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Melgarejo P., Sánchez M., Hernández F., Martínez J.J., Amorós A.

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Parameters for determining the hardness and pleasantness of pomegranates (*Punica granatum* L.)

P. Melgarejo, M. Sánchez, F. Hernández, J.J. Martínez and A. Amorós
Escuela Politécnica Superior de Orihuela, Universidad Miguel Hernández,
Ctra. de Beniel km 3,2, 03312 Orihuela (Alicante), Spain

SUMMARY – The quality of pomegranate seeds (the edible portion of the fruits) depends on certain parameters: basically colour, size, SS/A ratio, palatability and hardness. We have studied the hardness, pleasantness and palatability of the seeds. These are determining characteristics, as the seeds of some varieties are so hard as to be inedible, making the fruit unsuitable for fresh consumption. The study was carried out in 1996 and 1997. The difficulty in chewing the seeds was determined by two procedures: (i) measuring total fibre content; and (ii) measuring hardness (using a panel of tasters). The palatability was determined by the index of woody portion in the seeds. The results permit the pomegranate varieties analysed to be classified into hard seed (inedible) and soft seed (easily chewed). We observe a relationship between the total fibre and hardness. Palatability must be considered as a secondary index for measuring seed hardness compared with total fibre and chewing difficulty. The soluble solid (SS) content, evaluable acidity (A) and SS/A ratio make it possible to classify pomegranate clones into sweet, sour and sweet-sour.

Key words: Seeds, hardness, total fibre, pH, SS, evaluable acidity, colour, pomegranate.

RESUME – *"Paramètres pour déterminer la dureté et le caractère agréable des grenades (*Punica granatum *L.)". La qualité des graines de grenade (la portion consommable des fruits) dépend de certains paramètres : principalement la couleur, la taille, le ratio SS/A, la palatabilité et la dureté. Nous avons étudié la dureté, le caractère agréable et la palatabilité des graines. Ce sont des caractéristiques déterminantes, car les graines de certaines variétés sont si dures qu'elles sont inconsommables, le fruit étant ainsi impropre à la consommation en frais. L'étude a été menée en 1996 et 1997. La difficulté de mastiquer les graines était déterminée à travers deux procédures : (i) mesurer la teneur totale en fibres ; et (ii) mesurer la dureté (en utilisant un panel de dégustateurs). La palatabilité était déterminée par l'indice de proportion ligneuse dans les graines. Les résultats ont permis de classer les variétés de grenades analysées en graines dures (inconsommables) et graines tendres (facilement mastiquées). Nous observons une relation entre la fibre totale et la dureté. La palatabilité doit être considérée comme un indice secondaire pour mesurer la dureté des graines en comparaison avec la fibre totale et la difficulté à mastiquer. La teneur en solides solubles (SS), l'acidité évaluable (A) et le ration SS/A rendent possible de classer les clones de grenadier en doux, acides et doux-acides.*

Mots-clés : *Graines, dureté, fibre totale, pH, SS, acidité évaluable, couleur, grenade.*

Introduction

Seed quality in the pomegranate is determined by various sensory parameters which influence their acceptance or otherwise by the consumer. Some of these – such as hardness, total fibre content, index of woody portion and index of ripeness – can be determining factors, as the seeds can become inedible when they reach certain values, and they are therefore rejected by the consumers.

The aim of this study is to analyse these indexes in ten pomegranate clones which are cultivated in homogeneous conditions, determining the variation range in the parameters studied for seeds classified as: (i) *hard seed* (inedible because of the hardness of the seeds); (ii) *soft seed* (easily chewed, because the seeds have a low or acceptable hardness); and (iii) *semi-hard seeds* (with intermediately hard seeds). The pomegranate varieties can be classified by the ratio between SS (soluble solids) and A (evaluable acidity) as: (i) *sweet* (with a high SS/A ratio); (ii) *sour* (with a low SS/A ratio); and (iii) *sweet-sour* (with an intermediate SS/A ratio). Finally, the pleasantness can be measured by a panel of tasters who evaluate organoleptic characteristics (Melgarejo, 1993). In order to study these parameters in the pomegranate, the following points should be taken into account:

(i) The seeds of the pomegranate are the edible portion, whereas the rind and the carpellary membranes are non-edible (Melgarejo, 1993).

(ii) Two main parts can be distinguished in the seeds, anatomically and from a practical point of view:

- The *testa*: this is the seed coat; it has a fleshy or pulpy (watery) consistency and is very soft (Gilg and Schüroff, cited in Font Quer, 1959; Strasburger *et al*., 1986; Melgarejo, 1993). The juice of the seed is found here. It is rich in water, sugars, organic acids and anthocyanins. This part determines the *pleasantness* of the seeds, which can be measured from the SS or the A content, or the SS/A ratio, with the help of a panel of tasters, and from the colour of the seeds (determined by the anthocyanin composition). This colour is a sensory parameter which influences consumers greatly, but in normal conditions does not determine acceptance or otherwise of the product (Melgarejo, 1997).
- The *tegmen or interior portion*: made up of cotyledons and the embryo. This is the hard part of the seed, with a woody consistency, and it contains the embryo and the nutritive substances for seed germination and seedling development. It is rich in total fibre and fat. This part determines the *hardness* and the palatability of the seeds (Melgarejo, 1997).

Bearing all this in mind, we will concentrate our study on the parameters which determine the *hardness*, the *pleasantness,* and the *palatability* of the fruit.

Materials and methods

The vegetable matter used for this study is made up of fruits from the following pomegranate clones: ME1, ME11, ME12, ME14, MC1, SFB1, CRO2, PTO8, PDO1 and BA1, harvested ripe from the experimental estate of the Escuela Politécnica Superior de Orihuela (Universidad Miguel Hernández). They were cultivated in homogeneous conditions, reproduced by vegetative propagation (Melgarejo, 1993), and planted in a 4×3 m layout. The estate is in the municipal district of Orihuela (Alicante), and is watered by drip irrigation. The trees are goblet-trained.

Ten fruits were taken at random from each clone, they were peeled by hand in the laboratory, and each of the fruits were weighed whole and then, separately, their rind and carpellary membranes (non-edible part), thus calculating the seed content by the difference in these two weights; in this way the *seed yield* (SY) for the fruit of each clone was determined. The seeds of each clone were then mixed together to carry out the detailed study.

Seed morphology

In order to study seed morphology, a sample of 25 seeds were taken at random, they were individually weighed (Ws) and their length and width were measured; the testa was then separated and the interior part of the seeds was weighed (woody part, Wwp), also measuring its length and width. To weigh the seeds, Mettler AJ50 scales were used, and to measure the dimensions of the seed, both whole and with the testa removed, a Mitutoyo Digimatic digital gauge was used.

Woody portion index (Wpi)

This index, defined as: Wpi = (Wwp/Ws) × 100 (Melgarejo, 1993, 1997) is related to seed hardness, and allows us to measure palatability. It is a secondary index, in contrast with hardness and total fibre content.

Total fibre content (TF)

The total fibre, made up of fractions or structures from plants which reach the large intestine more or less unchanged (because they have not been digested in the stomach or the small intestine), includes very varied substances, amongst which are cellulose and lignin (abundant in the hard parts of plants), gums, mucilages, hemicelluloses, polysaccharides of many algae, pectins and other substances (Rotzman, 1978). This has been calculated following the official method of the Spanish MAPA (1993), using a Tecator 1026 Distilling Unit digester block.

Seed hardness and organoleptic characteristics

To evaluate the hardness of the woody part of the seeds, a panel of five tasters was set up. They gave points from 0 to 10 for seed hardness, in ascending order of chewing difficulty. Similarly, the organoleptic characteristics of the seeds, which (to a greater or lesser extent) determine the consumers' acceptance or otherwise, were evaluated. The fruits were classified as bad, acceptable, good and very good, and finally they were included in one of the established groups according to their ripeness index (sweet, sour, or sweet-sour) (Melgarejo, 1993, 1997).

To classify the seeds according to the hardness of their woody portion, the criteria shown in Table 1 were used.

Table 1. Criteria used in the classification of seed hardness

	Hardness
Soft seed	1.0-4.5
Semi-hard seed	5.0-6.0
Hard seed	6.5-10.0

Soluble solids

Soluble solid content was measured using an Atago N-20 refractometer at 20°C.

Evaluable acidity

This was measured by neutralising the acids in a 10 ml juice sample with 0.1N OHNa, with the content being shown as a percentage of anhydrous citric acid.

Ripeness index

The ripeness index (RI) was measured using the SS/A ratio, which produced a useful index to classify the pomegranate varieties as sweet, sour and sweet-sour. The classification shown in Table 2 can be established for the Spanish varieties studied up to now (Melgarejo, 1993, 1997).

Table 2. Classification of Spanish varieties according to ripeness index

	RI
Sweet varieties	31-98
Sweet-sour varieties	17-24
Sour varieties	5-7

Colour

The colour of the seeds as determined visually by the panel of tasters.

Results and discussion

The results of the study carried out are summarised in Tables 3 and 4, which indicate the average values of the two years studied (1996 and 1997).

Table 3. Palatability

Clone	SY (%)	Ws (g)	Wwp (g)	Wpi (%)	TF (%)	Hardness (1-10)	Visual Colour
ME1	59.76	0.371 ± 0.072	0.034 ± 0.006	9.65 ± 2.70	5.68 ± 1.12	3.0	Reddish-pink
ME11	49.34	0.420 ± 0.082	0.059 ± 0.016	14.90 ± 3.10	6.76 ± 0.62	3.0	Reddish-pink
ME12	58.66	0.391 ± 0.069	0.034 ± 0.009	9.22 ± 2.64	6.71 ± 0.44	3.0	Bright red
ME14	53.85	0.377 ± 0.064	0.030 ± 0.006	8.49 ± 2.34	5.63 ± 0.36	3.0	Bright red
MC1	50.54	0.371 ± 0.064	0.039 ± 0.012	11.17 ± 3.88	6.10 ± 0.14	4.0	Red
SFB1	61.55	0.593 ± 0.096	0.041 ± 0.011	7.11 ± 2.15	8.03 ± 1.76	4.0	Red
CRO2	60.89	0.617 ± 0.086	0.047 ± 0.005	7.84 ± 1.27	8.41 ± 1.43	4.2	Red
PTO8	63.32	0.646 ± 0.056	0.072 ± 0.006	6.94 ± 1.26	8.12 ± 1.34	4.5	Red
PDO1	63.73	0.611 ± 0.095	0.066 ± 0.013	11.19 ± 3.30	11.18 ± 2.21	7.0	Deep red
BA1	50.06	0.387 ± 0.071	0.055 ± 0.013	14.72 ± 4.19	14.05 ± 3.28	8.0	Deep red

Table 4. Organoleptic characteristics

Clone	pH	SS (°Brix)	A (%)	RI	Taste evaluation
ME1	4.27 ± 0.028	14.68 ± 1.909	0.205 ± 0.036	72.02 ± 3.458	Good
ME11	4.19 ± 0.141	14.29 ± 0.502	0.195 ± 0.004	75.07 ± 4.313	Good
ME12	3.96 ± 0.085	14.54 ± 0.360	0.201 ± 0.014	71.59 ± 5.558	Good
ME14	4.12 ± 0.269	14.37 ± 0.467	0.253 ± 0.023	56.97 ± 3.281	Good
MC1	3.93± 0.014	14.32 ± 0.876	0.227 ± 0.004	63.00 ± 2.602	Good
SFB1	3.88± 0.000	14.15 ± 1.336	0.304 ± 0.023	46.49 ± 0.933	Good
CRO2	3.87± 0.078	11.94 ± 0.855	0.316 ± 0.040	37.84 ± 2.164	Acceptable
PTO8	3.91± 0.092	14.79 ± 1.782	0.285 ± 0.023	52.33 ± 10.44	Acceptable†
PDO1	3.96± 0.014	14.58 ± 0.820	0.306 ± 0.007	47.71 ± 3.804	Poor
BA1	2.87± 0.028	14.84 ± 1.068	1.910 ± 0.113	7.75 ± 0.071	Poor

†Has a slight sweet-sour flavour.

The seed colour of all varieties is quite attractive for consumers, with deep red attracting more than red, and red attracting more than pinkish red.

Larger fruits have larger seeds, although their largeness is due to a smaller production on the tree.

Typical deviations and the variance coefficient of the analysed parameters are within acceptable limits, and we can therefore be sure that the woody portion index (Wpi) and the total fibre percentage (% TF) are independent of the seed size, as in the results shown in Table 3.

Seed hardness is independent of their size (Ws), weight of the woody part (Wwp) and Wpi.

There is a relationship between TF percentage and seed hardness, with those that have a higher TF percentage generally being harder, as also shown by Melgarejo and Martínez (1992); they found that seeds with a total fibre content of over 9% had hard seeds. This is confirmed for the clones in this study, in which we observed that PDO1 and BA1 had total fibre contents higher than 9%, and their hardness evaluation was 7 and 8 respectively, and therefore they are classified as having hard seeds according to the scale set out for this parameter. Clones ME1, ME11, ME12, ME14, MC1, SFB1, CRO2 and PTO8 have TF contents below 9%, and were classified by the panel of tasters as having soft seeds. The most acceptable clones according to their hardness are ME1, ME11, ME12 and ME14.

There is no correlation between seed hardness and Wpi, nor between Wpi and TF content. This could indicate that seed hardness not only depends on TF content, but also on the nature of the woody portion.

The Wpi should be considered as a secondary index compared with hardness and TF content, as it does not determine difficulty in chewing seeds, although it does help to a certain extent to establish the degree of palatability, which depends on the proportion of woody matter to the whole seed. Purohit (1985) used the percentage of testa in the whole seed (the opposite of Wpi) as a softness index, and therefore in the studied clones the softness index can not be considered as a main factor compared to hardness and TF content.

All the clones in the study are sweet, except BA1 which is sour.

The pH is a parameter which varies within very narrow limits (3.87-4.27) for sweet clones, but for the sour BA1 clone the value is significantly different (2.87), proving to be more acidic than the sweet clones.

The soluble solid content is very similar in all the clones, with CRO2 showing least SS content (11.94%). The SS content for the different clones is close to 15%, which tallies with values given by these and other Spanish clones, cultivated in non-homogeneous conditions by Melgarejo (1993), who sets the SS value between 14 and 16%. Other authors in other countries also obtain similar values for SS content; Ben-Arie *et al.* (1984) carried out studies in Israel on the Wonderful variety, considering it fit for consumption when the SS content was over 15%. For other foreign varieties, such as Manfalouty, Nab El-Gamal and Arabi, values between 14.67 and 17.06% were obtained (El-Sese, 1988).

The evaluable acidity, expressed as the percentage of anhydrous citric acid, is very similar for all the sweet clones (0.195±0.004-0.316±0.040), and significantly higher for clone BA1 (1.910±0.113). These results differ slightly from those obtained by Melgarejo (1993).

For foreign varieties such as Wonderful (which we find sour), the acidity is considered acceptable for consumption when it is lower than 1.8% (Chace *et al*., 1984); when the RI is between 7 and 12 it is considered acceptable for consumption, and when these values are between 11 and 16 it is considered tasty. This variety is similar in its RI to BA1, because when it is harvested late, the RI can reach higher values than those indicated in Table 4.

All the clones which are less acceptable in taste to consumers have a lower ripeness index (BA1, PDO1, PTO8 and CRO2), and poor or acceptable taste evaluations. Clone PTO8 has a slightly sweet-sour flavour which is pleasant for some consumers.

Conclusions

From the non-taste parameters studied, we deduce that:

(i) Seed hardness is decisive for consumer acceptance or rejection.

(ii) Hardness and total fibre content are related. In the clones which we studied, when the total fibre content is over 9% the seeds are classified as hard and are practically inedible, as confirmed by the panel of tasters.

(iii) The Wpi is secondary compared to hardness and total fibre content, although it is useful in measuring the relationship between the woody portion and the whole seed.

(iv) As well as the methods shown to measure hardness and palatability, a press would be recommendable to measure the hardness of the woody portion of pomegranate seeds.

(v) Colour is a very interesting sensory parameter for consumers, although it can be considered as secondary compared to seed hardness.

PTO8 behaves like a sweet clone with a slight sweet-sour flavour (RI = 52.33±10.44), whereas in its original area it behaves like a sweet-sour clone with RI = 23.1 (Melgarejo, 1993). The rest of the varieties are classified for ripeness index and pH the same as in their original areas, with slight variations in the average value of the parameters studied; this variation could be due to differences in the climate or in cultivation.

The pH value shows very little variation for all the sweet clones (3.87-4.27) and is significantly lower for the sour clone BA1 (2.87).

The SS content is close to 15% for all the clones, both sweet and sour, with their evaluable acidity being the factor which determines their classification as sweet or sour. This parameter has values of between 0.195±0.004 and 0.316±0.040% for all the sweet clones, and 1.910±0.113% for clone BA1; this important variation determines the RI value and therefore the classification of a clone as sour, sweet-sour or sweet, as the SS content has small variations for all the clones.

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