Article

Fruit quality of early orange cultivars in Nuevo León

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Abstract

The state of Nuevo León is one of the main producers of oranges in Mexico, since it has a planted area of 25 820 ha and an annual production of 339 138 t. The predominant cultivar is the Valencia orange, which is characterized by a late maturation cycle, which favors that production in the region concentrates in a relatively short period (February-April), although it can remain on the tree until June if water is available. For this reason, it is necessary to offer producers other cultivars, which are alternatives both in yield and in their commercialization. The objective of this study was to evaluate and characterize a group of early-maturing orange cultivars considering some parameters that affect fruit quality, such as fresh weight, polar and equatorial diameter, peel thickness, number of seeds, ºBrix, juice content and its hardness for postharvest handling. Seven early orange cultivars preserved in the Citrus Germplasm Bank of the National Institute of Forestry, Agricultural and Livestock Research, established in the General Terán Experimental Field, were used. According to the quality characteristics of the fruit, the early orange cultivars were classified into three different groups: the first group is represented by Marrs which has outstanding characteristics, the second group is composed of Parson Brown, Queen, San Miguel, Pineapple and Hamlin with outstanding and intermediate characteristics and the third group is composed of Temprana which has outstanding and low characteristics. The results obtained suggest that there is a wide variation between early orange materials in the state of Nuevo León, constituting themselves as a viable alternative to diversify production and not depend exclusively on the cultivar Valencia.

Keywords: *Citrus sinensis* L., early cultivars, genetic resources, quality characteristics.

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Introduction

The fruit trees included in the genus *Citrus* are crops of utmost importance in the world (Kubar *et al*., 2018). At the national level, citrus farming represents an economic segment of great relevance, since it generates an economic income of more than 375 million dollars per year (González *et al*., 2020). The area cultivated with citruses in the country increased by 7.5%, going from 530 364 to 569 914 h from 2010 to 2017. The harvested area also registered a significant increase, since it went from 514 740 to 530 381 ha in those same years (Solleiro and Mejía, 2019), which represents an increase of 3% and places Mexico in fifth place in citrus production worldwide.

In the state of Nuevo León, citrus cultivation is carried out in 25 820 ha with a production of 339 138 t and a value of 1 398.1 million pesos (SEDAGRO, 2021). The maximum production period (60%) is from October to February, while 40% is available from May to August (Franco *et al*., 2015). It is estimated that 75% of production is for the fresh market and the remaining 25% for agribusiness (Rocha-Peña, 2009). The state citrus farming includes groves established with various varieties of orange (83.6%), mandarin and their hybrids (11.3%) and grapefruit (5.1%).

According to the minimum maturity index required, orange cultivars in Nuevo León are classified into three categories: a) early-maturing oranges with a harvest period from September to January, such as Marrs, Washington Navel and Fisher Navel; b) intermediate-maturing oranges with a harvest period from October to January, such as Cadenera and Moro; and c) late-maturing oranges with a harvest period from February to April, although the fruit can remain on the tree until June if water is available, as is the case with the cultivars Valencia and Olinda (Padrón-Chávez and Rocha-Peña, 2009).

In Nuevo León, as in the rest of the country, there is a high demand for orange during the period from July to October, when production is scarce and acquires a high price, even though the fruit remains less time on the tree and has less tolerance to handling during transport (Medina *et al*., 2007). Because orange trees tend to produce earlier in the humid tropics than in subtropical regions (Passos, 1979), it is convenient to identify cultivars capable of producing fruit in times of scarcity in semidry subtropical climate.

There are few local reports on the fruit quality characteristics of early and intermediate-maturing oranges (Ray and Walheim, 1980; Saunt, 1990; Tucker *et al*., 1995), so there is no information on the response of such cultivars with respect to fruit quality under subtropical conditions (Durón *et al*., 1990; Gallash, 1996a and 1996b).

In the Citrus Germplasm Bank of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), located in the General Terán Experimental Field, there is an *in-situ* collection of national and international materials of different species and production cycles that can be used for characterization and subsequent use in genetic improvement programs.

Based on the above, the objective of the present study was to evaluate and characterize a group of early-maturing orange cultivars from some parameters that affect the quality of the fruit, such as fresh weight, polar and equatorial diameter, peel thickness, number of seeds, total soluble solids, juice content and its hardness for postharvest handling.

Materials and methods

Characteristics of the experimental site

The research was carried out in the General Terán Experimental Field (25° 02' north latitude, 99° 48' west longitude and 320 masl), in the municipality of General Terán, Nuevo León, Mexico. This municipality is characterized by having a semidry subtropical climate (Medina *et al*., 1998) with an average annual temperature of 23.9 °C, a minimum of 0.8 °C and a maximum of 41 °C. The lowest temperatures occur from November to March and the maximum in July and August. The average rainfall is 610 mm per year.

Cultivars and rootstock

Seven early orange cultivars grafted onto sour orange (*Citrus aurantium* L.) were used. The cultivars evaluated belong to the *ex-situ* collection of the INIFAP Citrus Germplasm Bank established in the General Terán Experimental Field. The origin of the germplasm evaluated represents diverse environments and genetic status that includes materials from the state of Nuevo León, as well as Florida, Texas and California, USA.

Planting and management

The trees were planted in duplicate at field level in 1972, at a distance of 8 m between rows and 4 m between trees. The management of the germplasm bank is carried out similarly to a commercial lot; chemical fertilization (200 kg ha^{-1} N and 70 kg ha^{-1} P), weed control (mechanical, manual and chemical), irrigation (by flood), as well as comprehensive pest and disease control.

Quality characteristics

For two consecutive years (2020 and 2021), at physiological maturity (October for varieties Marrs and Temprana and November for the varieties Hamlin, Parson Brown, Pineapple, Queen and San Miguel), samples of 20 fruits per tree were taken from the middle third of the crown of each cultivar, they were placed in properly identified paper bags and immediately transferred for quantification in the Laboratory of the Fruit Tree Program of the General Terán Experimental Field.

The quality of the fruit was evaluated by determining the following variables: fruit weight, polar diameter and equatorial diameter, peel thickness, number of seeds, total soluble solids, juice content and fruit hardness, which correspond to the descriptors established for this species by the International Union for the Protection of New Varieties of Plants (UPOV, 2019).

The content of total soluble solids was quantified in Brix with a pocket digital refractometer of the Atago® brand model Pal-1 with automatic temperature compensation. The juice content was obtained by manually squeezing each of the fruits collected, depositing it in a graduated cylinder of 250 ml and recorded in milliliters. The hardness or firmness of the fruit was determined with an Ametek penetrometer model LKG-14 Hunter Spring®, expressed in kg cm^{-2}.

Experimental design

The data were processed with the statistical program SAS (Statistical Analysis Systems) version 9.3 (SAS, 1999), in a completely randomized experimental design. The Tukey test (p= 0.01) was used for the comparison of means.

Results and discussion

In 2020, the Marrs variety stood out in all the variables evaluated (fruit weight, polar and equatorial diameter, peel thickness, number of seeds, total soluble solids, amount of juice and fruit hardness) and was statistically different from the rest of cultivars except for the attribute of fruit hardness. In this same year, the Temprana variety was the one that presented the lowest values in all the attributes of fruit quality, with the exception of fruit hardness, where there was no statistical difference between cultivars. In 2021, the Marrs variety was again the outstanding and the cultivars Temprana and Queen presented the lowest values in all fruit quality attributes, details are given below.

Quality characteristics

Fruit weight (FW)

The values ranged from 146.3 g for the Temprana cultivar to 251.4 g for the Marrs cultivar in 2020 and from 146.6 g in the Queen cultivar to 238.8 g with the Marrs cultivar in 2021 (Table 1). Based on the weight of the fruit, the cultivars were placed in three groups during the two years of study: a first group with high values represented by Marrs (2020 and 2021), another group with intermediate values, where were the cultivars San Miguel, Queen, Hamlin and Parson Brown (2020) and Pineapple, San Miguel and Parson Brown (2021), and a third group with low values, composed of the cultivars Pineapple and Temprana (2020) and Queen in 2021.

Table 1. Quality characteristics of the fruit of seven early orange cultivars evaluated *ex situ* in the Citrus Germplasm Bank of the General Terán Experimental Field, in two years of study. General Terán, Nuevo León.

Cultivar	FW (g)	PD (mm)	ED (mm)	PT (mm)	NS	°Brix	AJ (ml)	FH
				2020				
Queen	217.4±40.2ab	71.1±3a	75.1±4.8ab	3.8±0.5ab	17.9±3.8a	12.7±0.5abc	93.8±19.7ab	4.4±1.2a
Hamlin	213.5±39.9ab	71.6±6.5a	76.0±4.8ab	4.4±0.9a	7±2.3cd	11.9±0.8c	64.5±17cd	3.5±0.5a
Parson Brown	205.9±46.8ab	71.5±6.3a	73.1±5.6ab	4±0.8a	13.5±3.8ab	11.9±0.6c	89.4±24.3ab	4.5±1a
San Miguel	225±28.8ab	69.5±5.2ab	77.2±4.2ab	4.1±0.6a	14.6±5.1ab	12.6±0.7bc	110.6±12.5a	4.2±0.7a
Temprana	146.3±26.1c	62.6±4.2b	65.7±4.1c	3±0.3b	3.2±2.2d	13.1±0.8ab	49.7±12.1d	4±0.7a
Marrs	251.4±34.9a	75.3±5.2a	79.4±3.8a	4.5±0.6a	9.9±5.5bc	13.7±0.7a	100.7±14ab	4.4±0.8a
Pineapple	196.3±40.6bc	69.7±4.6a	72.9±4.8b	4.3±0.8a	16.5±2.7a	13.6±0.9ab	77.6±18.2bc	4.2±0.8a
Promedio	210.54	70.19	74.20	4.01	11.74	12.79	83.76	4.17

Cultivar	FW (g)	PD (mm)	ED (mm)	PT (mm)	NS	°Brix	AJ (ml)	FH
				2021				
Queen	146.6±9.9c	63.8±2d	65.7±1.5cd	3.9±0.5ab	15.1±5a	14.3±0.9a	64.5±9.4ab	3.4±0.5b
Hamlin	188.7±35.6bc	71.4±4.4abc	71.6±5bc	4.3±0.4a	3.8±1.5c	12.8±0.7bc	46.1±16b	3.9±0.3ab
Parson Brown	214.3±44.8ab	75.3±7.2ab	73.3±4.9ab	3.6±0.4bc	13.2±3.1ab	12.9±0.6bc	83.2±19.4ab	4.1±0.6a
San Miguel	209.9±34.8ab	70.6±3.6bc	75.7±4.4ab	3.2±0.4cd	13.1±3.3ab	12±0.5c	92±16ab	3.6±0.2ab
Temprana	151.8±34.3c	65.9±5.4cd	65.4±4.8d	2.9±0.3d	2.6±1.3c	12.9±0.9bc	42.2±10.2b	3.7±0.6ab
Marrs	238.8±39.8a	77.3±4.1a	77.8±5.2a	3.9±0.6ab	9.8±3.2b	13.1±0.6b	115.7±103a	3.3±0.2b
Pineapple	209.9±42.6ab	74.9±4.4ab	73.9±3.7ab	3.6±0.4bcd	16.7±4.2a	12.5±0.5bc	77.3±13.7ab	3.6±0.2ab
Promedio	193.66	71.33	71.91	3.62	10.61	12.93	74.43	3.66

FW= fruit weight; PD= polar diameter; ED= equatorial diameter; PT= peel thickness; NS= number of seeds; °Brix; AJ= amount of juice; FH= fruit hardness. Values with the same letter in columns are statistically equal according to Tukey at the significance level of 0.01.

These results coincide with those reported by Medina *et al*. (2007), who reported the Marrs orange with the largest fruit size (289 g) compared to the cultivars Queen (217.8 g), Pineapple (198.4 g) and San Miguel (196 g) in dry subtropical climate conditions.

Polar diameter (PD)

The values ranged from 62.6 mm in the Temprana cultivar to 75.3 mm with the Marrs cultivar (2020) and from 65.7 mm for Temprana to 77.8 mm in Marrs (2021). The cultivars formed three groups in 2020 and six groups in 2021. In the first year, the group with the highest values corresponded to the cultivars Marrs, Hamlin, Parson Brown, Queen and Pineapple, the group with intermediate values was formed by the San Miguel cultivar and the third group with the lowest values, by the Temprana cultivar. In the second year, the Marrs cultivar remained with the highest value of the polar diameter, the second group was constituted by the cultivars Parson Brown and Pineapple, in the third group was the Hamlin cultivar, in the fourth group the San Miguel cultivar, in the fifth group the Temprana cultivar and in the sixth group the Queen cultivar (Table 1). These are typical characteristics of the varieties under study regardless of the rootstock used and the age of the trees.

Equatorial diameter (ED)

A similar response was recorded in the equatorial diameter of the cultivars during the two years of study, where the values ranged from 65.7 mm in the Temprana cultivar to 79.4 mm for the Marrs cultivar (2020) and from 65.4 mm with the Temprana cultivar to 77.8 mm in the Marrs cultivar (2021). According to the data obtained, cultivars were placed in four groups in 2020 and five in 2021. In the first group the highest values were for the Marrs cultivar (2020 and 2021), the second group was made up of the cultivars San Miguel, Hamlin, Queen and Parson Brown (2020) and San Miguel, Pineapple and Parson Brown (2021), the third group with the cultivars Pineapple (2020) and Hamlin (2021), in the fourth group with the cultivars Temprana (2020) and Queen (2021), and in the fifth group of 2021 it was made up of the Temprana cultivar (Table 1).

Peel thickness (PT)

The values ranged from 3 mm in the Temprana cultivar to 4.5 mm with the Marrs cultivar (2020) and from 2.9 mm for the Temprana cultivar to 4.3 mm in the Hamlin cultivar (2021). In 2020 the cultivars were placed in three groups, the first group was made up of those that presented the highest values for this variable (Marrs, Hamlin, Pineapple, San Miguel and Parson Brown), the second group formed by the Queen cultivar which registered an intermediate value, the third group included the Temprana cultivar which had the lowest value for peel thickness. In the second year, the first group was represented by the Hamlin cultivar with the highest value; the second by the cultivars Marrs and Queen, the third by the Parson Brown cultivar, the fourth by the Pineapple cultivar, the fifth by the San Miguel cultivar and the sixth by the Temprana cultivar which presented the lowest value (Table 1).

The thickness of the peel is one of the most important fruit quality characteristics in early orange varieties, the fruits preferred by producers are thin-skinned and easy to peel. Although there is no specific value reported as ideal for peel thickness, Ariza *et al*. (2010) state that values of 5 mm in late orange Valencia are considered normal.

In this regard, Padrón-Chávez and Rocha-Peña (2009) point out that the Marrs variety fruits mainly in bunches, in the outermost parts of the tree, the peel of the fruit is smooth, not very thick and the fruits are easy to peel. For their part, Futch and Tucker (2020) report that the lower thickness of the peel is mainly due to phosphorus deficiency. This implies that possibly the sour orange tree as rootstock is ineffective to absorb phosphorus (Pérez-Zamora, 2004), but in this case, it is a favorable characteristic for the quality of the fruit.

Number of seeds (NS)

The values ranged from 3.2 seeds for the Temprana cultivar to 17.9 seeds in the Queen cultivar (2020) and from 2.6 seeds in the Temprana cultivar to 16.7 seeds for the Pineapple cultivar (2021). The cultivars showed a similar trend in the two years of study and were distributed into five groups in 2020 and four in 2021 (Table 1). The first group with the highest values was integrated by the cultivars Queen and Pineapple, this information was recorded during the two years of study; the second was formed by the cultivars San Miguel and Parson Brown, the third by the Marrs cultivar, the fourth included the Hamlin cultivar and the fifth the Temprana cultivar in 2020. In the second year, the cultivars Hamlin and Temprana formed a single group. The fruits of the cultivars Queen, Pineapple, San Miguel and Parson Brown had the highest number of seeds with respect to the Temprana cultivar, which showed the minimum value obtained, the cultivars Marrs and Hamlin had intermediate values.

According to Agustí *et al*. (2003) and Ladaniya (2008), seedless fruits are the most accepted by consumers, while fruits with large amounts of seed are commercially unviable. In this regard, Padrón-Chávez and Rocha-Peña (2009) point out that the fruits of the Marrs variety are characterized by having few or no seeds in the citrus-growing region of the state of Nuevo León. This is an important factor for the Marrs cultivar to be accepted by the consumer, as varieties with few seeds or no seeds are preferred over those that have abundant seeds in the fruit (Davies and Albrigo, 1994; Agustí *et al*., 2003; Ladaniya, 2008).

Notwithstanding the above, in Mexico the presence of seeds in the fruit is not a determining factor in consumer preferences. In the case of fruit whose final destination is the processing plants, the external quality requirements are of secondary importance and the production of lower quality consisting of fruit stained or beaten during the harvest goes practically to this destination (Ramírez-Díaz and Rocha-Peña, 2009).

Total soluble solids (TSS)

In this case the values were from 11.9 °Brix in the cultivars Hamlin and Parson Brown to 13.7 °Brix with the Marrs cultivar (2020) and from 12 °Brix for the San Miguel cultivar to 14.3 °Brix in the Queen cultivar (2021). The cultivars showed a variable trend in the two years of study, which led to the formation of five groups in 2020 and four groups in 2021. In the first group the highest values were recorded in the cultivars Marrs (2020) and Queen (2021), in the second were the cultivars Pineapple and Temprana (2020) and Marrs (2021), in the third were the cultivars Queen (2020), Parson Brown, Hamlin, Temprana and Pineapple (2021), in the fourth the San Miguel cultivar (2020 and 2021) and the fifth group formed in 2020, the cultivars Hamlin and Parson Brown (Table 1).

Although the values corresponding to the last two cultivars could be considered relatively low, these values meet the minimum required by the Mexican Standard (NMX-F-118-1984). Relative levels of total soluble solids are related to the taste and palatability of citrus fruit juices, so they are considered as an indicator of maturity and taste quality (Al-Mouei and Choumane, 2014).

The minimum maturity index required for the Marrs variety is reached at the beginning of September in the citrus-growing region of Nuevo León, but due to its low acidity; at this time its quality is not very good, it is sweet but somewhat tasteless; however, the flavor improves considerably if its maturation is allowed to advance more to harvest the fruit during November (Padrón-Chávez and Rocha-Peña, 2009).

Amount of juice (AJ)

The values ranged from 49.7 ml in the Temprana cultivar to 110.6 ml for the San Miguel cultivar (2020) and from 42.2 ml in the Temprana cultivar to 115.7 ml with the Marrs cultivar (2021). The amount of juice recorded in the different varieties was variable in the two years of study and resulted in the formation of five groups in 2020 and three in 2021. In the first year of study, the group with the high value was formed by the San Miguel cultivar, the second group by the cultivars Marrs, Parson Brown and Queen, the third group by the Pineapple cultivar, the fourth group by the Hamlin cultivar and in the fifth group was the Temprana cultivar (Table 1).

The second year, the first group formed by the Marrs variety, the second group by the cultivars San Miguel, Parson Brown, Pineapple and Queen and the third group by the cultivars Hamlin and Temprana (Table 1). Despite the great importance of the amount of juice in the quality of the fruit, to date there is no regional or local information available in this regard, the only certain thing is that there are juice processing plants that destine all their production for export, mainly to the United States of America and to a lesser extent to Canada, Japan and the European Union (Gaitán, 2002).

Fruit hardness (FH)

The values ranged from 3.5 kg cm^{-2} for the Hamlin cultivar to 4.5 kg cm^{-2} in the Parson Brown cultivar (2020) and from 3.3 kg cm^{-2} in the Marrs cultivar to 4.1 kg cm^{-2} with the Parson Brown cultivar (2021). The cultivars showed a variable trend in the two years of study and a single group was formed in 2020; that is, no significant difference was observed. However, in the second year, three groups were formed; the first was formed by the Parson Brown cultivar, the second by the cultivars Hamlin, Temprana, San Miguel and Pineapple and the third by the cultivars Queen and Marrs (Table1).

Fruits that are less firm are more susceptible to deterioration during postharvest handling (Villalba *et al*., 2014). Barbosa *et al*. (2003) point out that firmness, as an indicator of fruit maturation, determines the optimal levels of quality for consumption and is related to the conditions of transport and postharvest handling, therefore, the hardness of the fruit is a highly desirable characteristic in cultivars since it gives a high value for commercialization.

The results obtained in the present study suggest that, in the Citrus Germplasm Bank of the General Terán Experimental Field, there is a wide variation between the early-maturing orange materials in relation to their fruit quality characteristics, which constitutes a viable alternative to diversify the orange crop in the citrus-growing region of the state of Nuevo León. This diversification would be essential for the sustainable production of orange cultivars in two well-established harvest periods, one comprising at least six months (September-February) with the use of early-maturing cultivars and another of five months (March-July) with the use of late-maturing Valencia-type cultivars.

Conclusions

The variation recorded among the early orange materials evaluated was wide, with the Marrs variety standing out, since it was the only one with the record of outstanding in all the characteristics associated with the quality of the fruit during the two years of study. These results allow us to infer that there is potential to diversify citrus production in the state of Nuevo León and not depend almost exclusively on the Valencia cultivar. It does not escape the knowledge of the need to complement this information with molecular characterization studies in future genetic improvement work.

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