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Research Article

Physicochemical and Nutritional Characterization of Brebas for Fresh Consumption from Nine Fig Varieties (*Ficus carica* L.) Grown in Extremadura (Spain)

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The quality characteristics of brebas for fresh consumption from nine fig varieties at different commercial ripening stages were determined. Physicochemical and nutritional parameters were analyzed for both skin and flesh, and the findings were compared among varieties and ripening stages. The results revealed that the major nutrient components in brebas are sugars, such as glucose and fructose, and mineral elements, including K, Ca, P, and Mg. Most nutrients evaluated are important elements that contribute to the commercial quality of brebas. "Brown Turkey" and "Banane" varieties showed the highest weight and width. The concentrations of the monomer sugars studied were higher in flesh than skin, and the "Cuello Dama Blanco" and "Colar Elche" varieties showed the highest content of these sugars. The early ripening stage, coinciding with a fast increase in fruit size, was also associated with a higher fiber and protein contents, TA, and firmness for "Banane," "Brown Turkey," and "Blanca Bétera" varieties. Conversely, the later ripening stage was related to a significant increase of TSS, MI, and color intensity. Finally, no clear changes in the concentrations of organic acids were observed between different varieties and commercial ripening stages.

1. Introduction

Nowadays, the Mediterranean-style diet is considered to promote health and well-being of individuals [1, 2] and this effect has been attributed to nutritional properties present in fruit and vegetables [3]. In this context, both brebas (first crop) and figs (second crop) (*Ficus carica* L.) are important constituents of the Mediterranean-style diet, since they are among the most abundant fruits due mainly to fig trees being the earliest cultivated fruit trees [1]. Additionally, these fruits present the advantage that they are consumable either fresh, peeled or unpeel, or dried [4, 5]. Figs and brebas are nutritious fruits, rich in fiber (5.8%, w/w, with more than 28% of the fiber of the soluble type), potassium (14%, w/w), calcium (15.8%, w/w), and iron (30%, w/w) and are free of sodium, fat, and cholesterol [1, 6]. They are an excellent source of vitamins, minerals, amino acids, and phenolic compounds [1, 7, 8]. In fact, several studies have reported on the health-promoting potential of brebas and figs due to the presence of high concentrations of polyphenols, specifically in dried figs [9]. These nutritional and functional characteristics are closely related to fruit quality and are usually influenced by genotype and ripening stage, as well as by environmental conditions and orchard management practices [5, 10, 11]. The Scientific and Technological Research Center of Extremadura (CICYTEX-"Finca La Orden" in Guadajira (Badajoz)) is the national fig reference center in Spain, with over 200 different varieties that can be consumed either fresh or dried. Extremadura is located southwest of the Iberian Peninsula and is characterized by a Mediterranean climate with hot and dry summers and mild, wet winters, optimal conditions for the development of this crop [12]. Recently, the fresh breba trade, confined primarily to national markets, has gained international importance because of consumer interest in fresh brebas. This fact, along with a growing consumer awareness of the relationship between diet and health, makes it necessary to evaluate the physicochemical and nutritional characteristics of the most productive fig cultivars in Extremadura [13] and to understand the influence of the ripening stage on the breba quality, thus allowing the establishment of the optimal ripening stage to increase consumer consumption [11]. According to our knowledge, the literature regarding changes in quality and nutritional properties during the ripening process of figs is scarce. One study was carried out on four fig cultivars to evaluate the influence of ripening stage on fruit quality [11]. Nevertheless, no literature is available about the effect of ripening stage on the quality and nutritional characteristics of breba crops.

Therefore, the objective of this work was to study the physicochemical and nutritional characteristics of brebas for fresh consumption from nine fig varieties grown in Extremadura at different ripening stages.

2. Materials and Methods

2.1. Plant Material. This study was conducted using nine fig varieties grown in an experimental orchard located at an altitude of 217 m above sea level at the Finca "La Orden" of the Scientific and Technological Research Center of Extremadura (CICYTEX) (WGS −89, latitude 38° 51 7.78″ N, longitude 6° 40′ 16.59″ W, Guadajira, Badajoz, Spain).

The fig tree varieties studied were "Cuello Dama Blanco" (also known as "Kadota"), "Brown Turkey," "Tiberio," "San Antonio," "Cuello Dama Negro," "Banane," "Colar Elche" (also known as "Black Mission"), "Tres Voltas L'Any," and "Blanca Bétera." All of these varieties are considered "common type" except "Tiberio," which is of the "San Pedro type" and produces breba parthenocarpically. The plant material came from cuttings from the National Fig Germplasm Bank located in CICYTEX. These varieties were selected based on their fruit quality traits for fresh consumption. The experimental design of this trial, established in 2007, was carried out using four randomized blocks (three trees per block) with a planting density of 5 m × 4 m. Brebas samples were collected at random from three trees of each block for each variety during two consecutive biological cycles (2011 and 2012). The fruits were grouped into three commercial ripening stages in accordance with the field technician and based on texture and skin color. For all cases, the ripening stages correspond to the stage just prior to climacteric point (Stage 1), optimum stage for the fruit commercialization (Stage 2), and later stage of the climacteric point (Stage 3), respectively. Three replicates of ten homogeneous and healthy fruits for each ripening stage and variety were established for determination of weight, width, color, and other quality parameters. For compositional analyses, samples were frozen, packed in plastic bags, and stored at −80°C. All these analyses were realized from a homogenate of ten fruits by triplicate.

2.2. Weight and Width. The weight of brebas, in grams, was determined using a Mettler AE-166 balance, and fruit width, in mm, was determined using a DL-10 digital micrometer (Mitutoyo, Kawasaki, Japan).

2.3. Color. The skin and flesh colors of ten breba crops from each ripening stage and variety were measured using a spectrophotometer Konica Minolta CM600. Chromatic analyses were conducted in accordance with the CIELab system. Values of L^*, a^*, and b^* were used to define a three-dimensional color space and interpreted as follows: L^* indicates lightness, with values ranging from 0 (completely opaque or "black") to 100 (completely transparent or "white"). A positive a^* value indicates redness on the hue circle and a positive b^* value indicates yellowness. The hue angle (h^*) expresses the color nuance and the chroma (C^*) is a measure of chromaticity, which defines the purity or saturation of the color.

2.4. Firmness. The firmness of breba crops was measured using a TA.XT2i Texture Analyzer (Stable Micro Systems, Godalming, UK) connected to a computer. Force was applied to produce a 6% deformation by a 100 mm aluminium plate. The slope was determined in the linear zone of the force-deformation curve and the results were expressed as N mm^{-1}.

2.5. Soluble Solids, Titratable Acidity, pH, and Maturation Index. Total soluble solids (TSS), pH, titratable acidity (TA), and maturation index (MI) were measured for each ripening stage and variety. Ten brebas from each ripening stage and variety were homogenized using a model Braun 5 hand processor blender and filtered with nylon gauze to determine the TSS. TSS values were measured using a model RM40 Mettler Toledo digital refractometer. Results are expressed as °Brix. TA and pH were determined from the same juice for each replicate using 5 g of breba homogenate diluted to 50 mL with deionized water from a Milli-Q water purification system (Millipore, Bedford, MA). Analyses were conducted using an automatic titration Mettler Toledo T50 Compact Stirrer. Samples were titrated with 0.1 M NaOH up to pH 7.8 using the citric acid as reference. Results are expressed as g citric acid equivalent per 100 g fresh weight (FW). The maturation index (MI) was calculated as the ratio between TSS (°Brix) and TA (g citric acid 100 g^{-1} FW).

2.6. Sugars and Organic Acids. Sugar concentrations were measured in both skin and flesh and determined by high performance liquid chromatography (HPLC Agilent 1200) with refractive index (RI) detector, using 1 g of skin or flesh prepared from defrosted fruit diluted to 10 mL with deionized water [14]. Glucose, fructose, and sucrose concentrations are expressed as g kg^{-1} FW.

Organic acid concentrations were also analyzed in the same fractions using liquid chromatography (Agilent 1200), using a Supelcogel C610H column and a UV detector set at 210 nm [14]. Calibrations were carried out for each acid: malic, citric, and succinic, which were purchased from Sigma Aldrich (Madrid, Spain). Results are expressed as g kg^{-1} FW.

2.7. Protein and Crude Fiber. Total nitrogen content was determined by the direct combustion method LECO®/Dumas and the percentage of protein was determined from total nitrogen content, using the correction factor 6.25. Results were expressed in mg per 100 g of dry matter (DM).

Crude fiber was measured according to the Association of Official Analytical Chemists (AOAC) [15] Approved Procedure Ba 6a-05 by a fiber automatic analyzer Ankom 2000 through digesting with 0.255 N H_2SO_4 and 0.313 N NaOH.

2.8. Minerals. Brebas were weighed and dried at 65°C over two days. These fruits were then cut into small pieces and frozen at −80°C. Dried samples were ground in a mortar to a fine powder. Subsequently, 1 g DM in a porcelain cup was turned to ashes in a muffle oven at 550°C for 1 day. Once calcined, samples were digested in 2 mL distilled water and 1 mL of HCl (37%). The corresponding solution was heated until white fumes appeared. The clear solution was diluted up to 100 mL with distilled water and filtered with Whatman filter paper. The standard working solutions of the elements of interest were prepared to make the standard calibration curve.

The mineral elements potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), and iron (Fe) were analyzed by atomic absorption spectrometry (AAS), whereas phosphorus (P) was determined by a colorimetric reaction using a spectrophotometer at 430 nm. Mineral analysis was carried out according to the official method of plants (AOAC; MAGRAMA) [16].

2.9. Statistical Analysis. Statistical analysis of the data was carried out using SPSS for Windows, 19.0 (SPSS Inc., Chicago, IL, USA). Physicochemical characteristics and nutritional composition were studied by analysis of variance (ANOVA). This analysis allowed for a comparison of the mean differences between groups that have been split on two dependent between-subject factors: "variety" and "ripening stage." For the comparison of mean values, Tukey's honestly significant difference (HSD) test ($p \leq 0.05$) was used. The relationships among the parameters studied were evaluated by principal component analysis (PCA).

3. Results and Discussion

3.1. Weight and Width. The relationship between weight and size of the breba crops from nine varieties of fig tree studied is shown in Figure 1. Significant differences were found among varieties, showing the influence of genotype and ripening stages on weight and width. These findings are in agreement with those of other authors [11, 17, 18]. Breba crops with the highest weight and size were the "Brown Turkey" variety with mean values of 117.5 g and 63.1 mm, respectively, followed by "Banane" (98.6 g and 53.4 mm) and "Tiberio" (69.6 g and 51 mm). On the other hand, the weight and width were the lowest in the "Tres Voltas L'Any" variety (38.9 g and 44 mm, resp.). Diversity in the results for these parameters was also observed by Ferrara and Papa [19] in several breba varieties from Valenzano (Italy), whose values ranged between 62 and 125 g for weight and 49–67 mm for width. Additionally, our study also confirms the results reported previously by Souza et al. [20] for four breba varieties grown in Spain: "Colar Elche," "Tiberio," "San Antonio," and "Cuello Dama Negro."

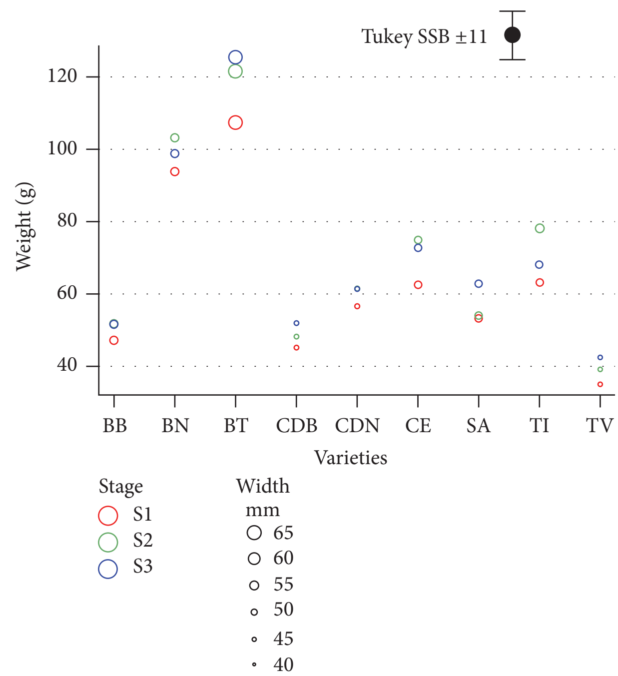

Figure 1: Weight and width of the brebas of nine fig tree varieties grown in Extremadura. BB: Blanca Bétera; BN: Banane; BT: Brown Turkey; CDB: Cuello Dama Blanco; CDN: Cuello Dama Negro; CE: Colar Elche; SA: San Antonio; Ti: Tiberio; TV: Tres Voltas L'Any. SSB: statistical significance bar using the Tukey HSD test.

Except for the "Tiberio" variety, both weight and width increased along the selected developmental stages (Figure 1), showing significant differences between stages 1 and 3. Weight and width are known to increase during phase III of fruit development on the tree and until the fruit are fully ripe [18]. Crisosto et al. [11] also observed this behaviour in fig varieties such as "Brown Turkey," "Calimyrna," and "Kadota."

According to the fig descriptor lists IPGRI and CIHEAM [21], the breba crops of the "Brown Turkey" and "Banane" varieties were classified as very large fruits, while "Tiberio," "San Antonio," and "Blanca Bétera" were considered as large fruit. The remaining varieties had a medium width.

3.2. Quality Parameters

3.2.1. Color. The genotype-maturity interaction is considered to be the main factor responsible for the color traits of fruit

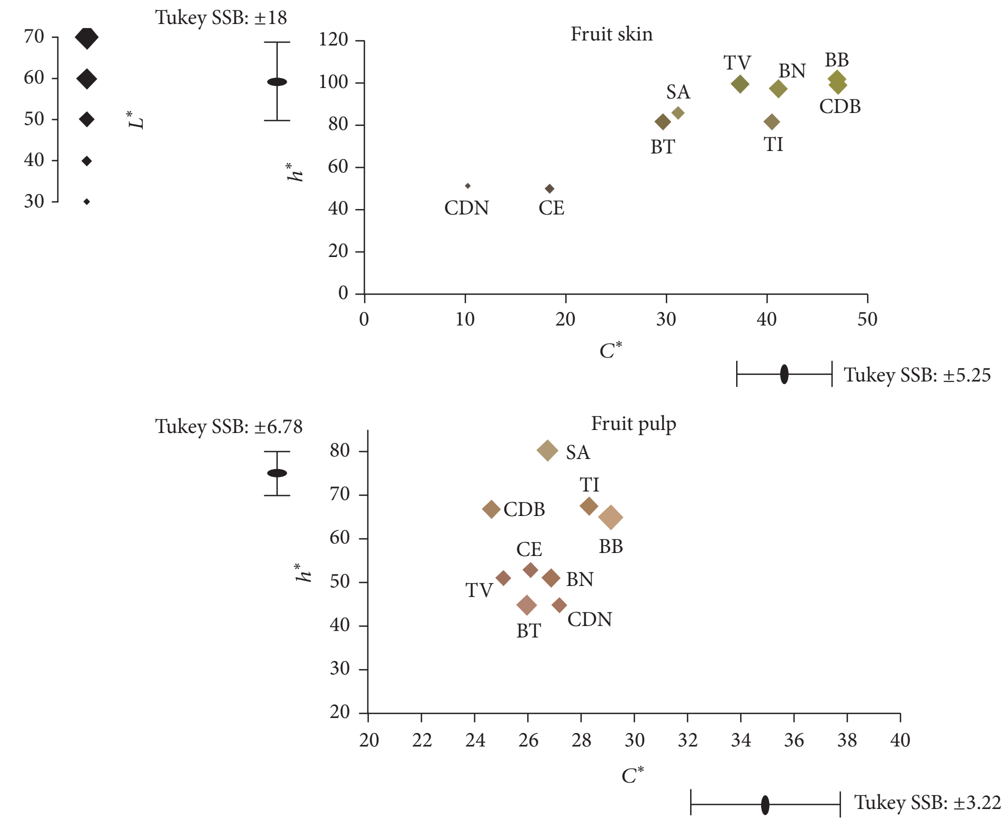

Figure 2: Values of color parameters (L^*, C^*, and h^*) for skin and flesh of the ten varieties of brebas studied. CDB: Cuello Dama Blanco; BT: Brown Turkey; Ti: Tiberio; SA: San Antonio; CDN: Cuello Dama Negro; BN: Banane; CE: Colar Elche; TV: Tres Voltas L'Any; BB: Blanca Bétera; RD: De Rey. SSB: statistical significance bar using the Tukey HSD test.

skin and flesh. Significant differences ($p < 0.05$) were found in all color parameters in both breba skin and flesh and among all varieties and ripening stages (Figure 2). For skin color, values ranged between 10.21 and 47.08 for C^*, 49.6 and 100.7 for h^*, and 36.5 and 57.1 for L^* depending on variety and ripening stage. The skin color of each variety studied varied from light green for "Banane," "Cuello Dama Blanco," "Tres Voltas L'Any," and "Blanca Bétera" (characterized by showing the highest values of L^*, h^*, and C^*) to yellow-green for "Brown Turkey," "San Antonio," and "Tiberio" (presenting moderate values of L^*, h^*, and C^*) to black for "Cuello Dama Negro," "Colar Elche," and "De Rey" (characterized by presenting the lowest values of L^*, h^*, and C^*). Flesh color varied from amber for "San Antonio," "Cuello Dama Blanco," and "De Rey" (with the highest values of L^*) to pink for "Blanca Bétera" and "Tiberio" (showing moderate values of L^*) to red for "Banane," "Tres Voltas L'Any," "Cuello Dama Negro," "Colar Elche," and "Brown Turkey" (showing the lowest values of L^*) (Figure 2). The mean values of flesh color varied from 24.6–29.1 for C^*, 44.7–80.1 for h^*, and 51.7–67.8 for L^*. These results are consistent with those reported by Crisosto et al. [11] in the fig varieties "Mission," "Brown Turkey," "Kadota," and "Calimyrna" grown in California. Other authors have also reported a high variability in skin color (yellow-green, green, light green, purple, brown, and black) and flesh color (pink, amber, and red fruit) for the fig varieties studied [1, 17, 22–24].

Regarding ripening stage, brebas showed a marked decline for all color parameters studied, in both skin and flesh, during the ripening process due in part to either an accumulation of anthocyanins or a degradation in chlorophyll content [1, 25]. These results are consistent with those obtained for other varieties grown in California and Turkey [11, 22, 26].

The skin and flesh color of breba crops are two of the most important factors for consumer preferences and are used to assess the status of ripening in brebas [27]. In general, breba crops with pink and red flesh are preferred by consumers for fresh consumption in several countries [17, 22], although Crisosto et al. [11] reported that "Cuello Dama Blanco," whose flesh color is amber, was the variety that presented the highest percentage of acceptance by consumers.

3.2.2. Firmness. Firmness values of the brebas crops are given in Table 1. The mean values for firmness ranged from 1.9 to 7.1 N mm^{-1}. The "Brown Turkey" variety showed the highest firmness value (7.1 N mm^{-1}), followed by "Blanca Bétera" (4.2 N mm^{-1}), "Banane" (4 N mm^{-1}), "Cuello Dama Negro" (3.5 N mm^{-1}), and "Colar Elche" (3.1 N mm^{-1}). Conversely,

Table 1: Values of firmness, TSS, pH, TA, and MI for the breba varieties and commercial ripening stages studied.

Varieties/stage	Firmness ($N\,mm^{-1}$)		TSS (°Brix)		pH		TA (g citric acid 100 g^{-1} FW)		MI (TSS/TA)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Variety										
"Cuello Dama Blanco"	1.9[e,2]	1.4	19.1[a]	3.9	6.1[a]	0.3	0.1[f]	0.02	221[a]	67.8
"Brown Turkey"	7.1[a]	3.3	15.2[e]	1.1	5.7[b]	0.3	0.1[e]	0.02	151[c]	56.9
"Tiberio"	2.5[d]	1.9	16.2[d]	1.6	5.7[b]	0.3	0.1[d]	0.03	141[c]	36.9
"San Antonio"	2.5[d]	1.3	16.2[d]	1.8	6.0[a]	0.3	0.1[f]	0.02	190[b]	60.1
"Cuello Dama Negro"	3.5[c]	2.1	18.9[b]	2.4	5.5[b]	0.3	0.2[b]	0.05	140[c]	57.2
"Banane"	4.0[b]	1.7	15.4[e]	1.5	5.4[c]	0.4	0.2[a]	0.06	112[d]	53.3
"Colar Elche"	3.1[c]	1.3	18.6[b]	1.5	5.5[b]	0.4	0.1[c]	0.04	148[c]	50.3
"Tres Voltas L'Any"	2.1[d]	1.1	18.0[c]	1.6	5.7[b]	0.3	0.1[c]	0.03	141[c]	47.9
"Blanca Bétera"	4.2[b]	1.8	16.9[d]	2.2	5.3[d]	0.3	0.2[a]	0.06	108[d]	54.4
Stage										
1	4.9[c]	2.7	15.6[c]	2.0	5.4[c]	0.3	0.2[a]	0.05	110[a]	44.8
2	3.2[b]	1.7	17.1[b]	1.9	5.6[b]	0.4	0.1[b]	0.05	133[b]	42.4
3	1.9[a]	1.2	19.1[a]	2.5	5.9[a]	0.4	0.1[c]	0.03	201[a]	57.1
p variety[2]	* * *		* * *		* * *		* * *		* * *	
p stage	* * *		* * *		* * *		* * *		* * *	
p variety* stage	* * *		* * *		**		* * *		*	

[1] In each column, different letter indicates a significant difference within variety or ripening stage ($p < 0.05$).
[2] p values: $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

"Cuello Dama Blanco" was the variety with the lowest firmness value ($1.9\,N\,mm^{-1}$). These results confirmed those obtained in our previous study for these varieties [13]. Significant differences were also found among ripening stages. In general, firmness was strongly affected by the ripening stage of fruit, decreasing gradually with maturity [11, 28, 29]. Consequently, stage 3 showed the lowest mean values of firmness ($1.9\,N\,mm^{-1}$) while stage 1 presented the highest mean values ($4.9\,N\,mm^{-1}$, Table 1). This is in agreement with previous results reported by Crisosto et al. [11] for four fig tree varieties, who found a pronounced decrease in firmness between commercial maturity and tree ripe fruit, and moreover these authors also found that the variety-maturity stage combinations studied were segregated into five different groups according to their firmness. The loss of firmness is partially due to changes in the structure of the cell wall by dissolution of the middle lamella and disruption of the primary cell wall during ripening process [25]. Therefore, it is very important to establish the optimum point of maturity with respect to firmness to avoid fruits becoming more susceptible to damage during transport and storage [27].

3.2.3. Soluble Solids, Titratable Acidity, pH, and Maturation Index. The mean values of total soluble solids (TSS), titratable acidity (TA), pH, and maturation index (MI) (TSS/TA) of the brebas are presented in Table 1. Differences were observed in these parameters between different breba varieties and ripening stages.

Mean values of TSS for these nine varieties ranged from 15.2 ("Brown Turkey") to 19.1 °Brix ("Cuello Dama Blanco"). Significant differences were found among varieties (Table 1), allowing us to classify the fruit into three groups according to their TSS content: the highest content (19 °Brix or more), followed by moderate content (around 18 °Brix) and the lowest content (15–17 °Brix). There is no literature available with which to compare the results obtained from this study, but several authors have reported that figs of these same varieties showed similar ranges of TSS [11, 30–32]. Additionally, Crisosto et al. [11] also found that figs of the "Kadota" variety, also called "Cuello Dama Blanco," presented high levels of TSS. On the other hand, in our study, TSS increased from stage 1 (15.6 °Brix) to stage 3 (19.1 °Brix) (Table 1). Similar results were reported by Crisosto et al. [11], who also found an increase in TSS between commercial maturity and tree ripe. In addition, these same authors also reported a significant positive correlation between TSS and degree of liking in fig fruit.

The pH levels of brebas varied between 5.1 and 6.1. The lowest pH values were obtained in the varieties "Blanca Bétera" and "Banane" (5.3 and 5.4, resp.), while the highest pH values were observed for "San Antonio" and "Cuello Dama Blanco" (6.0 and 6.1, resp.) (Table 1). The pH plays an important role in the sensory quality of fruit, affecting the perception of sweetness, with increased pH correlating with increased sweetness [33]. With respect to TA, concentrations varied from 0.1 to 0.2 g citric acid 100 g^{-1} FW. These results are in agreement with those obtained by Souza et al. [20] in breba crops of the same varieties grown in Spain. Nevertheless, values obtained in this study were lower than those obtained by Crisosto et al. [11] for figs grown in California. This discrepancy can be explained by the influence of environmental conditions on fruit quality [25]. In addition, TA decreased significantly from stage 1 to stage 3. This tendency was also found by Crisosto et al. [11] for figs obtained from these same varieties. TA has also been reported to present a negative correlation with degree of liking and, therefore, TA has a low impact on consumer acceptance.

Regarding MI (TSS/TA), values ranged from 108 ("Blanca Bétera") to 221 ("Cuello Dama Blanco"). High MI values were also found for "San Antonio" (190), "Brown Turkey" (151), and "Colar Elche" (148). However, the "Banane" and "Blanca Bétera" varieties showed the lowest values of MI with 112 and 108, respectively. This ratio is used as an index of consumer acceptability and fruit quality [25] since the perceived sweetness of ripened fruit depends on the TSS/TA ratio [33, 34]. In addition, Çalişkan and Polat [34] have also reported that figs with high TSS/TA ratio produce high quality dried fruit. On the other hand, the TSS/TA ratio showed a clear tendency toward greater values with increasing maturity, ranging from 110 in stage 1 to 201 in stage 3. In general, TSS/TA ratios obtained in this study were much higher than those obtained by Crisosto et al. [11] for the same varieties at two different ripening stages.

3.3. Composition

3.3.1. Sugars. The levels of sugars and organic acids in fruit and vegetables are the most important factors in determining the taste of ripe fleshy fruit and thus consumer acceptance [25, 34, 35]. The relative amount of these constituents depends on the metabolic activity of the fruit and the interaction of sugars and acids and are directly correlated with factors such as genotype, ripening stage, and storage conditions [20, 25, 28]. The concentrations of sugars and organic acids found in skin and flesh of the breba crops are given in Tables 2 and 3. According to other authors, glucose is the main sugar found in brebas and figs, followed by fructose and sucrose [8, 24, 36, 37]. Significant differences were observed in the sugar content for fruit skin and flesh among different varieties of brebas. Glucose values ranged from 27.3 g per kg of FW ("Brown Turkey") to 103.6 g per kg of FW ("Cuello Dama Blanco") for skin, whereas for flesh those values ranged from 47 g per kg of FW ("Brown Turkey") to 75.4 g per kg of FW ("Colar Elche"). Souza et al. [20] also found that the "Colar Elche" variety showed a higher content of glucose compared to the other varieties studied. For fructose, values ranged from 30.3 g per kg of FW ("Brown Turkey") to 90.0 g per kg of FW ("Cuello Dama Blanco") for skin, while in flesh values varied from 49.4 g per kg of FW ("Brown Turkey") to 74.7 g per kg of FW ("Tres Voltas L'Any"). Additionally, the "Colar Elche" variety showed high values of fructose in both skin and flesh with 63.7 g per kg of FW and 68.4 g per kg of FW, respectively. These values of glucose and fructose confirm the findings obtained from brebas by other authors [20, 36]. In general, glucose levels were higher than fructose levels in brebas. Nevertheless, there were varieties such as "Brown Turkey," "Cuello Dama Negro," "Tres Voltas L'Any," and "Blanca Bétera" that showed fructose levels higher than glucose. These results demonstrate the influence of genotype on the glucose/fructose ratio. This aspect is important since fructose is 80% sweeter than sucrose, while glucose is only 60% sweeter than sucrose [25] and therefore varieties with a lower glucose/fructose ratio should have a higher sweetness compared to other varieties studied. All varieties showed low amounts of sucrose, between 0.2 and 1.4 g per kg of FW for skin and 0.3 and 2.1 g per kg of FW for flesh. This is due to the hydrolysis of sucrose into fructose and glucose during fruit ripening [25]. "Banane" and "Cuello Dama Blanco" showed the highest values of sucrose in skin and flesh (2.5 and 2.1 g per kg of FW, resp.). These values are similar to those obtained from breba and figs in other studies [22, 24, 26, 36]. Therefore, the perception of sweetness of brebas depends on whether they are consumed whole or peeled. Regarding ripening stages, glucose and fructose values were increased significantly in both skin and flesh during ripening process. This tendency is in agreement with the accumulation of sugars with maturity reported in figs and other fruits such as pomegranate and sweet cherries [27, 38, 39]. The mean values for these sugars in breba skin ranged between 50.1 (stage 1) and 65.9 g per kg of FW (stage 3) for glucose and 43.5 (stage 1) and 69.3 g per kg of FW (stage 3) for fructose, whereas in flesh these values were 53.2 (stage 1) and 70.3 g per kg of FW (stage 3) for glucose and 51.8 (stage 1) and 69.1 g per kg of FW (stage 3) for fructose. On the other hand, no differences were detected in the sucrose level in both skin and flesh. To our knowledge, this is the first time that the sugar content of brebas has been studied in relation to maturity; hence our data cannot be compared to others, although our results are consistent with those of Serrano et al. [40] in sweet cherries.

3.3.2. Organic Acids. The amount of organic acids in both skin and flesh showed significant differences among varieties (Tables 2 and 3). Flesh presented a higher organic acid content than skin. The level of malic acid was higher than that of succinic acid or citric acid in skin. Organic acid contents for skin ranged from 0.1 to 0.9 g per kg of FW for citric acid, 0.8 to 3.6 g per kg of FW for malic acid, and 1 to 4.3 g per kg of FW for succinic acid. With respect to flesh, values fluctuated between 1.3 and 3.1 g per kg of FW for citric acid, 1.2 and 4 g per kg of FW for malic acid, and 1 and 2 g per kg of FW for succinic acid.

In skin, "Colar Elche" and "Cuello Dama Blanco" contained the highest levels of citric and malic acids (0.9 and 0.8 g per kg of FW for citric acid and 3.6 and 3.4 g per kg of FW for malic acid) while "Tres Voltas L'Any" and "Colar Elche" contained the highest concentrations of succinic acid (2.9 and 2.6 g per kg of FW, resp.). For flesh, values ranged between 1.3 and 3.1 g per kg of FW for citric acid, 1.2 and 4 g per kg of FW for malic acid, and 1 and 2 g per kg of FW for succinic acid. The brebas of the "Cuello Dama Negro" varieties had the highest values of malic and citric acid levels with values of 4 per kg of FW for malic acid and 2.8 g per kg of FW for citric acid. On the other hand, the "San Antonio" and "Blanca Bétera" varieties had high values of succinic acid, with both measuring 2 g per kg of FW. These results are in contrast to

Table 2: Sugars and organic acids in skin of the brebas according to fig tree varieties and commercial ripening stage (g kg^{-1} FW).

	Sugars						Organic acids					
	Glucose		Fructose		Sucrose		Citric acid		Malic acid		Succinic acid	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Variety[1]												
CDB	103.6^{a,2}	35.7	90.9^{a}	27.5	1.4^{a}	4.5	0.8^{a}	0.7	3.3^{a}	1.5	2.5^{a}	1.0
BT	27.3^{e}	16.4	30.4^{d}	15.8	0.2^{a}	0.2	0.3^{b}	0.6	1.6^{b}	0.8	1.0^{d}	0.6
Ti	69.4^{b}	21.2	57.9^{b}	22.5	0.2^{a}	0.2	0.4^{b}	0.4	1.5^{b}	0.6	1.5^{b}	0.6
SA	32.5^{e}	8.5	31.9^{e}	9.1	0.2^{a}	0.1	0.4^{b}	0.3	1.4^{b}	1.3	1.2^{c}	0.6
CDN	46^{c}	34	47.4^{c}	23.7	0.2^{a}	0.2	0.3^{b}	0.2	1.3^{b}	0.9	2.4^{a}	1.5
BN	62.6^{b}	30.4	50.6^{c}	20.8	2.5^{a}	6.6	0.5^{b}	0.3	1.7^{b}	1.1	2.2^{a}	1.2
CE	70.6^{b}	35.3	63.7^{b}	19.4	0.4^{a}	0.5	0.9^{a}	1.0	3.4^{a}	1.7	2.6^{a}	1.3
TV	40.8^{d}	21.4	59.5^{b}	31.1	0.6^{a}	0.5	0.2^{b}	0.2	1.7^{b}	1.8	2.9^{a}	3.0
BB	41.2^{d}	38.2	54.5^{b}	21.9	0.2^{a}	0.3	0.1^{b}	0.2	0.8^{b}	1.5	2.6^{a}	0.9
Stage												
1	50.1^{b}	32.8	43.5^{b}	23.8	0.9^{a}	3.8	0.5^{a}	0.7	1.7^{a}	1.4	2.2^{a}	1.2
2	55.8^{ab}	29	53.7^{b}	22.1	0.4^{a}	1.2	0.4^{a}	0.5	1.9^{a}	1.3	2.3^{a}	2.0
3	65.9^{a}	42.2	72.1^{a}	37.7	0.6^{a}	2.6	0.4^{a}	0.4	2.3^{a}	1.7	2.2^{a}	1.4
p variety[3]	* * *		* * *		ns		* * *		* * *		* * *	
p stage	* * *		* * *		ns		ns		ns		ns	
p v*s	ns		*		ns		ns		ns		ns	

[1]CDB: Cuello Dama Blanco; BT: Brown Turkey; Ti: Tiberio; SA: San Antonio; CDN: Cuello Dama Negro; BN: Banane; CE: Colar Elche; TV: Tres Voltas L'Any; BB: Blanca Bétera.
[2]In each column, different letter indicates a significant difference within variety or ripening stage ($p < 0.05$).
[3]p values: ns: not significant; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Table 3: Sugars and organic acids in flesh of the brebas according to fig tree varieties and commercial ripening stage (g kg^{-1} FW).

	Sugars						Organic acids					
	Glucose		Fructose		Sucrose		Citric acid		Malic acid		Succinic acid	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Variety[1]												
CDB	70.8^{a,2}	19.3	64.3^{a}	17.8	2.1^{a}	2.7	2.6^{a}	0.8	3.5^{a}	1.4	1.8^{a}	0.8
BT	47^{d}	25.3	49.4^{c}	12.3	0.3^{a}	0.7	1.3^{b}	0.9	1.8^{c}	1.2	1.4^{a}	1.2
Ti	61.4^{a}	17.2	55.7^{b}	18.2	1.5^{a}	2.2	1.9^{a}	1.5	1.2^{d}	0.9	1.0^{b}	1.1
SA	48.3^{d}	11.2	51.5^{b}	9.7	0.4^{a}	0.4	0.9^{c}	0.6	3.0^{a}	1.8	2.0^{a}	1.2
CDN	59.8^{a}	17.9	67.1^{a}	13.7	0.5^{a}	0.7	2.8^{a}	1.6	4.0^{a}	2.6	1.6^{a}	0.8
BN	54.3^{c}	22.7	48.7^{d}	15.8	1.9^{a}	2.6	2.6^{a}	1.9	2.0^{b}	0.9	1.3^{a}	0.9
CE	75.4^{a}	24.2	68.4^{a}	16.8	1.9^{a}	1.8	1.9^{a}	0.7	3.6^{a}	1.5	1.5^{a}	1.0
TV	60.0^{a}	13.5	74.7^{a}	29.4	0.4^{a}	0.4	2.1^{a}	1.1	4.0^{a}	1.6	1.2^{a}	0.5
BB	58.2^{b}	22	63.5^{a}	29.5	1.2^{a}	1.6	2.1^{a}	1.1	3.8^{a}	1.3	2.0^{a}	0.6
Stage												
1	53.2^{b}	20.4	51.8^{c}	13.8	1.5^{a}	2.4	2.2^{a}	1.4	3.0^{a}	1.9	1.6^{a}	0.9
2	59.1^{b}	20.9	60.5^{b}	16.9	0.9^{a}	1.3	2.2^{a}	1.5	3.0^{a}	1.8	1.7^{a}	1.1
3	70.3^{a}	19.3	69.1^{a}	23.7	0.9^{a}	1.3	1.9^{a}	1.1	2.9^{a}	1.5	1.5^{a}	1.0
p variety[3]	* * *		* * *		**		* * *		* * *		**	
p stage	* * *		* * *		*		ns		ns		ns	
p v*s	ns		ns		ns		ns		ns		ns	

[1]CDB: Cuello Dama Blanco; BT: Brown Turkey; Ti: Tiberio; SA: San Antonio; CDN: Cuello Dama Negro; BN: Banane; CE: Colar Elche; TV: Tres Voltas L'Any; BB: Blanca Bétera.
[2]In each column, different letter indicates a significant difference within variety or ripening stage ($p < 0.05$).
[3]p values: ns: not significant; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Table 4: Concentrations of protein, crude fiber, and main minerals according to fig tree varieties and commercial ripening stage.

	Fiber (%)		Protein (%)		Major minerals g/kg								Trace minerals (ppm)			
					P		K		Ca		Mg		Fe		Zn	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Varieties[1]																
CDB	$5.0^{e,2}$	0.5	5.2^{cd}	0.3	1.2^{bc}	0.07	11.4^{a}	0.85	2.2^{bc}	0.3	1.5^{a}	0.1	30.6^{ab}	4.5	10.9^{a}	1.3
BT	6.7^{abc}	1.6	5.9^{b}	0.8	1.3^{ab}	0.23	9.0^{cd}	1.1	2.3^{bc}	0.7	1.0^{c}	0.3	38.7^{a}	6.2	6.6^{b}	3.0
Ti	5.6^{de}	0.7	6.7^{a}	0.6	1.0^{c}	0.12	9.9^{abcd}	1.7	2.5^{bc}	0.7	1.2^{abc}	0.3	27.8^{b}	9.1	11.9^{a}	6.0
SA	5.1^{de}	0.9	5.9^{b}	0.6	1.2^{bc}	0.2	10.9^{ab}	2.4	3.1^{a}	0.6	1.4^{ab}	0.4	37.6^{ab}	12.8	10.5^{a}	3.7
CDN	6.0^{bcd}	1.0	4.7^{de}	0.3	1.0^{c}	0.16	8.9^{cd}	0.8	2.0^{bc}	0.3	1.0^{c}	0.2	31.6^{ab}	7.5	6.4^{b}	3.3
BN	7.4^{a}	1.3	5.6^{bc}	0.7	1.0^{c}	0.12	10.2^{abc}	2.7	2.3^{bc}	0.6	1.4^{a}	0.5	34.7^{ab}	16.7	10.2^{a}	3.7
CE	5.9^{cde}	1.7	4.4^{e}	0.6	1.0^{c}	0.10	9.6^{bcd}	1.9	2.1^{bc}	0.7	1.3^{abc}	0.3	30.2^{ab}	7.1	6.2^{b}	2.1
TV	6.9^{ab}	1.9	5.8^{b}	1.1	1.3^{ab}	0.27	8.2^{d}	1.2	2.1^{bc}	0.5	1.1^{bc}	0.3	37.1^{ab}	8.7	10.4^{a}	4.2
BB	4.0^{f}	0.7	5.8^{b}	0.9	1.4^{a}	0.24	8.9^{cd}	0.8	1.9^{c}	0.4	1.0^{c}	0.1	40.0^{a}	6.4	9.0^{ab}	2.6
Stages																
1	6.9^{a}	1.7	6.1^{a}	0.9	1.3^{a}	0.26	10.2^{a}	1.9	2.6^{a}	0.6	1.4^{a}	0.3	36.8^{a}	9.2	11.1^{a}	4.6
2	5.8^{b}	1.3	5.5^{b}	0.9	1.1^{b}	0.17	9.5^{ab}	1.8	2.3^{b}	0.6	1.2^{b}	0.3	34.5^{ab}	11.9	8.6^{b}	3.3
3	5.0^{c}	1.1	5.1^{c}	0.8	1.1^{b}	0.17	8.9^{b}	1.7	1.9^{c}	0.5	1.0^{c}	0.2	32.1^{b}	9.2	7.4^{b}	3.4
p variety[3]	* * *		* * *		* * *		* * *		* * *		* * *		* * *		* * *	
p stage	* * *		* * *		* * *		* * *		* * *		* * *		**		* * *	
p v*s	*		*		ns		ns		ns		ns		ns		ns	

[1] CDB: Cuello Dama Blanco; BT: Brown Turkey; Ti: Tiberio; SA: San Antonio; CDN: Cuello Dama Negro; BN: Banane; CE: Colar Elche; TV: Tres Voltas L'Any; BB: Blanca Bétera.
[2] In each column, different letter indicates a significant difference within cultivar or ripening stage ($p < 0.05$).
[3] p values: ns: not significant; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

those obtained by Melgarejo et al. [36], who demonstrated that, in general, breba tree varieties showed higher citric acid than malic acid content.

On the other hand, no significant differences in organic acid contents were found among the ripening stages studied (Tables 2 and 3). The mean amounts of citric, malic, and succinic acids found in flesh were 1.9–2.2 g per kg of FW, 2.9–3 g per kg of FW, and 1.5–1.7 g per kg of FW, respectively, while in skin these values were 0.4–0.5 g per kg of FW, 1.7–2.3 g per kg of FW, and 2.2–2.3 g per kg of FW, respectively. As previously stated, almost no information exists on the effect of ripening stage on organic acid content in brebas. Our results suggest that organic acid contents are gradually maintained throughout the third growth phase of fruit.

3.3.3. Protein and Crude Fiber. The mean values of protein for the nine varieties ranged between 4.4% and 6.7% (Table 4), confirming values found by Wendeln et al. [41] for fourteen fig species grown from Barro Colorado Island (Panama). Nevertheless, other authors have described higher protein values in different wild fruit of the genus *Ficus* grown in the Himalaya region (Pakistan), specifically *Ficus carica,* which showed a protein content of 8.6% [42]. In our study, the "Tiberio," "Brown Turkey," and "San Antonio" varieties showed the highest protein content, ranging between 5.9 and 6.7%. On the other hand, "Colar Elche" and "Cuello Dama Negro" showed protein values lower than 5%. Additionally, statistically significant differences were observed among ripening stages, showing a decrease from 6.1% to 5.1% of mean protein values between stages 1 and 3.

The values for crude fiber ranged from 4% to 7.4%. In this case, the variety "Banane" showed the highest crude fiber content (7.4%) followed by "Tres Volta L'Any" and "Brown Turkey" (6.9 and 6.7%, resp.), while "Blanca Bétera" had the lowest values of crude fiber (4%). With respect to commercial ripening stages, a significant decrease in crude fiber content was observed from stage 1 (6.9%) to stage 3 (5%). The "Brown Turkey," "Banane," and the "Tres Voltas L'Any" varieties showed the greatest differences among stages. The crude fiber content in figs was higher than that obtained in other fruits including apple, pear, or banana; those values ranged between 0.4 and 1% (FCNT) [43]. However, results obtained in this study were below those obtained by Sadia e al. [42], who demonstrated 14.2% crude fiber content in the species *Ficus carica*. On the contrary, Tanwar et al. [44] showed lower values (1.2%) than those obtained in this study in fig flesh. However, Vinson et al. [45] obtained crude fiber values of 2.9% in both the "Calimyrna" and "Mission" varieties of fresh figs.

3.3.4. Minerals. The mineral concentrations of the nine varieties studied are shown in Table 3. Mineral contents in plants are known to be affected by genotype, environmental conditions, use of fertilizers, and the nutritional status of the plant [46–48]. In concordance with other studies [42, 47], K and Ca were the primary minerals found in all varieties, with concentrations ranging from 8.2 (TV) to 11.4 g kg^{-1} DW

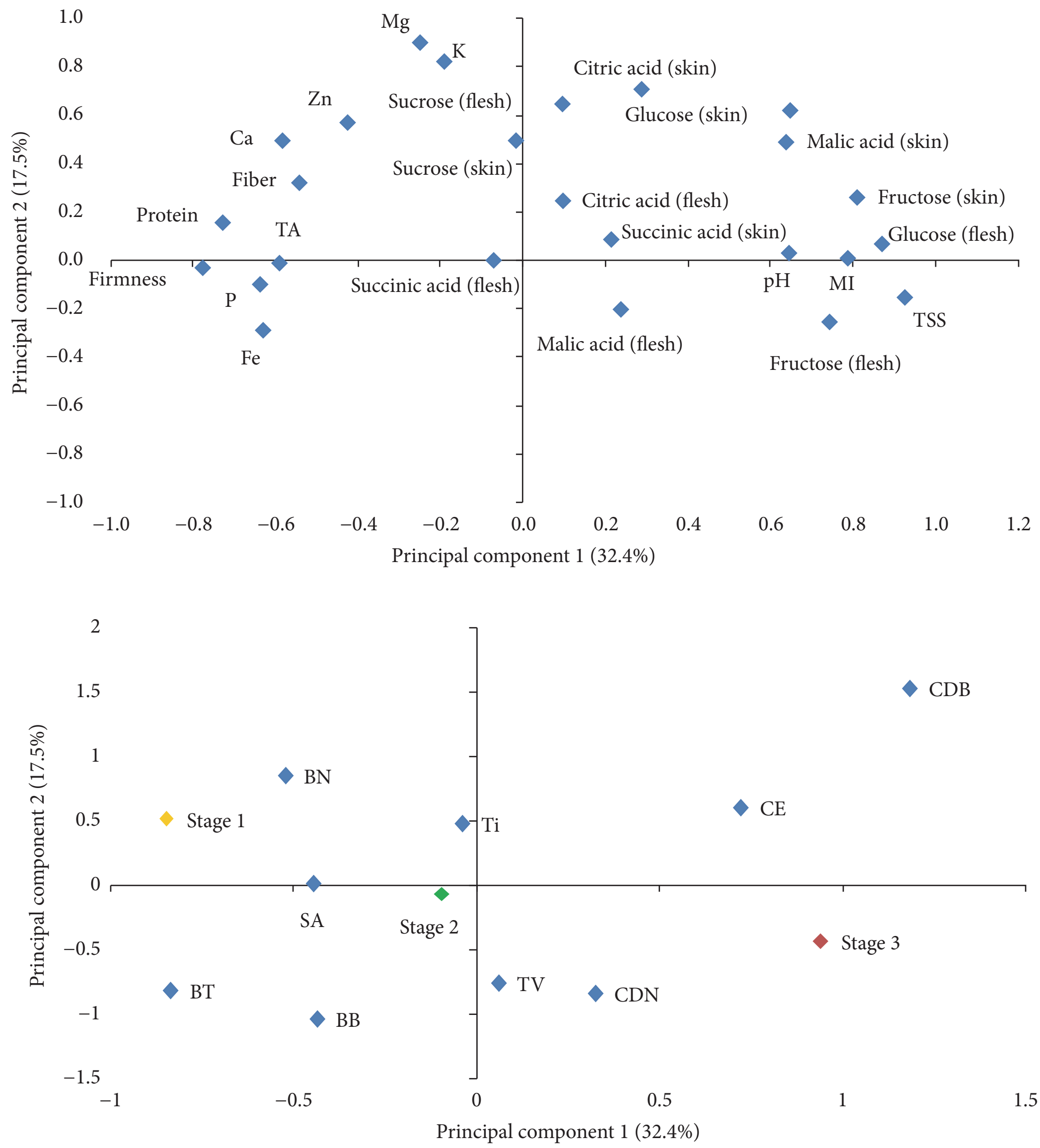

Figure 3: Loading plot and score plot after principal component analysis of the variables and individuals in the plane by two first principal components (PC1 and PC2). CDB: Cuello Dama Blanco; BT: Brown Turkey; Ti: Tiberio; SA: San Antonio; CDN: Cuello Dama Negro; BN: Banane; CE: Colar Elche; TV: Tres Voltas L'Any; BB: Blanca Bétera; TA: Titrable Acidity; TSS: Total Soluble Solids; MI: Maturation Index.

(CDB) for K and from 1.9 (BB) to 3.1 g kg^{-1} DW (SA) for Ca. These results were comparable with those obtained for several local fig varieties of Tunisia such as "Baghli," "Kahli," or "Marchini" [49, 50] and lower than those found by Khan et al. [47] and Vinson et al. [45] in figs and dried fruits. The values for P and Mg were above 1 g kg^{-1} DW for all cultivars. This is in contrast to the P levels measured by Khan et al. [47] in fig cultivars from Pakistan, who found lower values than those of our research. On the other hand, Fe and Zn were found in smaller amounts ranging from 30.2 (CE) to 40.0 ppm (BB) for Fe and from 6.2 (CE) to 11.9 ppm (Ti) for Zn. Significant differences in mineral content were also observed among different commercial ripening stages. A significant decline was observed in the mineral content during ripening, with stage 1 showing higher values than stage 3. A previous study reported that a loss of mineral composition is a crucial physical event for softening of fruit [51]. These findings have demonstrated that brebas can be considered a rich source of K, Ca, and Fe [8, 45, 49, 52]. Mineral elements play important roles in health and disease states in humans [42, 47, 53]. For example, K is an important nutrient for controlling human blood pressure; therefore fruit that contains high levels of K, such as brebas, might be recommended for hypertension. Similarly, Ca is a major component of bone and assists in tooth development [42, 54]; therefore consumption of Ca-rich foods may provide positive health outcomes related to these tissues.

3.3.5. Multivariate Analysis. In order to adequately characterize the varieties and the effect of commercial ripening stage on the composition of the brebas studied, a principal component analysis (PCA) was performed with the quality and chemical parameters (Figure 3). The TSS, sugars, MI, and pH were explained positively by the first principal component 1 (PC1) of the PCA, which explains 32.4% of the total variability. These parameters were clearly related to stage 3, mainly for the "Cuello Dama Blanco" and "Colar Elche" varieties. Conversely, the negative axis of PC1 was defined by firmness, protein, and, to a lesser extent, TA, fiber, and some minerals (P, Fe, and Ca), which were related to stage 1 mainly for the "Brown Turkey," "Blanca Bétera," "Banane," and "San Antonio" varieties. PC2, which explains 17.5% of the total variability, was positively related to the content of minerals such as Mg and K, sucrose levels (in skin and flesh), and citric acid concentration (in skin) and negatively associated with the "Brown Turkey," "Blanca Bétera," "Tres Voltas L'Any," and "Cuello Dama Negro" varieties.

4. Conclusion

In summary, because all fig trees were located in the same area and the samples corresponded to two agronomic years, the differences in the physicochemical composition of brebas depended basically on the biochemical characteristics of each variety and to a lesser extent on the commercial ripening stage. From the productive viewpoint, breba crops that showed the highest weight and size belonged to the "Brown Turkey" and "Banane" varieties and in concordance with the yields of these varieties. In addition, these varieties were characterized by being more firm and showed the highest amount of fiber, protein, and minerals such as Ca and P. High values of these parameters were also associated with the early commercial ripening stage (stage 1). From the quality viewpoint, the samples with higher values, in flesh, of the majority of sugars, as well as higher TSS and MI values were related to stage 3 and varieties such as "Cuello Dama Negro" and "Colar Elche." No clear tendency was observed for organic acids. In general, brebas may be considered a good source of K, Ca, P, and Mg, and their consumption as a vegetable might also meet the daily dietary requirements for fiber. Finally, in order to establish their commercial value, the sensorial and functional characterization of these varieties of brebas may be carried out.

Competing Interests

The authors declare that they have no competing interests.

Acknowledgments

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