

Fruit quality characterization of wild and cultivated blackberries (*Rubus* sp.)

List-Montesinos, Hildegard B.^{1*}; Cruz-Izquierdo, Serafín^{1*}; Rodríguez-Bautista, Geremias²; López-Osorio, Daniel³

¹ Colegio de Postgraduados, Campus Montecillo, Posgrado en Recursos Genéticos y Productividad-Genética, Texcoco, Montecillo, Estado de México, México. C. P. 56264.

² Universidad de Guadalajara, Centro Universitario de la Costa Sur, Departamento de Producción Agrícola, Autlán de Navarro, Jalisco, México. C. P. 48900.

³ Supervisor en Nutrición Vegetal Grupo ALTIARA, Jalisco, México.

* Correspondence: sercruz@colpos.mx; berenice.list@colpos.mx

ABSTRACT

Objective: To characterize wild and cultivated blackberries for fruit quality to identify those with outstanding traits for genetic improvement.

Design/methodology/approach: External and internal variables associated with fruit quality were evaluated in ripe blackberries. The variables evaluated were: fruit length, fruit width, fruit weight, fruit shape, seed area, pH, titratable acidity, and total soluble solids. Statistical analysis was performed for each variable. Cluster and multivariate analysis were assessed to determine variability and relationship between the germoplasm.

Results: The *Rubus glaucus* Benth. accession showed values similar to cultivated varieties in length, width, and fruit weight, number of drupelets per fruit, pH, and total soluble solids, while the *Rubus philyrophyllus* Rydb. accession exhibited values similar to cultivated varieties in seed area, pH, titratable acidity, and total soluble solids. One classic variety and three contemporary varieties stood out with large, heavy fruits and more drupeoles, and one commercial variety had the highest total soluble solids.

Limitations on study/implications: Fruit quality characterization of wild and cultivated blackberries is an initial and essential step to identify germplasm with outstanding traits. Integrate this species into breeding programs will contribute to broadening the genetic base and incorporate their favorable alleles, actions that contribute to their utilization by humans and their conservation.

Findings/conclusions: The characterization allowed to identify the *R. glaucus* Benth. and *R. philyrophyllus* Rydb. wild species with outstanding traits, which facilitates their appreciation and integration into breeding programs

Keywords: quality fruit, wild, cultivated varieties.

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INTRODUCTION

The blackberry is part of the berry group, whose consumption has increased internationally due to their visual and palatable appeal, including appearance, color, and taste. Additionally, their consumption provides various health benefits due to their high concentration of antioxidants, amino acids, organic acids, vitamins, and dietary



fiber (Bhat *et al.*, 2023; Schulz & Chim, 2019). These compounds give to blackberries antioxidant, neuroprotective, anti-inflammatory, antimicrobial, and antifungal properties (Mello *et al.*, 2023; González-Jiménez *et al.*, 2015; Risco *et al.*, 2019; Schulz & Chim, 2019; Villarruel-López *et al.*, 2025). High demand for blackberries has sparked farmers' interest in their cultivation for export, as it is a competitive and highly profitable activity (Zamora *et al.*, 2023). Michoacán is the region with the highest blackberry production due to land allocated to cultivation, climate, differentiated production methods, and cultural practices implemented (Rivas, 2016; Zamora *et al.*, 2023). This has made Mexico leading exporter of blackberries in America, with United States as primary commercial destination (SIACON, 2023). The most widely distributed and produced variety in Mexico is Tupy, developed by Embrapa in Brazil from cross between Comanche and Uruguay varieties and released in 1989 (Bassols *et al.*, 2022). Tupy variety replaced Brazos variety, released in 1959, because it produces large, firm fruits with a longer shelf life and no color reversion issues (Meza *et al.*, 2013).

Currently, blackberry production faces various field problems due to development of varieties from a reduced genetic base, leading to variability depletion. As a result, classic varieties developed in 1990s are being replaced. An alternative to overcome this barrier is crossing wild species with improved varieties, introducing new genes to broaden the genetic base and increase diversity.

Blackberries belong to genus *Rubus*, whose wild species are found on all continents and have adapted to diverse environmental conditions. China is considered Center of Origin for genus *Rubus*, while United States and China are Centers of Diversity due to their wide diversification of *Rubus* species (Meng *et al.*, 2022). However, in Mexico, several wild *Rubus* species have been described since arrival of Spanish conquistadors (BHL, 2006; UNAM, 2015). To date, 55 wild *Rubus* species have been reported, distributed in mountainous areas of Trans-Mexican Volcanic Belt, Sierra Madre del Sur, and Sierras of Chiapas and Guatemala (Rzedowski & Calderón, 2005; Reyes *et al.*, 2019; Rodríguez-Bautista *et al.*, 2021). These species grow in cold, temperate, and subtropical climates, at altitudes ranging from 1100 to 3600 meters above sea level, and are found in undergrowth, rural paths, ravines, and riverbanks.

Wild blackberry species are adapted to Mexico's diverse edaphoclimatic conditions, making them an important source of adaptation alleles for genetic improvement programs. It is important to note that several wild blackberry species in Mexico are threatened in their natural habitats due to invasive species, drastic climate changes, habitat destruction from human activities, urban growth (Hunter & Heywood, 2011; Rodríguez-Echeverry & Leiton, 2021), overharvesting of forest fruits, and societal unawareness of their conservation importance. Breeding programs would contribute to conservation of wild *Rubus* species by preserving live specimens in germplasm banks, botanical gardens, or botanical collections. Genetic improvement seeks to utilize wild species for human benefit and begins with understanding specific traits of each wild species that distinguish them from others through morphological, biochemical, physical, and quality evaluations. This evaluation allows selection of parental lines for crosses to develop new varieties. In Mexico, information on evaluation of wild blackberries is still limited. Evaluated species include *Rubus glaucus*

Benth., *Rubus adenotrichos* Schldl., *Rubus sapidus* Schldl., *Rubus cymosus* Rydb., *Rubus humistratus* Steud., and *Rubus coriifolius* Liebm., and *Rubus pringlei* Rydb. collected in Chiapas, Hidalgo, and Michoacán (Rodríguez-Bautista *et al.*, 2019; Rubio *et al.*, 2019; Rueda, 2017), as well as, *Rubus* spp. germplasm collected in Northeastern Sierra of Puebla and Sierra Centro of Veracruz (Ibañez, 2011). The objective of this research was to characterize fruit quality of wild and cultivated blackberries to identify those with outstanding traits for genetic improvement.

MATERIALS AND METHODS

Fruit collection

Blackberry fruits at commercial maturity were collected during 2021 and 2022 cycles. Germplasm identification and origin are presented in Table 1. Wild species accessions and classic varieties are part of *Rubus* collection of Colegio de Postgraduados Campus Montecillo, located in the State of Mexico (19° 27' 49.4" N and 98° 54' 19.5" W). The collection contains specimens of wild species from Chiapas, Hidalgo, Michoacán, and Puebla, and classic varieties from Michoacán. Name of classic varieties is due to time of their release between 1959 and 1990. Characterization included cultivars developed in recent years in Mexico (contemporary varieties) made up of public varieties of Autonomous University of Chapingo (UACH), identified with H, and commercial varieties provided by the company Splendor Produce, identified with V.

Determination of Quality Variables

The evaluation was carried out on 15 randomly selected ripe fruits without mechanical damage. External and internal variables associated with quality were: fruit length (FL),

Table 1. Blackberry genotype specifications.

Code	Wild species or variety	Class and type	Origin
ZS2	<i>Rubus</i> spp.	Accession	MEX
ZS7	<i>Rubus glaucus</i> Benth.	Accession	MEX
ZS10	<i>Rubus schiedeana</i> Steud.	Accession	MEX
ZS11	<i>Rubus philyrophyllus</i> Rydb.	Accession	PUE
ZC1	Brazos	Classical, Public	MIC
ZC2	Tupy	Classical, Public	MEX
ZC3	Kiowa	Classical, Public	MEX
ZH1	Uruapan	Contemporary, Public	JAL
ZH2	América	Contemporary, Public	MIC
ZH3	Leonel	Contemporary, Public	MIC
ZH4	Cituni	Contemporary, Public	MIC
ZV3	Advanced selection 1	Contemporary, Commercial	JAL
ZV5	Advanced selection 2	Contemporary, Commercial	MIC
ZV6	Advanced selection 3	Contemporary, Commercial	MIC
ZV7	Advanced selection 4	Contemporary, Commercial	MIC

MEX: State of México, JAL: Jalisco, MIC: Michoacán.

fruit width (WF), fruit weight (WGTF), fruit shape (FS), hydrogen ion potential (pH), titratable acidity (TA), and total soluble solids (TSS). Additionally, number of drupeoles per fruit (NDF) and seed area (SA) were evaluated. Fruit length and width variables were considered to be polar and equatorial diameters; these attributes were measured with a digital Vernier caliper (OBI Model 215140). Fruit weight was obtained with a digital granataria scale. Fruit shape was calculated as length-to-width ratio; elongated fruits have $FFS > 1$, round fruits have $FS = 1$, and flattened fruits have $FS < 1$ (Magallanes-López *et al.*, 2020). Seed area was obtained with ImageJ program by determining ellipses in a digital image with 15 seeds (Schneider *et al.*, 2012; Ferreira & Rasband, 2012).

Blackberry juice or supernatant was used to evaluate internal variables: pH, TSS, and TA. Prior to this, fruits were disinfected in a diluted sodium hypochlorite solution, dried, ground with an electric mill, and centrifuged at 1000 rpm for 10 min. pH was measured in 3 g of juice diluted in 50 mL of distilled water using a potentiometer (Hanna). TSS were obtained with a refractometer (Atago) by placing two drops of juice and expressed in °Brix. These variables were measured 5 times. TA was determined according to AOAC 942.15 (2005). To do this, 3 g of juice were weighed, diluted in 50 mL of distilled water, and titrated with a 0.1 M NaOH standard solution (J. T. Baker) to pH 8.1 using a potentiometer (Hanna). Titratable acidity was assessed in triplicate. Percentage of citric acid per 100 g of sample was determined by the Equation 1.

$$TA = (V_{NaOH} \times N_{NaOH} \times meq \text{ citric acid} / W) \times 100 \quad (1)$$

where V_{NaOH} = volume of sodium hydroxide spent; N_{NaOH} = normality of 0.1 M NaOH, 1 meq citric acid = 0.064 g of citric acid; W = weight of sample.

Statistical Analysis

Descriptive statistics were calculated for each variable and subjected to Kolmogorov-Smirnov normality test ($p > 0.05$) and Levene's homogeneity of variance test ($p > 0.05$). Kruskal-Wallis test was used to determine difference between variances, and DCG test was used to compare means (Di Rienzo *et al.*, 2002). Cluster analysis was performed using Ward's coefficient and squared Euclidean distance. Principal component analysis (PCA) was used to identify correlations between variables and with germplasm, and to determine similarity between genotypes by proximity. InfoStat Statistical Software (2008) was used to analyse the data.

RESULTS AND DISCUSSION

Table 2 presents average values for external fruit quality variables. Fruits of contemporary varieties were similar in width and length, except for varieties ZV6 and ZH1 (Uruapan), which stood out for their greater length, width, and weight, with a significant difference ($p < 0.05$). Fruits of accession ZS7 were similar in size to contemporary varieties, suggesting that *R. glaucus* Benth. has potential for genetic improvement. Accessions ZS2, ZS10, and ZS11 had smaller fruit width, length, and weight, with a significant difference ($p < 0.05$). Similar values for length, width, and weight of wild fruits have been reported for *R. pringlei*,

R. glaucus, and *R. adenotrichos* collected in Michoacán (Rubio *et al.*, 2019) and for fruits of *Rubus* spp. collected in Sierra de Puebla (Ibañez, 2011).

Regarding fruit shape, ZS2, ZS10, ZH3 (Leonel) and ZV6 presented flattened fruits, ZC1 and ZC2 presented round fruits and ZS7, ZH4 (Cituni), ZV3 and ZV7 presented elongated fruits, reiterating outstanding features of species *R. glaucus* Benth. In general, wild species of blackberry have rounded fruits, while improved varieties have an elongated shape. Shape of fruit is determined by the receptacle; therefore, complementary studies must be carried out to determine their relationship. Wild fruits of *Rubus* spp. with similar shapes were collected in Sierra de Puebla (Ibañez, 2011).

Number of drupeoles per fruit was similar in contemporary varieties. Commercial variety ZV6 stood out with a higher number of drupeoles, with a significant difference ($p < 0.05$). The fruits of varieties ZH1 (Uruapan), ZH3 (Leonel), and ZH4 (Cituni) from UACH had a similar number of drupeoles to commercial varieties. Accession ZS7 stood out with the highest number of drupeoles per fruit, with a significant difference ($p < 0.05$), verifying potential of *R. glaucus* Benth species for improvement. The fruits of accessions ZS2 and ZS10 had a lower number of drupeoles, with a significant difference ($p < 0.05$). These values are higher than those reported by Rodríguez-Bautista *et al.* (2019) in fruits of *R. adenotrichos*, *R. cymosus*, *R. humistratus*, *R. palmeri*, *R. pringlei* and *R. sapidus* collected in Chiapas, Hidalgo and Michoacán with 3 to 14 polydrupes per fruit. However, they are lower than number of drupeoles per fruit reported by Rubio *et al.* (2019) in *R. glaucus* and *R. pringlei* with 70 and 89 drupeoles, respectively, and by Ibañez (2011) in fruits of *Rubus* spp. with 30 to 89 drupeoles.

In this regard, it is important to note that fruit size is affected by anatomical, environmental, and genetic factors. Anatomically, position and number of stigmas in flower limits complete pollination, which affects number of drupeoles. Regarding environmental factors, fruit size depends on attraction of pollinators, absence of pests (vectors of diseases and/or viruses), nutrition, and environmental conditions. Genetically, fruit size depends on polyploidy. Blackberries are diploid (2x) or polyploid plants that can have from 2 to 18 pairs of chromosomes (Hummer *et al.*, 2016). Increase in size of fruits of improved varieties with respect to wild species is due to increase in ploidy (number of DNA copies), which generates plants with larger fruits due to greater number of drupeoles. In nature, this generates benefits such as more robust plants that are better adapted to climate changes (Alix *et al.*, 2017; Sattler *et al.*, 2016).

In general, seed area of blackberry fruits was lower in accessions of wild species. Accessions ZS2, ZS7, ZS10 and varieties ZV7 and ZH1 (Uruapan) from UACH stood out with the lowest seed area, with a significant difference ($p < 0.05$). Varieties with the largest seed area were ZV5 and ZC3, with a significant difference ($p < 0.05$). These values are similar to Indonesian *Rubus* species reported by Surya *et al.* (2021): *R. chrysophyllus*, *R. lineatus*, *R. niveus* and *R. glomeratus* with 3.39, 4.35, 6.73 and 6.99 mm², respectively. However, the genus *Rubus* presents wide diversity in this characteristic, as indicated by Surya *et al.* (2021), the species *R. pyrifolius*, *R. acuminatissimus* and *R. alpestris* have a larger seed area with 22.30, 19.56 and 14.7 mm², respectively, and the species *R. fraxinifolius*, *R. ellipticus* and *R. rosifolius* have a reduced seed area with 1.86, 2.03 and

2.66 mm², respectively. Seed area is related to surface area and size of seed, this variable is important because consumers prefer fruits with small or seedless seeds due to their ease of consumption, which has generated development of various seedless fruits such as: strawberry (*Fragaria × ananassa* Duchense ex Weston), grape (*Vitis vinifera* L.), papaya (*Carica papaya* L.), banana (*Musa paradisiaca* L.), etc.

Table 3 shows average internal fruit quality variables. pH was very similar among accessions and cultivated blackberries grown with pH between 3 and 4. Accessions ZS7 and ZS10 stood out with pH less than 3, with a significant difference ($p < 0.05$), indicating that these fruits are acidic. Varieties ZV5 and ZC1 stood out with pH greater than 4, with a significant difference ($p < 0.05$). pH of fruits is consistent with values obtained for species *R. adenotrichos*, *R. glaucus*, *R. pringlei* and Tupy variety from Michoacán with 3.1, 3.2, 3.3 and 3.3, respectively (Rubio *et al.*, 2019), as well as with wild materials collected in Sierra of Puebla with pH ranging from 2.8 to 3.2 (Ibañez, 2011) and with Tupy variety with pH 3.4 (Alonso, 2017). These results indicate that pH also varies depending on genetics of germplasm. It should be noted that pH is related to water activity and metabolites present in fruit, so detailed studies on the chemical composition of fruits are necessary to detect the cause of this variation.

Organic acids in fruit are determined by titratable acidity; acid present in blackberries is citric acid. Titratable acidity was very similar among accessions and cultivated blackberries, with average values close to 1.50. Accessions ZS7 and ZS10 stood out with higher titratable acidity, with a significant difference ($p < 0.05$), indicating that they have a higher citric acid concentration. This trait could be of interest in breeding to improve

Table 2. External fruit quality variables of wild and cultivated blackberries from México.

Code	FL (mm)	WF (mm)	WGTF (g)	FS	NDF	SA (mm ²)
ZS2	14.00±0.45d	15.20±0.86d	1.56±0.16d	0.93±0.05b	17.40±1.44e	3.10±0.22c
ZS7	27.40±1.12c	20.40±0.24c	7.08±0.24c	1.35±0.07a	139.40±5.72a	3.56±0.21c
ZS10	15.20±1.16d	16.00±1.52d	2.36±0.24d	0.96±0.06b	14.00±1.10e	3.67±0.26c
ZS11	17.00±0.45d	13.80±0.49d	1.66±0.10d	1.24±0.07a	33.60±1.72e	4.25±0.25b
ZC1	18.20±0.49c	17.80±0.49c	3.26±0.12c	1.03±0.05b	50.60±4.15d	4.30±0.26b
ZC2	24.40±0.40c	22.40±0.75c	5.86±0.15c	1.09±0.04b	78.80±8.38c	3.44±0.23c
ZC3	29.20±0.49c	24.20±1.24c	10.54±1.18b	1.22±0.07a	88.80±8.73c	6.22±0.62a
ZH1	51.32±7.87a	42.44±4.25a	11.40±0.25b	1.19±0.14a	80.50±1.50c	3.25±0.33c
ZH2	24.80±1.50c	20.60±0.93c	5.02±0.35c	1.21±0.08a	53.80±6.76d	4.96±0.41b
ZH3	19.40±0.40c	21.60±1.57c	4.40±0.15	0.92±0.07b	81.20±7.54	4.89±0.32b
ZH4	28.60±0.98c	19.40±0.60c	6.58±0.57c	1.48±0.05a	85.60±6.82c	4.36±0.44b
ZV3	28.80±1.11c	19.80±0.97c	10.30±0.87b	1.47±0.11a	86.00±3.65c	4.21±0.31b
ZV5	25.40±1.60c	19.80±0.66c	5.10±0.29c	1.29±0.09a	80.00±5.59c	6.27±0.51a
ZV6	28.00±4.15b	31.40±2.38b	13.18±0.83a	0.95±0.21b	110.40±12.09b	5.45±0.57b
ZV7	26.00±1.79c	19.40±0.24c	10.92±2.05b	1.34±0.10a	73.80±9.36c	3.20±0.10c

FL: fruit length, WF: fruit width, WGTF: fruit weight, FS: fruit shape, NDF: number of drupeoles per fruit, SA: seed area. Means with different letters indicate significant differences ($p < 0.05$) ± standard error.

Table 3. Internal fruit quality variables of wild and cultivated blackberries from México.

Code	pH	TA (%)	SST (°Brix)
ZS2	3.28±0.19b	1.88±0.09b	7.07±0.07c
ZS7	2.83±0.01e	3.64±0.06a	11.82±0.46b
ZS10	2.85±0.01e	3.32±0.04a	6.70±0.60c
ZS11	3.69±0.16b	1.05±0.14c	9.36±0.97c
ZC1	4.59±0.04a	0.47±0.01d	15.20±0.86b
ZC2	3.13±0.12d	1.73±0.11b	9.88±0.71c
ZC3	3.05±0.02d	2.15±0.23b	7.20±0.37c
ZH1	3.35±0.06b	1.72±0.30b	8.85±1.09c
ZH2	3.47±0.01b	0.94±0.08c	11.88±0.95b
ZH3	3.54±0.02b	0.79±0.01c	10.30±0.63c
ZH4	3.35±0.01b	1.14±0.05c	13.67±0.33b
ZV3	3.26±0.04b	1.24±0.07c	14.44±0.57b
ZV5	4.67±0.02a	0.39±0.14d	17.40±1.44a
ZV6	3.37±0.01b	1.05±0.06c	12.54±0.64b
ZV7	3.48±0.02b	0.92±0.01c	13.30±1.48b

pH: hydrogen ion potential; TA: titratable acidity; TSS: total soluble solids. Means with different letters indicate significant differences ($p < 0.05$) ± standard error.

nutraceutical quality of fruits. Varieties ZC1 and ZV5 presented lower titratable acidity, with a significant difference ($p < 0.05$). Titratable acidity was similar to those obtained in wild materials collected in Sierra of Puebla with 0.7 to 2.0 % citric acid/100 g of sample (Ibañez, 2011) and in *R. adenotrichos*, *R. glaucus*, *R. pringlei* and Tupy with 0.8, 0.9, 1.05 and 1.10% citric acid/100 g of sample, respectively (Rubio *et al.*, 2019).

It is important to mention that blackberry ripening process involves consumption of citric acid through metabolism, which decreases its concentration and increases concentration of amino acids and sugars, which is why presence of citric acid in ripe blackberries is low and total soluble solids increase. Ripening also modifies color of fruits, which is associated with secondary metabolites: anthocyanins and anthocyanidins, whose stability depends on pH and presence of glycosides (sugars). Variations in any of these conditions modify chemical conformation of anthocyanins and anthocyanidins, resulting in changes in color of blackberries (Reyes-Landa *et al.*, 2023; He and Giusti, 2020). Fruit ripening and quality are also related to longer shelf life (Clark *et al.*, 2007).

Total soluble solids determine the amount of sucrose present in fruits, which is associated with sweetness or sweetening power present in fruits. In general, contemporary varieties presented a higher concentration of total soluble solids than wild accessions, except for accession ZS7, with a significant difference ($p < 0.05$). Fruits of contemporary varieties are sweeter than wild fruits due to consumer preference; this preference has guided plant breeders towards selection of fruits with a higher concentration of total soluble solids, seeking greater market acceptance. In this regard, Clark & Finn (2011)

pointed out that sweet taste of fruits is detected by palate when they contain at least 10% of total soluble solids.

Variety ZV5 stood out with a higher concentration of total soluble solids, with a significant difference ($p < 0.05$), that is, it presented sweetest fruits. Accessions ZS10, ZS2, ZS11 and varieties ZC2, ZC3, ZH1 (Uruapan) and ZH3 (Leonel) presented fruits with a lower concentration of total soluble solids, with significant difference ($p < 0.05$). Fruits with similar concentrations of total soluble solids were obtained from *R. adenotrichos*, *R. glaucus* and *R. pringlei* collected in Michoacán with 12.4, 7.6 and 10.7 ° Brix, respectively (Rubio *et al.*, 2019). As well as in wild materials collected in Sierra of Puebla with 8.58 to 12.0 °Brix (Ibañez, 2011) and in Tupy variety with 9.0 and 9.8 °Brix (Alonso, 2017; Rubio *et al.*, 2019).

Accessions ZS2 and ZS11 presented pH and titratable acidity similar to cultivated varieties, accession ZS7 presented a quantity of soluble solids similar to cultivated varieties, so these accessions present traits of interest for genetic improvement.

The contrasts in fruit quality variables between wild accessions, classic varieties, and contemporary varieties indicate path followed by plant breeders in traditional genetic improvement of this species. Selected variables are related to fruit size, fruit shape, and total soluble solids. According to Clark & Finn (2011), another important point to consider in blackberry breeding is maintaining an adequate balance between titratable acidity and total soluble solids, as this balance imparts an intense flavor to fruit.

Clustering analysis is shown in Figure 1. Plant materials formed 3 groups: the first group was divided into two branches, one branch was made up of accession ZS7 and varieties ZV7, ZV3 and ZH4 (Cituni), which presented fruits with a similar number of drupeoles,

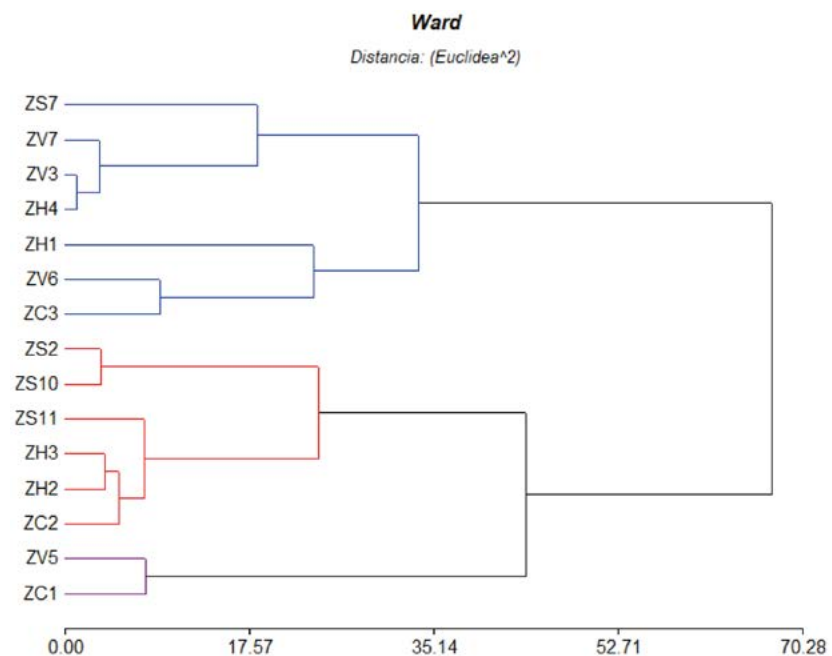


Figure 1. Clustering generated from Ward similarity index and squared Euclidean distance using quality variables from wild and cultivated blackberries.

this corroborates that species *R. glaucus* Benth. has outstanding characteristics. The other branch was made up of varieties ZH1 (Uruapan), ZV6 and ZC3 that share in common large fruits with a larger seed area. The second group was made up of two branches, one branch with accessions ZS2 and ZS10 that had in common small fruits with a lower number of drupeoles and a lower concentration of total soluble solids. The other branch was shared by accession ZS11, classic variety ZC2 and contemporary varieties ZH2 (America) and ZH3 (Leonel), these materials present similarity in fruit length and width, seed area, pH, titratable acidity and total soluble solids, so species *R. phillyrophyllus* Rydb. has novel traits. The third group consisted of varieties ZV5 and ZC1, which share a similar fruit width. Their fruits also had higher pH and soluble solids levels, and lower titratable acidity. It is important to reiterate that accessions ZS7 and ZS11 shared a group with several cultivated blackberries. Therefore, *R. glaucus* Benth. and *R. phillyrophyllus* Rydb. exhibit traits of interest for genetic improvement and should be considered for integration into genetic improvement programs. Further studies on ploidy of these materials will be necessary to determine feasibility of crosses between wild species and cultivated blackberries.

Table 4 and Figure 2 show Principal Component Analysis. Components PC1 and PC2 explain 65.9% of the variability. First component explained 36.4% of variation, with the largest contributions from variables: fruit weight, fruit length, number of drupeoles per fruit, and fruit width. Second component explained 29.5% through positive contributions of variables: pH and total soluble solids, and negative contribution of titratable acidity. Regarding correlation circle, external variables: number of drupeoles per fruit, length, width, and fruit weight were highly correlated. Meanwhile, the internal variables: total soluble solids and pH were negatively correlated with titratable acidity. Furthermore, there was a correlation between external and internal variables: total soluble solids and seed area. This indicates that fruits with larger seed areas will have a higher concentration of total soluble solids, meaning they will be sweeter.

Variety ZH1 (Uruapan) was characterized by high values of number of drupeoles per fruit and in length, width and weight of fruit, contrary to accession ZS11 and variety ZC1 located in the opposite quadrant, in the opposite direction to these mentioned

Table 4. Contribution of fruit quality variables to variability of Principal Components.

Variable	CP1	CP2
Fruit length	0.43	-0.16
Fruit width	0.49	-0.12
Fruit weight	0.50	-0.08
Fruit shape	0.27	0.12
Number of drupeoles per fruit	0.45	-1.8E-03
Seed area	0.12	0.33
pH	-0.04	0.56
Titratable acidity	-0.05	-0.52
Total soluble solids	0.19	0.50

CP: Main component

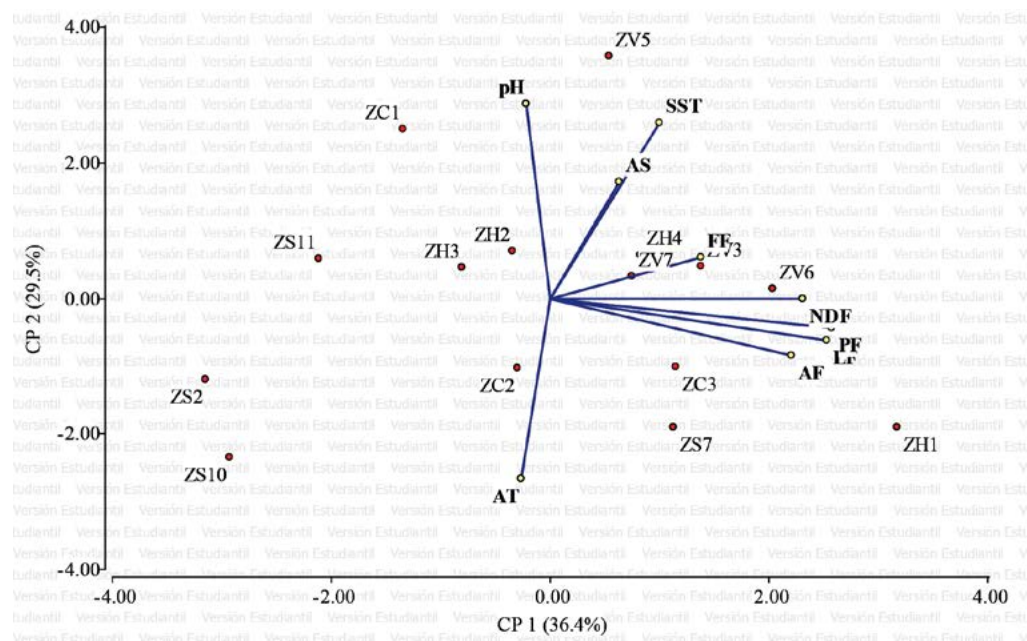


Figure 2. Principal Components Analysis obtained from Ward similarity index using external and internal variables of fruit quality determined in wild species and cultivated blackberries.

vectors (variables). Variety ZV5 was characterized by higher values in pH and total soluble solids. In PCA diagram, three groups were formed whose materials share quality variables between them. The first group was made up of accession ZS7 and varieties ZC3, ZH1 (Uruapan), ZV3, ZV4, ZV6 and ZV7, the second group was made up of accession ZS11 and varieties ZC1, ZC2, ZH2 (América) and ZH3 (Leonel) and the third group were accessions ZS2 and ZS10.

CONCLUSIONS

Characterization of blackberry fruit quality variables is essential for identifying wild species with outstanding traits, enabling their assessment and integration into genetic improvement programs. The results allowed to identify that *R. glaucus* Benth. and *R. phillyrophyllus* Rydb. wild species had outstanding traits, which facilitates their appreciation and integration into breeding programs. These actions contribute to their utilization by humans and their conservation.

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