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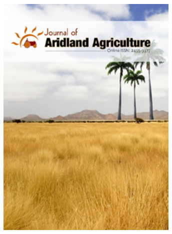
Research Article



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Investigation on the chemical properties of some pomegranate cultivars (*Punica granatum* L.) grown in the Messaad Algerian arid region under drip irrigation

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ABSTRACT

In Messaad a city, of Algeria central region, under arid climate, pomegranate (*Punica granatum* L.) is one of the main fruit crops in agricultural systems after apricot. To examine the ability of transformation and direct consumption, a chemical analysis study of pomegranate juice was conducted on fruits of three pomegranate cultivars: Khadraye KH1, Hamraye HM1, Senin Alouj SL1 from the drip-irrigated Messaad orchards. A study of chemical properties such as pH, titratable acidity TS, total solids TSS, crude fibers CF of pomegranate seed juices was carried out from the fruits of three cultivars. Descriptive statistics, analyze of variance and Principal Component Analysis based on quantitative parameters are used. The cultivars Senin Aloudj SL1 and Khadraye KH1 of Messaad are characterized as sweet with respectively 1.80 and 1.84% of crude fiber content. The cultivar Hamraye HM1 is qualified sour-sweet to sweet with 2.10% crude fiber rate. The SL1 and KH1 are suitable for the consumption in fresh and can be object of food transformation to which is added the therapeutic and medicinal interest that confers the pomegranate tree whereas the HM1 apart from its consumption can be used as excellence to food transformation in various products. The findings presented in this work justify the interest of germplasm variability not only for it fresh consumption and processing, but also in the broad sense of valorization and preserving phytogenetic resources for agriculture and food locally threatened.

KEYWORDS: Climate, Food, Fruit, Juice, Preserving, Processing

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INTRODUCTION

Pomegranate is a fruit tree with deciduous leaves, which in recent years has seen a great expansion in several countries, especially those with a Mediterranean-like climate, where fruit of excellent quality can be obtained (Martínez *et al.*, 2006).

Worldwide pomegranate (*Punica granatum* L.) production has expanded greatly due to recent evidence on fruit health attributes. Pomegranate has always been allocated for fresh consumption, but recently there is a huge demand for industrial processing to produce pomegranate juice and jams. Due to market demands, it has become increasingly important to characterize the different varieties and clones to obtain a high quality product with economical interest (Martínez *et al.*, 2006; Borochov-Neori *et al.*, 2011).

The fact that pomegranate was chosen as not arbitrary, the balance sheets related to production and areas was dedicated to its cultivation show its local and national economic importance and its ecological impact in the development of the land located in the central Algerian steppe, which is known mainly for its poverty. Due to its historical existence in this territory, pomegranate is considered as a terroir product for local Messaad region population, which is the phytogenetic resource to be considered. A few studies about their chemical and genetic diversity have been reported in the literature. Therefore, the aim of present work is to determine the level of pomegranate chemical variation produced in Algerian Messaad region, to evaluate some cultivars that are presenting the most interesting characteristics for agri-food point of view. Thus, a chemical characterization of this pomegranate juice is carried out and several results are derived for their suitability to fresh consumption and processing.

MATERIALS AND METHODS

Study Area

The Messaad region is located in the central steppe zone of Algeria, whereas soils are poor; arid type area with very low organic matter content and low phosphorus levels (Lahouel *et al.*, 2015). The dry season lasts for eight months, from April to November, and the difference between precipitation and temperature is high, indicating a considerable water deficit and a critical situation for agrosystems, making irrigation compulsory. Between the periods 1975-1996 and 1997-2018, the Messaad station shifted from the lower semi-arid bioclimatic stage to the middle arid stage, a transformation essentially due to the change in climatic conditions of precipitation and temperature between the two intervals in favor of a more arid zone (Lahouel, 2022; Lahouel & Belhadj, 2022).

Plant Material and Fruit Juice Samples

This study was conducted during the 2020 pomegranate (*Punica granatum* L.) fruiting season in the Messaad central region of Algeria. The selected plant material is among the main cultivars of pomegranate. The study was conducted on the fruits of three (03) cultivars of Messaad which are: Khadraye de Messaad (KH1), Hamraye de Messaad (HM1) and Senin Aloudj de Messaad (SL1) growing under the same conditions (Climate: Low precipitation less than 260 mm/year and high temperatures over 29 °C, Soil type: Calcimagnesic xeric soil, Irrigation: Drip irrigation) and with the same orchard management. Messaad Cultivars KH1, HM1 and SL1 which have good performances linked to the fruit and the seed show an interesting vigor and give acceptable yields due essentially to the correct cultural practices.

Two trees were harvested at ripening to obtain the fruit sample; 02 kg of each cultivar (On October 12, 2020 for KH1, HM1 on October 4, 2020 and SL1 on September 22, 2020). The fruit samples were then transported to the laboratory soon after harvest, and those pomegranates showing defects (sunburns, cracks, cutsor bruises in peel) were discarded. Afterwards pomegranates were stored in cold storage at a temperature of 5◦C and a relative humidity of 95%. In the following days, Fruits were washed in cold tap water and drained and were manually cut-open and the outer leathery skin was removed. Arils were manually separated from the fruits (990 g of KH1, 1100 g of HM1, and 860 g of SL1 arils were extracted). Juices were obtained by pressing arils and directly processed in the laboratory.

Parameters Studied and Coding, Chemical Analyses Carried out and their Principles

The pH, juice content, total soluble solids, titratable acidity, maturity index and crude fiber content were measured. Three repetitions per cultivar were carried out. Table 1 summarizes the main quantitative studied parameters and the principle chemical analysis carried out in the study.

Table 1: Parameters studied and coding, chemical analyses carried out and their principles

Parameter	Code	Unit	Chemical analysis principle
Juice content	Tj	%	Juice content (Tj), using an electric extractor and a 100 g aril sample
Ph	pH	/	pH is measured directly using a calibrated pH meter (HANNA Instruments-France), by dipping the electrode into the product
Total soluble solids	TSS	°Brix	Total soluble solids (°Brix), determined by an Atago N-20 Refractometer at 20 °C
Titratable acidity	TA	g/L	Titratable acidity: Acid/base titration with NaOH solution
Maturity index	MI	/	Maturity index: MI = (TSS×10/TA)
Crude fibers	CF	%	Determination of crude fibres (Weende method) using a fibre extractor (F_6p_Fiwe)

Statistical Analysis

Statistical analyses were carried out using XLSTAT software (Version 2014 for Windows). A descriptive statistical analysis was followed by an analysis of variance and a principal component analysis (PCA).

RESULTS

The results for Juice content (Tj), pH, total soluble solids (TSS), titratable acidity (TA), maturity index (MI) and crude fibers (CF) from the Messaad's three pomegranate cultivars (SL1, HM1 and KH1) are presented in Table 2.

Juice Content

For juice content, the three cultivars SL1, HM1 and KH1 show relatively similar values: 49.75, 50.49 and 50.42% respectively with non-significant effect (Figure 1).

pH, Titratable Acidity and Total Soluble Solids

For pH, a significant difference among the cultivars is recorded. Figure 2 shows that cultivar SL1 is the most acidic with a value of 4.36, followed by cultivar HM1 (4.62) whereas cultivar KH1 shows the highest value (5.10).

Showing statistically a very high significance between cultivars, Titratable acidity shows various values; the cultivar Hamraye HM1 records the highest value of 0.53 g/L followed by Senin Aloudj SL1 and Khadraye KH1 with 0.38 and 0.30 respectively (Figure 2 & Table 2).

Figure 1 shows that the total soluble solids of cultivar SL1 are highest with a value of 15.12 °Brix followed by cultivar HM1 with a value of 15.01 °Brix. Cultivar KH1 shows the lowest value at 14.30 °Brix. Differences between cultivars are statistically non-significant.

Table 2: Results for the main quantitative parameters studied

Parameter	Tj% ns	pH*	TSS (°Brix) ns	TA (g/L)***	MI***	CF% ns
R^2	0.27	0.83	0.47	0.99	0.98	0.73
Cultivar Pr>F	0.396	0.01	0.147	< 0.0001	< 0.0001	0.019
SL1	49.75±1.09	4.36±0.02	15.12±0.05	0.38±0.01	40.11±0.98	1.80±0.11
HM1	50.49±0.24	4.62±0.25	15.01±0.01	0.53±0.01	28.48±0.56	2.10±0.09
KH1	50.42±0.37	5.10±0.17	14.30±0.81	0.30±0.01	47.51±1.96	1.84±0.09

***Very highly significant, **Highly significant, *Significant, ns Non-significant

Table 3: Correlation matrix

Variables	pH	Tj	TSS	TA	MI	CF
pH	1	0,71	-0,97	-0,48	0,54	-0,06
Tj	0,71	1	-0,52	0,27	-0,21	0,66
TSS	-0,97	-0,52	1	0,68	-0,72	0,30
TA	-0,48	0,27	0,68	1	-1,00	0,90
MI	0,54	-0,21	-0,72	-1,00	1	-0,88
CF	-0,06	0,66	0,30	0,90	-0,88	1

Maturity Index and Crude Fibers

For the maturity index, very highly significantly differences among cultivars are recorded. According to Table 2 and Figure 1, the highest value is recorded for cultivar KH1 at 47.51, while the lowest value is recorded for cultivar HM1 at 28.48.

With statistically non-significant effect, differences in crude fiber content were noted for all three cultivars. Cultivar HM1 recorded a maximum value of 2.10%, while cultivars SL1 and KH1 recorded 1.80 and 1.84% respectively (Table 2).

Correlation Matrix and Principal Component Analysis PCA

Correlation matrix

Table 3 summarizes the correlations between the six parameters studied. pH and TSS are negatively correlated with -0.97. There is no causal factor to report. TSS and TA are positively correlated with 0.68. TA and pH are negatively correlated.

In addition, there is a positive correlation between crude fiber content CF and titratable acidity TA with a value of 0.90. Maturity index MI is negatively correlated with crude fiber content CF and titratable acidity TA with respectively values of -0.88 and -1.00.

Principal component analysis PCA

In Figure 3, the first two factors F1 and F2 on the PCA completely explain the source of variability with 100%, i.e., 61.01% for F1 and 38.99% for F2.

The first F1 component, which represents 61.01% of total variability, is positively linked to pH and MI. The second F2 component, accounting for 38.99% of total variability, is positively related to pH, juice content Tj, crude fiber content CF and titratable acidity TA. The two cultivars HM1 and KH1 are located on the positive axis of F2 and explain their

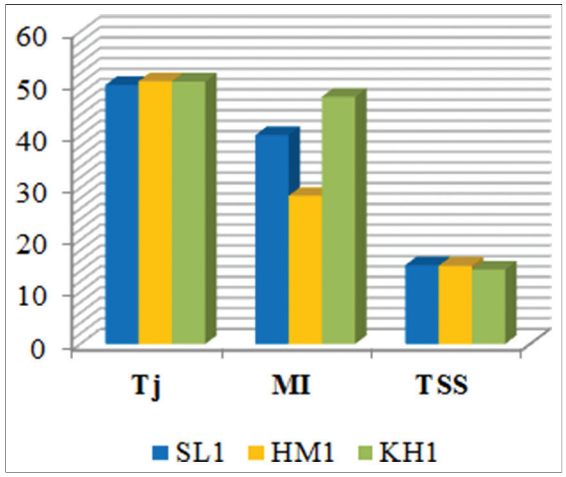

Figure 1: Histogram of Tj, MI and TSS for the three cultivars studied

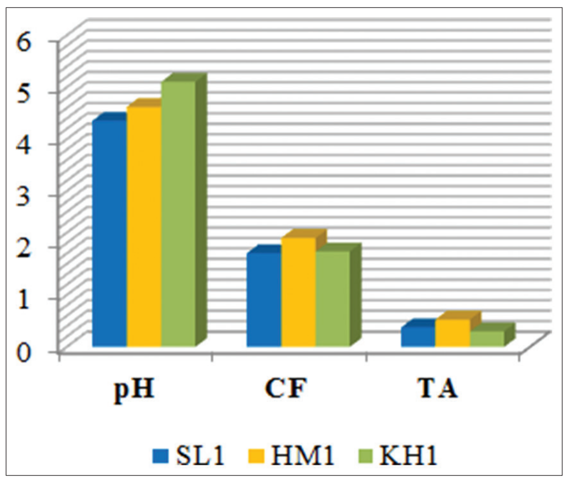

Figure 2: Histogram of pH, CF and TA for the three cultivars studied

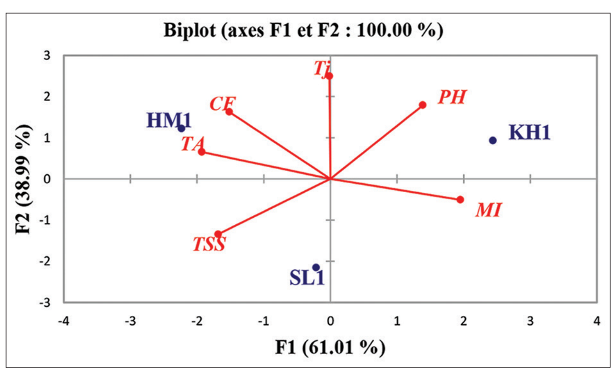

Figure 3: Distribution of cultivar groups according to the variables studied on the Principal Component Analysis (PCA)

differentiation from SL1, which is on the negative axis of the two factors F1 and F2. On the F1 axis, cultivar HM1 registers a negative result, thus distinguishing itself from the other cultivars.

DISCUSSION

Juice Content

One of the most industrially important parameters of pomegranate is its seed juice content. The values obtained in the cultivars studied are significantly close to those found by several authors under different growing conditions. In Spanish varieties, juice content varies from 50.25 (PTO7) to 64.17% in the PTO2 selection (Martínez *et al.*, 2006). Hernández *et al.* (2014) find comparable results for Spanish accessions (between 46 for ME16 and 60.33% for CRO2). Other authors (Al-said *et al.*, 2009) have found percentages ranging from 57.33 to 67.33% for Omani cultivars, 64.67 to 85.50 % for Tunisian accessions (Mansour *et al.*, 2011). As well as for some Indian, South African, Tunisian, and various varieties, which relatively corroborate the present results (Chandra *et al.*, 2012; Fawole & Opara, 2013, 2014; Fawole *et al.*, 2013; El Moujahed *et al.*, 2022). The values of 79.67% reported by Mir *et al.* (2012) are remarkably higher than those reported in this study after various foliar micro-nutrients sprays. However Tehranifar *et al.* (2010) report lower values (26.95-46.55%) for Iranian varieties, while the close ones have been recorded by Moroccan and Greek cultivars (Drogoudi *et al.*, 2005; Hmid *et al.*, 2018). Cultivars with juice content between 50 and 60% are described as medium value according to NRCP (2005) descriptor for Indian varieties. According to Hernández *et al.* (2014), these large differences may not only be due to a genetic variation, but also to different criteria for selecting the optimum harvesting time.

pH, Titratable Acidity and Total Soluble Solids

As shown in Table 2, The pH value obtained for KH1 and HM1 is higher than some reported for Spanish, South African, Omani, Moroccan, Tunisian, Indian, Turkian, Iranian, Egyptian, Pakistani, Georgian pomegranate cultivars (Tehranifar *et al.*, 2010; Ozlekci *et al.*, 2011; Gadže *et al.*, 2012; Caliskan & Bayazit, 2013; Fawole & Opara, 2013, 2014; Ismail *et al.*, 2014; Zaouay *et al.*, 2014; Fernandes *et al.*, 2017; Hota & Dahiya, 2017; Boussaa *et al.*, 2018; Hmid *et al.*, 2018; Usman *et al.*, 2018; Díaz-Perez *et al.*, 2019; Sassi *et al.*, 2020; Meena *et al.*, 2021; El Moujahed *et al.*, 2022), while the pH value obtained for SL1 is closer to the values recorded on some Moroccan varieties such as "Jaune Marrakech" (Legua *et al.*, 2011; Martínez *et al.*, 2012), on Algerian cultivar "Doux de Koléa" (Meziane *et al.*, 2016), on some Indian varieties such as Ganesh and Bhagwa (Hota & Dahiya, 2017) and on some pomegranate cultivars grown in Georgia (Díaz-Perez *et al.*, 2019). Alcaraz-Mármol *et al.* (2017) registered a higher pH than the reported values in the range of 6.02 to 6.78 for cultivars grown in Spain such as Mollar de Elche, Mollar de Orihuela and Valenciana de Albatera.

The TA content, which varies between 0.30 (KH1) and 0.53 (HM1) g citric acid/L, is similar to values reported with Spanish varieties such as PTO4 (0.30), Indian cultivars such as Ganesh (0.39), Bhagwa (0.36) and various ones from South Africa, Croatia, Tunisia, Algeria, Greece and China (subtropical monsoon climate) (Drogoudi *et al.*, 2005; Radunić *et al.*, 2011; Chandra *et al.*, 2012; Fawole & Opara, 2013; Mir *et al.*, 2012; Hernández *et al.*, 2014; Meziane *et al.*, 2016; Liu *et al.*, 2023). However, previous studies have shown that the TA of some local Moroccan varieties, ranging from 2.14 to 4.71 g/L, is higher than those reported in this study (Legua *et al.*, 2011; Martínez *et al.*, 2012). Likewise, Alcaraz-Mármol *et al.* (2017) recorded values ranging from 1.44 to 19.2 for cultivars grown in Spain and values varying from 1.80 to 2.50 for certain Tunisian cultivars (Boussaa *et al.*, 2018). Low values were found for some Omani cultivars (Al-Said *et al.*, 2009). According to the NRCP (2005) descriptor, those with a TA below 0.5 g/L are classified as low, between 0.5 and 1.25 g/L as medium, and above 1.25 g/L as high.

The TSS content of juices from the three cultivars studied which show non-significant difference is comparable to the levels indicated for Spanish, Indian, South African, Omani, Croatian, Tunisian, Iranian and Egyptian cultivars. (Al-Said *et al.*, 2009; Tehranifar *et al.*, 2010; Fawole *et al.*, 2011; Fawole & Opara, 2013; Hernández *et al.*, 2014; Ismail *et al.*, 2014; Zaouay *et al.*, 2014; Haridy *et al.*, 2020; Liu *et al.*, 2023). In studies carried out by Legua *et al.* (2011) and Martínez *et al.* (2012) for Moroccan cultivars, the TSS contents for the Sefri, Ounk Hman, Ruby, Rouge Marrakech and Bouaâdime cultivars varied between 15.30 and 17.60 ◦Brix, while Alcaraz-Mármol *et al.* (2017) found that in twenty cultivars grown in Spain, this varied between 15.1 and 17.7 °Brix. In some Tunisian cultivars, TSS content is higher than values cited here such as Zarat 3 cultivar with 17.42 °Brix value (Boussaa *et al.*, 2018). Akbarpour *et al.* (2009) also report high values for Iranian cultivars compared with the present results, mostly Naderi cultivar (29.83 °Brix) and Khazar-e-Bardeskan cultivar (27.09 °Brix). For other Iranian cultivars, TSS values are lower specifically for Ghojagh cultivar (9.35 °Brix) and Sour cultivar (9.75 °Brix) as indicated by Asadi-Gharneh *et al.* (2017). For some Indian cultivars Hota & Dahiya (2017) reported low TSS values such as for Bhagwa cultivar (11 °Brix) and Ganesh cultivar (13.66 °Brix). Abdel-Sattar *et al.* (2023) proves that applying integrated fertilization from calcium nitrate and ammonium sulphate ($Ca(NO3)2:(NH4)2SO4$ 30%:70%) ratios can increase total soluble solids by 11.2% for the cultivar 'Wonderful'.

According to the reference guideline for commercial juice from the pomegranate variety 'Mollar' based on the AIJN (Association of the Juice and Nectar Industry of the European Union) reference guideline for pomegranate juice (Vegara *et al.*, 2014), which proposed a lowest acceptable value for TSS (14 °Brix) and between 10-15 g/L for the TA content, the three cultivars reported in this study are acceptable and very low acid variety.

Maturity Index and Crude Fibres

For SL1 and KH1 cultivars studied, values of MI are close from those reported for Spanish cultivars PTO3, PTO4, PTO8, CRO1, ME14 and PTO2 (Martínez *et al.*, 2006; Hernández *et al.*, 2014).

Similar results were found for South African cultivars (Fawole & Opara, 2013; Fawole *et al.*, 2013) and for Moroccan cultivars such as Bouaâdime and Jaune Marrakech (Legua *et al.*, 2011; Martínez *et al.*, 2012). According to classification established for Spanish cultivars; sweet cultivars: MI = 31-98; sour-sweet cultivars: MI = 17-24; and sour cultivars: MI = 5-7 (Martínez *et al.*, 2006), cultivars abovementioned are sweet ones. Alcaraz-Mármol *et al.* (2017) claim that cultivars with soft seeds and high sweetness are optimal for fresh consumption, while Hasnaoui *et al.* (2011) stipulate that sour pomegranate, which are not meant for fresh consumption, showed very interesting characteristics too, that could be of great interest in food and health sectors.

For HM1 which registers maturity index of 28.48 is comparable to results recorded for the same parameter on Indian cultivars such as Kabuli Yellow, on Georgian cultivars such as Fleshman and some Croatian cultivars (Radunić *et al.*, 2011; Chandra *et al.*, 2012; Díaz-Perez *et al.*, 2019). These values classify these cultivars as sour-sweet to sweet according to the previous classification. Cultivars identified as sour are those mentioned by Zaouay *et al.* (2014) for the Tunisian cultivar Garsi (MI=6.90) and by Tehranifar *et al.* (2010) for the Iranian cultivar Torsh Shahvar Ferdows (MI=6.17) using the same classification as before. Hasnaoui *et al*. (2011) claim that Citric acid content seems to be the major determinant of sourness in pomegranate. Sweetness is due to a low content of this acid, since sour pomegranate cultivars contained more sugars than sweet ones. These authors proposed the sourness index (SI or MI); the ratio between total sugars and citric acid contents, as reliable scale of classification of pomegranate fruit taste. According to Alcaraz-Mármol *et al.* (2017), MI depends on the cultivar and climatic conditions.

Results of CF presented in this study are in concordance with those obtained in pomegranate cultivars from Spain such as Pinón Tierno de Ojós and Morocco such as Bouaâdime (Legua *et al.*, 2011; Martínez *et al.*, 2012; Alcaraz-Mármol *et al.*, 2015; Alcaraz-Mármol *et al.*, 2017). While Hellen *et al.* (2014) reported a high value for a Tanzanian cultivar Kimara with 4.2% of crude fibers. A number of Spanish and Moroccan cultivars record low crude fiber values of less than 1%, such as Mollar de Elche (Spain) and Sefri (Morocco) (Legua *et al.*, 2011; Martínez *et al.*, 2012; Alcaraz-Mármol *et al.*, 2015; Alcaraz-Mármol *et al.*, 2017). The crude fiber content observed in this study for the three cultivars SL1, HM1 and KH1 are relatively less than the EU/WHO (Hellen *et al.*, 2014) recommended limit of 2.5 g/100 g for fruits. Alcaraz-Mármol *et al.* (2015) stipulates that pomegranate arils contain juice, pulp and seed that is rich in CF and other compounds interesting for breeders and industry.

CONCLUSION

Evaluation of chemical characteristics, in particular pH, TA and MI, revealed great diversity in the local Messaad pomegranate. According to their recorded values, SL1 and KH1 are ranked as sweet cultivars, while HM1 is considered as sour-sweet to sweet. All cultivars studied SL1, HM1 and KH1 are suitable for industrial use, mainly for juice production; however, these pomegranates can be used on their own, without being mixed with other types of fruit. Finally, all Messaad's cultivars SL1, HM1 and KH1 can be used for both purposes processing and fresh market; depending on requirements.

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