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Influence of Rootstocks and Harvest Date on the Fruit Quality of the 'Nadorcott' Mandarin During Cold Storage

El Guilli M.[1] , Nadori EB[2] , Mediani M.[3] , Samdi A.[1] , Zelmat L[1]., Baiz Z.[1], Kharbouch E.[2] and Douaik A.[1]

mohammed.elguilli@inra.ma

1 : National Institute of Agricultural Research (INRA).

2 : Researcher and Citrus Grower, Sebnak ltd Kenitra, Morocco.

3 : Mazaria Packinghouse, Morocco.

Abstract

Cold storage is one of the main ways to coordinate harvesting and packinghouse operations for extending the marketing period. In Morocco, for the new citrus varieties, limited research has been undertaken on the evolution of the fruit quality during cold storage. In this paper, we present results of a cold storage trial of 'Nadorcott' mandarin fruits. Fruits were harvested from a rootstock trial carried out in SEBNAK orchard and stored in Mazaria packinghouse facilities in North-West of the Morocco. The objective of the study is to assess the effects of the harvest dates, the storage duration and three citrus rootstocks: 'Carrizo' citrange (CC), C-35 citrange (C35) and *Citrus macrophylla* L (M) on the internal quality and weight loss of the 'Nadorcott' mandarin fruits stored at 6 °C and 80% ±5 % humidity. Fruits were harvested at three dates and the quality parameters (juice content, titratable acidity, total soluble solids and weight loss) were evaluated after 0, 20, 40 and 60 cold-storage days. Fruit quality characteristics varied according to the rootstock type, storage duration and harvesting dates. At harvest, juice content was affected by different rootstocks: C-35 and CC showed the highest values, with about 50 % compared to that of M with only 44%. In addition, fruits harvested in March (D3) were less juicy than those harvested in January (D1) and early February (D2). The juice content falls more or less rapidly during the cold storage depending on the rootstocks and harvest dates. For the three harvest dates (D1, D2 and D3) and 60 days storage, the 'Nadorcott' mandarin fruits on M recorded the lowest juice percentage with values of 31, 38 and 30% respectively. At late period (D3), the acidity in fruit juice dropped to the lowest levels reaching a rate of 0.68 % for CC and M and 0.77 % for C-35. With regards to TSS, CC and C-35 had higher TSS (total soluble solids) percentage compared with fruits from trees on M. Date of harvest and cold-storage period have no significant effect on this parameter. Similarly, the weight loss of 'Nadorcott' fruit was not affected by the rootstock.

Keywords : Nadorcott, rootstock, cold storage, internal quality

Influence du porte-greffe et de la date de récolte sur la qualité des fruits de la mandarine ‘Nadorcott’ pendant la conservation frigorifique

Résumé

La conservation à froid des fruits est l'un des principaux moyens pour coordonner les opérations de récolte et de conditionnement afin de prolonger la période de commercialisation. Au Maroc, pour les nouvelles variétés d'agrumes, les recherches menées sur l'évolution de la qualité des fruits en chambre froide sont peu nombreuses. Dans cet article, nous présentons les résultats d’un essai d’entreposage frigorifique des fruits de la mandarine ‘Nadorcott’. Les fruits ont été récoltés à partir d'un essai de porte-greffes installé dans le verger de la société SEBNAK et la conservation a été réalisée dans les chambres froides de la station de conditionnement, Mazaria, au nord-ouest du Maroc. L'objectif de l'étude est d'évaluer les effets de la date de récolte, de la durée de conservation et de trois porte-greffes d'agrumes: Citrange ‘Carrizo’ (CC), Citrange C-35 (C35) et Citrus macrophylla L (M) sur la qualité interne et le pourcentage de perte de poids des fruits de la mandarines 'Nadorcott' conservées à 6 °C et à 80% ± 5% d'humidité. Les fruits ont été récoltés à trois dates différentes et les paramètres de qualité (Teneur en jus, acidité titrable, solides solubles totaux et perte de poids) ont été évalués après 0, 20, 40 et 60 jours de stockage en chambre froide. Les résultats obtenus montrent que les paramètres de qualité des fruits variaient selon le porte-greffe, la durée de stockage et la date de récolte. Déjà à la récolte, la teneur en jus des fruits variait selon le porte-greffe: En effet, le C-35 et le CC présentaient les valeurs les plus élevées, avec environ 50% par rapport au M qui a donné un taux de jus de seulement de 44%. De plus, les fruits récoltés en mars (D3) étaient moins juteux que ceux récoltés en janvier (D1) ou le début de février (D2). La teneur en jus diminue plus ou moins rapidement lors de la conservation en chambre froide et ceci en fonction du porte-greffe et de la date de récolte. Pour les trois dates de récolte (D1, D2 et D3) et après 60 jours de stockage, les fruits de la mandarine ‘Nadorcott’ greffés sur le M ont enregistré le pourcentage de jus le plus bas avec des valeurs de 31, 38 et 30% respectivement. A la date de récolte tardive (D3), l'acidité du jus des fruits a chuté aux niveaux les plus bas en atteignant un taux de 0,68% pour le CC et le M et un taux de 0,77% pour le C-35. En ce qui concerne le TSS, le CC et le C-35 avaient un pourcentage de TSS (Solides solubles totaux) plus élevé que les fruits des arbres greffés sur le M. La date de récolte et la durée de stockage au froid n'ont pas d'effet significatif sur ce paramètre. De même, la perte de poids des fruits ‘Nadorcott’ n’a pas été affectée par le porte-greffe.

Mots clés : Nadorcott, conservation, froid, qualité interne.

تأثير حامل الطعم وتاريخ الجني على جودة ثمار ماندرين "النادوركوت" أثناء التخزين البارد

الكيلي م، الناضوري إب، ميد ياني م، صامدي أ، زلماط ل، ابعيز ز، خربوش إ، دويك أ

ملخص

يعتبر التخزين البارد أحد الوسائل الرئيسية للتنسيق بين عمليات الجني والتعبئة من أجل تمديد فترة التسويق. بالنسبة لأصناف الحمضيات الجديدة في المغرب، توجد أبحاث محدودة حول تطور جودة الفاكهة في التخزين البارد. في هذه المقالة، نقدم نتائج تجربة التخزين البارد لثمار ماندرين "النادوركوت". تم جني الثمار من تجربة حوامل الطعم التي أجريت في بستان SEBNAK. وتم تخزينها في مرافق التعبئة والتغليف في محطة مزارع Mazaria المتواجدة في شمال غرب المغرب. الهدف من هذه الدراسة هو تقييم آثار تواريخ الحصاد ومدة التخزين وثلاثة أصناف من حوامل طعم الحمضيات: السترانج "كاريزو" (CC)، السترانج C-35 (C35) وحمضيات الماكروفيلا ل (M) على الجودة الداخلية وفقدان الوزن بالنسبة لثمار ماندرين "النادوركوت" المخزنة تحت 6 درجات مئوية و٪80 ± ٪5 من الرطوبة. تم جني الثمار في ثلاث تواريخ مختلفة وتم تقييم معايير الجودة (محتوى العصير، الحموضة القابلة للمعايرة، المواد الصلبة الذائبة الكلية وفقدان الوزن) بعد 0، 20، 40 و 60 يوم من التخزين البارد. تبين النتائج المحصل عليها أن خصائص جودة الفاكهة تختلف حسب نوع حامل الطعم ومدة التخزين وتاريخ الجني. عند الجني، يختلف محتوى العصير في مختلف حوامل الطعم : حيث C-35 و CC سجلا أعلى نسبة، بحوالي ٪50 مقارنة بمحتوى M بنسبة ٪44 فقط. بالإضافة إلى ذلك، كانت الثمار التي تم جنيها في مارس (D3) أقل عصير من التي تم جنيها في يناير (D1) وأوائل فبراير (D2). تتناقص نسبة العصير بسرعة أكبر أو أقل خلال التخزين في الغرفة الباردة حسب حامل الطعم وتاريخ الجني. بالنسبة لتواريخ الجني الثلاثة (D1 و D2 و D3) و 60 يومًا من التخزين، سجلت ماندرين "النادوركوت" في M أقل نسب مئوية من العصير بقيم 31 و 38 و ٪30 على التوالي. في الفترة المتأخرة (D3)، انخفضت حموضة عصائر الفاكهة إلى أدنى مستوياتها حيث بلغت ٪0.68 بالنسبة لـ CC وM و٪0.77 بالنسبة لـ C-35. فيما يتعلق بـ ٪ السكر، سجلت CC و C-35 أعلى نسب مئوية من المواد الصلبة الذائبة الكلية مقارنة بثمار الأشجار في M. لم يكن لدى تاريخ الجني وفترة التخزين البارد تأثير كبير على هذا العامل. وبالمثل، فإن فقدان الوزن في فاكهة "النادوركوت" لم يتأثر بحامل الطعم.

الكلمات المفتاحية : الحمضيات حامل الطعم ، العصير، الحموضة، السكريات.

Introduction

The area planted with tangerine/mandarin in Morocco has increased steadily since 2007/08 cropping season by 40.6 % from 40,292 hectares to 64,102 hectares in 2018 with a yield of around 18.86 tons / Ha (FAO, 2019). The total tangerines/mandarins harvested area has grown by 73% passing from 29,417 hectares in the 2007/08 to 58,678 hectares in the 2018/19 (USDA, 2019). Recently, the tangerines/mandarins production reached more than one million tons in 2018/19 (USDA, 2019).

The production is dominated by Clementine-type varieties ('Nour', 'Nules' and 'Clementine') followed by mandarins ('Nova' and 'Nadorcott') (Maroc citrus, 2020). New hybrid varieties, such as 'Nadorcott' (Moroccan selection) and 'Nova' are gaining popularity compared to local and old varieties. These varieties have the advantage of being of good quality and easy peeled harvested late in the season. That extends the marketing season through February-March.

Their high fruit quality and availability for a long season on the market made tangerines/mandarins the favorite fruit consumed by Moroccans. Domestic consumption is estimated at 600 000 Mt in 2017/18 (USDA, 2017). According to USDA (2019), total tangerines/mandarins exports in 2018/19 reached around 0.7 Million metric tons. Russia remains by far the most promising market; it has absorbed 206 610 tons (56 %) of Morocco's tangerines/mandarins total export followed by USA (166 614 tons) (USDA, 2017).

The stage of fruit maturity and time of harvest are important factors in citrus storability and affect directly fruit quality (Machado et *al*. 2015). Furthermore, cold storage is one of the main means that permit coordination between harvesting, packinghouse and marketing operations for the extension of the marketing period and getting suitable prices. However, the evolution of the fruit quality parameters during the postharvest phase depends of many factors. Among the main pre-harvest factors, the stage of fruit maturity at harvest (date of harvest) is an important factor that directly affects fruit quality. Rootstock is another factor that can also affects many fruit quality parameters (Grierson and Ben-Yehoshua, 1986; Castle et *al*., 1993; Machado and *al*., 2011 and Cronjé, 2013). In Morocco, for the new citrus varieties such as 'Nadorcott' mandarin, little research has been done on conditions and factors that can influence the fruit quality parameters during cold storage. The selection of a suitable rootstock, its adaptability to the soil conditions and the interactive effects with the scion cultivar has to be carefully considered (Shafieizargar and *al*., 2012).

The aim of this study is to assess the effects of the rootstocks, harvest date and storage duration on the internal fruit quality of the 'Nadorcott' mandarin during cold storage. This will provide the citrus growers and the packinghouse operators practical information on the fruit quality to expect for a given rootstock, for the choice of the optimum maturity stage at which fruits must be harvested and on the appropriate duration of cold storage to adopt.

Material and Methods

Experimental site and orchard management

The 'Nadorcott' fruits used in this study were harvested from an eight-year-old rootstock trial in SEBNAK farm located 2 km from Atlantic coast, in North-West of the Morocco (Latitude: 34°46' 41.5'' N, Longitude: 6° 19' 59.5'' W).

The weather in the farm zone is more humid compared to the other Moroccan citrus areas: yearly rainfall varies strongly (400 to 800 mm), high temperatures in summer, moderate sunlight during late autumn and winter with low temperatures that can drop to -5 °C in December, January or February. In this period, fog, mist and dew are frequent which reduce harvest time to few hours per day (HCP, 2013).

The land is undulating and the soil is well drained. It's texture is sandy to loamy in the 0-30 cm layer and loamy with porous rocks and red clay in lower strata. There is no lime and pH is neutral (7 to 7.5) (HCP, 2013).

Drip irrigation is achieved by pumped underground water, which is of good quality.

Adopted spacing for planting is 6 m x 2 m.

Plant Materials

Fruits were harvested from Nadorcott budded on three rootstocks: 'Carrizo' citrange (*C.sinensis* x *Poncirus trifoliate*), *Citrus macrophylla* L and C-35 citrange (*C. sinensis* × *Poncirus trifoliata*).

The fruits were harvested in 2016 at three different periods during the harvesting season: D1 (Beginning) 19th of January 2016, D2 (Mid-season): 1st of February 2016 and D3 (End): 2nd of March 2016. 'Nadorcott' fruits were sent to the MAZARIA packinghouse where they were sorted regarding color and fruit size (size 1: 63-74 mmand size 2-3: 54-69 mm). Then, they were stored at 6 °C inside cold storage room**.**

Measurements

In this study, monitored internal quality parameters were juice content (OECD, 2010), titratable acidity (TA) (Chahidi B, 2007), total soluble solids (TSS) (OECD, 2010), and weight loss of fruit.

Twenty fruits free from disease, injury or mechanical damage, are taken in three replications for the measurement of different variables considered.

Juice content was extracted from fruits with an electric juice extractor, weighed and expressed as a percentage of the total fruit weight. Then 10 ml of juice is taken to determine TA by sodium hydroxide (NaOH, 0.1N) titration with an endpoint of pH 8.1 and phenolphthalein (1 % w/v), as an indicator, according to the Association of Official Analytical Chemists (A.O.A.C, 2011) standards. Total soluble solids content (TSS) is determined with an infrared digital refractometer (PAL-1, Atago Co., Japan) using few drops of juice. The values are given in °Brix. Finally, maturity index is expressed as the TSS/TA ratio.

Weight loss of fruit was determined according to the following equation:

Weight loss (%) = [(w0 – w1)/w0] x 100, where w0 is the initial weight and w1 is the weight measured at sampling date.

Data Analysis

Data were expressed as means of the three replicates and determined using PROC ANOVA (SAS Inst. Cary, NC) with mean separation by Duncan' multiple range test to determine the difference among the means (DMRT).

Results and discussion

Effect of rootstock, date of harvest and cold storage on juice content

Results showed as the harvest date forward, that juice content for all the rootstocks and for all harvest dates decreases progressively during cold-storage period (Figures 1, 2 and 3).

Figure 1 shows that after 60 days of storage at 6 °C, the fruit juice content decreased by 28, 22 and 30 % respectively on CC, C-35 and M, compared to their initial contents at D1. Additionally, juice contents at D2 were similar to D1 and after 60 days in cold storage, the juice contents of D2 fruits were reduced only by 18% for fruit harvested on three rootstocks (Figure 2).

Figure 3 shows that in D3, the juice contents in the fruit are quite low compared to those recorded at D1 and D2 harvest dates. The percentages of juice at D3 are 38, 42 and 35 % respectively for CC, C-35 and M. It should be noted that M. gave the lowest juice % at harvest. Compared to D1, similar levels were recorded at D3 after 60 days of cold storage (Figure 3).

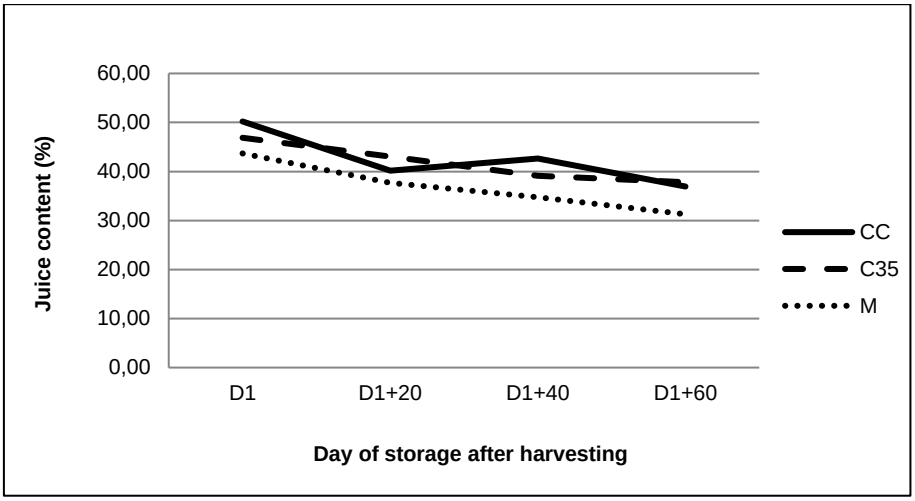

Figure 1. Effect of rootstock, harvest date (D1) and cold-storage duration on juice content (%) of 'Nadorcott' mandarin.

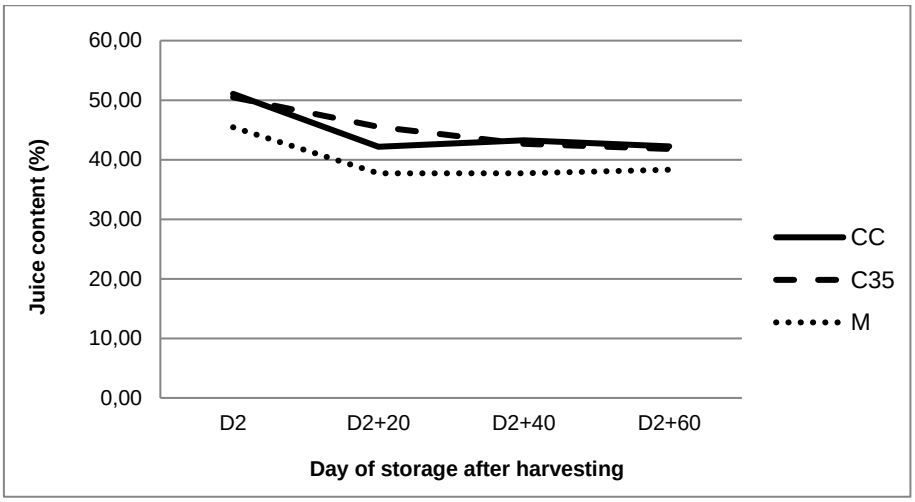

Figure 2. Effect of rootstock, harvest date (D2) and cold-storage duration on juice content (%) of 'Nadorcott' mandarin.

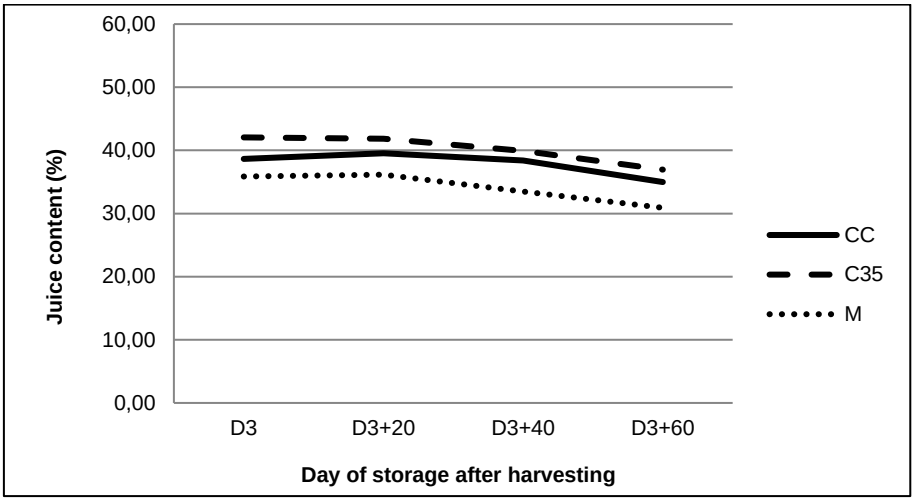

Figure 3. Effect of rootstock, harvest date (D3) and cold-storage duration on juice content (%) of 'Nadorcott' mandarin.

The rootstock affected the fruit juice content. Fruits produced on three budded on CC or C35 were more juicy and significantly differ from the fruit produced on M. This was noticed irrespective of the harvest date and cold storage duration. Nardello et *al.* (2017) reported that Nadorcott fruit juice yield decreased by about 10% when stored at 8 ° C, and by about 3% when stored at 4 ° C for up to 60 days. This behavior could be linked to the loss of mass during storage and also to the percentage of rot found during this period, since when the fruits were stored at 8 ° C, the percentage of rot was higher, reaching 20% of losses.

Effect of rootstock, date of harvest and cold storage on total acidity

Figures 4, 5 and 6 show a decrease in acidity in fruit juice of 'Nadorcott' mandarin for all rootstocks independently of the date and cold storage duration. This reduction of acidity followed the same linear curve for the three rootstocks. Hardy and Sanderson (2010) reported that the citric acid content of fruit is highest early in the season and decreases as fruit matures. The results show also that at D1 and D2 harvest dates the levels of acidity at harvest are at around 1 %, reaching average values of 0.75 at the end of the fruit cold storage period (Figures 4 and 5). Additionally, the acidity levels in the late period (D3) are low and are 0.68, 067 and 0.77% for CC, M and C35 respectively (Table1). These values reach 0.56 % at the end of their cold storage period.

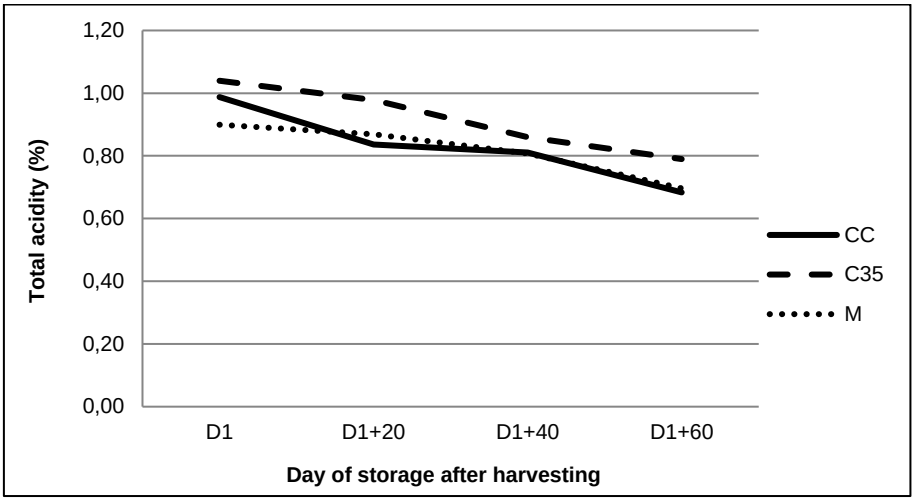

Figure 4 . Effect of rootstock, harvest date (D1) and cold-storage duration on total acidity (%) of ‘Nadorcott’ mandarin.

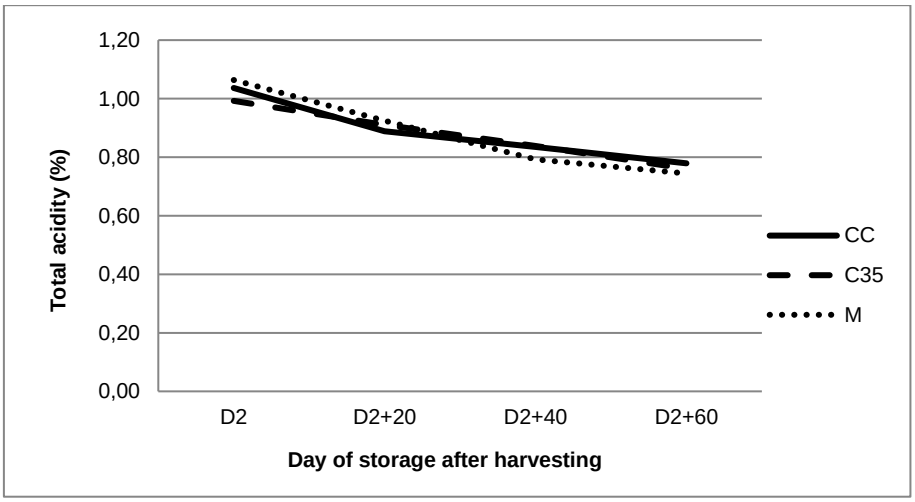

Figure 5. Effect of rootstock, harvest date (D2) and cold-storage duration on total acidity (%) of ‘Nadorcott’ mandarin.

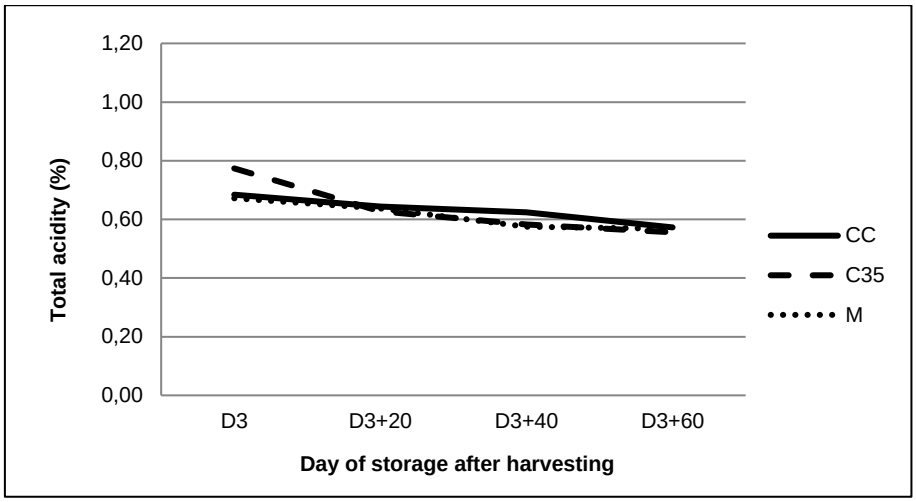

Figure 6. Effect of rootstock, harvest date (D3) and cold-storage duration on total acidity (%) of 'Nadorcott' mandarin.

The rootstock affected also the acidity content of Nadorcott. Furthermore, as described for juice content, the most acidic fruits at harvest or after cold storage were produced on CC and C35. There was always a significant difference between these two rootstocks and the M.

Effect of rootstock, date of harvest and cold storage on total soluble solids

Figures 7, 8 and 9 showed, in general and independently of the date of harvest, that the fruits from trees budded on CC and C-35 had higher TSS % compared with fruits from trees on M. Indeed, Zekri (2011) reported that besides cultivar, many of the horticultural characteristics of cultivars are influenced by the rootstock including tree vigor and size, and fruit yield, size, maturity date and quality. In addition, lower concentrations of TSS and acid in the juice are generally associated with cultivars budded on fast-growing, vigorous rootstocks such as rough lemon, Volkamer lemon, Rangpur and *Citrus macrophylla*. On the other hand, the same author has reported that cultivars budded on trifoliate orange and some of its hybrids rootstocks (citranges and citrumelos) generally tend to produce small to medium-size fruit with smooth peel texture and good quality fruit with high TSS and acid content in the juice.

However, for the three rootstocks in this field trial, Figure 7,8 and 9 showed that the highest TSS % was observed in D2 and not much changed after 40 days of harvesting in cold storage. Indeed, Hardy and Sanderson (2010) reported that sugar levels generally increase as fruit mature, but can decline if fruit become over-mature. The main changes in maturity are associated with a decline in acidity that why the harvest date is important.

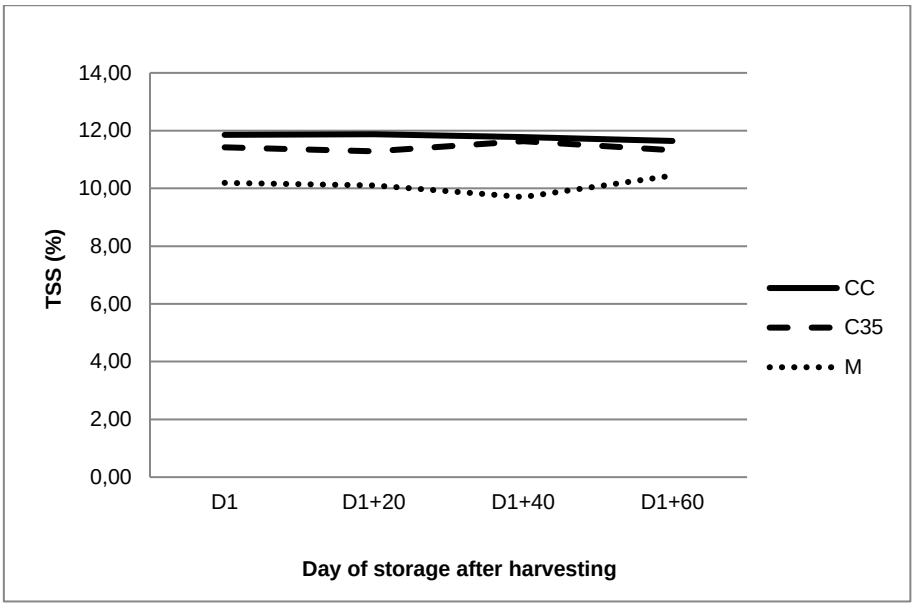

Figure 7. Effect of rootstock, harvest date (D1) and cold-storage duration on total soluble solids (%) of 'Nadorcott' mandarin.

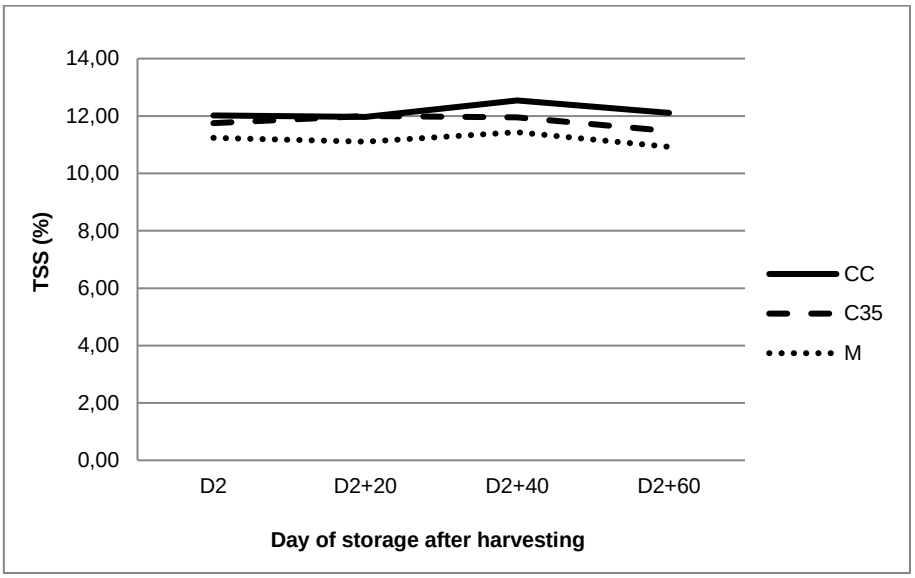

Figure 8. Effect of rootstock, harvest date (D2) and cold-storage duration on total soluble solids (%) of 'Nadorcott' mandarin.

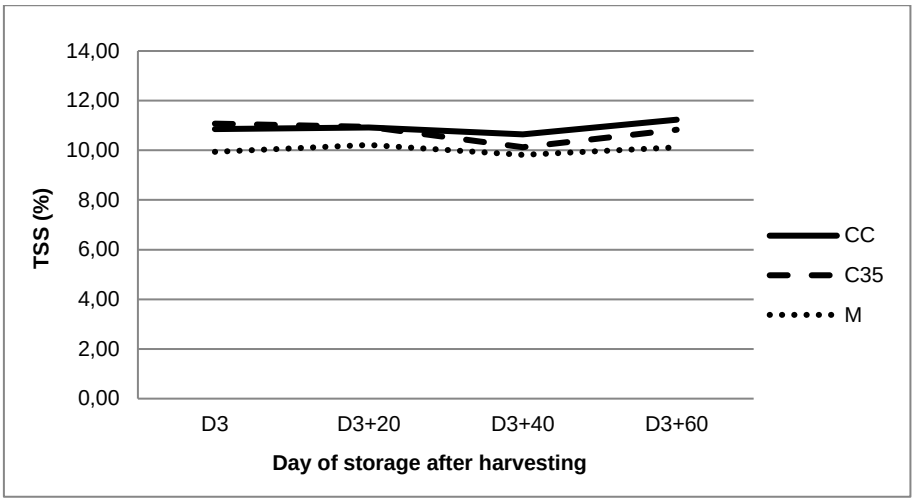

Figure 9. Effect of rootstock, harvest date (D3) and cold-storage duration on total soluble solids (%) of 'Nadorcott' mandarin.

Concerning the TSS % the data showed that the fruits from trees on CC had higher TSS % followed by those produced on C35 and finally by those produced on M. This was also noticed at all harvest dates and all the cold storage durations. Data of quality parameters are shown in (Table 1).

Table 1. Quality parameters of freshly harvested 'Nadorcott' mandarin grafted on *Carrizo citrange* (CC); C-35 citrange (C-35); *Citrus macrophylla* (MAC) rootstocks, harvested in January (D1), February (D2) and March (D3).

Quality parameters	**D1 : January**			**D2 : February**			**D3 : March**			**Export standards (DAFF, 2017)**
	CC	**C35**	**M**	**CC**	**C35**	**M**	**CC**	**C35**	**M**	**Late Mandarins**
Juice content (%)	50,20 a	46,87 b	43,68 c	51,07 a	50,48 a	45,46 b	38,65 b	42,06 a	35,84 c	40
TA (%)	0,99 ab	1,04 a	0,90 b	1,04 a	0,99 a	1,06 a	0,68 b	0,77 a	0,67 b	0.85
TSS	11,33 a	11,41 a	10,04 b	12,0 a	11,8 a	11,2 b	10,85 a	11,08 a	9,94 b	12
TSS/TA	11,49	11,01	9,15	11,66	11,84	10,66	15,87	14,32	14,82	10.1

For each harvest date, numbers followed by the same letter are not significantly different (P = 0.05) DMRT.

Effect of rootstock, date of harvest and cold storage on weight loss

During storage, cumulative weight loss increased with time for overall rootstocks. This increase is slow within 20 days after harvest in cold storage and crucial after this period. Figures 10, 11 and 12 showed that, no significant differences were detected in loss weight percentage between harvest date and during cold-storage period. These results suggest that the effect of the rootstock-harvest date interaction on weight loss depends on the cold-storage time.

In general, weight loss did not exceed 2 % of the initial weight 20 days after harvest in cold storage whatever the date of harvest. This relatively low loss of weight may be due to the appropriate conditions during storage (6 °C ± 1, 80 ± 5 % R.H.). The positive effects of low temperature and high relative humidity during storage on reducing weight loss in grapefruit was reported by Alferez et *al*. (2010) and Marchado et *al*. (2015). These results suggest that the fruits of 'Nadorcott' mandarin shall not exceed a period of 20 days in cold storage whatever the rootstock and the harvest date considered.

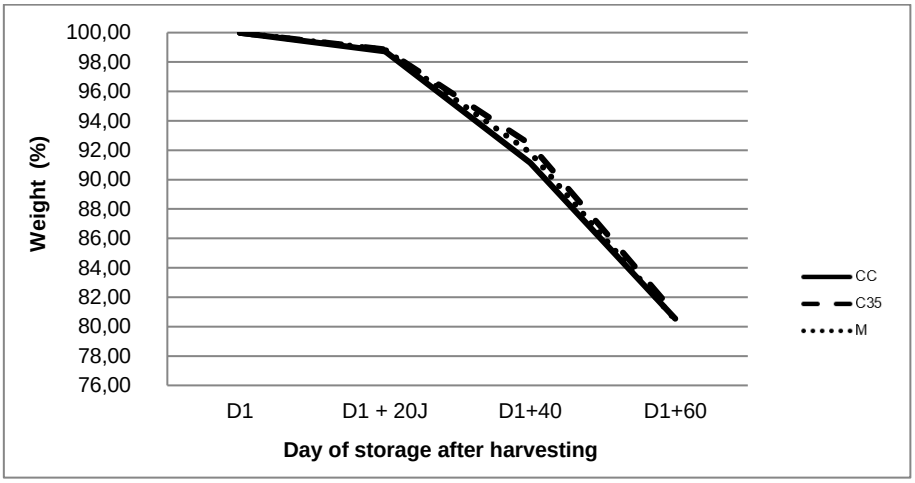

Figure 10. Effect of rootstock, harvest date (D1) and cold-storage duration on weight percentage of 'Nadorcott' mandarin.

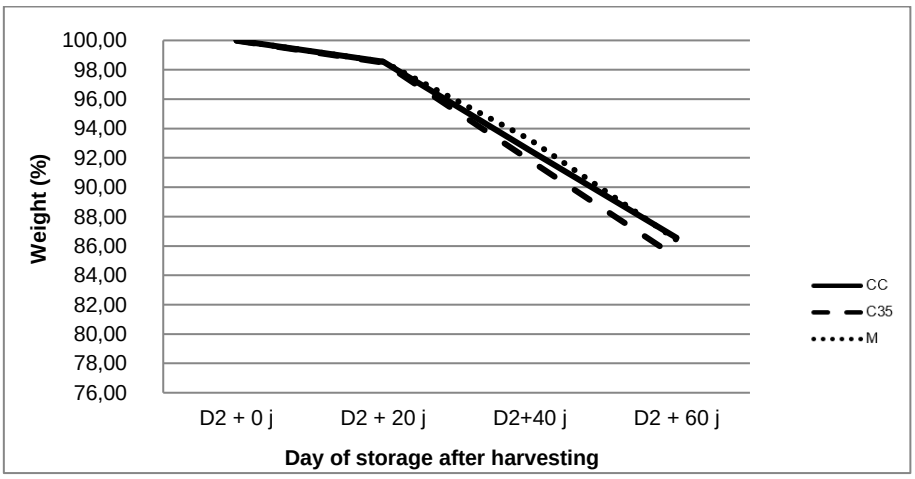

Figure 11. Effect of rootstock, harvest date (D2) and cold-storage duration on weight percentage of 'Nadorcott' mandarin.

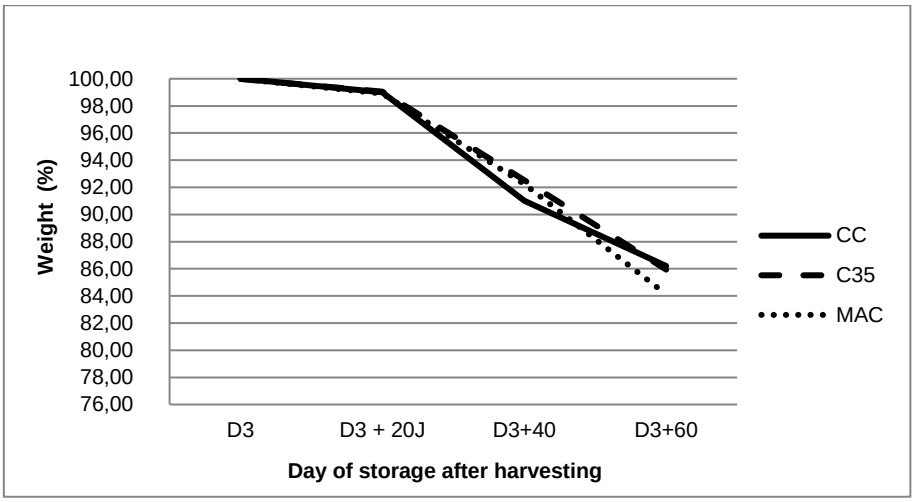

Figure 12. Effect of rootstock, harvest date (D3) and cold-storage duration on weight percentage of 'Nadorcott' mandarin.

The results show that the effect of rootstock, cold storage period and harvest date was clearly observed. Juice content, TA and TSS was clearly higher in fruits budded on CC and C35 and no big difference was shown on weight loss. Indeed, late harvest and cold storage affected fruit quality parameters.

Conclusion

The present study showed clearly the influence of rootstocks and harvesting dates on the fruit quality traits of 'Nadorcott' mandarin in cold storage. January-February-harvested 'Nadorcott" mandarin grafted either on CC or C35 have better quality parameters than those harvested in March. Even though they keep the required standards for export.

The quality of the fruits produced on trees budded on M remains lower than that of the fruits produced on the trees grafted on the CC and the C35. When harvested in March their quality is lower and it doesn't meet the standards required for export.

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