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CIÊNCIAS AGRÁRIAS

Qualitative potential of grape juices produced at Campanha Gaúcha, Brazil

Potencial qualitativo de sucos de uva produzidos na região da Campanha Gaúcha, Brasil

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ABSTRACT

This research investigated the qualitative potential of Concord and Ives (Bordô) grape juices from Campanha Gaúcha. The study was composed of three different experiments that evaluated and compared grape juices from different locations within Campanha Gaúcha (Experiment 1); grape juices from Campanha Gaúcha and Serra Gaúcha (Experiment 2); grape juices produced with different extraction systems (Experiment 3). Juice quality was assessed by analyses of physicochemical parameters and bioactive compounds. Within Campanha Gaúcha, the factors that influenced most on juice quality were, in descending order, grape variety, production cycle and production site (within the region). Juices from Campanha Gaúcha showed similar or even superior quality, if compared with those from Serra Gaúcha, considering the parameters under study. Extraction methods impacted largely on beverage quality. Juices extracted with the method employing enzymes and heat exchangers showed higher total soluble solids content and higher content of bioactive compounds. Therefore, it was possible to

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conclude that Campanha Gaúcha presents conditions for producing grape juices for the Brazilian market, complying with all the necessary quality parameters evaluated in this study.

Keywords: Ives; Vitis labrusca, concord, enzymatic extraction, steam juicer.

RESUMO

O presente estudo investigou o potencial qualitativo de sucos de uvas Concord e Bordô elaborados na região da Campanha Gaúcha. Para tanto, três experimentos foram desenvolvidos, avaliando-se e comparando-se: sucos de uva produzidos em diferentes locais da Campanha Gaúcha (Experimento 1); sucos de uva produzidos na Campanha Gaúcha e Serra Gaúcha (Experimento 2); sucos elaborados por diferentes sistemas de extração (Experimento 3). A qualidade dos sucos foi avaliada por análises físico-químicas e de compostos bioativos. Os fatores que mais influenciaram na qualidade dos sucos dentro da Campanha Gaúcha foram a variedade da uva, o ciclo produtivo e, por último, o local de produção (dentro da região). Os sucos elaborados com uvas provenientes da região da Campanha Gaúcha apresentaram qualidade igual ou superior à daqueles produzidos na região da Serra Gaúcha, de acordo com os parâmetros avaliados. O método de extração do suco impactou na sua qualidade. Sucos elaborados com o uso de enzimas e trocadores de calor tiveram maiores teores de sólidos solúveis e maiores teores de compostos bioativos. Dessa forma, pôde-se concluir que a região da Campanha Gaúcha apresenta condições para produção de sucos de uva ao mercado Brasileiro, atendendo a todos os parâmetros necessários de qualidade avaliados nesse estudo.

Palavras-chave*: Vitis labrusca; Bordô; Concord; extração enzimática; panela extratora.*

1. INTRODUÇÃO

The production of whole grape juice in Brazil is increasing. Within the state of Rio Grande do Sul, where more than 90% of the national grape juices and still wines are produced, whole grape juice production reached 61.841.495 liters, in 2021, while sales increased 67.13%, when compared to 2020. (MELLO; MACHADO 2022). Rich in vitamins and minerals for the human body, grape juices were included in the meals of public schools across the country, what has leveraged grape juice commercialization. (TROIAN; ARBAGE, 2016). It is estimated that the per capita consumption of grape juice in Brazil is around 1.37 L per inhabitant per year. (MELLO; MACHADO, 2022).

The Campanha Gaúcha region, bordering Uruguay and Argentina, has received investments in the installation of vineyards since the mid-1970s, but there, unlike Serra Gaúcha region, there is nor a traditional production of wine. (SILVA *et al.*, 2018), neither of grape juices. However, with the increasing consumption and commercialization of this beverage in Brazil, the production of grape juice becomes an alternative for the diversification of agricultural and industrial systems within this region. There, according to Sarmento (2016), viticulture has become a good alternative for diversifying production in family properties and is a profitable and sustainable activity.

The Serra Gaúcha region is the most important vitivinicultural region in Brazil. (COSTA, 2019). In comparison with Serra Gaúcha, at Campanha Gaúcha region there is higher solar radiation and drier climate. Such conditions allow greater production of phenolic compounds (PÖTTER *et al.*, 2010), greater maturation and sugar accumulation

(PÖTTER *et al*., 2010; SILVEIRA, 2021) less phytosanitary treatments, and longer life for the grapevines. (SILVEIRA, 2021).

Brazilian grape juice is predominantly made from Vitis labrusca varieties, with emphasis on Ives (mostly known in Brazil as Bordô), Concord and Isabel. (MOTA *et al*., 2018). Ives grapes have an excellent coloration, while Concord grapes have a balance between acidity and sugar, and for this reason they are widely employed for juice production. (FERRI *et al*., 2017).

Meteorological conditions, cultivar and maturation of the grapes are extremely important factors for obtaining quality grape juice, as well as the extraction method employed. (FERRI *et al*., 2017; BENDER *et al*., 2018). Grape juices can be extracted from the grapes using different equipment and processes such as heat exchangers, which modulate the temperature of the grape mass added of enzymes. (BENDER *et al*., 2018). Another common method is the steam juicer, which has a low acquisition cost, is easy to use, and produce good quality juices, but they can cause the incorporation of exogenous water into the juice. (MARCON *et al*., 2016).

Therefore, the present study aimed to evaluate the qualitative potential of grape juices from Campanha Gaúcha region, compare them with those from Serra Gaúcha region and test the two most common extraction methods employed to obtain this beverage.

2. DEVELOPMENT

2.1. MATERIAL AND METHODS

The research was divided into 3 experiments.

2.1.1. Experiment 1

The Experiment 1 was carried with Ives and Concord grapes acquired in the 2017 and 2018 crop seasons from commercial producers located in the municipalities of Dom Pedrito and Santana do Livramento. The climate type in the region is Cfa, according to the Köpen climate classification. (ALVARES *et al*., 2013).

Harvest dates were set according to the producers' harvest schedule. Grapes were manually harvested and placed in plastic boxes for transport to the laboratory. Bunches were manually de-stemmed. Samples of the grape berries were collected to carry out analyses of soluble solids (SS) before juice extraction. For this analysis, berries were removed from different parts of several bunches and pressed, yielding representative must samples. Must samples were filtered and analised in a digital refractometer PAL-1 (Atago® Japan) (Table 1). SS results were expressed in °Brix.

Juices were extracted using a stainless-steel steam juicer with a capacity of 20 kg of grapes. De-stemmed berries were deposited into the upper internal compartment (a perforated vessel, resembling a strainer) which was fitted within the external compartment (meant to hold the steam and the extracted juice). These two assembled pieces of equipment with a lid on top were then fitted on the water compartment. The entire set was accommodated on a gas stove. About 20 minutes after the start of heating, juice began to flow through the outlet tube. The bottling process was carried out at a temperature of 85ºC, in 1 L glass bottles. The bottles were left at room temperature to cool down for a few hours and then stored in a cold chamber at 5°C until analyzes.

Table 1 – Harvest dates and soluble solids content in Ives and Concord grape musts from Campanha region and Serra Gaúcha region.

Cultivar	Production site	Harvest date	Soluble solids (°Brix)
Ives	Dom Pedrito	26/01/17	15,00
Ives	Santana do Livramento	30/01/17	16,00
Concord	Dom Pedrito	26/01/17	16,20
Concord	Santana do Livramento	30/01/17	16,90
Ives	Dom Pedrito	23/01/18	16,50
Ives	Santana do Livramento	23/01/18	15,40
Ives	Serra Gaúcha	24/01/18	14,30
Concord	Dom Pedrito	23/01/18	18,20
Concord	Santana do Livramento	23/01/18	17,60
Concord	Serra Gaúcha	24/01/18	13,80

Source: Elaborated by the authors.

The following parameters were analyzed in juices, following the same methods which were developed by several other authors and adopted by Bender *et al.* (2018): soluble solids (SS), expressed in °Brix - determined with a digital benchtop refractometer with automatic temperature compensation (QUIMIS® Brazil); total acidity (TA), in $mEq.L^{-1}$ - by sample titration, with NaOH (0,1 N) solution, adopting pH = 8.2 as the end point of the titration; reducing sugars (AR), in $g.L^{-1}$ - by the DNS method, adapted for grape juice; pH - measured in a pHmeter Meter AD1030 (ADWA® Hungary). Total anthocyanins (ANT), expressed in mg of cyanidin equivalents 3-glycoside per liter of juice, were analyzed using the pH differential method. Total polyphenols (TP), in $mg.L^{-1}$ of catechin equivalents, were determined with the Folin Ciocalteu method. The antioxidant capacity (AC) was established through the adapted DPPH radical and the results expressed in Trolox (µM $TEAC.mL^{-1}$). To determine the color of the juices, a spectrophotometer from Konica Minolta® (Japan), model CM-5, recording as coordinates L *, a * and b * was used. L * represents the luminosity of the sample and the values of a * and b * were used in the calculations of the intensity (chroma) and hue (° Hue) of the color, prepared by the following formulas C * = [(a *) 2+ (b *) 2] 1/4 and ° Hue = arc tan b * / a *, respectively.

Hourly meteorological data was collected, comprising the following parameters: precipitation (P), in mm; global solar radiation (GR), in W m^{-2}; effective insolation (EI), in hours, counting the hours when there was radiation greater than 120 W m^{-2}; maximum (T max) and minimum (T min) temperatures, in °C ; relative humidity (RH), in %. The heliopluviometric maturation quotient (MQ) corresponds to the quotient of the total hours of insolation accumulated daily by the total rainfall in the same period. (WESTPHALEN, 1977).

All meteorological data (Table 2) was collected respectively in December and January, which coincides with the final of the maturation period and harvest of the cultivars under study. Data were obtained from the network of automatic meteorological stations of the National Institute of Meteorology. (INMET, 2020).

Table 2 – Meteorological data – Precipitation (P), Global Radiation (GR), Effective Insolation (EI), Mean daily maximum temperature (Tmax), Mean daily minimum temperature (Tmin), Relative Humidity (RH); Heliopluviometric Maturation Quotient (MQ) - for the months of December and January of the 2016/2017 and 2017/2018 production cycles in Dom Pedrito and Santana do Livramento.

Production site	Production cycle	Month	P (mm)	GR ($W.m^{-2}$)	EI (h)	Tmax (°C)	Tmin (°C)	RH (%)	MQ
Dom Pedrito	2016/2017	Dec	92,80	769392,60	393,00	29,52	17,99	67,15	4,23
		Jan	152,80	744943,40	396,00	29,42	19,32	76,88	2,59
	2017/2018	Dec	88,00	850642,00	398,00	30,86	18,04	60,85	4,52
		Jan	112,60	783151,00	403,00	30,11	18,76	67,32	3,58
Santana do Livramento	2016/2017	Dec	163,80	717415,30	392,00	28,77	17,39	67,20	2,39
		Jan	154,00	533047,90	321,00	27,85	18,59	77,98	2,08
	2017/2018	Dec	116,40	816949,10	394,00	30,12	17,11	61,28	3,38
		Jan	194,60	752972,60	393,00	29,42	18,09	66,61	2,02

Source: Elaborated by the authors.

Eight treatments resulted from the 2 cultivars, 2 locations and 2 crop seasons. Each of the eight treatments were represented by 3 replicates (i.e., in triplicate or 3 juice bottles). Principal component analysis (PCA) was carried out using the triplicates' arithmetic means for the analyzed parameters. A hierarchical cluster analysis (CA) based on Euclidean distance was also performed on this same dataset, to group individuals according to their main characteristics. For these multivariate analyses, the R software (RCORE TEAM, 2020) and the RStudio interface (RSTUDIO TEAM, 2020) were used, as well as the Factominer (LÊ; JOSSE; HUSSON, 2008) and Factoshiny (VAISSIE; MONGE; HUSSON, 2020) packages.

2.1.2. Experiment 2

The Experiment 2 was carried out in the 2018 crop season. This experiment included not just grapes from Campanha Gaúcha region but also Concord grapes from Farroupilha and Ives grapes from Antônio Prado - both locations belonging to Serra Gaúcha region - (Table 1).

Juice processing and analyses followed the same methodology applied in Experiment 1. Unifactorial experimental design was applied; grape production site was the treatment factor, for each of the two cultivars under study. The experimental design was completely randomized, using three replicates (3 juice bottles of 1 L, the experimental units). The results were subject to Dunnett's Test (at 95% significance level), considering the juices from Serra Gaúcha region as the controls.

2.1.3. Experiment 3

The Experiment 3 was carried out in the 2020 crop season, employing Concord grapes from Dom Pedrito, Campanha Gaúcha. They were harvested on January 25, 2020, and their must had an average soluble solids content of 19.0 °Brix.

The experimental design was completely randomized, with two treatments (extraction methods) and 4 replicates. The experimental units were grape juice bottles of 1 L.

After mechanical de-stemming, two different extraction method were applied. One (steam juicer) was the same one described in Experiment 1. The other method (heat exchanger + enzymes) was cinducted as follows. The berries were placed into a stainless steel 50 L pan fitted on a gas stove for heating to a temperature of 50 °C, under constant homogenization. After reaching the desired temperature, a commercial thermo-resistant enzymatic complex (Colorpect VR-C®) was added at a concentration of 3.0 $g.hL^{-1}$. This mixture was kept for one hour at 50°C. Then, the mixture was pressed to separate the liquid from the solids. The fluid fraction was placed in a cold room at 5 °C and remained there for 24 hours. After this period, the juice (supernatant) was separated, pasteurized, and bottled at a temperature of 85 °C. After cooling down at room temperature for a few hours, the bottles were stored in a cold room at 5 °C.

The physicochemical analyzes followed the same methodology described in Experiment 1, except for reducing sugars analyses, which could not be evaluated in this occasion.

Results were tested for homogeneity of variances and had their means tested by the T Test at 95% significance level.

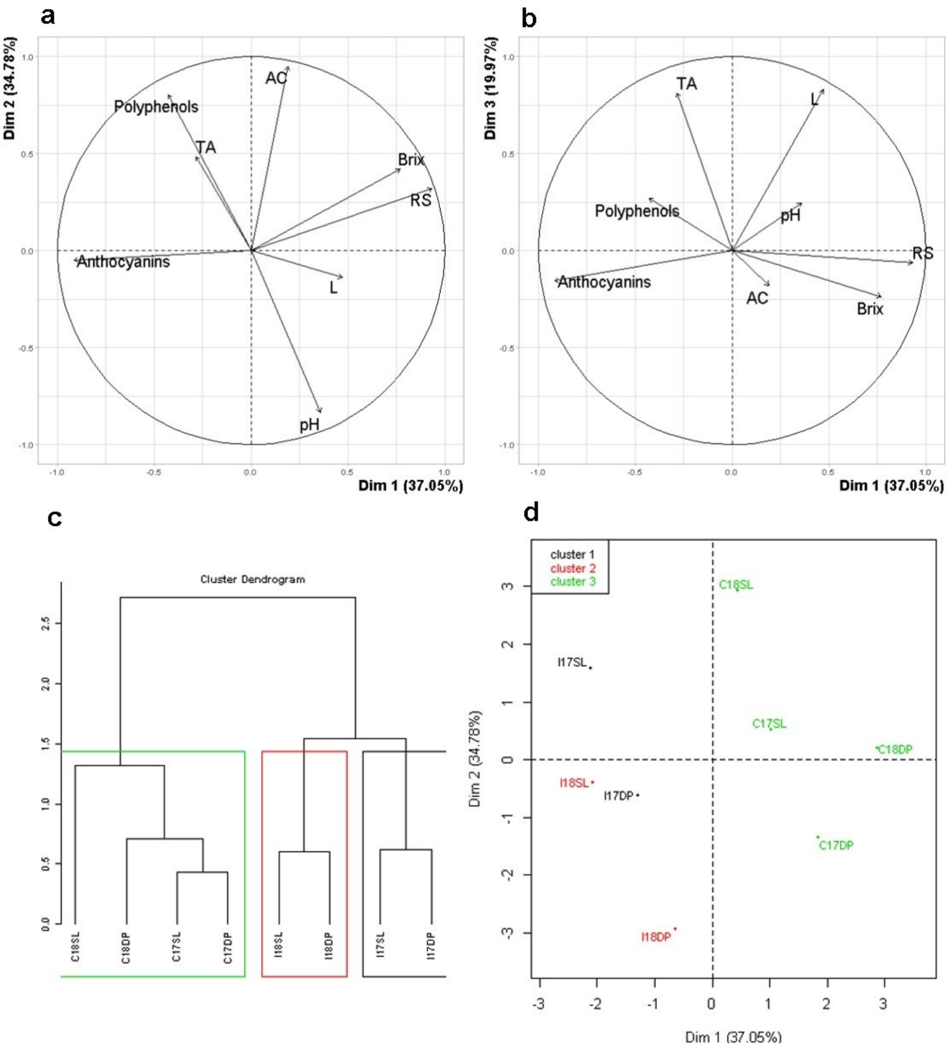
2.2. RESULTS AND DISCUSSION

Regarding the Experiment 1, multivariate analyses could clearly separate and characterize the samples based on the evaluated parameters. The loading plots (Figures 1a and 1b) showed excellent projections of the variables in the first three dimensions, which together comprise 91.8% of all the variance in this dataset. In the PCA score plot (Figure 1d) and in the CA dendrogram (Figure 1c) the samples differ mainly depending on cultivar (they are fully separated in in the first dimension). Samples from same cultivar and crop showed similar results in the two locations under study. These results suggest that the edaphoclimatic conditions of Dom Pedrito and Santana do Livramento are reasonably similar or, at least, that the differences between these two sites (distant almost 100 km) within Campanha Gaúcha region causes less noticeable impact on grape juice composition than the factors cultivar and crop season.

Differences and similarities between cultivars - already summarized by PCA - can be observed numerically into detail in the Table 3. Ives juices, in general, showed tendencies of lower SS, RS and L values. Low L values indicate very dark juices. According to Silva *et al.* (2019), the concentration of bioactive compounds in the juice depends mainly on the grape variety used in its preparation, as each variety has an individual phenolic composition. The anthocyanin content was higher in Ives juices.

Concord grape juices display less intense color than Ives grapes juices and are well known for a distinct aroma and flavor, displaying a perfect balance between sugar and acidity. (BORGES *et al.*, 2013; FERRI *et al.*, 2017).

Figure 1 – Principal component analysis and hierarchical cluster analysis of Ives and Concord grape juices produced in Dom Pedrito and Santana do Livramento, in the 2017 and 2018 crop seasons - Ives juice produced in 2017 with grapes from Dom Pedrito (I17DP), Concord juice produced in 2017 with grapes from Dom Pedrito C17DP, Ives juice produced in 2018 with grapes from Dom Pedrito (I18DP), Concord juice produced in 2018 with grapes from Dom Pedrito C18DP, Ives juice produced in 2017 with grapes from Santana do Livramento (I17SL), Concord juice produced in 2017 with grapes from Santana do Livramento (C17SL), Ives juice produced in 2018 with grapes from Santana do Livramento (I18SL), Concord juice produced in 2018 with grapes from Santana do Livramento (C18SL) – described by the variables Soluble Solids (Brix), Titrable Acidity (TA), pH, Reducing Sugars (RS), Total Polyphenols (Polyphenols), Anthocyanins, Antioxidant Capacity (AC) and Luminosity (L). Figure 1a - PCA loading plot, dimensions 1 x 2; Figure 1b: PCA loading plot, dimensions 1 x 3; Figure 1c: CA Dendrogram; Figure 1d: PCA score plot, dimensions 1 x 2.



Source: Elaborated by the authors.

Table 3 – Mean and standard deviation observed for the physicochemical parameters - Soluble Solids (SS), Titrable Acidity (TA), pH, Reducing Sugars (RS), Total Polyphenols (TP), Anthocyanins (ANT), Antioxidant Capacity (AC), Luminosity (L), Hue and Chroma - evaluated in Ives and Concord grape juices from Dom Pedrito and Santana do Livramento in the 2016/2017 and 2017/2018 production cycles - Ives juice produced in 2017 with grapes from Dom Pedrito (I17DP), Concord juice produced in 2017 with grapes from Dom Pedrito C17DP, Ives juice produced in 2018 with grapes from Dom Pedrito (I18DP), Concord juice produced in 2018 with grapes from Dom Pedrito C18DP, Ives juice produced in 2017 with grapes from Santana do Livramento (I17SL), Concord juice produced in 2017 with grapes from Santana do Livramento (C17SL), Ives juice produced in 2018 with grapes from Santana do Livramento (I18SL), Concord juice produced in 2018 with grapes from Santana do Livramento (C18SL).

Parameter	I17DP		I17SL		I18DP		I18SL	
SS (ºBrix)	11,63	±0,74	13,57	±1,19	12,60	±0,95	11,73	±0,25
TA (mEq L^{-1})	99,57	±3,59	99,74	±4,65	54,47	±1,96	74,54	±1,14
pH	3,56	±0,04	3,46	±0,03	3,69	±0,03	3,46	±0,03
RS (g L^{-1})	113,75	±1,15	120,58	±16,63	119,13	±19,47	116,00	±0,38
TP (mg L^{-1})	2115,15	±193,88	2551,80	±224,06	1663,35	±168,07	1952,60	±62,02
ANT (mg $100g^{-1}$)	117,47	±19,10	199,31	±11,92	138,85	±3,52	153,82	±4,36
AC (µM ml^{-1})	5596,67	±338,58	6525,00	±387,20	4581,67	±572,15	6030,00	±588,03
L	54,28	±2,24	40,78	±0,67	34,93	±5,53	28,92	±0,48
Hue	344,46	±0,46	349,28	±0,47	341,83	±1,12	352,97	±0,43
Croma	53,10	±2,08	59,96	±0,36	63,63	±1,11	61,40	±0,69
	C17DP		**C17SL**		**C18DP**		**C18SL**	
SS (ºBrix)	13,77	±0,68	13,30	±1,00	16,00	±0,10	14,53	±0,60
TA (mEq L^{-1})	90,82	±3,43	88,95	±9,14	60,69	±0,82	87,10	±2,94
pH	3,67	±0,07	3,63	±0,04	3,58	±0,03	3,34	±0,01
RS (g L^{-1})	152,75	±11,20	157,58	±2,74	171,50	±1,11	153,04	±8,70
TP (mg L^{-1})	1723,97	±130,62	2212,95	±16,70	1824,50	±17,22	2270,78	±174,60
ANT (mg $100g^{-1}$)	27,56	±0,95	39,16	±1,33	40,06	±2,14	63,72	±2,81
AC (µM ml^{-1})	5221,67	±151,77	6720,00	±194,87	6776,67	±286,37	8225,00	±263,58
L	55,94	±1,26	44,42	±0,23	46,67	±0,60	36,53	±0,90
Hue	5,72	±0,71	9,62	±0,16	9,01	±0,29	18,02	±0,68
Croma	44,72	±0,10	54,07	±0,08	54,43	±0,40	64,53	±0,83

Source: Elaborated by the authors.

The 2018 crop season was more favorable for the production of both Ives and Concord grapes in both production sites. Juices produced with grapes harvested in this crop season resulted in higher SS and lower TA values (Table 3). For the 2018 crop season, we could observe that during December and January, approximately the two months preceding harvest, there were lower rainfall volumes (Table 2). Lower rainfall favors the accumulation of soluble solids in the grape berries. (LUCIANO *et al.*, 2013). In years with heliopluviometric maturation quotient (MQ) ≥ 2.0, grapes to maturate better, displaying better quality for processing. (TONIETTO *et al.*, 2021; WESTPHALEN, 1977).

The December and January MQ values in both production sites were above 2.0 in both crop seasons, with emphasis on Dom Pedrito, which showed the highest values (Table 2). Regarding this same crop season, Alves and Tonietto, (2018) pointed out that the general quality of the grapes for winemaking at Campanha Gaúcha region was very good to excellent, placing this among the best crop seasons of its preceding three decades.

Brazilian legislation (BRASIL, 2018) establishes that whole grape juice must contain at least 14 ºBrix of SS and 55 mEq L^{-1} of TA. According to these criteria, all juices in this experiment complied with the TA minimum threshold, but only Concord grape juices produced in 2018 would comply with the SS minimum threshold (Table 3). Nevertheless, all the grapes’ SS levels before juice production (Table 1) in both years were higher than 15 ºBrix. Lower SS values in the juices are certainly caused by the extraction method employed, which incorporates exogenous water, from the steam. (BRESOLIN *et al*., 2013; DUTRA *et al*., 2014).There was an average reduction of 3.34 ºBrix for Ives juices and 2.83 ºBrix for Concord juices, relatively to the SS level of grapes. Marcon *et al*., (2016) also found greater incorporation of water in Ives juices than in Isabel juices. According to Bresolin *et al.* (2013) the amount of exogenous water incorporated depends on the extraction time. In our study, we noticed that Ives grapes require longer extraction times than Concord grapes until the juice starts to flow, what results in a greater incorporation of water. Marcon *et al.* (2016) state that in juices prepared using heat exchangers and enzymes for extraction, there is no incorporation of water. These results conducted to the development of the Experiment 3, to evaluate the influence of the different extraction methods on juice quality.

In the Experiment 2, Ives juices from Campanha Gaúcha region did not differ statistically from Ives juices from Serra Gaúcha with regard to SS, RS, TP, CA, while colors tones (Hue) were similar but with greater color intensities (Chroma) (Table 4). For TA, Ives juices from Dom Pedrito had lower mean values and those from Santana do Livramento had higher mean values, in comparison with juices from Serra Gaúcha. Ives juices from Santana de Livramento had a higher content of anthocyanins, while those from Dom Pedrito did not differ from Serra Gaúcha juices od this cultivar. Ives juices from Dom Pedrito had higher pH and higher values of luminosity (L), indicating slightly lighter juices than those from Serra Gaúcha.

Concord juices from both production sites within Campanha Gaúcha region, unlike Ives juices, differed in almost all the parameters evaluated, in comparison with Concord juices from Serra Gaúcha (Table 4). Anthocyanin content, luminosity (L) and color tone (Hue) in Concord juices from Campanha Gaúcha region did not differ statistically from Concord juices from Serra Gaúcha. Concord juices from Santana do Livramento showed TA values like Concord juices from Serra Gaúcha, lower pH values and higher color intensity (chroma). SS, RS, TP and CA were higher in Concord juices from Campanha Gaúcha region. Concord juices from Dom Pedrito showed lower lower TA, higher pH and less color intensity than those from Serra Gaúcha region.

The Serra Gaúcha region differs from Campanha Gaúcha region in many aspects that may help to explain the differences observed in the juices. According to Rizzon *et al*., (2008) the Serra Gaúcha region is a mountain region, with vineyards located at altitudes ranging from 200 to 800 m. In contrast, the Campanha Gaúcha region has altitudes between 75 and 420 meters and a very flat topography. (SILVA; RODRIGUES, 2018). At higher altitudes, the maximum and minimum temperatures tend to be lower, what tends to reduce the degradation of organic acids in grapes. (REGINA *et al*., 2010). Higher rainfall also favors higher must acidity. (LUCIANO *et al*., 2013).

Table 4 – Mean and standard deviation observed for the parameters - Soluble Solids (SS), Titrable Acidity (TA), pH, Reducing Sugars (RS), Total Polyphenols (TP), Anthocyanins (ANT), Antioxidant Capacity (AC), Luminosity (L), Hue and Chroma - evaluated in Ives and Concord grape juices from Serra Gaúcha, Dom Pedrito, and Santana do Livramento in the production cycle 2017/2018.

Parameter	Ives Serra Gaúcha*		Ives Dom Pedrito			Ives Santana do Livramento		
SS (ºBrix)	10,73	±0,12	11,93	± 1,43	ns	11,73	±0,25	ns
TA (mEq L^{-1})	66,69	±1,38	54,47	± 1,96	-	74,54	±1,14	+
pH	3,52	±0,02	3,69	± 0,03	+	3,46	±0,03	ns
RS (g L^{-1})	104,33	±9,69	119,13	±1 9,47	ns	116,00	±0,38	ns
TP (mg L^{-1})	1701,92	±80,58	1663,35	±168,07	ns	1952,60	±62,02	ns
ANT (mg $100g^{-1}$)	135,12	±5,02	138,85	±3,52	ns	153,82	±4,36	+
AC (µM ml^{-1})	4951,67	±67,88	4581,67	±572,15	ns	6030,00	±588,03	ns
L	23,08	±3,96	34,93	±5,53	+	28,92	±0,48	ns
Hue	350,34	±1,76	341,83	±1,12	-	352,97	±0,43	ns
Croma	55,04	±3,45	63,63	±1,11	+	61,40	±0,69	+
	Concord Serra Gaúcha*		**Concord Dom Pedrito**			**Concord Santana do Livramento**		
SS (ºBrix)	10,77	±0,25	16,00	±0,10	+	14,53	±0,60	+
TA (mEq L^{-1})	86,80	±1,76	60,69	±0,82	-	87,10	±2,94	ns
pH	3,43	±0,03	3,58	±0,03	+	3,34	±0,01	-
RS (g L^{-1})	112,04	±7,55	171,50	±1,11	+	153,04	±8,70	+
TP (mg L^{-1})	1273,57	±288,70	1824,50	±17,22	+	2270,78	±174,60	+
ANT (mg $100g^{-1}$)	60,05	±15,33	40,06	±2,14	ns	63,72	±2,81	ns
AC (µM ml^{-1})	3750,00	±1475,31	6776,67	±286,37	+	8225,00	±263,58	+
L	41,88	±7,84	46,67	±0,60	ns	36,53	±0,90	ns
Hue	13,12	±4,81	9,01	±0,29	ns	18,02	±0,68	ns
Croma	59,51	±2,27	54,43	±0,40	-	64,53	±0,83	+

SS = Soluble Solids; TA = Titrable Acidity; RS= Reducing Sugars; TP = Total Polyphenols; ANT = Anthocyanins; AC = Antioxidant Capacity; L = Luminosity. * - Control; + - Significantly different and higher than control, by Dunnett's test at 95% significance level; - - Significantly different and lower than control, by Dunnett's test at 95% significance level; ns – Not significantly different, by Dunnett's test at 95% significance level.

Source: Elaborated by the authors.

In comparison with Serra Gaúcha region, at Campanha Gaúcha region there is higher solar radiation and drier climate. Such conditions provide greater accumulation of sugars in the berries and greater production of phenolic compounds. (PÖTTER *et al*., 2010). According to Silveira (2021), the climate conditions at Campanha Gaúcha region are better for grape maturation and for lowering production costs, partially due to the lower requirements of phytosanitary treatments.

In the Experiment 3, except for pH and color tone (Hue), there were significant differences in all the other parameters analyzed in the Concord grape juices obtained from the different extraction methods (Table 5).

Table 5 – Mean and standard deviation observed for the parameters analyzed in 'Concord' grape juices produced in Dom Pedrito in the 2020 harvest under different extraction method (mean values ± standard deviation).

Parameter	Steam juicer			Heat exchanger + enzymes		
SS (ºBrix)	17,55	± 0,13	*	18,90	± 0,34	*
TA (mEq L^{-1})	58,22	± 2,32	*	88,19	± 0,58	*
pH	3,63	± 0,04	ns	3,55	± 0,07	ns
TP (mg L^{-1})	1241,94	± 39,64	*	2536,39	± 104,47	*
ANT (mg $100g^{-1}$)	1,86	± 0,57	*	5,47	± 0,58	*
AC (µM ml^{-1})	2410,00	± 721,16	*	6402,50	± 272,69	*
L	70,25	± 2,89	*	47,04	± 0,30	*
Hue	14,15	± 2,24	ns	10,89	± 0,45	ns
Croma	31,55	± 3,43	*	59,95	± 0,66	*

*: Significantly different, by a T test at 95% significance level;
ns: Not significantly different, a by T test at 95% significance level.

Source: Elaborated by the authors.

Juices produced in the steam juicer had lower values for SS, TA, TP, ANT and CA, had lighter color (larger L) and lower color intensity (lower chroma) (Table 5). The main problem related to this method is the reduction of SS and TA, which often make juices unsuitable for commercialization as 100% whole grape juice, a product with higher added value. Strictly by definition, any addition of exogenous water to a grape juice would declassify it as whole grape juice. In the present study, juices from both extraction methods have SS and TA contents that comply with the referred Brazilian legislation. However, the TA values in juices produced with the steam juicer had mean values of 58.22 mEq L^{-1}, while those produced by the other method (heat exchanger + enzimes) had 88.19 mEq L^{-1}. Considering that the minimum TA threshold for whole grape juice is 55 mEq L^{-1}, the juice produced with the steam juicer presents a value close to the minimum. There is a trend towards greater total acidity in enzyme-extracted grape juices. (DAL MAGRO *et al*., 2016; LIMA *et al*., 2015). Corroborating with this result, Bender *et al*. (2018) found TA values of 94.30 and 116.90 mEq L^{-1} in Niágara Branca grape juices obtained by steam extraction and another method that does not incorporate exogenous water into the juice.

The lower values of soluble solids found in juices obtained with the steam juicer are due to the dilution effect caused by the condensation of steam used in the process, what was already observed by Marcon *et al.* (2016). Although the average SS content in the juices from this method are in accordance with the legislation, it is important to emphasize that the SS content of the grapes was 19.0 ºBrix, while the SS of the juices were 17.55 ºBrix (steam extraction) and 18.9 ºBrix (heat exchanger + enzymes). Therefore, the steam juicer caused a significant SS drop of 7.63%. Marcon *et al*., (2016) stated that the percentage of water incorporation in juices made using steam juicers can vary from 7.56% to 20.7%. Other studies report the same negative effect of the steam juicer in juices from several grape cultivars, such as: Ives (BRESOLIN *et al*., 2013; CANOSSA *et al*., 2017; COSTA *et al*., 2019); Isabel Precoce (CANOSSA *et al.*, 2017); Concord (CANOSSA *et al*., 2017; COSTA *et al*., 2019); Niágara Branca (BENDER *et al*., 2018).

On the other hand, in the case of grape juices made with the addition of pectolytic enzymes and using heat exchangers or systems that simulate them (as in this Experiment 3), there is no incorporation of exogenous water. (MARCON *et al*., 2016). In a study with Niágara Branca grapes presenting 14.6 ºBrix, the following SS values for juices were obtained: 14.4 ºBrix, when employing pectolytic enzymes and a system that simulates industrial heat exchangers; and 12.4 ºBrix juices, when employing a steam juicer. (BENDER *et al.*, 2018). The results observed in Experiment 3 lead us to believe that if the juices elaborated in Experiment 1 had been produced by the enzymatic extraction method, they would have fitted all the requirements of the Brazilian legislation (Table 3), since all the must/grape samples (before steam extraction) presented mean values of SS greater than 14.0 ºBrix (Table 1).

The addition of pectolytic enzymes during grape maceration can be considered a complex process. It causes changes in the chemical composition of grape juices, mainly with respect to phenolic compounds. (DAL MAGRO *et al.*, 2016; LIMA *et al*., 2015). In the present study, the TP values were 1241.94 and 2536.39 mg of L^{-1} of catechin equivalents in juices from the steam juicer and the heat exchanger + enzymes, respectively (Table 5). These results are in accordance with those found by Bender *et al.* (2021). These authors noticed differences in the phenolic composition of the grape juices and attributed them to the juice processing techniques, such as type of extraction and the addition or not of enzymes. The mean values of ANT and CA follow the same trend: juices elaborated with the addition of enzymes showed higher levels of anthocyanins and antioxidant capacity. These results were already expected due to the higher phenolic content in these samples. (SILVA *et al*., 2019a).

The juices produced using heat exchanger + enzymes showed lower L and greater chroma values. These results are clearly correlated with the other variables involving phenolic compounds, as they – mainly anthocyanins, tannins and phenolic acids – are responsible for the color, as well as astringency and structure of grape juices. (SANTANA *et al*., 2008).

3. CONCLUSIONS

The factors that most influenced on the quality of grape juices within the region were the grape variety, the crop season and, finally, the production site inside Campanha Gaúcha region.

Grape juices from Campanha Gaúcha region are similar to or have even higher quality than those from Serra Gaúcha, according to the quality parameters analyzed in this research.

Grape juice extraction method influences largely on the qualitative parameters of this beverage. Juices made using heat exchangers + enzymes have higher levels of soluble solids and a higher concentration of bioactive compounds. If solely this method had been employed, all the juices produced in this study would have complied with the current Brazilian legislation for whole grape juice.

It was possible to conclude that Campanha Gaúcha presents conditions for producing grape juices for the Brazilian market, complying with all the necessary quality parameters evaluated in this study.

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