Citrus R&T (e-ISSN 2236-3122)
Citrus Research & Technology, v. 38, n. 2, 2017
http://dx.doi.org/10.4322/crt.ICC112

Artigo/Article

Characterization of different cultivars of citrus fruit for juice in the south of Spain

Francisco José Arenas-Arenas[1], Ana Belén González-Chimeno[1], Estefanía Romero-Rodríguez[1] & Aurea Hervalejo[1]

SUMMARY

The main destination of Spanish citrus is the fresh market; however, the cultivars destined to processed juice industries are gaining importance worldwide. The continuously emergence of citrus processing cultivars is an opportunity to the citrus sector. A comparative trial between several cultivars oriented to citrus processing juice industry based on internal fruit quality, yield and harvesting period has been studied: Ambersweet, Dahong, Hamlin, Salustiana, Shamouti, Cadenera, Pera, Barberina, Midknight Valencia, Valencia Delta Seedless and Valencia Rhode Red. Based on internal quality of the juice it is possible to discern between two groups of cultivars: early cultivars (Ambersweet, Dahong, Hamlin, Salustiana, Shamouti and Cadenera) and later cultivars (Pera, Barberina, Midknight, Valencia Delta Seedlees and Valencia Rhode Red). Between the early cultivars, Cadenera highlighted because obtained the highest values in juice percentage (J %), Dahong showed the highest titratable acidity (TA) and Salustiana the highest total soluble solids (TSS) and TA. However Dahong and Cadenera showed low yield in comparison to the rest of early cultivars. On the other hand, between the later cultivars, Barberina and Midknight highlighted because recorded the highest content in TSS and the largest J %. Valencia Delta Seedlees showed the highest TA and Valencia Rhode Red the highest color index of the juice. Valencia Delta Seedless was the most interesting cultivar due to the highest yield registered among the late cultivars.

Index terms: citrus processing cultivars, early cultivars, later cultivars, quality, productivity, optimal harvesting.

Caracterização de diferentes cultivares de citrinos para suco no sul de Espanha

RESUMO

O principal destino dos cítrios espanhóis é o mercado de fruta fresca; no entanto, as cultivares destinadas às indústrias processadoras de suco estão ganhando importância em todo o mundo. A emergência contínua de cultivares para a indústria é uma oportunidade para o setor citrícola. Um estudo comparativo entre várias cultivares orientadas para a indústria de suco de processamento de citros, com base na qualidade interna da fruta, rendimento e período de colheita tem sido estudado das seguintes vareidades: Ambersweet, Dahong, Hamlin, Salustiana, Shamouti, Cadenera, Pera, Barberina, Midknight Valencia, Valência Delta Seedless e Valência Rhode Red. Com base na qualidade interna do suco, é possível discernir entre dois grupos de cultivares: cultivares precoces

[1]Centro Las Torres, IFAPA, Alcalá del Río, Sevilla, Spain

Corresponding author: Francisco José Arenas-Arenas, Centro Las Torres, IFAPA, Ctra. Sevilla- Cazalla Km 12,2, 41200, Alcalá del Río, Sevilla, Spain. E-mail: fjose.arenas@juntadeandalucia.es

(Ambersweet, Dahong, Hamlin, Salustiana, Shamouti e Cadenera) e cultivares tardios (Pera, Barberina, Midknight, Valencia Delta Seedlees e Valencia Rhode Red). Entre as cultivares precoces, Cadenera destacou-se, pois obteve os valores mais altos na porcentagem de suco (J%), Dahong mostrou a maior acidez titulável (TA) e Salustiana os sólidos solúveis totais mais altos (TSS) e TA. No entanto, Dahong e Cadenera apresentaram baixo rendimento em relação ao resto das cultivares precoces. Por outro lado, entre as cultivares tardias, Barberina e Midknight destacaram-se, por apresentarem maior conteúdo em TSS e J%. Valencia Delta Seedlees mostrou maior TA e o Valencia Rhode Red o maior índice de cor do suco. Valencia Delta Seedless foi a cultivar mais interessante devido ao maior rendimento registrado nas cultivares tardias.

Termos de indexação: cultivares para indústria, cultivares precoces, cultivares tardios, qualidade, produtividade, ponto de colheita.

INTRODUCTION

Spanish citrus production, with 6.56 million of tonnes (2015), is concentrated between Comunidad Valenciana, Andalusia and Murcia with around 96% of the national production (España, 2015).

In Valencia, the citrus production is divided among oranges and mandarins, while in Andalusia dominate the sweet orange cultivation with more than 67% of the total production (España, 2014).

Although the main destination of the Spanish oranges production is the fresh market, the cultivation of oranges for processed juice industries has acquired a greater importance as a result of the establishment of these types of industries in the area.

However, the citrus industry destined to processed juices requires a conceptual and structural reform from the farm that bet by quality cultivars (high juice yield and sugar content).

The continuous emergence of citrus cultivars with interest for the processed juice industries is an opportunity for the sector. New cultivars require a field evaluation under different soil and climate conditions from Andalusian area.

Between sweet orange species (*Citrus sinensis*), the most interesting cultivars for processed juice industries are the Common Citrus Group. They are not only the most ancient and widely cultivated cultivars around the world, but also include the largest number of cultivars, being useful both to fresh market and for transformation in juice. Within this broad group is presented a comparative study of different cultivars based on yield, internal quality and harvesting period. The cultivars studied in this work were: Ambersweet, Dahong, Hamlin, Salustiana, Shamouti, Cadenera, Pera, Barberina, Midknight Valencia, Valencia Delta Seedless and Valencia Rhode Red.

MATERIALS AND METHODS

Plant material and experimental plot

During 2012-2013 and 2013-2014 seasons was analyzed the agronomic behaviour from eleven oranges cultivars of Common Oranges Group on citrange Carrizo in an experimental plot, located in Alcalá del Río (Seville, Spain).

Trees were nine years old and were planting with a tree spacing of 6 m x 4 m. The eleven cultivars studied were: two traditional cultivars in Spanish destined to processed juice industries (Salustiana and Cadenera), five introduced in Spain and from other countries (Ambersweet, Dahong, Hamlin, Pera, Shamouti and Valencia Rhode Red) and three cultivars obtained more recently (Barberina, Midknight and Valencia Delta Seedless).

Measurements

To evaluate the fruit quality and the optimum moment to harvest, several fruits sampling dates along each season was carried out and subsequently evaluated in laboratory. Different parameters of the quality of the juice were measure: juice content (J %), total soluble solids (TSS; ºBrix), titratable acidity (TA, g/100cc), maturity index (MI = TSS/acidity), color of the juice and the number of seeds.

The optimal period of harvest was determined by the internal quality of the fruit: juice content and well-balanced between total soluble solids and titratable acidity. However, in the case of the harvest destined to the processed juice, these periods can be delayed because the lost of acidity is not so important than for the fruits destined to the fresh market.

A colorimeter (Konica Minolta CR300, Ramsey, NJ, USA) was used to measure the juice colour. The Hunter parameters "a", "b" and "L" were used to calculate the Colour index (C.I.) according to Jiménez-Cuesta et al. (1981): C.I. = a × 100/ (L × b), where "L" indicates lightness and "a" and "b" are the chromaticity coordinates. TSS was measured by a digital refractometer (Atago, Palette PR100) and expressed as degrees Brix at 25 °C and TA was determined by titration of 5 ml of juice with 0.1N NaOH using phenolphthalein as indicator.

In the last sampling date, the yield of each studied cultivar was recorded (kg tree^{-1}).

RESULTS AND DISCUSSION

Maturity index is the basis for determining commercial maturity and organoleptical quality of the fruit (Agustí, 2000). According to Baier (1954) the juice flavor is related to the TSS and MI (Pritchett Tongue).

Optimal harvesting period

Ambersweet

Ambersweet fruit showed one of the highest MI, follow by Salustiana (Table 1), because of the low acidity of his juice (Figure 1). Taking into account the MI and the TSS, Ambersweet was one of the most precocious cultivars studied with an optimal harvesting period from mid-October to mid-end January. From January, it showed an unbalanced juice since with a maximun TSS of 10 ºBrix (Figure 2) is not recommended a MI above 14, according to Pritchett tongue (Baier, 1954).

Dahong

The juice showed the highest level in TSS (Figure 2), together with Salustiana and Cadenera (11.75 ºBrix). His optimal harvesting period is from of the beginning of December to end of April, date which the juice still has an optimal organoleptic quality.

Table 1. Maturity index (MI=TSS/TA) of the studied cultivars in the different sampling dates. 2012/2013 and 2013/2014 season

2012-2013	10/29/12	11/26/12	12/18/12	02/06/13	03/21/13	04/24/13	05/24/13
	----------TSS/TA----------						
Ambersweet	8.96	11.74					
Dahong	5.17	6.64	7.26	9.80	10.37		
Hamlin	6.43	9.29		12.18	13.47	24.55	
Salustiana	6.73	9.56	10.16	13.86	15.30	20.18	
Shamouti		6.38	7.90	9.22	11.31	15.13	
Cadenera		10.79	8.37	10.37	11.90	15.73	
Pera				9.66	11.07	14.42	13.15
Barberina					11.06	16.96	16.18
Midknight					11.34	16.36	16.58
V. D. Seedless					10.35	13.41	14.27
V. Rhode Red					10.50	15.23	17.01
2013-2014		11/26/13	01/14/14		03/03/14	04/07/14	05/05/14
Ambersweet		9.75	11.37		15.71		
Dahong		6.18	7.95		8.94	12.84	
Hamlin		6.99	8.81		14.05	15.80	
Salustiana		8.45	12.14		14.94	18.49	
Shamouti		4.84	6.59		10.05	11.02	
Cadenera		6.34	7.29		10.89	13.85	
Pera			8.27		10.37	12.44	14.27
Barberina					8.85	14.03	14.24
Midknight					9.52	12.96	15.19
V. D. Seedless					8.91	10.20	12.22
V. Rhode Red					11.43	12.87	20.36

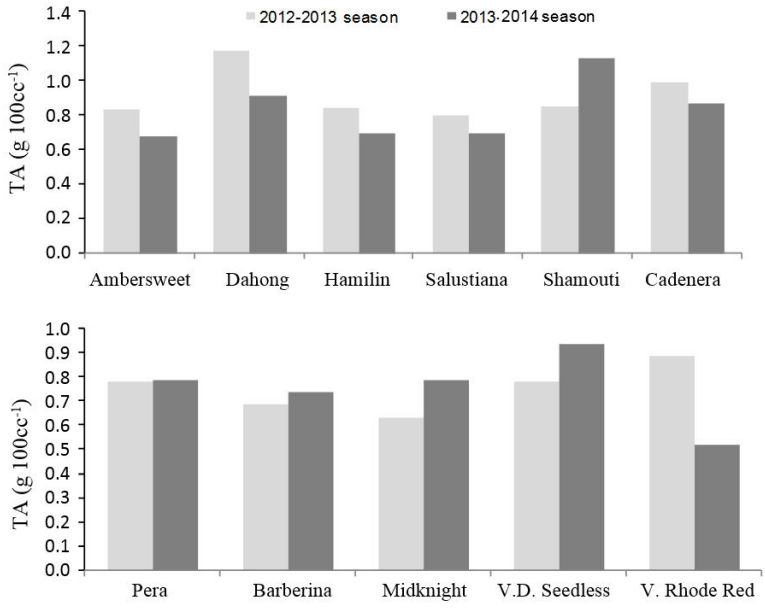

Figure 1. Titratable acidity (TA) corresponding to highest content in TSS dates of the early cultivars fruits in the different sampling dates. 2012/2013 and 2013/2014 seasons.

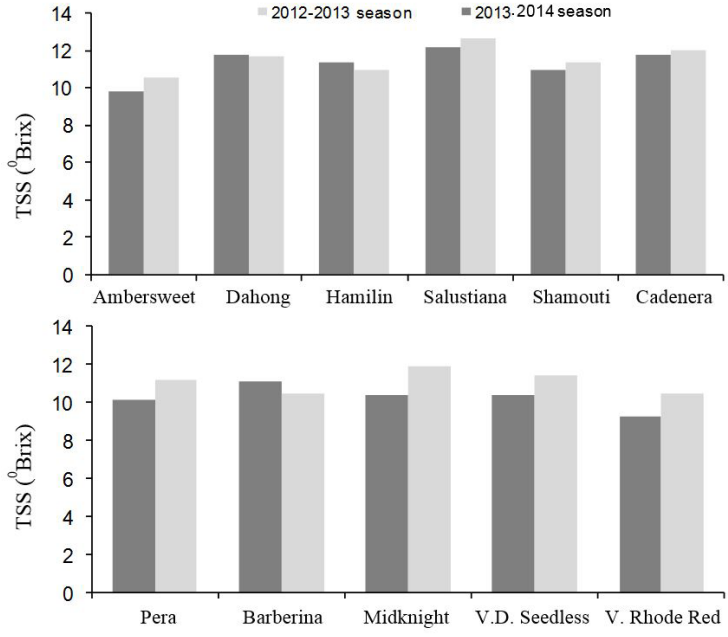

Figure 2. Highest total soluble solids (TSS) reached by the fruits of the later cultivars in the different sampling dates. 2012/2013 and 2013/2014 seasons.

Hamlin

His optimal harvesting period is from the beginning of December until mid-March. From mid-April, it showed an unbalanced juice since a maximun TSS of 12 ºBrix (Figure 2) with a MI above 16,5 is not recommended according to Pritchett tongue (Baier, 1954).

Salustiana

Salustiana fruits recorded the highest values in TSS (Figure 2), similar to Cadenera; and together with Ambersweet showed the lowest values of acidity (Figure 1). It recorded juices with highest MI. His optimal harvesting period is from end-November to the beginning of March.

From mid-March Salustiana showed an unbalanced juice according to Pritchett tongue (Baier, 1954).

Shamouti

Shamouti showed juice yields close to 50% until March, from this month, it suffered an important decrease in the juice content (Figure 3). This reduction in the juice content could cut the optimal harvest period while its high acidity (Figure 4) allowed getting well compensated juices until the middle of May.

Cadenera

The Cadenera juice showed one of the highest values of TSS (11.25 ºBrix) together with Salustiana and Dahong (Figure 2). The highest content in TSS and acidity turn into an intermediate MI. The optimal harvesting period was from end of November to end of April, date which the juice still has an optimal organoleptic quality.

Pera

Juice with slight lower sugar content than the other cultivars, it was only higher than Valencia Rhode Red and similar to Shamouti (Figure 2). Until May it recorded adequate levels of acidity. Optimal harvesting period is from end of December to end of May, date which the juice still has an optimal organoleptic quality

Barberina

It showed a good juice content (~50%) (Figure 3). Barberina juice recorded values higher than 11 ºBrix, higher than values recorded by Valencia Rhode Red (Figure 2) and the acidity was lower than recorded by Pera, but higher than Valencia Rhode Red (Figure 1). Taking into account also the results obtained in previous seasons (Hervalejo et al., 2010b), it was identified an optimal harvesting period from mid-January to mid-April, date in which the juice lost organoleptic quality according to the Pritchett tongue (Baier, 1954). These results contrast with other obtained in a trial carried out in Huelva (Spain) (Hervalejo et al., 2010a), where Barberina showed a good

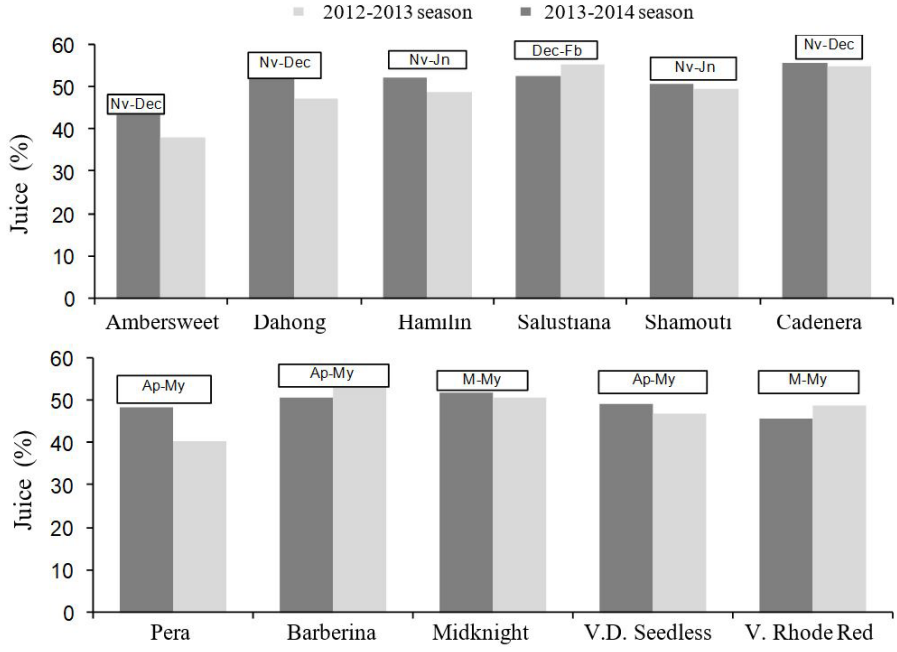

Figure 3. Highest juice percentage reached by the early cultivars in the different sampling dates. 2012/2013 and 2013/2014 seasons. Jn: January; Fb: February; Ap: April; My: May; M: March; Nv: November; Dec: December. The pictures placed on the top of the columns indicate the period of time in which the variety showed the maximum juice content.

organoleptical quality, high content in TSS (higher than Midknight, Valencia Delta Seedless and Valencia Rhode Red) and titratable acidity, and the fruit hold on the tree until June.

Midknight

An adequate TSS content in juice (Figure 2), reaching sometimes 11 ºBrix, exceeds to Barberina, Valencia Delta Seedless and Valencia Rhode Red and higher values of acidity than Barberina (Figure 1). His optimal harvesting period is from the beginning of March until end of May. After May juices were not well-balanced.

Valencia Delta Seedless

It obtained the lower MI recorded between the different cultivars studied (Table 1). Optimal harvesting period is from mid-March until end of the trial (May).

Valencia Rhode Red

Juice recorded a lower content in TSS (Figure 2) and acidity than Barberina, Midknight and Valencia Delta Seedless (Figure 1), showing very unbalanced juices from mid-April, date in which the juice lost organoleptic quality according to the Pritchett tongue (Baier, 1954).

Internal fruit quality and yield

Early cultivars

Ambersweet

Fruits of this cultivar showed barely seeds (data not showed) and recorded lower values in juice yield (38%) (Figure 3). Ambersweet showed a maximun TSS of 10.60 ºBrix (Figure 2). The color of the juice was the highest in early dates, very interesting characteristic in cultivars which are destined to processed juice industries (Figure 4). These results are in line with the description made by other authors (Jackson and Futch, 2003).

It could not record the yield due to the precocity of this cultivar. However, Jackson and Futch (2003) described this cultivar as commercially unsatisfactory based on low yields obtained.

Dahong

This cultivar had not many seeds. Dahong recorded one of the lowest yields in juice (~50%) only higher than Ambersweet (Figure 3). It showed a low CI of the juice (Figure 4) and a TSS of 11.75 ºBrix (Figure 2), one of the highest values together with Salustiana and Cadenera.

This cultivar showed not many productive recording a yield of 23 kg tree^{-1} in 2012/2013 season and 33 kg tree^{-1} in 2013/2014 season (Figure 5). This low productivity was also observed in previous seasons (Hervalejo et al., 2010b).

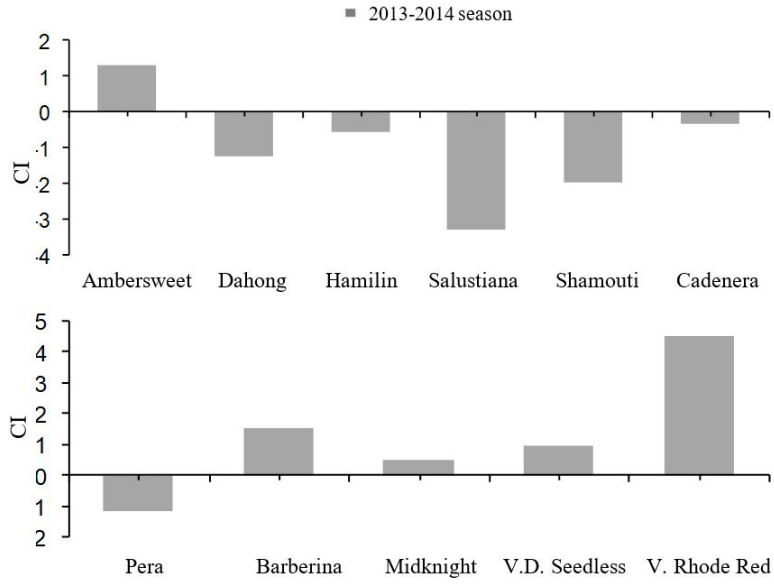

Figure 4. Highest Color Index (CI) reached by the early cultivars in the different sampling dates (2013/2014 season).

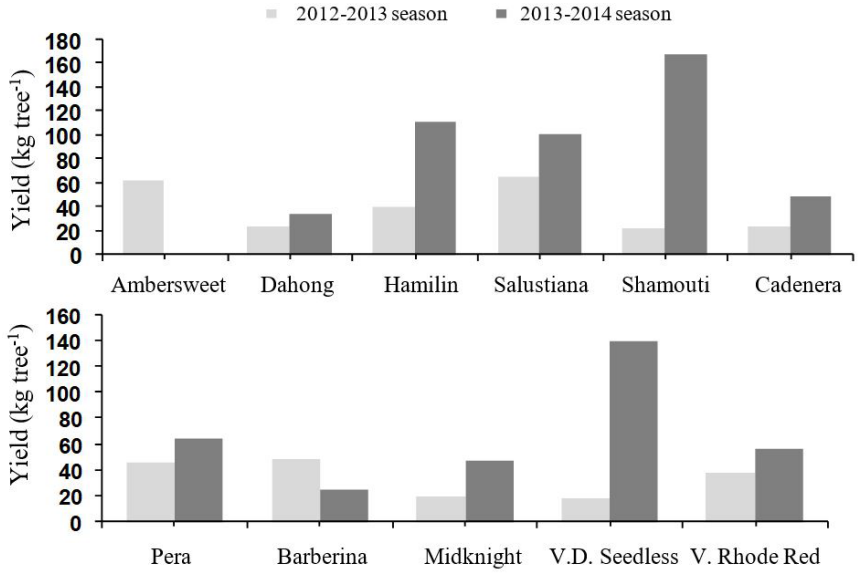

Figure 5. Yield (kg tree^{-1}) of the early cultivars in the different sampling dates. 2012/2013 and 2013/2014 season.

Hamlin

This cultivar showed not many seeds (0.46 seeds/fruit), being the second cultivar with the higher number of them, after Shamouti (data not showed). Low acidity juice (Figure 1), similar to Ambersweet and Salustiana, with low CI of the juice (Figure 4) and an intermediate value of TSS (Figure 2). Not very high juice yield (~50%), although higher than Ambersweet and Dahong (Figure 3).

Hamlin showed a medium yield of 75 kg/tree, higher than the most of studied cultivars (40 kg tree^{-1} in 2012/2013 season and 111 kg tree^{-1} in 2013/2014 season) (Figure 5). However, comparing the obtained yield in previous seasons (Hervalejo et al., 2010b) was observed a possible alternating of the harvest.

Salustiana

This cultivar was seedless (data not showed) and obtained one of the highest juice yield (Figure 3), only exceed by Cadenera. It showed the lowest CI (Figure 4) and the highest values of TSS (Figure 2).

Salustiana recorded an average yield of 83 kg tree^{-1} (66 kg tree^{-1} in 2012/2013 season and 100 kg tree^{-1} in 2013/2014 season), similar to Hamlin (Figure 5).

Shamouti

On the contrary of described by Hodgson (1967), this cultivar showed the higher number of seeds (data not showed), recording an average value of 2.36 seeds/fruit.

This cultivar showed one of the lowest CI of the juice together Salustiana (Figure 4), the same average value of TSS than Hamlin (Figure 2) and a juice percentage near to 50% (Figure 3).

Shamouti showed an average yield of 95 kg/tree, being the most productive cultivar. It was obtained a yield of 22 kg tree^{-1} in 2012/2013 season and 167 kg tree^{-1} in 2013/2014 season (Figure 5), showing alternate bearing.

Cadenera

It was seedless (data not showed) and recorded the highest juice yield (Figure 3), higher than 50%. It showed one of the highest values of TSS together with Salustiana (Figure 2) and the second CI value after Ambersweet (Figure 4).

Cadenera showed an average yield of 36 kg/tree, being one of the cultivars less productive together with Dahong, with a yield of 23 kg tree^{-1} in 2012/2013 season and 48 kg tree^{-1} in 2013/2014 season (Figure 5).

Later cultivars

Pera

This cultivar had not many seeds (0.32 seeds/fruit). Pera fruit recorded one of the lowest yields in juice (~45%) (Figure 3). Juice with slight lower sugar content (10.70 ºBrix) than the other cultivars, it was only higher than Valencia Rhode Red (Figure 2). Pera obtained the lowest CI (Figure 4). Until May it recorded adequate levels of acidity. On the contrary obtained in this trial, Hodgson (1967) referenced high juice content in this cultivar.

However, it is necessary to highlight that the material plant used in this trial, come from a first importation, could not be the same Pera describe in the bibliography, so it has been made a new importation of this cultivar, scioned again in new experimental trials.

The average yield of Pera was 55 kg/tree, and it showed more productive than Barberina, Midknight and Valencia Rhode Red, recording a yield of 45 kg tree^{-1} in 2012/2013 season and 65 kg tree^{-1} in 2013/2014 season (Figure 5). According to other works, Pera has been described as a very productive cultivar (Hodgson, 1967).

Barberina

A seedless cultivar that showed a good juice content (~50%) (Figure 3). Barberina juice recorded values higher than 11 ºBrix, higher than values recorded by Valencia Rhode Red (Figure 2) and the acidity was lower than recorded by Pera, but higher than Valencia Rhode Red. Barberina recorded the second highest value of CI.

Barberina showed an average yield of 37 kg/tree, being one of the less productive cultivars together Midknight. Regard to the yield, Barberina showed a yield of 49 kg tree^{-1} in 2012/2013 season and 25 kg tree^{-1} in 2013/2014 season (Figure 5).

Midknight

Seedlees fruits cultivar (data not showed). Midknight recorded a juice content of 50% or more, showing higher values than Pera, Valencia Delta Seedless and Valencia Rhode Red (Figure 3). An adequate TSS content in juice, reaching sometimes 11 ºBrix, exceeds to Barberina, Valencia Delta Seedless and Valencia Rhode Red (Figure 2) and higher values of acidity than Barberina (Figure 1). Midknight showed one of the lowest CI together with Pera.

Generally, Midknight showed as a low productive cultivar, with an average yield of 33 kg/tree. The yield obtained in each season were, 19 kg tree^{-1} in 2012/2013 and 48 kg tree^{-1} in 2013/2014 season (Figure 5). Regard to other works, Midknight has been described as a cultivar less productive than Valencia Late (Hodgson, 1967).

Valencia Delta Seedless

Seedless (data not showed). Despite of this cultivar did not reach higher values to 50%; it showed a good yield in juice, similar or slight higher than Pera or Valencia Rhode Red (Figure 3). Juice with a moderate content in TSS (Figure 2) and a high acidity (Figure 1). Valencia Delta Seedless has an intermediate CI, higher than Pera and Midknight and lower than Barberina and Valencia Rhode Red (Figure 4).

Valencia Delta Seedless was the most productive of the later cultivar with an average yield of 79 kg/tree. In 2012/2013 season showed yield of 18 kg/tree, while in 2013/2014 showed a yield of 140 kg tree^{-1} (Figure 5). These results are coherent with the description made by Hodgson (1967), where Valencia Delta Seedless is showed as a productive cultivar.

Valencia Rhode Red

Cultivar with barely seeds (data not showed). Juice was more attractive visually, recording the highest CI along 2013/2014 season, being a very interesting characteristic in juices destined to processing juice industry (Figure 4). This cultivar recorded together with Pera, the lowest juice content (~47%) and the lowest value of TSS (10.20 ºBrix).

Generally, Valencia Rhode Red showed as a low productive cultivar with an average yield of 47 kg tree^{-1} (38 kg tree^{-1} in 2012/2013 season and 56 kg tree^{-1} in 2013/2014 season) (Figure 5). Likewise, in other trial carried out in Huelva (data not showed), it was obtained a year-on-year average yield of 52 kg tree^{-1} with a slight trendy to the alternate bearing.

CONCLUSIONS

Taking into account the results of the internal quality of the juice (juice %, TSS, TA and CI) of the studied cultivars, it could be distinguished two groups of cultivars: early cultivars (Ambersweet, Dahong, Hamlin, Salustiana, Shamouti y Cadenera) and later cultivars (Pera, Barberina, Midknight, Valencia Delta Seedless y Valencia Rhode Red).

Regard to early cultivars, Cadenera highlighted because of the higher percentage of the juice; Salustiana showed the highest values of TSS; Dahong recorded the highest acidity and Ambersweet the highest values of CI. Dahong and Cadenera showed low yield comparing with the others early cultivars.

On the other hand, in the case of later cultivars, Barberina highlighted because recorded the highest values in TSS and the greater juice percentage together with Midknight. Valencia Delta Seedless showed the highest TA and Valencia Rhode Red recorded the highest CI. Moreover, Valencia Delta Seedless showed as the most interesting cultivar because it recorded the highest yield of all later cultivars group.

ACKNOWLEDGEMENTS

This work has been accomplished within the framework of "Transforma Cítricos: 2016-2018" project, 80% co-financed by the European Regional Development Funds, under the operational programme FEDER in Andalusia 2013-2020.

REFERENCES

Agustí M (2000) Citricultura. Madrid, Spain: Mundiprensa.

Baier WE (1954) The Pritchett tongue. The California Citrograph 37: 442.

Consejería de Agricultura, Pesa y Desarrollo Rural (2014) Junta de Andalucía. España. Histórico anual año 2013. Available from: www.cap.junta-andalucia.es

Hervalejo A, Arenas FJ, Carmona A, Reyes MC & Salguero A (2010a) Resultados preliminares en la caracterización de variedades tardías y de media estación de cítricos en la Comarca del Andévalo de Huelva. Vida Rural 306: 32-37.

Hervalejo A, Salguero A & Arenas FJ (2010b) Variedades de cítricos de interés para la industria de zumo. Vida Rural 317(Octubre): 62-67.

Hodgson RW (1967) Horticultural varieties of citrus. In: Reuther W, Webber HJ & Batchelor LD (Eds). The citrus industry. Berkeley: Universty of California. vol. 1.

Jackson LK & Futch SH (2003) Ambersweet orange. Gainesville: Institute of Food and Agricultural Sciences, University of Florida.

Jiménez-Cuesta M, Cuquerella J & Martínez-Jávega JM. (1981) Determination of a color index for citrus degreening. Proceedings of International Society of Citriculture 2: 750-753.

Ministerio de Agricultura Alimentación y Medio ambiente (2015) España. Anuario de Estadística. Available from: www.magrama.es

Received: March 29, 2017
Accepted: November 01, 2017