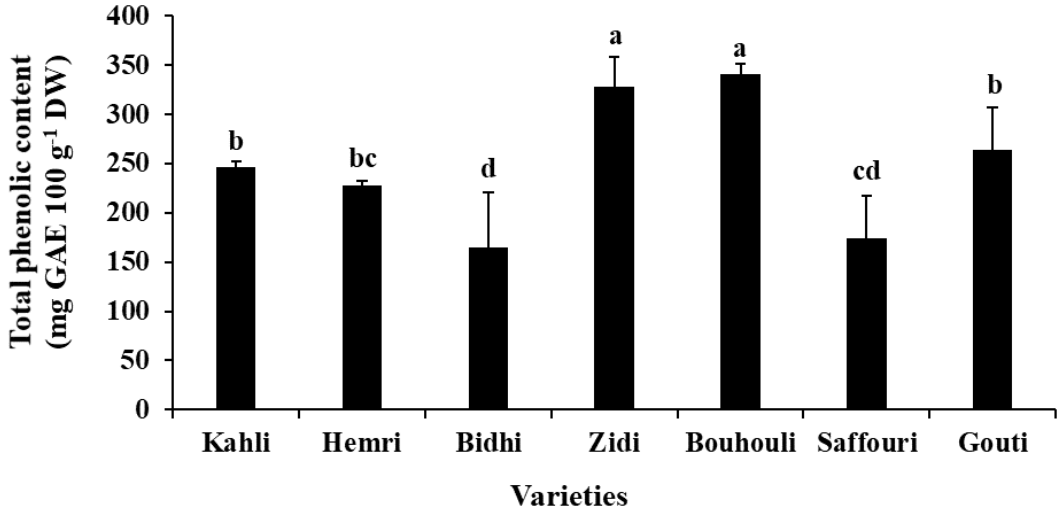

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282 **Figure 2.** Total phenolic content for the different dried fig varieties. Different letters (a, b, c, d) indicate significant differences between varieties
283 according to Duncan's multiple range test at $P \leq 0.05$.

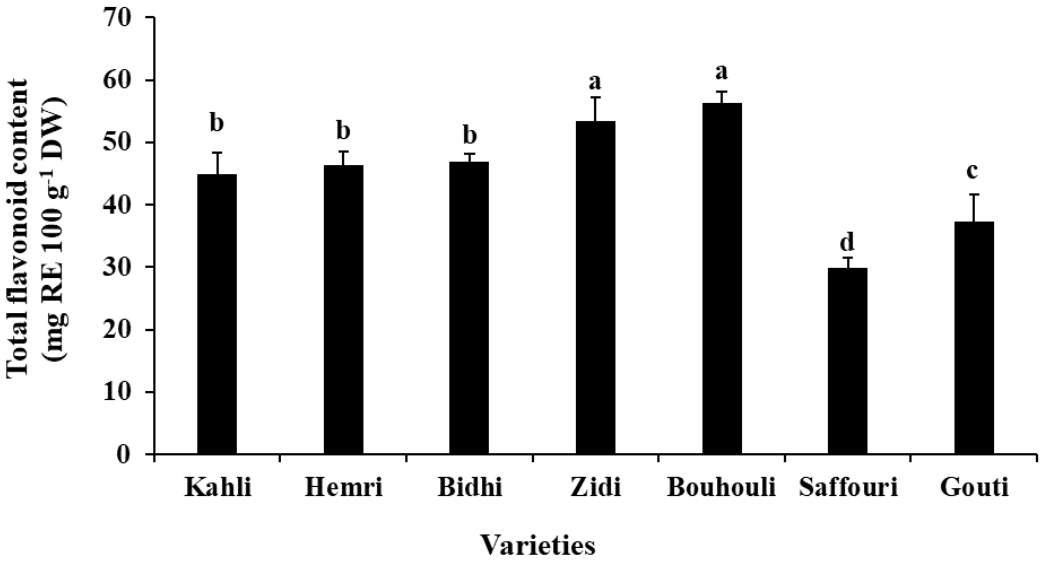

Figure 3. Total flavonoid content for the different dried fig varieties. Different letters (a, b, c, d) indicate significant differences between varieties according to Duncan's multiple range test at $P \leq 0.05$.

Correlation between physicochemical and phytochemical traits

Correlation analysis revealed significant relationships between physicochemical and phytochemical parameters (Table 3). In dried figs, fruit weight was positively correlated with diameter (r = 0.770**) and soluble sugar content as fructose (r = 0.652**), indicating that larger dried figs tend to be sweeter with more fructose content. This result can be explained by the change in the sugar profile caused by the long drying time of large fruits. Total phenolic content (TPC) was positively correlated with total flavonoid content (TFC) (r = 0.546*) confirming that flavonoids constitute a major class of phenolic compounds in figs. Both TPC and TFC showed positive correlations with moisture content (r = 0.476* and r = 0.848**, respectively), suggesting that fruits retaining higher residual moisture during drying may better preserve these bioactive compounds. Dark-skinned cultivars consistently contained higher levels of phenolics and flavonoids, further reinforcing these correlations. Previous studies showed that phenolic and flavonoid contents in dried figs were generally lower than in fresh fruits, which was mainly due to degradation caused by heat, oxidation, and light exposure during drying (Kamiloglu and Capanoglu, 2015; Bachir Bey *et al*., 2017; Kehal *et al*., 2021).

Table 3. Correlation coefficients (*r*) between physicochemical and phytochemical traits.

	FW	FD	TA	pH	TSS	Moisture	SS	Proteins	TPC
FD	**0.770****	1							
TA	-0.239	-0.492*	1						
pH	0.492*	0.256	-0.236	1					
TSS	-0.196	-0.400	0.080	0.266	1				
Moisture	0.143	0.094	0.184	-0.436*	0.034	1			
SS	**0.652****	0.356	0.030	**0.590****	-0.254	0.141	1		
Proteins	-0.253	-0.256	0.069	0.142	**0.602****	-0.163	-0.423	1	
TPC	0.084	-0.298	**0.474***	-0.047	0.373	**0.476***	0.204	-0.193	1
TFC	0.042	0.029	0.155	-0.336	0.063	**0.848****	0.179	-0.282	**0.546***

Significant and potential correlations were marked in bold.
** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level
FW: fruit weight; FD: fruit diameter; TA: titratable acidity; TSS: total soluble solids; SS: Soluble sugars; TPC: total phenolic content; TFC: total flavonoid content.

Mycological analysis

Mold counts and physicochemical traits of dried fig samples

Mean mold counts (log CFU g^{-1}) and physicochemical parameters varied significantly ($P < 0.01$) among the dried fig samples (Table 4). Mold counts ranged from 2.29 to 4.48 log CFU g^{-1}, consistent with previous findings (Javanmard, 2010; Guirguis, 2018). The highest contamination was observed in solar-dried *Bouhouli* figs, which also had the highest soluble sugar content (78.67 g 100 g^{-1} DW) (Table 4). High sugar levels provide a favorable substrate for osmophilic fungi, promoting microbial growth under suitable drying and storage conditions (Magan and Aldred, 2007; Ait Mimoune *et al*., 2018).

A commercial dried fig sample showed a mold count of 3.50 log CFU g^{-1}; however, such comparisons should be interpreted cautiously, as market products are affected by multiple uncontrolled factors, including harvest timing, drying methods, storage conditions, and transportation. Interestingly, solar-dried figs preserved with olive oil and salt showed the lowest mold counts (2.29 log CFU g^{-1}) (Table 4), highlighting the synergistic antifungal effect of this traditional preservation method. This approach offers a low-cost, natural alternative to chemical antifungals, although industrial application requires optimization of salt and oil concentrations, packaging, and shelf-life evaluation.

Moisture content is a critical determinant of dried fig quality and microbial safety (Galván *et al*., 2023). All samples remained below 26% (Table 4), in compliance with UNECE DDP-14 standards (UNECE, 2016). However, mold growth was detected in all samples, indicating the persistence of xerotolerant fungi under low-moisture conditions. The pH values ranged from 4.91 to 5.23, suggesting moderate acidity that may partially limit fungal proliferation but does

not entirely prevent contamination. These results confirmed that fungal risk in dried figs is multifactorial, influenced by sugar content, moisture, pH, and preservation methods.

Table 4. Mean values of physicochemical parameters and mold counts (log CFU g^{-1}) in dried fig samples.

Dried fig samples	Mold counts (log CFU g^{-1})	Soluble sugars (g 100 g^{-1} DW)	Moisture	pH
Market-purchased dried figs	3.50±0.12 b	53.09±2.55 c	16.65±0.47 c	4.91±0.01 d
Solar-dried *Kahli* figs (with olive oil and salt)	2.29±0.06 d	64.91±1.58 b	18.56±0.44 b	5.23±0.11 a
Solar-dried *Bouhouli* figs	4.48±0.34 a	78.67±1.30 a	25.65±1.26 a	5.06±0.04 b
Solar-dried *Saffouri* figs	3.03±0.15 c	64.41±1.78 b	18.04±1.01 bc	4.98±0.03 c
F-value	63.79**	94.58**	64.04**	84.20**

Values are means ± standard deviation. Means followed by different letters within the same column indicate significant differences according to Duncan's multiple range test at $P \leq 0.05$. **: highly significant ($P < 0.01$). Detection limit: 2 log CFU g^{-1}, refers to the minimum detectable mold count using the method applied.

Mold identification

A total of 10 fungal isolates were obtained from all samples and initially classified based on macroscopic and microscopic characteristics. Six isolates were further characterized by ITS rDNA sequencing using ITS1 and ITS4 primers, with sequences deposited in GenBank under accession numbers OQ608834, OQ608835, OQ608836, OQ608837, OQ608838, OQ608839, and OQ608840.

All samples were contaminated with molds, confirming that figs, despite dehydration, remain suitable substrates for fungal growth (Gilbert and Senyuva, 2008). Prolonged drying or storage under poor conditions, such as high humidity or limited airflow, increases fungal contamination, while proper practices reduce this risk (Karaca and Nas, 2008; Villalobos *et al*., 2019). Dried figs are particularly susceptible to xerophilic fungi, such as *Aspergillus* section *Flavi*, which are capable of growth and mycotoxin production at water activities as low as 0.73 and 0.85, respectively (González-Curbelo and Kabak, 2023). In this study, fungal diversity was relatively low, with three genera accounting for all isolates (Figure 4). The fungal microflora was predominantly composed of *Aspergillus*, representing 80% of all filamentous fungi (8/10 isolates). Species from this genus are well adapted to the physicochemical and nutritional characteristics of dried figs (Taniwaki *et al*., 2018), and their dominance has been consistently reported in previous studies (Javanmard, 2010; Heperkan *et al*., 2012; Galván *et al*., 2022). Nevertheless, the composition of dried fig mycobiota can vary considerably depending on factors such as sampling stage, geographical origin, processing method, and cultivar (Heperkan *et al*., 2012; Henriques *et al*., 2025). *Penicillium* spp. and *Alternaria* spp. were also detected, each at a low prevalence of 10% (Figure 4). Notably, *Penicillium* was found only in market-purchased dried figs, whereas *Alternaria* was detected exclusively in solar-dried *Bouhouli* figs.

Both genera have been previously reported as components of dried fig mycobiota (Javanmard, 2010; Galván *et al*., 2022; Henriques *et al*., 2025). Because *Aspergillus*, *Penicillium*, and *Alternaria* include major mycotoxin-producing species, accurate identification is critical for developing pre- and postharvest control strategies (Galván *et al*., 2023; Jafari *et al*., 2025). At the species level, *Aspergillus terreus* and *A. fumigatus* were the most prevalent (Figure 5), consistent with observations by Villalobos *et al*. (2019) in dried figs processed using different drying methods. *Aspergillus flavus* was also isolated, but at a low prevalence (10%), in contrast to Heperkan *et al*. (2012), who reported it as the most dominant species. Within the *Alternaria genus*, only *A. alternata* was detected in a single sample, confirming its sporadic occurrence, as also noted by Galván *et al*. (2022).

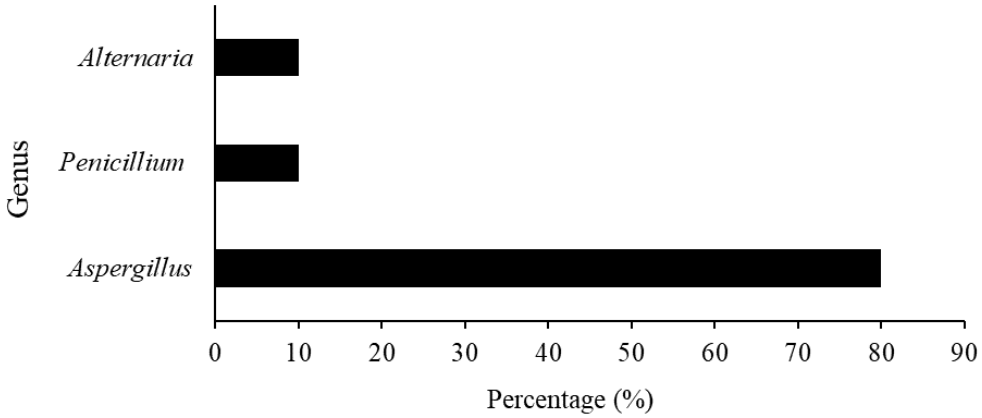

Figure 4. Frequency (%) of mold genera in dried fig samples.

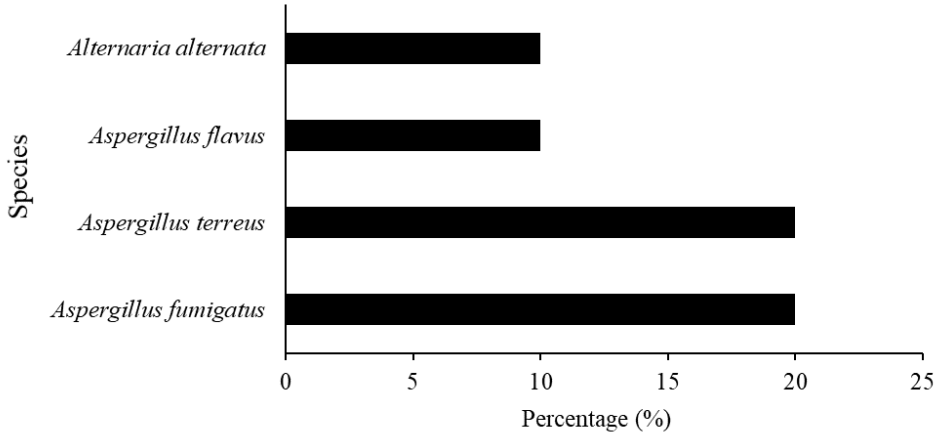

Figure 5. Frequency (%) of identified mold species in dried fig samples.

CONCLUSIONS

This study revealed significant inter-varietal differences among the analyzed dried fig varieties in their physicochemical and phytochemical traits, highlighting both their nutritional value and rich phenolic antioxidant content. However, the recurrent presence of mold contamination, predominantly *Aspergillus* species, emphasizes the need to balance nutritional benefits with food safety considerations, which are critical for consumer health, regulatory compliance, and commercial trade. Although glasshouse solar drying effectively preserved the nutritional and taste qualities of figs, it did not completely prevent fungal growth. Therefore, optimized drying protocols, improved storage conditions, and targeted antifungal strategies are essential to ensure the safety and quality of dried figs. Some limitations of this study should be acknowledged, including the relatively small sample size for mycological analyses, the absence of fresh fig controls, and the lack of mycotoxin assessments. These factors may limit the generalizability of the findings. Future research addressing these gaps will enable a more comprehensive evaluation of nutritional and microbiological quality and support the development of improved postharvest management strategies for dried figs.

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