Shell hardness in almond: cracking load and kernel percentage

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ABSTRACT

Shell-cracking load was measured in a sample of 54 almond cultivars, most of them from the autochthonous germplasm of Majorca (Spain), through a compression test. The shell-cracking load ranged from 58 N in ‘Nonpareil’ to 1415 N in ‘Alzina’, showing the large variability of shell hardness in almond nuts, distributed in 21 mean groups. The results confirmed the suitability of this method for estimating shell hardness due to its reproducibility and small variance within cultivars. Although shell hardness has been traditionally correlated with shelling percentage, our results show that shell hardness may be an independent variable due to its weak correlation with shelling percentage, nut weight and kernel weight. Additionally, our results show that the hardness scores in almond need to be revised.

Keywords: *Prunus amygdalus*, Almond, Endocarp, Shell hardness, Cracking force

1. Introduction

The almond nut is a drupe consisting of three main components: the outer hull, the intermediate shell and the inner kernel. The hull is a fibrous layer consisting of the pericarp and the mesocarp, equivalent to the flesh of the stone fruits, and splitting at maturity to show the shell. The shell consists of the endocarp, primarily composed of cellulose, hemicellulose and lignin. The shell contains the seed or kernel, which is the commercial part of the fruit (Socias i Company et al., 2017). Consequently, attention has mostly been directed to the study of the almond kernel, being the hull and the shell somehow neglected due to their lower economic importance, although the interest on their possible utilisation is continuously increasing (Ledbetter, 2008).

The hardness of endocarp or shell shows a very large variability among cultivars, from very soft paper shells to very hard stony shells. Their morphology is also very variable, with a large diversity of shape, size, and the presence of different modifications, such as wrinkles and pores, a more or less pronounced keel at the ventral suture, or a sting at the apex (Socias i Company et al., 2017). When almond descriptors were defined, Gülcan (1985) characterized nine states of expression for softness of shell (1 extremely hard, 3 hard, 5 intermediate, 7 soft and 9 paper) defined by easiness of shell cracking, from easy cracking with hands to nuts difficult to break with a hummer. On the other hand, shell hardness has been related to shelling percentage, from less than 20% in stony shells to more than 60% in paper shells. Consequently, five classes have also been considered according to shelling percentage (SP): very hard (SP: < 30%), hard (SP: 30-40%), semi-soft (SP: 40-50%), soft (SP: 50-60%) and paper (SP: > 60%) (Batlle et al., 2017). Both traits have an important genetic determinism, present continuous variation and are affected by environment (growing conditions, year, location, etc.), usual characteristic of quantitative traits, although a qualitative component has also been suggested for their inheritance (Grasselly, 1972). Moreover, the International Union for the Protection of New Varieties of Plants (UPOV) has expressed shell hardness as the resistance of the stone to cracking, with five states of expression (1 absent or very weak, 2 weak, 3 medium, 4 strong, and 5 very strong) (UPOV, 2017).

The preference for each shell type depends on the growing conditions and the prevalent industry in the region. In the Mediterranean region hard shells are preferred since these cultivars seem more adapted to non-irrigated conditions and more resistant to depredation by birds and rodents, and to penetration by insect larvae damaging the kernel. Furthermore their nuts can be stored for a long time with reduced problems of getting rancid or excessively dry, thus allowing their commercialization along the season. The Mediterranean shelling plants are consequently adapted to hard shells, using knocking hammers and being completely different from shelling plants for soft shells, using solid rubber rollers as it happens in California and other countries growing similar cultivars, including most growing regions of the southern hemisphere (Verdú et al., 2017).

The endocarp may be used as firewood because of a very high heating power, sometimes in the same processing plants to heat water for blanching kernels. It is also utilised in obtaining chipboards and active carbon and, reduced to powder, to polish some metals and as a natural wool colorant. New ways of research aim at increasing its possible utilization, such as organic inclusions in porous ceramic bodies, as additives in drilling of new wells, and as a substrate in soilless or hydroponic culture (Ledbetter, 2008; Socias i Company *et al*., 2013). Almond shell carbohydrates are mainly cellulose and hemicellulose, but it also contains tannins, pectin and mucilage, constituting a potential source of industrial chemicals (Saura Calixto et al., 1988; Schirra, 1997). The high xylan content of almond shells makes them a suitable substrate for the production of xylose (Pou-Llinás et al., 1990), furfural (Quesada et al., 2002) or for fractioning into cellulose, pentosans, and lignin (Martínez et al., 1995). More commonly, almond shells are considered a waste product and are composted, used as mulch, plowed back into the orchard, or used as a fuel. Several potential antimicrobial compounds have been reported associated with almond shells (Sachdiva, 1968; Bhatia, 1977), which could affect orchard soil ecology if allowed to form in significant quantities in new almond cultivars.

Shell hardness is a function of the proportion of cellulose, hemicellulose and lignin, as the main components of the shell, but also of the shell morphology, the fiber content and the outer shell adherence (Ledbetter, 2008). Shell hardness refers to the resistance of shell to be broken by hand or using a hammer (subjectively scored) or with a texturometer (objectively scored). Percentage of kernel is a complex trait resulting of the proportion between the dry kernel mass and the whole nut dry mass (kernel plus shell). Both traits, related to the almond nut, are very important for industrial processing. Shell hardness and percentage of kernel are usually related, since usually the higher the kernel percentage, the lower the shell hardness, and vice versa. Since shell hardness has shown a high correlation with kernel percentage, it has been often expressed as kernel percentage because kernel percentage is easily measured, although this correlation is not absolute. However, both traits are different and it is possible to find hard thin shelled cultivars with high kernel percentage, a desirable trait combination from the breeding and industry points of view. Among the hard shell cultivars, those producing nuts with thin hull and shell would be interesting for breeding and production since they would be more efficient in the use of inputs, such as macroelements, required to produce a given amount of crop (Alonso et al., 2012). Also, production of these cultivars would imply transport savings, since for a given kernel mass the volume of nuts would be lower.

The knowledge of the shell hardness is essential for a really effective cracking process. However, the objective measurement of shell hardness by a texturometer has not been clearly explained (Barbera et al., 1987; Ballester, 1998) or has been studied in a reduced number of genotypes (Ledbetter, 2008; Altuntas et al., 2010; Shirmohammadi and Fielke, 2010; Oliveira et al., 2017) or in genetically similar populations, such as full sibs (Ballester, 1998, Romero et al., 2017), thus not sufficiently reflecting the variability of the species. These measurements, in addition, may not fully reflect the real shell hardness, especially when soft-shell cultivars are tested (Ledbetter, 2008; Shirmohammadi and Fielke, 2010). Consequently, our objective was the analysis of the shell hardness of a group of almond cultivars by a new objective method in order to infer its adequate utilization in the measurement of shell hardness in almond.

2. Material and Methods

2.1. Plant material

This study included 54 almond cultivars, most of them from the autochthonous germplasm of the island of Majorca (Spain), although some foreign cultivars were also included as references (Table 1). Each cultivar is represented by three trees in the Sa Canova (Sa Pobla, Majorca) collection, grafted on the rootstock INRA GF-677, maintained according to the commercial management of almond orchards. Most of the cultivars come from the collection established in the Granja Experimental de la Ciutat de Mallorca during the years 1950s and 1960s, increased by further introductions by Joan Rallo. In addition, some samples were obtained from singular trees, identified by own prospection and growing in their original location, and a few foreign cultivars from other collections. The almond germplasm of Majorca is considered highly diversified

(Estelrich, 1907), showing at the same time several peculiar traits (Fernández i Martí et al., 2009 and 2015; Kodad et al., 2010).

The study was carried out with the crop of 2017. The almond nuts were collected once ripe, when the mesocarp was fully dry, split to show the inner endocarp, and easy peduncle abscission (Felipe, 1977). Samples of 100 nuts were collected from the ensemble of the different trees of each cultivar. Previously to any measurement, the nuts were placed at room temperature until constant moisture (≈ 6%) since uniform moisture is essential for hardness measurements because breaking force may decrease with increasing moisture content in almond (Shirmohammadi and Fielke, 2017) as well as in other nuts and grains, such as pistachio (Razavi and Edalatian, 2011) and oat (Zhao et al., 2017).

2.2. Shell-cracking load

Shell-cracking load (SCL) was measured with the compression test instrument Z100 of Zwick (Ulm, Germany), equipped with a charge cell of 100 KN (Fig. 1). The shell cracking load was estimated in ten nuts per cultivar. Each single almond nut was placed on a stationary metal plate at the base of the Z100 instrument such that the suture plane of the nut was parallel to the metal plate, and perpendicular to the direction of the compression force (Fig. 1). Compression of the nut was then begun from above applying firstly a pre-charge of 2N, and then a compression speed of 25 mm min^{-1}. Thus, the almond nut received the compression force perpendicularly to the transversal section. Shell-cracking load was defined as the force needed to crack the nut shell and was assessed by the maximum force during the compression test.

The end of the measurements was considered when the compression force reached 60% of the maximum value measured during the assay, with a limit of 3 mm (Fig. 2), because previous assays indicated that after this run the shell already cracked in hard-shell cultivars. For soft-shell cultivars, the end of the measurement was decided when after a sharp decrease a continued force was observed at the screen, followed by an ascendant force, when load was not applied any more to the shell, but to the kernel.

2.3. Kernel percentage

A random sample of 50 nuts from each cultivar was weighted in an AND Fx-2000 electronic balance (Japan). Once cracked, the kernels were also weighted and the shelling percentage (SP) obtained. The average mass of nuts (NM) and kernels (KM) were also obtained.

2.4. Statistical analysis

All statistical analyses were performed with Version 9.1 of SAS (SAS Institute, 2004). The analysis of variance with the PROC GLM procedure was applied to evaluate the genotype effect on the shelling strength variable. The mean separation was performed using Duncan test at $P = 0.05$. Simple linear regressions among the cultivar shell-cracking load (SCL), as dependent variable, and the cultivar shelling percentage (SP), nut mass (NM) and kernel mass (KM), as independent variables were performed using the PROC REG procedure.

3. Results and Discussion

A large variability for shell-cracking load was observed among the cultivars studied, ranging from 58 N in ‘Nonpareil’ to 1415 N in ‘Alzina’, widely distributed among the different cultivars, giving rise up to 21 mean groups (Table 1). This distribution is much wider than any previously described in almond, showing that the ensemble of the cultivars studied is clearly representative of the possible variability present in almond. With the exception of the two soft-shell cultivars, shell hardness showed uniform distribution, as observed by Romero et al. (2017). These results also confirm the usefulness of the method applied for measuring shell hardness in almond, due to the uniformity observed in the different samples, since this measurement is not affected by the position of the texturometer punch, which may coincide or not with a shell pore or any shell internal vascular vessel, thus affecting the measured hardness. The effects of the presence of pores or of the type of shell surface (Socias i Company et al., 2017) are excluded when measuring with compression tests, thus obtaining more consistent results.

This large variability may indicate that the subjective classification of shell hardness in five or nine groups, as established by several international descriptors (Gülcan, 1984; UPOV, 2017) may not fully reflect the real shell hardness, mainly when designing the cracking process in almond (Verdú et al., 2017). Additionally, ‘Bartre’ is considered as the example of very hard shell in these descriptors, although the shell-cracking load measured for this cultivar is much lower than for other cultivars, nearly half of that of ‘Alzina’, and approximately at the middle position of the ensemble of all the samples (Table 1). Consequently, the subjective consideration of ‘Bartre’ as the reference for the hardiest shell may be more related to the fact that ‘Bartre’ has the largest nut and kernel than to its real shelling strength. Furthermore, the utilization of a reduced sample of genotypes may lead to the conclusion that ‘Bartre’ showed the highest hardness (Barbera et al., 1987).

Special attention is required in evaluating the shell strength, particularly when the trend in the cracking process is towards cracking lots of single cultivars at a time (Ledbetter, 2008). Although nut size may change due to crop level and environmental conditions, nut shape is maintained (Kodad and Socias i Company, 2006). Thus, when cracking lots of single cultivars, homogeneous shapes are cracked, allowing a better adjustment of the cracking hammers and a higher efficiency of the process, reducing at the same the percentage of broken kernels, which are much less valued than whole kernels (Verdú et al., 2017).

As already stated, shell hardness has been usually correlated with shelling percentage. In our case, the relationship between shell-cracking load and shelling percentage was fitted to a linear model, as seen in Fig. 3:

Shelling percentage = 44.367 - 0.0198 x Shell-cracking load

This regression shows a very low negative slope (-0.0198), stating that the large differences in shell-cracking load do not clearly correspond to significant differences in shelling percentage. Also, this linear model, although significant, has a low determination coefficient ($r^2 = 0.4012$), and consequently, a small portion of shelling percentage variability was explained by the model.

The confidence limits resulted too high in order to allow the classification of almond cultivars on the basis of this relationship (Barbera et al., 1987). Moreover, the two soft-shell samples appear apart from all the others, in the high left corner of Fig. 3, showing that they are really outliers and that the utilization of the same methodology for measuring shell hardness of soft- and hard-shell almond cultivars implies a simplification of the cracking process (Shirmohammadi and Fielke, 2017). Consequently, the industrial plants are designed with different equipment when cracking soft- or hard-shell almond cultivars (Verdú et al., 2017).

When the two soft-shell cultivars are eliminated from the analysis, a different correlation is found:

Shelling percentage = 38.46 - 0.0126 x Shell-cracking load.

In this case, the determination coefficient ($r^2 = 0.2794$) decreased, but also the slope was even lower (0.0126), showing that the sshell-cracking load and the shelling percentage are somehow independent variables. This was the case observed in 'Verdereta', but Lebdetter (2008) had already noticed specific results contrary to the significant negative correlation between shell-cracking load and kernel percentage, indicating varietal compositional or structural differences in the almond shell.

Lebdetter (2008) also found significant correlations between nut and kernel mass with shell cracking load, but these correlations in our case had very low determination coefficients since the correlations were:

Nut mass = 3.5622 + 0.0015 x Shell-cracking load ($r^2 = 0.0882$)

Kernel mass = 1.5077 - 0.0002 x Shell-cracking load ($r^2 = 0.0525$)

In both cases, the determination coefficient and the slope were very low, showing that in a very large sample there is no real correlation between shell-cracking load and the other parameters examined.

4. Conclusion

Although shell hardness has been traditionally correlated with shelling percentage, as well as with nut mass and kernel mass in almond, our results show that shell hardness may be an independent variable when a sufficiently large sample of genotypes is studied. Maybe the methodology applied to measure shell hardness has been most appropriate in our case, since soft-shell cultivars are unsuitable for hardness testing using other procedures (Ledbetter, 2008). Additionally, the samples previously studied could include a too small number of genotypes or were made of a group of genetically similar genotypes, not representing the variability present in the species. Our results showed the efficiency of the methodology used for estimating shell hardness since it showed a small variance within samples and was a high reproducibility test. The study of the almond germplasm of Majorca (Spain) has allowed to show the large variability of shell hardness and that the reference cultivars for resistance to cracking must be revised, since half of the genotypes tested showed higher shell hardness, even some double shell-cracking load, than ‘Bartre’, scored as “very strong” (UPOV, 2017). Furthermore, shell hardness showed a very weak correlation with shelling percentage, nut mass and kernel m.

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References

Alonso, J.M., Espada, J.L., Socias i Company, R., 2012. Major macroelement exports in fruits of diverse almond cultivars. Span. J. Agric. Res. 10, 175-178.

Altuntas, E., Gercekcioglu, R., Kaya, C., 2010. Selected mechanical and geometric properties of different almond cultivars, Int. J. Food Prop., 13, 282-293.

Ballester, J., 1998. Localització i anàlisi de caràcters d’interès agronòmic de l’ametller. PhD Thesis, Univ. Autònoma de Barcelona, 183 pp.

Barbera, G., Bazzi, M., Monastra, F., Motisi, A., 1987. Remark on shell hardness and shelling percentage relationship in almond. Rap. EUR 11557, 253-258.

Batlle, I., Dicenta, F., Socias i Company, R., Gradziel, T.M., Wirthensohn, M., Duval, H., Vargas, F.J., 2017. Classical genetics and breeding. In: R. Socias i Company and T.M. Gradziel (Eds.). Almond: botany, production and uses. CABI, Oxfordshire, UK. pp. 111-148.

Bhatia, V.N., 1977. Some studies on *Pseudomonas aeruginosa* with special reference to antimicrobial sensitivity. J. All Ind. Inst. Medic. Sci. 3, 124–128.

Estelrich, P., 1907. El almendro y su cultivo en el mediodía de España e Islas Baleares. Hijos de J. Cuesta, Madrid - Antonio López, Barcelona, VIII + 216 pp**.**

Felipe, A.J., 1977. Almendro. Estados fenológicos. Inf. Técn. Econ. Agrar. 27, 8-9.

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.

Fernández i Martí, A., Font i Forcada, C., Kamali, K., Rubio-Cabetas, M.J., Wirthensohn, M., Socias i Company, R., 2015. Molecular analyses of evolution and population structure in a worldwide almond [*P. dulcis* (Mill.) D.A. Webb syn. *Prunus amygdalus* Batsch] pool assessed by microsatellite markers. Genet. Resour. Crop Evol. 62, 205-219.

Grasselly, C., 1972. L’amandier: caractères morphologiques et physiologiques des variétés, modalité de leurs transmissions chez les hybrides de première génération. PhD Thesis, Univ. Bordeaux, France, 156 pp.

Gülcan, R., 1985. Almond descriptors (revised). IBPGR, Rome, Italy, 32 pp.

Kodad, O., Socias i Company, R., 2006. Influence of genotype, year and type of fruiting branches on the productive behaviour of almond. Sci. Hort. 109, 297-302.

Kodad, O., Alonso, J.M., Fernández i Martí, À., Oliveira, M.M., Socias i Company, R., 2010. Molecular and physiological identification of new *S*-alleles associated with self-(in)compatibility in local Spanish almond cultivars. Sci. Hort. 123, 308-311.

Ledbetter, C.A., 2008. Shell cracking strength in almond (*Prunus dulcis* [Mill.] D.A. Webb.) and its implication in uses as a value-added product. Bioresour. Technol. 99, 5567–5573.

Martínez, J.M., Granado, J.M., Montané, D., Salvadó, J., Farriol, X., 1995. Fractionation of residual lignocellulosics by dilute-acid prehydrolysis and alkaline extraction: Application to almond shells. Bioresour. Technol. 52, 59-67.

Oliveira, I., Meyer, A., Afonso, S., Ribeiro, C., Gonçalvs, B., 2017. Morphological, mechanical and antioxidant properties of Portuguese almond cultivars. J. Food Sci. Technol. 55, 467-478.

Pou-Llinás, J., Cañellas, J., Driguez, H., Excoffier, G., Vignon, M.R., 1990. Steam pre-treatment of almond shells for xylose production. Carbohydr. Res. 207, 126–130.

Quesada, J., Teffo-Bertaud, F., Croué, J.P., Rubio, M., 2002. Ozone oxidation and structural features of an almond shell lignin remaining after furfural manufacture. Holzforschung 56, 32-38.

Razavi, S.M.A., Edalatian, M.R., 2011. Effect of moisture contents and compression axes on physical and mechanical properties of pistachio. Int. J. Food Prop. 15, 507-517.

Romero, A., Dicenta, F., Miarnau, X., Batlle, I., Chamakh, M., 2017. Variability of almond shell mechanical strength. VII Int. Symp. Almonds and Pistachios, Adelaide, South Australia, November 5-9.

Sachdiva, Y., 1968. A new antimicrobial agent from almond (*Prunus amygdalus*) shells. Ind. J. Physiol. Pharmacol. 12, 217–212.

SAS Institute, 2004. SAS/STAT User's Guide Release 9.0. Statistical Analysis Institute, Cary, NC, USA.

Saura Calixto, F., Cañellas, J., Soler. L., 1988. La almendra: Composición, variedades, desarrollo y maduración. INIA, Madrid, Spain, 173 pp.

Schirra, M., 1997. Postharvest technology and utilization of almonds. Hort. Rev. 20, 267–292.

Shirmohammadi, M., Fielke, J., 2017. Conditioning reduces kernel damage when impact shelling almonds. Int. J. Food Eng. 13, 20160324.

Socias i Company, R., Repollés, D., Kodad, O., Fernández i Martí, À., Alonso, J.M., 2013. La valoración de la calidad de las nuevas variedades de almendro por una cooperación multisectorial. Rev. Frutic. 29, 38-50.

Socias i Company, R., Ansón, J.M., Espiau, M.T., 2017. Taxonomy, botany and physiology: In: R. Socias i Company and T.M. Gradziel (Eds.). Almond: botany, production and uses. CABI, Oxfordshire, UK, pp. 1-42.

UPOV 2017. TG/56/4 Almond - *Prunus dulcis* (Mill.) D.A.Webb. Guidelines for the conduct of tests for distinctness, uniformity and stability. International Union for the Protection of New Varieties of Plants (UPOV). Geneva, Switzerland, 31 pp.

Verdú, A., Izquierdo, S., Socias i Company, R., 2017. Processing and industrialisation. In: R. Socias i Company and T.M. Gradziel (Eds.). Almond: botany, production and uses. CABI, Oxfordshire, UK, pp. 460-481.

Zhao, N., Fu, N., Li, D., Wang, L.J., Chen, X.D., 2017. Study on mechanical properties for shearing breakage of oat kernel. Int. J. Food Engineer. 13, 20170097.

Figure legends:

Fig. 1. Detail of an almond nut between parallel plates during a compression test to assess the shell-cracking load.

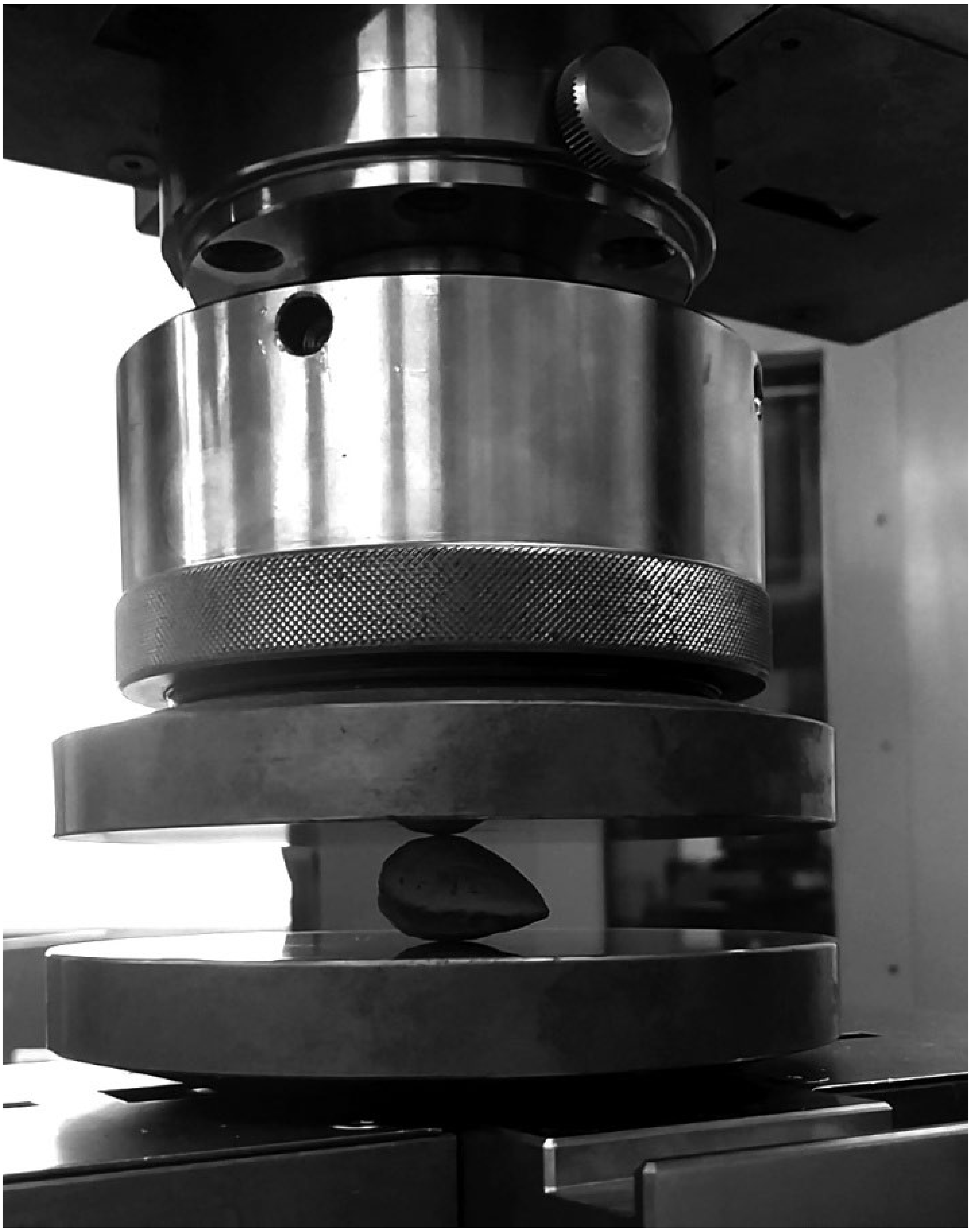

Fig. 2. Dynamics of the force during the compression tests of the hard-shell ‘Verdereta’ almond cultivar.

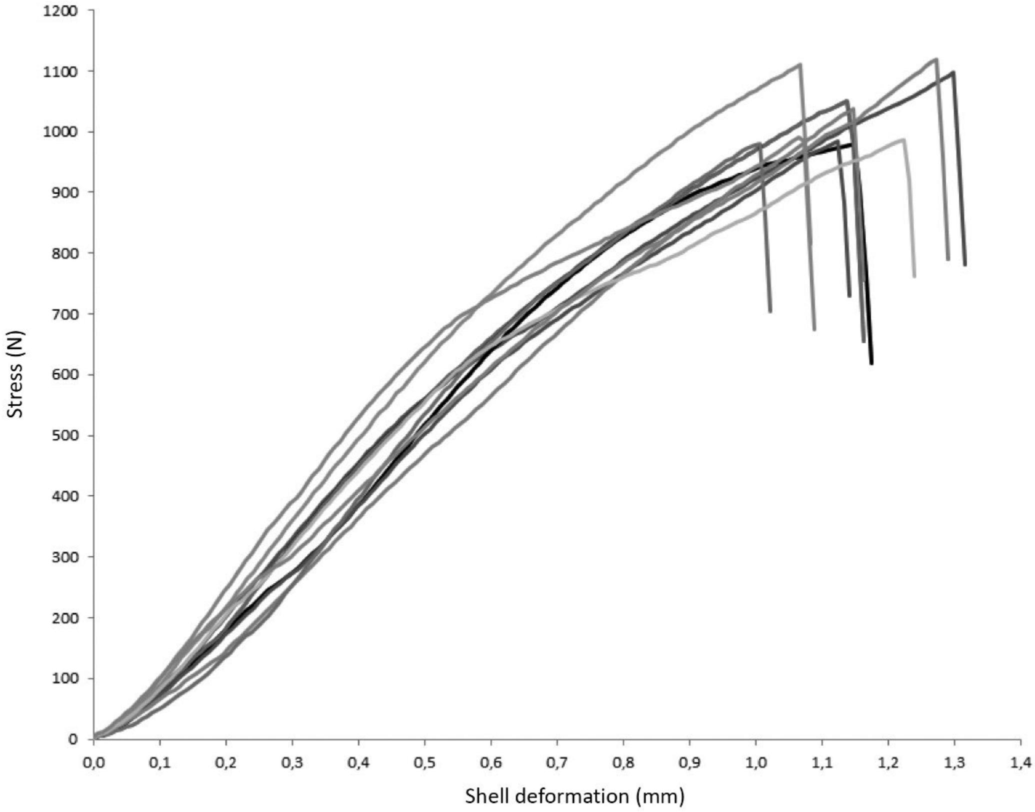

Fig. 3. Correlation between shell-cracking load and shelling percentage of the 54 almond genotypes studied.

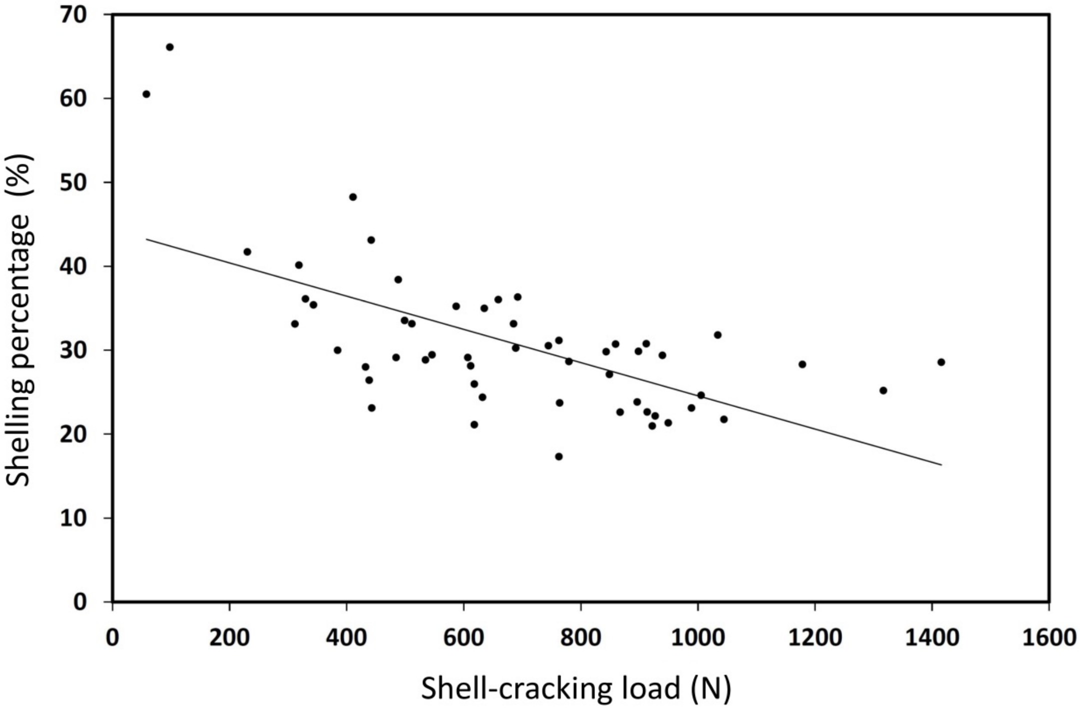

Table 1

Origin and nut traits studied in 54 almond cultivars for shell hardness estimation.

Cultivar	Origin	Shell-cracking load (N)	SD	Duncan group	Shelling percentage (%)	Nut Mass (g)	Kernel Mass (g)
Alzina	Majorca	1415,83	226,64	a	28,56	5,93	1,69
Ceba	Majorca	1316,77	202,88	a	25,19	4,13	1,04
Ponç	Majorca	1178,52	112,62	b	28,31	5,32	1,51
Pou d'Establiments	Majorca	1044,53	133,9	c	21,72	5,11	1,11
Verdereta	Majorca	1033,95	57,23	cd	31,8	3,79	1,21
Vinagrillo	Majorca	1005,48	177,46	cd	24,63	3,44	0,85
Canaleta	Majorca	989,18	115,51	cde	23,12	4,37	1,01
Bolic	Majorca	949,4	216,7	cdef	21,33	6,08	1,3
Primerenc	Majorca	939,41	151,15	cdef	29,39	4,5	1,32
Duet	Majorca	926,99	125,06	cdef	22,17	4,02	0,89
Feneret	Majorca	922,24	143,44	cdef	20,98	5,64	1,18
Mare de Déu	Majorca	913,6	185,94	cdefg	22,64	5,49	1,24
Filau	Majorca	912	153,95	cdefg	30,77	3,83	1,18
Guarín	Majorca	898,72	115,72	defgh	29,86	4,43	1,32
Agrina	Majorca	896,31	166,45	defghi	23,82	3,83	0,91
Càntaro	Majorca	867,15	193,37	efghi	22,61	4,26	0,96
Pou de Felanitx	Majorca	859,66	114,18	efghi	30,72	6,11	1,88
Binissalem	Majorca	849,1	158,83	fghi	27,11	6,68	1,81
Caragola	Majorca	843,4	153,85	fghi	29,81	3,84	1,14
Belona	CITA breeding	779,72	46,55	ghij	28,65	5,61	1,61
Mardía	CITA breeding	763,98	144,98	hijk	23,71	4,83	1,15
Duran	Majorca	762,9	118,62	hijk	31,15	3,98	1,24
Bartre	France	762,66	197,82	hijk	17,32	12,7	2,2
Jordi	Majorca	744,83	101,17	ijkl	30,54	3,43	1,05
Ribes (D'en)	Majorca	692,23	43,57	jklm	36,33	4,18	1,52
Rutló	Majorca	689,07	118,27	jklm	30,25	4,42	1,34
Vivot	Majorca	685,1	101,07	jklm	33,15	3,82	1,27
Pota	Majorca	659,21	218,55	jklmn	36,02	5,02	1,81
Viveta	Majorca	635,21	107,29	klmno	34,99	3,68	1,29
Marcona	E Spain	632,32	185,84	klmno	24,39	5,75	1,4
Desmayo Largueta	NE Spain	618,11	119,8	lmnop	25,97	5,34	1,39
Horrac	Majorca	618,1	155,16	lmnop	21,12	5,21	1,1
Lluca	Majorca	611,92	110,46	lmnop	28,12	5,23	1,14
Desmai	Majorca	607,12	87,06	lmnop	29,12	5,19	1,51
Capirró	Majorca	587,31	143,24	mnop	35,22	4,96	1,75

Talletó	Majorca	546,09	79,53	nopq	29,44	3,77	1,11
Vialfas	CITA breeding	534,9	87,09	nopq	28,84	5,72	1,65
Andreu	Majorca	511,57	168,29	opqr	33,14	4,29	1,42
Vera	Majorca	499,13	95,18	opqr	33,54	3,8	1,27
Vivero	Majorca	488,37	160,92	pqr	38,4	3,48	1,34
Glorieta	IRTA breeding	484,68	84,83	pqr	29,12	5,43	1,58
Trapa	Majorca	443,15	98,69	qrs	23,12	4,54	1,05
Magina	Majorca	441,97	108,07	qrs	43,12	3,12	1,35
Vairo	IRTA breeding	438,59	95,86	qrs	26,42	4,22	1,11
Negre	Majorca	432,46	80,18	qrs	27,99	4,6	1,29
Texas	California	411,03	87,52	qrs	48,25	2,88	1,39
Soleta	CITA breeding	384,69	103,19	rs	29,98	4,31	1,29
Ferragnès	INRA breeding	343,47	76,55	st	35,4	4,46	1,58
Mollar A	Majorca	329,97	94,03	st	36,12	2,95	1,07
Bord del Raiguer	Majorca	318,82	42,18	st	40,14	3,09	1,24
Totsol	Majorca	311,84	70,37	st	33,12	4,5	1,49
Monterey	California	230,66	79,43	t	41,72	4,25	1,78
Mollar B	Majorca	98,16	22,57	u	66,1	3,11	2,06
Nonpareil	California	58,11	11,19	u	60,5	2,2	1,33