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Fruit quality characterization of seven clementine cultivars

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Abstract

For a citrus grower to choose the right clementine cultivar for a given region or market, it is very important to know the characteristics of that cultivar particularly in terms of the development of its internal as well as external quality attributes. In particular, it is very important to know when the maturity index is attained along with the rate of color change, sugar accumulation, acid dissipation, firmness loss, etc. This paper describes the results obtained for several quality attributes (rind color, firmness, juice content, juice titratable acidity and soluble solids content) of seven clementine cultivars sampled at different stages of maturity. All of the cultivars reached minimum maturity index (sugar / acid ratio greater than 7.0) by early November. The rate of rind color change is significantly influenced by picking period and is the main attribute that differs among most of the clementine cultivars. In addition, 'Guerdane', the new clementine cultivar, is the only cultivar that matures much later (January-February) and has the characteristics of a late-maturing cultivar both internally (juice quality) and externally (rind color).

Key words: *Citrus clementina* Hort. ex Tan, maturity index, rind color, rind firmness, juice sugar content, juice titratable acidity.

Introduction

Morocco's annual citrus production is ~1.4 million tons, of which the major group is of easy-peeling mandarins, mainly clementine cultivars (*Citrus clementina* Hort. Ex Tan), representing 30% of total production. Morocco is ranked as second largest producer of this specialty fruit after Spain. Consumers of fresh fruit like to have a variety of fruit all the year around. In terms of citrus, preference trends are for a seedless, orange-colored fruit of medium size, with a balanced sugar/acid ratio, and with a relatively firm but easy-to-peel rind. Most of these characteristics are found in the clementine mandarin group (Hodgson, 1967; Saunt, 2000). This group is very diverse in terms of period of maturity, which starts in late September and extends to late January, but the majority of the production occurs in midseason (*i.e.* November-December) (Chapot, 1963; Devaux, 1981). Such great efforts are continuously made in the main clementine-producing countries to find cultivars that mature much earlier (September-October) or much later (January-February) to extend the period of commercial supply (Agustí *et al.*, 2002).

Internal and external quality of fruit are significantly affected by climate (Goldschmidt, 1997; Reuther, 1988). The major factors are temperature, wind and rain. Temperature is the most important environmental factor affecting the citrus crop (Davies, 1997; Goldschmidt, 1997). In general, a climate with low rainfall and plenty of sunshine is good for citrus trees (Goldschmidt, 1997). It promotes good flower differentiation, flower and fruit development, and fruit quality. Wind is a problem to citrus production as both tree and fruit damage can occur (Albrigo, 1988). It is noteworthy that for some varieties such as clementines, although fruit internal maturity can be attained early in the season, appearance of external signs of maturity, such as rind color, is often delayed by high fall temperatures which consequently delay chlorophyll degradation and carotenoid biosynthesis (Ikoma *et al.*, 2001). At commercial level, the development of orange color is often hastened postharvest through the ethylene degreening process which allows the attainment of good prices in the market early in the season (El-Otmani *et al.*, 2000).

Fruit growth and development are associated with morphological, anatomical and physiological changes (Bain, 1958; El-Otmani and Coggins, 1985; El-Otmani *et al.*, 1987). Fruit maturaty is associated with changes in rind texture, juice composition and taste (El-Otmani *et al.*, 1990; El-Otmani and Coggins, 1991). For the citrus grower, and clementine grower in particular, it is very important to have information on the differences in fruit quality among the cultivars and on the changes occurring in quality attributes and their rate of occurrence.

The objective of this paper is to present research findings on the time course of several quality attributes of seven cultivars of clementine mandarin during the period of harvest, in the same environmental conditions, and to evaluate new citrus cultivars for commercial potential.

Materials and methods

The experimental site is located in the Souss Valley of southern Morocco (Latitude 30° 20' N, Longitude 9° 22' W, Altitude 90 m) which has a semi-arid climate with rainfall of ~200 mm

year[1]. Mature trees of seven clementine cultivars included in the study were 'Caffin', 'Bruno', 'Nules', 'Esbal', 'Hernandina', 'Nour' and 'Guerdane', of which 'Caffin', 'Bruno', 'Nour' and 'Guerdane' are of Moroccan origin, and 'Guerdane' which is a mutation of clementine. The trees were budded on 'Carrizo' citrange rootstock, and were healthy and showed no signs of any deficiency. The origin of clementine cultivars are as follows:

'Caffin': cultivar discovered in 1968 in Azemour in Morocco.

'Bruno': cultivar discovered in Le Pontet orchard in Salé Morocco.

'Nour': discovered as bud mutation of 'Cadoux' in the Souss Valley in Morocco.

'Guerdane': previously named as KSN, it was discovered in 1987 as bud mutation of 'Fina' in Abbes Kabbage orchard in the Souss Valley of southern Morocco.

'Esbal': discovered in 1966 as a bud mutation of 'Fina' at Sagunto in Valencia Province.

'Nules': the most popular clementine in Spain, 'Nules' was discovered in 1953 near the town of the same name in Castellón Province as a bud mutation on a 'Fina'.

'Hernandina': discovered in 1966 as a bud mutation of 'Fina' at Picassent in Valencia Province.

To assess fruit quality attributes, fruit were harvested at 2- to 3-week intervals, samples were collected three to six times during ripening (depending on the cultivar) to demonstrate the effect of harvest date on quality, starting on 20 October, 2004, corresponding with the beginning of the maturity season, and ending on 25 January, 2005, corresponding with the last harvest date of the late maturing cultivar. Three single-tree replicates were used with three replications per replicate, each comprising of five fruit. The fruit were sampled from the outer portion of the canopy and from all four quadrants of the tree. At each harvest date, fruit of average size were sampled. The diameter of the sampled fruit was approximately 63 mm for 'Hernandina', 40 mm at the start and 56 mm at the end of the sampling period for 'Guerdane' and between 50 and 60 mm for the other cultivars.

In laboratory, the fruits were weighed and their average diameter was measured. Fruit color index (CI) was determined using a CR300 Minolta chromameter following the method described by Jimenez-Cuesta *et al.* (1981). Parameters "L" (lightness), "a" (greenness to redness) and "b" (blueness to yellowness) were determined at two different spots around the equatorial zone of the fruit and sample averages were calculated. Rind firmness, as measured by puncture resistance force, was determined using a puncture gauge following the method described by El-Otmani and Coggins (1991). Fruits were cut along their equatorial zone, their juice extracted and weighed. Juice pH, titratable acidity (using 0.1 N NaOH titration), and soluble solids content (using a laboratory refractometer expressing the amount of sugars in °Brix) were determined.

Statistical analyses: All analyses were based on 3 replications using SAS software (Statistical Analysis System) and the significance of differences between cultivars and harvest date x cultivars interaction were evaluated using ANOVA, followed by Scheffe's test. Differences between means were considered to be significant at $P \leq 0.05$. The standard deviations of each value was represented on all the figures by vertical lines.

Results

Rind colour index (CI): Harvest date and cultivar had highly significant effect on the rind color index. On the first sample date, overall rind color index (CI) of the clementine cultivars, varied from -3 for 'Bruno' (corresponding to yellow-green with orange patches), -6 for 'Caffin' (corresponding to light green-to-yellow color), -10 to -8 (light green-to-yellow) for 'Nules', 'Esbal' and 'Nour', and -14 to -12 (dark green-to-color break) for 'Hernandina' and 'Guerdane' (Fig. 1). The interaction between cultivar and harvest date was found to be highly significant. Peel color improved with time for all clementine cultivars with intense deep-orange rind colour for 'Caffin' by mid-November. 'Guerdane' was the last cultivar to develop color.

Firmness: Effects of harvest date and cultivar was highly significant on rind firmness and the effect of harvest date x cultivar interaction was highly significant. Rind firmness of all the cultivars declined over time as fruit matured (Fig. 2). Fruit rind firmness was lowest for 'Bruno', significantly higher for 'Guerdane' followed by 'Hernandina' and 'Nour'.

Juice content: On the first harvest date, juice content of all cultivars was >40% (Fig. 3). 'Caffin' and 'Bruno' started drying out by mid-November. The effects of cultivars, harvest date and their interaction were highly significant. The cultivars with the highest juice content were 'Nules' and 'Esbal', whereas 'Caffin'

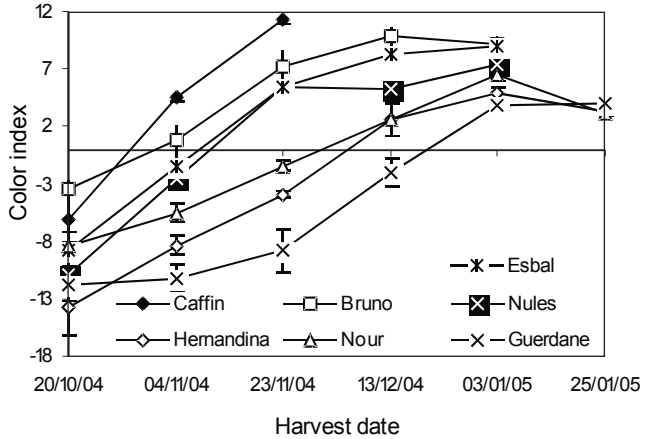

Fig. 1. Time course of the fruit rind color index (CI) of seven clementine selections

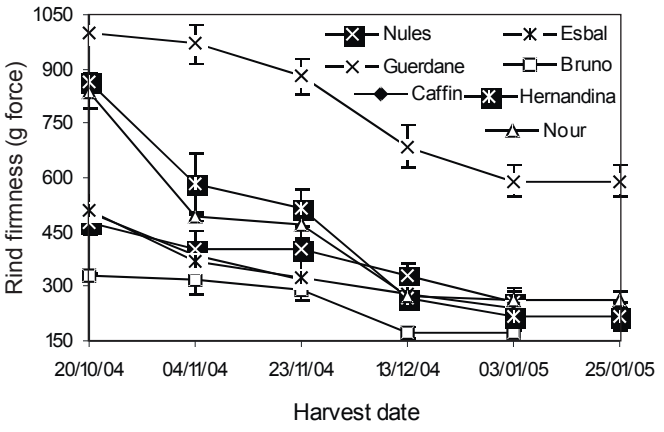

Fig. 2. Time course of rind resistance to puncture for seven clementine selections

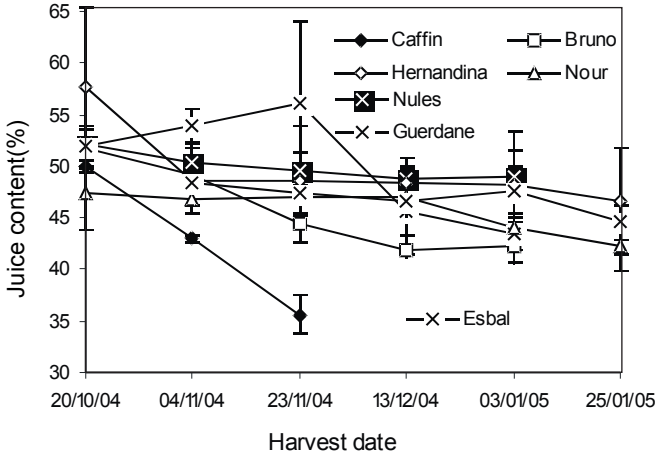

Fig. 3. Seasonal variation of juice content in fruit of seven clementine selections

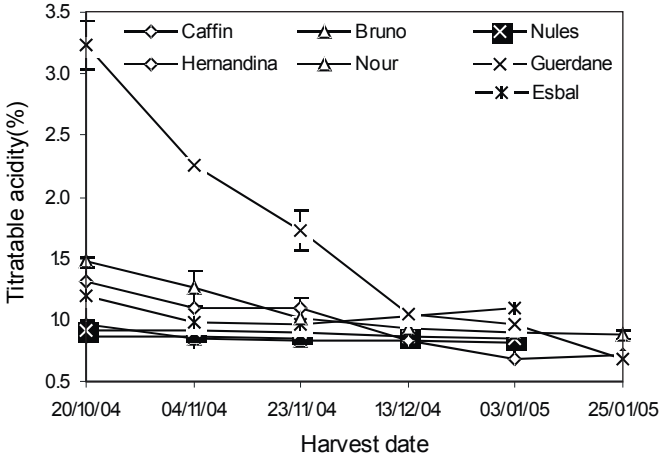

Fig. 4. Seasonal variations of titratable acidity (TA) in fruit juice of seven clementine selections

appears to have the lowest juice content. Juice content of the other cultivars remained more constant.

Titratable acidity (TA): Juice titratable acidity of all cultivars ranged between 0.8 to 1.5 %, except for 'Guerdane', which had the greatest value (3.2%) on the first harvest date (Fig. 4). Titratable acidity declined over time as fruit matured. Harvest date and cultivar had highly significant effects on the measured parameter and harvest date x cultivar interaction was also found to be highly significant.

Soluble solids content (SSC): The effects of cultivars, harvest date and their interaction were highly significant on juice soluble solids content. SSC was significantly lowest in 'Guerdane' (7.9°Brix) on the first harvest date and greatest (14°Brix) in 'Nour' on the last harvest date (Fig. 5), with a general trend to increase from the earliest maturing cultivars to the latest ones.

Maturity index (SSC/TA): Harvest date, cultivar and their interaction had highly significant effects on maturity index. On the first harvest date maturity index was similar for 'Caffin' and 'Bruno' (~12), 'Nules' and 'Esbal' (~10) and 'Hernandina' and 'Nour' (6 to 8). 'Guerdane' had the lowest maturity index (~2). The largest SSC/TA value was obtained for 'Hernandina' (19) on the last sampling date (Fig. 6).

pH: For most cultivars, juice pH was 2.1 to 3.0 on the first sampling date and increased slightly over time to reach 3.0 to

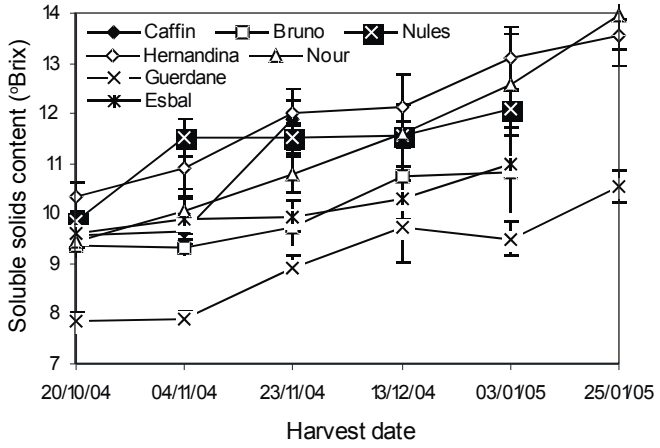

Fig. 5. Seasonal variation of soluble solids content (SSC) in fruit juice of seven clementine selections

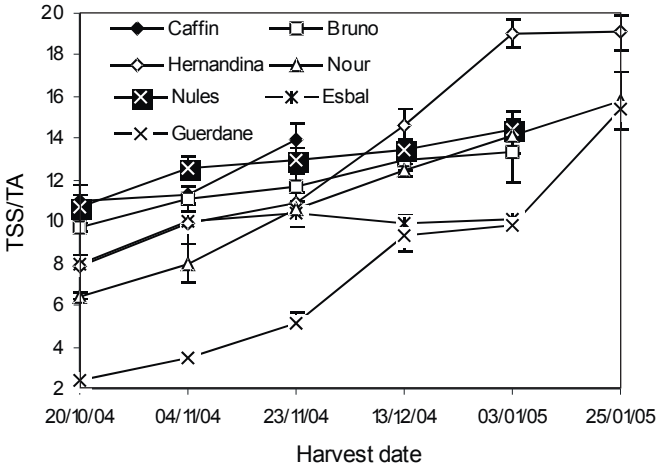

Fig. 6. Seasonal variation of the maturity index (SSC/TA) in fruit juice of seven clementine selections

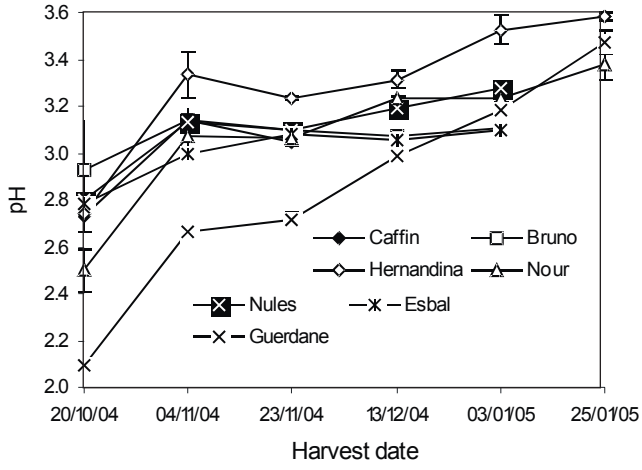

Fig. 7. Seasonal variation of pH in fruit juice of seven clementine selections

3.5. 'Guerdane' is distinguished from other cultivars by the lowest juice pH (Fig. 7) and highest juice titratable acidity (Fig. 4). Effects of harvest date and cultivar and their interaction were highly significant on juice pH.

Discussion

Maturation of citrus fruit, including clementine mandarin, is accompanied by a series of biochemical changes, including

color, texture, accumulation of sugars and reduction of acidity. The minimum values required for each of the quality attributes varies from country to country. For example, the export market for Moroccan clementines requires minimum soluble solids content (SSC) of 9 °Brix, a minimum maturity index value of 7.0, a minimum juice content of 40% and rind color must be typical of the variety on at least one-third of the surface of the fruit (EACCE, 1997). The same values for SSC are required for Corsican clementines (Agostini *et al.*, 1996), whereas for Spain, the minimum required values are 6.5 for the maturity index and 40% for juice content (Agustí, 2000).

Therefore, the seven clementine cultivars assessed in this study easily achieved values for internal quality. Based on the maturity time and fruit quality data, the order of maturity of the different cultivars was established. It is evident that 'Caffin' has the shortest harvest period, limited to only 1 month, and was the earliest maturing cultivar followed by the midseason cultivars 'Bruno', 'Esbal' and 'Nules' (Bono *et al.*, 1981), whereas 'Hernandina' (Tadeo *et al.*, 1981, Continella *et al.*, 1996), 'Nour' and 'Guerdane' had late maturity periods. From the data, only 'Guerdane' can really be considered as a true late maturing clementine cultivar.

Rind color of citrus is considered to be one of the most important external factors of fruit quality, as the appearance of fruit greatly influences consumer choice (Stanley, 1999; Olmo *et al.*, 2000). Moreover, although rind color development is not a limiting factor where fruit are degreened (El-Otmani *et al.*, 2000; Agustí *et al.*, 2002), for all cultivars studied the rind color increased with time. The early cultivars were of an acceptable orange color by mid-October (CI = 0 to +5) but the degreening treatment can enhance the development of orange color (Terblanche, 1999) thus allowing for harvest and marketing of fruit in early- to mid-October. The midseason cultivars developed an orange color naturally by mid-November and the late-maturing cultivars by mid-December to early January, except for 'Guerdane'. It is noteworthy that of all of the cultivars studied, 'Guerdane' had the slowest rate of color change and it reached adequate color 3 weeks later than the other cultivars of its group.

The minimum value of rind firmness (as measured by the puncture resistance force) of the fruit rind for which the fruit is still of good quality to travel over long distances appears to be close to 350 g. Below this value, the fruit is very soft and no longer elastic. This threshold value was attained in mid-October by the early-maturing cultivars, in mid-November by the midseason cultivars and in mid-December by the late maturing cultivars, except for 'Guerdane' which maintained firmness up to late January. The firmness values are therefore effective for evaluating fruit maturity (Olmo *et al.*, 2000), and rind firmness of clementine could be used as a maturity index (Burns and Albrigo, 1997) to determine how late fruit can be harvested and still ensure good quality after transport as reported for peaches by Crisosto (1994). Coggins (1986) also stressed that the rind is somewhat thicker in fruit of the early- and of the late-maturing cultivars and may be looked at as an advantage as thin rinds are more prone to blemishes, injury and decay.

Clementine mandarin loses the juice progressively after fruit color break (Agustí *et al.*, 2002). 'Caffin', the earliest maturing cultivar started to dry out by mid November, while other cultivars showed acceptable values (>40%) during the whole experimentation period (up to the end of January).

The duration of citrus cropping periods are related to the time of onset of rapid physiological changes, principally increases in soluble solids content and decreases in acid during development of citrus fruits (Grierson, 2006)**.** In this study, the soluble solids content minimum value (9%) was reached by mid October for all cultivars, except for 'Guerdane' which accumulated sugars at a much slower rate and did not reach this minimum level until December.

Juice acidity is an attribute often not taken into consideration as such, but it is becoming an important attribute in fruit quality definition. In fact, fruit taste is a balance between acids, sugars and volatile compounds. Holland *et al.* (1999) showed that total soluble solids content increased during maturity of 'Fortune' mandarin fruit, whereas acidity decreased, probably due to the use of the organic acids as respiratory substrates and the dilution of the remaining acids due to increases in size and water content of the fruit. Clementine mandarin fruit that have less than 0.8% acidity are considered of low quality as the sweetness prevails over the sourness and the fruit thus has a somewhat insipid taste and is also more prone to postharvest decay organisms (Coggins, 1986). According to the data presented in this paper, this problem may occur by early-October for the early cultivars, by mid-December for midseason cultivars and by early- to mid-January for the late-maturing cultivars.

It can be concluded that all of the cultivars, except 'Guerdane', reach minimum maturity index (sugar acid ratio >7.0) by early November. 'Guerdane' differed from the other clementine cultivars by a slow decrease in acidity and a slow increase of soluble solids content. In fact, 'Guerdane' is the only cultivar that has the characteristics of a late-maturing cultivar both internally (juice quality) and externally (rind color and firmness), allowing the period of commercial supply to be extended. The other late-maturing cultivars reach minimum maturity approximately 2-3 weeks later than the midseason group and the only attribute that is delayed in these clementine cultivars of the late-maturing group is rind color, which stays green for a longer period of time than that of the midseason group.

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