as the shelling percentage. The percentage of double kernels was not included because only 'Guara' showed this kind of kernel. These values agree with the descriptions of these cultivars (Felipe, 2000; Felipe and Socias i Company, 1987; Socias i Company and Felipe, 2007; Socias i Company *et al.*, 2008b) and with the previous observations in the *Unidad de Fruticultura* at CITA, within the levels of variability in the observations in different years.

When the full bloom data of each cultivar and selection were plotted against kernel weight (Fig. 1) the distribution of the dots was almost horizontal. This result concludes that the date of bloom has no effect on kernel size. Evidently, the late-blooming genotypes included in this study were selected in a breeding programme and kernel size has been an evaluation criterion during the selection process, but this same criterion was certainly applied when the traditional cultivars, such as 'Desmayo Largueta' and 'Ramillete' were noticed by our ancestors and clonally propagated because of their good characteristics, kernel size being surely one of the traits taken into account.

If a large number of cultivars was included in this study, as well as the complete offspring of some crosses of the breeding programmes, a different distribution of kernel size and blooming time could be obtained, other than that shown in Fig. 1. However, the objective of any breeding programme is the release of new cultivars possessing extraordinary characteristics distinguishing them from average cultivars. As already mentioned, late blooming has been a main objective of many almond breeding programmes and the results of the present study confirm the possibility of obtaining extremely late-blooming selections, such as 'Mardía', with an average kernel size. Furthermore, these results sustain the possibility of following this research path of obtaining new selections joining the two interesting traits of late bloom and large kernel size.

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KERNEL QUALITY OF LOCAL SPANISH ALMOND CULTIVARS: PROVENANCE VARIABILITY AND END USES

INTRODUCTION

Almond (*Prunus amygdalus* Batsch) is the most popular nut tree crop worldwide in terms of commercial production (faostat.fao.org/site). Spain is the second world producer, with an average production of 223,431 tons of in- shell nuts (Socias i Company *et al.*, 2011). Traditional almond culture utilized open-pollinated seedlings (Socias i Company *et al.*, 2012) which, together with self-incompatibility, produced a very high heterozygosity in this species (Kester *et al.*, 1990; Socias i Company and Felipe, 1992). This large variability has provided a useful genetic pool for almond evolution, allowing in each growing region for the selection of almond cultivars well adapted to this area (Grasselly and Crossa-Raynaud, 1980; Socias i Company *et al.*, 2012). In Spain, almonds are produced under different climatic conditions: from inland regions characterized by high frost risks at blooming time or soon after (Ebro Valley, Castilla-La Mancha), to coastal regions with mild winters and hot and dry summers (Andalusia, Murcia), and the Balearic and Canary islands with high relative humidity. The high climatic diversity of the different producing regions in Spain forced the local farmers to select genotypes to avoid the harsh environmental conditions that cause decreases in production. In the last 15 years more than 18 million almond plants were produced by the Spanish nurseries, and more than 60% of these plants came fromwere of cultivars released by breeding programmes (Socias i Company *et al.*, 2011). However, the traditional Spanish cultivars, with 24.57% of the plants, still represent nearly a quarter of this total.

The Spanish market only distinguishes two cultivars, 'Marcona' and 'Desmayo Largueta', whilst the rest of cultivars are grouped under the undefined name of "comunas" (Socias i Company *et al.*, 2012). Almond kernels are consumed raw, roasted, blanched, unblanched, served alone or mixed with other foods. Almond kernels are also used fresh or can be processed into many different confectioneries (Socias i Company *et al.*, 2008). The kernels of the "comunas" almonds are used in different confectioneries with unspecified requirements, being mainly processed for production of marzipan and in some types of nougat. However, the modern almond industry demands commercial cultivars characterized by kernels with well differentiated and high quality attributes , since the best end-use for each cultivar is a function of its chemical composition (Berger, 1969). Additionally, the best quality attributes may avoid the use of synthetic additives according to the consumers' trend for foods without any additive (Krings and Berger, 2001).

Determination of the compositional variability of the oil from different countries, locations or cultivars could be imperative for a proper classification of the product and the protection of its authenticity in the market (Kodad *et al.*, 2011a). The information on the chemical composition of the almond kernels available at present is restricted to a reduced number of cultivars, mostly from the country where these cultivars originated or are grown (Kodad *et al.*, 2011b). As a consequence, comparisons between cultivars from different countries are affected by possible differences related to the climatic conditions of each country and to the different management of the almond orchards. Therefore, the study of the chemical composition of a set of cultivars of different origin but grown in the same conditions was considered interesting, taking the opportunity of the almond collection belonging to the Spanish National Germplasm Network maintained at the CITA of Aragón (Espiau *et al.,* 2002). Thus, our objective was the determination of the oil, fatty acid and tocopherol composition of 44 traditional Spanish almond cultivars from different regions grown in the CITA almond collection, considering their possible industrial implication.

MATERIAL AND METHODS

A total of 44 local Spanish almond cultivars from seven different gene pools were included in the analysis (Table 1). The trees are maintained as living plants grafted on the almond × peach hybrid clonal rootstock INRA GF-677, using standard management practices (Espiau *et al.,* 2002). Nuts from open pollination were harvested during three consecutive years (2008-2010) at the mature stage, when fruit mesocarp was fully dried and split along the fruit suture and the peduncle abscission was complete (Felipe, 1977). Three samples of 20 nuts were collected for each treatment.

Oil content and fatty acid composition were determined during the three years of the study. Kernels were blanched, dried, and ground in a domestic electrical grinder until obtaining fine flour. Total oil content was determined with a 3 gram sample in a Soxtec Avanti 2055 fat extractor (Foss Tecator, Höganäs, Sweden). Fat content was expressed as the difference in weight of the dried sample before and after extraction (% of DW). The fatty acids in the oil were determined by capillary gas chromatography of the fatty acid methyl esters (FAMEs). These FAMEs were prepared according to the official method UNE-EN ISO 5509:2000. Tocopherol concentrations were determined in extracted kernel oil over two consecutive years (2009-2010) according to a modification of the method by López Ortiz *et al.* (2008).

All statistical analyses were performed with the SAS program (Cary, NC, USA). The mean separation was conducted using with the LSD test at $P < 0.05$.

RESULTS AND DISCUSSION

Oil and fatty acid variability. Oil content showed high significant variability among genotypes from different regions (Table 1). The range of variability for oil content in cultivars from the same region was evaluated and the results showed that this range was large in the genetic pools from Aragon (53.4% to 64.9) and the Canary Islands (50.58% to 61.3%), medium for Majorca (53.37% to 62.74%) and Valencia (53.98% to 62.92%), and low for Catalonia (58.9% to 64.95%) (Table 1). The highest mean value was obtained for the cultivars from Catalonia (61.75%), followed by Aragon (60%), and the lowest values were registered for the cultivars from the Canary Islands, Murcia and Andalusia (Table 1). The year effect was significant for all studied variables (Table 1). For oil content, the lowest value was obtained in 2010 (Table 1). It is to be noted that the oil content of the cultivars from Aragon and the Canary Islands were more stable over the three years of study, indicating the same trend of variation of the genotypes from these regions. The year effect has been reported to be significant for oil content in some studies at individual level (Abdallah *et al.*, 1998; Barbera *et al.*, 1994; Sathe *et al.*, 2008), but not at gene pool level such as that reported in the present study. The cultivars from Murcia and the Canary islands showed the highest reduction in oil content in 2010, as compared to the other provenances. These results may indicate the need to carry out the determination of oil content in almond over three years and not only two for a correct evaluation, coinciding with the results reported in olive (León *et al.*, 2004). This trait appears to be under polygenic control (Font i Forcada *et al.*, 2011), with a clear environmental effect (Abdallah *et al.*, 1998; Sathe *et al.*, 2008). Furthermore, these results show clearly that the magnitude of the year effect on the oil content is not limited to the genotype, but also to its geographical origin. This information is useful for breeders when breeding for high and stable oil content in order to take into account the geographical origin of the parents. Kernels with a high percentage of oil could be used to produce nougat or to extract oil, which is used in the cosmetic and pharmaceutical industries (Socias i Company *et al.*, 2008). In addition, high oil content is desirable because higher oil contents result in less water being absorbed by the almond paste (Alessandroni, 1980). On the contrary, low oil contents are preferred for the production of almond flour or almond milk. Since nuts from these cultivars are marketed under the name of "comunas", those from Aragon and Catalonia could be mostly used for the production of nougat

Table 1. Oil content (% of kernel DW) and major saturated fatty acid (% of total oil content) of the Spanish almond cultivars during the three years of study.

	Oil content				Palmitic ac.				Stearic ac.				SFA			
Region	2008	2009	2010	Mean	2008	2009	2010	Mean	2008	2009	2010	Mean	2008	2009	2010	Mean
Andalusia	57.7a	57.8a	56.7a	57.4	5.7a	5.7a	5.8a	5.7	2.13a	2.13a	2.08a	2.11	7.8a	7.9a	7.9a	7.9
Aragon	60.8a	60.3a	59a	60	6.2a	6.1a	6a	6.1	2.22a	2.03ab	1.84b	2.03	8.4a	8.2ab	7.8b	8.1
Canary Islands	58.4a	58.3a	55.1b	57.3	6.3a	6.1a	6.2a	6.2	1.91a	1.86ab	1.78b	1.85	8.2a	8a	8a	8.1
Catalonia	62.2b	60.5a	60.5a	61.1	6.4a	6.3a	6.4a	6.4	1.98a	1.92ab	1.89b	1.93	8.3a	8.3a	8.3a	8.3
Majorca	60.5a	60.2a	57.1b	59.3	6.2a	6.2a	6.3a	6.3	2.09a	2.12a	2a	2.07	8.3a	8.4a	8.3a	8.3
Murcia	57.9ab	58.6a	54.9b	57.1	6.2a	6.1ab	5.9b	6.05	2.04a	2.02a	2.06a	2.0425	8.2a	8.1ab	7.95b	8.125
Valencia	61.2a	60.1a	56.5b	59.3	6.32a	5.92b	5.97ab	6.07	2.07a	1.9ab	1.8b	1.97	8.4a	7.87a	7.8a	8.05
Mean	59.81a	59.4a	57.1b	58.79	6.19a	6.06b	6.08b	6.12	2.06a	2ab	1.92b	2.00	8.2a	8.1ab	8.01b	8.13

Mean values of each component followed by different letters are significantly different between years at $P < 0.05$.

Table 2. Major unsaturated fatty acid (% of total oil content) of the Spanish almond cultivars during the three years of study.

	Palmetoleic ac.				Oleic ac. (O)				Linoleic ac. (L)				R1 (O/L)			
Region	2008	2009	2010	Mean	2008	2009	2010	Mean	2008	2009	2010	Mean	2008	2009	2010	Mean
Andalusia	0.38b	0.44a	0.4ab	0.41	73.1b	75.2a	73.7b	74	17.9a	15.6b	17.4a	17.0	4.1b	4.9a	4.4b	4.4
Aragon	0.47b	0.49ab	0.51a	0.49	70.9b	74.2a	74a	73	19.6a	16.6b	16.7b	17.7	3.8b	4.8a	4.7a	4.4
Canary Islands	0.47b	0.51a	0.48b	0.48	71.9b	74.8a	72.4b	73	18.7a	16.1b	17.4ab	17.4	4.1b	4.9a	4.2b	4.4
Catalonia	0.45b	0.45b	0.49a	0.46	68.5b	70.9a	70.2a	69.9	22.1a	19.6b	20.6b	20.7	3.2a	3.7a	3.6a	3.5
Majorca	0.44c	0.46b	0.49a	0.46	69a	70.9a	69.6a	69.8	21.7a	19.6b	20.6b	20.6	3.2a	3.7a	3.5a	3.5
Murcia	0.43b	0.42b	0.46a	0.44	73.4a	73.3a	73.2a	73.3	17.5a	17.2a	17.5a	17.4	4.2a	4.3a	4.4a	4.3
Valencia	0.49a	0.48a	0.45b	0.47	68.4c	72.3a	70.5b	70.4	21.5a	17.4c	19.4b	19.4	3.2b	4.3a	3.7ab	3.8
Means	0.45a	0.46a	0.47a	0.46	70.7b	73.1a	71.9b	71.9	19.8a	17.4c	18.5ab	18.6	3.7b	4.4a	4.1ab	4.0

Mean values of each component followed by different letters are significantly different between years at $P < 0.05$.

and for extracting oil because of their high oil content. Conversely, the "comunas" from Andalusia, Murcia and the Canary islands could be used to produce almond flour and milk.

The region of origin was highly significant regardingf the fatty acid composition (Tables 1, 2). The concentrations of the different fatty acids over the three years ranged between 5.74% in Andalusia and 6.36% in Catalonia for palmitic acid, 0.41% in Andalusia and 0.49% in Aragon for palmitoleic acid, 1.85% in the Canary Islands and 2.11% in Andalusia for stearic acid, 69.81% in Majorca and 74.02% in Andalusia for oleic acid, and 16.97% in Andalusia and 20.74% in Catalonia for linoleic acid (Tables 1, 2). These results show clearly that the fatty acid composition of the kernel oil not only depends on the genotype (Kodad *et al*., 2013; Sathe *et al*., 2008), but also on the gene pool origin. The year effect was significant for all the fatty acids considered (Table 2). The highest values of oleic acid were obtained in 2009 and the lowest in 2008 (Table 2). However, the oleic content of the Murcia and Majorca gene pools was stable between years. Concerning the linoleic acid, the highest values were obtained in 2009 (Table 2). It should be pointed out that the variability of these two components is more important between regions than between years. Fatty acid composition appears to be under polygenic control (Font i Forcada *et al*., 2011), modified by environmental conditions (Kodad *et al*., 2010). All these results indicate that the magnitude of the percentage of the different fatty acids in almond oil depends on the number of additive genes accumulated under specific environmental conditions.

Concerning the variables used as indices of oil stability and resistance against rancidity, the O/L ratio ranged between 3.47 in Catalonia and 4.45 in Andalusia (Table 3), and the SFA content ranged between 7.85% in Andalusia and 8.32% in Majorca (Table 2). The statistical analyses showed that there were no significant differences between Aragon, the Canary Islands and Andalusia for the O/L ratio and for the oleic acid composition (Table 2). It must be taken into account that high O/L ratios imply higher oil stability and, therefore, an index of almond quality and of resistance to rancidity, a trait that must be considered for the Spanish almond cultivars. Considering both the O/L ratio and the SFA percentage, the gene pools of Aragon, the Canary Islands, Murcia and Andalusia, present the most stable almond oil.

Tocopherol concentration. The region effect was highly significant for the three tocopherol homologues (Table 3). The concentrations over the two years for α-tocopherol ranged from 437. 94 in Andalusia to 478.6 mg/kg oil in Majorca; for γ-tocopherol from 12.5 in Valencia to 23.11 mg/kg oil in Catalonia; and for δ-tocopherol from 0.62 in Valencia to 1.29 mg/kg oil in Aragon. Under the CITA climatic conditions, the genotypes from Valencia, Murcia and the Canary Islands showed the highest variability between years for α-tocopherol, whereas the most stable were those from Majorca and Andalusia (Table 3). For γ-tocopherol, the most stable genotypes were those from Catalonia and Valencia. Since tocopherols, mainly α-tocopherol, are considered important components for protecting almond oil against oxidative deterioration (Senessi *et al*., 1996; Zacheo *et al*., 1998; García-Pascual *et al*., 2003), the high concentration of α-tocopherol and of oil content of the almond kernels from the cultivars of Aragon and Catalonia indicate that these kernels could be intended for industrial processing with the assurance that the product could stand processing manipulation without noticeable oxidative deterioration, as well as to be stored for a long time in adequate storage conditions.

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Table 3. Tocopherol concentration (mg/kg oil) of the kernel oil of the Spanish almond cultivars during two consecutive years.

	δ-tocopherol			γ-tocopherol			α-tocopherol		
Region	2009	2010	mean	2009	2010	mean	2009	2010	mean
Andalusia	0.65b	0.91a	0.78	12.02a	14.72a	13.37	425.83a	449.15a	437.49
Aragon	1.04b	1.55a	1.30	17.12a	16.82a	16.97	422.93b	494.82a	458.87
Canary Islands	1.01a	1.04a	1.03	19.61a	17.64a	18.63	421.22b	523.02a	472.12
Catalonia	1.18b	1.61a	1.39	20.90b	31.56a	26.23	451.26b	526.51a	488.89
Majorca	1.08a	0.96b	1.02	18.62a	16.91a	17.77	466.75a	479.33a	473.04
Murcia	0.67a	0.72a	0.69	10.94b	17.73a	14.33	392b	484.62a	438.31
Valencia	0.64a	0.66a	0.65	10.29b	16.05a	13.17	403.02b	495.19a	449.11

Mean values of each component followed by different letters are significantly different between years at $P < 0.05$.

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PHYSICAL FRUIT TRAITS IN MOROCCAN ALMOND SEEDLINGS: QUALITY ASPECTS AND POST-HARVEST USES

INTRODUCTION

Almond is the most important nut tree cultivated in Morocco. The total almond acreage is about 146,100 ha and two important production systems could be differentiated: modern and traditional (Anonymous, 2011). The modern system is characterized by the dominance of four cultivars, 'Marcona', 'Fournat de Brézenaud', 'Ferragnès' and 'Ferraduel' (Lansari *et al.*, 1994), with a density of 150 to 300 trees/ha (Loussert *et al.*, 1989). Trees are mostly grafted on 'Marcona' seedlings and conducted according to modern techniques under favourable climatic conditions. Although most modern almond orchards are located in production areas where irrigation is possible, only a few are irrigated (Mahhou and Denis, 1992). The traditional system covers more than 70,000 ha and is found in inauspicious regions, mainly in mountain regions and arid areas (Lansari *et al.*, 1998). In this traditional system almonds are grown under conditions where one or more environmental requirements are limiting. These include water during the growing season, soil depth, and nutrient availability, primarily N. Trees (mostly open-pollinated seedlings) are planted on slopes and hillsides, along streams, or interplanted with field crops, and are given little or no care (Mahhou and Denis, 1992), at an average density of 80 trees/ha, and are neither pruned nor sprayed. This system represents more than 80% of the almond surface in Morocco, with an estimated average production of 80 kg/ha (Anonymous, 2011), harvested by the local farmers, used by the family or sold locally.

Despite their low productivity, seedling trees represent a potential source of germplasm, both for selecting new cultivars and for use as parents in breeding programmes. Several studies have been conducted to evaluate the genetic diversity of the local almond seedlings in Morocco in order to select the best genotypes to be introduced in reference collections. The genetic structure of these populations has shown the presence of a great variability between genotypes of the same population (Lansari *et al.*, 1994), but also between populations (Lansari *et al.*, 1998). Selection of local almond genotypes for late-bloom, and frost and disease resistance have been carried out since 1975 (Laghezali, 1985). These studies have allowed the identification of genotypes of