

Article

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

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Abstract: The eastern region of Morocco is renowned for the production of two varieties of figs, Ghoudane (GD) and Chetoui (CH), which are characterized by their high productivity and quality. To ensure a profitable selling price, producers often dry these figs, a process that not only increases their storage capability but also enhances their nutritional and health benefits. The aim of this study was to investigate the composition and potential health benefits of dried GD and CH figs. The findings of this study reveal that both varieties of dried figs have a rich composition of sugars, lipids, proteins, vegetable fibers, vitamins, minerals, polyphenols, and other nutrients. Moreover, both GD and CH figs that have been sun-dried meet the United Nations Economic Commission for Europe's standard in terms of dry matter and diameter. However, their marketability and commercial quality as dried figs are only classified as Category I or lower-caliber figs. In terms of color, CH figs are lighter and brighter than their GD counterparts, making them more appealing to consumers. Furthermore, this study investigated the extraction of polyphenols and flavonoids from both dried fig varieties using different solvents. Distilled water was found to be the best extraction solvent for polyphenols in both varieties, with GD figs showing a higher content (483.6 mg GAE/100 g) than CH figs (408.3 mg GAE/100 g). Meanwhile, ethanol was found to be the best extraction solvent for flavonoids, with GD figs (180.2 mg of QE/100 g) showing a higher content than CH figs (122.9 mg of QE/100 g). In addition, the majority of the extracts, particularly the ethanol extracts, showed high efficiency against the tested bacteria and yeast. Notably, dried GD figs had higher amounts of total phenolics, total flavonoids, and antioxidant and antimicrobial activities compared to dried CH figs. The study also revealed high correlations between phytochemical content and both antioxidant and antimicrobial activities. In conclusion, this study highlights the nutritional and health benefits of dried figs, particularly the GD variety, and their potential as a natural source of antimicrobial compounds. The findings suggest that dried figs could be an alternative source of natural antimicrobial agents for various applications in the food, pharmaceutical, and cosmetic industries.

Keywords: Eastern Morocco; figs; Ghoudane; Chetoui; drying process; nutritional benefits; polyphenols; flavonoids; biological activities

1. Introduction

The fig is a delectable, nutritious, and palatable fruit that possesses medicinal attributes. It is abundant with natural sugars, dietary fiber, mineral elements, phenolic compounds with antioxidant properties, and volatile molecules that impart a delightful aroma [1]. The antioxidative potential of the fig is accredited to the presence of phenolic compounds, which endow it with its health-promoting characteristics [2]. This fruit is highly recommended due to its possession of valuable antioxidants that are capable of quenching or mitigating the deleterious impact of free radicals on human health, which culminate in cancer and degenerative ailments [3]. In traditional healing practices, the fig has been extensively utilized for managing various maladies, including inflammation, ulcers, and hepatitis, in addition to exhibiting antiviral, antibacterial, and hypoglycemic properties and facilitating cell regeneration, courtesy of its profuse richness in vitamins and minerals. The post-harvest preservation of figs is contingent upon the ambient temperature and degree of ripeness. Due to their delicate skin, figs tend to deteriorate rapidly, with only a day's shelf life at room temperature. However, when kept in an environment with a temperature between 0 and 2 °C and a humidity level of 85–90%, figs can be stored for up to two weeks [4].

This fruit holds significant industrial importance due to its versatile uses, including as dried fig, jam, fig paste, juice, alcohol, syrup, and in other forms [5]. During pre-processing, figs undergo several unit operations such as washing, sorting, and grading to ensure a homogeneous presentation. Larger fruits are often intended for drying purposes [6,7]. The economic and nutritional value of the fig tree is widely acknowledged, with one kilogram of dried figs offering an energy value of 2750 calories, approximately equivalent to the daily caloric requirement of humans [8]. Proper packaging of dried fruits is crucial for adequate product protection, and the packaging materials used should be clean and not cause any external or internal alterations to the product [9]. Figs possess skin that can range from yellow to black, with light-skinned figs being yellow, yellow-green, or green in color and dark-skinned figs being red, purple, black, or brown, allowing for the classification of figs into two categories [10].

Ahfir is renowned for its abundant production of various fig types, notably the CH (with light skin) and GD (with dark skin) varieties, which are widely regarded as the most eminent fig cultivars in the eastern region of Morocco. This recognition has culminated in the location's designation as the host of the annual Aghbal festival, which pays homage to this fruit.

Sun-drying is the preferred method for farmers and the public to dry CH and GD figs, given the absence of drying ovens. However, there has been no previous investigation in the eastern region of Morocco that has expounded upon the characteristics, features, and qualities of these two sun-dried fig variants, CH and GD, including their antioxidant and antibacterial activities. Thus, it is crucial to elucidate these aspects. Due to the aforementioned rationales, three research sites located within Ahfir were chosen to fulfill the study's objectives. Employing a comprehensive approach, a range of standard analytical methods were utilized with the intention of comparing our findings to those of prior investigations or established benchmarks. Alternatively, we sought to demonstrate the nutritional value and benefits provided by the component under scrutiny and verify the degree of similarity or dissimilarity when making intra-variety or inter-variety comparisons between dried figs.

Given the outcomes of our research, we are able to confirm the appropriateness of utilizing the process of sun-drying for the two distinct fig varieties and also identify alternative techniques that can be adopted to enhance the valuation of this nutritional fruit.

2. Materials and Methods

2.1. Material Sampling

Fig trees were identified based on the vernacular of the local farmers, who specifically chose them for their extensive distribution and commercial worth in the region. To conduct the necessary prospection and sampling, traditional orchards belonging to farmers were selected in three distinct locations—Aichoun, Aghbal, and Dehamna—around the city of Ahfir in Eastern Morocco, with adult trees being the focus of the study. The identification process was aided by the cooperative Gharmawne, as well as by the provincial directorates of agriculture.

The samples of two naturally dried fig varieties, Chetoui and Ghoudane, used in our study were obtained through the Gharmawne agricultural cooperative from the three different sites (Figure 1, Table 1) during the harvest season of the year 2022. A fig is considered ripe when it withers, it is no longer erect on the twig, the skin of the fruit is slightly cracked, and the peduncle becomes dry and transparent, allowing the fruit to easily detach [5]. Three distinct kilograms of sample material were collected for each of the two types of dried fig under observation at each of the three designated study stations. In the instances where the study necessitated the examination of a total of 30 dried figs, we selected ten pieces at random from each of the three aforementioned samples belonging to the two types of figs being studied at each of the three study areas. Concerning the studies which were conducted in triplicate, each one was executed on the basis of a sample that was extracted from the grinding of one of the three kilograms of the specific variety being studied in all of the examined areas.

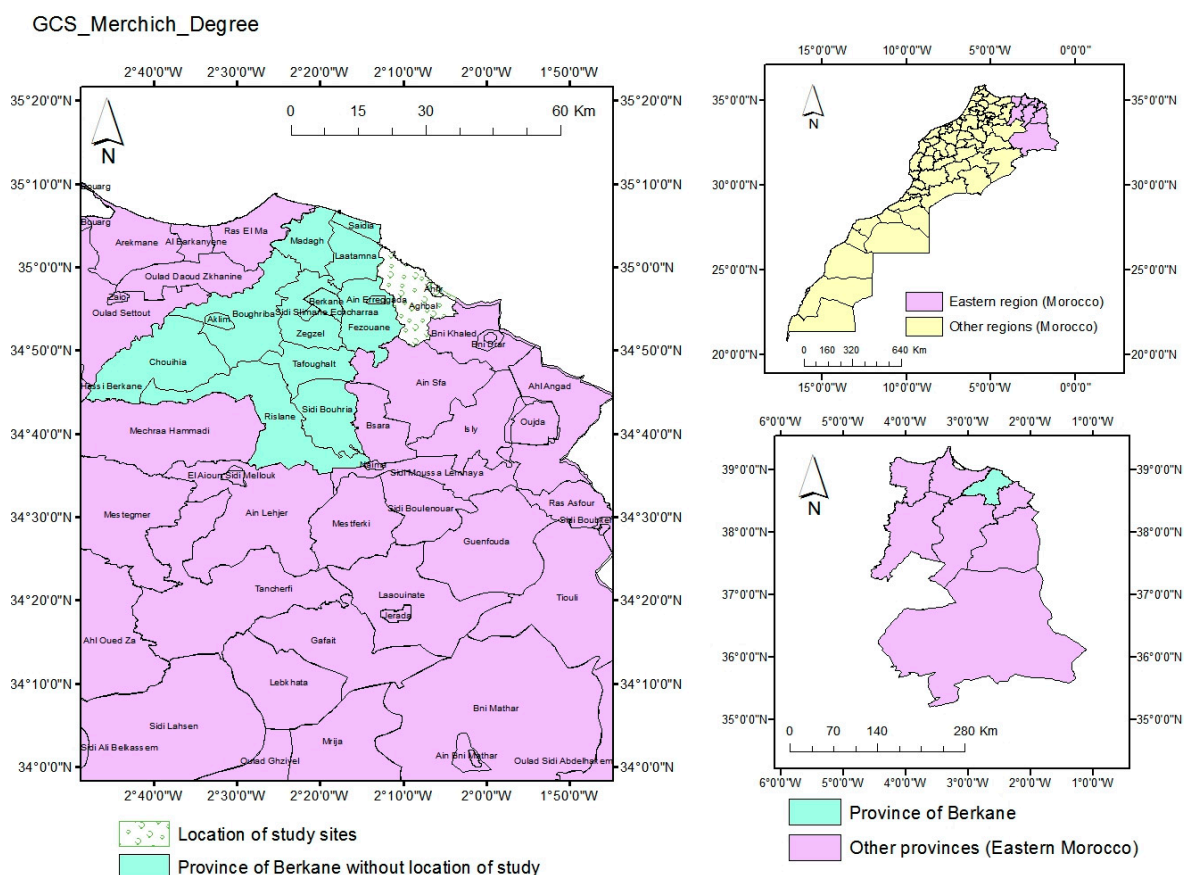


Figure 1. Geographical location of the study in Eastern Morocco. The area is around the city of Ahfir (geographical coordinates: latitude 34.9514, longitude $-2.102534^{\circ}57'5''$ N, $2^{\circ}6'9''$ W. Altitude: 252 m. Mediterranean climate with hot summer (Köppen classification: Csa). Province: Berkane.

Table 1. Short names (codes) and important features of the two studied sun-dried figs [11].

Figs	Location	Code	Category	Autumn Fig Skin Color	Consumption	Shape
Chetoui	Aichoun	CH ₁	Unifer	Green spotted in purple	Fresh/Dried	globose
	Aghbal	CH ₂				
	Dehamna	CH ₃				
Ghoudane	Aichoun	GD ₁	bifer	Black more than purple	Fresh/Dried	oblong
	Aghbal	GD ₂				
	Dehamna	GD ₃				



Pictures show dried Chetoui figs

Pictures show dried Ghoudane figs

2.2. Pomological and Colorimetric Study

Based on the qualitative and quantitative indicators outlined in Table 2, taken from the IPGRI for *Ficus carica* L. (dried fig) [12] and the UNECE DDP-15 STANDARD, which pertains to the marketing and commercial quality control of dried figs [13], we employed a digital scale (KERN PCB 2000-1 Max 2000 g d = 0.1 g, Germany), specifically to obtain measurements of dried fig weight. Additionally, we utilized a digital caliper (PAQUIMETRO DIGITAL INOX 0-150MM, China, Sichuan, Chengdu) to measure the diameter, thickness, and ostiole width of the dried fruit. The skin color measurements were determined from three distinct spots located on varying sides of the equatorial region of the dried fig using a KONICA MINOLTA CR-400 colorimeter. To ensure accurate readings, the Chroma Meter was calibrated to a white and black calibration plate. Each replicate constituted the mean of three measurements, with fifteen replicates being performed in total, in line with the 1976 International Commission on Illumination system of biochemical analysis.

Table 2. Qualitative and quantitative descriptors for the two dried fig varieties.

IPGRI Descriptors	Number of Dried Fruits per Kilogram (7.4.41)
	Color of Dried Fruit (7.4.42) Firmness of Dried Fruits (7.4.43)
ICI * color coordinates	L* = lightness 0 (black) to 100 (white)
	a* = (−a) redness to (+a) greenness
	b* = (−b) yellowness to (+) blueness
	c* = color intensity calculated as $C = (a^2 + b^2)^{1/2}$
UNECE ** STANDARD DDP-15	h = Hue, calculated using the formula $\text{hue} = \tan^{-1}(b/a)$
	h* = 0–360 (red-violet), h* = 90 (yellow), h* = 180 (green) and h* = 270 (blue)
	Provisions concerning quality (Minimum characteristics and water content)
Other descriptors	Sizing Provisions (depending on the number of fruits per kilogram and depending on the diameter)
	Seed quantity (Scarce–Intermediate–Numerous)
	Seeds size (Small–Medium–Large)

Numbers between brackets refer to the descriptor no. given by the IPGRI. * International Commission on Illumination. ** United Nations Economic Commission for Europe (UNECE).

2.3. Physicochemical Parameters

The analytical techniques were conducted in triplicate to obtain precise findings.

Moisture content was determined by steaming 5 g measures of finely ground dried fig in pristine capsules for 2 h at 103 ± 2 °C. The capsules were then cooled in a desiccator before being weighed, and the process was repeated until a consistent weight was obtained [14]. In order to assess the mineral content (ash), 5 g of the sample was incinerated in a muffle furnace for a period of 3–5 h at 550 °C. Following this, the crucibles were cooled in a desiccator and weighed until a constant weight was achieved. The end product was noted to be of a white or greyish-white color [15]. To determine the pH, 5 g of sample, ground into small pieces, was added to 50 mL of distilled water in a beaker, heated in a water bath for 1 h at 70 °C, and stirred occasionally with a spatula. The resulting mixture was then ground in a mortar, taking care to ensure that the electrode was fully immersed in the solution. The titratable acidity, represented as a citric acid percentage, was measured using the AFNOR method (NF V O5–101, 1970), which involved titration with a 0.1 N solution of sodium hydroxide until the pH reached 8.1, indicated by the indicator showing a persistent color change to pink for 30 s. Brix values, on the other hand, were determined using a digital refractometer (HANNA NUMERIQUE HI 96801- ECHELLE 0–85% BRIX, France). For the determination of conductivity, a 20% solids solution of dried fig was prepared, and the electrode of the conductivity meter (C833, Consort, Turnhout, Belgique) was inserted directly into the solution. The reading was taken directly from the display of the conductivity meter [14]. The determination of vitamin C involved the titration of the sample with a diiodine solution of 0.001 mol/L in the presence of a small amount of starch, and the endpoint was identified as the initial permanent appearance of a dark blue-black color due to the starch–iodine complex [15]. Meanwhile, lipid content was evaluated according to the AFNOR method (1982), as described in NF EN ISO 734-1 (2000). The extraction of dried fig samples was performed with non-polar organic solvents using the Soxhlet apparatus [16]. The protein content, on the other hand, was measured using the Kjeldhal method [17].

Two grams of wet mass were randomly selected from each sample composite and subjected to digestion in a closed Poly Tetra Fluoroethylene vessel (CEM MDS-200 microwave, USA, CA, Santa Clara) using a mixture of 65% HNO_3 (3 mL) and 30% H_2O_2 (2 mL). The resulting digested samples were diluted to a volume of 25 mL in a volumetric flask and stored in polyethylene vessels. Analysis of the samples was performed within fifteen days of their preparation. For the determination of Ca and Mg, the samples were diluted with a 0.1% (*w/v*) solution of lanthanum chloride. Analyses of metals of interest were conducted using a Perkin Elmer atomic absorption spectrophotometer (PE-3300) equipped with hollow cathode lamps. The flame technique was implemented for the determination of Ca, Mg, K, Na, Fe, Zn, and Cu. Duplicate solutions were created for every sample and a minimum of three distinct readings were collected to mitigate any errors. The mean values were utilized to calculate the concentrations. Merck (Darmstadt, Germany) provided standard solutions of metals (1000 mg/L in 0.1 N HNO_3), which were procured for this purpose. Stock solutions were created from the standard solutions, and working standards were generated by diluting the stock solutions [18]. The quantification of the amount of phosphorus in the dried figs was determined using the spectrophotometric molybdovanadate method [19].

To perform extraction, 50 g of the sample was homogenized with 500 mL of distilled water and stirred for 24 h at room temperature. The extracts were then filtered using Whatman n°1 filter paper. The samples were prepared using the modifications to the method described by Escarpa and Gonzalez (1998) [20]: specifically, 50 g of dried fruit were ground and homogenized in a blender, then extracted three times with 250 mL of 80% ethanol or 80% acetone containing 1% 2,6-di-tert-butyl-4-methylphenol using an ultrasonic bath. The resulting extracts were combined, filtered through Whatman No. 1 filter paper, and then evaporated using a rotary evaporator to obtain the crude dry extract. The dried extracts were stored at -20 °C until analysis was performed.

The determination of the total phenolic (TP) content of extracts was carried out by employing the Folin–Ciocalteu (FC) reagent, using 100 μL extract mixed with 500 μL FC

reagent and 400 μL of 7.5% (w/v) Na_2CO_3 . The mixture was stirred and incubated in the dark at room temperature for ten minutes, and then the absorbance was measured at 760 nm. The results are expressed as mg Gallic acid equivalent (GAE)/100 g dry weight (DW) of sample, with reference to the calibration curve for Gallic acid [21]. The AlCl_3 method was used for the determination of the total flavonoid (TF) content of prepared extracts. The analysis was performed by adding 500 μL of each extract to 1500 μL of 95% methanol, 100 μL of 10% (w/v) AlCl_3 , 100 μL of 1 M sodium acetate, and 2.8 mL of distilled water. For 30 min, the mixture was mixed and incubated in the dark at room temperature. The blank was made by replacing the extract with 95% methanol, and the absorbance at 415 nm was measured. Using quercetin (QE) as a standard, the TF of extracts was expressed on a dry weight (DW) basis as mg of QE equivalent per 100 g DW of sample [22]. The antioxidant activity was evaluated by the DPPH free-radical scavenging assay, where ascorbic acid was utilized as a positive control. Different concentrations of each extract and ascorbic acid standard were prepared. Afterwards, each concentration from the extract or standard was added to 2.5 mL of the prepared DPPH methanol solution (2 mg DPPH/100 mL methanol) to the final volume of 3 mL. After 30 min of incubation at room temperature, the absorbance was measured at 515 nm against a blank. The percentage (%) DPPH free-radical scavenging activity was calculated using the following formula:

$$\text{Radical Scavenging Activity (\%)} = \left[\left(\frac{A_{\text{blank}} - A_{\text{extract or standard}}}{A_{\text{blank}}} \right) \right] \times 100$$

where A_{blank} is the absorbance of the control reaction (all reagents except the extract or standard are present), and $A_{\text{extract or standard}}$ is the absorbance of the extract or standard at different concentrations of the extract or the standard. The IC_{50} values were graphically determined from the sigmoidal-shaped curve of antioxidant concentration (mg/mL) versus % inhibition, as described in [22].

2.4. Antimicrobial Activity Assay

2.4.1. Bacterial and Fungal Strains

In this study, a group of five microorganisms was used. This group included two Gram-negative bacterial strains, *Escherichia coli* (ATCC 25922) and *Pseudomonas aeruginosa* (ATCC 27853), as well as two Gram-positive bacterial strains, *Staphylococcus aureus* (ATCC 25923) and *Bacillus subtilis subsp. spizizenii* (ATCC 6633), and a pure fungal strain, *Candida albicans*. To maintain these microorganisms, they were grown on Biorad's Mueller–Hinton agar (MH) at +4 °C. The cultures were subcultured every two weeks to ensure growth and check for purity.

2.4.2. Antimicrobial Activities

The study utilized the agar disc diffusion test, following the guidelines of NCCLS (2005), to evaluate the antimicrobial activity of the extracts. The extracts were solubilized in either DMSO or distilled water. Petri dishes containing 20 mL of sterile Mueller–Hinton agar (Sigma, Paris, France) were prepared and inoculated with a cell suspension (200 mL) adjusted to a 10^6 cfu/mL concentration per the McFarland 0.5 technique. Sterile filter paper discs with a diameter of 6 mm were loaded with 20 mL of the extract solution and placed on the surface of the agar. Plates were incubated at 37 °C for 24 h. Positive controls such as gentamicin (15 mg) and amoxicillin (25 mg) were utilized, while paper discs containing 20 mL of DMSO or distilled water were used for negative controls. The inhibition zones were measured in millimeters using digital calipers, and tests were repeated thrice to minimize errors. An inhibition zone of 14 mm or more (including the disc diameter) indicated high antibacterial activity [23].

The minimum inhibitory concentration (MIC) for bacterial growth was determined using a serial dilution technique in 96-well microtiter plates [24]. This amount of extract, to be used in the assay, was calculated by evaporating the solvent of 1 mL of extract, solubilizing the dry extract in 20% v/v DMSO, and subsequently diluting it tenfold with

Mueller–Hinton broth. One hundred microliters of the broth bacterium or yeast solutions and dilutions were then transferred into microtiter plates and incubated for 24 h at 37 °C. The positive control contained 100 µL of bacterium solution plus 100 µL of Mueller–Hinton broth, while the negative control contained only 100 µL of diluent plus 100 µL of extract without bacteria. Compared to the control well, positive and negative results were evaluated based on turbidity after 24 h. MIC values were recorded as the lowest concentration of the extract that completely inhibited bacterial growth, as indicated by a clear well. All extracts were tested in triplicate.

2.5. Statistical Analysis

The data obtained were statistically analyzed using IBM SPSS Statistics V21.0 software for descriptive statistics to present them as mean $\pm$ SD. The analysis of variance (ANOVA) was performed to compare the average of the characteristics studied, followed by post-hoc testing (Tukey's test) at a 5% threshold. Graphs were generated using Graph-Pad Prism 9 software. The correlation coefficients (R^2) for spectrophotometric assays were determined using the Microsoft Office Excel 2010 software (Microsoft Corporation, Redmond, WA, USA).

3. Results and Discussions

The primary criteria for determining the marketing and commercial quality of dried figs are the number of units per kilogram and the unit diameter, with a maximum of 65 units per kilogram to obtain the “Extra” category and 120 units per kilogram for Category I, and a minimum diameter of 18 mm for black fig varieties and 22 mm for white fig varieties. Based on these criteria, the CH and GH varieties belong to Category I and meet the unit diameter requirements [13]. The dried CH figs were found to have a code number 8 (between 71 and 80 dried figs per kilogram), while the dried GD figs were assigned a code of 9 (from 81 to 90 dried figs per kg). GD₃ was the thickest dried fig among the samples tested, followed by GD₂, GD₁, CH₁, CH₃, and CH₂, in that order. This is attributed to the GD fruit's oblong shape and the CH fruit's globose shape, which is more suitable for trade.

The results also revealed that the dried figs from GD had a larger ostiole width, with GD₁ exhibiting the widest ostiole, followed by GD₃, GD₂, CH₂, CH₃, and CH₁, in that order. It should be noted that a larger ostiole diameter can facilitate the entry of pollutants and pathogens, making figs with this trait unsuitable for the fig industry or storage [25]. Dried CH figs had a higher moisture content than their GD counterparts (CH₃ 25.44%, CH₂ 25.61%, and CH₁ 24.12% vs. GD₂ 24.31%, GD₃ 24.12%, and GD₁ 24.31%). For untreated dried figs, moisture levels should not exceed 26.0% [13]. All the samples examined in this study met this recommended threshold. The ash content of the dried CH figs was higher than that of the dried GD figs (CH₁ 2.740%, CH₃ 3.037%, and CH₂ 2.347% vs. GD₃ 2.370%, GD₁ 2.347%, and GD₂ 2.370%). The variation in ash content between the two varieties may be attributed to differences in their geographic origin, climatic conditions, and soil characteristics [26]. Other ecological and genetic factors, such as plant age, vegetative cycle, and genetic makeup, may also play a role in the observed variations [27]. Finally, all the dried fig samples were firm, with GD containing an intermediate number of small seeds and CH containing a limited quantity of tiny seeds.

The statistical analysis results (Table 3) indicate no significant differences between the dried fig varieties CH and GD in terms of their weight and thickness. Both varieties were homogeneous in diameter, dry matter, moisture, ash, and organic material, but there were significant differences between them in these measurements. The only notable difference observed was in ostiole diameter, specifically between GD₁ and both CH₁ and CH₃.

Table 3. Pomological and physicochemical characters of dried fig varieties.

Dried Figs		CH ₁	CH ₂	CH ₃	GD ₁	GD ₂	GD ₃
Unitary weight (g)	Minimum	9.330	9.380	10.20	9.240	9.630	8.160
	Maximum	18.54	16.01	18.60	15.00	13.78	15.06
	Mean	12.66 ^a	12.72 ^a	12.41 ^a	11.77 ^a	11.47 ^a	11.65 ^a
	Std. Deviation	2.457	2.229	1.974	1.644	1.526	2.115
Units of dried figs per Kg		78.98	78.61	80.58	84.96	87.18	85.83
Diameter (mm)	Minimum	34.94	35.82	34.81	27.20	25.76	24.36
	Maximum	47.68	46.36	46.35	32.77	31.00	31.62
	Mean	40.54 ^a	41.82 ^a	40.05 ^a	29.63 ^b	27.87 ^b	28.04 ^b
	Std. Deviation	3.545	3.300	2.768	1.917	1.375	2.149
Thickness (mm)	Minimum	6.950	6.700	5.780	8.500	10.15	8.690
	Maximum	11.76	11.81	11.28	18.43	15.78	18.50
	Mean	8.671 ^a	8.814 ^a	8.596 ^a	13.06 ^a	13.52 ^a	13.57 ^a
	Std. Deviation	1.426	1.175	1.430	2.631	1.647	2.682
Ostiole (mm)	Minimum	2.810	2.650	2.700	2.840	2.570	3.220
	Maximum	4.910	5.350	4.950	5.680	4.830	4.800
	Mean	3.639 ^b	3.835 ^{ab}	3.689 ^b	4.165 ^a	3.940 ^{ab}	4.100 ^{ab}
	Std. Deviation	0.5619	0.6926	0.6427	0.7753	0.5906	0.5118
Dry matter %	Mean	74.4 ^b	74.5 ^b	74.6 ^b	75.7 ^a	75.9 ^a	75.8 ^a
Moisture Content %	Mean	25.61 ^a	25.47 ^a	25.44 ^a	24.31 ^b	24.12 ^b	24.22 ^b
	Std. Deviation	0.1314	0.4593	0.6899	0.4661	0.1976	0.4584
Ash Contents %	Mean	2.740 ^c	3.037 ^a	2.890 ^b	2.363 ^d	2.370 ^d	2.347 ^d
Organic material %	Mean	97.26 ^b	96.96 ^d	97.11 ^c	97.64 ^a	97.63 ^a	97.65 ^a
	Std. Deviation	0.1058	0.02887	0.0173	0.04163	0.04359	0.1021
Firmness of dried fruit		Medium	Medium	Medium	Medium	Medium	Medium
Seed quantity		scarce	scarce	scarce	Intermediate	Intermediate	Intermediate
Seeds size		Small	Small	Small	Small	Small	Small

Data represent average values $\pm$ standard deviation of ($n = 3$ for dry matter, moisture, ash, and organic material. $n = 30$ for the other parameters) independent samples. Ordinary one-way ANOVA using post-hoc testing (Tukey's test) at the 5% threshold. Means followed by a different letter in the same line are significantly different ($p < 0.05$).

Table 4 illustrates that the dried figs of the GD variety have a dark coloring, whereas the color of dried figs of the variety CH is medium. This color variation is attributed to the skin color of the fresh fig, which is black and purple for GD and green with purple spots for CH, as reported in [11]. The lightness values (L^*) of dried CH figs (CH₂: 39.62; CH₁: 40.22; CH₃: 41.90) and their chromacity values (c^*) (CH₂: 27.11; CH₃: 28.28; CH₁: 29.19) were higher than those of GD figs (L^* : GD₃: 23.64; GD₂: 23.65; GD₁: 24.08) (c^* : GD₂: 5.131; GD₁: 5.588; GD₃: 5.606). Consequently, dried CH figs possess a lighter, brighter, and clearer color as compared to GD figs. The a^* values of dried CH figs (CH₂: 11.91; CH₃: 12.79; CH₁: 13.16) indicate greenness, and their b^* values (CH₂: 24.32; CH₃: 25.12; CH₁: 25.93) indicate blueness. Similarly, the a^* values of dried GD figs (GD₂: 3.302; GD₃: 3.707; GD₁: 3.736) show greenness (close to redness), and their b^* values (GD₂: 3.842; GD₁: 4.065; GD₃: 4.107) indicate blueness (close to yellowness). As a result, dried CH figs are greener and bluer than GD figs. The tint angle values reveal that the dried CH figs—with H° values of 61.91 (CH₁), 62.52 (CH₃), and 63.75 (CH₂)—and GD figs—with H° values of 47.11 (GD₁), 48.06 (GD₂), and 49.26 (GD₃)—correspond to the red–yellow interval, with

the CH figs close to yellow and the GD figs close to the center of this interval. These color results demonstrate that dried CH figs are preferred by consumers over the GD variety, as reported in [3,28]. Polyphenols, such as anthocyanins and flavonols, in their native form—or after oxidation, such as via the enzymatic browning phenomenon—are known to be involved in color. They are abundant in many fruits and are often concentrated in the outer parts, as reported in [29]. Several reactions, such as pigment degradation, browning reactions such as the Maillard reaction of hexoses, and ascorbic acid oxidation, can affect the color of fruits or their derivatives during heat treatment [30]. Factors such as acidity, pH, temperature, processing time, fruit variety, and heavy metal contamination are other variables that can potentially affect fruit color, as reported in [31–33]. The statistical analysis of the data collected from the two dried fig varieties, CH and GD, using ordinary one-way ANOVA at a 5% significance level (Table 2) revealed a homogeneous distribution of the parameters L^* , a^* , b^* , and c^* . However, significant differences were observed between the two varieties for these parameters. The analysis showed that hue was not a significant parameter for distinguishing between the two investigated dried fig varieties.

Table 4. Color measurements of dried fig varieties.

		CH ₁	CH ₂	CH ₃	GD ₁	GD ₂	GD ₃
Color of Dried Fruit (7.4.42)		Medium	Medium	Medium	Dark	Dark	Dark
L* Lightness	Minimum	30.15	32.10	32.51	22.31	19.59	19.57
	Maximum	51.04	49.92	53.41	27.21	29.99	26.10
	Mean	40.22 ^a	39.62 ^a	41.90 ^a	24.08 ^b	23.65 ^b	23.64 ^b
	Std. Deviation	6.333	4.857	6.558	1.559	2.872	2.156
a* redness to greenness	Minimum	8.770	7.830	9.080	2.150	1.940	0.9200
	Maximum	17.85	16.28	17.85	5.260	5.360	5.950
	Mean	13.16 ^a	11.91 ^a	12.79 ^a	3.736 ^b	3.302 ^b	3.707 ^b
	Std. Deviation	2.753	2.494	2.324	0.9881	1.240	1.646
b* yellowness to blueness	Minimum	12.01	16.95	15.22	2.390	1.450	1.480
	Maximum	33.25	34.19	33.12	8.180	8.160	8.080
	Mean	25.93 ^a	24.32 ^a	25.12 ^a	4.065 ^b	3.842 ^b	4.107 ^b
	Std. Deviation	7.767	5.473	5.650	1.349	1.747	1.677
c* color intensity	Minimum	15.24	18.86	17.72	3.408	2.422	1.775
	Maximum	37.05	37.87	35.37	9.246	9.763	9.153
	Mean	29.19 ^a	27.11 ^a	28.28 ^a	5.588 ^b	5.131 ^b	5.606 ^b
	Std. Deviation	7.795	5.835	5.642	1.412	1.969	2.154
H Hue	Minimum	52.01	58.97	54.88	33.64	36.78	38.01
	Maximum	69.68	69.60	69.47	62.22	64.10	66.74
	Mean	61.91 ^a	63.75 ^a	62.52 ^a	47.11 ^a	48.06 ^a	49.26 ^a
	Std. Deviation	5.818	3.034	4.646	8.721	9.505	9.940

Data represent average values $\pm$ standard deviation of thirty independent samples. Ordinary one-way ANOVA using post-hoc testing (Tukey's test) at the 5% threshold. Means followed by a different letter in the same line are significantly different ($p < 0.05$).

Table 5 presents evidence that dried GD figs have a slightly acidic pH (GD₂: 4.613; GD₁: 4.617; GD₃: 4.623) in comparison to dried CH figs (CH₃: 4.713; CH₁: 4.717; CH₂: 4.72). pH is an important parameter in food quality control and a crucial criterion for categorizing fruits and vegetables as it plays a crucial role in their preservation. Indeed, an acidic product is better protected against biological and enzymatic alterations than a neutral-pH

product [34]. An acidic pH is observed in dried figs because the samples contain less water, and organic acids are the most predominant [35]. Moreover, GD dried figs exhibited a higher percentage of citric acid compared to CH figs. Titratable acidity refers to a measure of all the acids in a sample, and it is a significant indicator for predicting the harvest time and a sign of the fruit's ripeness and sugar content. Generally, organic acid content decreases during maturity, and a lack of acidity makes food tasteless, whereas excessive acidity results in an unpleasant taste [36,37]. Organic acids are intermediates in metabolic processes and influence the growth of microorganisms, thus affecting the preservation quality of products. They are, therefore, directly involved in growth, maturation, and fruit senescence, as well as influencing their sensory properties [38–40]. Dried CH figs contained a higher amount of Brix (19.18–19.25) than GD figs (18.72–18.75). Soluble solids comprise all solids dissolved in water, including sugars, salts, proteins, and carboxylic acid [41].

Table 5. Physicochemical characteristics of dried fig varieties.

Dried Figs Parameters	CH ₁	CH ₂	CH ₃	GD ₁	GD ₂	GD ₃
pH	4.717 ^a ± 0.040	4.723 ^a ± 0.030	4.713 ^a ± 0.030	4.617 ^b ± 0.030	4.613 ^b ± 0.015	4.623 ^b ± 0.032
Titrateable acidity (% of citric acid)	1.21 ^b ± 0.008	1.20 ^b ± 0.014	1.20 ^b ± 0.008	1.39 ^a ± 0.008	1.40 ^a ± 0.029	1.40 ^a ± 0.008
Vitamin C (mg/100 g)	1.13 ^a ± 0.010	1.14 ^a ± 0.012	1.14 ^a ± 0.015	0.99 ^b ± 0.009	1.00 ^b ± 0.005	1.00 ^b ± 0.009
soluble solids content (Brix)	19.25 ^a ± 0.050	19.18 ^a ± 0.163	19.32 ^a ± 0.087	18.72 ^b ± 0.060	18.75 ^b ± 0.055	18.73 ^b ± 0.07
Lipid content (%)	1.51 ^a ± 0.043	1.50 ^a ± 0.025	1.51 ^a ± 0.013	1.04 ^b ± 0.006	1.04 ^b ± 0.016	1.03 ^b ± 0.014
Protein content (%)	3.515 ^a ± 0.087	3.572 ^a ± 0.183	3.534 ^a ± 0.114	3.211 ^a ± 0.183	3.204 ^a ± 0.242	3.125 ^a ± 0.301
Total sugars (%)	52.45 ^{ab} ± 0.393	53.40 ^a ± 0.481	53.51 ^a ± 0.126	49.36 ^d ± 0.479	50.33 ^{cd} ± 0.458	51.01 ^{bc} ± 0.936
Crude fiber (%)	5.437 ^d ± 0.2458	5.677 ^{cd} ± 0.1963	5.583 ^{cd} ± 0.1201	5.990 ^{abc} ± 0.1400	5.743 ^{bcd} ± 0.1415	6.290 ^a ± 0.0700
Conductivity (mS.m ^{−1})	94.67 ^a ± 0.8159	95.08 ^a ± 1.08	94.89 ^a ± 2.46	81.80 ^b ± 1.72	81.29 ^b ± 1.298	82.2 ^b ± 0.9762

Data represent average values ± standard deviation of three independent samples. Ordinary one-way ANOVA using post-hoc testing (Tukey's test) at the 5% threshold. Means followed by a different letter in the same line are significantly different ($p < 0.05$).

Dried CH figs exhibit a higher vitamin C content (1.13–1.14 mg/100 g) than dried GD figs (0.99–1.00 mg/100 g). Vitamin C, which includes ascorbic acid and dehydroascorbic acid, is essential to food quality in many horticultural crops due to its biological actions in the human body. Numerous variables affect variations in vitamin C content in fruits, including fruit variety, post-harvest handling conditions, pre-harvest environmental variables (such as sun exposure, cultural practices, ripeness, and harvesting method), and genotypic characteristics [42,43]. Additionally, dried CH figs are richer in lipid content (1.50–1.51%) than dried GD figs (1.03–1.04%). Lipids are essential biological components that offer the necessary calories, fatty acid intake, and fat-soluble vitamins [44].

The protein content of dried CH figs ranges from 3.512 to 3.572%, while that of dried GD figs ranges from 3.125 to 3.211%. Although proteins from plants have a lower biological value than animal proteins, they perform essential functions in human diets, including enzymatic and transporter roles and even as defense agents that can trigger allergic reactions [45].

The total sugar content of dried CH figs (CH₁: 52.45%–CH₃: 53.51%) is higher than that of dried GD figs (GD₂: 49.36%–GD₃: 51.01%). Total sugars include all monosaccharides, oligosaccharides, and polysaccharides. Fruit carbohydrate content is crucial due to its impact on organoleptic properties and use as a ripeness criterion. Moreover, it affects the fruit's stability and preservation [46]. Sweeter figs are more popular in Turkish and Eastern markets, whereas less-sweet variants are preferred in European markets [47]. Dried GD figs have higher crude fiber content than dried CH figs. Dietary fibers, which are resistant

to human digestive enzymes, include the complex carbohydrate components of plant cell walls such as cellulose, hemicellulose, and pectins [48].

Conductivity measurement is a widely used and reliable method in quality control applications due to its low cost, sensitivity, and high reliability. It provides an estimate of the total number of ions in a solution. Dried CH fig samples exhibited the highest electrical conductivity values (CH₁ 94.67–95.08 mS/m, CH₂), while dried GD fig samples had the lowest values (GD₂: 81.29 mS/m–GD₃: 82.2 mS/m). These results are similar to those observed in dried fig varieties in Morocco's Rabat-Salé, Temara, and Casablanca markets (75.6–95.4 mS/m) [49].

The results of a standard one-way ANOVA with a 5% threshold (see Table 3) demonstrate that significant differences exist between the two varieties of dried figs, CH and GD, in terms of pH, titratable acidity, vitamin C content, soluble solids, lipid content, and conductivity. Moreover, these parameters exhibit a homogeneous distribution within each variety. However, no significant variation was observed between the two varieties in terms of protein content. The CH variety displays homogeneity for total sugars, whereas the GD variety exhibits heterogeneity, with significant variation detected between GD₁ and GD₃. The variation between CH₁ and GD₃ is not significant, however. In terms of crude fiber content, the GD variety is heterogeneous, with significant variation observed between GD₂ and GD₃, while the CH variety is homogeneous. Notably, a significant difference exists between GD₃ and CH, as well as between GD₁ and CH₁.

Table 6 presents data demonstrating that potassium is the predominant mineral element present in all of the samples analyzed. The range of variation for potassium was greater in dried figs of the CH variety (756 to 775.35 mg/100 g) than in those of the GD variety (570.5 to 609.7 mg/100 g). Given that potassium is a mineral that regulates blood pressure, the consumption of figs can be beneficial for hypertensive patients. Moreover, the potassium content of figs can offset the increased urinary calcium loss caused by high-salt diets, which in turn can help prevent rapid bone thinning [18]. Likewise, dried CH figs were found to be rich in minerals, including calcium (161.6 to 166.1 mg/100 g), sodium (76.25 to 83.76 mg/100 g), and phosphorus (82.76 to 84.76 mg/100 g), compared to dried GD figs, which had lower levels of calcium (116.84 to 120.8 mg/100 g), sodium (16.09 to 16.44 mg/100 g), and phosphorus (65.93 to 68.25 mg/100 g). On the other hand, dried GD figs had higher concentrations of other minerals, including magnesium (102.4 to 116.9 mg/100 g), iron (3.33 to 3.95 mg/100 g), copper (0.33 to 0.42 mg/100 g), and zinc (0.58 to 0.62 mg/100 g), compared to dried CH figs, which had lower levels of magnesium (52.5 to 56 mg/100 g), iron (2.4 to 2.76 mg/100 g), copper (0.27 to 0.3 mg/100 g), and zinc (0.39 to 0.46 mg/100 g). It is important to note that before phosphorus can be absorbed through the intestinal wall and into the bloodstream, the body requires one gram of calcium for every gram of phosphorus consumed in the diet. If the necessary calcium is not available from food, the body will extract it from the stored deposits in the bones. The Ca/P ratio found in both dried CH and GD figs (ranging from 1.73 to 1.98) is consistent with the recommendation of most nutritionists, who advise that optimal values should fall between 1.2 and 2 parts calcium to 1 part phosphorus [18]. According to the results of Tukey's multiple comparisons test presented in Table 6, there were significant differences observed in the potassium (K) and phosphorus (P) content between and within the two varieties of dried figs, CH and GD. Specifically, the distribution of sodium (Na) was homogeneous within the dried GD figs, whereas it was heterogeneous within the dried CH figs, and there was a significant variation between these two varieties for this mineral. Furthermore, the variation in calcium (Ca) was significant both between the two varieties of dried figs and within the CH and GD varieties (i.e., between CH₁ and CH₃ and between GD₁ and GD₃). The variation in magnesium (Mg) was also significant between the dried CH and GD figs, as well as between CH₁ and CH₂ and between the dried GD figs from all three sites. With regard to iron (Fe) content, its distribution was homogeneous within the dried CH figs, but heterogeneous within GD figs due to significant variation between GD₁ and GD₃, and there was likewise a significant difference in iron content between the dried CH and GD figs.

On the other hand, the distribution of copper (Cu) was homogeneous within both dried fig varieties, and the variation was significant only between GD₃ and both CH₁ and CH₂. Finally, there was no significant difference between the dried CH and GD figs regarding zinc (Zn) content.

Table 6. Mineral composition of dried figs *Ficus carica* in mg/100 g.

	Na	K	Ca	Mg	Fe	Cu	Zn	P	Ca/P
CH ₁	83.76 ^a ± 0.12	756 ^c ± 0.1	161.6 ^b ± 1.18	52.5 ^e ± 0.14	2.76 ^c ± 0.12	0.28 ^b ± 0.05	0.39 ^a ± 0.32	82.76 ^c ± 0.12	1.95
CH ₂	80.50 ^b ± 0.25	772.76 ^b ± 0.12	164.2 ^{ab} ± 0.75	56 ^d ± 0.1	2.4 ^c ± 0.08	0.27 ^b ± 0.02	0.46 ^a ± 0.12	84.76 ^a ± 0.1	1.93
CH ₃	76.25 ^c ± 0.24	775.35 ^a ± 0.15	166.1 ^a ± 1.12	54.35 ^{de} ± 0.15	2.6 ^c ± 0.1	0.3 ^{ab} ± 0.1	0.44 ^a ± 0.22	83.5 ^b ± 0.15	1.98
GD ₁	16.44 ^d ± 0.11	578.9 ^e ± 1.23	120.8 ^c ± 1.10	102.40 ^c ± 1.06	3.76 ^{ab} ± 0.12	0.37 ^{ab} ± 0.01	0.59 ^a ± 0.01	65.93 ^f ± 0.13	1.83
GD ₂	16.09 ^d ± 0.26	570.5 ^f ± 1.11	118.67 ^{cd} ± 1.04	111.70 ^b ± 1.14	3.95 ^a ± 0.33	0.33 ^{ab} ± 0.01	0.58 ^a ± 0.02	68.25 ^d ± 0.11	1.73
GD ₃	16.43 ^d ± 0.16	609.7 ^d ± 1.41	116.84 ^d ± 0.63	116.90 ^a ± 1.02	3.33 ^b ± 0.31	0.42 ^a ± 0.02	0.62 ^a ± 0.02	66.96 ^e ± 0.13	1.74

Data are expressed as mean in mg/100 g ± standard deviation ($n = 3$). Ordinary one-way ANOVA using post-hoc testing (Tukey's test) at the 5% threshold. Means followed by a different letter in the same column are significantly different ($p < 0.05$).

The polyphenol contents of extracts derived from two varieties of dried figs, CH and GD, were subjected to statistical analysis using ANOVA (5%) (Table 7). The results of the analysis demonstrate that the aqueous extract of GD fig, which exhibits the highest concentration of polyphenols, differs significantly from all other extracts. Furthermore, while the ethanol extract differs significantly from each of the extracts derived from CH figs, it does not show a significant difference compared to the acetone extract of GD fig. The GD acetone extract, which has the lowest polyphenol concentration among the GD extracts, does not differ from the CH aqueous extract, which has the highest polyphenol concentration among CH extracts. However, it differs significantly from the other two ethanol and acetone extracts of CH Fig. The aqueous extract of CH fig displays a significant difference in polyphenol concentration compared to the two other extracts of the same variety. Additionally, the ethanol and acetone extracts of CH fig show a significant difference only between ethanol extract CH₂ and the acetone extracts CH₂ and CH₃. The solubility of polyphenols is influenced by various factors, such as the type of solvent used, degree of polymerization, interaction with other components, and the formation of insoluble complexes. Methanol has been reported as the ideal solvent for high polyphenol recovery [50]. Polyphenol extract content estimation is affected by the extraction (nature of solvent, solvent concentration, extraction temperature, extraction time, sample to solvent ratio, and number of extractions) and quantification methods (colorimetric assay, HPLC/DAD analysis) used. The primary limitation of the colorimetric assay is its low specificity towards the Folin–Ciocalteu's reagent. This reagent is highly sensitive to reductions in hydroxyl groups, including those found in phenolic compounds and various sugars and proteins [51]. As a result, non-phenolic substances eluted by the extraction solvent, such as sugars, proteins, and dyes, could potentially impact the phenolic rating [52].

Table 7. Total phenolic and flavonoid content of dried fig varieties.

	Extracts	CH ₁	CH ₂	CH ₃	GD ₁	GD ₂	GD ₃
TP (mg of GAE/100 g)	Aqueous	403.7 ^c ± 3.143	408.3 ^c ± 1.752	405.7 ^c ± 2.654	479.8 ^a ± 6.252	483.6 ^a ± 3.998	479.3 ^a ± 3.387
	Ethanol 80%	369.5 ^{de} ± 8.322	372.5 ^d ± 10.95	365.9 ^{de} ± 12.21	430.7 ^b ± 4.149	429.1 ^b ± 3.702	427.2 ^b ± 4.179
	Acetone 80%	361.3 ^{de} ± 7.292	352.2 ^e ± 9.151	353.5 ^e ± 6.048	418.6 ^{bc} ± 3.702	414.2 ^{bc} ± 4.844	419.4 ^{bc} ± 1.217
TF (mg of QE/100 g)	Aqueous	113.5 ^{ef} ± 2.500	114.0 ^{ef} ± 2.237	112.2 ^{ef} ± 1.25	168.2 ^c ± 3.387	168.8 ^{bc} ± 5.393	167.4 ^c ± 4.336
	Ethanol 80%	122.9 ^d ± 3.763	120.8 ^{de} ± 0.6083	122.8 ^d ± 2.030	179.1 ^{ab} ± 5.143	180.2 ^a ± 4.368	179.1 ^{ab} ± 3.668
	Acetone 80%	100.2 ^f ± 3.329	101.5 ^f ± 4.388	103.8 ^{fg} ± 3.686	160.4 ^c ± 2.252	161.5 ^c ± 3.122	162.3 ^c ± 2.207

TP: total phenolic content, TF: total flavonoid content. Data represent average values ± standard deviation of three independent samples; ordinary one-way ANOVA using post-hoc testing (Tukey's test) at the 5% threshold. Means followed by a different letter in the same content (TP or TF) are significantly different ($p < 0.05$).

The statistical analysis of flavonoids in extracts derived from dried CH and GD figs revealed a uniform distribution of the ethanol GD extracts, which contain the highest concentrations of these compounds, and significant variation with all other GD and CH extracts except for that between the ethanol extracts GD₁ and GD₃ and the aqueous extract GD₂. There is no significant difference in flavonoids between the aqueous and acetone extracts of dried GD figs. Still, there is a significant difference between the acetone GD extracts and the ethanol CH extracts. Among the extracts of dried CH figs, the ethanol extract contains the highest concentration of flavonoids, and this distribution is uniform. The ethanol and aqueous extracts of CH fig show significant variation in flavonoid concentration, but not between the ethanol CH₂ extract and the aqueous extracts. The flavonoid content of the CH acetone extracts, which are the least rich in these bioactive compounds, differs significantly from the aqueous CH extracts, except for the difference between the CH₃ acetone extract and the aqueous extracts. Water and ethanol are two polar solvents used to extract glycosylated flavonoids and tannins in particular, while alcohols or water–alcohol mixtures are used to extract aglycone flavonoids [53].

According to the results of the extraction and quantification methods, it is evident that the polyphenol content of dried GD figs is higher than that of dried CH figs. Specifically, the aqueous extract of dried GD figs has the greatest phenolic fraction (479.3 to 483.6 mg EAG/100 g), followed by the ethanol extract (427.2 to 430.7 mg EAG/100 g), and finally, the acetone extract (414.2 to 419.4 mg EAG/100 g). Meanwhile, the less polyphenol-rich dried CH figs contain the aqueous extract (403.6 to 408.3 mg EAG/100 g), followed by the Ethanol extract (365.9 to 372.5 mg EAG/100 g), then the acetone extract (352.2 to 361.3 mg EAG/100 g). Previous research indicates that darker-colored fig varieties are known to have higher levels of phenolic compounds [54,55].

Furthermore, the dried GD fig extracts exhibit higher flavonoid content than CH extracts. The ethanol GD extracts had the highest total flavonoid concentration (179.1 to 180.2 mg of QE/100 g), followed by the GD aqueous extract (167.4 to 168.8 mg of QE/100 g), and finally, the acetone GD extracts (160.4 to 162.3 mg of QE/100 g). On the other hand, with the less flavonoid-rich dried CH figs, we find the ethanol extract (120.8 to 122.9 mg of QE/100 g) to have the highest total flavonoid concentration, followed by the aqueous extract (112.2 to 114 mg of QE/100 g), and the acetone extracts (100.2 to 103.8 mg of QE/100 g). Flavonoids such as rutin, catechin, and epicatechin can be found in figs [56]. It is worth noting that dried figs have a significantly higher flavonoid content compared to other dried fruits [57]. In addition, a bivariate Pearson correlation analysis with a significance level of ($p < 0.01$) indicates a strong positive correlation between polyphenols and flavonoid content in dried fig extracts (coefficient of correlation = 0.794).

The outcomes of the ANOVA analysis with Tukey's post-hoc test at a significance level of 5% are presented in Table 8, revealing that the IC₅₀ value of ascorbic acid reference substance significantly differs from all extracts of dried CH and GD figs. The IC₅₀ values of the GD aqueous extracts are significantly different from those of other GD and CH extracts, except for the GD₁ aqueous and GD₂ ethanol extracts, which show no significant difference. On the other hand, there are no significant differences in IC₅₀ values within and between the GD ethanol, GD acetone, and CH aqueous extracts, except for the GD₂ ethanol extract, which significantly differs from the GD acetone and CH aqueous extracts. The IC₅₀ values of all CH extracts are homogenous, although they significantly differ.

The study's results indicate that all tested extracts could scavenge DPPH radicals, and that the efficacy of free-radical scavenging varies significantly depending on the extraction solvent and fig variety. Among the tested extracts, those derived from the GD variety exhibited the most potent DPPH scavenging activity. Notably, the GD aqueous extract demonstrated the highest antioxidant activity, as indicated by the lowest IC₅₀ values (ranging from 2.034 to 1.948), followed by the GD ethanol extract, with IC₅₀ values ranging from 2.215 to 2.104, and finally, the GD acetone extract, with IC₅₀ values ranging from 2.228 to 2.218. Similarly, the CH aqueous extract displayed the most potent antioxidant activity among the CH extracts, with IC₅₀ values ranging from 2.241 to 2.232, followed by the CH

ethanol extract, with IC₅₀ values ranging from 2.464 to 2.416. Finally, the CH acetone extract had IC₅₀ values ranging from 2.627 to 2.604. A significant negative correlation was observed between polyphenol content and IC₅₀ (correlation coefficient = -0.961) and a high negative correlation between flavonoid content and IC₅₀ (coefficient of correlation = -0.783) using bivariate Pearson correlation at ($p < 0.01$). These results indicate that the phenolic and flavonoid compounds present in the extracts are responsible for the observed DPPH free-radical scavenging activity.

Table 8. IC₅₀ values obtained in DPPH radical scavenging assay.

Extracts		CH ₁	CH ₂	CH ₃	GD ₁	GD ₂	GD ₃
IC 50 mg/mL	Aqueous	2.234 ^e ± 0.030	2.241 ^e ± 0.018	2.232 ^e ± 0.022	2.034 ^{bc} ± 0.008	1.948 ^b ± 0.002	1.986 ^b ± 0.023
	Ethanol 80%	2.416 ^f ± 0.036	2.464 ^f ± 0.018	2.448 ^f ± 0.050	2.202 ^{de} ± 0.032	2.104 ^{cd} ± 0.019	2.215 ^{de} ± 0.002
	Acetone 80%	2.618 ^g ± 0.015	2.627 ^g ± 0.052	2.604 ^g ± 0.050	2.228 ^e ± 0.070	2.218 ^e ± 0.044	2.224 ^e ± 0.021
Ascorbic acid mg/mL		0.90 ± 0.008 ^a					

Data represent average values ± standard deviation of three independent samples. Means followed by a different letter are significantly different ($p < 0.05$).

The antibacterial activity of extracts from both dried fig varieties was found to be variable against the majority of microorganisms tested. GD figs exhibited more potent antimicrobial activity compared to CH figs, which can be attributed to the presence of more bioactive compounds, such as polyphenols, flavonoids, and tannins. Ethanol extracts in particular showed strong antibacterial activity, which may be due to their high concentration of flavonoids, as shown in Table 9. It is known that plants produce coumarins and flavonoids in response to microbial infections. The ability of these compounds to interact with extracellular and soluble proteins, as well as bacterial cell walls, may contribute to their observed activity. Additionally, lipophilic flavonoids may cause damage to microbial membranes [58,59]. The antibacterial activity of the extracts from both varieties was found to be variable against the tested microorganisms. Notably, the *C. albicans* strain was observed to be more sensitive to the extracts under study. Concerning Gram-negative bacteria, the ethanol extracts showed activity against only *E. coli* ATCC 25922. The GD ethanol extracts demonstrated a smaller inhibition diameter (12.6–12.78 mm) than the CH ethanol extracts (12–12.07 mm). All dried CH and GD fig extracts inhibited *P. aeruginosa* ATCC 27853; however, the highest activity was observed in GD aqueous extracts (15.8–16.1 mm), followed by the GD ethanol extracts (13.9–14.3 mm) and GD acetone extracts (12–21.2 mm). Among the CH extracts, the acetone CH extracts showed the highest inhibitory effect (14.2–14.6 mm), followed by the CH ethanol extracts (11.3–11.5 mm) and the aqueous CH extracts (10.7–10.9 mm). Concerning Gram-positive bacteria, only the ethanol and acetone extracts showed activity against *S. aureus* ATCC 25923, with the ethanol extracts exhibiting more inhibitory activity than the acetone extracts. The GD ethanol extracts showed the highest activity (11.4–11.8 mm), followed by the GD acetone extracts (10.1–10.3 mm), then CH ethanol extracts (10–10.2 mm), and finally, the CH acetone extracts (9.8–9.9 mm). Moreover, all dried CH and GD fig extracts inhibited *B. subtilis* subsp. *Spizizenii* ATCC 6633, with the GD Ethanol extracts exhibiting the highest inhibitory effect (14.2–14.6 mm), followed by the aqueous extracts (12–12.5 mm), and finally, the acetone extracts (10–10.4 mm). For CH extracts, the aqueous extracts showed the highest activity (11.8–12 mm), followed by the ethanol extracts (11.2–11.8 mm), and finally, the acetone extracts (8.4–8.6 mm). It is worth noting that all extracts from both varieties were highly efficient against *C. albicans*, with the CH aqueous extracts showing the lowest impact (20.8–21.5 mm), and the GD ethanol extracts exhibiting the highest effect (24.4–24.6 mm).

The analysis of the minimum inhibitory concentrations (MIC) values of the dried fig extracts from the CH and GD varieties (shown in Table 10) revealed that all ethanol extracts from both varieties exhibited the same MIC of 64 µg/mL against *E. coli* ATCC 25922, indicating resistance to the other extracts. On the other hand, the GD aqueous, GD ethanol, and CH acetone extracts demonstrated an MIC of 32 µg/mL against *P. aeruginosa*.

ATCC 27853, whereas all other extracts had an MIC of 64 µg/mL. *S. aureus* ATCC was found to be resistant to the GD aqueous and acetone extracts and the CH acetone extracts, but sensitive to the other extracts. The ethanol GD extracts had an MIC of 64 µg/mL, while the ethanol CH and acetone GD extracts had an MIC of 128 µg/mL, and the CH acetone extracts had an MIC of 256 µg/mL. The GD acetone extracts and GD and CH ethanol extracts had an MIC of 128 µg/mL against *B. subtilis* subsp. *Spizizenii* ATCC 6633, while the CH ethanol extracts CH and GD aqueous extracts had an MIC of 256 µg/mL and the CH acetone extracts had an MIC of 512 µg/mL. Finally, the GD and CH ethanol and acetone extracts exhibited an MIC of 32 µg/mL against *Candida albicans*, while the GD aqueous extracts had an MIC of 64 µg/mL and the CH aqueous extracts had an MIC of 128 µg/mL. These results indicate that the MIC value is determined by the complex interplay of various factors such as the variety, the extraction solvent, the amount of active principle extracted, and the microbial species being targeted by the extract.

The variation in antimicrobial activity observed between the different types of extracts tested against the different strains could be attributed to the variation in the chemical composition of minerals and the concentration of polyphenols in these samples. These factors can potentially influence the antibacterial and antifungal activity of the extracts. Polyphenols are bioactive molecules that can interact with microorganisms in various ways, potentially impacting their development and viability [60].

Table 9. Antimicrobial activity of the crude extracts of *Ficus carica* obtained via agar diffusion assay.

Dried Fig	Extracts	Microbial Strains Tested				
		<i>E. coli</i>	<i>P. aeruginosa</i>	<i>S. aureus</i>	<i>B. subtilis</i>	<i>C. albicans</i>
CH ₁	Ethanol	12.00 ± 0.10 ^a	11.30 ± 0.8 ^{ef}	10.00 ± 0.3 ^b	11.20 ± 0.3 ^d	22.60 ± 0.1 ^b
	Acetone	0 ^b	14.20 ± 0.1 ^d	09.80 ± 0.2 ^b	08.40 ± 0.1 ^f	21.50 ± 0.3 ^{de}
	Aqueous	0 ^b	10.70 ± 0.4 ^f	0 ^c	11.80 ± 0.2 ^c	21.00 ± 0.2 ^e
CH ₂	Ethanol	12.07 ± 0.05 ^a	11.50 ± 1.0 ^{ef}	10.20 ± 0.1 ^b	11.60 ± 0.2 ^{cd}	22.50 ± 0.4 ^{b c}
	Acetone	0 ^b	14.60 ± 0.1 ^{b cd}	09.90 ± 0.3 ^b	08.60 ± 0.1 ^f	21.40 ± 0.2 ^{de}
	Aqueous	0 ^b	10.90 ± 0.2 ^f	0 ^c	12.00 ± 0.1 ^{bc}	20.80 ± 0.3 ^e
CH ₃	Ethanol	12.05 ± 0.05 ^a	11.40 ± 0.6 ^{ef}	10.20 ± 0.2 ^b	11.80 ± 0.1 ^c	22.80 ± 0.2 ^b
	Acetone	0 ^b	14.40 ± 0.1 ^{cd}	09.85 ± 0.3 ^b	08.50 ± 0.2 ^f	21.80 ± 0.1 ^{cd}
	Aqueous	0 ^b	10.80 ± 0.4 ^f	0 ^c	11.80 ± 0.2 ^c	21.50 ± 0.2 ^{de}
GD ₁	Ethanol	12.6 ± 0.08 ^a	13.90 ± 1.0 ^d	11.40 ± 0.1 ^a	14.20 ± 0.4 ^a	24.40 ± 0.1 ^a
	Acetone	0 ^b	12.10 ± 0.4 ^{ef}	10.20 ± 0.3 ^b	12.40 ± 0.1 ^b	24.00 ± 0.4 ^a
	Aqueous	0 ^b	15.80 ± 0.3 ^{abc}	0 ^c	10.00 ± 0.2 ^e	23.00 ± 0.1 ^b
GD ₂	Ethanol	12.78 ± 0.07 ^a	14.20 ± 0.4 ^d	11.80 ± 0.2 ^a	14.60 ± 0.1 ^a	24.50 ± 0.2 ^a
	Acetone	0 ^b	12.20 ± 0.3 ^e	10.30 ± 0.2 ^b	12.50 ± 0.2 ^b	24.20 ± 0.3 ^a
	Aqueous	0 ^b	16.10 ± 0.4 ^a	0 ^c	10.40 ± 0.1 ^e	23.20 ± 0.2 ^b
GD ₃	Ethanol	12.73 ± 0.05 ^a	14.30 ± 0.1 ^d	11.50 ± 0.3 ^a	14.60 ± 0.1 ^a	24.60 ± 0.1 ^a
	Acetone	0 ^b	12.00 ± 0.4 ^{ef}	10.10 ± 0.4 ^b	12.40 ± 0.1 ^b	24.50 ± 0.2 ^a
	Aqueous	0 ^b	16.00 ± 0.2 ^{ab}	0 ^c	10.20 ± 0.2 ^e	23.10 ± 0.4 ^b
controls	Amoxicillin	26	0	25	0	N.T
	Gentamicin	28	23	26	20	N.T
	DMSO	0	0	0	0	0

E. co. *Escherichia coli* ATCC 25922; P. a., *Pseudomonas aeruginosa* ATCC 27853; S. a., *Staphylococcus aureus* ATCC 25923; B. c., *Bacillus subtilis* subsp. *Spizizenii* ATCC 6633; C. a., *Candida albicans*; N.T., not tested. Inhibition zones including the diameter of the paper disc (6 mm); 0, no activity. Each value is represented as mean ± standard deviation, (*n* = 3). Means followed by a different letter in the same column are significantly different (*p* < 0.05).

Table 10. Minimum inhibitory concentrations (MIC values) in µg/mL for the investigated extracts of *Ficus carica*.

Dried Fig	Extracts	MIC in µg/mL				
		<i>E. coli</i>	<i>P. aeruginosa</i>	<i>S. aureus</i>	<i>B. subtilis</i>	<i>C. albicans</i>
CH ₁	Ethanol	64	64	128	256	32
	Acetone	R	32	256	512	32
	Aqueous	R	64	R	256	128
CH ₂	Ethanol	64	64	128	256	32
	Acetone	R	32	256	512	32
	Aqueous	R	64	R	256	128
CH ₃	Ethanol	64	64	128	256	32
	Acetone	R	32	256	512	32
	Aqueous	R	64	R	256	128
GD ₁	Ethanol	64	32	64	128	32
	Acetone	R	64	128	128	32
	Aqueous	R	32	R	256	64
GD ₂	Ethanol	64	32	64	128	32
	Acetone	R	64	128	128	32
	Aqueous	R	32	R	256	64
GD ₃	Ethanol	64	32	64	128	32
	Acetone	R	64	128	128	32
	Aqueous	R	32	R	256	64

E. co., *Escherichia coli* ATCC 25922; *P. a.*, *Pseudomonas aeruginosa* ATCC 27853; *S. a.*, *Staphylococcus aureus* ATCC 25923; *B. c.*, *Bacillus subtilis* subsp. *Spizizenii* ATCC 6633; *S. a.*, *Staphylococcus aureus* ATCC 25923; *C. a.*, *Candida albicans*; R, resistant.

Many recent studies have highlighted the antimicrobial properties of certain mineral products used for medicinal purposes [61]. Certain minerals can interact synergistically with bioactive compounds in plant extracts, such as polyphenols, flavonoids, terpenoids and others, or act individually by changing the pH. These interactions can enhance or decrease the antimicrobial properties of the plant or the antibacterial activity of the extract depending on the exact chemical constituents of minerals and bioactive compounds [62]. The antimicrobial properties of minerals and bioactive molecules such as polyphenols are being investigated as part of functional food and dietary supplement research, as they may provide natural alternatives to traditional antimicrobial agents to combat certain bacterial and fungal infections.

4. Conclusions

Our study was conducted to comprehensively characterize sun-dried fig varieties, specifically Chetoui (CH) and Ghoudane (GD), in the eastern region of Morocco. Our multifaceted approach encompassed both qualitative and quantitative analyses, delving into aspects such as pomology, colorimetry, and phytochemistry. The results unveiled a multitude of positive attributes associated with these fig varieties. Chetoui in particular emerged as a standout with its remarkable features, including substantial weight, pleasing color, optimal moisture content, and consistent unit caliber. Both CH and GD showcased a robust nutritional profile characterized by elevated levels of readily assimilable sugars, while maintaining low lipid content. These dried figs also exhibited the presence of vital components like vitamin C, dietary fiber, and essential minerals such as calcium, potassium, phosphorus, and magnesium, contributing to their nutritional value. Notably, from a medic-

inal perspective, GD figs displayed a distinct advantage, boasting bioactive compounds in the form of phenolic compounds and flavonoids that confer significant antioxidant and antibacterial properties. The process of drying these two fig varieties not only extends their shelf life but also enhances their storage capacity and market profitability, offering a valuable means to regulate the fresh fig market while reaping substantial economic benefits. However, it is essential to categorize these dried figs as acceptable quality (Category I), prompting us to recommend their utilization as raw materials for the creation of diverse fig-based products, such as jams (with CH figs) and fig coffee (capitalizing on GD figs' unique attributes). This strategic approach allows for the extraction of the maximum value from each variety, producing higher-value products and diversifying market offerings effectively.

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