Article

Identification of discriminatory elements to characterize *Coffea arabica* L. using main components

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Abstract

The evaluation of cup quality in *Coffea arabica* L. agrosystems is necessary to generate alternatives that ensure the quality and differentiation of coffee in Coatepec, Veracruz, Mexico. The present study was carried out with the objective of evaluating the physical and sensory quality of the Typica and Mundo Novo varieties through the analysis of main components, during the 2017-2018 period, to identify the variables that are associated with the cup quality of the varieties. Eleven samples of cherry coffee were processed with wet benefit to assess their physical and sensory characteristics. The physical characteristics were evaluated according to the international standards of the Specialty Coffee Association of America (SCAA). According to the student's t-test, the results indicate that there are no significant differences between varieties with respect to physical quality defined by grain size, shape and defects. Sensory properties were analyzed using the principal component technique. The results show that two of the seven components explain 73.67% of total variability. The first refers to 47.24% and is negatively correlated with the variables taste, residual taste, acidity and overall appreciation. While, the second explains 26.43% and correlates positively with the body and balance variables. Finally, the results indicate that there were no significant differences in relation to the physical quality of the grain and cup between varieties, since both obtained 80 points and are considered very good quality coffees.

Keywords: main components, Mundo Novo, sensory quality of coffee, Typica.

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Introduction

The genus *Coffea* belongs to the *Rubiaceae* family and comprises approximately 70 species, of which *Coffea arabica* L. and *C. Canhephora* var. Robust are the most cultivated worldwide (Beckley, 2010; Bosselmann *et al*., 2009). Arabian coffee varieties contribute 80% of world production and are grown mainly in Central American, South American, India, Kenya and Ethiopia, while *C. Canhephora* is grown in Africa, Indonesia and Brazil (Beckley, 2010).

Traditional varieties of the Arabic species have a larger grain size, more color and chemical composition than the robust genotype (Regalado, 2006). However, grain size does not influence coffee quality (Kathurima *et al*., 2009). Arabic varieties also exhibit strong aroma, high acidity, light body, contrary to hybrids (Wintgens, 2004), although there is controversy over whether there are significant differences in their cup quality (Steiger *et al*., 2002).

In Mexico, the main varieties of Arabica coffee grown are: Typica, Bourbon, Red Caturra, Mundo Novo, Garnica, Catuai, Caturra Amarillo, Catimor and in a smaller scale Maragogipe, Pacamara, Villa Sarchi, Sarchimor, among others (Regalado, 2006; López-García *et al*., 2016).

Although traditional Arabic coffee varieties are sensitive to rust, they have genetic characteristics such as the physical quality of the grain, the chemical and organoleptic properties of the beverage that are associated with environmental conditions, agronomic and cultural practices, the way of harvest , the type and control during the benefit, storage, roasting and preparation of the beverage, influence the quality of coffee (Santoyo *et al*., 1996; Kathurima *et al*., 2009; Oberthür *et al*., 2011; Rodriguez *et al*., 2014; Puerta, 2016). Of the aforementioned factors, the benefit or process of transforming cherry coffee bean to dried parchment is the one that has been most investigated (Avelino *et al*., 2005; Beckley, 2010; Orozco *et al*., 2011).

The physical and organoleptic characteristics of the coffee bean affect the price of its sale. Consequently, the cup profile is an important tool in the characterization of the different coffee varieties, which are classified by the sensory methods of the Association of Special Coffee of America (SCAA, 2015; Sánchez-Hernández *et al*., 2018). In Mexico, the percentage of producers that produce quality coffees and the studies that address this are minimal, despite the fact that some regions of Veracruz produce coffee with extraordinary quality, which has received national and international recognition (Sánchez-Hernández *et al*., 2018). Therefore, the present study aims to evaluate the physical and sensory quality of the traditional Arabic varieties Typica and Mundo Novo, grown in Coatepec, Veracruz; from the analysis of main components to identify the variables that are associated with greater certainty to their cup quality.

Materials and methods

Geographic location

The investigation was carried out on a site located in Coatepec, Veracruz, between the coordinates 19° 28' 20" north latitude and 96° 54' 16" west longitude, at an average height of 1 250 meters above sea level. Its surface is 24.5 hectares and its type of soil is of volcanic origin, known as Andosol and consists of ashes with high allophone content that gives it lightness and smoothness, as well as the ability to fix nutrients, especially phosphorus (INEGI, 2004). According to INEGI (2009), the climate is semi-warm humid with rains throughout the year, with an annual rainfall range of 1 100 to 2 100 mm. Its vegetation is forest or jungle and its minimum and maximum temperature is 10 ºC and 35 ºC, respectively.

Description of the farm

The vegetation of the farm is mainly: *Inga* sp, *Inga edulis*, *Acacia Farnesiana*, *Leucaena leucocephala*, *Grevillea robusta* and *Bursera simaruba*, which serve as shade for coffee. Also, there are guavas, oranges, banana trees and mangoes, among others. To a lesser extent, there are coyolera palms and some specimens of oak. The cultivated coffee varieties are high-bearing Arabic: Typica in 80% and Mundo Novo 20%. Its planting densities are 1 111 and 2 415 plants per ha, respectively. The first variety is planted at a distance of 3 x 3 m with an arrangement in three bolillo where 2 grevilleas and 3 jinicuiles are located; while the second at a distance of 1.8 x 2.3, double posture in arrangement three bolillo where 3 huizaches, 3 chalahuites and 3 jinicuiles. The plantation age is approximately 40 years for both varieties.

Sampling of fruits

4 and 7 samples of Mundo Novo and Typica green coffee were obtained, respectively. It is were determined weight, volume and number of cherries per sample. The ripe fruits of the samples were processed by the wet benefit method. It is were pulped separately, fermented, washed, dried and finally threshed for physical and sensory analysis.

Physical and sensory analysis of the samples

The physical analysis and sensory evaluation of the coffee samples was carried out following the protocols of the SCAA (SCAA, 2015), in the tasting laboratory of the Graduate College-Campus Cordoba, located in Cordoba, Veracruz. The physical analysis consisted of: a) determining the moisture content in subsamples of 2.5 g of dust by means of the Mettler Toledo halogen moisture analyzer model HG63; b) classify coffee by its grain size with sieves from number 15 to 19 and base; c) weigh the amount of coffee retained by each sieve for each sample of cherry coffee; and d) calculate the percentage of grains retained per sieve.

The classification by form consisted of separating the triangle, snail, planchuela and elephant grains; while the classification of defects consisted of: a) separating immature grains, bitten, broken, black, sour, etc. in each of the samples; and b) obtain the percentage in relation to the total weight for each of these per sample.

The sensory evaluation consisted of analyzing the coffee samples by four professional tasters, based on the protocol SCAA (2015): a) roasting 100 g of each of the cherry coffee samples between 12 and 15 min in a brand roaster Promor; b) determine its degree of roasting when the coffee obtains a light roast; c) weigh 12 g of roasted grain per cup and grind to grade 3 in a Mahlkoning brand mill; d) determine the fragrance of the ground coffee to each of the samples, adding pure boiling water (93 °C) and wait 4 min for the fragrance, aroma, acidity and body attributes to be fully integrated; e) determine the aroma; f) clean the cup, removing with a spoon the foam formed on the surface of the drink; g) determine the acidity, body, uniformity, balance and sweetness of the drink; and h) evaluate sensory attributes with a scale from 0 to 10, where 0 is the lowest and 10 is the highest. The tastings were made per table, each table with 3 samples with five repetitions, where each taster gave the rating of each of the characteristics evaluated. In the end, an average of the tasters' ratings was made.

Analysis of data

For the analysis of data of the physical evaluation of the varieties under study, a comparison of means was made with the t-Student test (Ortiz and Moreno, 2011). The method consisted of: a) checking the assumptions of homogeneity of variances and normality of errors by means of the Bartlett and Shapiro-Wilk test, respectively; b) apply the Welch test in cases where the assumption of variance homogeneity is not met; and c) perform the t-Student test to compare the means of the variables; that is, evaluate their differences and test the following hypotheses:

$H_o: \mu_1=\mu_2$ *versus* $H_1: \mu_1\neq\mu_2$

Where: μ_1 and μ_2 is the average percentage of grain retained for the sieve and variety Mundo Novo and Typica, respectively. H_o and H_1 are known as null and alternate hypotheses, respectively. This last hypothesis is a bilateral hypothesis, because it can be true if $\mu_1<\mu_2$ or if $\mu_1>\mu_2$. Hypothesis tests were performed with a level of significance $\alpha=0.05$. Additionally, the Cohen 'd' test, also called effect size (TE), was applied in order to measure relatively the superiority of one treatment over another in the population from which the sample is obtained (Cerda and Villarroel, 2008; Ledesma *et al*., 2008).

In the data analysis of the sensory evaluation, the principal component analysis (ACP) method was applied, which is a tool that extracts components or factors that better explain the analyzed dimension (Johnson, 2000). Because there was no variability between the varieties, the ACP was applied to identify the components that best explain the quality of the beverage, evaluated through the analysis of sensory quality. This analysis considered the quantitative variables: aroma, flavor, residual flavor, acidity, body, overall appreciation, grain moisture.

Result and discussion

Green coffee physical analysis

Table 1 shows the results of the statistics obtained from the physical analysis for both varieties. The average percentage of grain retained in sieve 19 (7.5 mm) was $\bar{y}_1= 0.057\%$ for Mundo Novo, while for Typica it was $\bar{y}_2= 12.4\%$. These percentages indicate that Ho is rejected; that is, the

difference between them is statistically significant, for $\alpha \leq 0.05$, with the t-Student test, and that this difference is also large, according to the Cohen test. Regarding sieve 18 (7.1 mm), the results also indicate that there are statistically significant differences. Hence, the Typica variety retained more grain than Mundo Novo in sieves 18 (28.86% vs. 0.12%) and 19 (12.4 vs. 0.057%). In contrast, in sieves 13 (5 mm), 14 (5.6 mm), 15 (6 mm), 16 (6.3 mm) and 17 (6.7 mm), the results obtained indicate that there are no statistically significant differences in the average percentage retained grain between the two varieties.

Table 1. Averages of the granulometry of green coffee from Typica and Mundo Novo.

Variety	Variable	Mean (%)	$p > \|T\|^*$	Cohen's d	Effect size
Mundo Novo	Z19	00.057 b	0.05	1.1209	Big
Typica		12.4 a			
Mundo Novo	Z18	00.12 b	0.032	1.2849	Big
Typica		28.86 a			
Mundo Novo	Z17	20.72 a	0.187	0.8958	Big
Typica		14.9 a			
Mundo Novo	Z16	35.22 a	0.399	0.4191	Small
Typica		26.45 a			
Mundo Novo	Z15	18.71 a	0.213	0.8398	Big
Typica		11.43 a			
Mundo Novo	Z14	08.48 a	0.242	0.7852	Medium
Typica		04.86 a			
Mundo Novo	Z13	01.07 a	0.876	0.1009	Negligible
Typica		00.96 a			
Mundo Novo	(%) of moisture	09.39 a	0.656	0.2091	Medium
Typica		09.57 a			

Values with the same letter are statistically equal $p < 0.05$.

Regarding the percentage of grain retained by sieves, Mundo Novo and Typica retained about 50% and 27% of grains classified as medium, respectively, in sieve 16. In this regard, Lopéz-García *et al*. (2016) mention that Americans prefer seeds between sieve 15 and 16, while Europeans prefer sieve 17 and 18.

However, Lara (2005) suggests not to consider altitude, shade and fertilization, since they influence the physical quality of the grain (size, weight and imperfect grains), and organoleptic (aroma, body, acidity, taste and preference). In this sense, Vaast *et al*. (2005) mention that with increasing altitude the grain size increases and the percentage of defects decreases. In addition, Marín *et al*. (2003) emphasize that grain size is important for the physical quality of coffee, but it is not a criterion of sufficient quality. Therefore, it is necessary to evaluate the appearance and color of almonds. Regarding sieves 13 and 14, there were no grains retained in both varieties.

Regarding the moisture content of the grain in the two varieties, the results showed no statistically significant differences with α= 0.05. The average humidity percentages were 9, which based on the range (from 10 to 12%) of commercialization humidity of coffee established by the SCAA is low, although for the range (from 9 to 13%) established by Green Coffee Association of New York (GCA), is adequate.

In this regard, Reh *et al*. (2006) argue that a percentage of moisture content between 8 and 12.5% is considered adequate, because it avoids problems of microbial growth and mycotoxin formation, which alter the sensory quality in the cup due to the generation of unpleasant flavors. Also, Puerta (2006) emphasizes that a coffee bean that has not been dried properly develops bad smell and taste, crushes in the thresher and loses a lot of weight during the roasting process, consequently its quality is lower.

Table 2 shows the results obtained from the statistical analysis regarding the shape of the grains. The average percentages of flat grain and snail retained in sieves 19 and 18 between Mundo Novo and Typica varieties are statistically different with a level of significance less than or equal to 0.05, associated with the t-Student test, and this difference is large, according to Cohen's test. These results coincide with those found by López-García *et al*. (2016), both in the Typica variety and in the Mundo Novo, although, in their investigation they did not obtain significant differences at 95% reliability. In addition, according to Wintgens (2004a), flat-type coffee is considered normal for market requirements.

Table 2. Averages for classification of grain shape.

Variety	Variable	Mean (%)	$p > \|T\|^*$	Cohen's d	Effect size
Mundo Novo	Flat	55.86 b	0.0126	1.9456	Big
Typica		79.35 a			
Mundo Novo	Snail	34.54 a	0.0104	2.0208	Big
Typica		12.04 b			
Mundo Novo	Triangle	02.72 a	0.854	0.1186	Negligible
Typica		02.5 a			
Mundo Novo	Monsters	00.15 a	0.8214	0.1457	Negligible
Typica		00.08 a			
Mundo Novo	Shells	00.63 a	0.4534	0.4911	Small
Typica		01.2 a			
Mundo Novo	Broken	08.48 a	0.2511	0.7687	Medium
Typica		04.860 a			
Mundo Novo	Total defect	05.27 a	0.3192	0.6608	Medium
Typica		04.07 a			

Values with the same letter are not statistically different $p< 0.05$.

Regarding the grain triangular, the results indicate no statistically significant differences between the means of the two varieties, for a significance level of 0.05, and the difference is negligible as tested by Cohen. These results also coincide with what was found by López-García *et al*. (2016) in Arabic coffee varieties. However, there is little or no evidence that this type of grain has a negative effect on the quality of the beverage (Wintgens, 2004b). Under the same level of significance $\alpha = 0.05$, the average percentages obtained from monster grains and shells do not show statistically significant differences in both varieties. Cohen's test classified this difference as negligible.

As to the total defects, only secondary defects were presented as a partial black, partial sour philotes and Brocade mild. Their average percentages varieties are not statistically different; that is to say, is negligible according to test Cohen. The foregoing coincides with the results obtained by Marín *et al*. (2003), who found low percentage of almonds with defects in samples collected in mature state.

The results also show that the Typica variety obtained 1.5 partial black defects and 6 complete defects, while Mundo Novo obtained 1 partial black defect and 10 partial sour defects. According to the classification of green coffee SCAA mentioned that part 3 sour or black beans equals 1 full imperfection, Novo Mundo has 3 full imperfections and Typica none. The other secondary defects were not representative, with 1 to 2 defects of mild brocade and floats, respectively.

Sensory quality of coffee

Table 3 shows the results obtained from sensory quality. In general, all the organoleptic indicators obtained average scores above 7, except for the uniformity, sweetness and clean cup indicators that reached an average of 10. In this regard, Puerta (2000) mentions that the global appreciation is an indicator that allows to accept or reject A sample of coffee for its quality, and is related to all perceived properties with the sense of smell (aromas) and taste (body, bitterness and acidity).

Table 3. Quality of coffee obtained from the total score of the tasters.

Variety	Smell	Flavor	Residual flavor	Acidity	Body	Uniformity	Balance	Sweetness	Clean cup	Global appreciation	Total (%)
Mundo Novo	7.2	7.2	7	7.2	7.7	10	8	10	10	7.2	81.3
Mundo Novo	7.3	7.5	7.3	7.2	7.1	10	7.3	10	10	7.3	80.8
Mundo Novo	7.1	6.9	7.2	7	7	10	7.1	10	10	7.3	79.5
Mundo Novo	7.3	7.4	7.5	7.3	7.2	10	7.3	10	10	7.3	81.3
Typica	7.3	7.1	7.1	7.2	7.7	10	8.1	10	10	7.2	81.6
Typica	7.2	7.2	7.2	7.4	7.1	10	7.3	10	10	7.6	80.8
Typica	7	7	7	7.1	7.8	10	8	10	10	6.9	80.8
Typica	7.2	7	6.8	7.2	6.9	10	6.8	10	10	7	78.8
Typica	7.3	7.4	7.3	7.3	7.2	10	7.3	10	10	7.4	81.3
Typica	7.2	7.5	7.4	7.3	7.5	10	7.4	10	10	7.3	81.6
Typica	7.1	7.3	7.1	7.3	7.3	10	7.1	10	10	7.3	80.3

The overall average of the total score of the tasting was 80.7, indicating that coffee is of very good quality and listed as specialty coffee (80-84.99), according to the tasting protocols of the SCAA.

Aromatic descriptors

Table 4 shows the aromatic notes identified by the tasting panel in the coffee samples evaluated, according to the SCAA. Typica and Mundo Novo have the same aromatic subgroups, which coincides with that reported by Hernández (2017), who mentions that the coffee region of Coatepec is cataloged by chocolate notes, accompanied by fruity and caramel notes. These aromatic groups also coincide with what is found by Escamilla (2007), with the difference that the notes of nuts, flowers, fruit, phenolic and pyrolytic appear less frequently, and stand out better in coffee trees over 35 years old, average age of Plantations of the farm under study. As for the aromatic notes found and their relationship with the chemical compounds, according to Puerta (2011), the fruity and sweet notes are aldehydes, ketones, esters, alcohols and acids, the floral ones are mainly alcohols and the smoky smells are phenols.

Table 4. Aromatic notes of coffee in cup.

Variedad	Nota aromática	Subgrupo
Mundo Novo	Honey, Caramel, Almonds, Toast, Chocolate, Flowers, Peanut, Lemon, Hazelnuts, Butter, Walnut, Apricot, Apple, Cucumber, Spaced, Pea, Herbal.	Chocolates, Candies, floral, Fruit, Spaced, Herbaceous.
Typica	Caramel, Chocolate, Lemon, Honey, Herb, Almonds, Roasted, Walnut, Coffee Flower, Apple, Pea, Guava, Rose Tea, Floral, Bird Hoe, Hazelnuts.	Floral, Pyrolytic, Chocolates, Caramel, Walnut, Floral, Fruit, Herbaceous, Roasted Sugar.

Principal component analysis

The ACP allowed grouping the highest percentage of the variability (71.33%) into two components (Table 5) according to the Kaiser Criterion, which assumes that the observable variables have variance 1.

Table 5. Variance explained by the components.

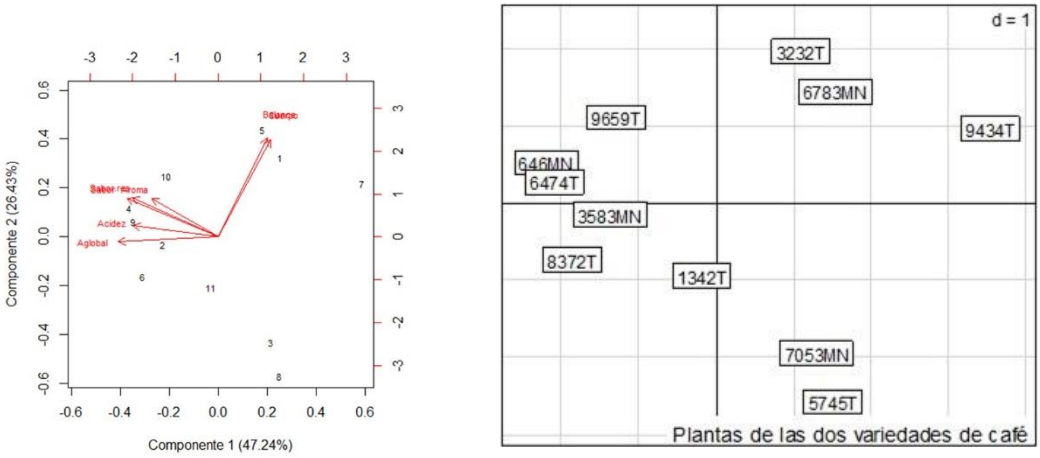
Components	Standard deviation	Variance	Proportion of the variance	Proportion of the accumulated variance	
1	1.819	3.307	0.472	0.472	**********
2	1.360	1.85	0.264	0.737	**********

The first component explained 47.20% of the total variability and consists of the variables taste (-0.442), residual taste (-0.417), acidity (-0.412) and global appreciation (-0.485), which are related to the ‘smell and taste’. The second component represented 26.4% of the total variation and was formed by the variables body (0.628) and balance (0.639), which are related to the ‘consistency of the cup’.

In Table 6 and in part a) of Figure 1, the results indicate that the variables are negatively correlated, in component one. The taste is negatively correlated, followed by global appreciation, acidity and residual taste. While in component two, body and balance correlate positively. In subsection b), it can be observed that the varieties of coffee plants evaluated are not determinants in their quality, because they are located interchangeably in the component plane. In this regard, Avelino *et al*. (2005) points out that the genetic factor does not influence cup quality; but the quality is more related to the terroir; that is, with the macro climate, which determines the sensory characteristics, including the typicities and the chemical content of the grains.

Table 6. Correlation between the variables and each of the main components.

Component load	Components	
	1	2
Aroma/fragrance	-0.323	0.251
Flavor	-0.442	-0.249
Beef flavor	-0.417	0.256
Acidity	-0.412	0.072
Body	0.255	0.628
Balance	0.24	0.64
Global appreciation	-0.485	-0.029



a) Main components b) Component plan

Figure 1. Main components of coffee sensory attributes.

Conclusions

The physical quality assessment of the traditional Arabica varieties Typica and Mundo Novo cultivated in Coatepec, Veracruz, presented significant differences in the average percentages of green grain retained in sieve 18 and 19. Mundo Novo reached three complete imperfections and Typica none agreed with the classification of the green coffee of the SCAA. Typica obtained the highest percentage of grain with 79.35%, while Mundo Novo the highest percentage of snail with

34.54%. Despite the differences in physical characteristics, the two varieties reached an average tasting score of 80.7, which means that the coffee is of very good quality and classified as specialty coffee according to the SCAA.

Two main components were selected that together explain 73.67% of the variability: 47.2% the first and 26.4% the second. The matrix of variable-component correlations (Table 6) shows that the first component correlates, directly proportionally, with taste, residual taste, acidity, and appreciation, and the second component with body and balance.

In general, the conditions of climate, soil and balanced nutrition on farms in Coatepec, Veracruz, do not make a difference in the physical and sensory quality of the beverage in the varieties evaluated. Both Typica and Mundo Novo have sensory quality potential and can continue to be planted in coffee plantations in the region.

Cited literature

Avelino, J.; Barboza, B.; Araya, J. C.; Fonseca, C.; Davrieux, F.; Guyot, B. and Cilas, C. 2005. Effects of slope exposure, altitude and yield on coffee quality in two altitude terroirs of Costa Rica, Orosí and Santa Maria de Dota. J. Sci. Food Agric. 11(85):1869-1876.

Beckley, V. 2010. La fermentación del café. Rev. Instituto de defensa del café de Costa Rica. 8:209-216.

Bosselmann, A. S; Dons, K.; Oberthur, T.; Smith, O, C.; Raebild, A. and Usma, H. 2009. The influence of shade trees on coffee quality in small holder coffee agroforestry systems in Southern Colombia. Agric. Ecosys. Environ. 1-3(129):253-260.

Cerda, L. J. y Villarroel, Del P. L. 2008. Evaluación de la concordancia inter-observador en investigación pediátrica: Coeficiente de Kappa. Rev. chilena de pediatría. 1(79):54-58.

Escamilla, P. E. 2007. Influencia de los factores ambientales, genéticos, agronómicos y sociales en la calidad del café orgánico en México. Tesis Doctoral, Colegio de Posgraduados en Ciencias Agrícolas-*Campus* Veracruz, México. 254 p.

Hernández, M. G. 2006. Regiones cafetaleras de Veracruz. Aroma de la biodiversidad. Bosques cafetaleros de Veracruz. PRONATURA.

INEGI. 2004. Instituto Nacional de Estadística Geografía e Informática. Guía para la interpretación de Cartografía edafología. 21 p.

INEGI. 2009. Instituto Nacional de Estadística Geografía e Informática. Prontuario de información geográfica municipal de los Estados Unidos Mexicanos. Coatepec, Veracruz de Ignacio de la Llave. México. 9 p.

Johnson, D. E. 2000. Métodos multivariados aplicados al análisis de datos. Traducción al español de applied multivariate methods for data analysts, Pérez, C. H. (traduc.). International Thomson Editors. México, DF. 566 p.

Kathurima, C. W.; Gichimu, B. M.; Kenji, G. M. and Boulanger, R. 2009. Evaluation of beverage quality and green bean physical characteristics of selected Arabica coffee genotypes in Kenya. Afr. J. Food Sci. 11(3):365-371.

Lara, E. L. D. 2005. Efectos de la altitud, sombra, producción y fertilización sobre la calidad del café (*Coffea arábica* L. var. Caturra) producido en sistemas agroforestales de la zona cafetalera norcentral de Nicaragua. Tesis de Maestría, CATIE. Turrialba, Costa Rica. 92 p.

Ledesma, R.; Macbeth, G. y Cortada, De K. N. 2008. Tamaño del efecto: revisión teórica y aplicaciones con el sistema estadístico ViSta. Rev. Latinoam. Psicología. 43(40):425-439.

López-García, F. J.; Escamilla-Prado, E.; Zamarripa-Colmenero, A. y Cruz- Castillo, J. G. 2016. Producción y calidad en variedades de café (*Coffea arabica* L.) en Veracruz, México. Rev. Fitotec. Mex. 3(39):297-304.

Marín, L. S. M.; Arcila, P. J.; Montoya, R. E. C. y Oliveros, T. C. 2003. Relación entre el estado de madurez del fruto del café y las características de beneficio, rendimiento y calidad de bebida. Cenicafé. 4(54):297-315.

Oberthür, T.; Läderach, P.; Posada, H.; Fisher, M. J.; Samper, L. F.; Collet, L.; Moreno, E.; Alarcón, R.; Villegas, A.; Usma, H. and Jarvis, A. 2011. Regional relationships between inherent coffee quality and growing environment for denomination of origin labels in Nariño and Cauca, Colombia. Food Policy. 6(36):783-794.

Orozco, C. N.; Guacas, S. A. y Bacca, A. 2011. Caracterización de fincas cafeteras por calidad de la bebida y algunas condiciones ambientales y agronómicas. Rev. Mex. Cienc. Agríc. 2(28):9-17.

Ortiz, J. E. y Moreno, E. C. 2011. ¿Se necesita la prueba t de Student para dos muestras independientes asumiendo varianzas iguales? Com. Estadística. 2(4):139-157.

Puerta, Q. G. I. 2000. Calidad en taza de algunas mezclas de variedades de café de la especie *Coffea arabica* L. Cenicafé. 1(51):5-19.

Puerta, Q. G. I. 2006. La humedad controlada del grano preserva la calidad del café. Cenicafé. 352(1):1-8.

Puerta, Q. G. I. 2011. Composición química de una taza de café. Cenicafé. 414(1):1-12.

Regalado, O. A. 2006. ¿Qué es la calidad del café? Universidad Autónoma Chapingo. Texcoco, Estado de México. 309 p.

Reh, C. T.; Gerber, A.; Prodolliet, J. and Vuataz, G. 2006. Water content determination in green coffee-Method comparison to study specificity and accuracy. Food Chem. 3(96):423-430.

Rodríguez, B. E.; Suarez, S. J. C. y Duran, B. E. H. 2014. Efecto de las condiciones de cultivo, las características químicas del suelo y el manejo de grano en los atributos sensoriales de café (*Coffea arabica* L.) en taza. Acta Agron. 4(64):342-348.

Rodríguez, B. E.; Vega, C. G. A. y Suárez, S. J. C. 2014. Fuentes de variación que tienen efecto sobre los atributos sensoriales de taza en sistemas agroforestales de café (*Coffea arabica*) en el sur de Colombia. Revista Sennova: Revista del Sistema de Ciencia, Tecnología e Innovación. 1(1):64-77.

Sánchez-Hernández, S.; Escamilla-Prado, E.; Mendoza-Briseño, M. A. y Nazario-Lezama, N. 2018. Calidad del café (*Coffea arábica* L.) en dos sistemas agroforestales en el centro de Veracruz, México. Agroproductividad. 4(11):80-86.

Santoyo, C. V. H.; Díaz, C. S.; Escamilla, P. E. y Robledo, M. J. D. 1996. Factores agronómicos y calidad del café. Universidad Autónoma Chapingo y Confederación mexicana y productores de café. Texcoco, Estado de México. 21 p.

Specialty Coffee Association of America (SCAA). 2015. SCAA Protocols cupping specialty coffee. 10 p.

Steiger, D.; Nagai, C.; Moore, P.; Morden, C.; Osgood, R. and Ming, R. 2002. AFLP analysis of genetic diversity within and among *Coffea arabica* cultivars. Theoretical and applied genetics. 2-3(105):209-215.

Vaast, P.; Cilas, C.; Perriot, J. J.; Davrieux, F.; Guyot, B. and Bolaño, M. 2005. Mapping of coffee quality in Nicaragua according to regions, ecological conditions and farm management. *In:* ASIC conference, 20th International Conference on Coffee Science. CIRAD. Bangalore, India. 842-850 pp.

Wintgens, J. N. 2004a. Factor influencing the quality of Green coffee. *In:* coffee: growing, processing, sustainable production: a guidebook for growers, processors, traders, and researchers. Wintgens, J. N. (Ed.). Wiley-VHC. Weinhein, Germany. 789-809 pp.

Wintgens, J. N. 2004b. Green coffee defects. *In*: coffee: growing, processing, sustainable production: a guidebook for growers, processors, traders, and researchers. Wintgens, J. N. (Ed.). Wiley-VHC. Weinhein, Germany. 758-788 pp.