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Research Article

Assessment of Nutritional, Technological, and Commercial Apricot Quality Criteria of the Moroccan Cultivar "Maoui" Compared to Introduced Spanish Cultivars "Canino" and "Delpatriarca" towards Suitable Valorization

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Apricot is among the most important fruits in Morocco. This study aimed to determine the main physical, physicochemical, and biochemical quality criteria of three principal apricot cultivars in Morocco, namely, "Maoui," "Canino," and "Delpatriarca." Different physicochemical and biochemical methods have been improved and adapted for the assessment of the apricot's quality. Fruit of "Canino" has shown a good organoleptic quality due to interesting biometrics, richness of carotenoids (up to 113.67 μg of β-carotene g^{-1} of fresh weight (FW)), and an important content of soluble solids (SS) that reached 17.20 °Bx. "Delpatriarca" is rich in organic acids (27.35 g/kg FW for total acids) while "Maoui" has high water content (83.77%) and a SS content of 16.03 °Bx. The association of the total acidity and soluble solids determination with the use of the HPLC for determining the organic acids was very practical and effective in determining the organoleptic quality of the fruit. High correlations were detected between several attributes. In addition, an important relationship between total carotenoids concentration and color parameters (L∗a∗b∗) demonstrated that these parameters are good for apricot quality and ripening indices. The obtained results also revealed the presence of a high variability among the quality criteria of the three apricot cultivars. These characteristics could be useful for promoting the consumption of the "Maoui" as fresh fruits and the use of "Canino" and "Delpatriarca" for industry derivatives products. The results could also be useful for new apricot breeding program among different eco-geographical groups of the Mediterranean region.

1. Introduction

Apricot (*Prunus armeniaca* L.) is a rich source of vitamins and minerals and is one of the most familiar crops worldwide [1]. Mediterranean countries, including Morocco, supply the greatest proportion of world apricot production and the totality of the varieties cultivated in this area belongs to *Prunus armeniaca* L. species. Exceptional fruit quality has become essential for the acceptance of apricot cultivars by consumers especially with the continuous competition increase in the market due to the presence of numerous new cultivars and other substitutive fruits and foods [2]. Generally, consumers buy fruit based on visual appearance at the first time and purchase repetitively by other sensory factors like taste and sweetness [3]. Fruit taste includes sweetness and acidity, which is correlated with the contents and profile of soluble sugars and organic acids [4]. Sensory quality of fruit was also affected by a series of factors, including cultivar

and maturity [5, 6]. The sensory properties of apricot fruits are mainly influenced by several physicochemical attributes [7, 8]. The characterization of the organoleptic quality in apricots depends on sugar/acid ratio. It is strongly influenced by the increase in total sugar and acidity in mature fruit [9] and principally by organic acids, sugars, volatile compounds, fruit color, size, and texture [10].

The assessment of these criteria questions the basis of used methods to determine the quality of the fruit. Indeed, the demand for improved food quality has been accompanied by a technological boost in the last years. This fact increases the possibility of improving the quality of horticultural products, leading to a healthier consumption of fruits, using different methods and new techniques. These techniques make it possible to determine and sometimes predict the various characteristics of the quality of the apricot with varying precision [5]. Several previous studies confirmed that a significant genetic diversity was observed in the apricot species for some quality studied parameters due to the different genetic origins of the cultivars [5, 11–13]. Investigation for the relation between quality parameters is helpful to determine the independent parameters that define the fruit quality. The main practical application for this is in breeding programs and orchard management since the knowing of the relationships among fruit quality parameters would reduce the number of traits needed to be studied. In this sense, multivariate analysis is a useful tool which is used to determine genetic relationship among cultivars and to study correlations among variables [8].

The mid-southwest of Morocco, especially Marrakesh region, is one of the most important apricot cultivation areas in the country. While local varieties are almost the only source of production, various renovations have occurred in recent years to introduce new interesting cultivars to meet market requirements and satisfy consumers and industry demands [5]. In this study, a large evaluation of physical parameters (fruit and stone weight, size, mesocarp percentage, skin color parameters L*a*b*, and firmness) and chemical parameters (water content, pH, soluble solids content (SS), titratable acidity (TA), SS/TA ratio, and total carotenoids) is provided using improved methods of quality characterization. This study covered the fruit quality criteria among three famous cultivars of apricot in Morocco, namely, "Canino," "Delpatriarca," and "Maoui," in order to investigate the variability of physical and chemical characters and to study the relationships among studied traits linked to the fruit quality. In addition, multivariate analysis was carried out to study correlations between variables, to examine the genotype impact and the apricots suitability either for fresh consumption or for industrial processing.

2. Materials and Methods

2.1. Plant Material and Fruit Samples. Three main apricot cultivars were studied: "Canino," "Delpatriarca," and "Maoui" (Figure 1). They were collected from apricot collection in Saâda experimental field belonging to the Regional Center for Agricultural Research in Marrakesh, National Institute for Agricultural Research, INRA, Morocco (30°21′8.4″ N, 9°30′29″ W). The experimental orchard has 184 trees gathered in a collection for a surface of 2 ha. It was planted in 1995 and used for drip irrigation. The trees were planted at a density of 4.5 × 2 m, arranged in 7 columns × 30 rows, and managed with standard cultivation practices: organic manure of 40 t/ha, major elements (NPK) equivalent to the annual needs (estimated at N: 100–150 U/ha; P205: 80–100 U/ha; K20: 150 U/ha), and an average size and thinning to adjust the load to the growth potential of the tree.

Apricots were harvested at the stage of commercial ripe in 2016 and 2017 seasons. For each cultivar, the ripening stage was based on assessing manually fruit firmness and skin color. Fruit is considered commercially ripe when it acquires its color and attains full size but yet is still very firm to withstand handling, transport, and storage conditions. The earliest apricot cultivar was "Maoui" (local cultivar) which was harvested on May, followed by the introduced Spanish cultivars, namely, "Delpatriarca" and "Canino," harvested on late May and on June consecutively.

Three trees per cultivar with a natural fruit set were used, and 10 fruits were collected from each tree. Fruit sampling was done early in the morning to minimize possible apricots quality changes. The fruits were placed in trays cartons blister and transported to laboratory for analysis. Thirty fruits of each cultivar were collected and separated in 3 lots of 10 fruits. Physical characterizations were done on individual fruits (30 replicates) while chemical analyses were realized in triplicate per lot of 10 fruits.

2.2. Physical Determinations. Various fruit characteristics were evaluated. The characteristics were weight, biometrics, firmness, and color. Fruit and stone weights were measured on electronic scale weight (Large View OHAUS® Scout® Pro Portable Electronic Balance-Model SPE401) and used to calculate the mesocarp percentage. Fruit biometric measurements (length, width, and thickness) were undertaken with an Absolute Scale Digital Caliper (Mitutoyo 500-196-30 Advanced Onsite Sensor).

Fruit firmness was measured by a manual penetrometer (Model Effegi FT 327, 8 mm plunger tip size) on the equatorial part of the fruit surface and expressed in kg/cm^2. Two colorimeter measurements on both sides (Un-Blush [UB] and Blush [B]) of each fruit were carried out using a Minolta Chroma Meter (CM-300, Minolta, Ramsey, NJ) and expressed in the CIE 1976 L*a*b* color space (illumination, 0 degrees and 8 mm diameter specimen area). L* indicates the lightness from black (0) to white (100), a* color from green (−60) to red (60), and b* color from blue (−60) to yellow (60). Un-Blush value corresponds to a measurement on the clear or less colorful side of fruit and Blush value shows the extent of a measure on the colored side of fruit.

2.3. Chemical Analysis. Each lot of 10 fresh fruits was mixed, then frozen, and stored at −20°C. Soluble solids content (SS), pH, titratable acidity (TA), water content (WC), total carotenoids, and organic acids were determined after thawing. The SS was determined using a hand refractometer (NOW, 0–32% °Bx) and pH measurements were performed using a

Figure 1: The three studied apricot cultivars: "Canino", "Delpatriarca," and "Maoui."

pH meter (WTW InoLab pH meter). Titratable acidity was measured by titration up to pH 8.1 with 0.1 N sodium hydroxide (Sigma-Aldrich, Germany) and expressed in percentage of malic acid. The ratio of soluble solids content and titratable acidity (SS/TA) was calculated and used as an indicator of taste quality [14]. The water content was determined gravimetrically by measuring the loss of mass after drying: about 2 g of fresh pulp was weighed into stainless steel capsule and then placed in an oven at 70°C under reduced pressure (–1 bar) for 12 hours. The water content was expressed in % of fresh material. For organic acids determinations, 10 g of each sample (10 flesh fruits mixed) was homogenized with distilled water (40 mL) and centrifuged at 10.000 rpm for 10 min at 22°C. The supernatant was filtered using Whatman filter paper. The extract was then filtered through a 0.45 μm membrane filter and filtrate was used for HPLC quantification of organic acids.

High-performance liquid chromatography (HPLC) system was composed of a pump (Waters Prep 3000 preparative chromatography Detta system), a column (Discovery® C18: 25 cm × 4.6 mm, 5 μ, Supelco), a detector (Jasco UV-975 Intelligent UV-Vis Detector, "degasser": Knauer advanced scientific instruments), and an integrator (Varian star 800 interface module). Organic acids were analyzed isocratically according to a validated method [10] with some modifications. HPLC elution was carried out at 35°C using 25 mM phosphate buffer KH_2PO_4/Methanol (99.9: 0.1) (pH 2.4 adjusted with H_3PO_4); the eluent flow rate was 1 mL/min. The detection was made at $\lambda = 210$ nm. The concentrations were expressed in g/kg of fresh weight (FW). Malic, citric, and oxalic acids standards were obtained from Sigma-Aldrich (St. Louis, MO, USA). Quinic, ascorbic, and fumaric acids standards were purchased from Fluka Chemical (USA). Standard solutions of each organic acid were made in the mobile phase by appropriate dilutions. Analysis of total carotenoids was performed according to a previous method [15]. A quantity of 1 g of each sample (the mixture of 10 flesh fruits) was homogenized in 1/1/2 ethanol/acetone/n-hexane solution using a pestle and mortar. After it was well shaken, the extract was allowed to stand for about 30 min, and the absorbance of the upper layer of hexane was measured in a spectrophotometer at $\lambda = 450$ nm. The total carotenoids content was calculated using molar absorption coefficient of 139×10^3 L mol^{-1} cm^{-1} and expressed in μg of β-carotene g^{-1} FW.

2.4. Statistical Analysis. Results were statistically evaluated by one-way analysis of variance (ANOVA). The means and standard deviations values of the three replicates measurements were calculated for the different variables analyzed. Differences between the average data were compared using least significant difference (LSD) and statistical differences with P values under 0.05 were considered significant. A principal component analysis (PCA) was performed using factor analysis of XLSTAT statistical software version 2011. It has been used previously to establish the relationships among cultivars, to study the correlations between fruit quality traits, and to examine other characteristics within sets of apricot cultivars [8, 16, 17]. In this study, PCA was used to highlight the correlations between physical and chemical attributes and to analyze the cultivars difference based on their quality characteristics.

3. Results and Discussion

3.1. Physical Characters in Apricot. There were significant differences between studied cultivars regarding physical traits (Table 1). Fruit length, width, thickness, and weight of "Canino" were significantly higher (45 mm, 45 mm, 41 mm, and 42 g, respectively) than those of "Maoui" (32 mm, 30 mm, 32 mm, and 20 g) and "Delpatriarca" (25 mm, 32 mm, 31 mm, and 25 g). Mesocarp percentage (MP) varied significantly between studied cultivars; "Canino" showed the highest MP (94%) followed by "Delpatriarca" (93%) and "Maoui" (89%). Biometrics and fruit weight are important physical indicators to distinguish between cultivars and it is commonly known that these criteria affect the organoleptic quality and attractiveness of the fruit [18]. The three studied cultivars showed a fresh weight below 50 g but they might produce larger fruit under better cultural practices [19]. Also, previous studies about apricot reported a high variability among cultivars regarding this parameter [7, 17, 20]. However, the characteristics that correlate best with most attractiveness fruit include fruit weight, stone weight, and mesocarp percentage. Medium-sized fruits are desired for apricot cultivar breeding [21] and the studied three cultivars have this size type. Apricot stones are commonly used in genotype identification and they have a high utilitarian value [22, 23]. "Delpatriarca" and "Maoui" have significantly lower stone weight than "Canino." Although, they belong to the same maturity stage, apricots of the three cultivars were characterized by different firmness values such as 3 kg/cm^2 for "Delpatriarca," 4 kg/cm^2 for "Canino," and 2 kg/cm^2 for "Maoui." Indeed, in addition to ripening stage, there are other factors which influence apricots firmness, namely, the genotype, the geographical origin, and the biochemical composition of the fruit [6, 24].

Table 1: Physical parameters of three apricot cultivars.

	Fruit length (mm)	Fruit width (mm)	Fruit thickness (mm)	Fruit weight (g)	Stone weight (g)	Mesocarp (%)	Firmness (kg/cm^2)	L* Un-Blush	a* Un-Blush	b* Un-Blush	L* Blush	a* Blush	b* Blush
Delpatriarca	24.87 ± 1.55^{c}	32.07 ± 2.11^{b}	30.95 ± 1.82^{b}	24.52 ± 2.02^{b}	1.78 ± 0.26^{c}	92.74 ± 0.99^{b}	2.66 ± 1.18^{b}	76.26 ± 2.72^{a}	1.62 ± 0.79^{b}	28.68 ± 3.71^{c}	70.38 ± 5.01^{a}	7.70 ± 7.07^{b}	26.07 ± 3.50^{c}
Canino	45.22 ± 1.41^{a}	44.87 ± 1.59^{a}	40.77 ± 2.11^{a}	42.47 ± 4.14^{a}	2.69 ± 0.16^{a}	93.61 ± 0.77^{a}	3.74 ± 1.21^{a}	65.86 ± 1.21^{b}	22.92 ± 2.12^{a}	54.55 ± 1.96^{a}	61.82 ± 3.11^{b}	26.79 ± 3.72^{a}	51.74 ± 4.54^{a}
Maoui	32.14 ± 1.05^{b}	30.11 ± 1.44^{b}	32.48 ± 1.56^{b}	20.08 ± 1.10^{c}	2.03 ± 0.08^{b}	89.17 ± 0.69^{c}	1.95 ± 0.94^{b}	72.74 ± 2.99^{a}	3.03 ± 1.76^{b}	37.79 ± 5.67^{b}	72.19 ± 2.06^{a}	8.19 ± 2.32^{b}	43.95 ± 4.85^{b}

Values are means ± standard deviation (SD); mean value represents the mean of thirty measures for each physical parameter. Data followed by different letters are significantly different from each other according to LSD test at $P \leq 0.05$.

The fruit color is an important indicator for fruit ripeness and harvest date of some fruits [5]. Besides, the cultivars with different fruit peel color can satisfy various consumer preferences [6, 25]. Color results presented in Table 1 showed significant differences between the three cultivars ($P \leq 0.05$). Concerning Un-Blush coloration, "Delpatriarca" and "Maoui" had the lightest aspect (L∗ between 76 and 72) and yellow color (low positive a∗ and b∗ from 28 to 38). However, "Canino" had darker (L∗ less than 70) and more orange fruits (a∗ close to 23 and b∗ to 55). The comparison between the two measurements revealed that Un-Blush analysis is the best to characterize the variability ($P \leq 0.005$) between cultivars. In addition, "Delpatriarca" may have red spot skin; "Canino" is distinguished with dark orange color while "Maoui" is characterized by a clear color (yellow-orange). The color parameters (L∗, a∗, b∗) values highlighted the presence of an important effect of genotype. The results were similar to those obtained by Ayour et al. [5] and Ruiz and Egea [17], who reported that the color of fruit changed based on apricot genotypes. Generally, the L∗ value was commonly used for objective color description in apricot [2]. However, in previous study [5], it has been reported that a∗ was the discriminant variable of the color evolution in apricot. Indeed, the evolution of a∗ between light side and colored side showed that it is an indicator in the development of orange and red colors. The increase of a∗ in parallel with decrease of L∗ reflected the darkening of the apricot fruits. These changes were due to the pigment changes during development and maturation of apricots and especially by carotenoids accumulation [2, 5].

3.2. Chemical Criteria of Apricot. Chemical traits results for the 3 cultivars are presented in Table 2. Water content (WC) is one of the most important parameters in the commercial value of apricots. In general, apricot varieties with high dry matter content (low water content) are preferred for industrial processing (dried apricot, mumps in syrup) while those with lower values are consumed freshly [26]. "Canino" was characterized by significantly higher dry matter content compared to "Delpatriarca" and "Maoui." This result is in accordance with the dual use of "Canino" in Morocco, for fresh consumption and industrial processing, while "Delpatriarca" and "Maoui" are dedicated only to fresh consumption. The word "Maoui" means in Moroccan Arabic dialect "rich in water" which is in concordance with the humidity of this cultivar. Soluble solids (SS) values confirmed this repartition with highest value for "Canino" (17 °Bx), then "Maoui" (16 °Bx), and finally "Delpatriarca" (15 °Bx). SS content is a very important quality trait which notably influences the fruit taste and flavor [17]. Previous studies have reported that apricot cultivars with a SS exceeding 12 represent an excellent gustative quality [13]. Our range of values agreed with these previous works and exceeded the minimum (10%) established by the European Union market apricots (R-EC No. 112/2001). Values of soluble solids content agreed quite well with those reported in several previous studies [24, 27] which generally ranged from 8 to 16 °Bx. Another study [27] reported higher levels of SS, which ranged from 12.73 to 20.00 °Bx, in fresh ripe apricots from Pakistan.

"Delpatriarca" showed the highest total acidity (2%), which was directly related to the lower pH (equal to 3) and the higher organic acids sum (27 g/kg of FW). "Canino" and "Maoui" fruits acidity was significantly lower, with an intermediate position for "Canino." Total acidity values were in accordance with previous study [24] and they are significantly lower than those reported in the literatures which fluctuate within a wide range (from 4.5 to 8.6 g malic acid/l) [27, 28]. Seven organic acids were detected by HPLC in analyzed cultivars and five were identified. Malic acid and citric acid were the two major organic acids as previously expected [24, 29, 30]. The citric acid concentrations were quite similar for "Delpatriarca" and "Canino" (around 13 g/kg) and divided by two for "Maoui" whereas "Delpatriarca" had the highest amount of malic acid (12 g/kg) and "Canino" the lowest (8 g/kg). This range of values aligned with those of previous works [7, 8, 26, 31], despite malic acid which was reported to be the predominant acid in apricot cultivars [32]. For the other organic acids, "Delpatriarca" significantly had the highest content of ascorbic acid (0.38 g/kg) followed by "Canino" (0.25 g/kg) and "Maoui" (0.16 g/kg). Ascorbic acid's levels in the three cultivars were in the same range (0.1–0.5 g/kg of fresh weight) as those obtained by [33]. Quinic acid contents, from nearly 3 g/kg for "Canino" to 1 g/kg for "Delpatriarca," were higher than fumaric acid concentrations in the 3 cultivars, lower than 0.7 g/kg for all of them.

Immature fruits have a sour taste as sugar/acid ratio is low. During the ripening process, fruit acids are degraded and sugar content increases driving a higher sugar/acid ratio. Overripe fruits have very low levels of fruits' acids and therefore lack their characteristic flavors. Moroccan apricot showed TSS/TA ratio significantly varied from 6 for "Delpatriarca" to 8 for "Canino," which agreed with previous studies about Spanish, Macedonian, and Turkish apricot [7, 34, 35]. The maturity index (MI = TSS/acidity) could be a good indicator for good fruit taste and can be a descriptive parameter in selecting cultivars for specific uses of fruit species [36]. Relationship between SS and TA has an important role in consumers' acceptance of some stone fruits such as apricot, peach, and nectarine. The interaction between TA and SS is more important than SS alone [13].

The acidity of apricots varied inversely with pH, SS, and MI. It was found that the total acidity decreases with fruit ripening [24]. However, pH, SS, and MI increase during apricots development and ripening. Such as in apricot, as in other fruits, declines in acidity are accompanied by increases in sugars. At least, a portion of this change may be due to the metabolic conversion of acids into sugars by gluconeogenesis reaction. A conversion of acids to sugars did not appear to take place to ripe stage because the decline in citric or malic acids was not accompanied by increases in the concentration of glucose and fructose (responsible for soluble solids change). Rather, the loss of organic acids in the mature fruit appears to be entirely due to respiration phenomenon [37]. For commercial ripe apricots, TA values recorded in this work, which varied between 1.83 and 2.21%

Table 2: Physicochemical and biochemical parameters of three apricot cultivars.

	Water content (%)	Total soluble solids (°Bx)	pH	Total acidity (% of malic acid)	SS/TA ratio	Citric acid (g/kg FW)	Malic acid (g/kg FW)	Ascorbic acid (g/kg FW)	Quinic acid (g/kg FW)	Fumaric acid (g/kg FW)	Sum of acids (g/kg FW)	Total carotenoids (μg of β-carotene/g FW)
Delpatriarca	82.25 ± 0.32^{b}	15.33 ± 0.06^{c}	3.33 ± 0.04^{b}	2.39 ± 0.04^{a}	6.42 ± 0.11^{b}	13.23 ± 0.75^{a}	12.2 ± 0.97^{a}	0.38 ± 0.06^{a}	1.19 ± 0.58^{b}	0.35 ± 0.05^{b}	27.35 ± 0.90^{a}	11.67 ± 0.39^{c}
Canino	79.75 ± 0.35^{c}	17.20 ± 0.001^{a}	3.76 ± 0.03^{a}	2.11 ± 0.001^{b}	8.14 ± 0.001^{a}	13.02 ± 0.42^{b}	7.78 ± 1.10^{c}	0.25 ± 0.04^{b}	2.96 ± 0.36^{a}	0.14 ± 0.01^{c}	24.15 ± 0.58^{b}	113.67 ± 1.76^{a}
Maoui	83.77 ± 0.14^{a}	16.03 ± 0.12^{b}	3.88 ± 0.15^{a}	2.00 ± 0.03^{c}	8.00 ± 0.11^{a}	6.97 ± 0.61^{c}	9.77 ± 0.61^{b}	0.16 ± 0.02^{c}	1.64 ± 0.12^{b}	0.67 ± 0.11^{a}	19.21 ± 1.46^{c}	19.03 ± 0.81^{b}

Values are means ± standard deviation (SD) of three replications. Data followed by different letters are significantly different from each other according to LSD test at $P \leq 0.05$.

Table 3: Correlation matrix of the physical and chemical variables.

Variables	FL	FWi	FT	FWe	SWe	Me	Fr	WC	SS	*p*H	TA	SS/TA	TC	Malic acid	Quinic acid	Ascorbic acid	Citric acid	Fumaric acid	L∗-UB	b∗-UB	L∗-B	a∗-B	b∗-B
FL	1																						
FWi	0.934∗	1																					
FT	0.922∗	0.993∗	1																				
Few	0.840∗	0.975∗	0.981∗	1																			
SWe	0.989∗	0.939∗	0.927∗	0.850∗	1																		
Me	0.253	0.568	0.595	0.731∗	0.264	1																	
Fr	0.658	0.825∗	0.846∗	0.884∗	0.677	0.752∗	1																
WC	−0.934∗	−0.984∗	−0.976∗	−0.954∗	−0.952∗	−0.520	−0.800∗	1															
SS	0.994∗	0.936∗	0.923∗	0.841∗	0.985∗	0.256	0.657	−0.933∗	1														
pH	0.600	0.297	0.289	0.104	0.582	−0.576	−0.092	−0.333	0.607	1													
TA	−0.379	−0.038	−0.021	0.150	−0.362	0.733∗	0.203	0.110	−0.343	−0.839∗	1												
SS/TA	0.732∗	0.451	0.432	0.267	0.716∗	-0.434	0.148	−0.504	0.707∗	0.899∗	−0.906∗	1											
TC	0.948∗	0.984∗	0.992∗	0.956∗	0.948∗	0.522	0.840∗	−0.968∗	0.943∗	0.359	-0.118	0.514	1										
Malic acid	−0.899∗	−0.742∗	−0.759∗	−0.643	−0.853∗	−0.070	−0.529	0.746∗	−0.864∗	−0.670∗	0.581	−0.826∗	−0.818∗	1									
Quinic acid	0.916∗	0.901∗	0.886∗	0.830∗	0.956∗	0.298	0.702∗	−0.915∗	0.900∗	0.459	−0.308	0.642	0.908∗	−0.755∗	1								
Ascorbic acid	−0.407	0.064	−0.066	0.115	−0.364	0.688∗	0.197	0.117	−0.388	−0.901∗	0.941∗	−0.877∗	−0.160	0.640	−0.231	1							
Citric acid	0.116	0.446	0.482	0.627	0.139	0.971∗	0.731∗	-0.402	0.127	−0.661	0.781∗	−0.525	0.408	0.055	0.192	0.752∗	1						
Fumaric acid	−0.512	−0.761∗	−0.789∗	−0.874∗	−0.534	−0.913∗	−0.811∗	0.710∗	−0.510	0.273	−0.526	0.165	−0.741∗	0.312	−0.578	−0.472	−0.831∗	1					
L∗-UB	−0.969∗	−0.861∗	−0.851∗	−0.754∗	−0.935∗	−0.159	−0.559	0.871∗	−0.966∗	−0.662	0.455	−0.775∗	−0.878∗	0.921∗	−0.802∗	0.521	−0.023	0.374	1				
a∗-UB	0.963∗	0.987∗	0.988∗	0.949∗	0.957∗	0.497	0.616	−0.973∗	0.957∗	0.381	−0.151	0.546	0.996∗	−0.837∗	0.904∗	−0.189	0.376	−0.704∗	−0.909∗				
b∗-UB	0.995∗	0.916∗	0.900∗	0.810∗	0.993∗	0.194	0.624	−0.922∗	0.994∗	0.645	−0.413	0.758∗	0.928∗	−0.875∗	0.925∗	−0.433	0.062	−0.470	−0.959∗	1			
L∗-B	−0.883∗	−0.976∗	−0.966∗	−0.969∗	−0.891∗	−0.628	−0.889∗	0.962∗	−0.872∗	−0.168	0.004	−0.398	−0.963∗	0.711∗	−0.888∗	−0.007	−0.514	0.787∗	0.795∗	−0.857∗	1		
a∗-B	0.948∗	0.989∗	0.980∗	0.953∗	0.954∗	0.513	0.633	−0.987∗	0.944∗	0.339	−0.133	0.525	0.986∗	−0.789∗	0.917∗	−0.149	0.389	−0.714∗	−0.881∗	0.932∗	−0.981∗	1	
b∗-B	0.955∗	0.796∗	0.788∗	0.659	0.934∗	−0.013	0.467	−0.801∗	0.954∗	0.800∗	−0.577	0.862∗	0.834∗	−0.922∗	0.828∗	−0.629	−0.138	−0.277	−0.962∗	0.964∗	−0.711∗	0.818∗	1

TA: titratable acidity; SS: soluble sugars; WC: water content; UB: Un-Blush; B: Blush; FL: fruit length; FWi: fruit width; FT: fruit thickness; Few: fruit weight; SWe: stone weight; Me: Mesocarp; Fr: Firmness; TC: total carotenoids. The values represent the correlation coefficients based on triplicate measurements for each parameter.

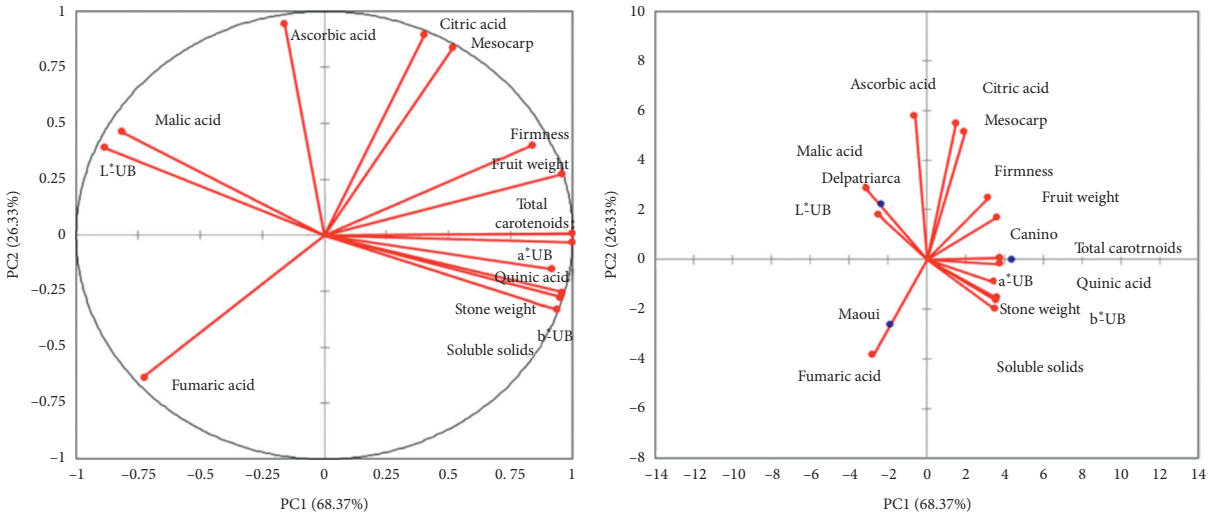

FIGURE 2: Biplots based on principal components analysis (PCA) for fruit quality attributes. (a) Correlation circle between physical parameters (fruit and stone weight, mesocarp percentage, Un-Blush skin color parameters (L∗-UB, a∗-UB, and b∗-UB), and firmness) and biochemical parameters (total soluble solids content, total carotenoids, and malic, citric, ascorbic, quinic, and fumaric acids). (b) Segregation of three cultivars according to their quality characteristics determined by PCA.

malic acid, were considerably higher as compared to the previous studies [2, 29] which, respectively, found the interval values from 0.08 to 1% citric acid and from 0.90 to 2.28% malic acid. Recently, Liu et al. [30] reported that malic acid and citric acid content of apricot did not differ significantly during shelf storage. Thus, storage temperature had no obvious effect on acid metabolism in apricot fruit. Similar conclusions were reached for tomatoes [38] and nectarines [39]. It is generally believed that organic acids are used as substrates for the glycolysis pathway and the tricarboxylic acid cycle pathway during fruit ripening [40].

Total carotenoids content in "Canino" was of 114 μg of β-carotene g^{-1} FW which was around 10 times higher than in "Delpatriarca" (12 μg of β-carotene g^{-1} FW) and 5.9 times higher than in "Maoui" (19 μg of β-carotene g^{-1} FW). We have previously reported that this difference was mainly related to the color of the fruit skin. Indeed, orange apricots were richer in carotenoids compared to light-colored ones [5]. Ruiz et al. [2] reported that carotenoids content in apricot fruit showed a good correlation with the skin and flesh color, with apricots having orange colored flesh containing higher levels of carotenoids than those having white color. Previous studies found that apricot fruits were regarded as a rich source of carotenoids especially β-carotene which represented more than 50% of total carotenoids content [5, 41, 42]. In another work, Echeverría et al. [3] reported that carotenoids content of Spanish apricot varieties ranged from 1 to 38 mg/100 g of FW. This average could be more important in some Portuguese cultivars [20].

3.3. Correlations of Variables. Correlation matrix (Table 3) reveals the presence of strong correlations between the different physicochemical properties of apricots. An interesting correlation was found between the parameters of biometrics, fruit weight, soluble solids content (SS), total carotenoids, and color variables ($R > 0.742$). However, the percentage of mesocarp and titratable acidity of fruits were the least correlated parameters with the group of studied variables; they were most correlated with ascorbic and citric acids. Fruit weight and stone weight were correlated with the size and firmness of fruits ($R = 0.850$), which showed that large apricots were firm and they had big stones [43]. Soluble solids content was significantly correlated with fruit size, carotenoids content, and color of fruits as it was reported [8, 14]. There was no relation between fruit weight and SS/titratable acidity ratio and that agrees with previous studies about apricot [7].

All organic acids (except quinic acid) were negatively correlated with the soluble solids (SS), SS/TA ratio, and color. This result explains the decrease of these compounds during fruit ripening as already mentioned in previous studies [7]. Malic acid and fumaric acid were correlated to water content, while the dry matter varied positively with citric acid and quinic acid in the three analyzed apricot cultivars. Ascorbic acid varied positively with the total acidity and negatively with pH and SS/TA ratio, while no relationship between concentration of ascorbic acid and water content or SS was noticed. A strong correlation was found between the color settings groups (Blush and Un-Blush). The variables a∗ and b∗ were positively correlated with the physical and chemical components, while the clarity (L) was negatively correlated with all these variables. Indeed, during maturation, the values of L decrease while a∗ and b∗ values increase. This can be explained by chlorophylls degradation and carotenoids accumulation during the ripening of apricots, as confirmed in previous studies [2, 5, 25, 35, 44].

Table 4: Correlations between variables and cultivars on both components (PC1 and PC2) of principal components analysis.

	Fruit weight	Stone weight	Mesocarp	Firmness	Soluble solids	Total carotenoids	Malic acid	Quinic acid	Ascorbic acid	Citric acid	Fumaric acid	L∗-UB	a∗-UB	b∗-UB	Delpatriarca	Canino	Maoui
PC1	0.958∗	0.955∗	0.517	0.836∗	0.948∗	0.998∗	−0.818∗	0.915∗	−0.162	0.401	−0.727∗	−0.888∗	0.998∗	0.934∗	0.539∗	0.952∗	0.404
PC2	0.275	−0.254	0.838∗	0.403	−0.274	0.009	0.464	-0.150	0.947∗	0.896∗	−0.633	0.394	−0.030	−0.331	0.316	0.001	0.563∗

UB: Un-Blush.

A previous study showed that a good correlation had been found between the variable a∗ and the carotenoids concentration in apricot [2]. In this study, it is found that the total carotenoid concentration was correlated with all color variables L∗-UB (R = -0.878), a∗-UB (R = 0.996), and b∗-UB (R = 0.928); these results demonstrate that these parameters were good to apricot quality determination and could be used as objective ripening indices. Moreover, the color variables recommended for prediction of both chemical and quality changes in food products have been reported [5, 45].

3.4. Variability of Quality Attributes between Cultivars. Data set was improved by reducing highly correlated variables, such as physical variables, water content, pH, total acidity, SS/TA ratio, and Blush-color components. The physical and chemical attributes allowed observing a high variability between the three apricot cultivars. More than 94.70% of the total variance was observed and explained by the first two components (Figure 2). The correlation between the variables studied and the two principal components (PC1 = 68.37% and PC2 = 26.33%) is shown in Table 4. Also, the representation of cultivars according to two factors is well explained in Table 4 such that the relation between each cultivar and main components was demonstrated.

The correlation's circle represents the distribution of variables studied and the relation between them. On the one hand, a strong correlation between the physical variables (except % mesocarp) and carotenoids content, soluble solids, firmness, and color components (a∗ and b∗) is observed. This showed that the color of the wall grew in parallel with the sugar content and especially with the development of carotenoids. On the other hand, the difference between organic acids compounds and the low correlation between these compounds was also highlighted on the circle.

The representation of cultivars (Figure 2) based on variables evolution shows that the three cultivars studied are different and are clearly distinguished. "Canino" is well explained by the first principal component PC1 ($R > 0.9$), characterized by a significant weight, an important sugar content (SS), and an attractive orange color (a∗ and b∗) explained by a high content of carotenoids. These attributes show that the fruits of the "Canino" have better organoleptic quality and explain why "Canino" apricots are used in double purpose for fresh consumption and especially for the production of mumps in syrup and jam and also for drying apricots. The diagram also shows that the fruits of "Delpatriarca" are characterized by lightness (L∗) of the peel and acidity of flesh (rich in malic acid), while "Maoui" fruits contain more fumaric acid and are characterized by high water content.

4. Conclusion

The combination of a total acidity assay supplemented by using the high-performance liquid chromatography (HPLC) has been found to be very practical and effective in determining the organoleptic quality of the fruit. Multivariate analysis allowed differentiating between the three studied cultivars based on the physical and chemical attributes of apricots. It highlighted the correlations between different variables and the prediction of some chemical compounds from a physical component, especially the strong correlation between carotenoids content and the color parameters (a∗, b∗, and L∗). The obtained results revealed the presence of an important variability among the quality criteria of studied cultivars. "Canino" is characterized by a large size and richness in soluble solids (sugars) and carotenoids; "Delpatriarca" is rich in organic acids especially ascorbic acid (0.38 g/kg) while "Maoui" fruits contain more juice (water content of 84%) and a good quality index. These characteristics could be useful for further developing the apricot industry in the Marrakesh region. Moreover, it could promote the consumption of "Maoui" fresh fruits and derived food products based on the apricot fruits "Canino" and "Delpatriarca."

Data Availability

The data used to support the findings of this study are included within this article and other data are published in the articles available at the link: https://www.researchgate.net/profile/Jamal-Ayour/research.

Disclosure

This research was performed as part of the research activities of the Regional Center for Agricultural Research in Marrakesh belonging to the National Institute for Agricultural Research (INRA Morocco).

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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