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Rootstock for the 'BRS Magna' grapevine grown in a tropical region affects the quality of the stored juice[1]

Porta-enxerto da videira 'BRS Magna' cultivada em região tropical afeta a qualidade do suco armazenado

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ABSTRACT - The 'BRS Magna' grapevine has the advantage of adapting to different regions of Brazil and producing juice of good quality. However, it is necessary to define the components of the cropping system, such as the rootstock, for each region. The aim of this study was to characterise the chemical composition and antioxidant capacity of grape juice collected from 'BRS Magna' grapevines grown on different rootstock under the tropical conditions of the Sub-middle São Francisco Valley. The grapes were harvested in the Experimental Area of Bebedouro/Embrapa Semiárido, in Petrolina, Pernambuco, Brazil. The treatments corresponded to the 'IAC 766', 'IAC 572', 'IAC 313', 'Freedom', 'Paulsen 1103', 'Harmony' and 'SO4' rootstock. The grape juice was prepared from two harvests for evaluation after storage. For each harvest, a randomised block design was used, with four replications. The quality of the juice varied with the treatment in each storage period. At nine months, the juice from the first harvest showed a loss of pigment and phenolic compounds, while the juice made with grapes from plants grafted onto 'Harmony' stood out for soluble solids content (SS), colour intensity (CI), anthocyanins, total polyphenol index (TPI) and antioxidant capacity. Juice from the second harvest was characterised at four months by higher levels of various compounds, especially the 'SO4' treatment for SS, CI, total extractable polyphenols, TPI and antioxidant capacity. Considering storage potential and the preparation process, the less-vigorous rootstock resulted in better quality juice.

Key words: Antioxidant capacity. Cropping systems. Hybrid grapes. Tropical viti-viniculture.

RESUMO - A videira 'BRS Magna' tem como vantagens a adaptação a diferentes regiões brasileiras e a elaboração de suco de qualidade. Entretanto, requer a definição de componentes do sistema de cultivo, como porta-enxerto, para cada região. O objetivo deste estudo foi caracterizar a composição química e o potencial antioxidante de sucos de uvas colhidas de videiras 'BRS Magna' cultivadas sobre diferentes porta-enxertos, nas condições tropicais do Submédio do Vale do São Francisco. As uvas foram colhidas no Campo Experimental de Bebedouro/Embrapa Semiárido, em Petrolina-PE, Brasil. Os tratamentos corresponderam aos porta-enxertos 'IAC 766', 'IAC 572', 'IAC 313', 'Freedom', 'Paulsen 1103', 'Harmony' e 'SO4'. Foram elaborados os sucos de uvas de duas safras, para avaliação após o armazenamento. Para cada safra, adotou-se o delineamento experimental em blocos ao acaso, com quatro repetições. A qualidade dos sucos variou com os tratamentos, em cada duração do armazenamento. Aos nove meses, os sucos da primeira safra apresentaram perda de pigmentos e de compostos fenólicos, sendo que aquele elaborado com uvas de plantas enxertadas sobre 'Harmony' distinguiu-se pelos teores de sólidos solúveis (SS), intensidade de cor (IC), antocianinas, índice de polifenois totais (IPT) e capacidade antioxidante. Os sucos da segunda safra, aos quatro meses, caracterizaram-se por maiores teores de alguns compostos, destacando-se o tratamento 'SO4' pelos SS, IC, polifenóis extraíveis totais, IPT e capacidade antioxidante. Os porta-enxertos menos vigorosos conferiram melhor qualidade ao suco, desde que se considere o potencial de armazenamento e o processo de elaboração.

Palavras-chave: Potencial antioxidante. Sistemas de cultivo. Uvas híbridas. Vitivinicultura tropical.

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INTRODUCTION

The Sub-Middle São Francisco Valley is one of the main grape-juice producing regions in Brazil. Producers have invested in technology with the aim of improving the quality and sensory characteristics of the grapes that can be transferred to the juice. Recent years have seen investments in producing grape juice from new cultivars. The most important being Isabel Precoce (*Vitis labrusca*) and the hybrids BRS Cora, BRS Violeta and, more recently, BRS Magna (LIMA *et al*., 2014), which are well-adapted to the region.

The BRS Magna cultivar was launched by Embrapa Uva e Vinho in 2012, with the advantage of adapting to the climate of different regions of Brazil and of promoting the sensory characteristics of grape juice. Juice made from the grapes of this cultivar has an intense colour, with a balance between sweetness and acidity, as well as levels of anthocyanins and polyphenols greater than those of other cultivars (RITSCHEL *et al*., 2014). Despite the quality attributes of the juice, there is little research relating components of the grape production system to the quality of the final product. Basic information, such as the scion/rootstock combination that provides better productive performance, its influence on the quality of the berries and consequently of the juice, still requires research.

However, despite the limited information, the production area of the BRS Magna cultivar has been growing in the Sub-Middle region of the São Francisco Valley. It is recognised that various attributes influence the chemical composition of grape juice, such as the region of origin, climate, cultivar, cropping practices, maturation stage, bioactive potential (GRANATO *et al*., 2016) and the relationship of the scion cultivar with the rootstock (JIN *et al*., 2016), among others. As a result, carrying out studies under local conditions should support recently observed growth and the technological evolution of the production chain.

In new growing regions, such as the Sub-Middle São Francisco Valley, there is still no scientific basis for indicating the best rootstock for the BRS Magna cultivar, or for other management decisions that might increase its performance. For this reason, the choice of rootstock has been based on empirical criteria. Bearing in mind that the rootstock replaces the root system of the scion, affecting the absorption of water and minerals as well as physiological processes, it is expected that vegetative growth, canopy exposure, yield and vigour in the producing cultivar should be affected (CHENG *et al*., 2017). There is also a need to ensure the quality and stability of the compounds in juice that show bioactive properties, such as phenolics, which account for antioxidant capacity.

The aim of this study therefore was to characterise the chemical composition and antioxidant capacity of the juice of grapes harvested from the 'BRS Magna' grapevine grown on different rootstock under the tropical conditions of the Sub-Middle São Francisco Valley.

MATERIAL AND METHODS

Grapes from the BRS Magna cultivar were harvested in the Experimental Area of Bebedouro/ Embrapa Semiárido (09º09' S and 40º22' W) in the district of Petrolina, in Pernambuco, Brazil, during the harvests in April and October 2017. According to the Köppen-Geiger classification, the climate in the region is of type 'BSwh', (ÁLVARES *et al*., 2013). Climate data during the experimental period are shown in Table 1.

The grapes used to prepare the juice were harvested from a vineyard planted on 20 August 2014, with grapevines of the BRS Magna cultivar grafted onto the 'IAC 572' ,'IAC 766', 'IAC 313', 'SO4', 'Paulsen 1103', 'Harmony' and 'Freedom' rootstock at a spacing of 3.0 x 2.0 m. The plants were grown on a trellis under drip irrigation, following the practice used for the crop in the region: pruning, thinning, tying, base fertilisation, fertigation and phytosanitary and invasive-plant control.

The grape juice was prepared at the Oenology Laboratory of Embrapa Semiárido, where the grapes were weighed, destemmed, cleaned and processed by steam-extraction in a stainless steel juicer. Extraction time was 60 minutes, after which the juice was packaged at around 80 ºC in transparent glass bottles with a capacity of 500 mL. The bottles were then subjected to thermal shock by immersion in a cold bath until the juice reached room temperature. The bottles were stored in an air-conditioned cellar (18 ºC). The juice from the first production cycle, made from grapes harvested in April 2017, remained under storage for nine months; those from the second cycle, prepared in October 2017, were stored for four months.

The analysis was carried out in triplicate, each employing one bottle. The relative density was obtained by reading on a hydrostatic scale at 20 °C. Turbidity was determined using a turbidimeter (ORGANISATION INTERNATIONALE DE LA VIGNE ET DU VIN, 2015). The hydrogen potential (pH) was measured using a previously calibrated pH meter. Total titratable acidity (TTA) was determined using the titrimetric method (ORGANISATION INTERNATIONALE DE LA VIGNE ET DU VIN, 2015). Volatile acidity was determined after distillation of the samples by steam entrainment and subsequent titration with NaOH 0.1N, using phenolphthalein as indicator (ORGANISATION

Table 1 - Monthly weather data for the Bebedouro Experimental Area of Embrapa Semiárido, for the two production cycles of the first and second semesters of 2017, evaluated from production pruning until harvesting the ‘BRS Magna’ grapevine

Period (month/year)	T (°C)			RH (%)	Rad. (MJ m^{-2} day^{-1})	Ws (m s^{-1})	Rainfall. (mm)	ET0 (mm day^{-1})
	Max.	Ave.	Mín.					
Production cycle January to April 2017								
Jan/17	36.0	29.3	23.4	45.1	18.23	2.41	10.0	6.26
Feb/17	35.8	29.1	23.4	54.0	19.81	1.96	24.0	5.81
Mar/17	34.2	28.8	22.6	57.6	19.81	1.77	6.0	5.49
Apr/17	32.7	28.0	21.9	62.0	17.37	2.41	3.0	5.37
Mean	34.7	28.8	22.8	54.7	18.80	2.13	43.0	5.73
Production cycle June to October 2017								
Jun/17	30.4	24.2	18.8	74.1	15.72	2.42	9.0	4.19
Jul/17	28.4	22.9	17.6	69.0	15.09	3.16	5.0	4.44
Aug/17	31. 8	25.1	19.1	64.7	21.53	2.71	1.0	5.70
Sep/17	30.7	24.1	18.5	68.7	20.24	3.46	12.0	6.01
Oct/17	34.9	27.8	21.7	65.6	25.34	3.52	0.0	7.61
Mean	31.2	24.8	19.1	67.1	19.58	3.05	27.0	5.59

T.Max. = Maximum temperature; T.Ave. = Mean temperature; T.Min. = Minimum temperature; RH = relative humidity; Rad. = Global solar radiation; Ws = Wind speed at a height of 2.0 m; Rainfall. = Accumulated rainfall; ET0 = Reference evapotranspiration; Source: Bebedouro Agro-meteorological Station, Petrolina, Pernambuco (EMBRAPA SEMIÁRIDO, 2017)

INTERNATIONALE DE LA VIGNE ET DU VIN, 2015). Since legislation does not require this analysis as a parameter in the control of juice quality, volatile acidity was determined in one bottle per treatment, and carried out to attest to the absence of contamination.

The level of soluble solids (SS) was read directly on a digital refractometer (ORGANISATION INTERNATIONALE DE LA VIGNE ET DU VIN, 2015). The level of total reducing sugars was determined by the Lane-Eynon method, using Fehling’s solutions A and B (RIBÉREAU-GAYON *et al*., 1980).

Colour analysis was carried out by reading the attributes L* (brightness), a* (+ red, -green) and b* (+ yellow, -blue) on a digital colorimeter. The colour intensity (CI) was determined from the sum of the values of the absorbance readings taken with a UV-Vis spectrophotometer, at wavelengths of 420 nm (yellow), 520 nm (red) and 620 nm (violet). The colour hue was determined from the ratio between the absorbance value at 420 nm and at 520 nm (OUGH; AMAERINE, 1988). The concentration of total monomeric anthocyanins was determined as per the method described by Lee, Durst and Wrolstad (2005).

To determine the total polyphenol index (TPI), the Harbertson and Spayd method (2006) was used. The level of total extractable polyphenols (TEP) was determined using Folin-Ciocalteau reagent, as per Larrauri, Rupérez and Saura-Calixto (1997).

The antioxidant capacity was determined by two methods, using the extracts obtained when quantifying the TEP. One method, based on capture of the ABTS radical (2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid), followed the recommendations described by Miller *et al*. (1993), with adaptations by Rufino *et al*. (2010). The other method, capturing the DPPH free radical (2,2-diphenyl-1-picrylhydrazil), followed a method described by Sánchez-Moreno, Larrauri and Saura-Calixto (1998) and adapted by Rufino *et al*. (2010).

The stored juice from the production of each harvest was studied separately. For each harvest, the treatments comprised juice produced with grapes from plants grafted onto different rootstock. The experimental design was of randomised blocks with four replications, where each plot corresponded to one bottle. The data were submitted to analysis of variance, and compared using Tukey’s test ($p \leq 0.05$). The statistical analysis was carried out using the Sisvar v5.6 statistical software.

RESULTS AND DISCUSSION

In each of the harvests under evaluation, it was found that, except for the chromaticity coordinates of the juice made from grapes harvested in the second half of 2017 and stored for 4 months, the other variables that determine quality were influenced by the rootstock used for the grapevines whose berries were processed (Tables 2 and 3). After nine months of storage, treatments that included the 'Harmony', 'SO4' and 'IAC 313' rootstock resulted in higher values (Table 2) for the relative density of the juice prepared from the first semester harvest. In the second semester harvest, after 4 months of storage, the highest values were seen in the 'Harmony' and 'SO4' treatments (Table 3). In both studies, the juice complied with Brazilian legislation, which regulates the minimum value for relative density to be 1.057 (BRASIL, 2004). Furthermore, even with different storage times, there was a match in the values for relative density, and a common response to the 'Harmony' and 'SO4' treatments, which may be related to the different capacity of the rootstock for accumulating some nutrients, such as carbohydrates, which are important constituents of soluble solids. Since the relative density of wine is mainly related to its alcohol and residual sugar content (OLIVEIRA; SOUZA; MAMEDE, 2011), it is recognised that sugars are the main compounds that contribute to this characteristic in juice. Research shows that some rootstock induce a greater accumulation of carbohydrates in the berries (JIN *et al*., 2016).

The greatest values for turbidity in the first semester harvest and after storage, were seen in the juice of grapes harvested from plants on 'IAC 766' (Table 2). In juice made with grapes from the second semester and stored for four months, the 'SO4' and 'Harmony' rootstock showed the highest values, of 275 and 200.85 NTU (Table 3). Turbidity and the presence of precipitates in grape juice are due to the presence of potassium bitartrate, calcium tartrate, pectin and gum. Although turbidity is a natural characteristic of juice, it can limit its quality and acceptance. The different response between rootstock may be associated with an increase in the absorption of ions such as potassium (K^+), which, according to Davies *et al*. (2006), accumulate in the plant and combine with tartaric acid, forming potassium bitartrate, which precipitates during processing and storage, and can affect

Table 2 - Physical and chemical characteristics, level of phenolic compounds and antioxidant capacity for the two methods for capturing the free radicals ABTS and DPPH of juice made with grapes from the BRS Magna cultivar produced on different rootstock, in the first semester harvest of 2017 and after nine months of storage[1]

Variable	Rootstock							ANOVA	
	IAC 766	IAC 572	IAC 313	Freedom	Paulsen 1103	Harmony	SO4	MS	CV (%)
Density (g mL^{-1})	1.068 e	1.070 d	1.075 b	1.074 c	1.070 d	1.076 a	1.075 b	0.0001**	0.06
Turbidity (NTU)	350.25 a	276.50 b	122.65 d	172.75 c	263.25 b	240.75 b	245.0 b	23217**	9.4
pH	3.33 c	3.56 a	3.38 c	3.39 c	3.52 ab	3.63 a	3.52 ab	0.048**	1.8
TTA (g.L^{-1})	8.13 b	7.38 d	8.77 a	7.72 c	6.90 f	7.01 ef	7.27 de	1.871**	1.7
SS (ºBrix)	16.6 c	16.9 c	18.8 a	18.1 ab	17.8 b	18.8 a	18.5 a	3.257**	1.8
RS (g L^{-1})	200.78 ab	235.07 a	173.77 b	206.34 ab	201.30 ab	173.77 b	201.30 ab	1761.3**	9.1
Colour L	16.15 ab	16.61 ab	17.18 a	16.07 ab	16.55 ab	15.22 b	16.08 ab	1.491*	5.1
Colour a*	2.93 b	0.85 d	8.11 a	7.51 a	2.14 bc	0.79 d	1.52 cd	38.482**	14.4
Colour b*	1.78 b	1.81 b	5.07 a	5.18 a	2.04 b	2.19 b	2.36 b	9.280**	15.5
I420 nm	4.84 a	4.79 a	2.44 d	2.87 c	4.01 b	4.92 a	4.72 a	4.232**	4.2
I520 nm	4.99 c	5.47 a	2.18 e	2.43 e	4.41 d	5.43 ab	5.02 bc	7.766**	4.4
I620 nm	1.70 a	1.73 a	0.68 c	0.89 c	1.39 b	1.81 a	1.37 b	0.849**	8.7
CI	11.53 a	11.99 a	5.31 c	6.20 c	9.82 b	12.17 a	11.52 a	32.998**	4.3
Hue	0.96 b	0.87 c	1.11 a	1.18 a	0.90 bc	0.90 bc	0.93 bc	0.056**	3.3
TMA (mg L^{-1})	142.90 b	203.14 a	81.31 c	73.47 c	140.18 b	197.55 a	144.44 b	10130.65**	9.3
TPI	59.60 c	55.26 d	31.70 e	32.81 e	60.78 c	66.20 a	63.32 b	834.10**	1.8
TEP (mg L^{-1})	1879.69 bc	1844.74 c	1052.79 d	972.07 e	1942.61 b	2334.14 a	2353.20 a	1237898**	1.7
ABTS (µM Trolox g^{-1})	3.51 c	3.99 b	0.93 f	1.71 e	3.77 bc	4.37 a	2.51 d	6.585**	4.3
DPPH (mL juice g^{-1})	5786 c	5908 c	1248b	1257 b	733 a	952 a	412 a	11218.104**	6.8

TTA = Total titratable acidity, SS = level of soluble solids, RS = level of reducing sugars, L = luminosity, a* = variations in green and red, b* = variations in blue and yellow, I420nm = yellow, I520nm = red, 1620nm = violet, CI = colour intensity, TMA = total monomeric anthocyanins, TPI = total polyphenol index, TEP = total extractable polyphenols, ANOVA = summary of the analysis of variance, MS = mean squares of the treatments for each variable. * = significant at 5% probability by F-test. ** = significant at 1% probability by F-test. CV = coefficient of variation. [1]Mean values followed by the same letter on a line do not differ by Tukey's test ($p \leq 0.05$)

Table 3 - Physical and chemical characteristics, level of phenolic compounds and antioxidant capacity for the two methods for capturing the free radicals ABTS and DPPH of juice made with grapes from the BRS Magna cultivar produced on different rootstock, in the second semester harvest of 2017 and after four months of storage[1]

Variable	Rootstock							ANOVA	
	IAC 766	IAC 572	IAC 313	Freedom	Paulsen 1103	Harmony	SO4	MS	CV (%)
Density	1.071 c	1.066 d	1.067 d	1.062 e	1.070 c	1.073 b	1.075 a	0.0001**	0.1
Turbidity (NTU)	217.12 c	212.0 c	226.87 c	206.75 c	268.75 b	200.85 a	275.0 ab	5490.244**	5.6
pH	3.57 c	3.64 b	3.52 d	3.58 c	3.96 a	3.52 d	3.57 c	0.120**	0.4
TTA (g L^{-1})	7.01 b	7.74 a	5.40 d	6.67 c	6.66 c	6.60 c	6.63 c	1.932**	1.5
SS (ºBrix)	17.4 b	16.4 c	16.4 c	15.5 d	18.1 a	17.4 b	18.3 a	4.211**	1.4
RS (g L^{-1})	189.63 ab	158.70 bc	171.23 bc	144.43 c	213.83 a	181.20 ab	172.26 bc	1984.699**	6.6
Colour L	14.33^{ns}	14.17	14.98	14.64	14.97	14.51	14.7	0.351^{ns}	2.6
Colour a*	-0.49^{ns}	-0.60	-0.51	-0.33	-1.07	-0.23	-0.39	0.304^{ns}	2.4
Colourr b*	2.83^{ns}	2.99	2.32	2.69	2.83	2.70	2.73	0.171^{ns}	12.7
I420 nm	3.27 e	3.43 e	4.30 d	3.35 e	5.29 c	7.19 b	7.66 a	13.743**	2.5
I520 nm	5.18 e	5.48 e	6.46 d	5.32 e	9.53 c	10.70 b	12.58 a	36.240**	2.8
I620 nm	1.44 d	1.59 d	1.54 d	1.42 d	2.10 c	3.04 b	3.64 a	3.156**	7.0
CI	9.90 e	10.50 e	12.30 d	10.10 e	20.94 b	16.92 c	23.88 a	130.247**	2.3
Hue	0.62 ab	0.62 ab	0.66 a	0.62 ab	0.66 a	0.54 c	0.60 b	0.006**	3.9
TMA (mg L^{-1})	450.87 bc	462.86 bc	483.54 bc	558.44 b	702.48 a	425.34 cd	336.10 d	53330.224**	9.6
TPI	85.43 c	78.32 e	63.26 f	81.41 d	97.63 b	80.10 de	101.37 a	649.376**	1.6
TEP (mg L^{-1})	2698.96 b	2343.67 d	1669.95 e	2417.40 cd	3046.00 a	2488.59 c	3128.23 a	960141.20**	1.5
ABTS (µM Trolox g^{-1})	5.41 c	5.23 c	3.59 d	5.55 c	6.61 b	6.36 b	8.69 a	9.754**	2.7
DPPH (mL juice g^{-1})	6537 e	7678 g	6818 f	4658 d	3378 c	1388 b	1128 a	2797124**	0.7

TTA = Total titratable acidity, SS = level of soluble solids, RS = level of reducing sugars, L = luminosity, a* = variations in green and red, b* = variations in blue and yellow, I420nm = yellow, I520nm = red, 1620nm = violet, CI = colour intensity, TMA = total monomeric anthocyanins, TPI = total polyphenol index, TEP = total extractable polyphenols, ANOVA = summary of the analysis of variance, MS = mean squares of the treatments for each variable. * = significant at 5% probability by F-test. ** = significant at 1% probability by F-test. CV = coefficient of variation. [1]Mean values followed by the same letter on a line do not differ by Tukey’s test ($p \leq 0.05$)

the sensory characteristics of wines and juice. There are no reports of studies characterising the influence of rootstock on the absorption of K^+ in the BRS Magna grapevine. However, research evaluating rootstock in ‘Dattier de Beiruth’ grapes has demonstrated that ‘SO4’ has a good capacity for absorbing K^+ (TOUMI *et al.*, 2014).

The pH values of juice prepared from the first semester harvest ranged from 3.33 to 3.63 (Table 2), while in the second semester, this variation was from 3.65 to 3.96 (Table 3). The four-month storage period resulted in a higher pH; however, the maximum difference between storage times was 0.32. In juice, the importance of pH is associated with colour stability, since at low values anthocyanins are characterised by a red colour (SILVA *et al*., 2015). Therefore, since the pH of the grape juice prepared from the BRS Magna cultivar is influenced by the rootstock on which the plant was grown, choosing this rootstock should consider its contribution to increasing the level of colouring material in the final product. According to Lima *et al*. (2014), the pH of the juice from the ‘BRS Magna’ grapevine produced in the Sub-middle São Francisco Valley was 3.62 on average. This value is close to that seen in this study, even after storage.

In the first semester harvest, the ‘IAC 766’ and ‘IAC 313’ rootstock determined juice with a higher TTA: 8.13 and 8.77 g L^{-1} respectively (Table 2). In the second semester harvest, the use of ‘IAC 572’ and ‘IAC 766’ resulted in the highest values: 7.74 and 7.01 g L^{-1} respectively (Table 3). The differences between cycles, for the storage period evaluated in each cycle, may be due to the value of the juice immediately after preparation. After four months of storage, the TTA was lower, which is probably due to the initial acidity of the berry being transferred to the juice. These values are close to those reported by Ritschel *et al*. (2014), in freshly prepared juice from the ‘BRS Magna’ grape. This variable is one of the principal sensory characteristics of the juice, influencing its chemical and microbiological stability (DUCHÊNE *et al*., 2014). The principal organic acids in the grapes are tartaric and malic, which represent more than 90% of the total of these compounds (LI *et al*., 2013).

The rootstock affect the chemical characteristics of the berries, modifying the minerals present, such as the potassium ion, which also acts as an enzyme activator in the transport of sugars and other minerals (TOUMI *et al*., 2014). Potassium neutralises free acids in the berry during ripening, contributing to a reduction in acidity and an increase in pH (MOTA *et al*., 2009). With the possibility of different levels of efficiency in absorbing this ion between rootstock, variations in the TTA of the grapes and their products are to be expected.

For volatile acidity, values of less than 0.5 g L^{-1} were seen in all samples, this being the maximum allowed under Brazilian legislation (BRASIL, 2004).

In the first semester harvest, the 'Freedom', 'Harmony', 'IAC 313' and 'SO4' rootstock determined a higher level of SS in the juice (Table 2). In the second semester harvest, the highest levels were associated with 'Paulsen 1103' and 'SO4' (Table 3). In both harvests, the levels associated with the above rootstock were greater than 18 and up to 18.8 ºBrix. In general, they were lower in juice prepared from the second semester harvest and stored for four months. It is possible that the high temperatures during the months of the first semester of 2017 close to the harvest, induced a greater accumulation of SS in the berries, benefitting the content of the resulting juice. Ritschel *et al*. (2014), pointed out SS levels of 17 to 19 ºBrix and a pH of 3.7, in juice from the 'BRS Magna' grape. However, sensory analysis could not distinguish the taste of the samples, which achieved good to excellent scores. In this study with the 'BRS Magna' grapevine on different rootstock, levels of SS and pH close to those presented by Ritschel *et al*. (2014), suggest good product acceptance. In addition, the levels exceed the minimum (14 °Brix) defined by Brazilian legislation (BRASIL, 2004).

According to Jin *et al*. (2016), the accumulation of SS in the grapes can be modified by the rootstock. The authors point out that rootstock which, due to their genetic characteristics are more vigorous, tend to prolong the vegetative period of the scion cultivar, delaying the accumulation of sugars in the berries. This explains the greater accumulation of SS, whose main constituents are sugars from the berries, in the juice associated with treatments including less vigorous rootstock, such as SO4, Harmony and Paulsen 1103.

With regard to the level of reducing sugars, the highest values, for juice prepared from grapes harvested in the first semester, were seen in the treatments with the 'IAC 572', 'IAC 766', 'Freedom', 'Paulsen 1103' and 'SO4' rootstocks (Table 2). In the second semester harvest, the 'Paulsen 1103', 'Harmony' and 'IAC 766' treatments afforded the highest levels (Table 3). Considering that some rootstock can anticipate or delay ripening in the grapes, this response should reflect in the levels of sugar, SS and TTA. According to Jin *et al*. (2016), the rootstock has a different effect on the composition of the soluble sugars. In the present research with juice from the 'BRS Magna' grape, only the reducing sugars were evaluated, which according to the same authors, are the predominant sugars in grapes, in the form of glucose and fructose, and which are transferred to the juice.

The colour of the juice is the first sensory attribute evaluated by consumers, and has a great influence on acceptance. In the juice made from grapes harvested in the first semester, the 'Harmony' rootstock resulted in a lower value for L and was therefore the darkest (Table 2). In turn, in the same harvest, the 'IAC 313' and 'Freedom' rootstock determined the highest values for the a* and b* coordinates. In the second semester harvest, the rootstock did not affect the values of L, a* or b* (Table 3). Positive values for a* are related to the red pigments in the juice after nine months of storage, whereas the negative values, which characterised juice from the second harvest stored for four months, are related to the green pigments. It should be noted that in the juice from both harvests, values for a* close to zero indicate a greyish hue, which is associated with darkening, oxidative processes or the presence of suspended particles (LOPES *et al*., 2016). In turn, positive values for the b* coordinate in the juice from both harvests represent yellowish tones, the origin of which may be in the characteristics of the grape, in the method of preparation or in the storage. It is likely that the method of processing plays an important role in this response. Research by Lopes *et al*. (2016), on juice prepared by different methods and evaluated during storage, concluded that the colour attributes were similar in industrialised juice and in juice prepared in a juicer. Juice from both methods was characterised by the presence of red (a* = 7.9) and yellow (b* = 1.6); however, since there is no second filtration and the juice is stored directly after steam entrainment, juice prepared in a juicer was turbid and contained sediments. The method of preparing the juice therefore influences the stability of the quality components, especially the pigments.

The juice from the 'IAC 766', 'IAC 572', 'SO4' and 'Harmony' treatments prepared in the first semester harvest were characterised by a higher CI (Table 2). Considering the components of the CI, this result agrees with that seen at 420 nm (yellow), with lower values than at 520 nm (red), and corroborating the readings carried out at 620 nm (violet). In the second semester harvest, the treatments with the ‘SO4’ and ‘Paulsen 1103’ rootstock gave the highest values for CI: 20.94 and 23.88 respectively (Table 3). In that harvest, optical density at 420 nm was lower than at 520 nm, and the results were consistent with those recorded at an absorbance of 620 nm, which highlights the violet nuances of the juice. Considering the storage period of four months employed in the second harvest, which was less than half that adopted in the first harvest, it is thought that by prolonging the period there was a loss of the components responsible for colour. It is recognised that higher CI values indicate red and violet nuances, which are mainly related to anthocyanin pigments (LOPES *et al*., 2016); while low values indicate an increase in hue, which reflects in the consumer desire to buy. Research by Lima *et al*. (2014), in juice from grape cultivars planted in the Sub-middle São Francisco Valley grafted onto ‘Paulsen 1103’, reported a CI ranging from 2.78 to 11.15, with 9.05 for ‘BRS Magna’. This value is consistent with that seen in this study, even after nine months of storage.

Hue was characterised by the opposite relation to that of CI (Tables 2 and 3). In juice made with grapes from the first semester harvest, those resulting from the ‘Freedom’ and ‘IAC 313’ treatments showed a stronger hue compared to the ‘IAC 572’ treatment (Table 2). In juice prepared in the second semester harvest from plants grafted onto ‘IAC 313’ and ‘Paulsen 1103’, higher values for hue were seen than with ‘Harmony’ (Table 3). The nine-month storage period reflected in a stronger hue, which may be caused by undesirable chemical changes during this period. These changes are mainly associated with oxidative processes (BORGES *et al*., 2013). In this study, juice prepared with grapes harvested from plants on genetically less-vigorous rootstock, such as ‘Harmony’ and ‘SO4’, showed a weaker hue and greater CI.

The level of total monomeric anthocyanins ranged from 73.46 to 203.14 mg L^{-1}, in juice prepared in the first semester harvest and stored for nine months, and from 336.10 to 702.48 mg L^{-1}, in juice from the following period (Tables 2 and 3). The influence of the rootstock varied between harvests together with the storage time associated with each harvest. The treatments with the ‘Harmony’ and ‘IAC 572’ rootstock resulted in higher levels of monomeric anthocyanins in juice produced in the first semester harvest, while in the second harvest, the same response was seen when using ‘Paulsen 1103’. The level of anthocyanins in the juice evaluated after four months was about 3.4 to 4.6 times higher than after nine months. Research by Lopes *et al*. (2016) reported a loss of 83% in grape juice after five months of storage. According to Dias *et al*. (2017), during ageing in the bottle, combinations or degradation reactions, and changes in pH, light, temperature and oxygen increase the hue and decrease the levels of anthocyanins. The authors also point out that the ideal scion and rootstock combination can increase the levels of anthocyanins.

The greatest values for TPI were seen in juice prepared with grapes from the treatment with the ‘Harmony’ rootstock in the first semester harvest and stored for nine months, and with ‘SO4’ and ‘Paulsen 1103’ in the second semester harvest (Tables 2 and 3). Ritschel *et al*. (2014) reported a TPI of 100 in juice from the ‘BRS Magna’ grape. This value was close to that seen in juice from treatments with some of the rootstock after four months of storage. The values for TPI at nine months suggest degradation of these compounds, which may be the result of oxidative processes (BORGES *et al*., 2013).

TEP levels increased in juice prepared with grapes harvested from the ‘Harmony’ and ‘SO4’ treatments in the first semester harvest and stored for nine months (Table 2). In the second semester harvest, the juice prepared from the ‘Paulsen 1103’ and ‘SO4’ treatments showed higher values, from 3046.0 to 3128.23 mg.L^{-1}, after four months of storage (Table 3). For both storage periods, the juice prepared with grapes harvested from plants grafted onto ‘SO4’ stood out for the high level of TEP, which points to stability in the juice promoted by the rootstock. The results also highlight that the juice stored for four months maintained a higher level of TEP. Research by Lopes *et al*. (2016), on the juice from red grapes, reported that the polyphenol content during five months of storage decreased by 27% as a result of deterioration during the period. Granato *et al*. (2016), analysing the juice of the ‘BRS Magna’ grape, reported levels of phenolic compounds of 2097 mg L^{-1}. These values agree with those found in this research despite the different storage time. However, it can be seen that combinations with different rootstock can enhance the phenolic composition of the juice.

Antioxidant capacity distinguished between the treatments in both harvests in a particular way, depending on the method of capturing the ABTS or DPPH free radical (Tables 2 and 3). When adopting the ABTS method, for the juice prepared in the first semester harvest, the treatments with the ‘Paulsen 1103’, ‘IAC 572’ and ‘Harmony’ rootstock stood out, with values of 3.77, 3.99 and 4.37 µmol Trolox.g^{-1} respectively (Table 2). In the second semester harvest, the highest values were seen in the treatment using the ‘Harmony’ rootstock, followed by ‘Paulsen 1103’ and ‘SO4’, with values of 6.36, 6.61 and 8.69 µmol Trolox.g^{-1} respectively (Table 3). For the two periods under evaluation, use of the ‘Harmony’ rootstock boosted the antioxidant capacity of the juice, measured by the capture of the ABTS free radical. In the juice stored for four months, the higher values can be explained by the shorter storage period, with no significant losses.

Using the method of DPPH free radical capture, interpretation of the results considers that the lower values represent greater antioxidant capacity. In the first semester harvest, the 'SO4', 'Harmony' and 'Paulsen 1103' treatments resulted in juice with different values for this characteristic, with values of 412, 733 and 952 mL g^{-1} DPPH (Table 2). In the second semester harvest (Table 3), the same treatments showed the best response, but with less antioxidant capacity than in the earlier cycle. The results indicate that suitable combinations of scion and rootstock reflect in a greater accumulation of phenolic compounds and antioxidant capacity (CHENG *et al*., 2017). Together, the characteristic conditions of each harvest can also promote the accumulation of various compounds that differentiate the products, the shelf life of which is linked to the time between packaging and consumption. Furthermore, according to Lopes *et al*. (2016), the time and conditions of storage can preserve the characteristics of grape juice, as long as the method used for extraction does not prevent changes in quality.

The distinct levels of quality and antioxidant capacity of the juice from the BRS Magna cultivar are noteworthy and can be better exploited by choosing techniques for grape production and processing that boost this response. With regard to the shelf life of regional juice, continuous production throughout the year results in a marketing dynamic that does not create stocks in either the production units or distributors. The products are consumed within a few months of preparation, and therefore there is no commercial demand for long-term stability, as is seen in regions where the harvest is limited to the period from January to March of each year.

CONCLUSIONS

1. The rootstock used for the 'BRS Magna' grapevine, with the storage time, determine the differences in quality of the prepared juice. After nine months of storage, juice prepared with grapes from plants grafted onto 'Harmony' have higher levels of soluble solids, anthocyanins, TPI and antioxidant capacity;
2. In juice evaluated after four months of storage, the level of quality compounds remains higher, with the plants grafted onto 'SO4' showing the highest levels of soluble solids, TPI and antioxidant capacity.

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