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ORIGINAL RESEARCH PAPER

IMPACT OF SUN DRYING ON THE PHYSICOCHEMICAL CHARACTERISTICS AND PHYTOCHEMICAL CONTENTS OF NINE FIG FRUIT VARIETIES: A COMPARATIVE STUDY

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Abstract

Understanding how sun drying affects the nutritional and physicochemical properties of figs is crucial for optimizing their post-harvest processing. This study investigates the physicochemical characteristics and phytochemical content of nine fig fruit varieties in both fresh and dried states. Parameters such as unit weight, dimensions, moisture content, acidity, carbohydrates, proteins, amino acids, ascorbic acid, carotenoids, and chlorophylls were measured. Significant reductions in weight (46-54%) and moisture content (65.41-74.74%) were observed after drying. For instance, the *Bouankik* variety exhibited the highest fresh weight (56.40g) and moisture content (82.36%), which decreased to 26.74% and 28.08%, respectively, when dried. Principal Component Analysis (PCA) highlighted the separation between fresh and dried figs based on these parameters, with fresh figs generally showing higher nutrient concentrations, while dried figs had increased carbohydrate content. This study underscores the need for optimized drying methods to preserve the nutritional quality of figs and provides valuable insights for the fig industry and consumers.

Keywords: Figs, sun drying, physicochemical properties, phytochemical content

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Introduction

Figs (*Ficus carica* L.) are highly valued for their nutritional and medicinal properties, making them a significant fruit in global agricultural markets. Fresh figs are known for their high moisture content and rich array of vitamins, minerals, and antioxidants. However, figs are also commonly consumed in their dried form, which presents a concentrated source of nutrients but with different physicochemical properties due to the drying process (Bachir Bey *et al.*, 2017; Sandhu *et al.*, 2023).

Figs are distributed widely across the world, with significant production in countries particularly in the outline of the Mediterranean regions. Turkey is the leading producer, contributing to over 25% of the global production, followed by Egypt, Morocco, and Algeria. This widespread distribution and substantial production underscore the importance of understanding fig properties to optimize post-harvest processes and improve marketability (AtlasBig, 2024).

The transformation from fresh to dried figs involves substantial changes in weight, moisture content, and nutrient composition. Understanding these changes is crucial for both producers and consumers, as it impacts the shelf life, storage conditions, and overall quality of the figs. Previous studies have documented variations in fig properties due to drying, but comprehensive comparisons across multiple varieties are limited (Çalişkan and Polat, 2012; Tikent *et al.*, 2023).

Measuring of key physicochemical parameters is essential for assessing the quality and nutritional value of fruits. These parameters influence the taste, texture, and health benefits, making them critical for both consumers and the food industry. Accurate measurements are crucial for developing better preservation techniques and ensuring high-quality products (Pereira *et al.*, 2017; Zidi *et al.*, 2020; Benkerrou *et al.*, 2024).

This study aims to address this gap by analyzing the physicochemical characteristics and phytochemical contents of nine fig fruit varieties in both fresh and sun-dried states. Parameters such as unit weight, dimensions, moisture, titratable acidity, carbohydrate, protein, free amino acid, carotenoid, chlorophyll, and ascorbic acid contents were measured. This study is particularly relevant for fig producers, food technologists, and consumers interested in maintaining the health benefits and quality of dried figs.

Materials and methods

Sampling

The present study was carried out on nine varieties of fresh and dried figs known locally as *Aberkane*, *Abiarous*, *Azandjar*, *Azegzaw*, *Bouankik*, *El-bakour*, *Taamriwth*, *Taghanimt*, and *Tahyounte*. All the fig fruit varieties used in this investigation came from the locality of Beni Maouche (Bejaia), 75km from the capital of the department of Bejaia. The samples were collected during September (2023) at altitudes ranging from 680 to 820m.

Some variation and shape traits characterize the analyzed fig fruit varieties. *Aberkane*: Globular fruit, smooth black peel; *Abiarous*: Pyramid-shaped fruit, flattened at the base. Greenish-yellow in color; *Azandjar*: Conical fruit, slightly flattened at the base, purple in color with white spots; *Azegzaw*: Small, rounded fruit with green peel and white spots; *Bouankik*: Fairly large, pear-shaped fruit with elongated neck and distinct stalk, peel purple and reddish at the base, lighter towards the neck; *El-bakour*: Medium-sized, rounded, green fig; *Taamriwth*: Short-necked pyriform fruit with light green peel; *Taghanimt*: Rounded fruit, almost flattened at the base, with a yellowish-green color; *Tahyounte*: Rounded fruit with a thin, greenish-yellow peel.

For each variety, six samples were harvested, three were kept in their fresh state and the other three fruits were dried. The harvest, consisting of approximatively 1kg of each sample, was carried out in the early morning under dry weather conditions. Ripe figs are distinguished from unripe fruits by their larger size, lighter color in the case of green or yellow varieties, and darker color in the case of purple or black varieties. They are firm to the touch, neither hard nor soft. Fresh figs are harvested in containers and directly transported to the laboratory.

The figs destined for drying are picked when they are perfectly ripe, have wilted and the stalk has become dry, enabling the fig to detach easily from the branch. This advanced state of ripeness is imperative for obtaining good-quality dried figs. Once picked, the figs are spread out on racks and exposed to the sun on well-ventilated, sunny ground. Sun drying is carried out in the same harvesting area (Beni Maouche) using traditional methods. The drying process is stopped when the fruit feels elastic to the touch. The drying time depends on the variety, but is around one week for all samples. Once dried, the figs are transferred to the laboratory.

Once in the laboratory, the fresh fig samples are crushed and the dried fig samples are cut into small pieces after taking the physical fruit parameters (dimensions and weight), frozen and then freeze-dried for 24 hours. The lyophilizates were reduced to fine powder using an electric grinder, sieved (Ø<0.5 mm) and stored at -18°C.

Physicochemical analysis

Dimensions of fresh figs

The dimensions of fig fruit varieties were measured for fresh fruit only. The unit lengths and diameters of ten fresh figs from each sample were measured using a caliper, and the results were reported in millimeters.

Weight measurement

The unit weights of ten fresh and dried figs from each sample were measured using an analytical balance. The average weight per fruit, expressed in grams, was reported for each variety.

Moisture measurement

The moisture content is determined from the crushed fresh fig or cut dried fig. A 4g aliquot of each sample was dried for 24 hours at 103°C, and the moisture content was calculated as a percentage.

Measurement of titratable acidity

The acids were extracted using a 10% solution of fig lyophilizate with distilled water. Subsequently, a titration using sodium hydroxide (0.01N) was conducted until reaching a pH of 8.1. The results were expressed in grams of citric acid per 100 grams of dry matter (DM).

Determination of carbohydrate content

The carbohydrates are extracted using 80% ethanol. An aliquot of 0.1g of fig lyophilizate was mixed with 15ml of the solvent, incubated in a water bath at 95°C for 15min, and the supernatant was recovered by centrifugation at 5000 rpm/10min.

Carbohydrate content is determined according to Djaoudene *et al.* (2019). A volume of 0.3ml diluted supernatant is mixed with 0.3ml phenol (5% w/v) and 1.5ml concentrated sulfuric acid. After incubation at 105°C for 5min and cooling for 30min, the absorbance is measured at 490nm. A glucose calibration curve is used to determine carbohydrate concentrations and results are expressed as mg glucose equivalent per 100g DM.

Determination of protein content

Proteins were extracted from 0.4g of fig lyophilizate using 10ml of 70% ethanol for 24h. After centrifugation at 5000 rpm/15min, the protein-containing supernatant is recovered. The protein assay is carried out following the method of Kielkopf *et al.*, (2020). A volume of 200µl of extract is mixed with 2.5ml of Bradford reagent. After 5 min of incubation, the absorbance is measured at 595 nm. The protein concentration is determined by referring to a calibration curve obtained with bovine serum albumin (BSA) and the results are expressed in g/100g DM.

Determination of free amino acids content

The amino acids are extracted from 0.1g lyophilizate with 15ml ethanol 80%. The mixture is incubated in a 95°C water bath for 15 min. After cooling, the supernatant is recovered by centrifugation at 5000 rpm/10min.

Amino acid assay was performed according to a modified procedure reported by de Souza Lacerda *et al.* (2019). To a 0.5ml aliquot of supernatant are added 0.5ml citrate buffer (0.2mol/l, pH 5.0), 1ml potassium cyanide (KCN, 0.01mol/l) and 0.2ml of 1% ninhydrin. The mixture is incubated at 95°C for 15 min. After cooling and adding 2.3ml of 60% ethanol, absorbance is measured at 570nm. The amino acid content was determined by reference to a calibration curve obtained from a glycine solution and the results were expressed in g/100g DM.

Determination of ascorbic acid

Ascorbic acid was extracted from 0.8g of lyophilized fig using 20ml of oxalic acid (1%) with stirring for 30 minutes in the dark. After centrifugation of the mixture at 5000 rpm for 10 minutes, 900µl of DCIP solution (2,6-dichlorophenol-indophenol, 15ppm) was mixed with 100µl of the supernatant; absorbance was read at 515nm after 15 seconds (Mehta *et al.*, 2018). The ascorbic acid content in figs is measured using a calibration curve, with the results expressed in mg per 100g of dry matter.

Determination of carotenoids and chlorophylls

The study measures carotenoids and chlorophylls in figs using a method involving extraction with diethyl ether, followed by absorbance readings at specific wavelengths. The concentrations are calculated and expressed in mg/100g of dry matter.

Statistical analysis

The comparison of the mean results was done using analysis of variance (ANOVA/MANOVA, LSD Test, Least Significant Difference) with STATISTICA 5.5 software, and the significance level was set at $p<0.05$. The means comparison between fresh and dried figs was performed using the Student's t-test at a significance level of 0.05. Principal component analysis (PCA) was conducted with XLStat 2014.

Results and discussion

This study focused on examining and comparing the physicochemical parameters of nine fig fruit varieties in both fresh and dried states. The analyses conducted on fresh and dried fruits included measurements of unit weight and dimensions, as well as moisture, titratable acidity, carbohydrate, protein, and free amino acid contents.

Fig weight

The weight of figs is a fundamental characteristic that can vary significantly between different varieties. Understanding the weight distribution among fig fruit varieties provides valuable insights into their physical attributes and potential commercial value. In this study, we investigated the weight profiles of various fig fruit varieties to assess their variability and potential implications in marketing.

The weight of fresh figs exhibits significant variation among the studied varieties (Figure 1.A), with *Bouankik* and *Abiarous* displaying the highest fruit weight, while *Azegzaw* shows the lowest. Drying leads to a considerable reduction in fig weight. The weights of dried figs exhibit a similar pattern to that of fresh fig fruit varieties. *Bouankik* and *Abiarous* are the dried figs with the highest weights, while *Azegzaw* and *Taghanimt* have the lowest weights, averaging 13.50g. Fig drying induces an approximately 46 to 54% reduction in fruit weight (Figure 1.B).

The results obtained in this investigation are consistent with several other studies. The weights of fresh fig fruit varieties from Turkey vary between 44 and 64 g (Teruel-Andreu *et al.*, 2023), while for dried varieties, the range is between 8 and 19 g (Tikent *et al.*, 2023). Various factors can influence fig weight, including variety, tree age, geographic region, and growing conditions.

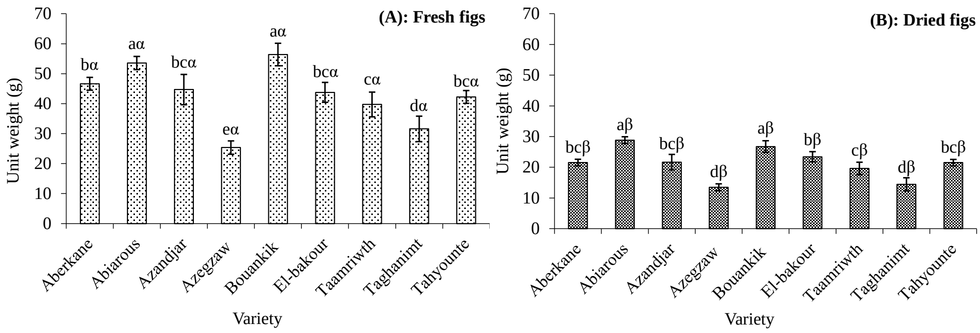

Figure 1. Unit weights of fresh (A) and dried (B) fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh or dried figs with different Latin letters are significantly different: LSD, $p<0.05$, with a>b>c>d>e. Results from the same variety, in fresh or dry states, bearing different Greek letters (α and β), are significantly different (Student's t-test, $p<0.05$), with α>β.

Dimensions of fresh figs

The dimensions of fresh figs, including length and diameter, played a crucial role in determining their visual appeal. This section examined the dimensions of fresh figs from different varieties, shedding light on their morphological diversity and potential implications in commercialization.

The measurement of fig dimensions was conducted solely on fresh fruits because dried figs do not maintain a distinct form. This is primarily due to the dehydration process during drying, which causes the fruit to lose moisture and become more elastic. As a result, dried figs can deform and change shape under slight pressure, making it challenging to obtain accurate and consistent measurements. Therefore, to ensure reliable data, measurements were performed only on fresh figs, where the fruit retains its original shape and dimensions.

The lengths and diameters of the fresh fig fruit varieties analyzed are depicted in Figure 2. Fig fruit lengths ranged from 33.05 to 52.55 mm. *Bouankik* and *Taamriwth* exhibited the longest lengths, followed by *Abiarous* (47.00 mm) and *El-bakour* (45.00 mm). *Aberkane*, *Azandjar*, *Taghanimt*, and *Tahyounte* varieties demonstrated similar lengths, approximately 41.32 mm. *Azegzaw* represented the variety with the shortest length. All varieties exhibited similar diameters, approximately 44 mm, except for *Taamriwth* (39.57 mm), which is comparable to *Aberkane*, and *Azegzaw*, which had the smallest diameter (35.35 mm).

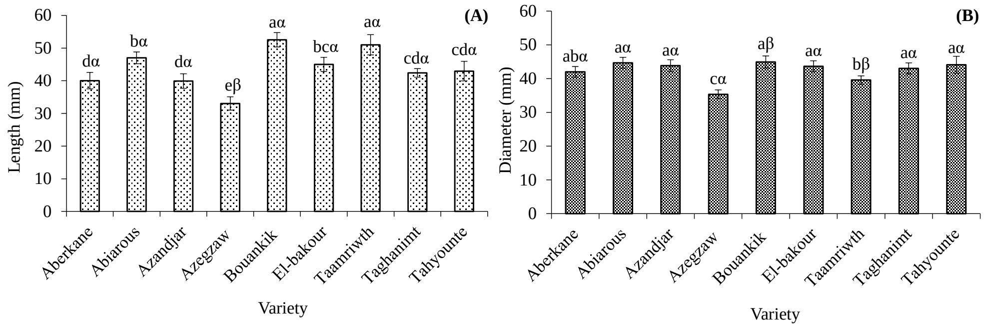

Figure 2. Lengths (A) and diameters (B) of fresh fig fruit varieties

Vertical bars represent standard deviations. Results for fresh or dried figs with different Latin letters are significantly different: LSD, p<0.05, with a>b>c>d>e. Results from the same variety, in fresh or dry states, bearing different Greek letters (α and β), are significantly different (Student's t-test, p<0.05), with α>β.

The lengths of the analyzed varieties closely aligned with findings reported by Teruel-Andreu *et al.* (2023), who observed fruit lengths ranging from 49 to 61 mm. Similarly, Çalişkan and Polat (2012) reported lengths spanning from 28 to 61 mm for several fig fruit varieties. The diameters of fig fruit varieties, as measured by several authors, exhibited considerable ranges of variation. Results of fig diameters ranging from 28 to 56 mm were reported in other investigations (Çalişkan and Polat, 2012; Teruel-Andreu *et al*., 2023).

Marketing often requires a well-defined fruit diameter/length index, which is a crucial parameter in the packaging process. The diameter/length index of the analyzed figs ranged from 0.78 to 1.10. Notably, the *Taamriwth* and *Bouankik* varieties exhibited the lowest diameter/length indices, with values of 0.78 and 0.85, respectively, while the other varieties ranged between 0.9 and 1.1. According to Çalişkan and Polat (2012), among the 76 cultivars analyzed, 49 had ratios between 0.9 and 1.1, 12 between 0.7 and 0.8, and 15 greater than 1.1.

Moisture content

Moisture content is a key parameter that influences the quality, shelf life, and processing characteristics of figs. Understanding the moisture content of figs is essential for determining their suitability for drying, storage, and various food processing applications. In this section, we analyze the moisture content of different fig fruit varieties, providing insights into their hydration status and potential implications for post-harvest handling and preservation methods. Additionally, moisture content serves as a crucial indicator for predicting yield post-drying and plays a significant role in determining the shelf life of dried figs. It helps prevent potential food and economic losses resulting from enzymatic activity or microbial degradation of preserved fruit. The United Nations Economic Commission for Europe (UNECE, 2004) has set standards for dried fig marketing and quality control, specifying that the moisture content should not exceed 26%.

The moisture content of fresh figs ranges from 70.33% to 82.36%. The *Bouankik* variety exhibits the highest moisture content, while the *Aberkane*, *Abiarous*, *El-bakour*, *Taamriwth*, and *Tahyounte* varieties show similar moisture percentages, averaging around 76% (Figure 3.A).

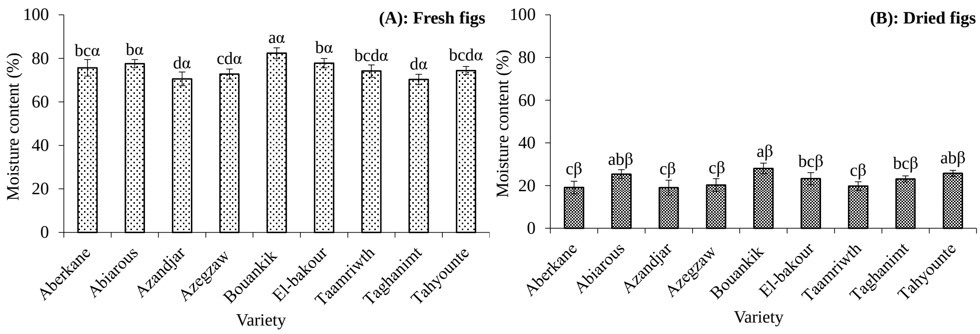

Figure 3. Moisture content of fresh (A) and dried (B) fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh or dried figs with different Latin letters are significantly different: LSD, $p<0.05$, with a>b>c>d. Results from the same variety, in fresh or dry states, bearing different Greek letters (α and β), are significantly different (Student's t-test, $p<0.05$), with α>β.

After drying, the varieties with the highest moisture content are *Bouankik* (28.08%), *Tahyounte* (25.74%), and *Abiarous* (25.41%), while the remaining varieties exhibit similar percentages, around 20.77%. The moisture content of fresh figs undergoes significant loss after drying, with reductions ranging between 65.41% (*Tahyounte*) and 74.74% (*Aberkane*) (Figure 3.B).

The moisture test results for the analyzed varieties align with existing literature. Fresh figs can exhibit moisture content ranging from 72 to 87% (Favier *et al.*, 1993). Moreover, various studies indicate a wide variation in the moisture content of dried figs, with reported ranges from 16.0 to 30.2% (Favier *et al.*, 1993; Tikent *et al.*, 2023).

Fig drying does not completely remove all the water present in the fruit; instead, a residual amount remains, contributing to the rheological characteristics of dried figs. This residual moisture includes water bound with various molecular groups such as hydroxyl, carbonyl, and amino groups found in simple sugars, polysaccharides, organic acids, proteins, and other compounds.

Among the varieties examined, *Bouankik* stands out for producing dried figs with a moisture content slightly higher than the norm (26%), as per UNECE (2004) standards. Typically, the moisture content of dried fruits falls within the range of 7 to 26% (Rybicka *et al.*, 2021). The elevated moisture content in the dried *Bouankik* variety (28.08%) can be attributed to its high sugar content (81.45 g/100g DM, as will be observed above). For the production of dried figs, it is recommended to use varieties with a high dry matter content to increase yield. Furthermore, varieties with high moisture contents are prone to transportation issues and do not fare well during handling. The elevated moisture content observed in the *Bouankik* variety, both in its fresh and dried states, underscores its preference for fresh consumption among the local population.

Titratable acidity

Titratable acidity is an important indicator of the flavor profile and sensory characteristics of figs. Variations in acidity levels can affect the overall taste perception and culinary versatility of fig-based products. This section investigates the titratable acidity of various fig fruit varieties, offering insights into their acidity profiles and potential implications for consumption, culinary, and industrial applications.

The titratable acidity results for the analyzed fresh fig fruit varieties are depicted in Figure 4.A. Among them, the *Azegzaw* and *Bouankik* varieties exhibit the highest acidity levels, approximately 1.5 g/100g DM, followed by the *El-bakour* variety (1.14 g/100g DM). The *Abiarous, Aberkane*, and *Taamriwth* varieties display similar acidity values. Conversely, the *Taghanimt* and *Tahyounte* varieties show the lowest acidity levels, at 0.50 and 0.53 g/100g DM, respectively.

Figure 4.B illustrates the acidity results for dried fig fruit varieties, which overall exhibit the same profile as fresh figs. The Student's t-test indicates a significant increase in acidity for the *Taghanimt*, *Bouankik*, and *El-bakour* varieties, a decrease for the *Azegzaw* variety, and stability for the other varieties.

Variations in fig acidity have been documented in the literature. Çalişkan and Polat (2012) reported that the acidity of fresh figs ranges from 0.10 to 0.35 g/100g. Additionally, acidity values ranging from 1.20 to 1.40 g/100g have been observed for dried figs (Tikent *et al.*, 2023). These variations in acidity between analyzed or reported varieties can be attributed to genotypic characteristics and ecological parameters.

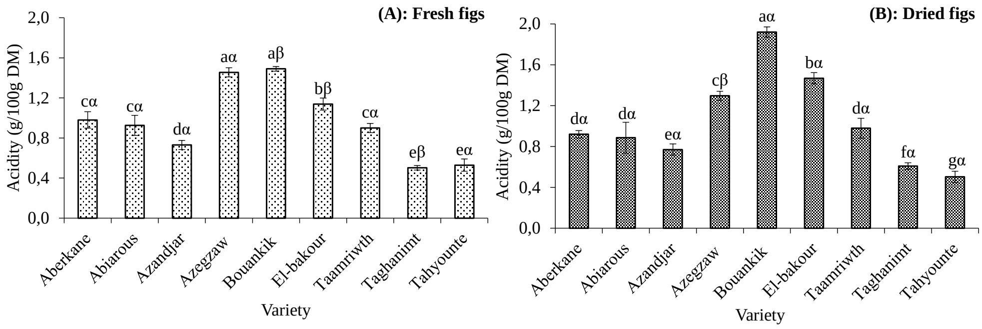

Figure 4. Titratable acidity of fresh (A) and dried (B) fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh or dried figs with different Latin letters are significantly different: LSD, $p<0.05$, with a>b>c>d>e>f>g. Results from the same variety, in fresh or dry states, bearing different Greek letters (α and β), are significantly different (Student's t-test, $p<0.05$), with $\alpha>\beta$.

Carbohydrate content

The primary macronutrients in figs are carbohydrates, which are instrumental in shaping their nutritional profile and sensory characteristics. Variations in carbohydrate content can significantly impact the sweetness, texture, and overall dietary benefits of fig-derived products. In this section, we explored the carbohydrate content of various fig fruit varieties, offering valuable insights into their nutritional composition and potential implications for industrial or culinary applications.

Figure 5 illustrates the carbohydrate content of the analyzed fig fruit varieties. In fresh figs, sugar content ranges from 44.77 (*Abiarous*) to 67.78 g/100g DM (*Tahyounte*). The *Bouankik* variety exhibited the highest sugar content in dried figs (81.45 g/100 g DM), while the *Abiarous*, *Azegzaw*, *El-bakour*, and *Taamriwth* varieties were the least concentrated. Drying generally increases the sugar content of most fig fruit varieties, ranging from 12.26 (*Taamriwth*) to 35.80% (*Bouankik*). On a dry basis, the Student's t-test indicated that the *Azegzaw*, *El-bakour*, and *Tahyounte* varieties had similar contents before and after drying.

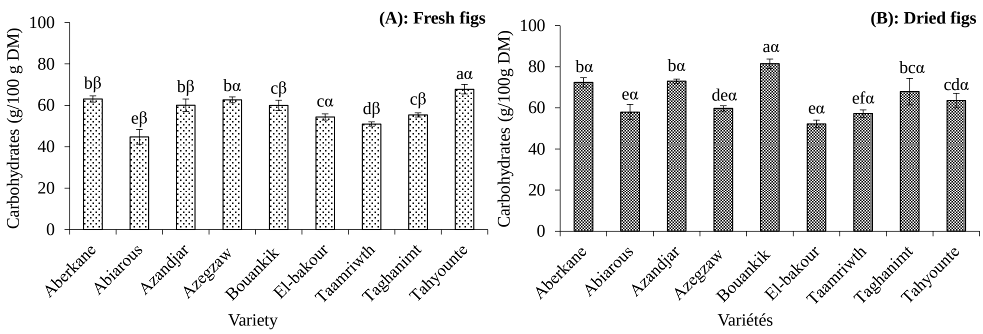

Figure 5. Carbohydrate content of fresh (A) and dried (B) fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh or dried figs with different Latin letters are significantly different: LSD, $p<0.05$, with a>b>c>d>e. Results from the same variety, in fresh or dry states, bearing different Greek letters (α and β), are significantly different (Student's t-test, $p<0.05$), with α>β.

The carbohydrate content of fresh and dried fig fruit varieties, expressed as raw material, obtained in this study ranged from 12.46 to 21.88g/100g fresh figs and from 49.64 to 73.30g/100g dried figs, respectively. These findings are consistent with several other studies. For instance, Favier *et al.* (1993) reported fresh fig sugar concentrations ranging from 9.50 to 16.50 g/100g, while for dried figs, amounts ranged from 48.60 to 61.60g/100g (Favier *et al.*, 1993; Tikent *et al.*, 2023).

The high concentration of sugars in dried figs plays a crucial role in their preservation. Sugar acts as a natural preservative by reducing water activity, which inhibits the growth of microorganisms and prevents spoilage. When fruits are dried, water is removed from the fruit, leaving behind a concentrated sugar solution. This high sugar concentration creates an environment where bacteria, yeasts, and molds cannot grow, thereby extending the shelf life of the dried fruits. Additionally, sugar helps to retain the flavor, texture, and color of the fruits during the drying process, making them more palatable and desirable for consumption.

Soluble protein content

Proteins are key nutrients found in figs, playing a crucial role in their nutritional value and functional attributes. Despite their lower presence compared to carbohydrates, understanding the protein content of figs is vital for evaluating their dietary benefits and exploring potential applications in food processing. This section examines the soluble protein content of different fig fruit varieties, shedding light on their protein profiles and the possible implications for dietary supplementation and food formulation.

The results of soluble proteins for both fresh and dried figs are presented in Figure 6. In the fresh state, the *Azegzaw* and *Bouankik* varieties exhibited the highest protein concentrations (around 0.58 g/100g), whereas the *Abiarous*, *Taghanimt*, and *Tahyounte* varieties were the least concentrated (about 0.25 g/100g). In the dried state, the *Azegzaw*, *Bouankik*, and *El-bakour* varieties exhibited the highest protein levels, averaging 0.63 g/100g, while the *Azandjar* and *Taghanimt* varieties had the lowest levels. Drying resulted in significant increases in protein content for the *Abiarous*, *Taamriwth*, and *Tahyounte* varieties, while the *Azandjar* variety experienced a 20% decrease. Conversely, drying had no effect on the protein concentrations of the other varieties. Protein concentrations between 0.8 and 1.3 g/100g for fresh figs and between 2.7 and 4.2 g/100g for dried figs were reported by Favier *et al.* (1993). Lim (2012) mentioned levels of 0.75 and 3.30 g/100g for fresh and dried figs, respectively.

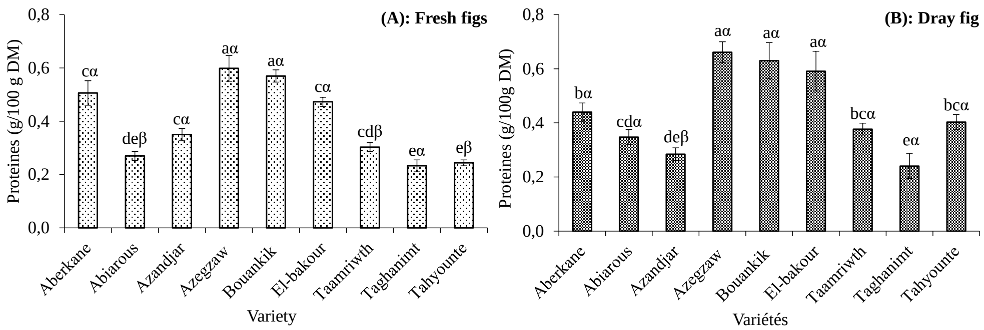

Figure 6. Protein content of fresh (A) and dried (B) fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh or dried figs with different Latin letters are significantly different: LSD, $p<0.05$, with a>b>c>d>e. Results from the same variety, in fresh or dry states, bearing different Greek letters (α and β), are significantly different (Student's t-test, $p<0.05$), with $\alpha>\beta$.

Free amino acid levels

Free amino acids are important constituents of figs that contribute to their flavor, nutritional value, and physiological effects. Variations in amino acid levels can influence the taste, aroma, and health benefits of fig-based products. This section investigates the free amino acid levels in different fig fruit varieties, providing insights into their amino acid profiles and potential implications for sensory perception and dietary intake.

The free amino acid contents of fresh figs ranged from 0.19 to 0.71 g/100g. The *Bouankik* and *Azegzaw* varieties exhibited the highest concentrations, followed by the *El-bakour* and *Aberkane* varieties, while the *Taghanimt* and *Tahyounte* varieties were the least rich (Figure 7A). The amino acid content of dried figs followed the same pattern as that of fresh figs (Figure 7B). The highest concentration was recorded in the *Bouankik* variety (1.14 g/100g), while the lowest was obtained in the *Tahyounte* variety (0.20 g/100g).

The analyzed fig fruit varieties exhibited varied responses to the drying process. A significant decrease of 12% was observed for the *Taamriwth* variety, while increases were noted for the *Azegzaw* (19%), *Azandjar* (26%), *Aberkane* (29%), and *Bouankik* (60%) varieties. Stability was observed in the case of the *Taghanimt*, *El-bakour*, *Tahyounte*, and *Abiarous* varieties.

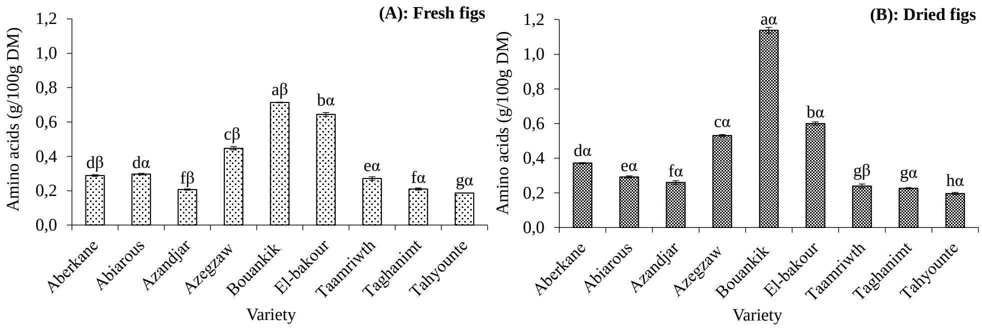

Figure 7. Amino acid content of fresh (A) and dried (B) fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh or dried figs with different Latin letters are significantly different: LSD, $p<0.05$, with a>b>c>d>e>f>g>h. Results from the same variety, in fresh or dry states, bearing different Greek letters (α and β), are significantly different (Student's t-test, $p<0.05$), with α>β.

Favier *et al.* (1993) reported free amino acid contents ranging from 0.8 to 1.3 g/100g in fresh figs. They observed a notable increase in amino acid levels after drying, from 2.7 to 4.2 g/100g. Similarly, Lim (2012) reported concentrations of 0.64 g/100g for fresh figs and 2.75 g/100g for dried figs. Huang *et al.* (2010) detected approximately 17 amino acids in figs, 9 of which were identified as essential (Arg, His, Ile, Leu, Lys, Met, Phe, Tyr, and Val).

Ascorbic acid content

Ascorbic acid, commonly known as vitamin C, is a vital nutrient and antioxidant found abundantly in various fruits. Its significance in fruit analysis extends beyond its nutritional value, as it plays a crucial role in preserving fruit quality and shelf life. Ascorbic acid contributes to the prevention of oxidative deterioration by neutralizing free radicals, thus maintaining the sensory attributes such as color, flavor, and texture. Additionally, its presence is indicative of the fruit's freshness and overall health benefits. Understanding the concentration of ascorbic acid in fruits not only helps in evaluating their nutritional profile but also provides insights into the effects of processing techniques such as drying and storage conditions. This information is essential for optimizing preservation methods and ensuring the delivery of high-quality, nutrient-rich fruits to consumers.

The ascorbic acid content of the studied fig fruit varieties is shown in Figure 8. For fresh figs, the highest concentrations were found in the *Abiarous*, *Azegzaw*, and *Bouankik* varieties, with an average of 10 mg/100g dry matter. The least rich fresh fig fruit varieties were *Azandjar*, *El-bakour*, *Taamriwth*, and *Tahyounte*, with about 6 mg/100g dry matter.

Drying induces a significant reduction in the ascorbic acid content across the nine analyzed fig fruit varieties. The most affected varieties are *Azegzaw*, *Abiarous*, and *Bouankik* (≈72% reduction), followed by *Aberkane*, *Taghanimt*, and *Azandjar* (≈62%), and finally *Tahyounte*, *Taamriwth*, and *El-bakour* (≈56%).

The vitamin C content of the fresh and dried figs analyzed is consistent with Piga *et al.* (2004), who reported a content of 12.56 mg/100g dry matter in fresh figs, which decreased to about 3 mg/100g dry matter after drying. Favier *et al.* (1993) also reported that fresh figs contained 5 mg/100g, but a considerable decrease was observed after drying (1 mg/100g).

Numerous studies have indicated a reduction in ascorbic acid content after drying fruits. The study by Asami *et al.* (2003) revealed a decrease in ascorbic acid concentration of about 87% after drying strawberries. Drying pears at a temperature of 70°C also resulted in a 70% decrease in vitamin C content (Mrad *et al.*, 2012). The degradation of this vitamin was due to its instability when exposed to heat and its interfering role in the regeneration of other phytochemicals, such as phenolic compounds.

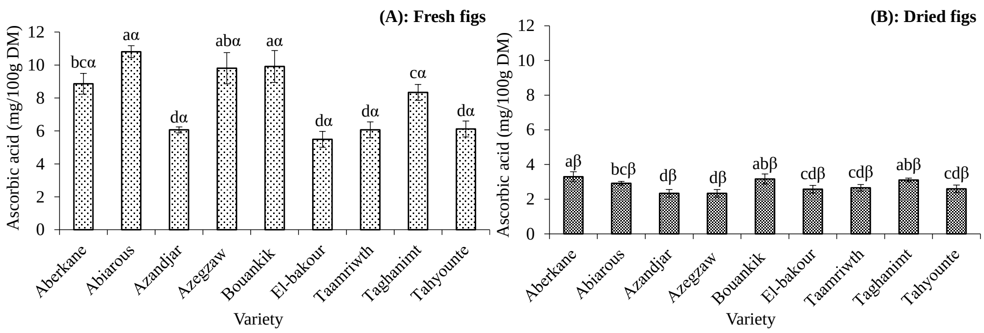

Figure 8. Ascorbic acid content of fresh (A) and dried (B) fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh or dried figs with different Latin letters are significantly different: LSD, p<0.05, with a>b>c>d. Results from the same variety, in fresh or dry states, bearing different Greek letters (α and β), are significantly different (Student's t-test, p<0.05), with α>β.

Carotenoid content

Carotenoids are exclusively present in fresh figs; however, upon drying, these compounds undergo complete degradation. Among the fresh varieties, *Azegzaw* and *Taamriwth* exhibited the highest levels of carotenoids, with 472.40 and 509.77 µg/100g, respectively. Notably, the *Aberkane*, *El-bakour*, *Taghanimt*, and *Tahyounte* varieties displayed notable levels, averaging around 309 µg/100g DM (Figure 9).

Analysis of fresh fig fruit varieties yielded a level of 352 µg/100g fresh matter (Petkova *et al.*, 2019). Karantzi *et al.* (2021) obtained carotenoid concentrations ranging from 140 to 1430 µg/100g fresh matter in fresh figs depending to repining stage and variety.

Carotenoids are prone to degradation during drying and heating processes, impacting their concentration and nutritional value in crops and food products. In this study, the entire carotenoids were degraded after drying in all analyzed varieties. Alasalvar (2013) reported a carotenoids content of 470 µg/100g in fresh fig, which was reduced by 92% after drying.

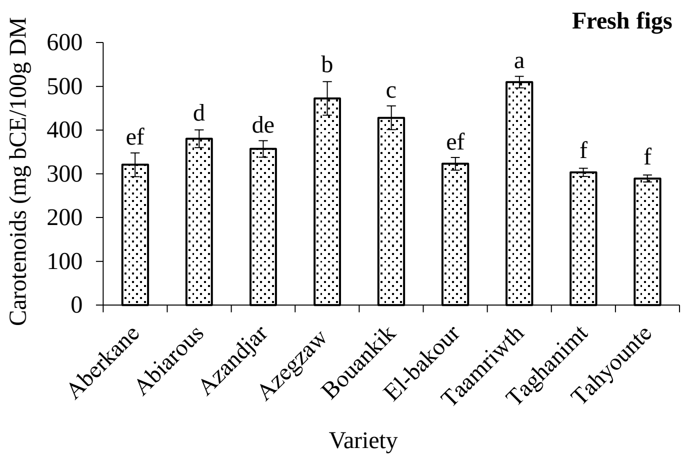

Figure 9. Carotenoid content of fresh fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh figs with different Latin letters are significantly different: LSD, $p<0.05$, with a>b>c>d>e>f.

The susceptibility of carotenoids is also observed in other products. In their study of sweet potato drying, Jing *et al.* (2010) found that the use of microwaves (95-105°C) significantly affected carotenoid levels, resulting in around 50% degradation, compared to hot air (65°C) which induced a 35% reduction. Similarly, Fratianni *et al.* (2013) demonstrated that drying apricots for 6 hours at two different temperatures showed a twofold reduction in carotenoid concentration with a 10°C rise in temperature (60 to 70°C). The authors also observed that carotenoid content halved by the end of the drying process.

Chlorophylls content

Chlorophylls are pigments present in all green plants, enabling them to perform photosynthesis. These antimutagenic and anti-carcinogenic molecules are chelators of pro-oxidant metals like iron and prevent the oxidation of oils and LDL.

Carotenoids are present exclusively in fresh figs, but they degrade entirely during the drying process; consequently, they are not detected in dried figs. The chlorophyll content of various fresh fig fruit varieties is shown in Figure 10. The *Bouankik* variety contains the highest concentration (1813.64 µg/100g), followed by the *Azegzaw* and *Taamriwth* varieties. The lowest concentration is found in the *Tahyounte* variety (313.60 µg/100g).

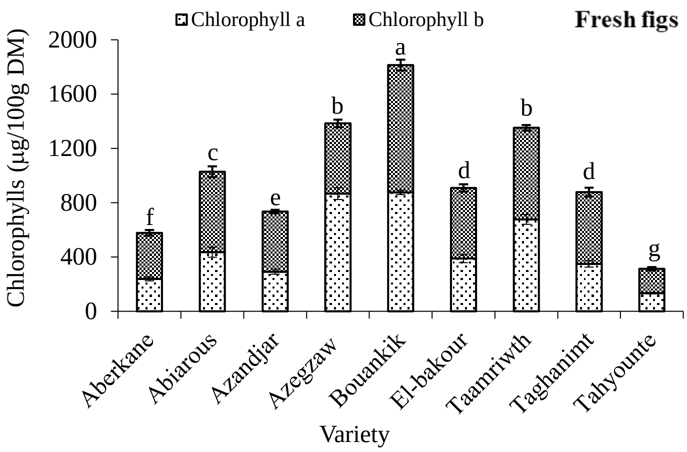

Figure 10. Chlorophylls content of fresh fig fruit varieties.

Vertical bars represent standard deviations. Results for fresh figs with different Latin letters are significantly different: LSD, p<0.05, with a>b>c>d>e>f>g.

For chlorophyll a, the highest concentrations in fresh fig fruit varieties are found in the *Azegzaw* and *Bouankik* varieties with 866.71 and 876.17 µg/100g, respectively. The *Tahyounte* variety has the lowest concentration. Regarding chlorophyll b, the *Bouankik* variety has the highest content (937.47 µg/100g), followed by the *Taamriwth* variety. The *Tahyounte* variety is the least concentrated with only 133.52 µg/100g. Petkova *et al.* (2019) reported the presence of chlorophylls in fresh figs with concentration of 595 µg/100g, of which 362 to 61% is chlorophyll a and 231 to 39% is chlorophyll b.

Drying results in the complete degradation of chlorophyll in the studied fig fruit varieties. Similarly, according to Gomes *et al.* (2003), drying soybean seeds at temperature of 25°C leads to the complete degradation of chlorophylls. Drying chive leaves in open air reduces chlorophyll content from 770 to 295 mg/100g (Cui *et al.*, 2004). Other studies indicated that numerous factors, including the presence of oxygen, light, heat, and enzymes, could significantly promote the breakdown of chlorophylls. These elements accelerate the degradation process, leading to the loss of chlorophyll pigments in plants. For example, exposure to high temperatures and light can increase the rate of chlorophyll breakdown by enhancing photo-oxidative stress. Additionally, the presence of oxygen facilitates oxidative reactions that further break down chlorophyll, while enzymatic actions also play a critical role in this process.

Principal Component Analysis

The aim of the Principal Component Analysis (PCA) in this study is to elucidate the variations and relationships between several physicochemical and antioxidant properties of different fig fruit varieties in both fresh and dried forms. The PCA reduces the dimensionality of the dataset, highlighting the key patterns and clusters among the fig fruit varieties based on their shared characteristics.

The PCA biplot of Figure 11 illustrates the first two principal components, which together account for 67.50% of the total variance. The fresh fig fruit varieties, such as *Azegzaw*, *El-bakour*, and *Taamriwth*, are characterized by higher values of Weight, Length, Diameter, Moisture, and Vitamin C, as indicated by their position on the right side of the plot. These properties are crucial indicators of the main dimensional characteristics of fresh figs. In contrast, dried fig fruit varieties like *Aberkane* and *Azegzaw* are associated with higher carbohydrate content and show significant reductions in moisture, chlorophyll, and carotenoid levels, reflecting the impact of the drying process on these compounds.

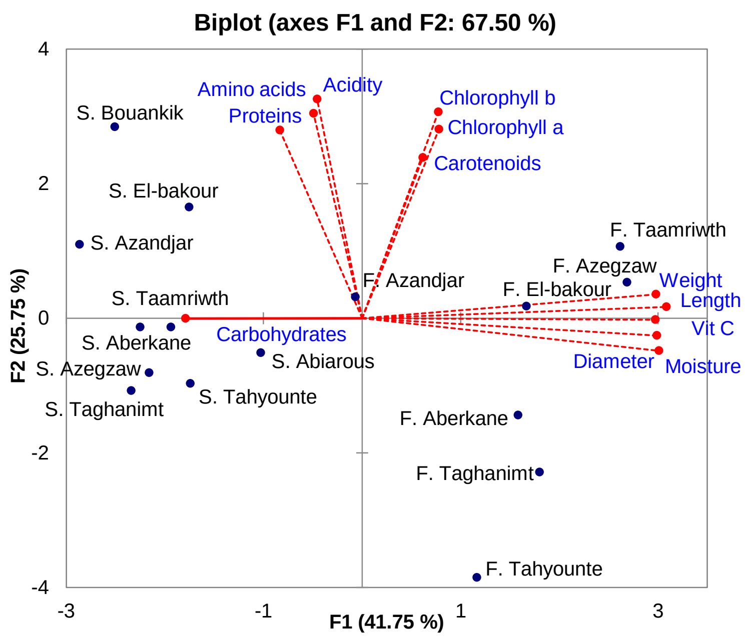

Figure 11. Graph of Principal component analysis plot of physicochemical and antioxidant properties for fig fruit varieties.

The clustering of dried figs on the left side of the biplot indicates a notable shift in their physicochemical post-drying profile, mainly due to the substantial loss of moisture and degradation of sensitive compounds such as chlorophylls and carotenoids. This separation between fresh and dried figs underscores the pronounced impact of drying on their nutritional and antioxidant properties.

Fresh figs exhibit higher values for several key nutrients and physical properties, while dried figs are characterized by an increased concentration of carbohydrates and a significant reduction in moisture and certain antioxidants. This analysis emphasizes the need for optimized drying methods to preserve the nutritional quality of figs.

Conclusion

The comparative analysis of fresh and dried fig fruit varieties revealed significant differences in their physicochemical and antioxidant properties. Sun drying of figs lead to a substantial reduction in weight and moisture content, along with the degradation of sensitive compounds such as carotenoids and chlorophylls. The PCA results highlighted the distinct nutritional profiles of fresh and dried figs, emphasizing the need for optimized drying methods to preserve essential nutrients. These findings are valuable for the fig industry, offering guidelines for improving fig preservation and ensuring the delivery of high-quality, nutrient-rich figs to consumers.

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