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Agromorphological Characterization and Nutritional Value of Traditional Almond Cultivars Grown in the Central-Western Iberian Peninsula

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Abstract: In this study, 24 traditional almond cultivars grown in the central-western Iberian Peninsula, all of them clearly in decline or close to extinction, were characterized from the agromorphological and chemical points of view. A total of 40 agromorphological and chemical descriptors, mainly defined by the IPGRI and the UPOV, were used to describe the flowers, leaves, fruits and the trees themselves over three consecutive years (2015–2017). Some of the cultivars showed distinctive and interesting agronomical characteristics from a commercial point of view, such as high yields and high quality fruit. This was the case of the almond cultivars called "Gorda José" and "Marcelina". Their fruits were quite heavy (nuts: >9.1 g; kernels: >1.9 g), with very low percentages of double kernels (<3%) and high nutritional value (>50% lipids; >21% proteins). The results of the PCA and cluster analysis showed that agromorphological and chemical analysis can provide reliable information on the variability in almond genotypes. This work constitutes an important step in the conservation of genetic almond resources in the central-western Iberian Peninsula.

Keywords: almond descriptors; conservation; endangered cultivars; fruit quality; genetic resources; *Prunus dulcis*

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1. Introduction

The almond (*Prunus dulcis* [Miller] D.A. Webb syn. *P. amygdalus* (L.) Batsch, Rosaceae, 2n = 2x = 16) is one of the oldest and most important nut crops grown commercially worldwide. It originated in the arid mountainous regions of southwestern and central Asia [1] and spread rapidly towards the Mediterranean Basin via seeds carried by caravans along the old Silk Route [2]. The almond is cultivated for its edible seed (the kernel), which is used for direct consumption and for almond-based products and confections [3,4]. In 2019, world production of almonds was 3.49 million metric tons [5]. The United States, Spain, Iran, Australia, Morocco and Syria are the most important almond-producing countries (approximately 80% of world almond production). Concretely, the Iberian Peninsula (the first European producer) has 717,870 ha dedicated to almond production and produces 373,970 metric tons of fruit per year. The main almond-producing regions in the Iberian Peninsula are close to the Mediterranean Sea, such as Andalusia, Murcia and Valencia, but also include inland regions such as Aragón and Castilla–La Mancha. In these regions, most of the almond orchards are not irrigated (92.2%), resulting in very low productivity [6]. Some of the most common cultivars cultured in the Iberian Peninsula are "Marcona", "Desmayo Largueta", "Tuono", "Cristomorto", "Ferragnés", "Ferraduel", "Guara", "Belona", "Soleta", "Mardía", "Masbovera", "Glorieta", "Francolí", "Constantí", "Marinada", "Tarraco", "Vayro", "Parada", "Bonita" and "Casanova". Moreover, many other named cultivars of local origin have evolved from localized ecological niches that are found in different valleys extending inland from the Mediterranean coast [7–9]. The conservation and characterization of these local cultivars is important to avoid the loss of genetic variability and as a potential source of genetic variation for future almond breeding programs. Some of these cultivars show distinctive agronomic characteristics, such as self-compatibility, late blooming, frost tolerance and shell hardness.

Many studies addressing the agromorphological and biochemical characterization of almond cultivars have been undertaken in countries mainly located around the Mediterranean basin [10–24]. In the Iberian Peninsula, studies have been carried out by Montero-Riquelme et al. [25], Felipe [26], Cordeiro et al. [27], Arquero et al. [28], Kodad and Socias i Company [29,30], Vargas et al. [31], Kodad et al. [32–34] and Ramos and Costa [35].

The objective of the present study was to survey, identify and characterize from the agromorphological and nutritional points of view the traditional almond cultivars existing in the central-western region of the Iberian Peninsula in order to avoid their disappearance and so that they can be included in future almond breeding programs.

2. Materials and Methods

2.1. Plant Material

A survey was carried out in the regions known as "Arribes del Duero" (Salamanca, Spain) and "Trás-os-Montes e Alto Douro" (Bragança, Portugal) during 2014. A total of 192 adult almond trees at least ten years old, corresponding to 24 cultivars ("Agapitina", "Bravía", "Cascafina", "Cascona", "Cornicabra", "De Convite", "Desmayo Largueta", "Desmayo Rojo", "Esperanza", "Gorda José", "Marcelina", "Marcona", "Molar de Chavés", "Mollar de Arribes", "Pestaneta de Bragança", "Pestañeta de Arribes", "Peta", "Picuda", "Portuguesa", "Recia", "Redondilla", "Valenciana", "Verdeal" and "Verdinal"), were selected for study at full fruit maturity. Eight trees were evaluated per cultivar.

2.2. Agromorphological Characterization

The agromorphological description of the almond cultivars was based on 19 descriptors established by the UPOV [36] and IPGRI [37] and a further 14 descriptors that were considered relevant for identification. For the determination of some of the descriptors, samples of flowers, fruits and leaves were taken during 2015, 2016 and 2017, using UPOV guidelines. The measurement for each parameter was performed as follows: Flowers were collected at full bloom. Ten flowers were taken from each of the eight trees studied per cultivar and year, and the following quantitative parameters were measured using an electronic digital caliper (COMECTA 5900603, Barcelona, Spain): open flower diameter (cm), petal length (cm), petal width (cm) and pistil length (cm). The numbers of petals, pistils and stamens were also counted. Leaves were collected at the adult stage, at approximately the end of July. Seven leaves were sampled per tree and year, and the following quantitative parameters were measured: petiole length and leaf blade length and width. Anthocyanin pigmentation of the nectaries was indicated by a reddish tonality observed in leaf glands. Two ratios were calculated: the length/width of the leaf blade and the petiole length/leaf blade length. Almond fruits were collected at maturity. The time of maturity was reached when the mesocarp started to dry off. All observations on dry fruits and kernels were made when the ripe fruits had a water content of less than 8%; that is, at least one month after harvesting. A total of 20 fruits per tree and year were taken to determinate each parameter. The three principal dimensions of the nut and kernel, namely length (L), width (W) and thickness (T), were measured using a digital caliper with a sensibility of 0.01 mm. The geometric mean diameter (Dg), sphericity (ø) and surface area (S) were calculated using the following equations: $Dg = (LWT)^{0.333}$, $ø = [(LWT)^{0.333}]/L$ and $S = \pi\, Dg^2$ [38–41]. Also, following Jain and Bal [42] and Özgüven and Vursavuş [43], the volume (V) was expressed as follows: $V = \pi B^2 L^2/6(2L\text{-}B)$, where $B = (WT)^{0.5}$. Shell hardness was evaluated according to the categories established in the guidelines (extremely hard, hard, intermediate, soft and paper). Mass was measured on an electronic balance (Mettler XPR603S, Toledo, Spain) with a sensitivity of $\pm$0.001 g. The percentage of doubles (number of kernels per nut) and kernel taste were also determined. Finally, with regard to whole trees, the vegetative bearing habit of the different cultivars was evaluated by considering growing habits from extremely upright to drooping.

2.3. Chemical Composition

One hundred almonds were randomly selected per cultivar and their shells were removed to obtain the kernel. They were then finely ground by an electric grinder (Moulinex MC3001, Barcelona, Spain) and analyzed, with three replicates, for the following parameters: dry weight, lipids, proteins, dietary fiber, carbohydrates and ash (AOAC procedures [44]). Dry matter (%) was determined in a drying oven (Indelab, mod. IDL.AI 80, Navarra, Spain) at 100 °C using 25 g per sample. The crude protein content (%) of the samples was estimated with the macro-Kjeldahl method, with sulfuric acid digestion (Bloc-Digest 12P SELECTA, Barcelona, Spain) performed prior to the distillation and titration process, which was carried out with IDK132 VELP equipment and a conversion factor (N-Protein) of 5.18. The crude fat/lipids content (%) was determined with a Soxhlet extractor (VELP SER-158 Technilab, Lisses, France) by extraction from a 5 g sample of powdered almond with petroleum ether (boiling point range = 38.2–54.3 °C). The ash content (%) was determined by quantifying the residue after combustion of the dry sample in an analogical muffle furnace (HD230PAD Hobersal, Barcelona, Spain) at 550 ± 15 °C for 6 hours under incineration conditions corresponding to the gravimetric method. Total dietary fiber (%) was measured with an enzymatic–gravimetric method, determining the fiber's hydrolyzed polysaccharides by HPLC and lignin gravimetrically. Total carbohydrates (%) were estimated through the difference between the dry extract and the rest of the components. The energy value (kcal/100 g) was calculated using the general Atwater coefficients: 4 * (% protein) + 9 * (% crude fat) + 4 * (%total carbohydrates).

2.4. Statistical Analyses

Means and standard deviations were calculated for each of the quantitative parameters studied over the 3 years for the 24 traditional almond cultivars. The unit of measurement of each of the parameters studied was based on the individual value of each of the eight trees sampled per cultivar. Finally, based on all the studied parameters, principal component analysis (PCA) was carried out using the SPSS 17.0 program, and a dendrogram of genetic similarities among cultivars was compiled using the furthest neighbor method (Statgraphics Plus 17.0 program).

3. Results

3.1. Flowers

Flower parameters are shown in Table 1. Open flower diameter ranged from 3.48 to 5.51 cm, the cultivars with the largest flowers being "Peta", "Marcelina", "Gorda José" and "Portuguesa". All genotypes had five petals, except "Picuda" and the "Pestañetas" group.

In all cases, the petal length was highly correlated (0.91) with the flower size. Petal width varied from 1.11 to 2.04 cm. The lowest values were observed for "Pestañeta Arribes", "Desmayo Rojo" and "Esperanza". These last two cultivars, together with "Cascafina", "Cascona", "De Convite", "Desmayo Largueta" and "Peta", showed more than one pistil. The length of pistils ranged from 1.26 to 2.05 cm. "Portuguesa" was the cultivar with the largest pistil. The stamen number varied between 28 and 53.

Table 1. Means, standard deviations and ANOVA analyses for some flower parameters in almond cultivars.

Cultivar	Open Flower Diameter (cm)	Number of Petals	Petal Length (cm)	Petal Width (cm)	Number of Pistils	Pistil Length (cm)	Number of Stamens
Agapitina	4.38 (0.18) defg	5	1.89 (0.04) c	1.27 (0.03) cd	1	1.83 (0.03) hi	32.28 (1.97) bcdef
Bravía	4.35 (0.14) cdef	5	1.72 (0.07) b	1.61 (0.04) h	1	1.26 (0.05) a	31.06 (3.01) abcdef
Cascafina	4.91 (0.12) jkl	5	2.25 (0.05) j	1.91 (0.02) l	1–2	1.88 (0.04) jk	30.84 (1.98) abcde
Cascona	3.48 (0.22) a	5	1.45 (0.04) a	1.44 (0.05) g	1–2	1.51 (0.02) c	28.12 (2.11) a
Cornicabra	4.02 (0.11) b	5	1.72 (0.07) b	1.23 (0.04) c	1	1.73 (0.03) ef	30.87 (2.64) abcde
De Convite	4.70 (0.15) hij	5	2.05 (0.05) efg	1.71 (0.02) ij	1–2	1.95 (0.02) lm	39.38 (1.08) g
Desmayo Largueta	4.31 (0.13) cde	5	2.02 (0.06) ef	1.45 (0.05) g	1–2	1.65 (0.04) d	29.51 (2.06) abc
Desmayo Rojo	4.23 (0.16) bcd	5	2.14 (0.04) hi	1.17 (0.04) b	1–3	1.79 (0.03) gh	28.62 (2.35) a
Esperanza	4.26 (0.14) bcde	5	2.15 (0.05) hi	1.18 (0.02) b	1–3	1.81 (0.03) hi	28.17 (2.54) a
Gorda José	5.03 (0.21) kl	5	2.25 (0.06) j	2.04 (0.03) m	1	1.83 (0.03) hi	41.28 (2.64) g
Marcelina	5.11 (0.17) l	5	2.39 (0.05) k	1.63 (0.05) h	1	1.76 (0.04) fg	29.28 (0.82) ab
Marcona	4.62 (0.20) ghi	5	2.12 (0.04) gh	1.35 (0.04) f	1	1.48 (0.02) bc	28.64 (1.71) a
Molar de Chavés	4.60 (0.18) fghi	5	2.10 (0.05) fgh	1.32 (0.03) ef	1	1.45 (0.03) b	29.64 (1.99) abc
Mollar de Arribes	4.81 (0.17) ijk	5	2.22 (0.08) ij	1.75 (0.03) j	1	1.71 (0.05) e	34.02 (1.82) ef
Pestaneta de Bragança	4.16 (0.19) bcd	5–6	1.79 (0.05) b	1.16 (0.04) b	1	1.84 (0.03) ij	28.09 (1.48) a
Pestañeta de Arribes	4.10 (0.20) bc	5–6	1.72 (0.07) b	1.11 (0.03) a	1	1.83 (0.02) hi	28.14 (1.05) a
Peta	5.51 (0.17) m	5	2.49 (0.05) l	1.70 (0.02) i	1–2	1.92 (0.03) kl	31.02 (1.49) abcdef
Picuda	4.52 (0.17) efgh	5–6	1.99 (0.06) de	1.28 (0.04) de	1	1.45 (0.04) b	53.64 (3.02) h
Portuguesa	5.02 (0.22) kl	5	2.21 (0.07) ij	1.86 (0.05) k	1	2.05 (0.02) n	33.05 (2.64) def
Recia	4.99 (0.14) kl	5	2.25 (0.03) j	1.62 (0.08) h	1	1.98 (0.02) m	34.21 (2.19) f
Redondilla	4.31 (0.12) cde	5	1.93 (0.02) cd	1.23 (0.02) c	1	1.89 (0.04) k	29.15 (1.43) ab
Valenciana	4.72 (0.11) hij	5	2.02 (0.05) ef	1.71 (0.03) ij	1	1.95 (0.03) lm	32.64 (0.97) cdef
Verdeal	4.18 (0.16) bcd	5	1.80 (0.04) b	1.35 (0.04) f	1	1.75 (0.03) efg	30.56 (1.99) abcd
Verdinal	4.11 (0.10) bc	5	1.78 (0.03) b	1.31 (0.04) def	1	1.72 (0.04) ef	30.67 (1.35) abcd

ANOVA, analysis of variance; a–n Different letters in the same column indicate statistically significant differences between cultivars at the 95% confidence level.

3.2. Leaves

Leaf parameters are summarized in Table 2. Petiole length varied from 1.46 to 3.40 cm, the cultivars with the shortest and the longest leaf peduncles being "Cornicabra" and "Mollar de Arribes", respectively. This last cultivar also showed the highest leaf blade length. At the opposite end for this parameter was the "Bravía" genotype. Its leaves were also the narrowest (2.07 cm). The length/width ratio of the leaf blades ranged from 3.76 cm to 7.91 cm. "Valenciana", "Desmayo Rojo" and "Esperanza" were the cultivars with the highest ratios (5.96, 6.54 and 7.91, respectively). The other ratios calculated (petiole/leaf blade length) had values of around 0.22. The leaf glands showed green or reddish anthocyanin colorations.

3.3. Fruits

Fruit agromorphological parameters are shown in Table 3. Regarding dry fruit, "Gorda José" was the local cultivar that had the largest size and weight parameters, at 4.98 cm length, 3.41 cm width, 2.49 cm thickness and 16.35 g mass. Its nuts had geometric mean diameters close to 3.50 cm and volume and surface area values of around 15.64 cm^3 and 38.02 cm^2, respectively. At the other extreme was the cultivar "Bravía", with mean dry fruit dimensions of 2.82 cm (length), 1.82 cm (width) and 1.31 cm (thickness) and a mean mass value of about 2.70 g. Its nuts also had the lowest values of volume (2.42 cm^3) and surface area (11.17 cm^2). Nut sphericity ranged from 60.31 to 79.00%, the cultivars with the longest and roundest fruits being "Cornicabra" and "Marcona", respectively. It is also important to point out the relevant differences recorded for this parameter between the two "Mollar" cultivars. The "Molar de Arribes" genotype showed more elongated nuts than "Molar de Chavés" (64.22 and 72.29%, respectively). With respect to shell hardness, high resistance to cracking was observed for all the cultivars studied, except for "Desmayo Rojo", "Mollar" and "De Convite". This latter cultivar has dry fruit which can easily be opened by birds. In relation to kernels, "Marcelina" was the traditional cultivar that had the largest size and weight parameters at 2.52 cm length, 1.94 cm width, 0.90 cm thickness and 2.11 g mass. Its kernels recorded geometric mean diameters close to 1.63 cm and volume and surface area values of around 1.56 cm^3 and 8.41 cm^2, respectively. With respect to sphericity, the kernels of this last cultivar were, together with those of the cultivars "Marcona" and "Agapitina", the roundest (values close to 65%). The "Marcelina" genotype also recorded low values of double kernels (3%). This tendency to produce only a single, well-formed kernel is a highly desirable cultivar trait. On the other hand, "Desmayo Largueta", "De Convite", "Cascona", "Cascafina", "Peta", "Esperanza" and "Desmayo Rojo" registered double kernel values higher than 14%. With respect to the kernel/dry fruit mass ratio, "Cascafina" and "De Convite" were the cultivars with the highest yield values (0.34). It could be interesting to use these cultivars in future almond breeding programs. With respect to taste, all the cultivars were sweet except for the "Bravía" and "Recia" genotypes.

Table 2. Means, standard deviations and ANOVA analyses for some leaf parameters in almond cultivars.

Cultivar	1	2	3	4	5	6
	Petiole Length (cm)	Leaf Blade Length (cm)	Leaf Blade Width (cm)	2/3 Ratio	1/2 Ratio	Anthocyanin Coloration of Leaf Glands
Agapitina	2.18 (0.31) ^{cdefgh}	9.27 (1.27) ^{abcd}	1.91 (0.34) ^{bcdefg}	4.85 (0.62) ^{abcd}	0.24 (0.03) ^{def}	Green
Bravía	2.06 (0.55) ^{bcdefgh}	7.79 (1.19) ^{a}	2.07 (0.38) ^{cdefgh}	3.76 (0.60) ^{a}	0.26 (0.05) ^{f}	Reddish
Cascafina	2.56 (0.39) ^{ghij}	10.15 (1.18) ^{bcdefg}	1.89 (0.21) ^{bcdefg}	5.37 (0.58) ^{bcd}	0.25 (0.03) ^{ef}	Green
Cascona	2.29 (0.23) ^{defghi}	10.90 (1.19) ^{cdefgh}	2.33 (0.34) ^{efgh}	4.68 (0.65) ^{abc}	0.21 (0.02) ^{bcde}	Green
Cornicabra	1.46 (0.38) ^{a}	9.60 (1.93) ^{abcde}	2.18 (0.50) ^{efgh}	4.40 (0.69) ^{ab}	0.15 (0.03) ^{a}	Green
De Convite	3.06 (0.33) ^{jk}	8.42 (0.45) ^{ab}	1.88 (0.11) ^{bcdef}	4.48 (0.10) ^{ab}	0.36 (0.02) ^{g}	Reddish
Desmayo Largueta	1.95 (0.32) ^{abcd}	10.21 (1.15) ^{bcdefg}	1.93 (0.43) ^{bcdefg}	5.29 (0.90) ^{bcd}	0.19 (0.02) ^{abc}	Green
Desmayo Rojo	2.43 (0.40) ^{efghi}	12.09 (1.21) ^{ghi}	1.85 (0.36) ^{bcde}	6.54 (1.15) ^{e}	0.20 (0.02) ^{bcd}	Reddish
Esperanza	2.03 (0.39) ^{abcdefg}	10.52 (0.92) ^{cdefgh}	1.33 (0.16) ^{a}	7.91 (0.90) ^{f}	0.19 (0.03) ^{abc}	Reddish
Gorda José	2.47 (0.22) ^{fghi}	11.89 (0.98) ^{fgh}	3.11 (0.35) ^{i}	3.82 (0.82) ^{a}	0.21 (0.03) ^{bcde}	Green
Marcelina	2.46 (0.39) ^{efghi}	10.11 (1.02) ^{bcdef}	2.17 (0.20) ^{defgh}	4.66 (0.42) ^{abc}	0.24 (0.02) ^{def}	Green
Marcona	2.21 (0.27) ^{cdefghi}	11.07 (0.94) ^{defgh}	2.47 (0.33) ^{h}	4.48 (0.58) ^{ab}	0.20 (0.04) ^{bcd}	Reddish
Molar de Chavés	2.30 (0.38) ^{defghi}	11.52 (2.01) ^{efgh}	2.51 (0.37) ^{h}	4.58 (0.72) ^{abc}	0.19 (0.03) ^{abc}	Reddish
Mollar de Arribes	3.40 (0.55) ^{k}	14.03 (2.34) ^{i}	2.36 (0.39) ^{fgh}	5.94 (0.79) ^{de}	0.24 (0.02) ^{def}	Reddish
Pestaneta de Bragança	2.03 (0.21) ^{abcdefg}	8.51 (0.85) ^{ab}	1.68 (0.23) ^{abcd}	5.06 (0.55) ^{bcd}	0.23 (0.03) ^{cdef}	Green
Pestañeta de Arribes	1.94 (0.10) ^{abcdef}	8.37 (0.50) ^{ab}	1.60 (0.16) ^{abc}	5.23 (0.62) ^{bcd}	0.23 (0.01) ^{cdef}	Green
Peta	2.76 (0.41) ^{ij}	11.10 (1.10) ^{defgh}	2.38 (0.30) ^{gh}	4.66 (0.56) ^{abc}	0.25 (0.02) ^{ef}	Reddish
Picuda	2.63 (0.54) ^{hij}	11.46 (1.10) ^{efgh}	3.04 (0.40) ^{i}	3.77 (0.59) ^{a}	0.23 (0.04) ^{cdef}	Reddish
Portuguesa	1.89 (0.28) ^{abcde}	11.39 (1.04) ^{efgh}	2.26 (0.28) ^{efgh}	5.04 (0.51) ^{bcd}	0.17 (0.02) ^{ab}	Green
Recia	2.45 (0.43) ^{efghi}	12.49 (1.66) ^{hi}	2.37 (0.58) ^{fgh}	5.27 (0.90) ^{bcd}	0.20 (0.03) ^{bcd}	Green
Redondilla	2.01 (0.31) ^{abcdefg}	9.09 (1.31) ^{abc}	1.60 (0.26) ^{abc}	5.68 (1.18) ^{cde}	0.22 (0.02) ^{cdef}	Reddish
Valenciana	1.74 (0.19) ^{abcd}	8.28 (0.96) ^{ab}	1.96 (0.43) ^{bcdefg}	5.96 (0.83) ^{de}	0.21 (0.03) ^{bcde}	Green
Verdeal	1.59 (0.27) ^{ab}	8.03 (1.08) ^{a}	1.49 (0.38) ^{ab}	5.38 (0.53) ^{bcd}	0.19 (0.02) ^{abc}	Green
Verdinal	1.64 (0.36) ^{abc}	8.12 (1.21) ^{a}	1.50 (0.29) ^{ab}	5.41 (0.86) ^{bcde}	0.20 (0.03) ^{bcd}	Green

ANOVA, analysis of variance; $^{a–k}$ Different letters in the same column indicate statistically significant differences between cultivars at the 95% confidence level.

Table 3. Means, standard deviations and ANOVA analyses for some fruit parameters in almond cultivars.

Cultivar	Nut					
	Weight (g)	Length (cm)	Width (cm)	Thickness (cm)	Volume (cm^3)	Geometric Mean Diameter (mm)
Agapitina	6.49 (1.31) ^{fg}	3.10 (0.25) ^{abc}	2.60 (0.15) ^{efg}	1.64 (0.17) ^{cd}	5.18 (1.02) ^{bcdef}	23.62 (2.16) ^{bcd}
Bravía	2.72 (0.37) ^{a}	2.82 (0.15) ^{a}	1.82 (0.28) ^{a}	1.31 (0.06) ^{a}	2.42 (0.67) ^{a}	18.86 (1.94) ^{a}
Cascafina	3.17 (2.02) ^{ab}	3.38 (0.19) ^{bcdefgh}	2.42 (0.15) ^{cde}	1.56 (0.08) ^{bc}	4.68 (1.15) ^{bcde}	23.34 (2.00) ^{bcd}
Cascona	5.50 (1.15) ^{cdefg}	3.45 (0.27) ^{cdefghi}	2.40 (0.22) ^{cde}	1.61 (0.14) ^{bcd}	4.88 (1.09) ^{bcdef}	23.69 (2.08) ^{bcd}
Cornicabra	5.11 (1.28) ^{cdef}	3.83 (0.45) ^{ij}	2.07 (0.17) ^{ab}	1.56 (0.08) ^{bc}	4.23 (0.98) ^{bc}	23.10 (1.96) ^{bc}
De Convite	3.86 (0.30) ^{abc}	3.70 (0.09) ^{ghij}	2.37 (0.21) ^{bcde}	1.45 (0.10) ^{ab}	4.44 (1.12) ^{bcd}	23.32 (2.28) ^{bcd}
Desmayo Largueta	4.31 (1.33) ^{abad}	3.56 (0.51) ^{efghi}	2.21 (0.20) ^{bcd}	1.34 (0.13) ^{a}	3.63 (0.94) ^{ab}	21.90 (1.83) ^{ab}
Desmayo Rojo	5.00 (0.77) ^{cdef}	3.24 (0.18) ^{bcdef}	2.46 (0.13) ^{cde}	1.64 (0.14) ^{cd}	4.95 (1.22) ^{bcdef}	23.53 (2.07) ^{bcd}
Esperanza	4.80 (0.59) ^{bcde}	3.38 (0.08) ^{bcdefgh}	2.52 (0.13) ^{de}	1.64 (0.11) ^{cd}	5.22 (1.41) ^{bcdef}	24.08 (1.96) ^{bcd}
Gorda José	16.35 (0.87) ^{j}	4.98 (0.23) ^{k}	3.41 (0.15) ^{j}	2.49 (0.11) ^{g}	15.64 (3.83) ^{j}	34.79 (2.41) ^{f}
Marcelina	9.14 (0.52) ^{i}	3.48 (0.15) ^{cdefghi}	2.88 (0.10) ^{ghi}	1.85 (0.10) ^{ef}	7.26 (1.42) ^{hi}	26.44 (2.17) ^{de}
Marcona	5.77 (1.15) ^{defg}	3.13 (0.20) ^{abcd}	2.65 (0.20) ^{efg}	1.83 (0.16) ^{ef}	6.13 (1.00) ^{efgh}	24.73 (2.09) ^{bcde}
Molar de Chavés	5.65 (0.99) ^{defg}	3.30 (0.39) ^{bcdefg}	2.54 (0.20) ^{ef}	1.62 (0.14) ^{cd}	5.13 (1.08) ^{bcdef}	23.85 (1.99) ^{bcd}
Mollar de Arribes	5.43 (0.90) ^{cdefg}	3.79 (0.60) ^{hij}	2.40 (0.22) ^{cde}	1.59 (0.12) ^{bc}	5.10 (1.14) ^{bcdef}	24.34 (1.86) ^{bcd}
Pestaneta de Bragança	6.87 (1.01) ^{gh}	3.20 (0.21) ^{abcdef}	2.64 (0.19) ^{efg}	1.64 (0.10) ^{cd}	5.37 (1.20) ^{cdefg}	23.99 (1.99) ^{bcd}
Pestañeta de Arribes	6.80 (0.56) ^{gh}	3.13 (0.15) ^{abcd}	2.63 (0.06) ^{efg}	1.63 (0.06) ^{cd}	5.24 (1.05) ^{bcdef}	23.74 (2.11) ^{bcd}
Peta	8.22 (1.04) ^{hi}	4.09 (0.17) ^{j}	2.67 (0.12) ^{efg}	1.99 (0.12) ^{f}	7.92 (1.52) ^{i}	27.87 (2.30) ^{e}
Picuda	4.90 (0.85) ^{cdef}	3.54 (0.21) ^{defghi}	2.85 (0.20) ^{fgh}	1.60 (0.06) ^{bcd}	6.05 (1.29) ^{defgh}	25.24 (2.04) ^{cde}
Portuguesa	6.51 (0.92) ^{fg}	3.61 (0.22) ^{fghi}	2.68 (0.16) ^{efg}	1.76 (0.09) ^{de}	6.37 (1.04) ^{fghi}	25.70 (2.15) ^{cde}
Recia	5.43 (0.69) ^{cdefg}	2.98 (0.24) ^{ab}	2.19 (0.22) ^{bc}	1.62 (0.26) ^{cd}	4.04 (0.97) ^{abc}	21.93 (1.78) ^{ab}
Redondilla	6.18 (1.81) ^{efg}	3.17 (0.47) ^{abcde}	2.50 (0.33) ^{cde}	1.72 (0.15) ^{cde}	5.30 (1.11) ^{cdefg}	23.86 (1.96) ^{bcd}
Valenciana	6.51 (0.98) ^{fg}	3.30 (0.24) ^{bcdefg}	2.57 (0.18) ^{efg}	1.85 (0.12) ^{ef}	6.13 (1.26) ^{efgh}	25.01 (2.07) ^{bcde}
Verdeal	6.23 (1.02) ^{efg}	3.40 (0.20) ^{cdefgh}	3.17 (0.25) ^{hij}	1.63 (0.11) ^{cd}	6.90 (1.47) ^{ghi}	25.97 (2.13) ^{cde}
Verdinal	6.38 (0.78) ^{efg}	3.42 (0.16) ^{cdefghi}	3.20 (0.28) ^{ij}	1.65 (0.09) ^{cd}	7.11 (1.33) ^{hi}	26.21 (2.24) ^{cde}

Table 3. *Cont.*

Cultivar	Nut			Kernel		
	Sphericity (%)	Surface Area (cm^2)	Shell Hardness	Weight (g)	Length (cm)	Width (cm)
Agapitina	76.19 (6.22) ^{ef}	17.52 (1.82) ^{bcd}	Hard	1.47 (0.23) ^{ef}	2.26 (0.22) ^{ab}	1.69 (0.22) ^{ijk}
Bravía	66.87 (5.16) ^{abcde}	11.17 (2.03) ^{a}	Hard	0.89 (0.14) ^{a}	2.26 (0.11) ^{ab}	1.10 (0.18) ^{a}
Cascafina	69.05 (5.62) ^{abcde}	17.11 (1.96) ^{bc}	Hard	1.09 (0.14) ^{abcd}	2.43 (0.14) ^{bcdef}	1.53 (0.07) ^{fghi}
Cascona	68.66 (5.47) ^{abcde}	17.63 (2.15) ^{bcd}	Hard	1.40 (0.28) ^{def}	2.43 (0.17) ^{bcdef}	1.48 (0.13) ^{defg}
Cornicabra	60.31 (4.98) ^{a}	16.76 (1.85) ^{bc}	Hard	1.27 (0.14) ^{cdef}	2.65 (0.23) ^{def}	1.35 (0.20) ^{bcde}
De Convite	63.02 (5.29) ^{abc}	17.08 (2.31) ^{bc}	Soft	1.35 (0.12) ^{cdef}	2.67 (0.12) ^{ef}	1.50 (0.06) ^{efg}
Desmayo Largueta	61.51 (5.73) ^{ab}	15.06 (1.67) ^{b}	Hard	1.05 (0.37) ^{abc}	2.60 (0.24) ^{cdef}	1.21 (0.13) ^{ab}
Desmayo Rojo	72.62 (6.00) ^{cdef}	17.39 (1.95) ^{bc}	Intermediate	1.18 (0.14) ^{abcdef}	2.30 (0.15) ^{abc}	1.33 (0.09) ^{bcd}
Esperanza	71.25 (6.43) ^{bcdef}	18.21 (2.04) ^{bcde}	Hard	0.92 (0.07) ^{ab}	2.23 (0.06) ^{ab}	1.30 (0.08) ^{bc}
Gorda José	69.85 (5.48) ^{abcdef}	38.02 (3.52) ^{h}	Hard	1.94 (0.18) ^{g}	2.61 (0.18) ^{cdef}	1.80 (0.11) ^{kl}
Marcelina	75.97 (6.11) ^{ef}	21.96 (2.01) ^{fg}	Hard	2.11 (0.23) ^{g}	2.52 (0.22) ^{bcdef}	1.94 (0.05) ^{l}
Marcona	79.00 (5.87) ^{f}	19.21 (1.93) ^{cdefg}	Hard	1.30 (0.14) ^{cdef}	2.08 (0.10) ^{a}	1.58 (0.14) ^{ghi}
Molar de Chavés	72.29 (5.00) ^{cdef}	17.87 (1.87) ^{bcd}	Intermediate	1.33 (0.16) ^{cdef}	2.32 (0.21) ^{abc}	1.55 (0.16) ^{fghi}
Mollar de Arribes	64.22 (5.42) ^{abcd}	18.61 (2.26) ^{cdef}	Intermediate	1.39 (0.13) ^{def}	2.51 (0.24) ^{bcdef}	1.52 (0.14) ^{fgh}
Pestaneta de Bragança	74.98 (6.31) ^{ef}	18.08 (2.38) ^{bcde}	Hard	1.37 (0.11) ^{cdef}	2.32 (0.16) ^{abc}	1.76 (0.09) ^{jk}
Pestañeta de Arribes	75.84 (6.19) ^{ef}	17.70 (1.68) ^{bcd}	Hard	1.36 (0.04) ^{cdef}	2.30 (0.09) ^{abc}	1.75 (0.07) ^{jk}
Peta	68.14 (5.87) ^{abcde}	24.40 (2.49) ^{g}	Hard	1.39 (0.22) ^{def}	2.72 (0.15) ^{f}	1.67 (0.09) ^{hijk}
Picuda	71.29 (6.01) ^{bcdef}	20.01 (2.09) ^{cdefg}	Hard	1.21 (0.11) ^{abcdef}	2.25 (0.15) ^{ab}	1.50 (0.08) ^{efg}
Portuguesa	71.19 (5.99) ^{bcdef}	20.74 (2.14) ^{defg}	Hard	1.48 (0.22) ^{f}	2.55 (0.13) ^{bcdef}	1.62 (0.08) ^{ghij}
Recia	73.59 (6.14) ^{def}	15.10 (1.52) ^{b}	Hard	1.23 (0.17) ^{bcdef}	2.29 (0.13) ^{abc}	1.40 (0.08) ^{cdef}
Redondilla	75.26 (5.62) ^{ef}	17.07 (1.76) ^{bc}	Hard	1.19 (0.21) ^{abcdef}	2.34 (0.14) ^{abad}	1.55 (0.16) ^{fghi}
Valenciana	75.78 (5.76) ^{ef}	19.65 (1.64) ^{cdefg}	Hard	1.15 (0.19) ^{abcde}	2.24 (0.14) ^{ab}	1.55 (0.09) ^{fghi}
Verdeal	76.38 (6.20) ^{ef}	21.18 (2.37) ^{defg}	Hard	1.30 (0.17) ^{cdef}	2.39 (0.17) ^{abcde}	1.46 (0.11) ^{cdefg}
Verdinal	76.63 (6.07) ^{ef}	21.58 (2.43) ^{efg}	Hard	1.31 (0.21) ^{cdef}	2.41 (0.20) ^{bcdef}	1.47 (0.13) ^{defg}

Table 3. *Cont.*

Cultivar	Kernel						
	Thickness (cm)	**Volume (cm^3)**	**Geometric Mean Diameter (mm)**	**Sphericity (%)**	**Surface Area (cm^2)**	**Doubles (%)**	**Taste**
Agapitina	0.85 (0.08) ^{bc}	1.16 (0.21) ^{c}	14.80 (1.02) ^{cd}	65.49 (4.94) ^{hi}	6.88 (0.62) ^{de}	2	Sweet
Bravía	0.84 (0.06) ^{abc}	0.69 (0.23) ^{a}	12.77 (1.11) ^{a}	56.54 (3.21) ^{bcd}	5.12 (0.59) ^{ab}	6	Bitter
Cascafina	0.73 (0.06) ^{ab}	0.91 (0.20) ^{abc}	13.94 (0.96) ^{abc}	57.38 (4.89) ^{bcdef}	6.10 (0.70) ^{abcd}	17	Sweet
Cascona	0.85 (0.08) ^{bc}	1.04 (0.19) ^{bc}	14.50 (1.20) ^{bc}	59.70 (3.93) ^{cdefghi}	6.60 (0.71) ^{abcd}	16	Sweet
Cornicabra	0.80 (0.06) ^{abc}	0.93 (0.20) ^{abc}	14.19 (0.99) ^{abc}	53.55 (3.65) ^{abc}	6.32 (0.68) ^{abcd}	3	Sweet
De Convite	0.70 (0.06) ^{ab}	0.91 (0.22) ^{abc}	14.09 (1.14) ^{abc}	52.79 (4.07) ^{ab}	6.23 (0.67) ^{abcd}	15	Sweet
Desmayo Largueta	0.68 (0.09) ^{a}	0.68 (0.18) ^{a}	12.88 (0.90) ^{ab}	49.54 (4.62) ^{a}	5.21 (0.62) ^{abc}	14	Sweet
Desmayo Rojo	0.80 (0.06) ^{abc}	0.83 (0.21) ^{ab}	13.47 (0.94) ^{abc}	58.57 (3.94) ^{bcdefg}	5.70 (0.66) ^{abcd}	21	Sweet
Esperanza	0.70 (0.07) ^{ab}	0.68 (0.19) ^{a}	12.66 (1.03) ^{a}	56.77 (3.82) ^{bcde}	5.03 (0.60) ^{a}	20	Sweet
Gorda José	0.70 (0.04) ^{ab}	1.10 (0.23) ^{bc}	14.86 (1.00) ^{cd}	56.95 (3.81) ^{bcde}	6.93 (0.72) ^{de}	0	Sweet
Marcelina	0.90 (0.06) ^{c}	1.56 (0.21) ^{d}	16.37 (1.28) ^{d}	64.99 (4.83) ^{ghi}	8.41 (0.78) ^{e}	3	Sweet
Marcona	0.78 (0.06) ^{abc}	0.92 (0.22) ^{abc}	13.68 (0.97) ^{abc}	65.77 (5.02) ^{i}	5.87 (0.70) ^{abcd}	4	Sweet
Molar de Chavés	0.80 (0.07) ^{abc}	0.99 (0.18) ^{abc}	14.22 (1.09) ^{abc}	61.30 (4.15) ^{defghi}	6.35 (0.75) ^{abcd}	7	Sweet
Mollar de Arribes	0.82 (0.10) ^{abc}	1.05 (0.20) ^{bc}	14.61 (1.04) ^{c}	58.24 (4.41) ^{bcdef}	6.70 (0.69) ^{bcd}	5	Sweet
Pestaneta de Bragança	0.80 (0.06) ^{abc}	1.15 (0.23) ^{bc}	14.83 (1.11) ^{cd}	63.92 (4.87) ^{efghi}	6.90 (0.71) ^{cde}	3	Sweet
Pestañeta de Arribes	0.80 (0.07) ^{abc}	1.13 (0.19) ^{bc}	14.76 (1.13) ^{cd}	64.17 (5.06) ^{fghi}	6.84 (0.70) ^{de}	4	Sweet
Peta	0.69 (0.09) ^{ab}	1.02 (0.21) ^{bc}	14.62 (0.98) ^{c}	53.78 (3.94) ^{abc}	6.71 (0.73) ^{bcd}	17	Sweet
Picuda	0.85 (0.06) ^{bc}	1.00 (0.22) ^{abc}	14.20 (1.17) ^{abc}	63.12 (4.08) ^{defghi}	6.33 (0.69) ^{abad}	4	Sweet
Portuguesa	0.79 (0.05) ^{abc}	1.10 (0.20) ^{bc}	14.82 (1.20) ^{cd}	58.14 (4.61) ^{bcdef}	6.89 (0.72) ^{de}	2	Sweet
Recia	0.80 (0.08) ^{abc}	0.87 (0.23) ^{abc}	13.68 (0.99) ^{abc}	59.75 (4.19) ^{cdefghi}	5.87 (0.67) ^{abcd}	8	Intermediate
Redondilla	0.79 (0.06) ^{abc}	0.98 (0.21) ^{abc}	14.19 (1.02) ^{abc}	60.67 (3.76) ^{defghi}	6.32 (0.70) ^{abcd}	4	Sweet
Valenciana	0.70 (0.08) ^{ab}	0.83 (0.22) ^{ab}	13.44 (0.97) ^{abc}	60.00 (4.99) ^{cdefghi}	5.67 (0.68) ^{abcd}	3	Sweet
Verdeal	0.79 (0.06) ^{abc}	0.93 (0.19) ^{abc}	14.01 (1.06) ^{abc}	58.64 (4.52) ^{bcdefgh}	6.16 (0.73) ^{abcd}	5	Sweet
Verdinal	0.80 (0.05) ^{abc}	0.96 (0.21) ^{abc}	14.14 (1.10) ^{abc}	58.70 (3.84) ^{bcdefgh}	6.28 (0.69) ^{abcd}	5	Sweet

ANOVA, analysis of variance; $^{a–l}$ Different letters in the same column indicate statistically significant differences between cultivars at the 95% confidence level.

Fruit chemical parameters are summarized in Table 4. The kernel dry weight value was quite similar in all the cases (95.54–96.56%). “Mollar de Arribes” was the cultivar with the lowest water level in kernels. Greater differences were recorded for the rest of the chemical parameters. Lipid content varied from 48.82% to 56.80%, “Mollar de Arribes”, “Cascafina” and “Peta” being the cultivars with the most oleaginous kernels. Lipids content is highly correlated with energy levels (r = 0.95). On the other hand, it is also important to note that the “Molar de Chavés” cultivar, the other genotype called “Mollar” by the local growers, recorded a very low lipids level, close to 49%. Protein content ranged between 15.54% and 23.39%, “Peta” and “Esperanza” being the cultivars with the lowest and the highest values, respectively. It can be observed that protein content is inversely correlated with the lipid fraction (r = −0.87). Dietary fiber content varied from 14.03 to 17.99%. “Picuda”, “Gorda José” and “Peta” were the cultivars that had the highest values. Carbohydrates content varied from 2.86% to 4.82%, “Recia”, “Desmayo Rojo” and “Esperanza” being the cultivars with the highest levels. Finally, ash content ranged from 3.02% to 4.17%. It can be observed that the results were very similar for all the almond cultivars.

3.4. Vegetative Tree Habits

Very different vegetative habits were observed, ranging from very upright or upright to completely drooping. The habit of the “Agapitina” cultivar was between upright and very upright. On the opposite side, “Desmayo Largueta’, “Verdeal” and “Verdinal” were the only almond genotypes that had drooping growth habits. The rest of the cultivars showed vegetative habits between medium and spreading. This was the case for “Mollar de Arribes”, “Pestaneta de Bragança”, “Pestañeta de Arribes” and “Valenciana” (medium-upright); “Cascafina”, “Desmayo Rojo”, “Esperanza”, “Mollar de Arribes” and “Peta” (medium); “Bravía” (medium-spreading); “Cascona”, “De Convite”, “Gorda José” and “Portuguesa” (spreading); and “Cornicabra”, “Marcelina”, “Marcona”, “Picuda”, “Recia” and “Redondilla” (spreading-drooping). Finally, it is also important to note that the two genotypes called “Mollar” by the local growers, “Molar de Chavés” and “Mollar de Arribes”, showed medium-upright and medium growth habits, respectively.

3.5. Statistical Analyses

Principal component analysis (PCA) was used to identify the traits with the highest variation between cultivars and the greatest impact on separation of them in the dataset [45]. PCA results based on flower, leaf, fruit and tree traits showed that more than 54% of the variability observed was explained by the first three components (PC1–PC3). The first component (PC1), accounting for 27.65% of the total variance, was influenced by nut weight and size parameters such as thickness, volume, geometric mean diameter and surface area. The second component (PC2) accounted for 15.27% of total variation and was mainly explained by leaf petiole length and nut and kernel sphericity. Finally, the third principal component (PC3), explaining 11.72% of total variation, was integrated by the kernel thickness and the lipid content. Figure 1 shows a scatterplot of the first two principal components (PCs) for the 24 traditional almond cultivars based on agromorphological and chemical characteristics. It can be observed that there was high variation between genotypes, indicating that the studied germplasm is a good gene pool candidate for breeding programs.

Table 4. Means, standard deviations and ANOVA analyses for some parameters of nutritive composition in almond cultivars.

Cultivar	Dry Weight (%)	Lipids (%)	Proteins (%)	Dietary Fiber (%)	Carbohydrates (%)	Ash (%)	Energy (kcal/100 g)
Agapitina	95.82 (0.71) ^{ab}	52.76 (2.06) ^{cd}	20.81 (0.92) ^{cd}	15.03 (0.96) ^{ab}	3.82 (0.42) ^{cde}	3.55 (0.31) ^{bcdef}	573.28 (15.07) ^{bcdef}
Bravía	95.69 (0.86) ^{ab}	50.87 (2.92) ^{abc}	23.06 (1.04) ^{efg}	14.84 (1.13) ^{ab}	4.04 (0.58) ^{cdef}	3.03 (0.29) ^{a}	566.15 (20.11) ^{abcd}
Cascafina	96.14 (0.79) ^{ab}	56.13 (2.00) ^{fg}	18.57 (0.87) ^{b}	14.81 (1.35) ^{ab}	3.69 (0.50) ^{c}	3.16 (0.34) ^{abcd}	593.83 (12.79) ^{ef}
Cascona	95.67 (0.69) ^{ab}	52.67 (2.76) ^{cd}	21.09 (0.96) ^{cd}	15.19 (1.27) ^{ab}	3.97 (0.52) ^{cde}	3.09 (0.39) ^{abc}	573.59 (18.34) ^{bcdef}
Cornicabra	95.76 (0.74) ^{ab}	52.94 (3.01) ^{cdef}	20.75 (0.83) ^{cd}	14.78 (1.76) ^{ab}	3.76 (0.57) ^{cd}	3.77 (0.30) ^{efghi}	574.26 (13.92) ^{bcdef}
De Convite	96.33 (0.77) ^{ab}	52.83 (2.61) ^{cde}	21.63 (0.91) ^{def}	14.97 (0.92) ^{ab}	3.91 (0.45) ^{cde}	3.11 (0.33) ^{ab}	577.59 (14.67) ^{cdef}
Desmayo Largueta	95.69 (0.80) ^{ab}	50.77 (2.42) ^{abc}	21.64 (0.94) ^{def}	15.56 (1.51) ^{ab}	4.05 (0.51) ^{cdef}	3.82 (0.36) ^{efghi}	559.49 (16.82) ^{abc}
Desmayo Rojo	96.21 (0.74) ^{ab}	52.83 (2.38) ^{cde}	21.02 (1.02) ^{cd}	14.33 (1.10) ^{a}	4.63 (0.47) ^{ef}	3.55 (0.29) ^{bcdef}	577.95 (11.30) ^{bcdef}
Esperanza	95.80 (0.79) ^{b}	49.08 (1.97) ^{ab}	23.39 (1.11) ^{g}	15.07 (1.60) ^{ab}	4.56 (0.49) ^{def}	4.09 (0.38) ^{ghi}	553.28 (17.83) ^{ab}
Gorda José	96.55 (0.68) ^{ab}	50.26 (2.49) ^{abc}	21.64 (0.99) ^{def}	16.26 (1.09) ^{b}	4.47 (0.60) ^{cdef}	4.17 (0.28) ^{i}	556.50 (14.12) ^{abc}
Marcelina	95.94 (0.83) ^{ab}	52.52 (2.61) ^{cd}	20.95 (0.86) ^{cd}	14.74 (1.54) ^{ab}	3.71 (0.58) ^{c}	4.12 (0.33) ^{hi}	571.28 (15.99) ^{abcde}
Marcona	96.03 (0.78) ^{ab}	52.47 (2.46) ^{cd}	21.16 (0.94) ^{cd}	15.03 (1.49) ^{ab}	4.10 (0.52) ^{cdef}	3.46 (0.37) ^{abcdef}	573.27 (21.67) ^{abcde}
Molar de Chavés	95.54 (0.84) ^{a}	49.91 (1.95) ^{abc}	23.21 (0.97) ^{fg}	14.96 (0.90) ^{ab}	3.99 (0.43) ^{cde}	3.64 (0.30) ^{defgh}	557.63 (17.22) ^{abc}
Mollar de Arribes	96.56 (0.80) ^{ab}	56.80 (2.81) ^{g}	19.67 (0.87) ^{bc}	15.08 (1.82) ^{ab}	2.13 (0.46) ^{a}	3.02 (0.28) ^{a}	598.28 (10.65) ^{f}
Pestaneta de Bragança	96.08 (0.75) ^{ab}	52.73 (3.02) ^{cd}	20.73 (0.85) ^{cd}	15.36 (1.74) ^{ab}	4.04 (0.52) ^{cdef}	3.36 (0.37) ^{abcde}	573.49 (18.34) ^{bcdef}
Pestañeta de Arribes	95.91 (0.87) ^{ab}	52.97 (2.43) ^{cdef}	20.57 (0.92) ^{cd}	15.14 (1.66) ^{ab}	3.80 (0.44) ^{cd}	3.64 (0.33) ^{defgh}	574.21 (13.96) ^{bcdef}
Peta	95.82 (0.78) ^{ab}	56.06 (3.07) ^{efg}	15.54 (0.97) ^{a}	17.99 (1.04) ^{c}	2.86 (0.47) ^{ab}	3.62 (0.30) ^{defg}	577.90 (19.57) ^{bcdef}
Picuda	95.59 (0.69) ^{a}	48.82 (2.09) ^{a}	23.35 (0.90) ^{g}	15.64 (0.98) ^{ab}	4.07 (0.50) ^{cdef}	3.85 (0.27) ^{fghi}	548.78 (12.83) ^{a}
Portuguesa	95.54 (0.68) ^{a}	50.06 (2.31) ^{abc}	23.33 (1.00) ^{g}	14.93 (1.16) ^{ab}	3.83 (0.53) ^{cde}	3.53 (0.35) ^{bcdef}	559.06 (15.71) ^{abc}
Recia	95.96 (0.81) ^{ab}	54.77 (2.73) ^{defg}	18.78 (0.83) ^{b}	14.04 (1.07) ^{a}	4.82 (0.56) ^{f}	3.79 (0.37) ^{efghi}	587.25 (19.80) ^{def}
Redondilla	95.94 (0.75) ^{ab}	51.86 (2.64) ^{abcd}	21.56 (1.06) ^{de}	14.82 (0.93) ^{ab}	3.86 (0.49) ^{cde}	4.04 (0.33) ^{ghi}	568.18 (11.82) ^{abcd}
Valenciana	96.23 (0.70) ^{ab}	52.24 (2.82) ^{bcd}	21.82 (0.98) ^{defg}	14.99 (1.02) ^{ab}	3.71 (0.47) ^{c}	3.61 (0.40) ^{cdefg}	572.24 (21.23) ^{abcde}
Verdeal	96.17 (0.83) ^{ab}	52.73 (2.71) ^{cd}	20.73 (1.11) ^{cd}	14.88 (1.14) ^{ab}	3.93 (0.60) ^{cde}	4.05 (0.36) ^{ghi}	573.09 (16.79) ^{bcdef}
Verdinal	96.02 (0.75) ^{ab}	53.05 (2.00) ^{cdef}	22.14 (0.94) ^{defg}	14.03 (0.91) ^{a}	3.65 (0.54) ^{bc}	3.38 (0.31) ^{abcdef}	580.41 (14.27) ^{cdef}

ANOVA, analysis of variance; $^{a–i}$ Different letters in the same column indicate statistically significant differences between cultivars at the 95% confidence level.

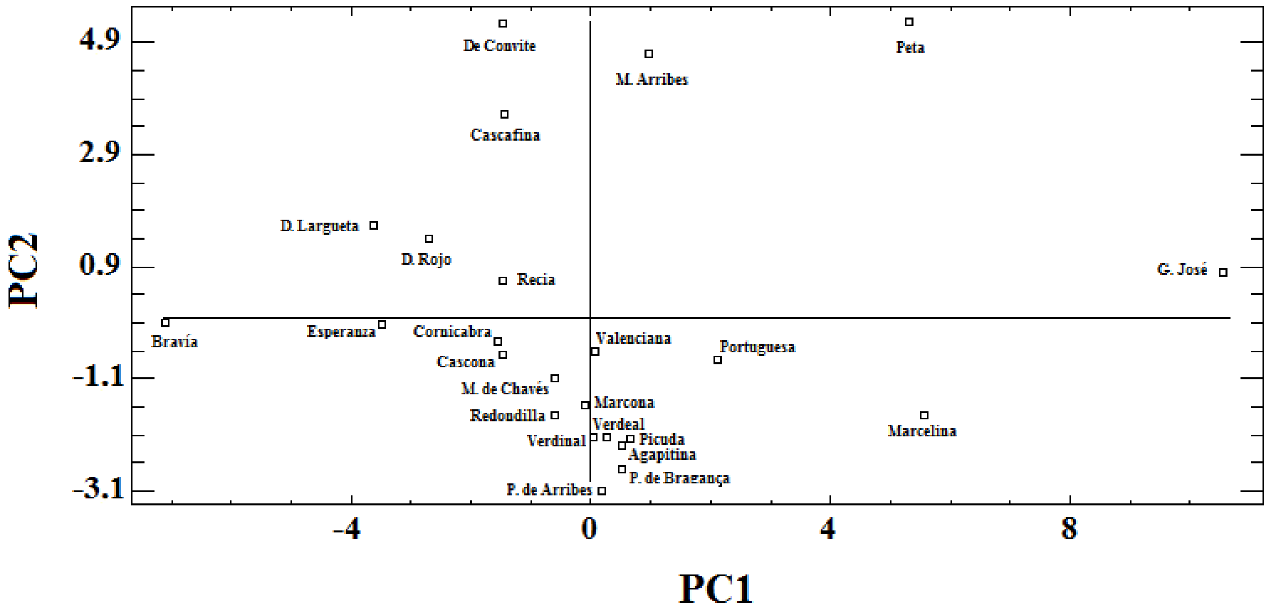

Figure 1. Scatterplot of the first two principal components (PCs) for the 24 traditional almond cultivars based on agromorphological and chemical characteristics.

Figure 2 shows a dendrogram of the relationships among the almond cultivars from the analysis of all the agromorphological and chemical parameters studied. It can be observed that the "Gorda José" cultivar showed the greatest differences compared to the rest of cultivars included in the study. Its nuts showed a large size in comparison with the others.

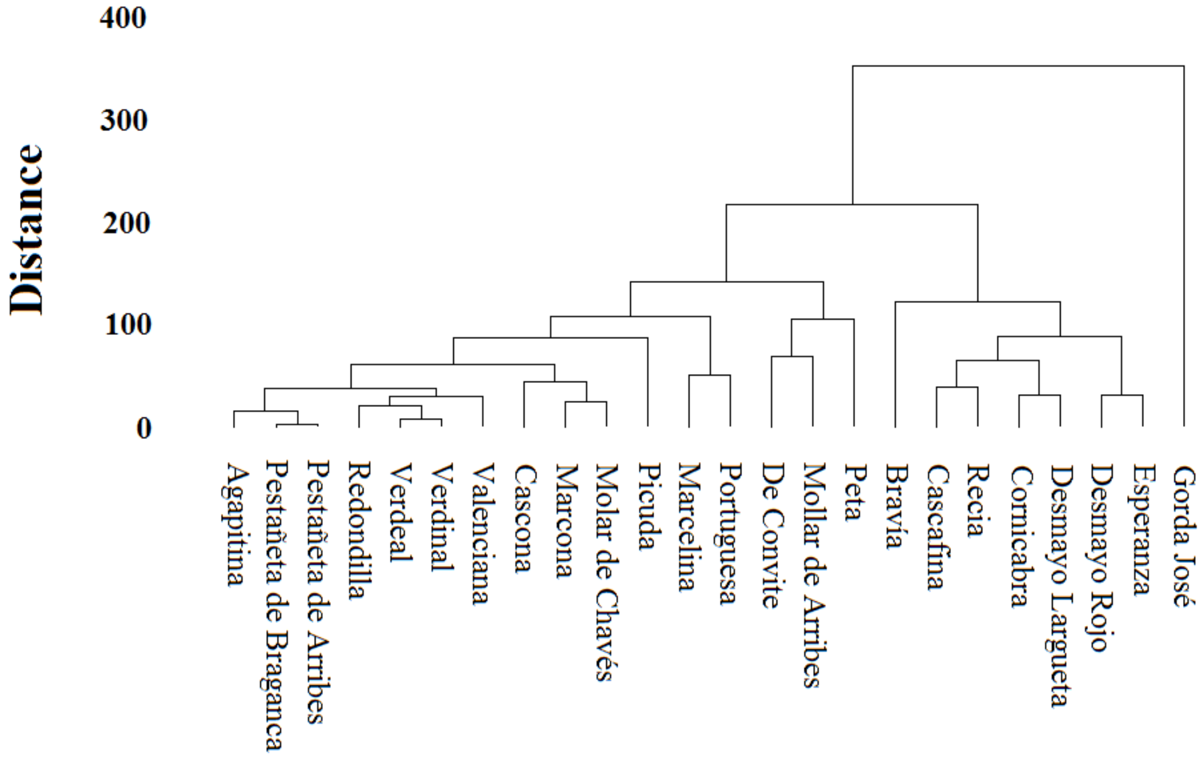

Figure 2. Dendrogram produced using the furthest neighbor method (Euclidean) from the agromorphological and chemical characteristics of traditional almond cultivars included in the study.

4. Discussion

4.1. Agromorphological and Chemical Characterization

The traditional almond cultivars from the central-western Iberian Peninsula showed great variability from an agromorphological point of view. Many of them, despite being practically unknown in the scientific literature, presented very interesting productive characters. Some previous researchers have provided information about some of the cultivars included in the study ("Marcona" and "Desmayo Largueta").

With respect to the flowers, Socias i Company et al. [46] also observed that there are important variations among almond cultivars. They indicated that the flower size is frequently related to the nut size and that the numbers of petals and pistils can range in relation to the type flower. With regard to the stamens, they established that their number can oscillate between 20 and 30, but may reach 40. In our study, a reduced number of cultivars showed six petals or two/three pistils and the number of stamens varied between 28.09 and 53.64. Arquero et al. [28] defined the "Marcona" flowers as small and elongated. In our case, the flowers of this last cultivar had a medium size in relation to the rest of cultivars included in the study.

According to Felipe [26], despite there being important differences among cultivars, almond leaves are generally narrow, long and pointed. Leaf characteristics are also affected by environmental conditions and the general health and vigor of the plant [47]. Moreover, leaf size also varies with position, with shoot leaves tending to be large and spur leaves small [48]. Moreover, Grasselly [49] have pointed out that wild cultivars generally have very small leaves, a probable adaptation to the xerophytic conditions under which these cultivars evolved. This was probably the case for the "Bravía" cultivar. Its leaves had the lowest leaf blade length/width ratio (3.76).

Regarding fruit parameters, Socias i Company et al. [46] also observed that the almond parameters are highly variable depending on the cultivar. Moreover, they indicated that traditional cultivars may produce dry fruits of only 2–3 g. This was the case with the cultivars "Bravía" (2.72 g), "Cascafina" (3.17 g) and "De Convite" (3.86 g). It is important to note that the first cultivar showed small nuts (geometric mean diameter = 18.86 mm, surface area = 11.17 cm^2 and volume = 2.42 cm^3) and the other two had thin and soft shells, respectively. Sorkheh et al. [50] considered small fruit size as one of the most common obstacles to the use of the bitter cultivars for breeding. The weight registered by the almonds of the "Gorda José" cultivar was much higher (16.35 g). It might be said that the nuts of this traditional cultivar are among the heaviest (usual maximum weight of 20 g [46]). Other researchers who have also characterized "Marcona" almonds include Melhaoui et al. [24]. Their productive results were slightly lower than those recorded in this work (almond weight = 3.58 g, geometric diameter = 21.54 mm, volume = 5.28 cm^3). These results could have been due to the arid conditions of the cultivation area. With respect to the sphericity, all the nuts were more or less elongated (mean value = 71.24%). Aydin [51] also reported mean sphericity values of almond nuts close to 70%. The "Marcona" cultivar showed the roundest nuts (79%). This result agrees with that obtained by Melhaoui et al. [24] (79.24%). Muncharaz [52] also identified "Desmayo Largueta" nuts as elongated. Finally, an important number of cultivars showed hard or very hard stony shells. This is due to the fact that hard shells are preferred in the Mediterranean region since the cultivars then seem to be more adapted to non-irrigated conditions, and more resistant to depredation by birds and penetration by insect larvae damaging the kernel. Furthermore, the nuts can be stored for a long time, with reduced problems of becoming rancid or excessively dry, thus allowing their sale throughout the year [46]. Moreover, Aydin [51] also stated that the rupture strength of almond nuts decreased with increasing moisture content. Felipe [26], Mañas et al. [53], Muncharaz [52], Arquero et al. [28] and Batlle et al. [47] also reported that the dry fruits of "Marcona", "Desmayo Largueta" and "Pestañeta" were very hard.

With regard to the kernel, its size and weight are cultivar traits. In general, it can be said that the average weight and size of the almond kernels were quite high (1.36 g and 0.97 cm^3). "Marcelina" and "Gorda José" were the cultivars that registered the largest

(>1.10 cm^3) and heaviest (>1.94 g) kernels. Socias i Compañy et al. [46] indicated that the range of kernel weight varies between 0.5 to 1.5 g, those that exceed 1.2 g being preferred for most uses. They also commented that the general trend in the industry is the preference for large kernels in order to facilitate and cheapen the processes of cracking and blanching. Nonetheless, for some special confectioneries very small sizes are chosen, as well as those with definite shapes. For sugared almonds ("peladillas" or dragées) and for chocolate almonds, large kernels are selected, preferably round to reduce the layer of sugar or chocolate covering the kernel. For chocolate bars, small and particularly flat kernels are preferred to ensure that they are covered by the chocolate and that the thickness of the bar is maintained. In addition, there is a strong environmental and seasonal effect on size, including crop load, tree vigor, soil moisture and weather patterns [47]. With respect to kernel yield, the average value was around to 23%. Concretely, "Marcona" almonds had a shelling percentage of 22%. Identical results for nuts of this cultivar were recorded by Melhaoui et al. [24]. Muncharaz [52] also indicated that the shelling percentages for "Marcona" and "Desmayo Largueta" almonds ranged between 22–28% and 24–28%, respectively. With regard to the sphericity, the kernel values (average data = 59.10%) were lower than those recorded for the nuts. In this sense, Gradziel and Lampinen [54] indicated that very large-sized kernels often bring increased market prices but appear to be associated with lower final tree yields. Felipe [26], Muncharaz [52], Arquero et al. [28] and Melhaoui et al. [24] also defined the "Marcona" kernel as globular and rounded. In addition, a significant number of the almond cultivars showed low percentages of double kernels, among them, the "Marcona" nuts, with a double kernels ratio of 4%. Similar results (0–5%) were obtained for the fruits of this cultivar by Melhaoui et al. [24] and Arquero et al. [28]. However, there is a slight difference between the value recorded in this study and that reported by Muncharaz [52] for "Desmayo Largueta" almonds (14% and 2%, respectively). In this regard, Batlle et al. [47] have noted that, although double kernels are considered to be a negative trait, lowering crop value, organoleptic quality does not appear to be affected. In this sense, Grasselly and Crossa-Reynaud [55] have pointed out a possible dominance effect with strong seasonal differences. Low temperatures before blooming [56] or at flowering time [57,58] have been mentioned as promoting higher percentages of double kernels. In relation to taste, an important number of cultivars had sweet kernels. According to Batlle et al. [47], the main trend under almond domestication was selection of types with sweet, non-poisonous seeds. Most cultivated almonds produce sweet kernels, but some have a slightly bitter flavor. This was probably the case with the "Recia" cultivar. A mild bitter flavor can be detected in some cultivars and can be considered pleasing in some special confectioneries. It is also important to point out that the sweet or bitter taste depends on the cultivar, so all the fruits of each cultivar will be sweet or bitter, regardless of the genotype of the pollen parent. Finally, regarding all these agromorphological fruit parameters, Socias i Company et al. [59] have pointed out that, although the physical traits of the almond do not affect the sensory characteristics of the almond kernel, they are very important for the processing industry and must be taken into account in the ensemble of requirements for any cultivar, together with the production and consumer sectors.

With respect to chemical characterization of the almonds, there were important differences among cultivars. In general, almond kernels are a rich lipid source, essentially composed of mono- and polyunsaturated fatty acids. Concretely, the average value of lipid fractions for the almonds analyzed was 52.42%. This result is in agreement with that reported by Kodad [60] for Spanish almond cultivars (40–67% oil content of the kernel dry weight). As previously mentioned, "Peta", "Cascafina" and "Mollar de Arribes" were the cultivars that presented the highest levels of lipids in the kernels (>56%). This lipid content is a very important factor in the confectionery industry because higher oil contents result in less water absorption by the almond paste [61]. Kernels with a high percentage of oil can be used to produce nougat or to extract oil, which is used in the cosmetic and pharmaceutical industries. However, kernels with a low percentage of oil are required to produce almond milk [62], almond flour and several kinds of food because of their correlated high protein content [63].

Protein was the second major chemical component of the almond kernels after the lipid fraction. Its average content was 21.13%, with values above 23% in the cultivars "Bravía", "Molar de Chavés", "Portuguesa", "Picuda" and "Esperanza". This average result is in agreement with that reported by Kodad [60] for Spanish almond cultivars (15.7–21.1% protein content of the kernel dry weight). According to Alessandroni [61], protein content is inversely correlated with the lipid fraction and the ratio between these two components (R1: % lipids/% protein) is important in the preparation of some processed products because the absorption of water by almond paste is dependent on the balance between these two components. For marzipan production, a low index would be desired, whereas for nougat production, a high index would be preferred.

Dietary fiber was the third major chemical component of the almond kernels. Its average content was 15.10%. Ruggeri et al. [64] reported slightly lower dietary fiber contents than those registered in this study for Italian almond cultivars (11–14% dietary fiber content of the kernel dry weight). These contents have positively effects on colonic health and cholesterol levels [65].

The average content of carbohydrates was 3.89%. It can be observed that these results for kernel carbohydrates composition again agree with those reported by Kodad [60] for Spanish almond cultivars (1.8–7.6% carbohydrates content of the kernel fresh weight). In this sense, it is also important to point out that sugars, starch and some sugar alcohols are the only carbohydrate forms present in the almond kernels that can be digested, absorbed and metabolized by humans to provide a source of energy [60]. Moreover, soluble sugars, while present in relatively low amounts, are sufficient to make kernels sweet-tasting [66].

In addition, the average content of ash was 3.60%. The almond kernel is considered a good source of mineral elements, playing an important role in human health [60]. Regarding this, Romojaro et al. [67] and Saura-Calixto et al. [65] also reported low variability for this parameter in Spanish almond cultivars (3.05–3.45%).

In relation to energy, the high nutritive value of almond kernels arises mainly from their high lipid content, which constitutes an important source of calories [68]. The average caloric content of the kernels analyzed was 571.70 kcal per 100 g fresh weight of edible portion. A similar result (578 kcal/100 g FW) was reported by Gradziel [69].

Finally, the growth habits were highly variable among cultivars, ranging from very upright or upright (the "Agapitina" cultivar) to completely drooping (the "Desmayo Largueta" cultivar, among others). Socias i Company et al. [46], Mañas et al. [53], Felipe [26] and Muncharaz [52] have also observed that "Desmayo Largueta" has a fairly common drooping growth habit. Arquero et al. [28] classified the vegetative habits of "Marcona" and "Desmayo Largueta" cultivars as spreading. In this regard, Espada and Connell [70] have indicated that upright trees have better shaking efficiency than trees with roundish or hanging canopies. However, when the habit is very erect, the tree may have a canopy with insufficient spread. This makes orchard management difficult but may be useful in new developments of high density plantings. Generally an upright to spreading habit is preferable, as it facilitates formation of the tree and mechanization of the different operations [46]. Thus, the tree habit of modern European cultivars is generally spreading [47].

4.2. Statistical Analyses

Principal component analysis (PCA) results showed that more than 54% of the variability observed was explained by the first three components. These results agree with those obtained by Gouta et al. [71], Čolić et al. [72] and Khadivi-Khub and Etemadi-Khah [73] for almond cultivars of the Mediterranean area. PCA revealed that the first three components explained comparable values (from 34% to 57%) of the total variation, based on morphological and biochemical traits. Furthermore, Lansari et al. [74], Talhouk et al. [11], and Sorkheh et al. [50], who used a similar analysis to compare kernel, nut and leaf characters in different almond collections, found that the variables contributing to nut and kernel size were more important than leaf traits.

By analyzing the dendrogram, and taking into account all the results shown above, a series of synonymies among the almond cultivars can also be detected. Such is the case with "Pestaneta de Bragança" and "Pestañeta de Arribes", and with "Verdeal" and "Verdinal". Significant similarities were observed between the cultivars for these two cases of synonymies for all agromorphological and chemical traits. By contrast, a homonym was also detected: "Molar de Chavés" and "Mollar de Arribes". Despite their major agromorphological and chemical differences, both names are often used interchangeably by some growers.

The results of the PCA and cluster analysis showed that agromorphological and chemical analysis can provide reliable information on the variability in almond genotypes. In correspondence with our findings, Ledbetter and Shonnard [75], Talhouk et al. [11], Sorkheh et al. [76], Zeinalabedini et al. [77] and Khadivi-Khub and Etemadi-Khah [73] have also shown that morphological evaluation is an efficient tool for characterization of almond germplasm and for species distinction. The overall analysis of all traits illustrates a wide diversity that may have important implications for management of genetic resources.

5. Conclusions

Twenty-four traditional almond cultivars grown in the central-western Iberian Peninsula, all of them clearly in decline or close to extinction, were characterized from the agromorphological and chemical points of view. Some of the cultivars showed distinctive and interesting agronomical characteristics from a commercial point of view, such as high yields and high quality fruit. This was the case for the almond cultivars called "Gorda José" and "Marcelina". Their fruits were quite heavy (nuts: >9.1 g; kernels: >1.9 g), with very low percentages of double kernels (<3%) and high nutritional value (>50% lipids; >21% proteins). The results of PCA and cluster analysis showed that agromorphological and chemical analysis can provide reliable information on the variability in almond genotypes. Two synonymies ("Pestaneta de Bragança" and "Pestañeta de Arribes"; "Verdeal" and "Verdinal") and one homonym ("Molar de Chavés" and "Mollar de Arribes") were also detected. This work constitutes an important step in the conservation of genetic almond resources in the central-western Iberian Peninsula.

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