



Pomological and biochemical characterization of almond cultivars in Morocco

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Abstract

Commercial and local (*PrunusDulsus* L.) cultivars vary considerably in their fruit and kernel characteristics. In the present study, fruit and kernel traits and kernel biochemical composition of 14 almond cultivars grown in Morocco, were examined. Results showed significant differences exist among all genotypes across a number of morphological traits and bioactives properties. The imported cultivars generally showed improved physical traits, such as larger fruit and kernels and. However, the Moroccan cultivars such as Rhizlane-1 and "Rhizlane-2 had a higher phenolic content (59 and 54 mg/g⁻¹ DW), had a polyphenol content in kernel skin than all imported cultivars. Rhizlane-1 showed some advantages such higher antioxidant capacity (73%), very low radical scavenging capacity (IC₅₀= 2mg/ml). Biochemical analysis revealed that local cultivars present a potential sources for qualitative traits in breeding programs.

Keywords: Almond, antioxidant capacity, radical scavenging capacity, polyphenol.

Introduction

Cultivated almond (*Prunusdulcis* (Mill.) D.A. Webb; syn. *P. amygdalus*Batsch, 2n = 2x = 16) belonging to the genus *Prunus* (Rosaceae) is one of the oldest and most important nut crops grown commercially across the globe. Established literature suggested that the almond originated in the arid mountainous and desert regions from Central Asia to the Middle East (Zeinalabedini et al. (2012).

Almonds encompass a wide range of values from nutritional to ecological applications (Martínez-Gómez et al., (2007); Zeinalabedini et al., (2008). The almond is used in food, pharmaceutical and cosmetic industries. It is used as an ingredient in many snacks and other processed foods. According to many studies, almonds have been identified as good sources of natural antioxidants with bioactive properties Cassady et al, (2009). When consumed on a regular basis, almonds provide varied health effects. They reduce the risk of hypertension, type 2 diabetes, and obesity Chen et al. (2006). Almonds, when incorporated in the diet, have been reported to reduce colon cancer risk (Davis & Iwahashi, (2001) and increase HDL cholesterol and reduce LDL cholesterol levels in humans, Hyson, et al. (2002). These activities may be due to the

flavonoids and other phenolic compounds in nuts. The high content of monounsaturated and polyunsaturated fatty acids (mainly oleic acid) gives almonds protective qualities against heart disease.

Almond trees are widely grown in the Mediterranean area Martínez-Gomez et al., (2007). In Morocco, they are cultivated through the whole country under different distinctive pedoclimatic conditions. They are grown mainly in mountainous regions with poor soil Kodad et al. (2013), Lansari et al. 1994). The variability in the environment and climate has led to an extensive diversity of almond genotypes in each productive region Lansari et al. (1994). As a consequence, the genetic variability of the local Moroccan almond populations is very large.

Collection and characterization of these local populations was done progressively in Morocco Barbeau and Elbouami, (1980); Laghezali, (1985); Lansari et al., 1994; Oukabli et al., (2006, 2007). Their genetic diversity was assessed mainly on phenotypic characteristics of the fruits and leaves Lansari et al., (1994); Oukabli et al., (2008). Almond quality was defined until now ostensibly by morphological descriptors such as kernel size, shape, and double kernels, Marti el al. (2012). However, the different uses of almonds

necessitate a thorough investigation of chemical composition of kernels and possibly refining breeding goals. It is worth noting that the chemical composition has hardly been considered as an objective in almond breeding programs (Moayed et al. (2011), Sociasi Company et al. (2008, 2010).

Regardless of the wide distribution of local and commercial almond cultivars in Morocco, there are very limited to nonexistent biochemical data to corroborate their high nutritional values, and potential use in industrial and food application. Subsequently, a thorough investigation of the biochemical compositions of the kernels from local cultivars will strengthen the current insufficient data. This may be of great help to breeders in developing new cultivars that suit Moroccan conditions with desirable higher nutritional values. In the present study, fruit and kernel quantitative

traits, biochemical composition, and some quality attributes of oil are investigated in local and commercial cultivars. To our knowledge, this is the first biochemical characterization of different almond cultivars in Morocco coming from different regions.

Material and Methods

Plant material

The plant material examined was collected from the experimental orchard at the National Agronomic Research Institute (Meknes, Morocco). The name and geographic origins are reported in Table 1, Figure 1. The fourteen cultivars included eight major commercial cultivars and six local Moroccan cultivars.

Table 1. List of the studied cultivars and their origins

SourOrigin	Cultivar name	origin
A	Toundout 3J	Errachidia
	Amekchoud 15	Errachidia
	Rizlane 1	Oujda
	Rizlane 2	Oujda
	Tizin'addi 2	Tiznit
	Tahala	Tiznit
B	Marcona	Espagne
	Ferraduel	France
	Tuono	Italie
	Ferragnès	France
	Fournat de Brezenaud	France
	DesmayoRojo	Espagne
	Laurane	France
	Texas	USA

A: local cultivars (Morocco) **B:** Foreign cultivars

Pomological traits

Quantitative traits were investigated on the basis of the almond descriptors developed by the International Plant Genetic Resources Institute (IPGRI), Gulcan (1985). The pomological research was conducted on 30 fruits per cultivar. Data were recorded on fruit and kernel weight (g), fruit and kernel width (mm), fruit and kernel length (mm), fruit and kernel thickness, and kernel percentage (%). The percentages of the empty fruits and double kernels were also recorded.

Biochemical analysis

Almond blanching and skin removal was carried out according to Bolling et al. (2009). Briefly, almonds were blanched by soaking 100g of almonds in hot water (40°C) for 40 min, and almond skins were removed by hand and air-dried at room temperature over night. The extraction of

phenolic compounds was performed as described by Sanders et al. (2000) with minor modifications (Ling Xie and Bolling, 2014). Almond skins (1 g) and kernels (10 g) were powdered and mixed in a methanol–water mixture (80:20 v/v). Powdered samples and solvent were vortexed at 4°C for 5 min. The mixture was then centrifuged at 3000 g for 5 min. The residue was homogenized and supernatant removed. The same procedure was replicated three times, and the supernatant was filtered through a paper filter (0.45 µm). Then the solvent was evaporated in a rotavapor. The supernatants were then combined and stored at 20°C. All of the samples were re-dissolved in water and analyzed for their contents in terms of phenols, flavonoids, and DPPH radical-scavenging activity.

Total polyphenols analysis was performed colorimetrically by the Folin-Ciocalteu method as

modified by Singleton et al. (1965). Samples of 0.2 ml extracts (skin and tegument), 1 mL of Folin-Ciocalteu reactive, and 18.8 mL of 4.25% aqueous solution of Na₂CO₃ were added. The mixture was kept for 20 min in near-boiling water (70°C). The samples were incubated for 20 min at 70°C. The absorbance was measured at 750 nm versus a reference solution consisting of all the reaction agents except the sample's extract. Gallic acid was used as a reference compound. Total phenol content (TPC) was expressed as mg of gallic acid equivalents (GAE)/100 g of extract. Each determination was performed in triplicate.

To determine total flavonoid content, a colorimetric assay Jia et al. (1999) with some modifications was used. Briefly, 250 µL of the sample was added to 1.25 mL of dH₂O. Subsequently, 75 µL of 5% NaNO₂ was added to the mixture. After the mixture was allowed to stand for 5 min, 150 µL of 10% AlCl₃ was added. The mixture was incubated at ambient temperature (25°C) for an additional 5 min. 500µL of 1 M NaOH was then added to the mixture. The mixture was immediately diluted by adding 275 µL of dH₂O. The test solution was shaken, and the absorbance of the mixture was measured at 510 nm against a reference solution. (+)-Catechin was used as a standard and the results were expressed as means (mg of catechin equivalents g⁻¹ dry weight) Barreira et al.,(2008).

Antioxidant activity assay was conducted. Briefly, 2.7 mL solution of DPPH (1, 1-Diphenyl-2-picryl-hydrazyl) was added to 0.3 mL of methanolic extracts of almond teguments at different concentrations. The absorbance was measured at 517 nm after 60 min. The absorbance of the DPPH radical without antioxidants (the control) was measured. The DPPH scavenging activity was determined by IC₅₀ value, which is defined as the concentration of the antioxidant needed to scavenge 50% of DPPH present in the test solution.

Oil content and analysis

Oil content was measured on dried kernels (30-40g) using nuclear magnetic resonance (NMR) (oxford 4000, oxford analytical instruments ltd.) AOCS, 1998.

Data analysis

The results reported in this work are the averages of at least three measurements. Significant variables were calculated, subjecting results to a linear regression, using SPSS statistical version 10.0 (SPSS Inc., Chicago, Illinois). Only variables with a confidence level superior to 95% (P<0.05) were considered as significant; The results

of all genotypes studied are submitted to the groupe (CAH) analysis

Results and discussion

Fruit and kernel characteristics

Descriptive statistics of the 14 studied morphologicalcultivars are shown in Table 2. Physical characteristics of the almond fruit and kernels differed significantly among cultivars (Table 2) and Figure.1. The length, width, and thickness of almond fruit ranged from 23.16 mm to 37.74 mm, 14.42 mm to 25.42 mm and 11.27 mm to 17.51 mm, respectively. The corresponding value for almond kernels was found to be 16.74 mm to 27.49 mm, 10.72 mm to 16.10 mm and 3.74 mm to 9.94 mm, respectively. Significant differences were observed for kernel yield among cultivars. All cultivars produced fruit and kernel weight greater than 3 and 1 g, respectively. Kernel weight ranged from 0.63 g for Ghizlane-2 to 2.12 g for Tizinaddi-2, Local cultivar Tizinaddi-2 recorded the highest kernel weight of 2.12 g followed by Fournat de breznaud and Ferragnès with an average weight of 1.48 and 1.43 g, respectively.

Texas and Ferragnestrees produced the largest fruit (average fruit weight 4.66 g and 4.6 g, respectively), while Ghizlane-1 and Tizinaddi-2 produced the smallest fruits (weighing 1.41 g and 2.36 g, respectively) (Table 2). Regarding width and length (Table 2), Ferragnes and Fournat de breznoudshowed the longest fruits and kernel (over 36 and 26 mm, respectively) while Tahala produced the smallest (23 mm and 16 mm). The kernel thickness trait was significantly higher for Texas and Amerchoud (close to 10 mm), and lower in Tizinaddi-2 (3.74 mm). The percentage of the empty fruits of the genotypes was null. Only Toundout, Amekdouch, Ghizlane-1, Laurane, and Texas recorded double kernels. The mean values of the double kernels varied from 3 to 27%.

All examined genotypes are highly adapted to the environmental conditions in Morocco and could be a very interesting source of genetic diversity. The results of this study indicated a high morphological diversity of almond genotypes. High levels of variation in fruit and kernels werereported by other authors Čolic et al. (2012).These results can be explained by self-incompatibility of almond trees. This high phenotypic variability corresponds with previous reports on molecular characterization using different markers as nuclear and chloroplast simple sequence repeats (Martínez-Gómez et al. (2003); Fathi et al. (2008); Zeinalabedini et al. (2008) or amplified fragment length polymorphisms Sorkheh et al. (2007). Our results revealed a significant correlation between the weight of almond fruit

and kernels; similar results were reported by Talhouk et al. (2000), Ledbetter (2008), Tavassolian (2008), and Sorkheh et al. (2010).

The results of the empty kernels agree with the previous ones generated by Dicenta et al. (1993) and Sánchez-Pérez et al. (2007). Kester et al. (1977) observed a highly significant influence of the environment on the expression of this particular trait. In addition, the influence of the environment on the production of double kernels is also well known Kester and Asay, (1975); Spiegel-Roy and Kochba, (1981). Dicenta et al. (1993) reported that the development of double kernels was a quantitative trait, with high heritability, which is difficult to estimate due to the environmental effects.

Biochemical analysis

Phenolic compounds, known to possess antioxidant activity, are commonly found in both the edible and inedible parts of almonds. Total phenolic content of the almond kernel and skin extracts are displayed in Figure.2. The highest total phenolic content in kernel skins was 59.1 and 54.5 mg GAEs/g DW for the cultivars Rizlane-1 and Rizlane-2, respectively. The lowest total phenolic content was recorded in Fournat de Brezenaud and Ferragnès cultivars with an average concentration of 27.1 mg/g DW. All other cultivars recorded an average of 40.3 mg/g DW. Such differences in data may be due to the different cultivars. Our data for total phenols in almond skins are lower than those previously reported in other studies (Garrido et al., 2008; Sang et al., 2002), but are similar to those obtained by Barreira et al. (2008) who evaluated 10 almond cultivars (both commercial and regional) and showed that the phenolic content of extracts from whole almond kernels can range from 9.22 to 163 mg/g.

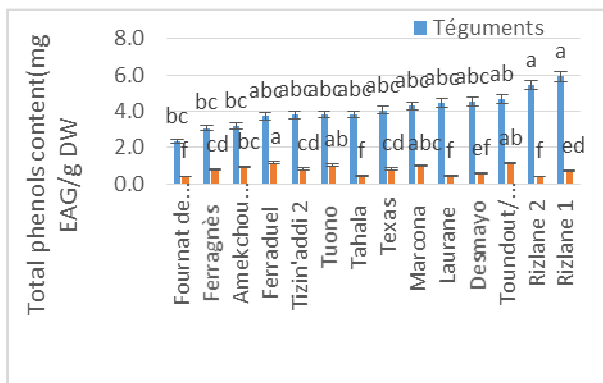


Figure.2. Variation of Total phenol content for different part (Skin and tegument) of cultivars studied

Mean values of examined quantitative traits observed in 14 almond cultivars. ^{a,b,c,d}Significantly different at Duncan's Multiple Range Test (95%)

As expected, almond skins contain more phenolic compounds per gram of extract than blanched almond kernels (Figure.2). These results showed a significant loss of phenolic content resulting from blanching.

TPC ranged from an average of 4 mg/g in Rizlane-2 and Laurane. Such significant difference in TPC between almond kernel with and without skin has been well established by Monagas et al. (2007), Siriwardhana et al. (2006), Wijeratne et. al. (2006). Kornsteiner et al. (2006) reported a range of 130-456 mg of GAE/100 g fresh weight in almond kernels with skin versus a range of 45-49 mg of GAE/100 g fresh weight in blanched kernels without skin. The effect of the blanching process on antioxidant compounds is well documented Saura-Calixto et al., (2007), reported a significant loss (89%) in the total polyphenol content of peanut skins due to blanching processes.

The total flavonoids content of the different almond cultivars is shown in Figure.3. Total flavonoids levels were significantly affected by cultivar ($p < 0.001$). Of the cultivars, Rizlane-2 and Ferragnès exhibited the highest contents of these compounds (25.7 and 22.1 mg/g), while Fournat de Breznau, Toundout and Amekchoud/3J showed the lowest concentrations (between 14.1 and 16.3 mg/g). The Rizlane-2 cultivar reached the highest value of total flavonoids, more than all commercial cultivars. These results are in agreement with those previously reported by Barreira et al. (2008), who reported a significant variation in total flavonoids content ranging from 6.25 to 25.02 mg/g among 10 almonds cultivars.

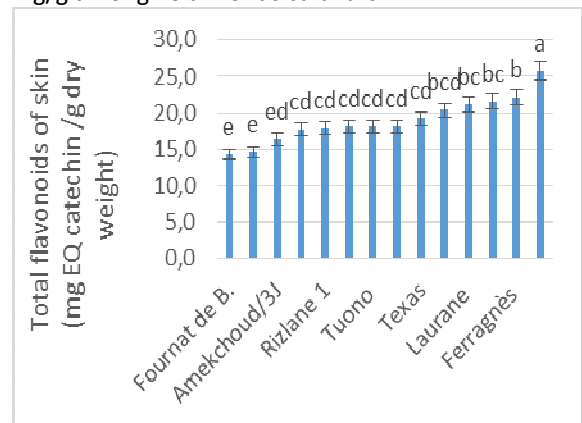


Figure.3 . Variation of Total flavonoids content for different cultivars of almond studied%) Mean values of examined quantitative traits observed in 14 almond cultivars. ^{a,b,c,d}Significantly different at Duncan's Multiple Range Test (95%)

Cultivar	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Fruit thickness (mm)	Kernel Weight (g)	Kernel length (mm)	Kernel Width (mm)	Kernel Thickness (mm)	Empty fruit	Double kernels	Kernel percentage (%)
Toundout/1R	2,46 ^f	27,84 ^e	23,04 ^{dc}	16,47 ^{cd}	1,16 ^c	21,46 ^c	14,35 ^b	8,74 ^b	0	3,33	47,15 ^a
Amekchoud/3J	3,35 ^{ed}	33,3 ^c	22,69 ^{ed}	17,19 ^{abc}	1,39 ^{ab}	24,02 ^b	13,83 ^b	9,63 ^a	0	26,67	41,49 ^b
Rizlane 1	1,41 ^g	24,07 ^g	14,42 ^j	11,28 ^g	0,63 ^e	17,9 ^e	15,24 ^a	6,67 ^g	0	3,33	47,43 ^a
Rizlane 2	3,37 ^{ed}	25,75 ^f	20,84 ^f	16,1 ^d	0,63 ^{ef}	19,43 ^d	11,37 ^d	5,78 ^h	0	0	18,69 ^f
Tizin'addi 2	2,36 ^f	24,11 ^g	15,65 ^j	11,27 ^g	2,12 ^f	17,91 ^e	10,72 ^d	3,74 ⁱ	0	0	22,8 ^{ef}
Tahala	2,42 ^f	23,16 ^g	17,96 ^h	12,68 ^f	0,55 ^{ef}	16,74 ^f	15,98 ^a	6,26 ^{gh}	0	0	23,1 ^{ef}
Marcona	4,28 ^b	29,23 ^d	25,03 ^a	17,62 ^a	1,05 ^d	19,97 ^d	15,59 ^a	7,45 ^{ef}	0	0	24,53 ^{ef}
Ferraduel	4,43 ^{ab}	35,02 ^b	24,11 ^b	16,28 ^d	1,21 ^c	24,6 ^b	14,38 ^b	7,54 ^{def}	0	0	27,4 ^{cde}
Tuono	3,16 ^e	28,46 ^{ed}	22,01 ^e	17,27 ^{ab}	0,97 ^d	19,93 ^d	12,97 ^c	8,55 ^{bc}	0	0	30,83 ^{cd}
Ferragnès	4,6 ^a	37,74 ^a	23,68 ^{cb}	16,63 ^{bcd}	1,43 ^a	27,49 ^a	14,39 ^b	8,17 ^{bcd}	0	0	31,13 ^{cd}
Fournat de B.	4,48 ^{ab}	36,69 ^a	25,42 ^a	15,07 ^e	1,48 ^a	26,69 ^a	16,1 ^a	6,94 ^{fg}	0	0	33,2 ^c
Desmayo	3,71 ^c	29,16 ^d	23,24 ^{cbd}	16,73 ^{bcd}	0,95 ^d	20 ^d	12,95 ^c	8,37 ^{bc}	0	0	25,80 ^{de}
Laurane	3,47 ^{cd}	35,15 ^b	25,8 ^a	17,51 ^a	1,3 ^b	24,97 ^b	15,36 ^a	7,98 ^{cde}	0	6,9	42,26 ^{ab}
Texas	4,66 ^a	27,37 ^e	19,84 ^g	17,25 ^{abc}	1,18 ^c	20,14 ^d	12,79 ^c	9,94 ^a	0	3,33	25,73 ^{de}

Table 2. Mean values of examined quantitative traits observed in 14 almond cultivars. ^{a,b,c,d,e,f,g,h,i}Significantly different at Duncan's Multiple Range Test (95



Figure.1. Morphological Trait of different almond local and Foreign cultivars from Ain taoujdat collection (INRA Meknes Morocco)

The antioxidant activity of phenolic compounds is mainly due to their redox properties, which can play an important role in absorbing and neutralising free radicals, quenching singlet and triplet oxygen, or decomposing peroxides (Osawa, 1994). Radical-scavenging capacity varied significantly amongst genotypes and their hulls. The percentage of antioxidant activity vary in function of genotypes (Table 3). Indeed, the highest value was observed in the genotype Ferragnès which % of AO activity was 84.3%. The lowest value was obtained from the local genotype Toundout with a AO of 46.3%. The other genotypes recorded AO activity average of 66%.

The minimum concentration of the extracts of the kernel can trap 50% of DPPH radicals in the present (IC50) are given in Table 3 and expressed as mean \pm standard type. The IC50 value of the antioxidant activity of different cultivars of almond evaluated by the DPPH method have oscillated between 2.25 and 20mg / ml genotypes. Rizlane1 revealed the best antioxidant property with a value of the IC50 equal to 2.25 mg / ml. Other interesting IC50 values were obtained with the cultivars Ferraduel and Tizzinaddi 2 whose recorded concentrations fluctuate between 4.34 and 6.33 mg / ml. While other cultivars recorded higher values of IC50. These results were en concordance to the

previously work reported by Barreira et al, (2008), the IC50 value varying from 0.2 to 6.5 mg / ml. For the almond oil polyphenol content determined by the method of Singleton and Rossi (Singleton et al, 1965). The results are expressed in milligrams of gallic acid equivalents per gram of oil. From these results the most significant content of phenolic compounds is observed in the variety Marcona, followed by the genotype Rizlane1, the values

fluctuate between 20 and 16 mg / g. These values are much higher than those obtained by the cultivars Amekchoud / 3d and Tahala which recorded the lowest values and whose contents are respectively 3.1 and 8.1 mg / g, lowest oil content (3.1 and 8.1 mg/g, respectively) (Figure 4).

Table.3.Antioxidant capacity of Almond cultivars Within each column, values followed by different letters are significantly at p < 0.05 level

Cultivar	Antioxidant capacity % RSA	IC50 (mg/ml)
Toundout/1R	46,3±1,76 ^a	20 ± 0,46 ^a
Desmayo	50,5±0,31 ^a	20 ± 1,2 ^a
Texas	50,9±0,05 ^a	20 ± 1,01 ^a
Tuono	51,5±0,31 ^a	20 ± 0,53 ^a
Marcona	54,7±1,76 ^a	20 ± 0,58 ^a
Amekchoud/3J	56,5±1,45 ^a	20 ± 0,35 ^a
Rizlane 2	61,6±1,31 ^b	18,77 ±0,81 ^b
Rizlane 1	72,6±3,05 ^h	2,25 ± 0,7 ^h
Fournat de Brezenaud	73,1±0,69 ^e	6,60 ± 0,87 ^e
Tahala	79,5±0,31 ^d	9,84 ± 0,58 ^d
Ferraduel	81±2,27 ^g	4,34 ± 0,46 ^g
Tizin'addi 2	82,6±1,18 ^f	6,33 ± 0,35 ^f
Laurane	84±1,45 ^b	18,74 ± 1,38 ^b
Ferragnès	84,3±0,17 ^c	10,87 ± 0,35 ^c

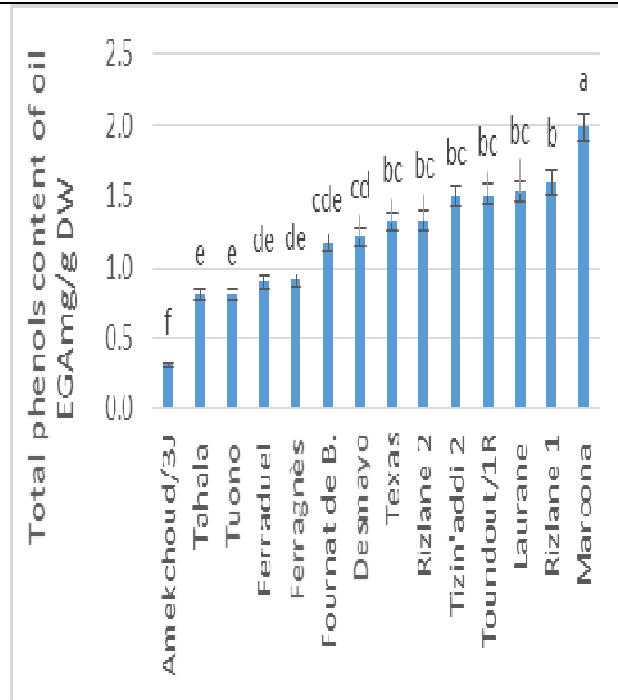


Figure.4.Variation of total phenols content of oil almond from different cultivars studied Mean values of examined quantitative traits observed in 14 almond cultivars. a,b,c,d,Significantly different at Duncan's Multiple Range Test (95%)

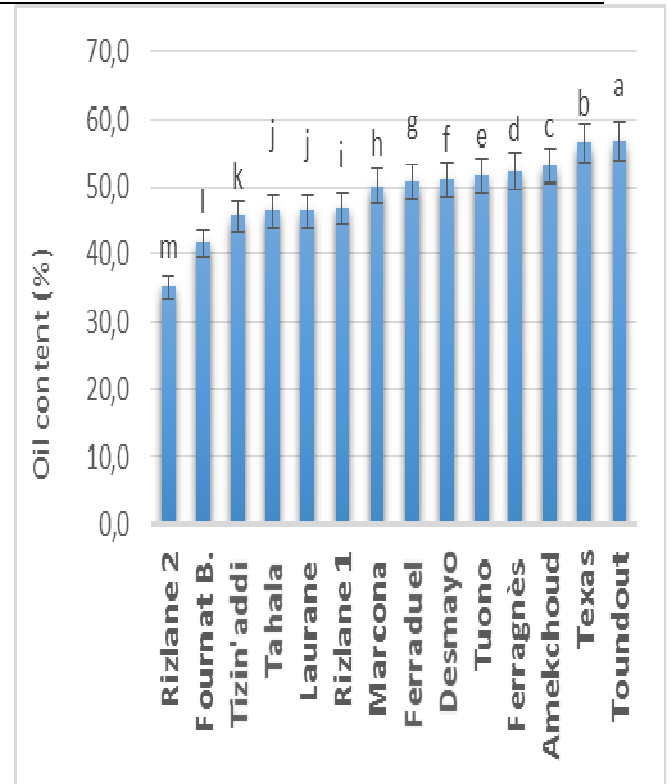


Figure.5. Variability of Oil content of the 14 almond cultivars studied

Table 4 .Correlation matrix among traits studied in almond cultivars.

	Fruit weight	Fruit length	Fruit width	Fruit tickness	Kernel weight	Kernel length	Kernel Width	Kernel Tickness	Kernel percentage
Fruit weight	1								
Fruit length	,600**	1							
Fruit width	,614**	,766**	1						
Fruit tickness	,557**	,492**	,721**	1					
Kernel weight	,535**	,660**	,567**	,482**	1				
Kernel length	,530**	,876**	,676**	,443**	,701**	1			
Kernel Width	0,086	,361**	,377**	,177**	,301**	,328**	1		
Kernel Tickness	,294**	,343**	,448**	,553**	,492**	,335**	,162**	1	
Kernel percentage	-,373**	,156**	0,068 ^{ns}	0,018 ^{ns}	,393**	,239**	,330**	,255**	1

* Significant at the 0.05 level

** Significant at the 0.01 level

The results of oil content show that the Oil content varying between 35 to 57% for all genotypes studied (Figure 5). The lower value are enregistered by Rizlane2 and FOURNAT of Brezenaud cultivars with 35.2 and 41.74 % respectively. However, the Toundout and Texas cultivars have the higher content exceeding 56 %, while the others cultivars have a average of oil content of 49.5%.

These results are in agreement with those reported by Abdallah et al (1998) .

Correlation analysis

Correlation coefficients between the fruit traits of the almond cultivars included in the study are given in Table 4. Strong correlations ($p < 0.01$) were observed among most of the studied traits (Table.4) ($r = 0.48-0.77$). In addition to the high correlations among fruit traits (length, width, thickness, and weight) ($r = 0.48-0.77$), kernel traits (length, width, thickness, and weight) were also correlated with each other ($r = 0.16-0.70$) and with fruit traits. However, no correlation ($r = 0.086$; $p > 0.05$) was found between the fruit weight and kernel width. Similar findings were reported in 32 almond cultivars investigated by Zeinalabedini(2012). Fruit weight had significant positive correlation with kernel weight ($r = 0.53$; $p < 0.01$), fruit length ($r = 0.60$; $p < 0.01$) and the fruit width ($r = 0.58$; $p < 0.01$). Talhouk et al. (2000), Ledbetter (2008), Tavassolian (2008), and Sorkheh et al. (2010) established significant correlations between fruit weight and kernel weight. A negative correlation was determined between the fruit weight and the kernel percentage ($r = -0.37$; $p < 0.01$). The results of the empty kernels agree with the previous ones generated by Dicenta et al. (1993) and Sánchez-Pérez et al. (2007). Kester et al. (1977) observed a highly significant influence of the environment on the expression of this

particular trait. In addition, the influence of the environment on the production of double kernels is also well known, Kester and Asay, (1975). Dicenta et al. (1993) reported that the development of double kernels was a quantitative trait, with high heritability, which is difficult to estimate due to the environmental effects.

The morphological dendrogram (Figure.6) clustered the genotypes into two main groups. The first group consists only of local accessions, the second group includes, in addition to local genotypes, a mixture of foreign genotypes. The heterogeneous cluster obtained, maybe the cause of an exchange of plant material as seeds between Morocco and other countries. D . De Giorgio, And G.B. Polignano, 2001 evaluated the variability of 88 almonds cultivars using 20 traits for trees, shell and kernel in southern of Italy. The cluster analysis placed these traits in 7 groups. The most important factors in cluster formation were the percentage of double kernels, followed by nut thickness and the percentage of kernels.

The results of correlation analyses among bioactive compounds exhibited significant correlations among the total phenolic content, the flavonoid content, and antioxidant activity. Statistically significant ($P < 0.05$) correlation was found among the total phenolics in both almond skin and blanched almonds ($r = 0.29$ and $r = 0.33$, $P < 0.05$). Strong correlation between antioxidant activity and total phenolic content has been reported (Amarowicz et al. (2004), Esfahlan and Jamel, (2011), Ferreira et al. (2007), Velioglu et al. (1998). Unlike in other studies Colic et al. (2011), Kodad et al. (2006). The biochemical markers was able to differentiate varieties in two groups (Figure.7). The first group contained 9 genotypes, a mixture of local and foreign genotypes while the

second group include 4 local genotypes and 1 genotype from Spain.

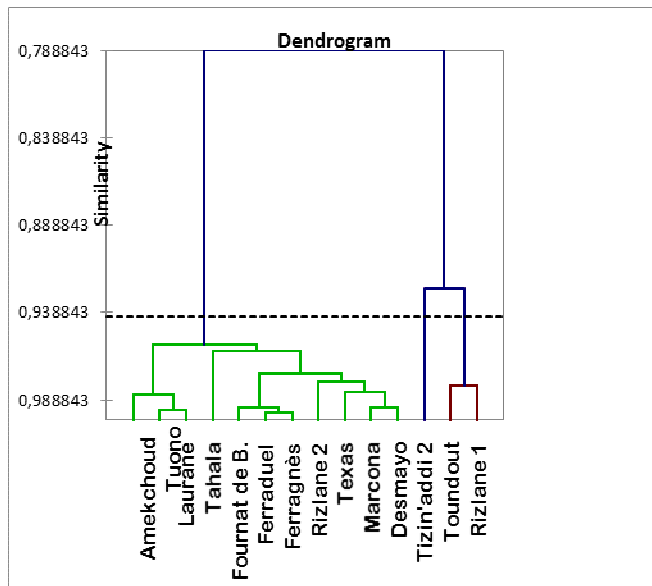


Figure.6. Dendrogram of degree of Similarity of 14 Almond *Prunus Dulcis* (L) taxonomic groups, using morphological descriptor

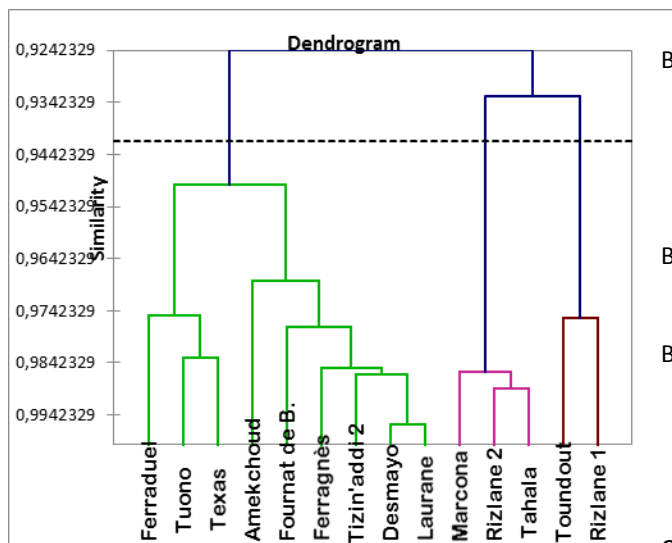


Figure.7. Dendrogram of degree of Similarity of 14 Almond *Prunus Dulcis* (L) taxonomic groups, using biochemical markers.

Conclusion

In this study, morphological and pomological and biochemical composition of 14 almond cultivars grown in Morocco, were evaluated. The cultivars studied do not represent the whole almond germplasm in Morocco, but considerable genetic diversity was observed at morphological traits and biochemical component indicating that there are rich and valuable plant

materials. Morphotypes of almond studied here differed in fruits, kernel morphology and biochemical composition. The biochemical markers was able to differentiate varieties. The information obtained will be useful for collections, conservation and various almond breeding programs.

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