Investigation note

Quality of cob and grain in creole corn of the Costa Chica, Guerrero

Omar Ramírez Reynoso[1]
José Luis Escobar Álvarez[2]
María de los Ángeles Maldonado Peralta[3]
Adelaido Rafael Rojas García[3]
Elías Hernández Castro[4]
José Luis Valenzuela-Lagarda[1§]

[1]Regional Center for Higher Education of the Costa Chica-Autonomous University of Guerrero. Ayutla-Cruz Grande highway km 0.5, Cruz Grande, Guerrero, Mexico. CP. 41800. [2]Faculty of Biological and Agricultural Sciences-University of Colima. Colima-Manzanillo Highway km 40, La Estación, Tecomán Colima, Mexico. CP. 28930. (jescobar1@ucol.mx). [3]Faculty of Veterinary Medicine and Animal Husbandry no. 2-Autonomous University of Guerrero. Av. Highway Acapulco-Pinotepa Nacional km 197, Cuajinicuilapa, Guerrrero, Mexico. CP. 41940. [4]Faculty of Agricultural and Environmental Sciences-Autonomous University of Guerrero. Iguala-Tuxpan highway km 2.5, Iguala de la Independencia, Guerrero, Mexico. CP. 40054.

[§]Corresponding author: joseluislagarda@uagro.mx.

Abstract

Corn (*Zea mays* L.) is the most consumed cereal in México and Latin America, it is important to know the physical quality of the cob and grain to obtain data that serve as a basis for the selection of the best varieties and with it contribute to the conservation and improvement of local varieties, which since the introduction of improved seeds have been at risk of disappearance due to their low yield and poor use. In the spring-summer cycle of 2018, in the town of Cruz Grande municipality of Florencio Villarreal, Guerrero. An experiment was established under a completely randomized block design. The objective was to determine the physical quality of grains and cobs of two genotypes of pigmented corn (red and yellow) belonging to the Dos Puntas variety. The quality of the cob and seed anatomy was evaluated. The results showed that there were no statistical differences between varieties; the grain with the best endosperm is yellow (80.82%) and germ is purple (11.61%); as well as, the yellow variety has a larger grain size (length 10.09 and width 4.31 mm). It is concluded that the corn with the best characteristics for sale as whole grain and use in the dough and tortilla industry, is yellow, and purple for oil extraction.

Keywords: *Zea mays* L., anatomy, corn breeds, pigment.

Reception date: April 2020
Acceptance date: May 2020

Mexico is considered as the center of origin and diversity of corn, within this country there are more than 59 native races of corn throughout the territory (Fernández-Suarez *et al*., 2013), about 80% of the area planted with corn it is cultivated by small producers in rural areas, for whom the production of creole varieties is basic for their food and economic sustenance (Franco-Martínez *et al.*, 2015; Sierra-Macías *et al.*, 2016).

Being genetic material that develops in adverse edapho-climatic conditions, they present better adaptation to being cultivated (Sierra-Macías *et al*., 2016). Although the improved varieties present high grain yield per hectare, high investment is required to achieve their maximum productive potential. The native varieties have lower yield; however, the requirements for production are less; mainly due to lack of water, poor and little fertile soils, and the investment for inputs is minimal (Salazar and Boschini, 2002; Franco-Martínez *et al*., 2015).

Among the existing corn breeds identified in the Mexican territory, 23 of them present a variant of pigmented grain, with shades ranging from black, brown, red to pale pink. Being the most abundant varieties of purple and red hue (Sierra-Macías *et al*., 2016), this is due to the content of phenols present in the endosperm and pericarp of the grain.

In purple varieties, anthocyanins are found, which provide high antioxidant activity and higher iron and zinc content, while carotenoids are found in yellow varieties (Salinas-Moreno *et al*., 2012), which have a higher amount of starch in wet milling and high content of β-carotene, which benefits the immune system (Coutiño-Estrada *et al*., 2008).

Pigmented varieties are highly appreciated by consumers, due to the attractiveness that it provides to processed products such as tortillas, atoles, tortilla chips, etc., which are part of the human diet and are the basic sustenance of small producers in rural areas (Hernández-Quintero *et al*., 2017). Although pigmented varieties are highly appreciated by the consumer, their production does not exceed 7% of the national total (SIAP, 2018), due to their low yield (Salazar and Boschini, 2002).

The characterization of varieties is of relevance in the preservation of the species that comprise it, these measures range from vegetative growth to grain and cob yield (Bonamico *et al*., 2004). Empirically, small producers select their grains visually, leaving the largest ones coming from long cobs with a high grain content (Navarro-Garza *et al*., 2012). These criteria have allowed the survival and adaptability of native grains (Miranda-Colin, 2000). Therefore, the objective of the present work was to characterize the cob and corn grain pigmented of local varieties.

Experimental site

The experiment was carried out at the Costa Chica Regional Higher Education Center located in the municipality of Florencio Villareal in the state of Guerrero, on the Cruz Grande-Ayutla highway, km 0.5, at the geographic coordinates of 16° 44’ 02.2’’ north latitude and 99° 07’ 48.5’’ west longitude; with a warm sub-humid climate (Aw), precipitation 1 100 mm, average annual temperature of 25 °C, average relative humidity of 85% at 16 masl (INEGI, 2009).

The purple and yellow pigmented corn cobs, used for the experiment, were cultivated during the spring-summer (SS) 2018 cycle. The experimental plot consisted of 8 plots of 25 m^2 each, with dimensions of 5 $*$ 5 m, the distance between rows was 0.8 m and between plants 0.4 m in which three seeds were deposited, to later thin two plants per point; which represented a population density of 61 500 plants per hectare. The agronomic management was carried out by what was reported in the Guerrero Technical Agricultural Agenda (INIFAP, 2017).

Cob quality

For the cob quality variables, the primary cob weight (EW) in g was evaluated, with an Ohaus Scout® balance, cob length (EL), cob diameter (ED), diameter index on cob length (DIEL), number of rows per cob (NRE), row index over cob diameter (RID), grains per row (GR), pot diameter (PD) and grain depth (GDE) in millimeters, with digital vernier (Surtek®) and was reported in mm. In addition, variables related to grain were measured.

Grain length (GL), grain thickness (GT), grain width (GW) and width over grain length index (WGLI) were reported in mm. The indices were calculated with the following equations:

$\text{DIEL}=\frac{\text{cob diameter}}{\text{cob length}}$ $\text{RID}=\frac{\text{number of rows per cob}}{\text{diameter of cob}}$ GDE=cob diameter-cob diameter

$\text{WGLI}=\frac{\text{grain width}}{\text{grain length}}$

Thousand seed weight (TSW)

One thousand viable seeds were selected for each repetition and weighed on an Ohaus Scout® brand digital scale. The result was calculated as the mean of the data obtained according to that proposed by (Salinas-Moreno *et al*. (2012).

Seed anatomy

For this variable, 100 viable seeds were randomly taken and left to imbibition for 12 h, then, with a scalpel, the endosperm, pericarp, pedicel and germ were separated. After dissection, they were dried in a forced air stove (Figueroa-Cardenas, 2013), once they were dried, they were weighed and the results were calculated with the following equation: $\%\ \text{part}=\frac{\text{part weight}}{\text{total weight}}\ \text{x}\ 100$

For example: $\%\ \text{endosperm} =\frac{\text{endosperm weight}}{\text{total weight}}\ \text{x}\ 100$

Experimental design and data analysis

The experimental design consisted of completely random blocks with two treatments and 15 repetitions. Treatments consisted of purple and yellow creole maize. The data obtained were subjected to analysis of variance, and when it was significant ($p\leq 0.05$), mean comparisons were made between the treatments with the Tukey test ($\alpha= 0.05$) with the MiniTab18 statistical package (Montgomery, 2004).

Cob quality

Table 1 summarizes the data obtained from the variables evaluated in this study. It is observed that there is no significant difference between the varieties of creole maize, only that a statistical difference was found in the NRE variable, as the yellow creole presented a greater number of rows compared to the purple one (12.93 and 10 rows, respectively).

Table 1. Cob quality in two creole varieties of corn collected in Florencio Villareal, Guerero.

Variable	Creole	
	Purple	Yellow
EW (g)	133.80 ±17.22* a**	139.73 ±24.61 a
ED (mm)	36.80 ±4.97 a	39.98 ±2.35 a
EL (mm)	149.10 ±16.84 a	134.27 ±33.8 a
NRE (mm)	10.00 ±0.32 b	12.93 ±1.67 a
NGR (mm)	32.40 ±2.7 a	29.93 ±3.66 a
PD (mm)	21.14 ±1.92 a	22.04 ±2.81 a
PGM (g)	110.20 ±16.38 a	107.53 ±18.56 a
PO (mm)	22.45 ±4.76 a	32.07 ±8.51 a
GDE (mm)	15.66 ±5.06 a	17.94 ±3.48 a
DIEL (mm)	0.25 ±0.04 a	0.28 ±0.03 a
RID	0.28 ±0.05 a	0.32 ±0.03 a

*= mean ± standard deviation; **= means that do not share literal are statistically different (Tukey α= 0.05); n= 15.

Regarding the rest of the variables evaluated (EW, ED, EL, GR, PD, DIEL and RID), no significant differences were found (p> 0.05), which can be attributed to the fact that both corn variants correspond to the so-called punta cuata corn or two points; therefore, they share some characteristics of the grain. The cob length (EL), although statistically the same, the purple creole presented greater length compared to the yellow pigmented (149.1 and 134.27 mm, respectively). Likewise, purple stood out 8.25% in the number of grains per row (GR).

Espinosa-Calderón *et al*. (2013) reported average values of 11.5 to 13.8 cm in cob length, rows per cob (13 to 16 rows) and grains per row (26 to 29 grains) in 13 cobly varieties of yellow corn established in two environments, values similar to the obtained in the present work. These authors established the trials in temperate climate with rains in summer, compared to the climate (warm sub-humid) that predominates in the Costa Chica de Guerrero; therefore, it is attributed that the climate did not influence this variable. For their part, Pecina-Martínez *et al*. (2011) evaluated the performance in 29 populations of native corn breeds in Tamaulipas, in three different environments. The possible races were Tuxpeño, Olotillo, Chalqueño, Valdeño and Tepecintle.

Where they reported values of EL, ED, PD, NRE and GR of 15. 5, 4.4, 2.5 cm and 12.9, 33.5 grains, respectively. The best performance was expressed in High Valleys, while the lowest yield was obtained in the dry tropics. Santa-Rosa *et al*. (2012) reported in native populations of the

Poblano Altiplano, ranges between 11.5 to 12.4 cm for EL and 43.5 to 48.9 cm for ED, of these two values, what was reported in this work exceeded the EL reported by those authors, just as they present values for NRE and GR of 10.2-14.1 and 20.4-22.5 respectively.

Physical quality of grain

It was found that the two pigmented varieties did not present significant statistical differences ($p > 0.05$) in grain length and thickness; as well as, in the ILAG except in the grain width variable that presented the highest value the purple pigmented variety of 9.88 mm (Table 2).

Table 2. Quality parameters in pigmented creole corn grains established in Florencio Villareal, Guerrero.

Variable	Creole	
	Purple	Yellow
Length (mm)	9.97 ±0.9 a	10.09 ±1.25 a
Width (mm)	9.88 ±0.26 a	8.34 ±0.19 a
Thickness (mm)	4.23 ±0.16 a	4.31 ±0.63 a
ILAG (mm)	1.01 ±0.08 a	0.84 ±0.13 a

Mean ± standard deviation. Means that do not share literal are statistically different (Tukey α= 0.05). n= 15.

It can be mentioned that the variety with the longest grain length is the yellow pigmented (10.09 mm) and the thickest (4.31 mm). Sierra-Macías *et al*. (2016) found grain values in the Olotillo breed of 7.5 mm for width, 11.5 mm in length and 2.8 mm thickness in creole breeds in the state of Puebla. On the other hand, Figueroa-Cárdenas *et al*. (2013) report grain dimensions in racial groups that vary between 10.1 to 12.8 mm in length and for width and thickness values of 6.7 to 10 mm and 4.5 to 5.5 mm respectively.

Weight of a thousand seeds and anatomical analysis

For the weight of 1 000 seeds, the values obtained in the present work (Table 3) are similar to those obtained by Pérez-Mendoza *et al*. (2006) where he obtained on average 326.7 g in six different forage corn hybrids. As the purple creole had the highest seed weight (335.78 g). In the anatomical analysis, a difference was found in the content of the endosperm ($p < 0.05$), where yellow creole presented 4.17% more in content, compared to purple.

Table 3. Anatomy of grains and weight of pigmented creole corn seeds cultivated in Florencio Villareal, Guerrero.

Variable (%)	Creole	
	Purple	Yellow
Endosperm	76.69 ±1.47 b	80.82 ±1.14 a
Pericarp	5.82 ±0.5 a	5.53 ±0.66 a
Peduncle	2.88 ±2 a	3.71 ±0.17 a
Germ	11.61 ±0.99 a	9.93 ±1.67 a
TSW	335.78 ±0.77 a	301.56 ±0.38 b

Mean standard deviation. Means that do not share literal are statistically different (Tukey α= 0.05); n= 40.

The yellow pigmented variety has a higher endosperm (80.82%). FAO (1993) mentions that the endosperm represents 82-84% of the weight of the grain and this is characterized by high starch content, it is divided into mealy and hard endosperm and they differ from each other by their ease of milling (Leyva-Ovalle *et al*., 2002).

It was found that both varieties have a statistically similar pericarp (p> 0.05), although among these it can be said that the yellow pigmented variety presented a lower value (5.82%). The pericarp is the layer that covers the grain and has the role of protecting the grain from the medium, the size of the pericarp is related to the ease that the main radicle has to emerge from the grain, since this being smaller is easier to break.

A high percentage of pericarp is said to be consistent with good tortilla texture, and a low percentage of pericarp is palatable in products made from young cobs (corn) (Vázquez-Carrillo *et al*., 2010). There was no significant difference (p> 0.05) in relation to the grain pedicel, although the yellow pigmented variety has a higher value (3.71%), this structure, as it contains tubular cells, serves as an anchor to the cob and together with the endosperm are fiber sources, especially lignin (Wolf *et al*., 1952).

The values for the germ content do not show significant statistical differences (p> 0.05). The purple pigmented variety (11.61%) can be considered as the variety that has the highest germ content, it is known that the germ is the living part of the grain, the seedling is located in it, it is rich in minerals, especially phosphorus, Because they are responsible for activating the seed and activating the enzymatic processes that allow the emergence of the seedling (Agama-Acevedo *et al*., 2013), the values found are similar to those reported by the FAO (1993), usually the grain size influences the fat content of the grain.

Vázquez-Carrillo *et al*. (2010) found in three varieties of yellow pigmentation in the state of Hidalgo germ contents of 9.26%, 10.62% and 10.75% and pericarp of 6.45%, 6.55% and 5.94% respectively. This author mentions that for the dough and tortilla industry high pericarp contents are not a problem when processing tortillas and that the quality of fatty acids of the germ, help to improve the texture of the resulting tortillas.

Conclusions

The purple pigmented variety had a larger cob and grain size; therefore, it can be used in animal feed grinding and sold as whole grain for oil extraction. The grain of the yellow variety presented a higher percentage of the endosperm and because the starch is located in that part of the grain, its use goes to nixtamalization and dough, tortilla and its derivatives.

Cited literature

Agama, A. E.; Juárez, G. E.; Evangelista, L. S.; Rosales, R. O. L. y Bello, P. L. A. 2013. Características del almidón de maíz y relación con las enzimas de su biosíntesis. Agrociencia. 47(1):01-12.

Bonamico, N. C. and Ibañez, M. A. 2004. Caracterización y clasificación de híbridos simples de maíz con marcadores SSR. Revista de Investigaciones Agropecuarias. 33(2):129-144.

Coutiño, E. B.; Vázquez, C. G.; Torres, M. B. y Salinas, M. Y. 2008. Calidad de grano, tortillas y botanas de dos variedades de maíz de la raza comiteco. Rev. Fitotec. Mex. 31(3):9-14.

Espinosa, C. A.; Tadeo; R. M.; Turrent, F. A.; Sierra, M.M.; Gómez, M. N. y Zamudio, G. B. 2013. Rendimiento de variedades precoces de maíz grano amarillo para valles altos de México. Agron. Mesoam. 24(1):93-99.

FAO. 1993. Food and Agriculture Organization. El maíz en la nutrición humana. Roma. FAO. http://www.fao.org/3/t0395s/T0395S00.htm

Fernández, S. R.; Morales, C. L. A. y Gálvez, M. A. 2013. Importancia de los maíces nativos de México en la dieta nacional: Una revisión indispensable. Rev. Fitotec. Mex. 36(3-A):275-283.

Figueroa, C. J. D.; Narváez, G. D. E.; Mauricio, S. A.; Taba, S.; Gaytán, M. M.; Vélez, M. J. J.; Rincón, S. F. y Aragón, C. F. 2013. Propiedades físicas del grano y calidad de los grupos raciales de Maíces nativos (criollos) de México. Rev. Fitotec. Mex. 36(3-A):305-314.

Franco, M. J. R. P.; González, H. A.; Pérez, L. D. J. y González, R. M. 2015. Caracterización fenotípica de híbridos y variedades de maíz forrajero en Valles Altos del Estado de México, México. Rev. Mex. Cienc. Agríc. 6(8):1915-1927.

Hernández, Q. J. D. D.; Rosales, N. A.; Molina, M. A.; Miranda, P. A.; Willcox, M.; Hernández, C. J. M. y Palacios, R. N. 2017. Cuantificación de antocianinas mediante espectroscopia de infrarrojo cercano y cromatografía líquida en maíces pigmentados. Rev. Fitotec. Mex. 40(2):219-225.

INEGI. 2009. Instituto Nacional de Estadística y Geografía. Prontuario de información geográfica municipal de los Estados Unidos Mexicanos. Florencio Villareal, Guerrero. Clave geoestadística 12030. INEGI. 9 p.

INIFAP. 2017. Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias. Agenda Técnica Agrícola, Guerrero. INIFAP. 120 p.

Leyva, O. O. R.; Carballo, C. A.; Mejía, C. J. A. y Vázquez, C. M. G. 2002. Procesamiento digital de imágenes para la estimulación de textura de endospermo en líneas de maíz. Rev. Fitotec. Mex. 25(4):355-365.

Miranda-Colín, S. 2000. Mejoramiento genético del maíz en la época prehispánica. Agric. Téc. Méx. 1(1):3-15.

Montgomery, D. C. 2004. Control estadístico de la calidad. Núm. 658.562 M66 2004.). Limusa Wiley. 797 p.

Navarro, G. H.; Hernández, F. M.; Castillo, G. F. y Pérez, O. M. A. 2012. Diversidad y caracterización de maíces criollos: Estudio de caso en sistemas de cultivo en la Costa Chica de Guerrero, México. Agric. Soc. Des. 9(2):149-165.

Pecina, M. J. A.; Mendoza, C. M. C.; López, S. J. A.; Castillo, G. F.; Mendoza, R. M. y Ortiz, C. J. 2011. Rendimiento de grano y sus componentes en maíces nativos de Tamaulipas evaluados en ambientes contrastantes. Rev. Fitotec. Mex. 34(2):85-92.

Pérez, M. C.; Hernández, L. A.; González, C. F. V.; García de los Santos, G.; Carballo, C. A.; Vázquez, R. T. R. y Tovar, G. M. R. 2006. Tamaño de semilla y relación con su calidad fisiológica en variedades de maíz para forraje. Agric. Téc. Méx. 32(3):341-352.

Salazar, J. A. E. y Boschini, F. C. 2002. Producción de forraje con maíz criollo y maíz híbrido. Agron. Mesoam. 13(1):13-17.

Salinas, M. Y.; Cruz, C. F. J.; Díaz, O. S. A. y Castillo, G. F. 2012. Granos de maíces pigmentados de Chiapas, características físicas, contenido de antocianinas y valor nutracéutico. Rev. Fitotec. Mex. 35(1):33-41.

Santa-Rosa, R. H.; Gil, M. H.; Santacruz, V. A.; López, S. H.; Antonio, L. P. y Miranda, C. S. 2012. Diversidad fenotípica de maíces nativos del Altiplano centro-oriente del estado de Puebla, México. Rev. Fitotec. Mex. 35(2):97-109.

Sierra, M. M.; Andrés, M. P.; Palafox, C. A. y Meneses, M. I. 2016. Diversidad genética, clasificación y distribución racial del maíz nativo en el estado de Puebla, México. Rev. Cienc. Nat. Agropec. 3(9):12-21.

SIAP. 2018. Sistema de Información Agroalimentaria y Pesquera. Atlas Agroalimentario 2012-2018, SIAP. 102-104 pp.

Vázquez, C. M. G.; Pérez, C. J. P.; Hernández, C. J. M.; Marrufo, D. M. L. y Martínez, R. E. 2010. Calidad de grano y de tortillas de maíces criollos del Altiplano y Valle del Mezquital, México. Rev. Fitotec. Mex. 33(4):49-56.

Wolf, M. J.; Buzan, C. L.; MacMasters, M. M. and Rist, C. E. 1952. Structure of the mature corn kernel. I. Gross anatomy and structural relationships. Cereal Chemistry. 29(5):321-333.