

# Sensory preferences for pomegranate arils in Italy: A comparison between different varieties and cultivation sites

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## Abstract

Despite the growing worldwide interest on pomegranate due to its health benefits, little is known about the varieties produced and consumed in Italy. In this context, the aim of our study was to evaluate the factors affecting preferences of Italian consumers towards pomegranate arils of different varieties and cultivation sites. Three samples of pomegranate arils were analysed. Two retrieved from the local (Veneto) agricultural market: one of Turkish origin and one of Sicilian (Italy) origin. The third was retrieved from local producers in Veneto. Selected varieties were 'Wonderful' for Italian samples and 'Hicaz' for Turkish. Samples have been characterized by panel tests and physicochemical analyses. Consumers' preferences were assessed by submitting a questionnaire to 203 college students. Results showed that samples were significantly different in sensory and physicochemical characteristics among varieties and the cultivation sites. Significant differences also emerged on consumers preferences. Wonderful from Sicily was the most preferred sample: highest overall liking (6.65) due to a higher appreciation of sweetness (6.47), juiciness (6.18) and size of the arils (6.57); Wonderful from Veneto was the least appreciated (5.48). Despite this, Wonderful from Veneto showed the highest content of polyphenols. Sensory evaluation of pomegranates arils of different varieties and cultivation sites can effectively predict consumers' preferences in the Italian market. The traits contributing the most to the overall liking are the juiciness of arils, their red colour, firmness and size, while bitterness, seed intrusiveness and astringency are the products' traits that affect preferences the least.

## KEYWORDS

consumers, panel test, physicochemical analysis, pomegranate, sensory analysis

**Abbreviations:** WOND\_S, wonderful variety grown in Sicily; WOND\_V, wonderful variety grown in Veneto.

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## 1 | INTRODUCTION

The pomegranate is one of the oldest edible fruits known and there are more than 500 acknowledged varieties in the world, a few dozen of which are commonly grown. Thus, in the last few years, pomegranate has seen a great diffusion in various countries, especially those with a Mediterranean climate, such as Turkey, Tunisia, Egypt, Spain, Morocco and Italy, where it is mostly produced in Sicily, but also, in Iran, Afghanistan, India, the United States (California), China, Japan and Russia.<sup>1</sup> Due to its ability to grow at high temperatures, the potential for its expansion in arid or semi-arid areas is enormous, in particular where salinity and water deficiency are limiting for other crops.<sup>2</sup> It is harvested from September to early December, depending on the climate and the variety. Due to the growing market demand, it has become increasingly important to identify varieties and crosses of high quality and economic interest.<sup>2</sup>

One of the reasons why pomegranate is gaining importance is that consumers are starting to focus on a healthier diet. Recently, this fruit has been promoted as one of the new 'superfoods', because of its bioactive phytochemical compounds based on ellagitannins, such as punicalagins and punicalins, anthocyanins, gallagic and ellagic acid, and on a distinct profile of fatty acids. All of them could have a positive effect on health, like prevention from serious chronic diseases, such as diabetes and cardiovascular diseases, and, even, from cancer.<sup>3-7</sup> Some scientific publication have shown that the pomegranate and its juice have anti-atherogenic, antioxidant and antihypertensive effects, generally associated with its content of polyphenols, as they contribute to the high antioxidant activity of the fruit.<sup>8</sup> On the other hand, however, the hydrolysable tannins (punicalagin, in particular) are responsible for the astringent sensation typical of the pomegranate. High levels of astringency can alter the overall sensory satisfaction of the consumer.<sup>9</sup> This attribute assumes a relevant role for pomegranate considering that the willingness of consumers to compromise taste for health properties is narrowing more and more.<sup>10,11</sup>

Considering the consumers' acceptance for pomegranate, it should be recalled that red colour is one of the major quality attributes that affects consumers sensory acceptability, and it depends on the quantity of anthocyanins, the molecules responsible for the bright red colour of pomegranate juice.<sup>12</sup>

Despite the increase in the commercial importance of pomegranate and despite its aromatic profile varies significantly among cultivars, as well as among the places where it is grown, relatively little is known about its genetic diversity related to its aromatic traits or consumer preferences.

Concerning sensory analysis and cultivar characterization, the literature shows that there are more researches and analyses for the pomegranate juice, compared to the fruit itself, perhaps for the greater industrial and economic interest that the juice finds, as it is easier to use and consume than the arils. The sensory profile of pomegranate juice has been studied with different analytical and sensorial measurements to define the differences among varieties,<sup>13</sup> post-harvest conditions,<sup>14</sup> climatic effects,<sup>15</sup> adulteration<sup>16</sup> and

process.<sup>17</sup> The taste of the juice is usually measured by a combination of analytical instruments and sensory analysis.<sup>18</sup> Generally speaking, it emerges, from the related literature, that pomegranate juice is generally described with positive attributes such as sweet and sour taste, earthy and fruity smells, while astringency and bitterness have been classified by the tasters as negative attributes. Ferrara et al<sup>1</sup> pointed out that defined smells such as fermented, molasses, vinegar, vinous, woody, apple, berry, cranberry, cherry, grape, beet and carrot can be found in pomegranate. Mayuoni-Kirshenbaum et al<sup>19</sup> claimed that there are between 18 and 23 aroma volatiles responsible for pomegranate aromatic notes. Koppel et al<sup>20</sup> found that consumers from different countries have heterogeneous preferences in terms of preferences of flavour combinations for pomegranate juice. Fermented, metallic, high sourness and too high astringency are considered negative flavour attributes regardless of country. Similarly, Mayuoni-Kirshenbaum et al<sup>21</sup> stated that the most preferred varieties were characterized by high sweetness, moderate to low sourness scores, low bitterness and astringency scores, and medium to soft seeds, while, on the other hand, for their consumers, the least preferred varieties were those very sour and very bitter and with extremely hard seeds. Moreover, Calín-Sánchez et al<sup>22</sup> found out that consumers' overall liking seemed to be related more to sweetness, fresh flavour and fresh odour, while again sourness and astringency are the less appreciated by consumers. On the contrary, pomegranate varieties with high level of sourness could have good opportunity for the industrial use (eg, juice manufacturing) to moderate the excess of sweetness of some fruits<sup>23</sup> or to improve juices health proprieties.

When it comes to fresh fruit consumption, seed hardness is the key factor for consumers' acceptability. If seeds are too hard, consumer satisfaction will be drastically reduced.<sup>24</sup> Mayuoni-Kirshenbaum and Porat<sup>13</sup> demonstrated that sensory quality of pomegranate fruit greatly depends on the following factors: (a) cultivars; (b) degree of ripening; and (c) prolonged storage. The cultivars mainly determine the perception of sour taste, fruity odour and seed hardness mouthfeel. This is in line with evidences derived from the study of Chater et al,<sup>25</sup> in which six cultivars were utilized to determine consumer acceptance compared to the industry standard, 'Wonderful'. There were significant differences among cultivars for all traits assessed by the panellists: aril colour, sweetness, tartness, seed hardness, bitterness and overall desirability. There were also differences in acceptance among consumers for Wonderful cultivar depending on whether it was grown on the coast or in the inland. Therefore, this investigation indicated that site and cultivar have significant effects on fruit quality traits, which affected consumer acceptance of pomegranate fruit. This means that, in line with what Mayuoni-Kirshenbaum and Porat<sup>13</sup> said, the locus in which the plant grows also affects consumers' acceptability.

Despite the growing spread of pomegranate worldwide due to its health benefits and the stressed importance of characterize the cultivars traits preferred by consumers, little is known about the varieties produced and consumed in Italy. In Italy, the cultivation of pomegranate has at the moment a limited but growing diffusion. The

Italian Institute of Statistics (ISTAT) estimate in 2019 the total area under pomegranate in 1234 ha (Table 1), while in 2013, the total area was only 133 ha. The main growing regions are Sicily and Apulia (respectively, 386 and 374 ha of total area), followed by Veneto, which is growing (210 ha).

In this context, the aim of our study is to assess consumers' preferences for pomegranate arils by comparing products produced in a newly grown area in Italy (namely in Veneto) with two products widely available on the local market: (a) Wonderful variety grown in Sicily and (b) Hicaz variety grown in Turkey. The study characterizes sensory and physicochemical characteristics of the products, and allows making a prediction on which attributes influence consumers overall liking for pomegranate in a growing market like Italy.

## 2 | EXPERIMENTAL PROCEDURES

The study has been performed between October and November 2019 in three steps: panel test, physicochemical analyses and consumer test.

### 2.1 | Sensory analysis

Sixteen students, five men and eleven women in the age range of 20-30 years, with a university training in sensory analysis, were recruited as panellists. During the panel selection, judges were subjected to three tests: a test for the discrimination of four tastes (salty, sweet, sour and bitter) in model solutions, a test for the recognition thresholds (sweet, acid and bitter tastes) and a test for the intensity of astringency.

For the discrimination of the tastes, each candidate had to try a set of 10 dilutions of reference substances, corresponding to the four specific tastes. In addition, in one of the cups, there was only water. The samples were identified by a three-digit code and randomized; the participants had to recognize and indicate the correct taste. For the second test, five cups containing different increasing concentrations of the reference substances for each taste (sweetness, sourness and bitterness) were presented to each judge in a random order, as can be seen in Table 2. Every judge had to indicate

the sample at which he perceived every taste. For the last test, the candidates were given five cups containing water solutions of tannic acid at increasing concentration. They were asked to identify which cup had the same concentration of tannic acid of an additional cup with an unknown level of tannic acid.

As regards the score awarded, in the first test judges could score a maximum of 10 points. In the second one, they could score a maximum of nine points (three points per taste); the highest score (three points) was given to the judge who recognized the taste at the lowest concentration. In the third one, the judges obtained a maximum of one point if they indicated the correct concentration of tannic acid. To select the most suitable judges, the minimum score to be selected was 12 points out of 20, chosen by the panel leader.

The training required three sessions of 2 hours each. In the first session, judges were trained on two sensory aspects: texture (firmness, crunchiness, juiciness and seed intrusiveness), using a commercial pomegranate as standard, and taste, with standard taste solutions (Table 2). In the second one, judges were trained on three sensory aspects: kinaesthetic characteristics (size and colour of the arils), taste and aroma. Young red wine, apple juice and red fruit juice were used to become familiar with typical aromas of pomegranate.<sup>26</sup> Judges were instructed on taste and aromas also in the last session.

Sensory evaluation was carried out in the Sensory Laboratory in compliance with the UNI-ISO standard 8589.<sup>27</sup>

Samples were retrieved the day before the training of the panel and have been kept at refrigeration temperatures. They were randomly selected without any visible physical defects and with as similar shape and size as possible within the same cultivar. The studied samples were as follows:

- WOND\_V: Wonderful variety, produced by a local (Veneto, Italy) co-operative;
- WOND\_S: Wonderful variety produced in Sicily (Italy) bought from the local wholesales market, considered the standard commercial competitors;
- HICAZ: Hicaz variety produced in Turkey origin bought from the local wholesales market.

The shelling of pomegranates and the preparation of samples took place in the sensory laboratory, 1 hour before the arrival of

**TABLE 1** Area and production of pomegranates in Italy (2019)

	Total area (ha)	Production area (ha)	Total production (t)	Harvested production (t)
Italy	1234	1033	14 446	13 956
Region				
Sicily	386	371	4038	4018
Apulia	374	258	3926	3897
Veneto	210	210	4046	3702
Latium	81	61	960	879
Calabria	70	58	593	584
Emilia-Romagna	49	32	182	182

Source: ISTAT, estimated area and production of agricultural crops.

**TABLE 2** List of the attributes and definitions used to explain sensory characteristics of pomegranate

Attributes	Meanings of the attributes	Reference/standards used
<b>Appearance</b>		
Size	Size of the arils	
Colour	Colour of the arils, ranging from white to purple, almost black	
<b>Aroma</b>		
Apple	A sweet, light, fruity, somewhat floral aromatic commonly associated with processed apple juice and cooked apples	Apple juice
Red wine	Sharp fruity alcohol-like aromatics associated with young red wine	Young red wine
Red fruits	The sweet, fruity, slightly sour and sharp aromatics commonly associated with red fruits, such as strawberry, blackberry, blueberry, raspberry, cherry and red and black currant	Red fruits juice
<b>Taste</b>		
Sweetness	The fundamental taste factor associated with a sucrose solution	12.5-25-37.5-50 g/L of sucrose
Sourness	The fundamental taste factor of which citric acid in water is typical	5-10-15-20 g/L of citric acid
Bitterness	The fundamental taste factor of which caffeine or quinine is typical	5-10-15-20-25 g/L of caffeine
<b>Texture</b>		
Firmness	The degree of force required in the initial bite of an aril with the molars until it ruptures or erupts	
Crunchiness	The perception of hearing a noise like the sound of something firm being crushed	
Juiciness	The quality of containing a lot of juice	
Seed intrusiveness	Perception of the woody part compared to the perception of the whole pomegranate aril	
Astringency	The dry puckering mouthfeel associated with an alum solution	5-10-15-20 g/L of tannic acid

Source: Our elaboration based on Mayuoni-Kirshenbaum et al.<sup>26</sup>

the judges. The fruits have been washed with water, and the arils have been manually separated from the rind. The three samples (pomegranate arils) were served into odour-free, disposable 80 mL

covered plastic cups at room temperature; every cup was randomly labelled with a three-digit code and contained about twenty arils. Order and number assigned to each sample were randomized. Unsalted crackers and water were used to clean palates between samples.

A descriptive sensory analysis was conducted by using 9-point structured scales, where the value one indicated the lower intensity of the attribute, while nine indicated the greater intensity; the value five represented the central term, identified as standard. A list of 13 descriptors was generated using previously published lexicons as guides.<sup>20,28</sup> The assessed sensory attributes were as follows: size and colour of the arils for the appearance; apple, red wine and red fruits for the aromas; sweetness, sourness, bitterness for the taste; firmness, crunchiness, juiciness, seed intrusiveness, astringency for mouthfeel sensations. The descriptors, their meanings and the reference standards used are presented in Table 2.

## 2.2 | Physical and chemical analyses

### 2.2.1 | Sample preparation

Morpho-pomological measurements of fruits, arils and seeds characteristics and chemical analyses were carried out on samples of 20 mature fruits per type. The selected fruits were initially washed with cold distilled water, drained and then cut. The arils were hand-separated from the skin and pith and collected to form a homogeneous mixture for each product, then thoroughly mixed.

The following arils characteristics were analysed: size, colour, texture, total soluble solids, titratable acidity, total polyphenols and tannins and chromatographic analysis.

### 2.2.2 | Size

For the size attribute, the maximum diameter and length (mm) of the arils were measured by a digital caliper (Mitutoyo) with a 0.01 mm accuracy.

### 2.2.3 | Colour

The colour was measured using the CIE  $L^*$ ,  $a^*$ ,  $b^*$  coordinates with a calibrated Minolta CM-600d, with a reflectance spectrum in the range from 400 to 700 nm.

The total anthocyanins concentration was determined with the Ribéreau-Gayon method<sup>29</sup> based on a calibration curve prepared from a mixture of anthocyanins of *Vitis vinifera* (Uvikon 930-Kontron Instrument). The test provided the total anthocyanins in mg/L. Then, the anthocyanins characterization was implemented through a chromatographic analysis,<sup>30</sup> as described below.

## 2.2.4 | Texture analysis

For the seed intrusiveness, a woody portion index was measured as seed weight/aril weight ratio (mg/mg); weight of arils and seeds was determined with a precision weighing device (AND HR-120 METTLER TOLEDO) with an accuracy of 0.0001 g. For the analysis, 30 replications were performed, because of the heterogeneity of the arils, as confirmed by Szychowski et al.<sup>24</sup> Texture profile analysis (TPA) and puncture test (PT) were conducted for each product, using a TEXTURE ANALYSER TA.TX plus (Stable Micro System), with a load cell capacity of 50 N. The TPA was performed according to Rosenthal.<sup>31</sup> Two compression cycles were made, and the following texture profile attributes were evaluated: hardness (N), cohesiveness (mm), springiness (mm) and chewiness (N).

All these measurements were associated with the attributes used to represent the texture of an aril in the evaluation by the trained panel: firmness and crunchiness.

## 2.2.5 | Total soluble solids and titratable acidity

For the sweetness, the sugar content or total soluble solid (TSS, °Brix) from pomegranate juice was measured using a digital refractometer, calibrated with distilled water at 20°C.

For the sourness, titratable acidity (TA) and pH were detected. TA was measured by diluting 10 mL of fresh juice with 50 mL of distilled water and titrated with 0.1 mol/L NaOH to an end point of pH 8.2 using an automatic titrator (Tritrator titrex ACT2, Steroglass Srl), while the pH values were determined at room temperature using a calibrated pH-meter (EC/TDS/C meter, PC7 XS Instruments).

## 2.2.6 | Polyphenols and tannins

The total phenolic (TP) concentration was determined in triplicate using Folin-Ciocalteu method as described by Makkar et al.<sup>32</sup> The value obtained provided the total polyphenols concentration in mg/L, expressed as gallic acid equivalents.

The total tannins concentration was determined, using the Bate-Smith method<sup>33</sup> (Uvikon 930-Kontron Instrument). The obtained value provided the total tannins content in g/L.

## 2.2.7 | Chromatographic analysis (HPLC)

Analysis of anthocyanins and ellagitannins was performed as described by Simonato et al.<sup>34</sup> on a C18 Kinetex column (4.6 mm × 150 mm, 5 µm; Phenomenex) using an HPLC system (Nexera, Shimadzu) equipped with a PDA detector (SPD-M20A). The mobile phases were 0.1% v/v of TFA in water (solvent A) and 0.1% v/v of TFA in methanol (solvent B). The gradient programme was as follows: 5% B for 2 minutes, followed by 5%-12% B in 5 minutes,

12%-55% B in 31 minutes, and 55%-100% B in 1 minute. After washing for 2 minutes with solvent B, the column was re-equilibrated with 95% solvent A. The flow rate was 1.0 mL/min. The injection volume was 20 µL, and the column temperature was set to 37°C. Identification and quantification were performed at 520 nm for anthocyanins and 350 nm for ellagitannins. Before injection, the juices, manually extracted from the three sample (see Section 2.2.1 for more details), were centrifuged in an Eppendorf tube (10 minutes at 14 000 g) and the centrifuged supernatant was passed through a 0.45 µm cellulose acetate filter (Advantec, CA).

Quantification for each compound was obtained comparing each peak area against the standard curve for the reference solutions: cyanidin chloride (Cy) for the anthocyanins and ellagic acid for the ellagitannins.

## 2.3 | Consumer evaluation

The consumer test was used to assess consumer liking of the pomegranate samples for the different attributes described by the panel, through 9-point Just-About-Right (JAR) scales and 9-point hedonic scales. The JAR scale was used for the evaluation of the taste (sweet, sour and bitter) and astringency. The scale ranged from one, representing an insufficient presence of the attribute (eg, 'too little sweet'), to nine, corresponding to an excessive intensity (eg, 'too much bitter'). The central value, five, represented the point in which the attribute was 'just about right', which means that had the right intensity. The morphological traits (size and colour of the arils) and the texture traits (firmness, juiciness and seed intrusiveness) were evaluated through a 9-point hedonic scale, ranging from one, 'unattractive/unpleasant', namely totally negative, to nine, 'attractive/pleasant', namely totally positive, while five was neither like nor dislike. The overall liking was evaluated through a 9-point hedonic scale, ranging from one, 'I don't like it at all', to nine, 'I like it very much'.

About 20 arils, manually extracted 1 hour before the test, were served during the test into odour-free plastic cups with 80 mL capacity, coded with three-digit random numbers. The survey was administered to 203 students aged between 18 and 35 years. Since in Italy pomegranate is a product still not very widespread and little consumed in general and since young people are generally more inclined to try new products than older consumers,<sup>35</sup> we considered young people as target consumers, selecting students and university employees for the test.

Participants were instructed on how to use the scale; they were also allowed to re-taste and change their previous scores, if needed. Water and unsalted crackers were provided to consumers to rinse their palate before and between tasting. Lastly, consumers answered questions related to their sociodemographic profile (age, gender, education level, income and number of family members), as well as questions measuring their consumption patterns and frequency purchasing about pomegranate and fruits, in general.

## 2.4 | Statistical analysis

The analysis of differences on physicochemical values started verifying the ANOVA assumptions: normality distribution of the residuals and homoscedasticity. All the variables have a normal distribution of the residuals. When heteroscedastic distribution was detected, the Welch ANOVA was performed instead of the classical ANOVA. Tukey-Kramer test and Games-Howell post hoc tests were performed, respectively, used ( $P$ -value < .05). The same approach has been adopted for the analysis of the panel test data. According to McDonald<sup>36</sup> in the case of balanced samples, for non-normally distributed variables (ie, 'wine', 'crunchiness' and 'colour') the classical ANOVA and Tukey-Kramer post hoc is applied when the distribution is homoscedastic (ie, 'crunchiness' and 'wine') and Welch ANOVA and Games-Howell post hoc test for 'colour' variable.

Referring to the consumers evaluation, according to McDonald,<sup>36</sup> the Likert scales are considered as continuous variable, in line with the coherent literature in consumers' studies.<sup>35,37</sup> Given to the structure of the data (balanced design and large sample size), the classical ANOVA is applied with homoscedastic variables and Welch ANOVA if heteroscedasticity was detected. Tukey-Kramer test and Games-Howell post hoc tests were performed, respectively. The statistical analyses have been performed with IBM SPSS Statistics 26 and Rstudio 1.2.5042.

## 3 | RESULTS AND DISCUSSION

### 3.1 | Consumer evaluation

Descriptive statistics on consumers' habits are presented in Table 3. The 44.3% of respondents affirmed that they consume pomegranate

**TABLE 3** Frequency and ways of pomegranate consumption by the consumers (n = 203)

	Consumers (%)
Frequency of consumption over the last year	
Never	15.3
Only once	28.1
Several times a year but less than once a month	44.3
At least once a month	10.8
At least once a week	1.5
Purchased product	
Whole pomegranate	63.6
Ready-to-eat arils	36.4
Preferred ways of consumption	
Fresh arils	74.9
Juice	15.3
Preparations in the kitchen	5.4
Other	4.4

Source: Our elaboration.

several times a year but less than once a month. The favourite form of purchased product was the whole fruit, rather than the ready-to-eat arils (63.5%) preferring the consumption of fresh arils (74.9%).

Table 4 shows mean value and standard deviation of the nine sensory traits and the overall liking, assessed by consumers for the three samples of pomegranate differing for cultivar and origin: Wonderful from Veneto (WOND\_V), Wonderful from Sicily (WOND\_S) and Hicaz from Turkey (HICAZ). There is a significant difference ( $P$ -value < .05) in the following characteristics: sourness, bitterness, firmness, juiciness, seed intrusiveness, size and colour of

Attribute	WOND_V	HICAZ	WOND_S	$P$ -value
Sweetness	6.20 ± 2.10 <sup>a</sup>	6.40 ± 2.10 <sup>a</sup>	6.47 ± 2.05 <sup>a</sup>	.410
Sourness	6.17 ± 1.94 <sup>a</sup>	6.48 ± 2.11 <sup>ab</sup>	6.77 ± 1.90 <sup>b</sup>	.010
Astringency*	6.77 ± 1.97 <sup>a</sup>	6.51 ± 2.34 <sup>a</sup>	6.86 ± 2.06 <sup>a</sup>	.252
Bitterness	5.33 ± 2.49 <sup>a</sup>	5.81 ± 2.59 <sup>b</sup>	5.88 ± 2.63 <sup>b</sup>	.001
Firmness	5.55 ± 1.63 <sup>a</sup>	5.73 ± 1.66 <sup>a</sup>	6.15 ± 1.58 <sup>b</sup>	.001
Juiciness	5.15 ± 1.74 <sup>a</sup>	6.28 ± 1.58 <sup>b</sup>	6.18 ± 1.68 <sup>b</sup>	<.001
Seed intrusiveness*	3.67 ± 1.74 <sup>a</sup>	4.52 ± 1.96 <sup>b</sup>	4.64 ± 1.81 <sup>b</sup>	<.001
Size*	5.73 ± 1.79 <sup>a</sup>	7.13 ± 1.29 <sup>b</sup>	6.57 ± 1.45 <sup>c</sup>	<.001
Colour*	6.36 ± 2.02 <sup>a</sup>	6.33 ± 1.81 <sup>a</sup>	7.18 ± 1.44 <sup>b</sup>	<.001
Liking	5.48 ± 1.60 <sup>a</sup>	6.36 ± 1.33 <sup>b</sup>	6.65 ± 1.38 <sup>c</sup>	<.001

Note: Values expressed in means ± standard deviation. Means not sharing a letter within a row are significantly different ( $P$ -value < .05). To test the statistically significant differences, we used ANOVA or Welch ANOVA(\*) and Tukey-Kramer test or Games-Howell(\*) post hoc tests, respectively.

Abbreviations: HICAZ, Hicaz pomegranate; WOND\_S, wonderful pomegranate from Sicily; WOND\_V, wonderful pomegranate from Veneto.

Source: Our elaboration.

**TABLE 4** Mean preference scores, standard deviation and  $P$ -values of attributes from consumer evaluation, based on sample effect

the arils and overall liking of the product. From the post hoc tests, it appears that for the attributes bitterness, juiciness and seed intrusiveness, WOND\_V has a significant difference with both WOND\_S and HICAZ. For the bitterness, WOND\_V has obtained the lowest score (5.33), while HICAZ and WOND\_S have similar scores (respectively, 5.81 and 5.88). Sourness seems to be more appreciated in the sample WOND\_S, with a score of 6.77, while WOND\_V is the one in which it is less appreciated, with 6.17. Juiciness is more appreciated in HICAZ, with 6.28, while it is less appreciated in WOND\_V (5.15). Regarding seed intrusiveness, this attribute was averagely evaluated as negative (<5). The highest rating is associated with WOND\_S, with an average score of 4.64, slightly higher than HICAZ (4.52). WOND\_V got the worst rating for this attribute (3.67). For the firmness and colour of the arils, WOND\_S has a significant difference with both WOND\_V and HICAZ. WOND\_S obtained the highest rating for the firmness, 6.15, while WOND\_V the lowest one, 5.55. As for the colour, WOND\_S is much higher (7.18) than the other two samples, WOND\_V and HICAZ, which obtained, respectively, 6.36 and 6.33. For the size of the arils, a significant difference is observed between all three samples WOND\_V, HICAZ and WOND\_S. HICAZ obtained the best rating for size (7.13), which is higher than the other two, with 5.73 for WOND\_V and 6.57 for WOND\_S. Although there is no significant difference for

sweetness and astringency, the sample WOND\_S has obtained the best scores for these two attributes: 6.47 for sweetness and 6.86 for astringency.

The overall liking has a significant difference for all three WOND\_V, HICAZ and WOND\_S samples. The sample that received a higher liking is WOND\_S, with an average rating of 6.65, against 6.36 for HICAZ and 5.48 for WOND\_V.

### 3.2 | Physicochemical analysis

Table 5 shows mean value and standard deviation of the physical and chemical analyses of the three samples of pomegranate. As regards the visual appearance, results underlined that, when it comes to the size of the arils, a significance difference was observed among WOND\_S and WOND\_V and HICAZ. The first one had, also, the higher length (9.98 mm) and the higher width (6.91 mm), while HICAZ had the smaller size: 8.94 mm of length and 6.36 mm of width. The Sicilian Wonderful also shows the lowest seed/aril ratio (0.14) which is important when the consumer eats pomegranate arils because if the seed is too hard or too big and thus too difficult to chew, consumer satisfaction can be drastically reduced.<sup>24</sup> This could explain why WOND\_S obtained a higher

**TABLE 5** Physical and chemical analyses of three samples of pomegranate, differing for cultivar and origin

Attribute	Analysis	WOND_V	HICAZ	WOND_S	P-value
Size of the arils (mm)	Length*	9.14 ± 0.60 <sup>a</sup>	8.94 ± 0.53 <sup>a</sup>	9.98 ± 0.94 <sup>b</sup>	.001
	Width	6.51 ± 0.49 <sup>a</sup>	6.36 ± 0.43 <sup>a</sup>	6.91 ± 0.52 <sup>b</sup>	.004
Colour*	Colorimeter*	1.75 ± 1.21 <sup>ab</sup>	2.42 ± 1.48 <sup>a</sup>	1.04 ± 0.43 <sup>b</sup>	.024
	Total anthocyanins (mg/L)	1445.72 ± 70.38 <sup>a</sup>	688.63 ± 13.63 <sup>b</sup>	873.25 ± 37.86 <sup>c</sup>	.002
Seed intrusiveness (mg/mg)	W/w seed/aril	0.19 ± 0.03 <sup>a</sup>	0.17 ± 0.02 <sup>ab</sup>	0.14 ± 0.02 <sup>b</sup>	.026
Texture					
Hardness (N)*	Puncture test	0.12 ± 0.05 <sup>a</sup>	0.10 ± 0.03 <sup>a</sup>	0.11 ± 0.03 <sup>a</sup>	.100
	TPA*	2.74 ± 1.42 <sup>a</sup>	1.33 ± 0.54 <sup>b</sup>	2.39 ± 1.04 <sup>a</sup>	<.001
Cohesiveness (mm)	TPA	0.70 ± 0.07 <sup>a</sup>	0.75 ± 0.09 <sup>b</sup>	0.70 ± 0.07 <sup>a</sup>	.004
Springiness (mm)	TPA	0.14 ± 0.06 <sup>a</sup>	0.24 ± 0.66 <sup>a</sup>	0.15 ± 0.06 <sup>a</sup>	.592
Chewiness (N)*	TPA	1.96 ± 1.12 <sup>a</sup>	1.02 ± 0.46 <sup>b</sup>	1.70 ± 0.85 <sup>a</sup>	<.001
Gumminess (N)*	TPA	1.56 ± 0.95 <sup>a</sup>	0.82 ± 0.43 <sup>b</sup>	1.35 ± 0.77 <sup>a</sup>	<.001
Sweetness (°Brix)	Refractometer	14.6	15.1	18.4	
Sourness	pH	3.13	3.28	3.30	
	Titrateable acidity (% citric acid)	2.56	2.02	1.63	
Bitterness (mg/L in GAE)	Total polyphenols	2118.88 ± 187.51 <sup>ab</sup>	1612.31 ± 184.08 <sup>a</sup>	2476.58 ± 311.97 <sup>b</sup>	.012
Astringency (g/L)	Total tannins	0.57 ± 0.06 <sup>a</sup>	0.66 ± 0.05 <sup>a</sup>	0.88 ± 0.03 <sup>b</sup>	<.001

Note: Means not sharing a letter within a row are significantly different ( $P$ -value < .05). To test the statistically significant differences, we used ANOVA or Welch ANOVA(\*) and Tukey-Kramer test or Games-Howell(\*) post hoc tests, respectively.

Abbreviations: HICAZ, Hicaz pomegranate; WOND\_S, wonderful pomegranate from Sicily; WOND\_V, wonderful pomegranate from Veneto.

Source: Our elaboration.

score in the consumer test for seed intrusiveness, while WOND\_V obtained the lowest score as confirmed by the highest seed/aril ratio (0.19). For the colour attribute, a significant difference was found, and the colorimeter recorded the highest score in the HICAZ sample (2.42), while the Wonderful sample from Sicily had the lowest (1.04). Nevertheless, analysing the total anthocyanins content (responsible for the bright red colour of pomegranate) with the Ribéreau-Gayon method, it was discovered that WOND\_V had the greatest content in anthocyanins (1445 mg/L) and HICAZ had the lowest (688 mg/L).

Similar results have been recorded through chromatographic analysis. In particular, as shown in Table 6, the content of Cyanidin 3-glucoside (Cy3) is significantly higher in WOND\_S (196.08 mg/L) than in WOND\_V (160.95 mg/L) or in HICAZ (132.20 mg/L). The amount of Cyanidin 3,5-diglucoside (Cy3,5) in HICAZ (219.34 mg/L) was significantly lower than in WOND\_V (349.81 mg/L) or in WOND\_S (362.31 mg/L). The same happens for Delphinidin 3-glucoside (Dp3), which was present in lower amount in HICAZ (63.22 mg/L) than in WOND\_V (252.55 mg/L) or in WOND\_S (217.80 mg/L). The content of Delphinidin 3,5-diglucoside (Dp3,5) and Pelargonidin 3,5-diglucoside (Pg3,5) was significantly different in all the three samples. In particular, the highest content of Dp3,5 was detected in WOND\_V (426.25 mg/L) and the lowest in HICAZ (164.74 mg/L). Pg3,5, on the other hand, was more abundant in WOND\_S (99.71 mg/L), where its content was three times higher than in HICAZ (33.24 mg/L). These results can be seen more clearly in Figure 1, where it is possible to observe that there is homogeneity in the content of anthocyanins within the same variety, despite the different origin. In fact, it can be observed that the two Wonderful samples have a higher anthocyanins content than HICAZ, except for Pg3.

In the supporting information, a typical HPLC chromatogram showing the anthocyanins peak for WOND\_V sample can be seen (Figure S1).

Recovering the results of the consumers, we can observe that the favourite one considering the colour has been the WOND\_S, this could mean that the consumers prefer in the arils a more brilliant red colour rather than a dark red one, tending to the violet. As regard the texture measurements, there was no significant difference only in springiness of the three samples; however, HICAZ resulted the one with the higher value (0.24 mm). It presented also the higher cohesiveness (0.75 mm). WOND\_V got the highest score in all the other texture characteristics (hardness: PT = 0.12 N, TPA = 2.74 N, chewiness = 1.96 N, gumminess = 1.56 N). Looking at consumer results, people seem to prefer arils having such attributes with lower values, as WOND\_S took the highest rating. Analysing the refractometer results, it was found that the content of soluble solids (TSS) was higher in WOND\_V (18.4 °Brix) than in other samples. Being the sample with the highest sweetness rating, consumers may have preferred a sweeter pomegranate. Sourness has been measured by pH-meter and with titratable acidity (TA, % of citric acid): WOND\_S had the highest pH value (3.30) and the lowest titratable acidity value (1.63), namely it was the least sour sample. For this reason, it was found to be the sample with the highest rating in terms of liking for sourness from a consumers' perspective. As evidence of this, WOND\_V, on the other hand, had the lowest pH value (3.13) and the highest one for TA (2.56), and obtained the lowest score of sourness by the consumers. WOND\_V had the least overall desirability, likely because it was sour and had hard and big seeds.<sup>25</sup> In the present study, total polyphenol content was determined by Folin-Ciocalteu method and a notable variation is observed. The content ranged from 1612 mg/L (HICAZ) to 2476 mg/L (WOND\_S), which got the highest score

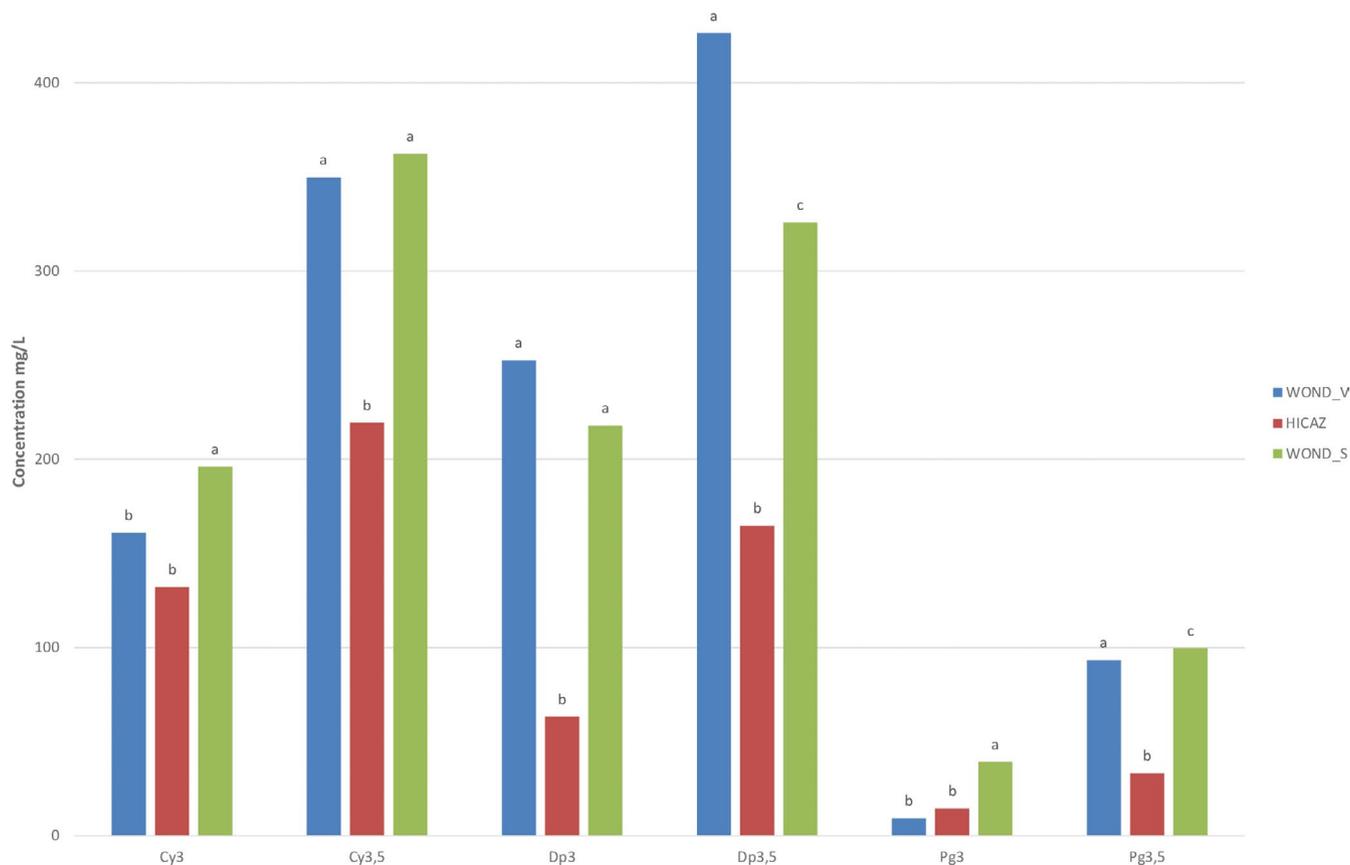
Compound	WOND_V	HICAZ	WOND_S	P-value
<b>Anthocyanins</b>				
Cy3	160.95 ± 2.12 <sup>b</sup>	132.20 ± 9.81 <sup>b</sup>	196.08 ± 18.75 <sup>a</sup>	.002
Cy3,5	349.81 ± 13.82 <sup>a</sup>	219.34 ± 33.97 <sup>b</sup>	362.31 ± 8.39 <sup>a</sup>	<.001
Dp3	252.55 ± 7.86 <sup>a</sup>	63.22 ± 26.61 <sup>b</sup>	217.80 ± 15.98 <sup>a</sup>	<.001
Dp3,5	426.25 ± 4.76 <sup>a</sup>	164.74 ± 45.01 <sup>b</sup>	325.91 ± 12.65 <sup>c</sup>	<.001
Pg3	9.33 ± 0.76 <sup>b</sup>	14.43 ± 5.65 <sup>b</sup>	39.36 ± 2.36 <sup>a</sup>	.001
Pg3,5	93.22 ± 6.50 <sup>a</sup>	33.24 ± 34.82 <sup>b</sup>	99.71 ± 73.99 <sup>c</sup>	<.001
<b>Ellagitannins</b>				
Punicalagin A	14.00 ± 1.35 <sup>a</sup>	12.59 ± 0.39 <sup>a</sup>	14.89 ± 2.15 <sup>a</sup>	.240
Punicalagin B	18.30 ± 0.98 <sup>b</sup>	36.67 ± 5.75 <sup>a</sup>	22.72 ± 3.78 <sup>b</sup>	.003
Ellagic acid	29.50 ± 0.33 <sup>a</sup>	18.74 ± 2.34 <sup>b</sup>	30.81 ± 2.14 <sup>a</sup>	<.001

**TABLE 6** Mean scores, standard deviation and *P*-values of anthocyanins and ellagitannins peak area (mg/L) based on sample effect

Note: Means not sharing a letter within a row are significantly different (*P*-value < .05). To test the statistically significant differences, we used ANOVA and Tukey-Kramer post hoc test.

Abbreviations: Cy3, cyanidin 3-glucoside; Cy3,5, cyanidin 3,5-diglucoside; Dp3, delphinidin 3-glucoside; Dp3,5, delphinidin 3,5-diglucoside; HICAZ, Hicaz pomegranate; Pg3, pelargonidin 3-glucoside; Pg3,5, pelargonidin 3,5-diglucoside; WOND\_S, wonderful pomegranate from Sicily; WOND\_V, wonderful pomegranate from Veneto.

Source: Our elaboration.



**FIGURE 1** Anthocyanins profiles of different pomegranate samples. Cy3, cyanidin 3-glucoside; Cy3,5, cyanidin 3,5-diglucoside; Dp3, delphinidin 3-glucoside; Dp3,5, delphinidin 3,5-diglucoside; HICAZ, Hicaz pomegranate; Pg3, pelargonidin 3-glucoside; Pg3,5, pelargonidin 3,5-diglucoside; WOND\_S, wonderful pomegranate from Sicily; WOND\_V, wonderful pomegranate from Veneto. Within each component, bars not sharing a letter are significantly different ( $P$ -value < .05)

for bitterness in the consumer test. There was a significant difference between HICAZ and WOND\_S. To measure astringency, the total tannins content was analysed using the Bate-Smith method. It emerges that there is a significant difference between WOND\_S and the other two products. WOND\_S has the highest content in tannins (0.88 g/L) and WOND\_V the lowest one (0.57 g/L). Despite the higher tannin content, WOND\_S achieved the highest rating in the consumer test. This could be partly explained by the fact that, although the Bate-Smith method was used to detect the total tannins content, this method measures only proanthocyanidins. On the other hand, it is well known that in pomegranate juice a share of the tannins belong to the ellagitannin family, which is not detected by the Bate-Smith method. For this reason, ellagitannins analysis in HPLC was also performed. As reported in Table 6, it emerged that the content of punicalagin B was significantly lower in WOND\_S (22.72 mg/L) than in HICAZ (36.67 mg/L). However, the ellagic acid content was higher in WOND\_S (30.81 mg/L) and in WOND\_V (29.50 mg/L) than in HICAZ (18.74 mg/L).

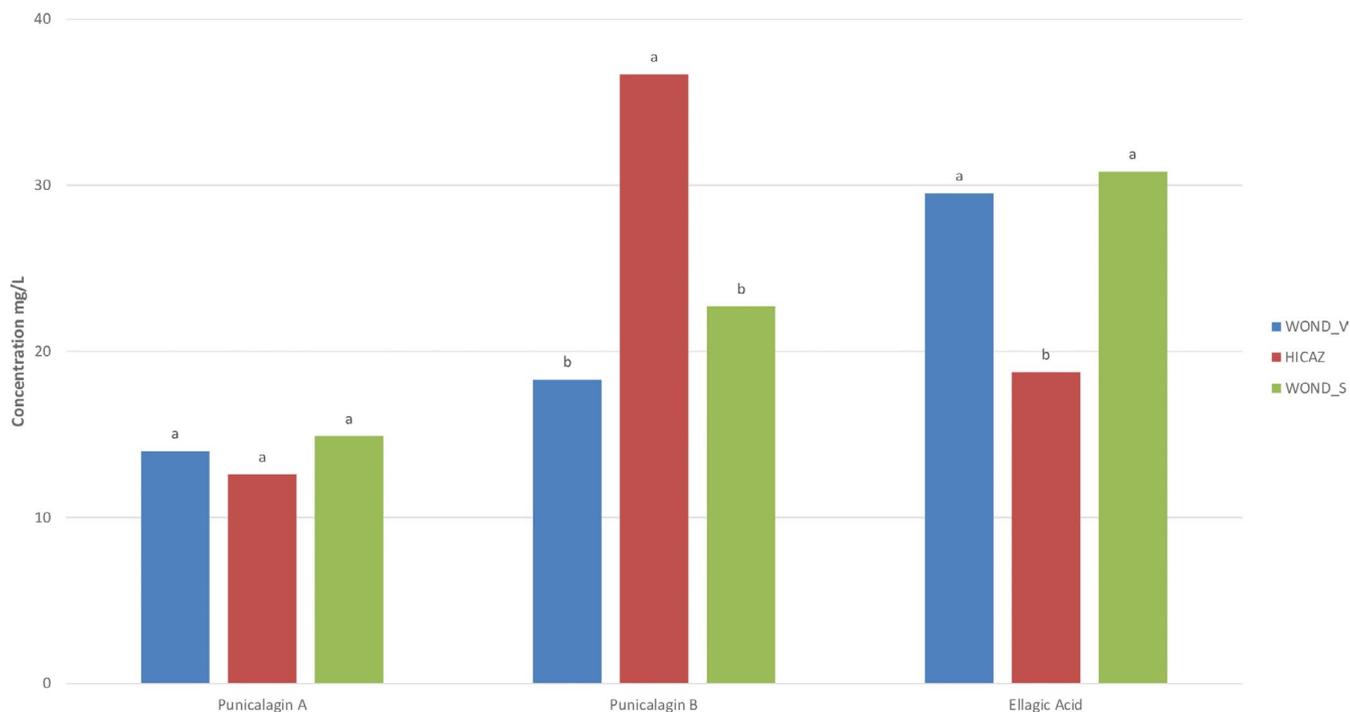
As can be seen in Figure 2, the two different varieties, Wonderful and Hicaz, differ in the content of the ellagitannins, since the ellagic acid prevails in the samples WOND\_S and WOND\_M and the punicalagin B in HICAZ sample, while there is no significant difference in the content of punicalagin A between the samples.

In the supporting information, a typical HPLC chromatogram showing the ellagitannins peak can be seen (Figure S2).

### 3.3 | Sensory analysis

Thirteen attributes describing appearance (size and colour of the arils), aromas (apple, red wine and red fruits), taste (sweetness, sourness and bitterness), texture (firmness, crunchiness, juiciness and seed intrusiveness) and mouthfeel sensations (astringency) were generated to characterize the sensory profile of the three types of pomegranate, as it can be seen in Table 7. 'Apple', 'Wine', 'Red fruits' and 'Crunchiness' attributes, evaluated by the trained panel, were not included in the consumer test. For these attributes, however, there was no significant difference and, for aromas, the judges recorded rather low mean values (below 4, despite a 9-point scale). For the attribute 'Astringency', also, there was no significant difference, as in the consumer test; despite that, the WOND\_V obtained the highest value (3.38), while the WOND\_S had the lowest one (2.50).

Sweetness has higher value in the WOND\_S sample (6.06) and lower in the WOND\_V (3.81), as confirmed by the TSS obtained from chemical analyses. Although in the consumer test there is no significant difference for this attribute, WOND\_S got the highest score (which is



**FIGURE 2** Ellagitannins profile of different pomegranate samples. HICAZ, Hicaz pomegranate; WOND\_S, wonderful pomegranate from Sicily; WOND\_V, wonderful pomegranate from Veneto. Within each component, bars not sharing a letter are significantly different ( $P$ -value < .05)

Attributes	WOND_V	HICAZ	WOND_S	$P$ -value
Sweetness	$3.81 \pm 1.8^a$	$4.31 \pm 1.70^a$	$6.06 \pm 1.29^b$	<.01
Sourness	$5.31 \pm 1.01^a$	$3.69 \pm 1.01^b$	$2.88 \pm 1.1^c$	<.01
Astringency	$3.38 \pm 1.45^a$	$3.19 \pm 1.33^a$	$2.50 \pm 0.63^a$	.104
Bitterness	$2.38 \pm 0.72^a$	$1.75 \pm 0.68^b$	$1.75 \pm 0.6^b$	.013
Apple	$2.87 \pm 0.96^a$	$2.69 \pm 1.25^a$	$2.63 \pm 1.50^a$	.834
Wine	$1.88 \pm 0.89^a$	$2.31 \pm 1.35^a$	$1.87 \pm 0.89^a$	.517
Red fruits	$2.63 \pm 1.54^a$	$3.06 \pm 1.53^a$	$3.69 \pm 1.58^a$	.162
Firmness	$4.81 \pm 1.38^a$	$4.38 \pm 1.31^a$	$4.44 \pm 0.96^a$	.558
Crunchiness	$5.75 \pm 1.06^a$	$5.06 \pm 1.24^a$	$5.13 \pm 1.20^a$	.183
Juiciness	$4.12 \pm 1.15^a$	$4.75 \pm 1.06^{ab}$	$5.31 \pm 1.08^b$	.014
Seed intrusiveness	$7.25 \pm 0.68^a$	$6.50 \pm 0.73^b$	$6.25 \pm 0.93^b$	<.01
Size	$3.31 \pm 0.60^a$	$3.88 \pm 0.72^b$	$4.19 \pm 0.54^b$	<.01
Colour*	$7.44 \pm 0.81^a$	$6.73 \pm 0.89^b$	$6.88 \pm 0.62^c$	<.01

Note: Means not sharing a letter within a row are significantly different ( $P$ -value < .05). To test the statistically significant differences, we used ANOVA or Welch ANOVA(\*) and Tukey-Kramer test or Games-Howell(\*) post hoc tests, respectively.

Abbreviations: HICAZ, Hicaz pomegranate; WOND\_S, wonderful pomegranate from Sicily; WOND\_V, wonderful pomegranate from Veneto.

Source: Our elaboration.

**TABLE 7** Mean scores, standard deviation and  $P$ -values of sensory attributes from sensory analysis, based on sample effect

the sweetest sample according to chemical and sensory analysis). As for sourness, the sourest sample according to the panel was WOND\_V, with a rather higher value (5.31) than the other two (HICAZ = 3.69; WOND\_S = 2.88), confirming the chemical analysis. This sample

obtained the lowest score for sourness from consumers, thus further demonstrating that consumers seem to prefer a sweeter and less sour fruit. For bitterness, WOND\_V obtained the highest value (2.38) while HICAZ and WOND\_S had the same average value, equal to 1.75.

However, from chemical analysis, WOND\_S had the highest content in total polyphenols, the molecules responsible, among others, of bitterness. Although the consumer test did not reveal a significant difference for the bitterness, the most appreciated sample for this attribute was WOND\_V; this discrepancy in the results could be due to interactions with other tastes, as stated by Keast and Breslin.<sup>38</sup> The values attached to juiciness are found to be higher in WOND\_S (5.31) and lower in WOND\_V (4.12); comparing these results with consumer reviews, we observe that the highest score was assigned to HICAZ, immediately followed with a slight difference from WOND\_S. This would seem to indicate that consumers still prefer a fruit with greater juiciness.

Observing the seed intrusiveness, a negative attribute, the panel indicated WOND\_V as the sample with the most intrusive seed (7.25) while WOND\_S has the least intrusive one (6.25). This confirms the chemical analysis, where similar results have been obtained. Moreover, in the consumer test, we found that the highest rating is associated with WOND\_S. It follows that consumers likely prefer a fruit with a less intrusive seed. According to the panel results, we found that WOND\_S had the arils with the larger size (4.19) while WOND\_V was the one with the smaller arils (3.31). This is in line with results from laboratory analysis that underline that WOND\_S presented the larger-sized arils. However, consumers have assigned a higher rating to HICAZ, from the medium-small arils. Finally, for colour, panel results suggest that the highest score in colour intensity is given to WOND\_V (7.44) while HICAZ had the lightest colour arils (6.73); this is in line with chemical analysis, observing the content of total anthocyanins, that is a colour indicator, highest in WOND\_V and lowest in HICAZ. In fact, the consumers have assigned the lowest rating to HICAZ; therefore, they seem to prefer a darker colour in the arils.

### 3.4 | Factors affecting preferences

The importance of pomegranate and its consumption is growing in Italy, as in other parts of the world, thanks to its important nutritional contributions to the human diet. Despite that, very little is known about consumers' sensory preferences for pomegranate fruits.<sup>21</sup> In addition, as mentioned earlier, according to ISTAT data from 2019, in Italy the area dedicated to the cultivation of pomegranate is increasing, in particular in Veneto, one of the newly cultivated areas for pomegranate.

For these reasons, this study focuses on the comparison of the Wonderful pomegranate grown in Veneto (WOND\_V) with two samples representing the commercial standards available in the local market: WOND\_S (same cultivar but different site: ie, Sicily) and HICAZ (different cultivar and foreign origin: ie, Turkey). WOND\_S was chosen in accordance with Chater et al,<sup>25</sup> who considered Wonderful as a market standard. HICAZ was chosen due to its market prevalence and low price. Indeed, according to Lawless et al,<sup>39</sup> consumers tend to assign higher scores of overall liking to the products consumed more frequently and prefer to buy products they have already experienced, underlying the importance of taste and familiarity in purchasing choices and overall liking score. Concerning price, our study evaluated the overall liking assigned to the different

products independently from consumers' willingness to pay. Due to the relevance of price in pomegranate choice in Italy, as highlighted by Stiletto et al,<sup>35</sup> we expected that previous consumption experiences may lead consumers to place higher overall liking to HICAZ.<sup>39</sup>

From consumer test, we found that Wonderful pomegranate from Sicily (WOND\_S) was the most preferred sample by consumers as it reached the highest overall liking value. In relation to the other samples, WOND\_S is characterized by a greater sweetness, juiciness and size of the arils. The significant differences in the results of chemical and sensory analysis suggest that site and cultivar may have a significant effect on fruit quality traits, which affect consumer preferences and acceptance. This is in line with evidences pointed out by Chater et al<sup>25</sup> that found different levels of sourness and sweetness, as well as different overall consumer acceptance, among Wonderful pomegranate grown on the coast compared to the same cultivar produced on inland, with cooler climate conditions.

In this framework, it is not wondered to found that Wonderful pomegranate from Veneto (WOND\_V) was the least (after WOND\_S and HICAZ) in terms of overall acceptance, probably due to its high levels of sourness, astringency and seed intrusiveness. This is in accordance with Mayuoni-Kirshenbaum et al<sup>19</sup> and Mayuoni-Kirshenbaum et al,<sup>21</sup> which stated that the least preferred varieties were very sour and very bitter and had extremely hard seeds. As regards bitterness, chemical analyses showed that WOND\_V from Veneto was second in total polyphenol content, which are the main chemical compounds that elicit this taste, as stated by Lesschaeve and Noble.<sup>40</sup> This is in accordance with the scores of the panel, who identified it as the most bitter sample.

Given its sensory characteristics, it could be a problem for commercial growers producing WOND\_V to compete with WOND\_S producers in the fresh fruit market. However, as reported by Alcaraz-Mármol et al,<sup>23</sup> the cultivars too sour for the fresh consumption can be profitably destined to the processing industry, especially in the juice manufacturing field. As suggested by Carbonell-Barrachina et al,<sup>41</sup> these varieties could be used in the juice industry to dampen the excessive sweetness of some varieties. From a consumer's perspective, indeed, also the excessive sweetness is considered a negative feature of the products and this could lead to a decrease in their willingness to pay. Moreover, also the issue of excessive astringency was a typical trait of WOND\_V, as can be seen from the chemical analyses, which showed that this sample had a highest content in total tannins, strictly correlated with the astringent perception.<sup>39</sup> It can be partly solved by adopting an appropriate juice extraction technique. According to Mayuoni Kirshenbaum et al,<sup>26</sup> consumers' liking and acceptance for the juices obtained from separated arils are significantly higher than those for juice extracted pressing the whole fruit. These results suggest that consumers' acceptability, subordinated to the negative product features such as sourness or astringency, could be different according to the nature of the product. Polyphenols (which include also tannins) and anthocyanins are not only responsible of the astringency sensation, but they are closely linked to the renowned health properties of pomegranate and the red colour of husk and arils. In this context, it should be recalled that

the success of pomegranate lies properly in its health benefit properties and it is often used as an additional product in juice blends not only because of its sensory profile but also because of its antioxidant properties, which ensure better preservation, intended as technological features,<sup>42</sup> and greater palatability by consumers.

In this sense, due to the growing interest in healthy diets, it may be interesting to study the product WOND\_V more in depth with regard to potential health properties and antioxidant activity. Indeed, our results highlight the highest content in total anthocyanin (1445 mg/L). These data are comparable with the study of Adiletta et al,<sup>43</sup> carried out on pomegranates cultivated in Southern Italy, where again the Wonderful is the variety with highest content of anthocyanins (555 mg/L) and total polyphenols (1494 mg GAE/L). Similarly, Mena et al<sup>44</sup> found out that Wonderful cultivars had the largest number of anthocyanins (ranged from 280 to 1080 mg/L). What is more, according to our results, is that the same variety presents different levels of anthocyanins according to the different site and climatic zone of Italy. The higher anthocyanin content in WOND\_V could be due to the cultivation area and the local climate conditions that may improve the content of such fruit quality traits. In fact, anthocyanins are more easily degraded at higher temperatures, as for example in Sicily (region in which WOND\_S was cultivated), rather than in Veneto (region of WOND\_V). This is confirmed by Schwartz et al,<sup>15</sup> who described differences in the chemical composition of the arils of 11 cultivars grown in Mediterranean and desert climates in Israel. The level of total anthocyanins was significantly higher in fruits obtained from the Mediterranean area compared to those from the desert area. However, although WOND\_V is the richest variety among those analysed in anthocyanin, it should be stressed that explaining these characteristics on the label may not be enough to guide consumers' purchasing choices towards this product, considering that the willingness of consumers to compromise taste for health is narrowing more and more.<sup>10,11</sup>

## 4 | CONCLUSIONS

In the present study, we looked for the factors affecting preferences of Italian consumers towards pomegranate arils of different varieties and cultivation sites. This has been possible thanks to three different types of analysis: sensory characterization through a trained panel, physicochemical analyses and a questionnaire for consumer preferences.

To sum up, we found that site and cultivation area affect consumers' perception and acceptance. Wonderful pomegranate from Sicily (WOND\_S) was the most preferred sample, with the highest overall liking (6.65). Juiciness, arils size, colour and firmness are the attributes that affect the most the overall liking. Sourness, bitterness and astringency are the product features that are negatively correlated to consumers' acceptance. However, even products that do not fully reflect the needs of consumers as fresh products, as in the case of Wonderful pomegranate from Veneto (WOND\_V), could be used in the food chain as processed products (such as juices). Therefore, our results highlight that even others less-known varieties grown in new production areas, such as Veneto, can have commercial potential. Further studies could be carried out on other local varieties in

Veneto, such as Parfianka, S. Pietro, Mondrone, Dente di Cavallo, Mollar and Valenciana, to have a more appropriate overview of pomegranate cultivation and its consumers' acceptance.

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## CONFLICT OF INTEREST

The authors have declared that no competing interests exist.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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