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Research article

Physicochemical and sensory characteristics of plums accesses (*Prunus salicina*)

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Abstract: The selection of new fruit cultivars is a challenge for researchers and producers. Sensory attributes and physicochemical aspects should be simultaneously considered in the selection of new cultivars. However, it is difficult to correlate these two types of analysis because there is no appropriate technique of sensory analysis for the sampling conditions of fruit. The aim of this study was to employ the Free Choice Profile to describe sensory plum accesses and to correlate the accesses sensorial attributes to the physicochemical analysis in order to support the selection of new potentially commercial cultivars. Fruits from eleven plum accesses cultivated in the experimental fields of the Agronomic Institute of Paraná-IAPAR, PR, Brazil, were harvested. Color parameters, weight, volume, pH, titratable acidity and soluble solids content of five fruits from each plum access were evaluated. Free Choice Profile was used to describe sensory characteristics. A physicochemical evaluation in combination with Free Choice Profile sensory analysis allowed for a complete description of accesses, providing subsidies for selection and future cultivar launches, thus ensuring benefits for researchers, producers and consumers.

Keywords: Free Choice Profile; sensorial description; principal component analysis; hierarchical cluster analysis; titratable acidity; soluble solids; color; new cultivars

1. Introduction

Brazil is the world's 3rd largest producer of fresh fruits, with approximately 43 million tons, of which 3% are exported and the remainder is used domestically for "*in natura*" consumption or processing [1]. The Brazilian fruit and vegetables consumption is 36.5 kg per capita per year, which is below the daily consumption of 400 g or 120 kg per capita per year, as recommended by the World Health Organization (WHO) [1]. According to the Ministry of Agriculture (MAPA) and the National Commission of Fruits of the Agriculture Confederation of Brazil (CNA), this low consumption is due mainly to the unhealthy eating habits of the population. The lack of information about benefits consumption of fruits and the high costs of production and commercialization, handling and transport of fruits also contributed to low consumption [1]. The cultivation of plums in Brazil takes place in temperate regions, and the production is still insufficient to meet demand of domestic market and then requiring imports of large volumes from countries such as Argentina, Chile, Spain and other European countries [2]. The production of temperate fruits in Brazil, including plums, was approximately 7.5% of the total production of fruit and corresponded to 8% of the overall fruit cultivation area in 2011 [3].

The poor adaptation to local climatic conditions and diseases of current cultivars are the major limiting factors for the expansion of production of plums in Brazil. Thus, the main objectives of breeding programs for this fruit are to find cultivars highly adapted to different growing regions resistant to diseases, and still meeting the physicochemical and sensory characteristics demanded by consumers [3]. However, the method of achieving this goal requires many tests, which may or may not result in the expected success of the cultivars. Breeding programs for plums must therefore conduct an efficient selection of cultivars and require new tools to characterize the quality of agricultural products [4].

The quality of fruits such as plums, strawberries and peaches is related to external characteristics, such as the size and color of the pulp and skin, which are associated with chemical composition [5]. Total titratable acidity and soluble solids content are analyses commonly used to indicate quality and to account for consumer acceptability of fruits [6].

Sensory attributes are expressions of the chemical composition (sugar, acids, phenolics, compounds) and physical characteristics (hardness, diameter, density bulk and color, for example) of the fruits, and some of these characteristics can be described by correlations between chemical composition and sensory attributes [4,7]. Sensory evaluation of fruits is not an easy task due to the variable characteristics of fruits from the same collection [5,8]. Currently sensory attributes are the responsibility of the researchers, who rely on their own perceptions of quality attributes as indicated by consumers [7,9]. Often, sensory acceptance tests are conducted, but these tests do not provide information about the aroma, flavor, texture and color attributes, which are all significantly influenced by the chemical compounds, such as acids, sugars and phenols and volatile compounds, which are present in fruit [10].

Among the several techniques of sensory analysis, we highlight a descriptive technique, the Free Choice Profile (FCP). The FCP provides information about the most important attributes in describing fruit [7] and other foods [11,12]. This technique allows for the development of a concordant terminology, and it reduces analysis time by eliminating training and taster selection, which are required in conventional analyses.

The aim of this study was to employ the FCP to describe sensory plum accesses and to correlate the sensory attributes to the physicochemical traits in order to support the selection of new cultivars possessing the sensory characteristics that are most accepted by consumers.

2. Materials and Methods

2.1. Plant materials and field experiments

The plum fruits were collected from the experimental fields of the IAPAR—Agronomic Institute of Paraná, Ponta Grossa, PR, Brazil, which is located in the temperate climate region of Paraná state (25°05′S, 50°09′W, 840 m a.s.l.) during the 2015 harvest. From the experiments of the germplasm bank of the fruit plant breeding program, accesses were chosen that presented a higher yield and better resistance to disease and pests. Fruit from 12 plum accesses were hand harvested at the stage of physiological maturity (visualized by the mature aspect of the skin). All harvested fruits, approximately 500 g from each access, were kept under refrigeration until analysis.

2.2. Measurement of the physical properties

Color parameters were measured using CIE illuminant C, with a 10° angle and a CIE standard observer (Minolta CR-410, Japan). A reading from the skin of five whole fruits of uniform ripening at diametrically opposite sides was performed [6]. Five fruits of uniform size and ripening were selected and weighed in an electronic balance and then lowered into a graduated measuring cylinder containing 1000 mL of water. After the fruit was submerged, the increase in volume was noted and represented the fruit volume [13].

2.3. Measurement of the chemical properties

The pulp and skin of five fruits were grounded in a blender and filtered through a fine mesh cloth to obtain homogenized juice. Titratable acidity, pH and soluble solids content were determined from the homogenized juice. The pH was determined using a potentiometer (Metrohm, mod. 744). Titratable acidity (TA), such as malic acid (%), was determined by titrating 2 mL of juice and 10 mL of distilled water with 0.1 N NaOH to pH 8.2 using an autotitrator [5]. The calculation of the percent acidity was carried out using the equation: malic acid (%) = [(mL NaOH × 0.1 × 0.067)/2 mL] × 100. The soluble solids content (SSC) was measured using a hand refractometer (RT-90 ATC) at 20 ºC (ºBrix). Once the SSC and TA contents were measured, the SSC/TA ratio was determined.

2.4. Sensory analysis

2.4.1. Selection of samples and experimental conditions

For the sensory analysis, fruits with visually similar skin coloring, similar size and absence of defects or spots were selected. The fruits were presented on plastic plates coded with three-digit numbers and served at room temperature. Mineral water was served to rinse the mouth and clean the palate between samples.

Sensory evaluations were carried out in individual sensory booths at room temperature and ambient day-light in a tasting room. Sample preparation and sensory analysis were conducted in the Physiology Laboratory of the IAPAR.

2.4.2. Panelists and sensory evaluation

Sensory evaluations were carried out by a panel of eleven panelists who were selected due to their interest in sensory analysis and preference for plums. The panelists were between 26 and 65 years old, and 80% had taken at least one college course. Panelists had already participated in sensory evaluations of other foods using the FCP sensory technique; thus, in this study, panelists were given an explanation about plum evaluations. The attribute terms for the evaluation of the plum samples were developed by the panel using the Repertory Grid method [7]. The panelists were instructed to record the similarities and differences between a pair of plums in order to describe the sensory attributes of appearance, aroma, flavor and texture of the samples, which were selected for their distinct sensory characteristics. After this procedure, an individual score sheet and a glossary based on the generated individual descriptors were prepared by the team leader. Individual score sheets ranged from 1 to 10, anchored at the ends with intensity expressions for each attribute [14]. In each session, 2 to 4 samples were evaluated based on how the sample plums were harvested and as soon as the maturation point for consumption was reached.

2.5. Data analysis

Pearson's correlation, principal component analysis (PCA) and hierarchical cluster analysis (HCA) using the Euclidean distance and Ward's algorithm to identify the formation of groups among the accesses were applied to the recorded physicochemical data.

In the FCP sensory technique, panelists have the freedom to use their own vocabulary to describe and evaluate the samples. The values of panelists' attributes given to the same samples were initially subjected to translation, scaling and rotation procedures by applying the generalized Procrustes analysis (GPA) [15-17]. After these procedures, the average configurations of the samples were obtained and then subjected to principal component analysis [17]. The PCA promotes the formation of new dimensions from the matrix that was formed by the samples and attributes from each panelist. In the space formed by the first-two components, the attributes and samples are designed and can be interpreted. In the present study, twelve columns (corresponding to the number of samples) were inserted, and the number of lines ranged from 13 to 23 according to the number of attributes from each panelist. All statistical analyses were performed using software XLSTAT [18].

3. Results and Discussion

3.1. Physicochemical evaluations

Fruit quality can be determined by chemical and physical parameters that are correlated with fruit sensory attributes and that are crucial for consumer acceptability [5,19,20]. In the present study, plum accesses presented variability in their physicochemical characteristics, as shown in Table 1.

Table 1 Description of physicochemical characteristics, maximum, minimum, standard deviation, and average of each plum accesses.

Access	Weight (g)	Volume (g/cm^3)	pH	SSC (Brix)	TA (% of malic acid)	SSC/TA ratio	L*	a*	b*
74-01-04	44.23	146	2.83	11.4	2.47	4.62	29.94	18.91	4.27
10-02-x	76.20	176	3.08	10.2	1.85	5.52	31.89	19.65	10.45
70-91-27	38.20	38	4.02	11.8	0.62	19.18	27.48	19.98	8.12
10-02--06	41.48	41	2.99	8.9	1.85	4.80	29.26	13.63	1.03
35-01-05	44.29	45	2.97	8.9	1.97	4.52	36.26	25.80	16.19
74-01-09	39.58	39	2.96	11.3	1.98	5.70	29.22	23.78	8.24
77-92-6	29.12	29	3.10	12.8	1.70	7.52	31.34	21.09	9.95
41-91-54	27.94	28	3.01	12	1.60	7.51	28.77	21.76	6.04
BY-81-5850	46.29	47	3.94	10.8	0.64	16.78	27.10	22.45	8.37
BY-81-5580	46.65	47	3.75	10.9	0.92	11.91	26.82	19.79	5.88
74-01-03	26.37	126	4.00	7.8	0.89	8.74	28.41	28.66	9.54
84-95-273	45.81	141	3.71	11.3	1.15	9.80	39.94	13.59	16.00
Minimum	26.37	28	2.83	7.80	0.62	4.52	26.82	13.59	1.03
Maximum	76.20	176	4.02	12.80	2.47	19.18	39.94	28.66	16.19
Average	42.18	75.25	3.36	10.68	1.47	8.88	30.54	20.76	8.67
Standard deviation	13.01	54.62	0.47	1.47	0.60	4.84	3.93	4.36	4.36

SSC: soluble solids content, TA: Titratable acidity.

Correlations among some characteristics were observed (Table 2). A significant negative correlation was found between acidity and pH (−0.96) and between acidity and SSC/AT (−0.89). Significant positive correlations were observed between pH and SSC/AT (0.85), and between lightness (L*) and component b* (0.77).

Table 2. Pearson correlation matrix between the physicochemical variables.

Variables	Weight	Volume	pH	SSC	TA	SSC/TA	L*	a*	b*
Weight	**1.00**								
Volume	0.54	**1.00**							
pH	−0.13	0.02	**1.00**						
SSC	−0.10	−0.25	−0.12	**1.00**					
TA	0.17	0.18	**−0.96**	0.02	**1.00**				
SSC/TA	−0.11	−0.26	**0.85**	0.27	**−0.89**	**1.00**			
L*	0.22	0.37	−0.21	−0.05	0.28	−0.37	**1.00**		
a*	−0.32	−0.15	0.13	−0.30	−0.11	0.01	−0.28	**1.00**	
b*	0.15	0.24	0.18	−0.06	−0.13	0.02	**0.77**	0.25	**1.00**

Bold values are different from 0 with a significance level alpha = 0.05.

Multivariate analysis (PCA and HCA), where samples were evaluated considering all variables simultaneously were conducted to demonstrate the relationship between physicochemical characteristics

(Figures 1 and 2) and consumer sensory perceptions (Figure 3). The PCA results are shown graphically as a biplot (Figure 1). PC1 accounted for 35% of the variability found among plum accesses, and it was negatively correlated to the pH (−0.85) and SSC/AT ratio (−0.91), and positivity to TA (0.92). Similar to PC1, PC2 accounted for 23% of the variability and had a positive correlated to fruit weight (0.45), volume of fruit (0.60), lightness (0.64) and component b* (0.79). The SSC and component a* variables had low correlation to both PC1 and PC2.

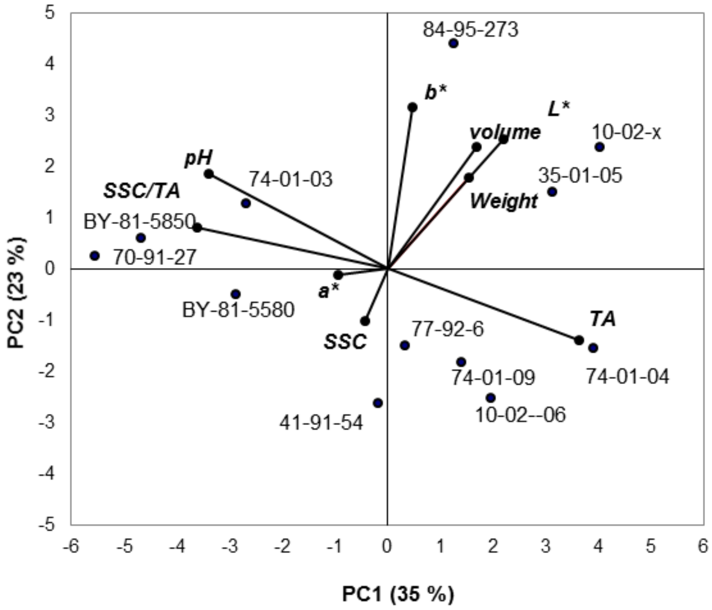

Figure 1. Principal component analysis of the physicochemical characteristics of plum accesses.

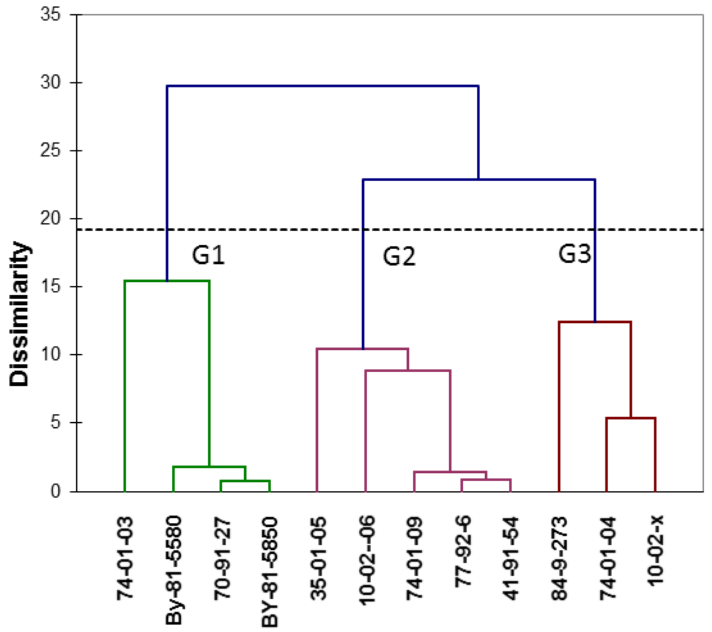

Figure 2. Hierarchical cluster analysis of physicochemical characteristics of plum accesses.

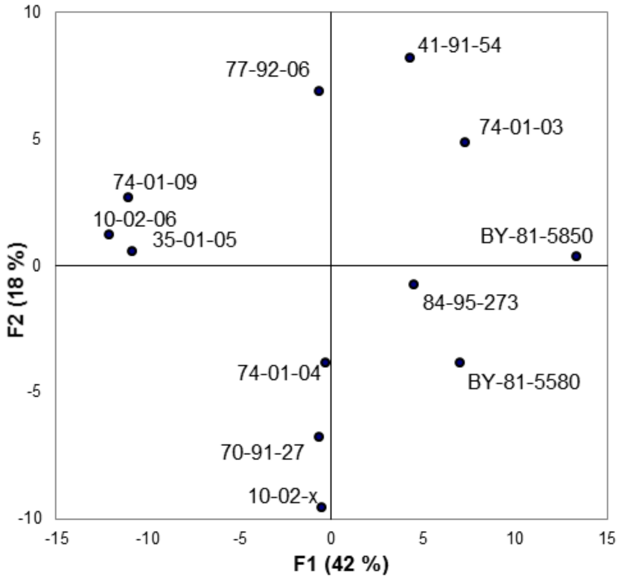

Figure 3. Configuration consensus of sensory attributes of the plum accesses.

Plotting 12 plums accesses in the space formed by the two most important principal components (PC1 = 35%, and PC2 = 23%, Figure 1) allowed to associate to the plum accesses with their physicochemical characteristics. This plotting segregated the plum accesses into two groups in the horizontal direction (PC1). The accesses located in the left side of Figure 1 (74-01-03, BY-81-5850, 70-91-27, BY-81-5580 and 41-91-54) were separated by negative PC1 (PC1−), which was associated with the high pH values and SSC/AT and lower TA values. These characteristics are very important for fruit fresh consumption [6].

The pH values of plum accesses in this group showed variation from 3.01 to 4.02, and plums within this pH range of values are considered low-acid fruits. The pH data that were obtained are higher than those found in the literature [21], where pH values from 2.72 to 3.84 were noted in evaluations of commercial plums from different origins.

The SSC/TA ratio is usually used as an indicator of ripeness. In this study, apparently ripe plums had values between 7.51 and 19.18, showing great variability for this characteristic among plum accesses. Similar variability was also observed in a study of Brazilian plum genotypes, which showed values between 4.67 and 19.40 [3].

The plum accesses plotted on the right side of Figure 1 (84-95-273, 10-02-x, 35-01-05, 74-01-04, 74-01-09, 10-02-06 and 77-92-6) showed higher acidity. According to many authors [3,21,22], the acidity of plums must be expressed in malic acid because it is the predominant acid in plums. The titratable acidity values of these accesses ranged from 1.15 to 2.47% and were in accordance with the values, 0.5 to 3.0%, that were presented by Chitarra and Chitarra [22], Costa [21], and Queiroz [3]. Fruit acidity is influenced by fertilization, climatic conditions, degree of ripeness, location and genetic diversity of each cultivar [23].

Studies have shown that consumers prefer fruits with low acidity because the perception of fruit sweetness is higher [6]. When the TA value was less than 0.6% and when the SSC content varied between 10 and 12%, the fruits are perceived as sweet. However, if the TA value was greater than 1%, the SSC values had to be above 15% in order for to the consumer to be able to perceive the sweetness of the fruit [6]. In the present study, plum accesses showing high acid value (0.62–2.27%) were associated with SSC values below 15% (8.9 to 12.8%). Based on concepts above mentioned the combination of TA and SSC suggests that the sweetness could be difficult to be perceived in some of these accesses.

Alternatively, PC2 promoted the separation of plum accesses as a function of volume, weight and color parameters (L* and b*) variables. Plum accesses located at the top of Figure 1 (84-95-273, 35-01-05, 10-02-x, 74-01-03, BY-81-5850 and 70-91-27) exhibited higher volume and weight, while those accesses located towards the bottom of the figure exhibited darker coloration (low L* value) and has a paler yellow color (lower b* values). Fruit size is also a criterion of choice for consumers, as well as being an important factor for packaging and transportation. Fruit weighing less than 50 g are classified as small, fruit weighing 50 to 65 g are considered moderate, and fruit exceeding 65 g are classified as large [24].

In the PC2 group, the average weight of the plum accesses ranged from 38.20 to 76.20 g, and the volume ranged from 38 to 176 g/cm^3. The great variability in the weight and the volume of this group indicated that probably other variables showed also influence on the separation of these accesses, but that these two parameters was the main responsible for the separation of the accessions belonging to the group PC1− and the group PC1+.

3.2. Hierarchical cluster analysis

PCA showed the possibility of forming groups with similar characteristics. Then, a hierarchical cluster analysis (HCA) was conducted using the physicochemical data. In this analysis, three groups of plum accesses formed, showing different characteristics (Figure 2).

The G1 and G2 accesses have similar weight, but G1 has a higher volume, less acid, and higher SSC/TA ratio, and it exhibited a dark colored skin. The G2 accesses have high acidity and a low SSC/TA ratio, with lighter skin color than the G1. A higher acidity and a lighter skin color were the main features of the G3 accesses. Considering the physicochemical characteristics of each group, it can be concluded that the G1 fruits presented more characteristics that were desired by consumers and that had the greatest potential for consumer acceptance (Table 3) [6].

Table 3 Average values for physicochemical characteristics of plum accesses for each group formed in HCA.

Groups	Weight	Volume	pH	TA	SSC/TA	L*	a*	b*
G1	39.38	64.50	3.92	0.77	14.15	27.45	22.72	7.98
G2	35.23	35.25	3.01	1.81	6.31	31.40	23.11	10.10
G3	55.41	154.33	3.21	1.82	6.65	33.92	17.38	10.24

However, both the external appearance and the sensory attributes should be considered in the selection of new cultivars because similar external appearances of fruit may in fact have different sensory aspects and result in different levels of consumer acceptance.

3.3. Sensorial evaluation

The results of sensory analysis contribute to the classification of cultivars, and the comparison of sensory results with physicochemical characteristics provides knowledge on the influence of these characteristics on the sensory attributes of the fruits.

In this study, the F1 and F2 dimensions formed by the attributes cited by the panelists, were analyzed as positive (F+) and negative (F−). Those attributes that showed a correlation greater than |0.40| and that were cited by three or more panelists (Table 4) were used in the F1 and F2 formation.

The first two dimensions (F1 and F2) accounted for 60% of the variability present in the original samples. Studies involving FCP usually found variability ranging between 50 and 80%, depending on the complexity and the number of products evaluated and panelists [7,11].

Attributes such as a sweet taste, sweet aroma, red pulp color, red skin color and soft texture were correlated to the F1 positive dimension (Table 4). In contrast, an astringent, acidic, bitter or green fruit taste; firm texture; green aroma; and red color of the skin and pulp were also perceived by the panelists and were associated to F1 negative dimension. The attributes of acidic or sour taste and firm texture were correlated to the F2 negative dimension, whereas the attributes of soft texture and sweetness contributed the F2 positive dimension.

Table 4 Attributes with a higher correlation to |0.40| and high citation for each dimension (> 3 panelist citations).

F1 (42%)		F2 (18%)	
F1−	F1+	F2−	F2+
Astringent taste (5)	Sweet taste (10)	Acid taste (7)	Soft texture (3)
(−0.90 to −0.47)	*(0.84 to 0.49)*	*(−0.77 to −0.43)*	*(−0.67 to −0.45)*
Acid taste (5)	Plum aroma (7)	Firm texture (7)	Sweet taste (3)
(−0.86 to −0.71)	*(0.76 to 0.43)*	*(−0.81 to −0.46)*	*(0.57 to 0.44)*
Bitter taste (5)	Sweet aroma (5)	Red skin color (3)	
(−0.86 to −0.47)	*(0.77 to 0.60)*	*(0.64 to 0.42)*	
Green fruit taste (5)	Red pulp color (5)	Red pulp color (3)	
(−0.89 to −0.59)	*(0.66 to 0.45)*	*(0.681 to 0.48)*	
Firm texture (8)	Green fruit aroma (4)		
(−0.77 to −0.55)	*(0.65 to 0.74)*		
Green aroma (3)	Soft texture (8)		
(−0.84 to −0.43)	*(0.79 to 0.63)*		
	Red skin color (3)		
	(0.71 to 0.58)		

In sequence, the results of FCP (sensorial attributes) were used to describe the plum accesses. For this purpose, samples projected in an FCP two-dimensional space (F1 and F2) were described, associating the plum accesses to the attributes that formed the two dimensions (Figure 3 and Table 4).

Plums accesses located in the left side of Figure 3 (77-92-6, 74-01-09, 10-02-06, 35-01-05, 74-01-04, 70-91-27 and 10-02-x) presented astringent, acid, bitter and green fruit taste, green aroma and firm texture (Table 4). Attributes such as large size and yellow skin color were also cited two or only one citation for this group of accesses, that lesser than three citations contributed to accesses sensory characterization. On the other hand, accesses located to the right of Figure 3 (41-91-54, 74-01-03, BY-81-5850, 84-95-273 and BY-81-8850) showed sweet taste, plum, green fruit and sweet aroma, red pulp color, red skin color and soft texture. This group presented attributes such as uniform appearance, plum taste, fibrous, succulence and smooth texture (attributes with lower citation).

The attributes forming the F2 positive dimension promoted separation of accesses 41-91-54, 74-01-03, By-81-5850, 77-92-6, 74-01-09, 10-02-06 and 35-01-05. Such accesses were distinguished with main attributes soft texture and sweet taste. The F2 negative dimension separated BY-81-5580, 84-95-273, 74-01-04, 70-91-27 and 10-02-x and these accesses have attributes such as red skin and pulp color; firm texture and acid taste, in addition to attributes such as oval shape and uniform appearance; sweet and fruity aroma; green fruit, astringent, bitter and sweet taste; and fibrous firm texture with less citation.

Comparing the physicochemical and sensory characteristics was found that the accesses 77-92-6, 74-01-09, 10-02-06, 35-01-05, 74-01-04 and 10-02-x presented as more acid taste with a bitter and astringent taste and yellowish pulp color. These accesses, except access 10-02-x, showed that the size and volume, pH and SSC/TA ratio were low (Table 1, Figures 2 and 3).

Accesses 41-91-54, 74-01-03, BY-81-5850 and BY-81-8850 presented as sweeter, less acid taste, smaller in size, and with reddish skin color.

Considering these results, it was noted that these four accesses (41-91-54, 74-01-03, BY-81-5850 and BY-81-8850) showed sensory attributes and physicochemical characteristics indicative of high quality, concerning literature data [6]. Therefore, these accesses have the potential to be accepted by consumers and could be identified in the germplasm bank of the fruit plant breeding program [6].

4. Conclusion

The plum accesses examined in this study showed great variability in physicochemical characteristics; it was possible to identify those with the greatest potential for consumer acceptability.

Moreover, the FCP technique provided a specific sensory description for plum accesses through the use of the most important attributes. It should be noted that aroma and taste were the main attributes used to describe the samples. It was also possible to correlate the sensory attributes to the physicochemical parameters. Thus, physicochemical evaluation, together with sensory analysis using the FCP, allowed for the description of accesses, indicating those with the greatest potential of being accepted by consumers. Thus, these analyses have shown it is appropriate to provide subsidies for the selection of new cultivars, ensuring benefits for both producers and consumers.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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