ALMOND COMPOSITION AND QUALITY: ASSUMPTIONS AND FACTS

Hard-shell almond nuts, more favourable to maintain kernel quality.

INRODUCTION

The quality of any product is a concept of very difficult definition. This difficulty is usually increased in all agricultural products because their composition is often very complex and, most of times, unknown. As a consequence, not only the quality concept is difficult to establish, but also ephemeral (Janick, 2005), because of the continuous changes in the market preferences. In a species very close to almond such as peach, these continuous changes in the market demands is clearly evident giving rise to constant changes in many qualitative aspects, such as skin and flesh color, shape, skin hairiness, etc.

Almond is the most important tree nut crop in terms of commercial production. This production is limited to areas characterized by a Mediterranean climate (Kester and Asay, 1975), including regions in the Mediterranean countries, the Central Valley of California, the Middle East, and some equivalent areas in the Southern Hemisphere. Traditional almond culture utilized open-pollinated seedlings (Grasselly, 1972; Rikhter, 1972) 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 the selection of almond cultivars well adapted to this area (Kester et al., 1990). Some cultivars, however, have shown high plasticity, being adapted to different growing conditions (Felipe, 2000).

Traditional almond production was centered in the Mediterranean countries, but in the 20th century it shifted to new growing regions. At present there is a clear dominance of the Californian production and an increasing importance of the Australian production, with a clear possibility of displacing the Spanish production from the second to the third place. From the commercial point of view, the Spanish almond imports from California represent an important volume of the exports from the United States, giving rise to continuous controversies on the possible differential quality of both productions. These discussions, however, lack of a sound scientific basis to establish clear criteria on quality differentiation. Some parameters can be clearly measured and used to characterize each cultivar. This information is crucial not only in order to increase the knowledge of the almond diversity, but also the nutritional and healthy value of the kernels, and the possibility of selecting the most adequate cultivars for the industry (Socias i Company et al., 2008). The modern almond industry requires commercial cultivars characterized by kernels with high quality attributes, because the best end-use for each cultivar is a function of its chemical composition (Berger, 1969) and of the consumers' trend for foods without synthetic additives (Krings and Berger, 2001). 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 absorption by the almond paste (Alessandroni, 1980). On the contrary, high oil contents are not desirable in the production of almond flour or almond milk. In the case of individual fatty acids, low content of linoleic acid is correlated with high oil stability (Zacheo et al., 2000), whereas high content of oleic acid is considered a positive trait from the nutritional point of view (Socias i Company et al., 2008).

The information available at present on the chemical composition of the almond kernels is restricted to a reduced number of cultivars, mostly from the country where these cultivars originated or are grown. As a consequence, comparisons among 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 from 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). This collection was initially assembled by A. J. Felipe and shows a very large genetic diversity as related to all traits taken into account for almond description (Gülcan, 1985), including not only the morphological traits of the tree, the vegetative organs and the fruit, but also the physiological traits, such as blooming time and susceptibility to pests, diseases, and frosts (Socias i Company and Felipe, 1992), as well as their molecular characterization (Fernández i Martí et al., 2009).

The knowledge of the chemical composition of the almond kernels would allow establishing not only quality criteria, but also consumption criteria, due to the incidence of some compositional parameters on the nutritional and healthy values of almond kernels (Socias i Company et al., 2011). Some recent studies point out that almond consumption in the Mediterranean region represents a complementary source of vitamin E (Gimeno, 2000). Almond consumption has also been related to a decrease of the problems of colon cancer and of high blood pressure (Davis et al., 2003), as well as a decrease in the risk of heart diseases (Chen et al., 2006).

The high nutritive value of almond kernels arises mainly from their high lipid content, which constitutes an important caloric source but does not contribute to cholesterol formation in humans. This is due to their high level of unsaturated fatty acids, mainly monounsaturated fatty acids (MUFA), since MUFAs are inversely correlated with serum cholesterol levels (Sabate and Hook, 1996). Kernel tendency to rancidity during storage and transport is a quality loss and is related to oxidation of the kernel fatty acids (Senessi et al., 1996). Thus, oil stability and fatty acid composition, essentially the O/L ratio (Kester et al., 1993), are considered an important criterion to evaluate kernel quality. The presence of natural anti-oxidants in almond kernels, such as tocopherols, is another determinant of almond quality (Socias i Company et al., 2008).

Thus, our main objective was the study of the genetic diversity present at the Spanish National Almond Collection present at the CITA of Aragón in relation to their kernel oil content, as well as for oil composition in the main fatty acids. This knowledge would be essential for establishing the value of the different cultivars from the quality point of view.

Table 1. Average oil content and composition in the main fatty acids of almond cultivars from different countries.

Country	Oil	Oleic	Linoleic	O/L	Palmitic	Palmitoleic	Stearic
Argentina	65,19 a	70,60 ab	20,91 ab	3,40 b	5,86 ab	0,40 ab	1,65 c
Spain	60,40 bc	72,20 a	18,46 bc	4,02 ab	6,15 a	0,45 ab	2,05 bc
USA	60,90 bc	70,26 ab	20,56 ab	3,59 b	6,03 a	0,46 ab	1,94 bc
France	60,51 bc	72,42 a	18,22 c	4,13 a	5,83 ab	0,44 ab	2,17 bc
Greece	58,68 c	69,39 ab	21,09 ab	3,42 b	6,19 a	0,48 a	2,30 b
India	64,08 a	66,25 b	23,85 a	2,83 c	6,22 a	0,42 ab	2,41 a
Italy	61,30 b	72,93 a	18,06 c	4,22 a	5,81 ab	0,45 ab	2,07 bc
Portugal	60,57 bc	70,39 ab	20,11 ab	3,63 b	6,02 a	0,45 ab	2,31 ab
Syria	55,63 d	71,75 a	19,76 b	3,66 b	5,65 b	0,35 b	1,83 bc
Ukraine	60,44 bc	71,85 a	19,02 bc	3,92 ab	5,98 a	0,39 ab	1,96 bc

MATERIALS AND METHODS

The kernels of 73 almond cultivars coming from 10 different countries were analyzed for this study (Kodad et al., 2011). The trees are maintained as living plants grafted on the almond x peach hybrid clonal rootstock INRA GF-677, using standard management practices (Espiau et al., 2002). Nuts from open pollination were harvested in 2008 and 2009 at mature stage, when fruit mesocarp was fully dried and split along the fruit suture and peduncle abscission was complete (Felipe, 1977). Two samples of 20 fruits were collected for each treatment.

Fruits were left to dry and then shelled to obtain the kernels. The kernels were blanched in hot water. After drying, the kernels were ground in an electrical grinder to obtain almond flour. Oil was extracted from 4-5 g of ground almond kernel in a commercial fat-extractor. The oil content was expressed as the difference in weight of the dried kernel sample before and after extraction. The oil sample was utilized to determine the different fatty acids according to the official method UNE-EN ISO 5509:2000 (ISO, 2000). The ratio O/L (relation between the concentrations of oleic acid and linoleic acid) was also obtained.

The results of the two years of analysis were averaged for all the cultivars of each country. The means were compared by LSD at 5%.

RESULTS AND DISCUSSION

When considering the average values of each cultivar (data not shown), the first notion to be deduced was the large variability for the oil content and the concentration of the different fatty acids among the different almond cultivars, independently of their country of origin. The average value of oil content, on a dry matter basis, ranged from 51.39% in 'Siria-3' and 66.80% in 'Filippo Ceo'. When this range of variability was examined for the cultivars of each country, the widest range was observed among the cultivars from Spain (from 54.75% to 66.40%), followed by a medium range of variability for the cultivars of France (from 54.75% to 64.73%) and Italy (from 56.23% to 66.80%), being low for the cultivars of Portugal (from 58.33% to 63.66%) and the USA (from 57.36% to 63.60%). It is worth noting that nearly all cultivars from France, Italy and the USA showed a mean value of oil content higher than 60%. This range of variability for the cultivars of Argentina, India, Ukraine and Syria, present in a much lower number than those from the other countries, was found to be between the limits observed for the cultivars of the other countries. These results showed the inconsistency of the opinion often manifested that the Californian cultivars have lower oil contents than the European cultivars.

Blanched almond kernels with rugous surface, a trait decreasing quality.

The range of variability for the main fatty acids was also wide. For oleic acid it was from 62.86% in 'Ne Plus Ultra' to 77.35% in 'Yosemite', being both cultivars from the USA. For linoleic acid it was from 14.04% in 'Yosemite' to 26.85% in 'Spilo'. For palmitic acid it was from 4.88% in 'Tardive de la Verdière' to 7.01% in 'Desmayo Largueta'. For stearic acid it was from 1.47% in 'Nonpareil' to 3.41% in 'Filippo Ceo'. Finally, for palmitoleic acid it was from 0.31% in 'Siria-3' to 0,61% in 'LeGrand'.

Considering oleic acid, the fatty acid with the highest content in almond oil, the widest range of variability was observed among the cultivars from the USA (from 62.86% to 77.35%), followed by those from France (from 65.31% to 76.99%), Greece (from 64.00% to 74.97%), Spain (from 67.42% to 74.92%) and Portugal (from 67.66% to 74.10%). The highest mean value for the content in oleic acid (Table 1) was found for the cultivars from Italy (72.93%), followed by those of France (72.42%), Spain (72.20%), Portugal (70.39%), the USA (70.26%) and Greece (69.39%), although the differences between these countries were not significant. Only for the cultivars from India (present only with three accessions), the content of oleic acid was significantly lower than the content of the cultivars from the other countries.

For linoleic acid, the widest ranges of variability were observed for the cultivars of the USA (from 14.04% to 26.63%) and France (from 14.29% to 24.71%), and the shortest for those of Portugal (from 17.03% to 23.22%) and Spain (from 15.37% to 22.44%). The lowest values for the content of linoleic acid were found among the cultivars from Italy, France and Spain, with values significantly lower than those for the cultivars of some countries. In relation to the O/L ratio, the highest values were found among the cultivars from Italy, France and Spain, whereas the values from India were significantly lower (Table 1). It must be taken into account that a high O/L ratio implies higher oil stability and, therefore, an index of almond quality and of resistance to rancidity must be considered.

The three other main fatty acids are present in much lower amounts, and the differences observed between cultivars from different countries are not important (Table1).

As a whole, thus, the lipid composition of the almond kernels is a characteristic trait of each cultivar, independently of its country of origin. Therefore, the nutritive value and the quality stability of the kernel depend on the genotype and not on the geographic origin. These results show that the valorization of the almond quality must not take into account the geographical origin of the cultivar, but other aspects of its composition, not only the lipid fraction. The oil content and the percentages of the different fatty acids do not directly affect the subjective appreciation of the kernel quality, but the different possibilities of its industrial utilization, showing again that the definition of quality is extremely difficult.

The present industrial trend for specific requirements in relation to the kernel quality for the different confectioneries made with almond implies a better knowledge of the kernel composition in order to establish selection criteria for the best adequate cultivars for each product. These criteria have been incorporated into the almond breeding program of the CITA of Aragón and have been an important point for the commercial qualitative kernel valorization of the new releases such as 'Belona', 'Soleta', and 'Mardía', with low content of linoleic acid, because this low content is correlated with a high oil stability.

The results of this study show the wide variability present in the lipid fraction of the almond kernels, independently of their country of origin, as cultivars of 10 countries were included, not only from the Mediterranean area, but also an important group of cultivars from the USA, as well as some representatives from Argentina and India. However, it was impossible to establish a compositional pattern of any region because in each region there are cultivars with very different values for each component. In addition, it has been also impossible to establish valorization criteria based only on the lipid composition. However, these results are extremely important for the industry in order to choose the adequate cultivar for each confectionery. Thus, as already mentioned, kernels with high oil content are the best for making "Jijona" turrón (soft nougat) or for extracting oil, as required by the pharmaceutical and cosmetic industries.

However, it is note worthy to stress the high O/L ratio of the cultivars from Italy, France and Spain. This fact may allow increasing the storage ability not only of the kernels of these cultivars, but also of their derivative products, such as nougat, marzipan, etc. This implies all the intermediate steps, from the field, at harvesting, to consumption of each of these products. From this point of view the Spanish cultivars can be distinguished from the Californian ones, thus showing a distinctive quality trait, not only interesting from the consumers' point of view, but also in any breeding program, taking into account the breeding objective of increasing the organoleptic and nutritive quality of the almond kernels.

ACKNOWLEDGEMENTS
Review funded by the Spanish projects CICYT AGL2010-22197-C02-01 and INIA RF2008-00027-00-00, the European project AGRI GEN RES 870/2004 068 (SAFENUT) and the activity of the Research Group A12 of Aragón. We appreciate the technical assistance of J. Búbal and O. Frontera.

REFERENCES

Alessandroni, A., 1980. Le mandorle. Panific. Pastic. 8 : 67-71.

Berger, P., 1969. Aptitude à la transformation industrielle de quelques variétés d'amandier. Bull. Techn. Inf. 241: 577-580.

Chen, C.Y., Lapsley, K., Bloomburg, G.J., 2006. A nutrition and health perspective on almonds. J. Sci. Food. Agric. 86: 2245-2250.

Davis, P., Iwahashi, C.K., Yokahama, W., 2003. Whole almonds activate gastrointestinal tract anti-proliferative signaling in APCmin (multiple intestinal neoplasia) mice. FASEB J. 17: A1153.

Espiau, M.T., Ansón, J.M., Socias i Company, R., 2002. The almond germplasm bank of Zaragoza. Acta Hort. 591: 275-278.

Felipe, A.J., 1977. Almendro: estados fenólogicos. Inf. Técn. Econ. Agrar. 27: 8-9.

Felipe, A.J., 2000. El almendro: el material vegetal. Integrum, Lérida.

Fernández i Martí, À., Alonso, J.M., Espiau, M.T., Rubio-Cabetas, M.J., Socias i Company, R., 2009. Genetic diversity in Spanish and foreign almond germplasm assessed by molecular characterization with simple sequence repeats. J. Amer. Soc. Hort. Sci. 134: 535-542.

Gimeno, E., Calero, E., Castellote, A.I., Lamuela-Raventós, R.M.. de la Torre, M.C., López-Sabater, M.C., 2000. Simultaneous determination of a-tocopherol and b-carotene in olive oil by RP-HPLC. J. Chromatogr. A 881: 255-259.

Grasselly, C., 1972. L'amandier: caractères morphologiques et physiologiques des variétés, modalité de leurs transmissions chez les hybrids de première génération. PhD Thesis, Univ. Bordeaux.

Gülcan, R., 1985. Almond descriptors (revised). IBPGR, Rome.

ISO, 2000. Animal and vegetable fats and oils – Preparation of methyl esters of fatty acids. International Organization for Standardization, Standard 5509. Geneva. Switzerland.

Janick, J., 2005. Breeding intractable traits in fruit crops: dream the impossible dream. HortScience 40: 1944.

Kester, D.E., Asay, R., 1975. Almonds: 387-419. In: J. Janick and J.N. Moore (eds.). Advances in fruit breeding. Purdue Univ. Press, West Lafayette, IN, U.S.

Kester, D.E., Gradziel, T.M., Grasselly, C., 1990. Almonds (*Prunus*). Acta Hort. 290: 699-758.

Kester, D.E., Cunningham, S., Kader, A.A., 1993. Almonds: 121-126. In: Encyclopedia of food science, food technology and nutrition. Academic Press, London, UK.

Kodad, O., Alonso, J.M., Espiau, M.T., Estopañán, G., Juan, T., Socias i Company, R., 2011. Chemometric characterization of almond germplasm: compositional aspects involved in quality and breeding. J. Amer. Soc. Hort. Sci. 136: 273-281.

Krings, U., Berger, R.G., 2001. Antioxidant activity of some roasted foods. Food Chem. 72: 223-229.

Rikhter, A.A., 1972. Biological bases for the creation of almond cultivars and commercial orchards (in Russian). Glavny Botanical Garden, Moscow, Russia.

Sabate, J., Hook, D.G., 1996. Almonds, walnuts, and serum lipids: 137-144. In: Spiller, G.A. (ed.). Lipids in human nutrition. CRC Press Inc., Boca Raton, FL, U.S.

Senessi, E., Rizzolo, A., Colombo, C. Testoni, A., 1996. Influence of pre-processing storage conditions on peeled almond quality. Ital. J. Food Sci. 2: 115-125.

Socias i Company, R., Felipe, A.J., 1992. Almond: a diverse germplasm. HortScience 27: 717-718, 863.

Socias i Company, R., Kodad, O., Alonso, J.M., Gradziel, T.M., 2008. Almond quality: a breeding perspective. Hort. Rev. 34: 197-238.

Socias i Company, R., Alonso, J.M., Kodad, O., Gradziel, T.M., 2011. Almond *[Prunus dulcis syn. P. amygdalus*]. In: Badenes M.L. and D. Byrne (eds.). Fruit Breeding. Springer Verlag, Berlin, Germany (in press).

Zacheo, G., Capello, M.S., Gallo, A., Santino, A., Capello, A.R., 2000. Changes associated with postharvest ageing in almond seeds. Lebens. Wissens. Technol. 33: 415-423.

O. Kodad and R. Socias i Company
Unidad de Fruticultura, CITA de Aragón,
Av. Montañana 930, 50059 Zaragoza, Spain
E-mail: rsocias@aragon.es