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Morphological characteristics of okra fruits [*Abelmoschus esculentus* (L.) Moench.] cultivated in the dry tropic

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ABSTRACT

Objective: The objective was to evaluate the morphological characteristics of okra fruit [*Abelmoschus esculentus* (L.) Moench.], an endemic crop of the Afro-Mexican region, in the dry tropics.

Design/Methodology/Approach: Materials were collected in Cuajinicuilapa, in the state of Guerrero in Mexico. Using a completely randomized design (CRD), 4 repetitions of 100 fruits were selected, and each was evaluated for the following: weight, number, size and shape of fruits and seeds. Data were analyzed using measures of central tendency, utilizing SAS.

Results: The fruits are heterogeneous and some are deformed, they have a long and fluted shape, with an average weight of 10.4 g and 95 seeds each weighing 0.05 g. The seeds are round with a conical micropyle, the testa is dark grey, and the embryo white.

Study Limitations/Implications: It is necessary to keep studying the morphological characteristics of okra fruit for a longer period of time and to establish farming in order to widen the outlook of decision making.

Findings/Conclusions: Okra fruits from backyard farming have better quality and potential for fresh or processed consumption. There is a lack of management and improvement of this crop.

Keywords: Congo coffee, shape index, morphological quality, Mazorquita coffee.

INTRODUCCIÓN

Okra [*Abelmoschus esculentus* (L.) Moench.], also known as Congo coffee or Mazorquita coffee, is consumed by people of African descent. It is a species of the Malvaceae family, native to tropical Africa (Díaz *et al*., 2007), where it has been grown for more than 4,000 years (Ayyub *et al*., 2013). It is an annual crop which develops in tropical and subtropical areas all over the world (Saifullah and Rabbani, 2009), mainly in India, Nigeria, Pakistan, Ghana and Egypt, where temperatures range above 26 °C. In Mexico it is a non-traditional vegetable, between 4,000 and 7,000 ha are sown per year, in the states of Morelos, Michoacán, Guerrero and Tamaulipas, with an average yield of 10 t ha^{-1} (Díaz *et al*., 2007).

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It is a profitable crop for developing countries (Tamura and Minamide, 1984), it generates currency and it is an important source of employment, okra as a vegetable is mainly exported to the United States (Adiger *et al*., 2011).

Okra can be grown year round; however, it is mainly produced during the summer, due to the demand of certain climatic factors such as light, temperature and water. It completes its productive cycle with an average volume of 665 mm (Tiwari *et al*., 1998), and it is also known to have germination problems. Studies have shown that the whole plant is edible (Fekadu *et al*., 2015), the fruit is mucilaginous, and it can be used as a fresh or cooked vegetable, or added to salads or soups. It can be stored in a freezer or as seeds (Ayyub *et al*., 2013), which are rich in unsaturated fatty acids (Kumar *et al*., 2013); they provide water, proteins, carbohydrates and fiber (Saifullah and Rabbani, 2009); and they have high content of polysaccharides, which gives them their medicinal properties (Sengkhamparn *et al*., 2009).

The plant is a shrub, with a height of 1 to 2 m, ramified, with large leaves ranging from 20 to 40 cm in length and 3-7 lobes each; they have cross pollination, the seeds are round, large, and grey in color (Akinyele and Osekita, 2006). Studies indicate that the number of fruits per plant has a direct effect on the seeds yield, followed by the plant's height, branching and bloom time (Kumar and Reddy, 1982), the weight of the fruit is directly related to the yield (Ariyo, 1987). In Mexico there are limited scientific studies on okra cultivation (Díaz and Ortegón, 1996; Díaz *et al*., 2003; Díaz *et al*., 2007), aimed toward crops with a potential for fresh consumption and dried seeds are processed in order to make a drink similar to coffee.

In the Costa Chica region in the states of Guerrero and Oaxaca in Mexico, inhabited by people of African descent, okra was farmed in the past, yet due to pests and climate factors this species has become a backyard crop in these municipalities, and its seeds are used to make a beverage to substitute coffee (Cuata and Manzaneda, 2018) which is commonly known as Congo coffee or Mazorquita coffee. Due to its color and aroma it is often called "chocolate de los negros" (black-men's coffee). Recent studies have shown that it contains pectin and lecithin which act as substitutes of chocolate (Datsomor *et al*., 2019). Therefore, the objective of this study was to evaluate the morphological characteristics of okra [*Abelmoschus esculentus* (L.) Moench.] fruits and seeds, as an endemic crop in the Afro-Mexican region with commercial potential for Mexico.

MATERIALS AND METHODS

This research was carried out in June, 2019, in the Fodder Laboratory of the School of Veterinary Medicine and Zootechnics No. 2, in Cuajinicuilapa, Guerrero, Mexico. This municipality is located at 16° 28' 16'' LN and 98° 24' 55'' LW at an altitude of 45 m, with an average annual temperature of 27 °C and dry tropical climate, with up to 1200 mm per year of summer rains (INEGI, 2012). Okra fruits [*Abelmoschus esculentus* (L.) Moench.] were harvested from backyards, from visibly healthy plants, associated with maize, hibiscus and sesame.

In order to determine the number of fruits per plant, these were trimmed and placed in transparent plastic bags, they were labeled and taken to the laboratory where they were counted and the healthy and complete ones were selected. Using a completely randomized design (CRD) four repetitions of 100 fruits were chosen, in order to evaluate morphological quality. The collection of fruits was carried out according to field availability, taking into account characteristics of variation and production based on backyard cultivation tasks. The polar and equatorial diameters were measured with the use of a Vernier (Truper Stainless® Steel); for the polar diameter the apical end was measured until the base, and the middle section was measured for the equatorial diameter. These data generated the shape index, by dividing the polar diameter by the equatorial diameter (Alia-Tejacal *et al*., 2012; Maldonado *et al*., 2016).

The dry weight of fruits and seeds, per fruit and individual, was obtained using an analytical balance (Scientech ZSA120, Boulder, USA). The number of channels, seeds per channel, and seeds per fruit were counted, as well as the hollow seeds. A Vernier was used to measure the polar and equatorial diameter of the seeds and the shape index was determined. The color of the seeds was determined using a colorimeter (Chroma Meter Cr-400, Ramsey, USA) which registers luminosity values (L*), hue angle (H*) and chromaticity (C*).

The results from the variables were analyzed using Measures of Central Tendency with the statistical program SAS® 9.2 (SAS, Institute, 2009).

RESULTS

Okra fruit is elongated and originates individually on the axil of the leaf; it is exposed in an erect manner, perpendicular to the stem, joined to the plant by a small pedicle, with an ellipsoid basal end and a conical apical end; each plant developed an average of 10.4 fruits (Table 1), with 7 to 14 mature fruits.

The average weight of dried fruits was 10.4 g, with a polar diameter of 11.48 cm, and an equatorial diameter of 3.99 cm; the plants used in this study have never been genetically modified, which makes them resistant and allows for heterogeneity in the fruits. In addition, the fruits found near the apex had an arched shape, probably due to pollination or because the first fruits usually are of better quality. Because of this, the fruits in this study are considered of large size, fluted, they have between 6 and 9 channels each, and an average of 12.58 seeds.

The fruit has between 53 and 118 viable seeds, with few or no hollow seeds, with a shape index of 2.93 giving it its elongated shape, typical of this species.

The seeds have semi-hard testa; the average color showed a luminosity (L*) of 45.48, chromaticity (C*) of 5.31 and a hue angle (H*) of 10.20, respectively, which gives it a dark grey almost black color with a touch of green. Each seed weighs an average of 0.05 g, with a polar diameter of 0.54 and an equatorial diameter of 0.49 cm. The seeds shape index is on average 1.14, considering they are round, but with a micropyle with a conical apex (Figure 1); inside, they have a large, round, white embryo. It is worth mentioning that dehydrated seeds are toasted on a skillet and ground, resulting in a powder with aroma similar to coffee used to make a comparable drink.

DISCUSSION

Okra fruits are heterogeneous in size. Atijegbe *et al.* (2014) evaluated the okra crop and reported between 2 to 10 fruits per plant; in this study a higher number of fruits were reported, considering that being a backyard crop it did not receive any specific treatment and the production period was seasonal during the raining season. Akinyote *et al.* (2011) applied nitrogenous fertilizer and found better fruit yield when compared to the control. Akinyele and Temikotan (2007) mentioned that okra plants that grow in sandy soils present fruits with lower weight and size compared to those grown in

Table 1. Description of quantitative characteristics and statistical parameters of okra [*Abelmoschus esculentus* (L.) Moench.] fruits and seeds.

Variables evaluated	Minimum	Maximum	Average	Range	CV	EE
Fruit						
Number of fruits per plant	7	14	10.4	7	20.79	2.16
Nug weight (g)	7.29	15.31	10.4	8.02	16.52	1.72
Fruit polar diameter (cm)	8.32	14.36	11.48	6.04	16.55	1.9
Fruit equatorial diameter (cm)	2.85	5.28	3.99	2.43	17.68	0.71
Number of carcasses per fruit	6	9	7.6	3	16.2	1.23
Number of seeds per carcasses	8.83	15.33	12.58	6.5	13.07	1.64
Number of seeds per fruit	53	118	95	65	16.57	15.74
Number of vain seeds	0	4	0.6	4	174.38	1.05
Fruit shape index (Polar diameter/Equatorial diameter)	2.03	4.3	2.93	2.27	19.15	0.56
Seeds						
Seed weight (g)	0.04	0.07	0.05	0.03	17.34	0.01
Polar diameter of the seed (cm)	0.45	0.61	0.54	0.16	7.42	0.04
Equatorial diameter of seed (cm)	0.42	0.55	0.49	0.13	6.73	0.03
Seed shape index	0.98	1.31	1.14	0.33	7.77	0.09
Seed color						
Brightness (L*)	36.70	51.40	45.48	14.70	10.15	4.62
Chromaticity (C*)	1.70	8.60	5.31	6.90	50.33	2.67
Hue (H*)	8.60	13.00	10.20	4.40	12.83	1.31

N:400 fruits; Range: Range of Variation; CV: Coefficient of Variation; SE: Standard Error.

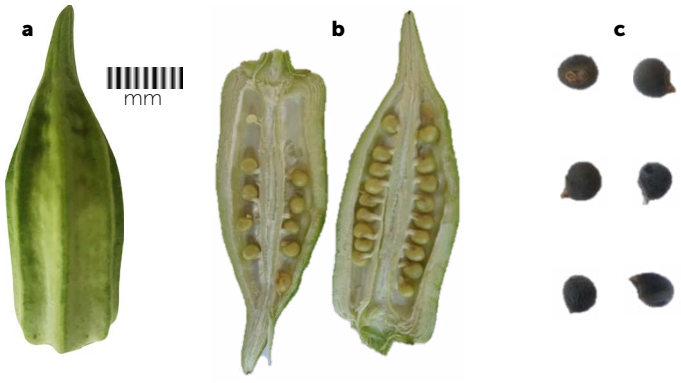

Figure 1. Fruits and seeds of okra [*Abelmoschus esculentus* (L.) Moench.]. a) complete fruit in physiological maturity, b) fruit split longitudinally with arranged seeds, c) dehydrated seeds in different positions, with the micropyle exposed.

loam clay soils; likewise, the number of seeds also varied, with a lower count in fruits with lower weight and size.

The average fruit weight was 10.4 g and in the region no fruits as large were found, which contradicts the research reported by Cuata and Manzaneda (2018), but agrees with figure 10 which is reported in their study; in addition, this study reports similar diameters to those reported in their study.

Studies carried out in northeastern Mexico, evaluating the quality of okra fruit as a vegetable in different cultivars, found an fruit yield of 9.8 up to 18.1 t ha^{-1}, tender fruits are different tones of green, depending on the cultivar and their quality, which also depended on the materials used (Díaz *et al*., 2007); these authors also mention that in the state of Guerrero this crop was abandoned due to pests, which coincides with what is mentioned by the farmers.

Fekadu *et al*. (2015) studied okra and found diverse qualities, focusing on health benefits and referring to okra as a food able to reduce malnutrition for the whole community, which is not uncommon in regions of African descent; mentioning once more that the seeds are toasted, ground, and used as a coffee substitute (Moekchantuk and Kumar, 2004).

Okra seeds have been used for consumption, but they are rarely studied; however, the use and description of their morphological traits can improve our knowledge about its production and the relationship which exists with the environment (Luck *et al*., 2012). Cuata and Manzaneda (2018) reported similar values to those reported in this study in terms of number, weight, and size of the seeds.

Considering that the seed is the most representative part of a plant and that in Afro-Mexican regions this crop has been preserved for generations, without improvemewnt or records of production, as a result this is the first study on the subject in the region and it is unknown if there have been changes in the yield or quality of the fruits. In this study a heterogeneous number of total seeds per fruit were found, but shape and color were homogeneous, and the majority was complete and healthy. Huayamave and Maldonado (2002) and Cuata Manzaneda (2018) found that the color of the seeds is grey with tendency toward green, which is consistent with this study.

In Mexico few advances have been made on okra cultivation, while in other countries this crop has been studied, resulting in a wide range of health benefits, nutritional, pharmaceutical, etc. Therefore, it is necessary to give more importance to this crop and to seek alternative production options for fresh consumption, dehydration or processing, in addition to having useful characteristics for national and international sales.

CONCLUSION

Okra fruits can be consumed fresh or processed; on average they measure 10.4 cm in length, and weigh 10.4 g, they have 9 channels and in each one an average of 12.58 seeds. In total they have 95 seeds, each weighing 0.05 g, round, with a semi-hard dark grey testa and a white embryo.

In the Cost Chica region, okra is a backyard crop, which should be taken into account for commercial farming; however, there is a lack of research and improvements in order to increase the quality and homogenize the fruits.

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