Article

Characterization and evaluation of fruits of 'nanche' (*Byrsonima crassifolia* L.)

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Abstract

In Mexico, nanche grows as a shrub in a dry tropic and as a tree in humid tropics; it produces fruits with acceptance in the market, where it is increasingly popular. The objective of this research was to study the physical and chemical quality properties of the fruit and the characteristics of the endocarp and embryo of the nanche (*Byrsonima crassifolia* (L.) H. B. K) collected in the state of Oaxaca, Mexico. The research was conducted in the Seed Analysis Laboratory of the Graduate College, *Campus* Montecillo. Four repetitions of one hundred fruits, endocarps and embryos were evaluated. The analysis of measures of central tendency indicated that the fruits are in the form of an oblate, have white cream mesocarp, yellow epicarp and characteristic flavor to the species. The fruit has an endocarp with cavities for three embryos, but one or two develop, the endocarp is woody, dark brown, elliptical in shape and an accumulated limb, with sinuous grooves. The embryo is white, oval, with spirally wound cotyledons, covered with a thin brown tegument. Without endosperm There was variation in morphological and quality characters.

Keywords: quality, shape index, taste index, woody endocarp.

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Introduction

Mexico is a country that in all its extension has a mega-diverse vegetation, which presents ornamental, nutritional and medicinal principles; tropical and sub-tropical regions stand out for the production of native fruits, with a perspective for economic exploitation; one of these is the nanche (*Byrsonima crassifolia* (L.) H.B. K., which belongs to the Malpighiaceae family (Johnson, 2003), is originally from Mexico and Central America, where it is popularly known as nanche, yellow nanche, changunga, mezcal nanche, etc. (Herrera-Ruiz *et al*., 2011).

It is distributed in the states of the slope of the Gulf of Mexico and the Pacific Ocean, due to its rusticity, it adapts to poor and water-deficient soils (Maldonado-Peralta *et al*., 2015). It presents fruits with morphological characteristics accepted by local and national consumers (Bayuelo-Jiménez *et al*., 2006), being wild or backyard, they have quality for fresh, processed and even export consumption; however, the little management and improvement (Borys and Boris, 2001) makes them heterogeneous in terms of shape, color and size.

The nanche is not only important for the quality of fruits it presents, with antioxidants (Silva *et al*., 2007; Rufino *et al*., 2010) and nutraceutical properties (Bicas *et al*., 2011), but because the whole plant is medicinal (Maldini *et al*., 2011), rich in galacturonic acids, flavonoids, aromatic esters, among others (Sannomiya *et al*., 2007), prevents the development of diseases (Pawlowska *et al*., 2006). Studies conducted by Rivas-Castro *et al*. (2019), indicate that there is a relationship between the color and the shape of the fruit, yellow phenotypes tend to be wider and the greens more elongated; also, that senescence causes a decrease in firmness and an increase in total soluble solids.

The greatest fruit production occurs during the months of May to October, these are small drupes, inside they have an endocarp with one to three developed embryos (Costa *et al*., 2003), the fruit measures 1 to 2 cm in diameter (Guilhon-Simplicio and Pereira, 2011), has a cheese aroma (Mariutti *et al*., 2014), the mesocarp is attached to the woody endocarp, which envelops the embryos; studies on the viability and vigor of the embryos indicate that they are large, without endosperm, with high viability (Maldonado-Peralta *et al*., 2016b) but low germination.

Today there is great concern in consumers in choosing functional, safe and safe foods that improve the quality of life, with nutritional properties and prevent diseases (Lima *et al*., 2014). The fruits of nanche have important properties and are accepted in human food, as they are a source of vitamins, minerals, antioxidants and other properties that are not known in detail.

What requires research, in addition to presenting qualities to be the complement of a healthy diet; However, in Mexico these fruits are still exotic, because they are attractive because of their size, shape and aroma, therefore, the objective of this research focused on identifying the physical and chemical quality properties of the fruit, and the characteristics of the endocarp and embryo of the nanche (*Byrsonima crassifolia* (L.) H. B. K).

Materials and methods

The fruits of nanche were harvested on 8-year-old trees, in a backyard orchard, in Santo Domingo Tehuantepec, Oaxaca. Tehuantepec is located at 16° 19' 28'' north latitude and y 95° 14' 20'' west longitude, at 50 m altitude. The climate is warm tropic, with little thermal oscillation throughout the year (INEGI, 2012). The collection was made in August 2014. The fruits were transferred to the Seed Analysis laboratory of the Graduate College, Montecillo *Campus*. Healthy, complete and mature fruits of consumption were selected, washed and dried at room temperature. Four repetitions of 100 fruits from different individuals were chosen, which were included in the present study to obtain morphology and quality data.

The polar diameter of the fruit is defined as the apical end to the base and the equatorial diameter was measured in the middle portion of the fruit, for this a vernier (Vernier Truper Stainless® Steel) was used with an accuracy in mm. The fruit shape index resulted from dividing the polar diameter by the equatorial diameter (Gaona-García *et al*., 2008; Alia-Tejacal *et al*., 2012). The color of the epicarp and pulp were determined with a colorimeter (Chroma meter CR-400) that records the values of L^*, a^* and b^*, reported as luminosity (L^*), hue angle ($\tan^{-1} b^*/a^*$) and chromaticity ($\sqrt{(a^*)2 + (b^*)^2}$), fruit weight, fresh pulp weight and dry pulp weight were obtained with an electro-analytical balance (Scientech ZSA120).

The fruits were dried in an oven for seventy-two hours at 70 °C. Total soluble solids (SST) were measured with a refractometer (Hanna HI 96801) using a drop of pulp juice from each fruit, titratable acidity (AT) was evaluated by the volumetric method described below: a) samples were taken from 10 g of pulp and ground using distilled water; b) the water was filtered; c) five ml aliquots were taken; and d) two drops of phenolphthalein (1%) were added to the aliquots and titrated with 0.1 N NaOH, reported as a percentage of malic acid in 100 g^{-1} of pulp. A taste index was obtained considering the division of the SST and AT values. The firmness was measured with a universal texturometer (Force-Five brand. Model: FDV-30) with precision in Newton, considering the parameters designated by Folder (1986) for *Fragaria* spp.

The polar and equatorial diameter of the endocarp and embryos were measured (Truper Stainless® Steel), a shape index was calculated (polar diameter between equatorial diameter); this species has one endocarp per fruit with three embryos, also the number of embryos per endocarp was evaluated. The weight (g) was taken with an analytical balance. The relationship between embryo weight and endocarp was calculated. The variables were analyzed with the procedure of central tendency measures (SAS, 2009).

Results

The fruits of nanche had a homogeneous weight, between 4.31 and 4.65 g (Table 1), the average weight of fresh pulp was 4.16 g, losing up to 3.43 g of water when dehydrated, indicating that a large part of the pulp is water, reducing more than five times its weight when dehydrated. The polar and equatorial diameter of the fruits ranged between 16.9 and 19.66 mm.

Table 1. Descriptors of quantitative characteristics and statistical parameters of quality of the sample of fruits of nanche.

Variable	Average	CV	EE
Weight (g)	4.65	4.22	0.09
Fresh pulp weight (g)	4.16	4.22	0.08
Dry pulp weight (g)	0.73	16.25	0.06
Polar diameter (mm)	16.9	2.39	0.18
Equatorial diameter (mm)	19.66	2.32	0.21
Quality parameters			
Epicarp color			
Brightness (L^*)	54.97	3.46	0.85
Chromaticity (C^*)	2.52	54.64	0.62
Hue (H^*)	28.81	4.23	0.54
Mesocarp color			
Brightness (L^*)	67.46	5.02	1.51
Chromaticity (C^*)	-2.38	-19.59	0.21
Hue (H^*)	21.61	10.08	0.98
Total soluble solids (°Brix)	11.76	3.64	0.19
Titratable acidity (%)	0.64	6.44	0.02
Shape index (polar diameter/equatorial diameter)	0.86	1.64	0.01
Flavor index (SST/AT)	18.44	7.72	0.64
Firmness (Newton)	0.99	21.95	0.09

n= 400; range= variation range; CV= coefficient of variation; EE= standard error.

The fruits evaluated are in the form of an oblate; that is, they are wider than long, this being an important quality parameter, since it determines the type of packaging to be used and at the same time the consumer's preference, considering that the fruits studied are from seed trees, there is heterogeneity between them.

Fruits with a mucronized apex were found, which, when making the selection, were separated, because, when harvested in physiological maturity, the apex causes mechanical damage to other fruits and consequently a rapid senescence.

The nanche had an average of 89.47% of pulp, in relation to the weight of the fruit, which states that they have commercial and export quality, therefore, with potential for use in tropical areas with poorly productive edaphoclimatic conditions, combined with the above, another quality attribute is the SST, which presented between 11.25 and 12.25 of Brix.

The malic acid present in the fruits of nanche varied between 0.59 and 0.67% in 100 g of pulp. The acidity is a useful characteristic to know the state of maturation, also it has relation with the SST that determine the characteristic of the flavor; the taste index in ripe fruits showed a variation of 16.79 to 20.59, so they are considered delicious and sweet; these particularities (SST/AT) are intended to establish the harvest index and the selection of varieties for export, consumption of fresh and processed fruits.

The firmness of the fruits in edible maturity was from 0.75 to 1.35 Newton, indicating that, in this phase, they are fragile and resist little manipulation. The fruits of nanche are non-climacteric and are characterized by presenting diversity in shapes and colors (Figure 1), in addition to brightness and aroma, characteristics that are lost or changed as the degree of deterioration increases. The color of the epicarp is light yellow with a tendency to green. The mesocarp varied between white and cream to yellow; however, the yellow color indicates the presence of lutein and cryptoxanthin.

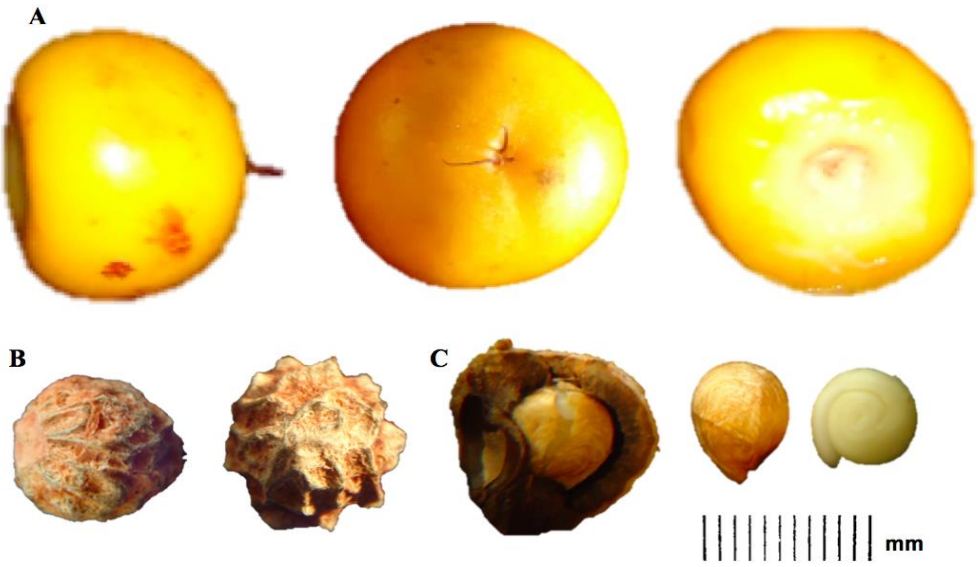

Figure 1. A) fruit of nanche (*Byrsonima crassifolia* (L) H. B. K.) in maturity of consumption; B) side and front view of the endocarp; and C) embryo contained within the endocarp showing the tegument and embryo provided and devoid of tegument.

The fruits have an endocarp with a cavity for three embryos; however, in this species one or two are developed and rarely all three, on average it was found that each endocarp presents 1.18 complete embryos. When the three embryos develop in an endocarp, the testa occupies 35.7%.

The endocarps are arranged in a compressed form, illuminated at one of its extremities, woody and with sinuous grooves, light brown when they retain pulp residues, but if this is removed, they turn to dark brown or black.

The average weight of fresh endocarp was 0.49 g (Table 2) and dry is reduced by almost a third, this is due to the characteristics of the species. The average length of the endocarp is 9.73 and 7.98 mm in polar and equatorial diameter, respectively.

This species has no endosperm, but it has large, well-developed cotyledons where it accumulates reserves. The embryos weigh on average 0.016 g, are oval, with 4.02 and 3.31 mm of polar and equatorial diameter, exposed in a spiral (Figure 1), compact and on the surface of the oval is the radicle, it is white to cream, covered by a thin brown tegument, with a small point in the thread, dark brown.

Table 2. Morphological characteristics of the endocarp and nanche embryo.

Variable	Average	CV	EE
Endocarp			
Wet weight (g)	0.49	14.73	0.04
Dry weight (g)	0.33	15.15	0.03
Polar diameter (mm)	9.73	8.89	0.39
Equatorial diameter (mm)	7.98	1.53	0.06
Number of embryos per fruit	1.18	11.44	0.06
Endocarp weight (g)	0.28	4.55	0
Shape index (polar diameter/equatorial diameter)	1.22	10.08	0.06
Embryo			
Weight (g)	0.016	11.88	0.0008
Polar diameter (mm)	4.02	11.41	0.21
Equatorial diameter (mm)	3.31	5.5	0.08
Shape index (polar diameter/equatorial diameter)	1.22	9.74	0.53

n= 400 endocarpios; range= variation range; CV= coefficient of variation; EE= standard error.

Discussion

Backyard trees often produce heterogeneous fruits; Martinez-Moreno *et al*. (2006) studied wild nanche fruits and obtained values between 2.28 and 6.35 g of average weight, Hernandez (2002) reported that yellow nanche fruits are small in size when they weigh 4.06 g and large 8.09 g, in this investigation small fruits were found , since they range between reported weights.

In fruits of nanche, Hernández (2002) reported 18.29 and 20.04 mm of polar and equatorial diameter, being values greater than those of this research. The shape of the fruit determines the type of packaging to be used and consumer preference (Pérez-Arias *et al*., 2008), in addition to the fact that the fruits studied were harvested from seed trees, but with agronomic management (irrigation, fertilization and pruning) which allowed homogeneity in these.

In relation to the amount of pulp with the total weight of the fruit, studies conducted in species of this family, specifically in acerola, indicate that the fruits have a variation between 41.93 to 93.88% of pulp (Freire *et al*., 2008) and 64.42% were found in red nanche (Maldonado-Peralta *et al*., 2016a), considered of good quality for fresh or processed consumption; the fruits evaluated had 89.47%, attribute that affirms that they are of commercial and export quality; in addition, with potential for cultivation in tropical areas with low productivity, as indicated by Silva (2008) in *M. emarginata*.

The fruits of the nanche have diversity in shapes and colors, the yellow color indicates the presence of lutein and cryptoxanthin (Bezerra, 2013), which requires research for its determination, ripe acerola fruits contain anthocyanins from the flavonoid group, responsible of color (Medrazi *et al*., 2008; Maciel *et al*., 2010), these fruits have different amounts of pigments related to said quality (Herrera-Ruiz *et al*., 2011).

These showed higher SST values than those reported by Brunini *et al*. (2004); Godoy *et al*. (2008) in acerola and those obtained by Maldonado-Peralta *et al*. (2016a) in red nanche, but lower than the values (11.97 and 11.46 °Brix) found by Freire *et al*. (2008); Maciel *et al*. (2010).

Fructose, glucose and small amounts of sucrose are the main sugars present in acerola (França and Narain, 2003); however, the values of total sugars in nanche fruits may vary according to the time of year, amount of precipitation or degradation processes and biosynthesis of polysaccharides. Therefore, it is considered that this species of Mexico can be used for export or for industry, due to its SST values higher than those required by the export market (Europe 7% and Japan 7.5%) (Lopes and Pavia, 2002).

The malic acid present in the fruits was similar to that found by Brunini *et al*. (2004), Godoy *et al*. (2008) and Matsuura *et al*. (2001) in acerola (0.5 to 1.11, 0.83 to 1.35 and 0.69 to 1.65%) and lower than those reported by Maciel *et al*. (2010), who found 1.97%, while in red nanche it was obtained between 0.85 and 1.13% (Maldonado-Peralta *et al*., 2016a). Organic acids are responsible for the acidity and the particular aroma of the fruits (Maciel *et al*., 2010), the nanche has a particular flavor and aroma of the species.

The variation in the taste index indicated that they are delicious and sweet fruits; however, in species such as acerola, Matsuura *et al*. (2001) found 9.42, while França and Narain (2003) obtained lower values in taste index as well as Maldonado-Peralta *et al*. (2016a) in red nanche. Other acerolas genotypes reached 7.06 of SST/AT ratio (Maciel *et al*., 2010). Alves (1993) mentions that the proportion of SST/AT increased from 4 to 6.5 during maturation.

Ripe fruits are fragile and do not support handling. Folder (1986) mentions that ordinal values between 3 and 4 correspond to fruits with firmness and hardness; however, when the fruits of nanche have physiological maturity they can be easily managed, as is the case with the red nanche, which when evaluated presented between 4.53 and 7.09 Newton, indicating that they are resistant fruits (Maldonado-Peralta *et al*., 2016a). Anderson (2005), mentions that any external force greater than the one supported causes change in flavor, color and aroma, there being a direct relationship between harvest time and fruit firmness, data that in nanche has not been studied.

Endocarps are small and woody, characteristic of the species. Maldonado-Peralta *et al*. (2016a) studied red nanche embryos and found that each fibrous endocarp weighs 0.39 g and are larger than those of this species.

Each fruit has an endocarp with a cavity for three embryos, but usually one or two developed, rarely all three. Nassif and Cicero (2006) in acerola fruits (*M. emarginata*) found one and two fertile endocarps, who at the same time reported that 29.4, 40 and 43% of 100 endocarp evaluated presented normal embryos, results similar to those found here investigation.

The above is possibly related to biological or genetic factors, malformation or lack of fertilization of the ovule and degeneration of the embryo sac (Costa *et al*., 2003), who evaluated 300 endocarps and found 51.33% of normal embryos.

Nanche embryos have no endosperm and are exposed in the form of a compact spiral, their cotyledons are attached to the radicle that ends at the apex on the outside of the embryo. Maldonado-Peralta *et al*. (2016a) studied red nanche embryos and found that they are 6.59 and 4.42 mm long and wide, are flattened, the radicle and cotyledons are observed with the naked eye, without endosperm and covered with a brown tegument.

Conclusions

The fruits of nanche have morphological and quality qualities for fresh consumption, industrialization and commercialization, but in the characteristics, there was variation, indicating that these components should be homogenized.

The characteristics of the fruit showed that it has a dark brown endocarp, with 1 to 3 viable embryos, the spirally coiled cotyledons, the radicle on the outside, is white to cream, covered by a thin tegument, without endosperm.

The nanche has potential, but more research is needed to know all the nutritional properties, domesticate and homogenize the production, to establish technical and technological bases for its cultivation.

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