Kuwait J. Sci. **46 (3)** pp. 103-113, 2019

Morphological, mechanical and sensory properties of almond (Prunus dulcis L.) and pistachio (Pistacia vera L.) cultivars grown in Spain

Adrián Rabadán, Manuel Álvarez-Ortí, José E. Pardo*
Escuela Técnica Superior de Ingenieros Agrónomos y de Montes, Universidad de Castilla-La Mancha, Campus Universitario s/n, Albacete, Spain
**Corresponding author: adrian.rabadan@uclm.es,*

Abstract

Most research that investigates the differences of the characteristics of kernels from different almond and pistachio genotypes has focused on chemical characteristics, paying little attention to physical parameters. In this study, the analysis morphological, mechanical and sensory properties using technical procedures and consumer preferences was performed for almond and pistachio genotypes grown on the same plot. Results show that physical parameters are useful for cultivar discrimination even when the nuts are grown in the same conditions. In almonds, significant differences were reported which focused on crucial parameters of length (19.40 – 25.80 mm), width (11.60 - 16.60 mm) and hardness (47.90 – 72.47 N). In pistachios, significant differences were also reported, with the Kerman cultivar standing out from the rest due to higher values for length (19.00 mm), width (10.10 mm) and weight (0.8 g). Napoletana was the pistachio cultivar with the highest value for hardness (53.84 N), followed by Kerman (46.52 N). In regards to sensory analysis, consumers showed significant preferences in overall visual acceptance and taste for some almond (Vairo, Belona and Penta) and pistachio cultivars (Larnaka, Aegina and Sirora). For almonds, kernel width and color parameter b* inside the kernel can be correlated with higher consumer valuations for overall visual acceptance and taste, respectively. In pistachios, no correlation of physical parameters in regards to consumer preference was reported.

Keywords: Consumer preferences; genotypes; morphological properties; nuts; Spain

1. Introduction

The quality of nuts has been primarily based on their nutritional composition, mainly their fatty acid profile and bioactive compounds (Chen *et al*., 2006; Rabadán *et al*., 2017a; Roncero *et al*., 2016a; Yada *et al*., 2011). Almonds and pistachios show a similar fatty acid profile dominated by unsaturated fatty acids which are mainly oleic and linoleic (Catalán *et al*., 2017; Roncero *et al*., 2016b), and a wide range of health promoting components such as fiber, tocopherols, minerals and phytonutrients (Kamil & Chen, 2012). Some studies have analyzed the chemical differences of different cultivars (Rabadán *et al*., 2017b; Roncero *et al*., 2016b), while less attention has been paid to physical differences among cultivars (Contador *et al*., 2015; Rabadán *et al*., 2017c). Yet, these differences should also be considered as quality-related parameters.

Physical parameters in nuts have effects on consumer preference and industrial processes (Rabadán *et al*., 2017d; Tsantili *et al*., 2010). They can be evaluated by using technical procedures or sensory analysis (Aktas *et al*., 2007; Tsantili *et al*., 2010). By using technical procedures, significant differences have been reported in kernel size, color, crispness and firmness in kernels from different pistachio cultivars (Kader *et al*., 1982; Tsantili *et al*., 2010). Differences in color related to the cultivar have been also found in pistachio byproducts (Rabadán *et al*., 2017d). In almonds, the mechanical properties of the shell and kernel have been widely studied using technical procedures (Aktas *et al*., 2007; Aydin, 2003; Ledbetter and Palmquist, 2006).

Regarding sensory analysis of almonds and pistachios, most of the studies have analyzed processing parameter effects, mainly roasting time and temperature, roasting system and salting on sensory characteristics (Milczarek *et al*., 2014; Penci *et al*., 2013; Rabadán *et al*., 2017c; Shakerardekani *et al*., 2011; Vázquez-Araújo *et al*., 2009). In pistachios, the aroma after roasting has been identified as a determinant for consumer acceptance (Aceña *et al*., 2010), while storage at different temperatures, which increases roasting flavor, did not significantly increase overall flavor intensity (Kader *et al*., 1982). Roasting almonds decreased sweetness but increased bitterness and grittiness (Gou *et al*., 2000).

Sensory characteristics of almonds and pistachios have been mainly described the roasted kernel (Mokhtarian *et al*., 2017; Penci *et al*., 2013; Shakerardekani *et al*., 2011; Varela *et al*., 2006; Varela *et al*., 2008; Vázquez-Araújo *et al*., 2009), while there has been less focus on fresh almonds (Contador *et al*., 2015) and pistachios (Kader *et al*., 1982). Nut flavor, texture, color, and appearance are modified with roasting, resulting in a completely different product (Nikzadeh and Sedaghat, 2008; Shakerardekani *et al*., 2011). Ergo, the results of the sensory analysis of roasted almonds and pistachios should not be directly assumed as proportional to those obtained for fresh nuts. This is because the appearance and evolution of the main components of sensory odor and flavor aromas with roasting also differ depending on the genotype (Vázquez-Araújo *et al*., 2009).

Some sensory studies have investigated the descriptive characterization and the sensory evaluation of nuts by trained and semi-trained judges (Contador *et al*., 2015; Kader *et al*., 1982; Lynch *et al*., 2016; Nikzadeh and Sedaghat, 2008; Vázquez-Araújo *et al*., 2009). Few studies evaluate consumer preferences. In almonds, trained judges have reported differences in chief physical parameters of kernels from different cultivars, including flavor intensity, color, roughness, crispness, crunchiness and hardness (Contador *et al*., 2015). In pistachios, trained judges did not find significant differences in the flavor of four cultivars grown in the same orchard (Kader *et al*., 1982). However, Tsantili *et al*. (2010a) carried out a later study performed by minimally trained panelist, which considered a larger number of cultivars. The subjects reported significant differences in flavors. In the same study, differences in visual acceptance of kernels were not reported.

This research evalutated the usefulness of physical parameters to discriminate almond and pistachio kernels obtained from different genotypes. Differences regarding consumer acceptance of kernels from these different cultivars were also reported. The correlation of the results of the physical analysis and consumer perception provide useful information about the consumer preferences.

2. Materials and methods

2.1 Plant material

Almonds and pistachios were collected in 2016 in the south of Spain from experimental orchards. These experimental orchards aim to evaluate the response of different cultivars for nut production purposes in the south of Spain. By analyzing cultivars grown on the same plot, the effect of environmental and land management practices on cultivar characteristics can be controlled (Pervez *et al*., 2017; Rabadan *et al*., 2017d; Temizel *et al*., 2015). Ten different almond cultivars (Antoñeta, Ayles, Belona, Ferraduel, Ferragnes, Guara, Marcona, Penta, Tardona and Vairo) and ten different pistachio cultivars (Aegina, Alpina, Avidon, Kerman, Larnaka, Mateur, Napoletana, Ouleimy, Sfax and Sirora) were collected. All almond and all pistachio kernels were collected from the same six-hectare orchard. Sample collection was made according to Rabadán *et al*. (2017a). One kilogram of kernels was collected randomly from every one of the three trees analyzed within each cultivar. Nuts were picked at the most appropriate harvest date for each cultivar.

2.2 Almond and pistachio characterization

2.2.1 Physical properties

Kernel length, width and weight were recorded on sub-samples of 10 kernels for each almond and pistachio cultivar.

The color of almond and pistachio kernels was measured in the kernel peel and inside the kernel. The color of the kernels was measured by reflection in three zones for ten different kernels for each cultivar using a Minolta CR-200 colorimeter (Minolta Camera Co., Ltd., Osaka, Japan). As almonds show more homogeneous color, color was measured in random zones, while for pistachios, the color in the darkest zone (pink-purple to black area) was measured in the kernel membrane. The tristimulus values obtained were used to calculate the CIELAB chromatic coordinates a* (red–green component) and b* (yellow–blue component) (CIE, 1986).

To evaluate the texture of almonds and pistachios, 10 kernels of each variety were analyzed. The cutting force was measured using a TA-XT Plus texture analyzer (Stable Micro Systems, Godalming, UK) using a procedure similarly to Penci *et al*., (2013). The kernels were cut perpendicularly to their major axis with a Warner Bratzler blade with a rectangular slot blade at a constant velocity of 2 mm s^{-1}

2.2.2 Sensory analysis

An affective test was used to evaluate the acceptance of consumers. Testing was carried out in the sensory laboratory of the university center. In the affective test, almonds and pistachio kernels were randomly labelled and 102 consumer-type panelists were asked to evaluate overall visual acceptance and taste of nuts from every single cultivar. Each hedonic description was assigned a nine-point scale (−4: dislike extremely, 0: neither like nor dislike, 4: like extremely).

2.3 Statistical analysis

Physical parameters and sensory attributes were processed using variance analysis (ANOVA). Differences between means were compared using a Duncan test with a 95% significant level ($p < 0.05$). Correlation analyses were performed using the Pearson´s test. A multivariate statistical analysis with variables that had previously shown significant differences between cultivars was performed using principal component analysis (PCA). All statistical analyses were carried out using the SPSS program, release 23.0 for Windows.

3. Results and discussion

3.1 Physical parameters

3.1.1 Almonds

All physical parameters of almond kernels considered showed significant differences between cultivars (Duncan test, $p < 0.01$) (Table 1). Lengths ranged between 19.40 to 25.80 mm, widths were from 11.60 to 16.60, and weights were between 0.72 to 1.63 g. Figure 1 shows the principal component analysis of almond cultivar kernels. According to color data, the popular Spanish cultivar Marcona showed some of the lowest values for parameter a* (almond peel) and parameter b* (inside the kernel). Some cultivars show similar values for the analyzed parameters. This is the case of Ferraduel, Antoñeta, Vairo, Guara and Penta. These five cultivars show average size and weight, with similar and average values for the colors inside and outside the kernel.

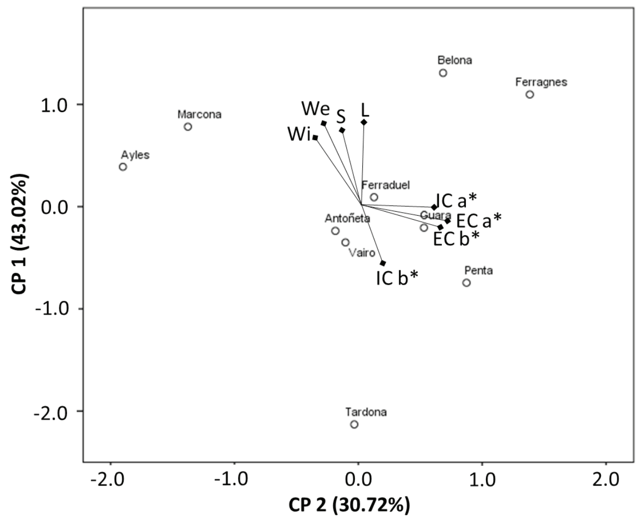

Fig. 1. Principal component analysis of physical parameters in kernels from different almond cultivars. L: kernel length; S: hardness; We: kernel weight; Wi: kernel width; ICa*: internal color a* parameter; ICb*: internal color b* parameter; ECa*: external color a* parameter; ECb*: external color b* parameter

As expected, strong correlations exist among the parameters for length, width, weight and hardness on almond kernels (Table 2). Those kernels that are longer are also wider, heavier and, as a result, harder. Belona and Ferragnes have the longest kernels, while Marcona and Ayles the widest. As for length and width, cultivars

Table 1. Physical parameters of almond kernels from different cultivars

Cultivar	Length (mm)	Width (mm)	Weight (g)	ECa	ECb	ICa	ICb	Hardness (N)
Antoñeta	22.60^{d}	14.80^{b}	1.20^{de}	17.61^{ab}	35.25^{a}	-0.23^{c}	12.12^{bcde}	61.15^{abc}
Ayles	24.70^{b}	16.60^{a}	1.57^{ab}	14.81^{c}	29.26^{c}	-0.23^{c}	12.06^{bcde}	64.16^{abc}
Belona	24.40^{bc}	16.40^{a}	1.45^{c}	18.68^{a}	35.69^{a}	-0.15^{c}	11.55^{de}	72.47^{a}
Ferraduel	24.5^{bc}	14.40^{b}	1.31^{d}	18.47^{ab}	34.20^{a}	-0.20^{c}	11.59^{de}	53.44^{cd}
Ferragnes	25.80^{a}	14.60^{b}	1.48^{bc}	18.46^{ab}	34.91^{a}	0.28^{a}	11.74^{cde}	60.60^{bc}
Guara	23.60^{bcd}	14.50^{b}	1.26^{de}	18.17^{ab}	35.59^{a}	-0.02^{bc}	12.66^{abc}	54.07^{cd}
Marcona	23.90^{bc}	16.60^{a}	1.63^{a}	14.62^{c}	31.31^{bc}	-0.07^{bc}	11.10^{e}	66.74^{ab}
Penta	23.40^{cd}	12.80^{c}	1.05^{f}	17.88^{ab}	35.30^{a}	0.22^{ab}	13.53^{a}	55.37^{bcd}
Tardona	19.40^{e}	11.60^{d}	0.72^{g}	18.21^{ab}	35.29^{a}	0.03^{abc}	12.33^{bcd}	47.90^{e}
Vairo	24.60^{b}	15.00^{b}	1.17^{e}	17.33^{b}	33.93^{ab}	-0.11^{c}	12.89^{ab}	52.67^{cd}
P	***	***	***	***	***	***	***	***

ECa: external color, parameter a*; ECb: external color, parameter b*; ICa: internal color, parameter a*; ICb: internal color, parameter b*. Numbers are means. Means in a column not sharing the same letter are significantly different by Duncan test ($p < 0.05$). **Significant at $p < 0.05$. ***Significant at $p < 0.01$.

Ferragnes, Tardona, Marcona and Penta can be completely discriminated. As the weight of almond kernels is more intensively correlated with the width than with the length, Marcona and Ayles are also the cultivars with the heaviest kernels. Between these four largest cultivars (Belona, Ferragnes, Marcona and Ayles), there are no significant differences in the cutting force needed to cut the kernel (hardness). Contador *et al*. (2015) reported that Marcona produce one of the hardest cultivars. Although, this study found that the values of Belona are even higher.

Color differs significantly between almond kernels, both in the peel and in the inside of the kernel. On the peel, a* and b* parameters are strongly correlated (0.677, $p < 0.01$). Belona is the cultivar that shows the highest values for the parameters a* and b*, while Ayles and Marcona show the lowest values for the color parameters. In general, results agree with those obtained for other cultivars of commercial interest, such as Nonpareil (Jeong *et al*., 2017). Peel color in almonds can be affected irrigation factors (Conelli *et al*., 2010). However, when grown on the same plot, kernels of some of the cultivars can be differentiated by their external color.

Table 2. Correlations between almond kernel physical parameters

	Length	Width	Weight	ECa	ECb	ICa	ICb	Hardness
Length	1	.605**	.734**	-.150	-.227*	.041	-.125	.128
Width		1	.874**	-.386**	-.339**	-.222*	-.314**	.362**
Weight			1	-.397**	-.362**	-.086	-.329**	.344**
CEa				1	.677**	.109	.185	-.092
CEb					1	.160	.245*	.005
CIa						1	.084	-.076
CIb							1	-.218*
Hardness								1

ECa: external color, parameter a*; ECb: external color, parameter b*; ICa: internal color, parameter a*; ICb: internal color, parameter b*. *Significant at $p < 0.05$. **Significant at $p < 0.01$.

The parameter b* of kernel peel is correlated with the same parameter for the intern color of the kernel (0.245, $p < 0.05$). This means that the yellower the kernel peel is, the yellower the kernel is on the inside. Penta, Vairo and Guara are the cultivars with the higher values for b* on the inside, while Marcona shows lower values. Values for a* parameter inside the kernel are close to zero in all cultivars, with Penta showing the highest average value (0.28) and Antoñeta and Ayles (-0.23) showing the lowest value.

The color parameter b* inside the almond kernel is negatively correlated with the strength (-0.218, $p < 0.05$). This means that the yellower the kernels are inside, the less hard they are. However, the strength required to cut the kernel is also strongly correlated with the width (0.344, $p < 0.01$) and the weight (0.362, $p < 0.01$) of the kernel.

3.1.2 Pistachios

For pistachio kernels, all parameters showed significant differences with the exception of the color parameter b* measured in the interior of the kernel (Table 3). Figure 2 shows that the main differences in pistachio cultivars are related to the size, weight and strength (CP1), but also to color parameters (CP2). In accordance to previous studies, the Kerman cultivar produces the largest kernels (Tsantili *et al*., 2010). Only length, width or weight are enough to differentiate Kerman kernels from the rest of the cultivars even when pistachios are grown in the same orchard, and management and environmental effects are controlled. For pistachios, the correlation of kernel weight with size is higher with the length (0.825, $p < 0.01$) than with the width (0.739, $p < 0.01$).

The peel color is also useful for cultivar discrimination. The higher values of a* and the lower values of b* correspond to the kernels with the stronger pink to purple

Table 3. Physical parameters of pistachio kernels from different cultivars

Cultivar	Length (mm)	Width (mm)	Weight (g)	ECa	ECb	ICa	ICb	Hardness (N)
Aegina	16.80^{bcd}	7.80^{e}	0.60^{c}	66.31^{ab}	14.67^{cde}	-0.30^{a}	9.35	33.51^{de}
Alpina	16.20^{de}	7.90^{e}	0.54^{d}	61.65^{b}	14.03^{cde}	-0.28^{a}	9.41	31.73^{e}
Avidon	16.40^{cd}	7.90^{e}	0.60^{c}	77.25^{a}	15.34^{cd}	-1.26^{ab}	15.12	28.84^{e}
Kerman	19.00^{a}	10.10^{a}	0.80^{a}	65.58^{ab}	19.20^{ab}	-2.13^{ab}	6.93	46.52^{ab}
Larnaka	17.10^{bc}	8.80^{bcd}	0.63^{c}	70.73^{ab}	15.04^{cde}	-7.72^{c}	9.58	45.79^{abc}
Mateur	16.90^{bcd}	8.50^{cde}	0.63^{bc}	75.06^{ab}	17.10^{bc}	1.63^{a}	8.54	42.17^{bcd}
Napoletana	16.70^{bcd}	7.80^{e}	0.52^{d}	44.39^{c}	6.26^{f}	-1.20^{ab}	7.50	53.84^{a}
Ouleimy	17.40^{b}	9.40^{b}	0.69^{b}	62.66^{ab}	12.04^{de}	-5.39^{bc}	9.32	44.42^{abc}
Sfax	15.50^{e}	8.20^{de}	0.50^{d}	74.72^{ab}	20.91^{a}	0.41^{a}	5.24	41.81^{bcd}
Sirora	17.30^{b}	9.00^{bc}	0.65^{bc}	71.50^{ab}	11.65^{e}	-0.13^{a}	4.42	36.29^{cde}
P	***	***	***	***	***	***	NS	***

ECa: external color, parameter a*; ECb: external color, parameter b*; ICa: internal color, parameter a*; ICb: internal color, parameter b*. Numbers are means. Means in a column not sharing the same letter are significantly different by Duncan test ($p < 0.05$). **Significant at $p < 0.05$. ***Significant at $p < 0.01$.

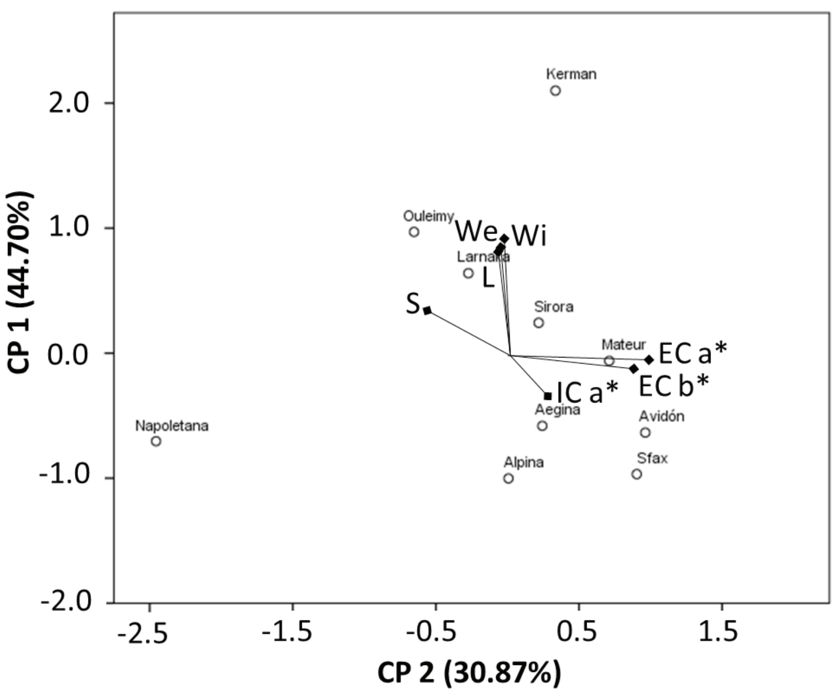

Fig. 2. Principal component analysis of physical parameters in kernels from different pistachio cultivars. L: kernel length; S: hardness; We: kernel weight; Wi: kernel width; ICa*: internal color a* parameter; ECa*: external color a* parameter; ECb*: external color b* parameter

colors. This is the case of Napoletana and Sirora kernels. On the other hand, the cultivars with the less purple colors on their kernel membrane are Kerman and Sfax.

On the inside, pistachio kernels show bright green to yellow color. Cultivars with the lower values for a* measured inside the kernel are those with greener colors. This is the case of Larnaka and Ouleimy. Cultivars Mateur and Sfax have the kernels with less green color inside. Cultivar Avidon shows that b* values are especially higher, which indicates yellower colors inside the kernel.

As reported by Kader *et al*. (1982), Kerman kernels show high resistance to cutting. Yet when considering a larger number of cultivars, no significant differences were found with Napoletana and Ouleimy. In fact, Napoletana is the hardest cultivar and, at the same time, the cultivar with the lower values for external color parameters a* and b*, indicating greener colors. As had also been observed in the almond kernels, the hardness of a pistachio kernel is negatively correlated with the measure of parameter b* on the inside of the nut (-0.227, $p < 0.05$) (Table 4). As every cultivar was picked up at the most appropriate harvest date, these differences in color and hardness cannot be considered the result of different maturity stages. In pistachios, none of the size parameters considered showed correlation with kernel hardness.

3.2. Consumer preference

3.2.1. Almonds

Significant differences appear in the valuation that consumers do on visual acceptance and taste of almond kernels (Duncan Test, $p < 0.01$) (Table 5). All cultivars receive positive scores for kernel visual acceptance and taste (average ratings above 0).

Belona and Vairo are the cultivars that obtain the highest scores for visual acceptance,, although significant differences were not found with other cultivars (Marcona, Antoñeta and Ferragnes). Belona and Vairo show some physical similarities that must be analyzed to understand the characteristics that may influence consumer preference. Both produce kernels slightly wider than the average, while their values of weight and external color parameters a* and b* are average.

In terms of taste, the cultivars that consumers valued more positively are Penta and Vairo (although no significant differences were found with Tardona). Penta and Vairo kernels have some common physical characteristics, as they both have higher internal values for b* (yellower) and medium hardness. Although the Spanish cultivar Marcona is widely known for its high sensory quality, Marcona kernels received low scores in taste. Yet, this result is in agreement with outcomes from

Table 4. Correlations between pistachio kernel physical parameters

	Length	Width	Weight	ECa	ECb	ICa	ICb	Hardness
Length	1	$.614^{**}$	$.825^{**}$	-.130	-.103	-.113	.011	.118
Width		1	$.739^{**}$	.069	.173	-.075	-.148	.118
Weight			1	.033	.085	-.072	.018	.013
CEa				1	$.555^{**}$	.180	-.044	-.091
CEb					1	.144	-.020	-.098
CIa						1	$-.655^{**}$	.008
CIb							1	$-.227^{*}$
Hardness								1

ECa: external color, parameter a*; EC: external color, parameter b*; ICa: internal color, parameter a*; ICb: internal color, parameter b*. *Significant at $p < 0.05$. **Significant at $p < 0.01$.

previous studies performed on fresh Marcona almonds (Contador *et al*., 2015). The consumer panelists gave the lowest scores to Ayles and Ferraduel kernels.

3.2.2. Pistachios

Significant differences were found in the consumer scores for physical aspect and taste of different pistachio cultivars, but the differences where higher regarding the physical parameters than regarding the kernel taste (Table 5). The results are opposite to those obtained by a study developed using minimally trained judges (Tsantili *et al*., 2010). That study found more significant differences in overall flavor than in visual acceptance. However, as the analyzed cultivars are different, and due to the high variability reported in the physicochemical characteristics of pistachio cultivars (Rabadán *et al*., 2017c; Rabadán *et al*., 2017d), different results can be expected depending on the considered cultivars.

Consumers positively valued the visual acceptance and taste of all pistachio cultivars with the exception of the visual acceptance of *Sfax* kernels. The negative valuation of *Sfax* kernels can be the result of the lower values of color parameter b* in the kernel peel combined with their smaller size. Cultivars *Aegina* and *Larnaka* received the higher valuation regarding physical aspect, whereas no significant differences were found with *Kerman* kernels. If the physical similarities of *Aegina* and *Larnaka* are considered, it can be observed that they both have a medium size and weight, medium values for a* parameter and medium to low values of b* parameter on the kernel peel.

Table 5. Sensory attributes of almond and pistachio kernels

Almonds			**Pistachios**		
Cultivar	Visual acceptance	Taste	Cultivar	Visual acceptance	Taste
Antoñeta	$2.03^{ab} \pm 1.10$	$1.30^{bcd} \pm 1.62$	*Aegina*	$2.47^{ab} \pm 1.01$	$1.63^{ab} \pm 1.25$
Ayles	$1.47^{bcd} \pm 1.36$	$0.30^{e} \pm 2.04$	*Alpina*	$1.67^{c} \pm 1.37$	$1.70^{ab} \pm 1.06$
Belona	$2.43^{a} \pm 1.22$	$1.47^{bc} \pm 1.55$	*Avidon*	$0.87^{d} \pm 1.36$	$0.70^{c} \pm 1.68$
Guara	$1.47^{bcd} \pm 1.28$	$0.87^{cde} \pm 2.01$	*Kerman*	$1.97^{abc} \pm 1.52$	$1.03^{abc} \pm 1.30$
Ferraduel	$1.00^{d} \pm 1.58$	$0.37^{de} \pm 1.77$	*Larnaka*	$2.60^{a} \pm 1.40$	$1.53^{abc} \pm 1.36$
Ferragnes	$1.93^{abc} \pm 1.36$	$0.93^{cde} \pm 1.57$	*Mateur*	$1.77^{bc} \pm 0.97$	$1.33^{abc} \pm 1.56$
Marcona	$2.10^{ab} \pm 1.49$	$0.80^{cde} \pm 2.12$	*Napoletana*	$0.43^{de} \pm 1.72$	$0.79^{c} \pm 1.45$
Penta	$1.20^{cd} \pm 1.54$	$2.40^{a} \pm 1.16$	*Ouleimy*	$0.57^{de} \pm 1.77$	$1.00^{bc} \pm 1.76$
Tardona	$0.80^{d} \pm 1.88$	$1.67^{abc} \pm 1.47$	*Sfax*	$-0.10^{e} \pm 1.52$	$1.50^{abc} \pm 1.46$
Vayro	$2.33^{a} \pm 1.15$	$2.03^{ab} \pm 1.06$	*Sirora*	$1.77^{bc} \pm 0.94$	$1.87^{a} \pm 1.33$
P	***	***	P	***	**

The evaluation guidelines considered a continuous scale, ranging from -4 (lowest score) to 4 (highest score). Numbers are means of total scores. Means in a column not sharing the same letter are significantly different by Duncan test ($p < 0.05$). **Significant at $p < 0.05$. ***Significant at $p < 0.01$.

Regarding taste, cultivars *Alpina* and *Sirora* received the highest scores from consumers, but significant differences with most of the cultivars were not identified. These two cultivars that received the highest scores showed high values for a* parameter inside the kernel (less green color) and low hardness.

3.3 Matching physical traits with consumer preference

3.3.1 Almonds

When it came to outward appearance, consumers more positively valued the cultivars with wider kernels that were also the hardest (Table 6). However, it should not be considered that consumers prefer harder almonds, as this is only the result of the high correlation between width and hardness (0.820, $p < 0.01$).

Table 6. Correlation of physical parameters and sensory evaluation by consumer type panelist of almond and pistachio kernels from different cultivars

	Length	Width	Weight	ECa	ECb	ICa	ICb	Hardness
Almonds								
Visual acceptance	.509	.696*	.540	-.156	-.041	-.181	-.284	.667*
Taste	-.344	-.512	-.635*	.355	.535	.422	.687*	-.277
Pistachios	Length	Width	Weight	ECa	ECb	ICa	ICb	Hardness
Visual acceptance	.453	.189	.421	.189	.099	-.191	.070	-.206
Taste	-.186	-.051	-.151	.298	.205	.167	-.495	-.337

ECa: external color, parameter a*; ECb: external color, parameter b*; ICa: internal color, parameter a*; ICb: internal color, parameter b*. *Significant at $p < 0.05$. **Significant at $p < 0.01$.

An analysis of the correlations of taste punctuations and physical parameters shows that consumers give higher ratings for taste to those cultivars which produce the lighter kernels. The relationship in the breakdown of the almond kernel and higher consumers acceptability reported in a previous study (Varela *et al*., 2008) was not found to correlate to hardness and taste (-0.277). On the other hand, cultivars with kernels that are more yellow on the inside (higher values of b*) got more positive scores in taste.

3.3.2 Pistachios

Previously, some studies have shown that sensory evaluations of some parameters could be explained by instrumental measurements (Moghaddam *et al*., 2016). Although significant correlations are not shown for pistachios in this study, some tendencies can be observed (Table 6). Regarding the external appearance, the highest values are obtained by the cultivars with the longest and heaviest kernels. The less homogenous color of pistachio kernels hampers the measurement of kernel color, especially the kernel membrane color. Consumers did not show a preference for any particular kernel membrane color.

The taste is partially correlated with the interior color parameter b*. The favored cultivars are those that have a less yellowish color on the inside. However, no significant correlations appear relating color or hardness to consumer preference.

4. Conclusions

Physical parameters on almond and pistachio cultivars, related to kernel size, weight, color and hardness are useful for cultivar discrimination. Additionally, significant differences were reported in the overall visual acceptance and taste of kernels from different cultivars. The almond cultivar *Aegina* and pistachio cultivar *Vairo* received higher valuations than some widely recognized cultivars. These results show that it is important to consider consumer preferences in cultivar selection and breeding, beyond traditional factors such as crop yield or industry preferences.

Correlations between physical parameters and consumer valuations can be the first step in the study of the formation of consumer preferences. Our results prove that for almonds, the consumers prefer wider almonds, while taste is correlated with the weight (lighter almonds) and higher values of b* parameter inside the kernel (*yellower* colors). In pistachios, although some tendencies can be observed, significant correlations between physical parameters and consumer preferences were not found.

ACKNOWLEDGEMENTS

This research has been partially supported by a grant from the University of Castilla-La Mancha (Ref. [2015/4062]). The authors declare no conflicts of interest.

References

Aceña, L., Vera, L., Guasch, J., Busto, O. & Mestres, M. (2010). Comparative study of two extraction techniques to obtain representative aroma extracts for being analysed by gas chromatography-olfactometry: Application to roasted pistachio aroma. Journal of Chromatography A, **1217**(49): 7781-7787.

Aktas, T., Polat, R. & Atay, U. (2007). Comparison of mechanical properties of some selected almond cultivars with hard and soft shell under compression loading. Journal of Food Process Engineering, **30** (6): 773-789.

Aydin, C. (2003). Physical properties of almond nut and kernel. Journal of Food Engineering, **60** (3): 315-320.

Catalán, L., Alvarez-Ortí, M., Pardo-Giménez, A., Gómez, R., Rabadán, A. & Pardo, J.E. (2017). Pistachio oil: A review on its chemical composition, extraction systems, and uses. European Journal of Lipid Science and Technology, **119** (5).

Chen, C.Y., Lapsley, K. & Blumberg, J. (2006). A nutrition and health perspective on almonds. Journal of the Science of Food and Agriculture, **86** (14): 2245-2250.

CIE (1986). Colorimetry, 2nd ed. Central Bureau of the Commission Internationale de L´Eclairage, Austria.

Conelli, G., Cornacchia, R., Amodio, M.L. & Tortosa, P.A.N. (2010). Effect of irrigation water reduction strategies on quality at harvest and during storage of in-shell almonds. Acta horticulturae, **877**: 251-259.

Contador, L., Robles, B., Shinya, P., Medel, M., Pinto, C., Reginato, G. & Infante, R. (2015). Characterization of texture attributes of raw almond using a trained sensory panel. Fruits, **70** (4): 231-237.

Gou, P., Diaz, I., Guerrero, L., Valero, A., Arnau, J. & Romero, A. (2000). Physico-chemical and sensory property changes in almonds of Desmayo Largueta variety during toasting. Food Science and Technology International, **6** (1): 1-7.

Jeong S.G., Baik, O.D. & Kang, D.H. (2017). Evaluation of radio-frequency heating in controlling Salmonella enterica in raw shelled almonds. International Journal of Food Microbiology, **254**: 54-61.

Kader, A.A., Heintz, C.M., Labavitch, J.M. & Rae, H.L. (1982). Studies related to the descripticon and evaluation of pistachio nut quality. Journal of the American Society for Horticultural Science, **107**: 812-816.

Kamil, A. & Chen, C.Y.O. (2012). Health benefits of almonds beyond cholesterol reduction. Journal of Agricultural and Food Chemistry, **60** (27): 6694-6702.

Ledbetter, C.A. & Palmquist, D.E. (2006). Comparing physical measures and mechanical cracking products of 'Nonpareil' almond (Prunus dulcis [Mill.] D.A. Webb.) with two advanced breeding selections. Journal of Food Engineering, **76** (2): 232-237.

Lynch, C., Koppel, K. & Reid, W. (2016). Sensory profiles and seasonal variation of black walnut cultivars. Journal of Food Science, **81** (3): S719-S727.

Milczarek, R.R., Avena-Bustillos, R.J., Peretto, G. &McHugh, T.H. (2014). Optimization of microwave roasting of almond (Prunus dulcis). Journal of Food Processing and Preservation, **38** (3): 912-923.

Mohammadi Moghaddam, T., Razavi, S.M.A., Taghizadeh, M. & Sazgarnia, A. (2016). Sensory and instrumental texture assessment of roasted pistachio nut/ kernel by partial least square (PLS) regression analysis: Effect of roasting conditions. Journal of Food Science and Technology, **53** (1): 370-380.

Mokhtarian, M., Tavakolipour, H. & Kalbasi Ashtari, A. (2017). Effects of solar drying along with air recycling system on physicochemical and sensory properties of dehydrated pistachio nuts. LWT-Food Science and Technology, **75**: 202-209.

Nikzadeh, V. & Sedaghat, N. (2008). Physical and sensory changes in pistachio nuts as affected by roasting temperature and storage. American-Eurasian Journal of Agricultural & Environmental Sciences, **4** (4): 478-483.

Penci, M.C., Martinez, M.L., Fabani, M.P., Feresin, G.E., Tapia, A., Ighani, M., Ribotta, P.D. & Wunderlin,

D.A. (2013). Matching Changes in Sensory Evaluation with Physical and Chemical Parameters: A Case Study: Argentinean Pistachio Nuts (Pistachia vera L. cv Kerman). Food and Bioprocess Technology, **6** (12): 3305-3316.

Pervez, K., Ullah, F., Mehmood, S. & Khattak, A. (2017). Effect of Moringa oleifera Lam. leaf aqueous extract on growth attributes and cell wall bound phenolics accumulation in maize (Zea mays L.) under drought stress. Kuwait Journal of Science, **44** (4): 110-118.

Rabadán, A., Álvarez-Ortí, M., Gómez, R., de Miguel, C. & Pardo, J.E. (2017a). Influence of genotype and crop year in the chemometrics of almond and pistachio oils. Journal of the Science of Food and Agriculture, **98** (6): 2402-2410.

Rabadán, A., Álvarez-Ortí, M., Gómez, R., Pardo-Giménez, A. & Pardo, J.E. (2017b). Suitability of Spanish almond cultivars for the industrial production of almond oil and defatted flour. Scientia Horticulturae, **225**: 539-546.

Rabadán, A., Álvarez-Ortí, M., Pardo, J.E., Gómez, R., Pardo-Giménez, A. & Olmeda, M. (2017c). A comprehensive approach to pistachio oil production. British Food Journal, **119** (4): 921-933.

Rabadán, A., Pardo, J.E., Gómez, R., Alvarruiz, A. & Álvarez-Ortí, M. (2017d). Usefulness of physical parameters for pistachio cultivar differentiation. Scientia Horticulturae, **222**: 7-11.

Roncero, J.M., Álvarez-Ortí, M., Pardo-Giménez, A., Gómez, R., Rabadán, A. & Pardo, J.E. (2016a). Almond virgin oil: Parameters of regulated physicochemical quality and stability. Rivista Italiana delle Sostanze Grasse, **93**: 237-243.

Roncero, J.M., Álvarez-Ortí, M., Pardo-Giménez, A., Gómez, R., Rabadán, A. & Pardo, J.E. (2016b). Virgin almond oil: Extraction methods and composition. Grasas y Aceites, **67** (3).

Shakerardekani, A., Karim, R., Mohd Ghazali, H. & Chin, N.L. (2011). Effect of roasting conditions on hardness, moisture content and colour of pistachio kernels. International Food Research Journal, **18** (2): 723-729.

Tsantili, E., Takidelli, C., Christopoulos, M.V., Lambrinea, E., Rouskas, D. & Roussos, P.A. (2010). Physical, compositional and sensory differences in nuts among pistachio (Pistachia vera L.) varieties. Scientia Horticulturae, **125**: 562-568.

Temizel, K.E. (2015). Estimation of the phenolics content of St. John's wort (Hypericum perforatum L.) grown under different water and salt levels based on reflectance spectroscopy. Kuwait Journal of Science, **42** (3): 210-222.

Varela, P., Chen, J., Fiszman, S. & Povey, M.J.W. (2006). Crispness assessment of roasted almonds by an integrated approach to texture description: Texture, acoustics, sensory and structure. Journal of Chemometrics, **20** (6): 311-320.

Varela, P., Salvador, A. & Fiszman, S. (2008). On the assessment of fracture in brittle foods: The case of roasted almonds. Food Research International, **41** (5): 544-551.

Vázquez-Araújo, L., Verdú, A., Navarro, P., Martínez-Sánchez, F. & Carbonell-Barrachina, A.A. (2009). Changes in volatile compounds and sensory quality during toasting of Spanish almonds. International Journal of Food Science and Technology, **44** (11): 2225-2233.

Yada, S., Lapsley, K. & Huang, G. (2011). A review of composition studies of cultivated almonds: Macronutrients and micronutrients. Journal of Food Composition and Analysis, **24** (4): 469-480.

Submitted: 16-01-2018
Revised: 06-03-2018
Accepted: 26-03-2018

الخصائص المورفولوجية والميكانيكية والحسية لأصناف اللوز (.Prunus dulcis L) المزروعة في إسبانيا (.Pistacia vera L) والفستق

أدريان رابادان، مانويل ألفاريز أورتي، خوسيه باردو*[*]

[*]المدرسة الفنية العليا للمهندسين الزراعيين والغابات، جامعة كاستيا لا مانشا، الباسيتي، إسبانيا
المؤلف: *adrian.rabadan@uclm.es*

الملخص

تم تحليل الإختلافات في خصائص النواة من أنماط جينية مختلفة من اللوز والفستق على نطاق واسع مع مراعاة الخصائص الكيميائية وبعض المعلمات الفيزيائية. في هذه الدراسة، تم إجراء تحليل الخصائص المورفولوجية والميكانيكية والحسية باستخدام الإجراءات التقنية وتفضيلات المستهلكين في الأنماط الجينية للوز والفستق المزروعين في نفس المنطقة. وأظهرت النتائج أن المعلمات المادية مفيدة لتمييز الأصناف حتى عند زراعة المكسرات في نفس الظروف. ففي اللوز، تم تسجيل فروقات ذات دلالة في المعلمات الهامة مثل الطول (19.40 - 25.80 ملم)، والعرض (11.60 – 16.60 ملم) والصلابة (47.90 - 72.47 ن). وفي الفستق، تم كذلك تسجيل اختلافات ذات دلالة حيث إرتفعت قيم الطول (19.00 مم)، العرض (10.10 ملم) والوزن (0.8 جم). وكان نابوليتانا هو صنف الفستق ذو القيمة الأعلى من حيث الصلابة (53.84 ن)، يليه كرمان (46.52 ن). ومن خلال التحليل الحسي، أظهر المستهلكون تفضيلات كبيرة من حيث القبول البصري والتذوق العام لبعض أنواع اللوز (Vairo، Belona و Penta) وأصناف الفستق (Larnaka، Aegina و Sirora). ففي اللوز، ارتبط عرض النواة واللون بتقييمات المستهلك الأعلى من حيث القبول البصري والتذوق بشكل عام، على التوالي. وفي الفستق، تم الإبلاغ عن عدم وجود علاقة بين المعلمات المادية وتفضيلات المستهلك.