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The juice incorporation from grape pomace pressing positively influence the yield and chemical composition without affecting its sensory profile

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ABSTRACT

The quality of juice obtained by pressing grape pomace and the viability of its incorporation into whole grape juice was investigated for the first time on an industrial scale. Two pressing systems were tested: hydraulic and pneumatic and the evaluated treatments were as follows: whole grape juice (CJ - control), juice 100% from hydraulic press (HP), juice 100% from pneumatic press (PP), juice with a blend of 87% CJ + 13% HP (CJHP), and 87% CJ + 13% PP (CJPP). Analyses were conducted to determine the physicochemical profiles of the juices, levels of primary and secondary metabolites, antioxidant capacity, sensory profile, and consumer acceptability. Pressing increased the yield in the hydraulic and pneumatic systems by 20.5% and 27.3%, respectively, the concentration of phenolic compounds, especially flavanols, flavonols, and stilbenes, and the antioxidant capacity. However, HP and PP juices obtained the lowest overall sensory acceptability scores compared with the control, whereas CJPP and CJHP did not differ from CJ. The pneumatic press stood out for providing better results in juice quality and yield. In this study, the incorporation of juice from pressing grape pomace collected during the maceration stage positively influenced the product's chemical composition without altering its sensory profile or negatively affecting its acceptance by consumers.

1. Introduction

Currently, grape juice is a product of expressive commercial value, ranking third in the world's most exported fruit juices. Its demand has been growing, mainly due to the stimulus at a global level to the consumption of non-alcoholic grape products and because of its high sensory acceptability and biological functionality (El Kersh et al., 2023; Spinelli et al., 2024; Toscano et al., 2017). Various factors influence the phenolic composition of grape derivatives, including processing techniques and grape cultivars (Czaplicka et al., 2022; Zubaidi et al., 2023). The major groups of polyphenols in grape juice are anthocyanins, flavanols, flavonols, phenolic acids, and stilbenes, which are strongly associated with the sensory quality and nutraceutical characteristics of beverages derived from grapes, owing to their antioxidant properties and other health benefits (Biasoto et al., 2010; Dutra et al., 2023; El Kersh et al., 2023; Guler, 2023).

Among the industrially employed processes for the production of whole grape juice, the hot-press method stands out (Silva et al., 2019). This method involves destemming and grape crushing, followed by heating, the addition of pectinase enzyme, and maceration for the extraction of grapes with great clarity to obtain a satisfactory process yield. Juice extraction is usually performed by draining the must after maceration, followed by filtration, pasteurization, and hot filling. To improve the process yield, grape pomace pressing and incorporation into the juice can also be performed before filtration (El Kersh et al., 2023; Lima et al., 2015; Silva et al., 2019).

The yield of grapes processed into whole juice can reach up to 73.8%, depending on the cultivar, pectinase enzyme, and efficiency of the processing method employed (Lima et al., 2015; Morris, 1988). In this sense, the grape pomace pressing and reincorporation, besides increasing the process yield, can have a direct impact on the quality of the final product, increasing, for example, the concentration of anthocyanins, mainly present in the grape skins, which are the pigments responsible for the purple coloration of the juice (El Kersh et al., 2023;

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Zemanek et al., 2019). In addition to anthocyanins, the incorporation of juice obtained from grape pomace pressing can increase the concentrations of other metabolites, such as (+)-catechin, quercetin-3-glucuronide, and gallic acid (Darias-Martín et al., 2000; Zemanek et al., 2019). For this stage of grape pomace pressing, different operating mechanisms can be used, such as a hydraulic press, which uses hydraulic oil to generate pressure and squeeze the juice from the grapes and a pneumatic press, which uses compressed air to generate pressure, which is faster and more suitable for processing delicate grapes (Zemanek et al., 2019).

The addition of grape pomace to whole juice can optimize the industrial process, particularly with respect to yield. As the pulp consists of 85–92% grapes (Machado et al., 2023), considerable juice loss occurs along with maceration waste. Eventually, pressing the grape pomace and reincorporating it into the whole juice may reduce the acceptability of the beverage by the consumer as it may increase the sensations of astringency and bitterness owing to greater contact with grape seeds and skin (Cosme, Pinto e Vilela, 2018).

Although some studies have reported the impacts of reincorporating pressed juices, especially on the yield and sensory parameters, the present study confirms these findings, for the first time applied to industrial-scale production. Besides, it sheds an understanding of the influence of reincorporating the juice obtained by pressing in hydraulic and pneumatic systems on aspects of quality, antioxidant, and sensory properties of whole grape juice, based on the profile of the phenolic compounds, sugars, and organic acids. Thus, this research aimed to evaluate, the chemical composition, sensory profile, acceptability, and yield of juices obtained by pressing grape pomace in hydraulic and pneumatic presses, as well as to study the impact of reincorporating these juices into the whole juice produced on an industrial scale.

2. Material and methods

2.1. Grape juices

Whole grape juice was prepared by the Brazilian Tropical Fruits Company (EBFT/ASA) in duplicate using the Hot Press method (Silva et al., 2019) and a system manufactured by the company JAPA (Garibaldi, Rio Grande do Sul, Brazil), containing tanks with a capacity of 3000 kg. For the elaboration of the juice, a blend between grapes of the Isabella (80%) and BRS Cora (20%) varieties was used, both cultivated by the company in the Sub-middle San Francisco Valley region (latitude 09° 27′ S and longitude 40° 38′ W, 350 m, Petrolina, Pernambuco State, Brazil, with tropical semi-arid climate). The Isabella cultivar was harvested with soluble solid content of 19°Brix, acidity of 0.81% in tartaric acid, and ratio of 23.4. The BRS Cora cultivar was harvested with soluble solid content of 18°Brix, acidity of 0.87%, and ratio of 20.6.

During the juice elaboration process, 400 kg of residue was removed after from the maceration stage (composed of grape skins, seeds, and residual must) was collected and taken to the oenology laboratory of the Brazilian Agricultural Research Corporation (latitude 9° 9′S, longitude 40° 22′W, and altitude 365.5 m Petrolina, Pernambuco State, Brazil). The residue was pressed using hydraulic and pneumatic presses, both in duplicate (100 kg/batch). The hydraulic press used was made of AISI 304 stainless steel, with a manual pressing system ($5.1 \leq X$ kgf/cm^2) and a capacity of 200 L (Riceffer Metalúrgica Recifer, Gabribaldi, RS, Brazil). The pneumatic press used was the MRPPR model (Metalúrgica Recifer, Gabribaldi, RS, Brazil) at a working pressure of 1.8 Kgf/cm^2 and a capacity of 1045 kg. After pressing, an average volume of 18.9 L of juice was collected from the hydraulic press and 25.20 L from the pneumatic press. These juices were analyzed separately and blended with whole juice prepared by the partnering company. The proportion of the blend, 13% by weight, was chosen based on preliminary tests conducted together with the grape juice industry partner.

The juices were subjected to pasteurization (85 °C for 60 s) and packaged in 500 mL clear glass bottles (Saint-Gobain®, São Paulo, Brazil). After bottling, the juices were cooled to 45 °C and stored at room temperature (22 ± 2 °C) until the time of analysis. The treatments consisted of juice without pressing residue addition (control - CJ), juice obtained by a 100% hydraulic press (HP), juice obtained by a 100% pneumatic press (PP), blend of 87% control juice + 13% hydraulic press juice (CJHP), and blend of 87% control juice + 13% pneumatic press juice (CJPP).

2.2. External standards and chemicals

The chemicals Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), 2,2-azino-bis (3-ethylbenzothiazoline-6 sulfonic acid) (ABTS$^{\bullet+}$), 2,2-diphenyl-1-picrylhydrazyl (DPPH$^{\bullet}$), ferric chloride hexahydrate, and TPTZ (2,4,6-Tri(2-pyridyl)-s-triazine) were obtained from Sigma-Aldrich (St. Louis, MO, USA). Ultrapure water was obtained using a Marte Scientific System (São Paulo, Brazil). Ethanol, Folin-Ciocalteu reagent, potassium persulfate, and sodium carbonate were purchased from Merck (Darmstadt, Germany). Tartaric, malic, citric, succinic, lactic, acetic, propionic, butyric, and formic acids and glucose, maltose, sucrose, rhamnose, and fructose were purchased from Química Vetec (Rio de Janeiro, Brazil). Methanol HPLC grade was obtained from J. T. Baker (Phillipsburg, NJ, USA). External standards (HPLC) of Procyanidin A2, (−)-epicatechin gallate, (−)-epigallocatechin gallate, quercetin-3-rutinoside (rutin), quercetin-3-β-D-glucoside, kaempferol-3-*O*-glucoside, myricetin, cyanidin-3-*O*-glucoside, malvidin-3-*O*-glucoside, peonidin-3-*O*-glucoside, delphinidin-3-*O*-glucoside, petunidin-3-*O*-glucoside, and pelargonidin-3-*O*-glucoside were from Extrasynthese (Genay, France). Caffeic, gallic, ρ-coumaric, chlorogenic, *trans*-caftaric, and syringic acids and hesperidin, procyanidins B1 e B2, (+)-catechin, (−)-epicatechin, naringenin, isorhamnetin-3-*O*-glucoside, cyanidin-3.5-*O*-diglucoside, and malvidin-3.5-*O*-diglucoside were from Sigma-Aldrich. The isomers, *trans*-resveratrol e *cis*-resveratrol, were obtained from Cayman Chemical Company (Michigan, USA).

2.3. Quality parameters and yield

The yield of control juice (CJ) was calculated as the mass of juice (kg) obtained from 100 kg of fresh grapes. For HP and PP juices, the yield was calculated as the mass of juice in kilograms obtained from 100 kg of grape pomace, added to the yield of CJ juice. For CJHP and CJPP juices, the yield was obtained by adding 13%, corresponding to the addition of pressed juice, to the yield obtained in CJ juice. The soluble solids (SS) in °Brix, titratable acidity (TA), ratio (SS/TA), pH, volatile acidity, alcohol content, color intensity, and hue were evaluated according to the protocols of the International Organization of Vine and Wine (OIV, 2022). SS was assessed using a digital refractometer HI 96801 (Hanna, United States), titratable acidity (TA) was measured by titration up to pH 8.2, pH was measured using a digital pHmeter PHS-3B (Tecnal, Brazil), volatile acidity was determined by steam distillation using a SuperDee enological distiller (Gibertini, Italy), followed by titration with 0.1 M NaOH, and alcohol content was determined after simple distillation of the sample and reading at 20 °C on an automatic hydrostatic balance model Super Alcomat (Gibertini, Italy). Color intensity was determined by the sum of the absorbances at 420, 520, and 620 nm and hue was determined by the ratio of the absorbances at 420 and 520 nm, measured using a UV–visible spectrophotometer UV 2000A (Instrutherm, Brazil). Additionally, the color was measured using a portable colorimeter (HunterLab, ColorQuest XE model) with the CIELab color system to determine the coordinates L*, a*, and b*.

2.4. Antioxidant capacity

The antioxidant capacity (AOX) of the juices was measured using the *in vitro* spectrophotometric methods DPPH$^{\bullet}$ (Kim et al., 2002), ABTS$^{\bullet+}$ (Re et al., 1999) and FRAP (Rufino et al., 2006). Additionally, the reducing capacity of the Folin-Ciocalteu reagent (Singleton & Rossi,

1965) to determine the total phenolic compound content was also used as a methodology to evaluate the juice AOX, as recommended by Granato et al. (2018). All absorbance readings were performed using a UV–Vis spectrophotometer model UV 2000A (Instrutherm, São Paulo, Brazil).

The reducing capacity of Folin-Ciocalteu was quantified using 50 μL of the sample, 3.95 mL of distilled water, 250 μL of Folin-Ciocalteu reagent, and 750 μL of 20% saturated sodium carbonate solution. The mixture was incubated in the dark for 120 min and the absorbance was determined at 765 nm. The results were expressed in mg of gallic acid equivalent per liter of juice (GAE mg/L) and compared to the calibration curve with gallic acid (25–500 mg/L, $R^2 = 0.998$).

For the FRAP assay, the FRAP reagent was prepared by mixing acetate (300 mmol; pH 3.6), TPTZ (10 mM TPTZ in 40 mM HCl), and $FeCl_3$(20 mM). Further, a mixture was prepared with 90 μL of the sample, 270 μL of distilled water, and 2.7 mL of the FRAP reagent, incubated at 37 °C in a thermo-reactor (AAKER model IT2002, Brazil) for 30 min. The absorbance was measured at 595 nm and the results were expressed as mmol Fe^{2+} per liter of juice (mmol.Fe^{2+}/L). The calibration curve was prepared using ferrous sulfate, in concentrations from 100 to 2000 μmol/L ($R^2 = 0.999$).

The activity of DPPH$^{\bullet}$ radicals was determined by measuring the extinction of the absorption maximum at 517 nm. A mixture of 100 μL of sample in 2.90 mL of ethanol solution containing 1.0 mM DPPH$^{\bullet}$ radical, diluted to an absorbance between 0.900 and 1.000, was prepared and incubated in the dark for 30 min. The results are expressed as Trolox equivalents per liter of juice (mM.TE/L). The calibration curve was prepared with Trolox, in concentrations from 200 to 1200 μmol/L ($R^2 = 0.998$).

AOX by $ABTS^{\bullet+}$ was measured through the scavenging activity of $ABTS^{\bullet+}$ radicals from the samples by the rate of decay in absorbance at 734 nm, determined at t = 0 min and t = 6 min after the addition of samples in the absence of light. The radicals were prepared using a solution of 7 mmol $ABTS^{\bullet+}$ and 140 mmol potassium persulfate and incubated in the dark for 16 h. And the solution was diluted in ethanol to an absorbance of 0.700 ± 0.050. The results are expressed as Trolox equivalents per liter of juice (mM.TE/L). The calibration curve was prepared with Trolox, in concentrations from 200 to 2000 μmol/L ($R^2 = 0.997$).

2.5. Phenolic compounds, sugars, and organic acids

Phenolic compounds, sugars, and organic acids were measured by high-performance liquid chromatography (HPLC), using an Agilent liquid chromatograph, model 1260 Infinity LC System (Agilent Technologies, CA, USA), equipped with a quaternary solvent pump (model G1311C), degasser, column compartment (model G1316A), and autosampler (model G1329B) and coupled with a diode array detector (DAD) (model G1315D) and a refractive index detector (RID) (model G1362A). Data were processed using OpenLAB CDS ChemStation EditionTM software (Agilent Technologies, CA, USA).

To evaluate the phenolic profile using HPLC/DAD, the protocol validated under the same analytical conditions described by Padilha et al. (2017) was used with adaptations from Dutra, Rodrigues, et al. (2018). The chromatographic conditions were as follows: oven temperature at 35 °C and injection volume of 20 μL. The sample was previously filtered through a 0.45 μm membrane (Millex Millipore, Barueri, SP, Brazil). The column used was Zorbax Eclipse Plus RP-C18 (100 × 4.6 mm, 3.5 μm), with a Zorbax C18 precolumn (12.6 × 4.6 mm, 5 μm) (Zorbax, USA). The solvent flow rate was 0.8 mL min^{-1} using two solvents, solvent A and solvent B, where solvent A was an aqueous solution of 0.52% phosphoric acid (pH = 2.0) and solvent B was methanol acidified with 0.52% H_3PO_4. The gradient applied for compound separation was: 0–5 min: 5% B; 5–14 min: 23% B; 14–30 min: 50% B; and 30–33 min: 80% B. Thirty phenolic compounds were identified and quantified by comparison with external standards and the calibration curves showed $R^2 > 0.998$.

The methodology described by Coelho et al. (2018) was used to determine sugars and organic acids. These metabolites were simultaneously detected in HPLC-DAD/RID, using an ion exchange column (300 × 7.7 mm) with 8.0 μm internal particles and a PL Hi-Plex H precolumn (5 × 3 mm) (Agilent Technologies, Santa Clara, CA, USA). The chromatographic conditions were as follows: column oven temperature maintained at 70 °C, injection volume of 10 μL, and solvent flow rate of 0.6 mL min^{-1}. The samples were previously diluted in ultrapure water and filtered through a 0.45 μm nylon membrane (Millex Millipore, Barueri, SP, Brazil). The mobile phase was a 4 mmol/L H_2SO_4 solution. Organic acids were detected with a DAD detector (210 nm) and sugars with RID. Identification and quantification were performed by comparison with external standards, with the calibration curves showing $R^2 > 0.997$.

2.6. Sensory analysis

The sensory evaluation was approved by the Ethics Committee for Research on Human Subjects (CAAE No. 64362022.9.0000.8052). All samples were evaluated by 100 consumers of whole grape juice (regular consumption of at least one glass per week) recruited to participate in the sensory analysis, including food science undergraduate and postgraduate students, laboratory technicians, and teachers. Twenty-six male and seventy-four female volunteers aged between 18 and 59 years were selected. The judges described the sensory profiles of the samples and assessed their acceptability in a single evaluation session, with the samples served in a monadic presentation order. The test was conducted in individual booths with the laboratory temperature maintained at 22 ± 2 °C. Thirty microliters of the samples were served at a temperature of 8 ± 2 °C in standard crystal wine-tasting glasses (ISO 3591:1977), coded with three digits. The presentation order of the samples among the participants followed the completely balanced block design proposed by Macfie et al. (1989) for the evaluation of five samples. The evaluators were instructed to clean their palates with mineral water and unsalted crackers before each sample.

2.7. Descriptive sensory analysis

The Rate-All-That-Apply (RATA) method (Ares et al., 2014) was used to describe the sensory profile of grape juice samples. The selection of descriptor terms for the evaluation form was previously conducted by a focus group (Alencar et al., 2019), comprising nine experts in the sensory evaluation of grape juice. The focus group selected 12 descriptive terms to characterize the sensory profiles of the grape juice samples: violet color, limpidity, aromatic intensity, sweet aroma, cooked aroma, grape juice aroma, sweet taste, acidic taste, grape juice flavor, cooked flavor, refreshment, and astringency. The selected terms were presented in the sensory evaluation form and for each term, the judges ($n = 100$) were instructed to assess whether the term applied or not to describe the sample and identify the perceived intensity using a structured 5-point scale anchored with the terms: “1- very little,” “2- little,” “3- medium,” “4- much,” and “5- very much.”

2.8. Consumer test

The acceptance and purchase intention tests were conducted during the same sensory evaluation session. To assess the appearance, aroma, flavor, and overall acceptability of the grape juices, a 9-point hybrid hedonic scale (1 = extremely disliked, 5 = neither liked nor disliked, and 9 = extremely liked) proposed by Biasoto et al. (2014) was applied. For the purchase intention test (Meilgaard et al., 2006), a 5-point scale was used: 1 = certainly would not buy, 2 = possibly would not buy, 3 = would have doubts if I would buy, 4 = possibly would buy, and 5 = certainly would buy.

2.9. Statistical analysis

The data were subjected to one-way analysis of variance (ANOVA) and Tukey's test at a 5% probability level to compare means. Additionally, multivariate analyses, including Principal Component Analysis (PCA), Partial Least Squares regression (PLS), and Extended Internal Preference Map (EPM) were conducted using XLStat software (Addinsoft, Paris, France, 2015).

3. Results and discussion

3.1. Yield and quality parameters

Regarding the process yield, the CJ juice obtained an average value of 67%. A value close to the values reported by Lima et al. (2015), who studied different maceration processes for the production of whole grape juice in the same industrial unit. After the pressing stage, the average yield increased by 20.5% for HP and 27.3% for PP, potentially reaching an industrial yield of 87.5%–94.3% if the hydraulic and pneumatic presses were added to the processing line, respectively, and all the juice pressed was used. This is an excellent result from an economic perspective, achieving extraction of the entire pulp present in the grape berry, which, according to Machado et al. (2023), represents approximately 92%. Alleria et al. (2016) studied the influence of pressing methods on the quality and yield of pomegranate juice and also reported higher yield values using a pneumatic press. Adding only 13% of the juice obtained from pressing the grape pomace (samples CJHP and CJPP), the yield of the whole juice increased from 67% to 80%.

The physicochemical quality parameters of whole grape juice are directly related to the consumer acceptability of the product. Legislation determines the quality standards for grape juice, which mainly include variables such as soluble solids and total titratable acidity, as well as alcohol and volatile acidity (Brazil, 2018; Codex Alimentarius, 2005). These parameters were related to the concentrations of primary grape metabolites, particularly sugars and organic acids. Table 1 presents the average values of quality parameters, sugars, and organic acid contents in the evaluated juices. The treatments were as follows: control whole grape juice (CJ), 100% hydraulic press juice (HP), 100% pneumatic press juice (PP), a blend of 87% control juice and 13% hydraulic press juice (CJHP), and a blend of 87% control juice and 13% pneumatic press juice (CJPP).

The quality parameters of the evaluated juices (Table 1) complied with Brazilian legislation (Brazil, 2018) and CODEX STAN 247 2005 (Codex Alimentarius, 2005). Soluble solids ranged from 19.60 °Brix in CJ juice to 20.40 °Brix in HP juice. The pH ranged from 3.1 in CJHP juice to 3.4 in HP juice; the ratio ranged from 21.8 (CJHP) to 23.1 (CJPP); volatile acidity yielded results between 2.75 mEq/L (CJHP) and 3.20 mEq/L (PP); and alcohol content ranged from 0.13% in CJ juice to 0.18% in PP, CJHP, and CLPP juices, respectively, indicating good sanitary conditions in the process and microbial stability of the beverages (Sharma et al., 2017). Another important quality attribute is color intensity, for which juices obtained with 100% pulp pressing yielded the best results, which can be explained by the mechanical force exerted on the grape skins, possibly extracting higher concentrations of anthocyanin. For hue, a variable related to the ratio of yellow/red colors (absorbance at 420 nm/520 nm), all juices had low values (<0.48), demonstrating the predominance of red color, which is desirable for this beverage. This result is supported by the values found in the L* (luminosity) coordinates, lower than 14.86, and a* (green-red variation) ranging from 0.47 in CJHP juice to 1.46 in HP juice. According to Campbell et al. (2021), lower L* values indicate more colorful juice.

Table 1
Quality parameters, sugars and organic acids of whole grape juices obtained without and with pressing grape pomace*.

Parameters	Grape juices				
	CJ	HP	PP	CJHP	CJPP
Classical analyses					
pH	3.20 ± 0.01^{c}	3.30 ± 0.02^{b}	3.40 ± 0.01^{a}	3.10 ± 0.01^{d}	3.30 ± 0.03^{b}
Soluble solids (°Brix)	19.60 ± 0.00^{d}	20.40 ± 0.10^{a}	20.00 ± 0.06^{b}	19.70 ± 0.00^{cd}	19.80 ± 0.00^{c}
Titratable acidity % (TA)	0.87 ± 0.00^{ab}	0.90 ± 0.00^{a}	0.90 ± 0.01^{a}	0.90 ± 0.01^{a}	0.85 ± 0.01^{b}
Ratio °Brix/TA	22.30 ± 0.12^{b}	22.50 ± 0.30^{ab}	22.20 ± 0.32^{b}	21.80 ± 0.24^{b}	23.10 ± 0.27^{a}
Volatile acidity (mEq/L)	3.00 ± 0.01^{d}	3.10 ± 0.04^{c}	3.30 ± 0.03^{a}	2.75 ± 0.04^{e}	3.20 ± 0.04^{b}
Alcohol (% v/v)	0.13 ± 0.01^{b}	0.16 ± 0.02^{ab}	0.18 ± 0.01^{a}	0.18 ± 0.01 ^{a}	0.18 ± 0.01^{a}
Color Intensity	8.65 ± 0.06^{c}	11.59 ± 0.32^{a}	12.70 ± 0.90^{a}	10.05 ± 0.03^{bc}	9.25 ± 0.61^{bc}
Tonality	0.46 ± 0.01^{a}	0.46 ± 0.00^{a}	0.44 ± 0.00^{a}	0.46 ± 0.00^{a}	0.47 ± 0.01^{a}
CIELAB Color					
L*	12.80 ± 0.07^{b}	13.80 ± 0.76^{ab}	14.05 ± 0.79^{ab}	14.86 ± 0.85^{a}	12.52 ± 0.17^{b}
a*	0.73 ± 0.11^{b}	1.46 ± 0.15^{a}	0.68 ± 0.14^{b}	0.47 ± 0.11^{b}	0.74 ± 0.03^{b}
b*	0.67 ± 0.01^{c}	5.72 ± 0.03^{b}	6.56 ± 0.16^{a}	6.56 ± 0.28^{a}	6.69 ± 0.01^{a}
Sugars (g/L)					
Sucrose	0.87 ± 0.12^{a}	0.34 ± 0.00^{b}	0.38 ± 0.01^{b}	0.77 ± 0.24^{a}	0.40 ± 0.00^{b}
Glucose	108.70 ± 0.90^{a}	105.30 ± 0.60^{ab}	102.40 ± 3.90^{b}	104.30 ± 0.03^{ab}	104.20 ± 0.37^{ab}
Fructose	114.90 ± 0.90^{a}	111.90 ± 0.70^{b}	106.80 ± 0.99^{c}	110.30 ± 0.02^{b}	110.20 ± 0.38^{b}
Rhamnose	ND	ND	ND	ND	ND
Σ Sugars	224.47 ± 2.88	217.54 ± 1.94	209.58 ± 6.57	215.37 ± 0.39	214.80 ± 1.12
Organic acids (g/L)					
Citric acid	0.42 ± 0.08^{a}	0.29 ± 0.00^{b}	0.27 ± 0.00^{b}	0.29 ± 0.00^{b}	0.29 ± 0.00^{b}
Tartaric acid	5.25 ± 0.20^{a}	3.48 ± 0.12^{c}	3.36 ± 0.04^{c}	4.71 ± 0.10^{b}	4.56 ± 0.04^{b}
Malic acid	2.61 ± 0.02^{c}	3.05 ± 0.01^{a}	2.90 ± 0.03^{b}	2.59 ± 0.01^{c}	2.59 ± 0.02^{c}
Succinic acid	0.30 ± 0.00^{a}	ND	ND	0.30 ± 0.00^{a}	0.31 ± 0.00^{a}
Lactic acid	0.55 ± 0.05^{b}	0.66 ± 0.01^{a}	0.67 ± 0.01^{a}	0.48 ± 0.00^{c}	0.49 ± 0.00^{c}
Formic acid	0.04 ± 0.00^{b}	0.07 ± 0.01^{a}	0.08 ± 0.00^{a}	0.05 ± 0.01^{b}	0.05 ± 0.00^{b}
Acetic Acid	ND	ND	ND	ND	ND
Propionic acid	ND	ND	ND	ND	ND
Butyric acid	ND	ND	ND	ND	ND
Σ Organic acids	9.17 ± 0.15	7.54 ± 0.22	7.27 ± 0.01	8.42 ± 0.13	8.29 ± 0.05

*The results are expressed as mean ± standard deviation (n = 3 evaluations of each batch). Means followed by equal letters, in lines, do not differ among themselves by the Tukey test at 5% error probability. ND: Not detected or below the limit of quantification. CJ: Control juice (without pressing the grape pomace); HP: 100% hydraulic press juice; PP: 100% pneumatic press juice; CJHP: Blend of 87% control juice + 13% hydraulic press juice, and CJPP: Blend of 87 % control juice + 13% pneumatic press juice.

3.2. Sugars and organic acids profiles

The predominant sugars in the juices were glucose and fructose, with average concentrations above 100 g/L for all treatments, followed by sucrose at low concentrations (less than 1 g/L). Tartaric acid was found to be the predominant organic acid, followed by malic acid (Table 1). The type and quantity of sugars and organic acids present in grapes are important indicators of juice flavor and the amount of these metabolites is mainly related to grape ripeness at harvest (Czaplicka et al., 2022; Wang et al., 2024).

The juice obtained by pressing grape pomace influenced the profile of organic acids, decreasing the amount of tartaric acid. The juices CJ (5.25 g/L), CJHP (4.71 g/L), and CJPP (4.56 g/L) showed higher values of tartaric acid than the juices HP (3.48 g/L) and PP (3.36 g/L). Conversely, malic acid content was higher in HP (3.05 g/L) and PP (2.90 g/L) juices.

Partial Least Squares (PLS) regression analysis was applied to correlate the physicochemical parameters and the concentration of sugars and organic acids with the overall acceptability of the whole grape juice, which showed that a higher concentration of tartaric acid was positively related to the acceptance of the product, while malic acid showed a negative correlation (Supplementary Fig. 1). According to Gancel et al. (2022), malic acid is described as a "green" and "aggressive" acid, with high acidifying power, and its perception threshold is higher than that of tartaric acid, which may justify the lower acceptance of juices with higher malic acid concentration. In the production of red wines, aiming to achieve better sensory acceptance of the beverage, malolactic fermentation is generally carried out to convert the malic acid into lactic acid (Tian et al., 2024).

Table 2
Bioactive compounds and antioxidant capacity of whole grape juices obtained without and with pressing grape pomace*.

Phenolic compounds (mg L^{-1})	Grape juices[5]				
	CJ	HP	PP	CJHP	CJPP
Flavanols					
(+) -Catechin	1.63 ± 0.15^{ab}	2.11 ± 0.15^{a}	2.10 ± 0,17^{a}	1.41 ± 0.19^{b}	1.69 ± 0.06^{ab}
Procyanidin B1	9.18 ± 1.05^{b}	23.57 ± 3.56^{a}	22.57 ± 2.91^{ab}	13.35 ± 1.10^{ab}	16.44 ± 0.90^{ab}
Procyanidin B2	14.49 ± 0.04^{a}	5.91 ± 0.41^{c}	6.84 ± 0.90^{c}	12.49 ± 0.67^{ab}	12.10 ± 0.33^{b}
Procyanidin A2	19.17 ± 0.95^{a}	20.37 ± 2.49^{a}	24.24 ± 4.36^{a}	19.84 ± 1.18^{a}	22.72 ± 0.77^{a}
(−) -Epigallocatechin gallate	0.96 ± 0.04^{c}	4.41 ± 0.83^{a}	3.88 ± 0.47^{a}	1.77 ± 0.22^{b}	1.96 ± 0.33^{b}
(−) -Epicatechin gallate	9.40 ± 1.33^{b}	11.85 ± 1.02^{a}	11.47 ± 0.67^{a}	10.01 ± 0.42^{b}	10.80 ± 0.02^{ab}
(−) -Epicatechin	ND	ND	ND	ND	ND
Σ Flavanols	54.83 ± 4.29	68.22 ± 10.41	71.10 ± 8.75	58.87 ± 1.97	65.71 ± 0.69
Flavonols					
Quercetin-3-*β*-*D*-glucoside	1.15 ± 0.03^{b}	2.13 ± 0.04^{ab}	2.71 ± 0.02^{a}	1.77 ± 0.29^{ab}	2.23 ± 0.20^{a}
Rutin	12.06 ± 0.04^{b}	27.99 ± 7.51^{ab}	35.71 ± 2,46^{a}	23.82 ± 4.89^{ab}	32.56 ± 3.73^{a}
Kaempferol-3-*O*-glucoside	1.68 ± 0.02^{c}	4.41 ± 0.20^{ab}	5.13 ± 0.02^{a}	3.39 ± 0.61^{bc}	4.39 ± 0.52^{ab}
Isorhamnetin-3-*O*-glucoside	1.27 ± 0.01^{c}	2.61 ± 0.41^{ab}	3.13 ± 0.03^{a}	2.07 ± 0.34^{bc}	2.65 ± 0.20^{ab}
Myricetin	34.24 ± 0.03^{b}	71.25 ± 16.33^{a}	94.98 ± 3.82^{a}	59.31 ± 10.28^{b}	78.10 ± 7.40^{a}
Σ Flavonols	50.40 ± 0.01	108.39 ± 27.84	141.66 ± 7.79	90.36 ± 19.29	119.93 ± 14.30
Anthocyanins					
Cyanidin-3.5-*O*-diglucoside	15.70 ± 0.08^{ab}	15.76 ± 1.48^{ab}	18.34 ± 1.7^{a}	14.50 ± 0.57^{b}	16.62 ± 0.01^{ab}
Delphinidin-3-*O*-glucoside	12.96 ± 0.04^{a}	11.70 ± 1.20^{a}	12.28 ± 1.53^{a}	10.51 ± 0.55^{a}	12.00 ± 0.19^{a}
Cyanidin-3-*O*-glucoside	10.57 ± 0.06^{a}	9.97 ± 0.79^{ab}	9.58 ± 0.57^{ab}	8.56 ± 0.35^{b}	9.39 ± 0.17^{ab}
Peonidin-3-*O*-glucoside	10.81 ± 0.01^{a}	11.17 ± 0.91^{a}	10.90 ± 0.42^{a}	9.30 ± 0.41^{b}	10.23 ± 0.14^{ab}
Malvidin-3.5-*O*-diglucoside	13.84 ± 0.03^{b}	19.66 ± 1.62^{a}	19.54 ± 0.79^{a}	13.93 ± 0.69^{b}	14.98 ± 0.40^{b}
Malvidin-3-*O*-glucoside	44.14 ± 0.03^{ab}	48.55 ± 4.27^{a}	47.28 ± 2.86^{ab}	39.33 ± 1.83^{b}	43.68 ± 0.61^{ab}
Petunidin-3-*O*-glucoside	ND	ND	ND	ND	ND
Pelargonidin 3-*O*-glucoside	10.21 ± 0.01^{ab}	10.83 ± 0.90^{a}	10.51 ± 0.77^{a}	8.53 ± 0.37^{b}	9.51 ± 0.09^{ab}
Σ anthocyanins	118.23 ± 0.21	127.64 ± 10.79	128.43 ± 10.68	104.66 ± 3.53	116.41 ± 0.28
Stilbenes					
trans-resveratrol	2.49 ± 0.02^{b}	5.35 ± 0.50^{ab}	7.03 ± 0.11^{a}	4.74 ± 0.93^{ab}	6.46 ± 0.72^{a}
cis-resveratrol	ND	0.91 ± 0.25^{a}	1.21 ± 0.01^{a}	0.94 ± 0.03^{a}	0.94 ± 0.13^{a}
Σ stilbenes	2.49 ± 0.03	6.26 ± 2.16	8.24 ± 0.15	5.68 ± 0.19	7.40 ± 1.05
Flavanones					
Hesperidin	2.29 ± 0.64^{b}	2.47 ± 0.05^{b}	5.19 ± 0.80^{a}	2.07 ± 0.02^{b}	2.68 ± 0.17^{b}
Naringenin	ND	ND	ND	ND	ND
Σ Flavanones	2.29 ± 0.64	2.47 ± 0.05	5.19 ± 0.80	2.07 ± 0.02	2.68 ± 0.17
Phenolic acids					
Gallic acid	6.15 ± 0.12^{b}	17.07 ± 1.73^{a}	15.49 ± 2.75^{a}	6.44 ± 0.34^{b}	6.93 ± 0.98^{b}
Syringic acid	ND	ND	ND	ND	ND
trans-caftaric acid	344.47 ± 11.81^{ab}	424.32 ± 3.03^{a}	313.05 ± 1.22^{b}	296.61 ± 51.80^{b}	354.40 ± 59.75^{ab}
Chlorogenic acid	0.76 ± 0.01^{a}	0.78 ± 0.12^{a}	0.73 ± 0.15^{a}	0.60 ± 0.09^{a}	0.76 ± 0.01^{a}
ρ-coumaric acid	ND	ND	ND	ND	ND
Caffeic acid	0.46 ± 0.01^{c}	1.20 ± 0.02^{a}	0.78 ± 0.04^{b}	0.67 ± 0.06^{c}	0.78 ± 0.14^{b}
Σ phenolic acids	351.84 ± 14.60	443.37 ± 1.47	330.05 ± 4.74	304.32 ± 63.22	362.87 ± 72.54
Total Phenolics quantified	580.08 ± 19.14	756.35 ± 49.73	684.67 ± 6.75	565.96 ± 89.19	675.00 ± 88.86
Antioxidant activity					
DPPH (mM TE L^{-1})	6.12 ± 0.11^{b}	9.98 ± 0.74^{a}	10.86 ± 1.03^{a}	7.90 ± 0.28^{b}	7.64 ± 0.50^{b}
ABTS (mM TE L^{-1})	12.34 ± 0.60^{c}	17.88 ± 1.30^{ab}	21.28 ± 1.74^{a}	13.98 ± 0.60^{bc}	13.90 ± 0.73^{bc}
FRAP (mM Fe^{2+} L^{-1})	20.87 ± 0.28^{b}	30.87 ± 2.72^{b}	41.60 ± 5.44^{a}	23.28 ± 0.79^{b}	23.62 ± 0.02^{b}
Folin Ciocalteu (mg L^{-1} GAE)	1953.33 ± 27.87^{b}	2980.01 ± 30.34^{a}	2552.61 ± 311.03^{ab}	2023.01 ± 45.51^{b}	2069.47 ± 212.41^{b}

*The results are expressed as mean ± standard deviation (n = 3 evaluations of each batch). Means followed by equal letters, in lines, do not differ among themselves by the Tukey test at 5% of error probability. ND = not detected or below the limit of quantification. TE = equivalent to Trolox. GAE = equivalent to gallic acid. CJ: Control juice (without pressing the grape pomace); HP: 100% hydraulic press juice; PP: 100% pneumatic press juice; CJHP: Blend of 87% control juice + 13% hydraulic press juice, and CJPP: Blend of 87 % control juice + 13% pneumatic press juice.

3.3. Phenolic profile and antioxidant capacity

The phenolic profiles of the juice samples are shown in Table 2. In general, polyphenols are chemical structures that influence the sensory characteristics of color, astringency, and bitterness in grape-derived products and are distributed in two major classes: flavonoids and non-flavonoids (El Kersh et al., 2023; Machado et al., 2023). Six flavanols, five flavonols, seven anthocyanins, and one flavanone were detected in the flavonoid class, whereas four phenolic acids and two stilbenes were identified in the non-flavonoid class. Supplementary Fig. 2 shows a chromatogram of the phenolic compounds quantified in the samples using HPLC/DAD.

In the flavanol class, the juices that showed the highest quantities in descending order were PP > HP > CJPP > CJHP > CJ (Table 2). The predominant flavanol was procyanidin A2, with results ranging from 24.24 mg/L in PP juice to 19.17 mg/L in CJ juice. Other notable flavanols in the samples were procyanidins B1 and B2, and (−)-epicatechin gallate. According to Cosme et al. (2018), proanthocyanidins in grapes are mainly present in the skin and seeds of berries, which explains the higher presence of flavanols in PP and HP juices. (+)-Catechin, (−)-epicatechin, and procyanidins, especially procyanidin B2, were present in the seeds, whereas higher concentrations of prodelphinidins and procyanidins, mainly procyanidin B1, were found in the skin. The sensory characteristics associated with flavanols include astringency, which is mainly related to the presence of less polymerized flavanols. This sensory perception is commonly described as a "dry pucker-like sensation on the mouth" (Gibbins & Carpenter, 2013; Zhao et al., 2023), and in fruit juices, it tends not to be a feature appreciated by consumers (Cosme et al., 2018).

Regarding flavonols, the juices obtained from pressing grape pomace showed the highest levels and myricetin was the predominant compound in all juices, with particular prominence in the juice obtained 100% from pneumatic pressing (PP) and in the blend of the control juice and 100% pneumatically pressed juice (CJPP). This indicates that the pressing method influences the concentration of this phytochemical compound. According to El Kersh et al. (2023), myricetin is one of the major flavonols found in the skin of red grapes. An important sensory quality associated with this class of phenolic compounds is their ability to produce more stable color pigments, which influences the stability of grape juice color (Machado et al., 2023).

The anthocyanins found in high quantities in the juice were malvidin-3-*O*-glucoside, malvidin-3.5-*O*-diglucoside, and cyanidin-3.5-*O*-diglucoside. Overall, the juices differed in anthocyanin concentration, suggesting that the extraction of these compounds was affected by the incorporation of juice obtained from pressing grape pomace as well as by other stages of beverage processing, such as maceration (Lima et al., 2015). Differentiation occurred mainly for cyanidin-3-*O*-glucoside, pelargonidin-3-*O*-glucoside and peonidin-3-*O*-glucoside when comparing the control juice with the CJHP juice. Moreover, the concentration of malvidin-3-*O*-glucoside and malvidin-3.5-*O*-diglucoside in the juices obtained 100% from pressing grape pomace (HP and PP) increased. According to El Kersh et al. (2023), anthocyanins are biosynthesized compounds in grape skin that are extremely important for the sensory quality of grape juices because they are the major pigments responsible for the red color of the beverage, which is highly appreciated by consumers (Cosme et al., 2018). In the stilbene class, *trans*-resveratrol and *cis*-resveratrol were detected in the juices (except in the CJ juice), and only hesperidin was detected in the flavanone group. The tested pressing methods increased the concentration of stilbenes, with particular prominence in the juice obtained from pneumatic pressing (PP), and an increase in hesperidin concentration was observed only in PP juice.

Regarding phenolic acids, gallic, chlorogenic, caffeic, and *trans*-caftaric acids were identified in the juices, and *trans*-caftaric was predominant in all samples, with average values ranging from 424.32 mg/L in PP juice to 296.61 mg/L in CJHP juice. Juice obtained 100% by pressing grape pomace using pneumatic press (PP) showed higher concentrations of *trans*-caftaric, gallic and caffeic acids. While the chlorogenic acid content did not differ between the juice samples. According to Cosme et al. (2018), this class of compounds is mainly found in the pulp and skin of grape berries, which may explain the higher concentrations of some of these compounds in the PP juice owing to greater contact with grape skins.

In addition to influencing the sensory characteristics of grape-derived products, phenolic compounds can modify the functional properties of these products primarily because of their antioxidant activity, which can mitigate the effects of oxidative stress (Hussain et al., 2016). In the present study, antioxidant capacities (AOX) were measured using the DPPH$^{\bullet}$, ABTS$^{\bullet+}$, FRAP, and Folin-Ciocalteu assays. All juices exhibited antioxidant values (Table 2), consistent with other studies that evaluated whole grape juice produced in the same region, which is characterized by a semi-arid tropical climate (Dutra, Rodrigues, et al., 2018; Padilha et al., 2017). DPPH$^{\bullet}$ data ranged from 6.12 mM TE/L in CJ juice to 10.86 mM TE/L in PP juice. For ABTS$^{\bullet+}$, the results ranged from 12.34 mM TE/L in CJ juice to 21.28 mM TE/L in PP juice. For the FRAP method, AOX ranged from 20.87 mM Fe^{2+}/L in CJ juice to 41.60 mM Fe^{2+}/L^{-1} in PP juice. In the evaluation of the reducing capacity of the phenolic compounds using the Folin-Ciocalteu reagent, the results ranged from 1953.33 mg GAE/L in CJ juice to 2980.01 mg GAE/L in HP juice. In summary, all juices showed satisfactory AOX, with an emphasis on juice obtained from 100% pressing of grape pomace in pneumatic presses (PP) (Table 2). Principal Component Analysis (PCA) was performed to correlate the AOX with the phenolic profile of the evaluated grape juices (Supplementary Fig. 3). The phenolic compounds that correlated best with antioxidant activity were cyanidin-3.5-*O*-diglucoside, malvidin-3.5-*O*-diglucoside, procyanidin B1, caffeic acid, and gallic acid. Dutra et al. (2023) reported that procyanidin B1 and gallic acid are grape juice polyphenols with high bioaccessibility using the Infogest protocol.

3.4. Metabolic profiling of the grape juices

Principal Component Analysis (PCA) was the statistical tool used to show the differences in the metabolomic profiles of the grape juices (Fig. 1). Principal components 1 and 2 (PC1 and PC2) represented 85.09% of the variability among the samples, with PC1 representing 56.63% and PC2 representing 28.46%.

PC1 separated the treatments into distinct groups (Fig. 1). The vectors closest to the HP treatment represent the organic acid malic, phenolic acids *trans*-caftaric, caffeic, gallic, and chlorogenic acids, flavanols (−)-epicatechin gallate, (+)-catechin, and procyanidin B1, as well as the anthocyanins malvidin-3.5-*O*-diglucoside and peonidin-3-*O*-glucoside. Conversely, the PP and CJPP juices have more similar metabolomic profiles as they are closer together and they stand out for the presence of metabolites kaempferol-3-*O*-glucoside, isorhamnetin-3-*O*-glucoside, myricetin, quercetin-3-β-D-glucoside, *trans*-resveratrol, *cis*-resveratrol, and procyanidin A2.

Meanwhile, the control juice (CJ) is closer to the vectors representing sugars (glucose, fructose, and sucrose), organic acids (tartaric and citric acids), and the flavanol procyanidin B2. In contrast, CJHP is separated from CJ in PC2 and did not stand out among any of the quantified metabolites. In summary, PCA demonstrated that the incorporation of juice obtained by pressing grape pomace influences the metabolomic profile of grape juice and, consequently, the quality of the product. The choice of the pressing method must be considered, thus combining quality and yield. In support of this statement, Zemanek et al. (2019) emphasized the influence of the pressing system (hydraulic or pneumatic) on the quality of grape products.

3.5. Sensory analysis

The sensory profiles of the juices are presented in Table 3. The intensity of most sensory attributes evaluated did not differ significantly

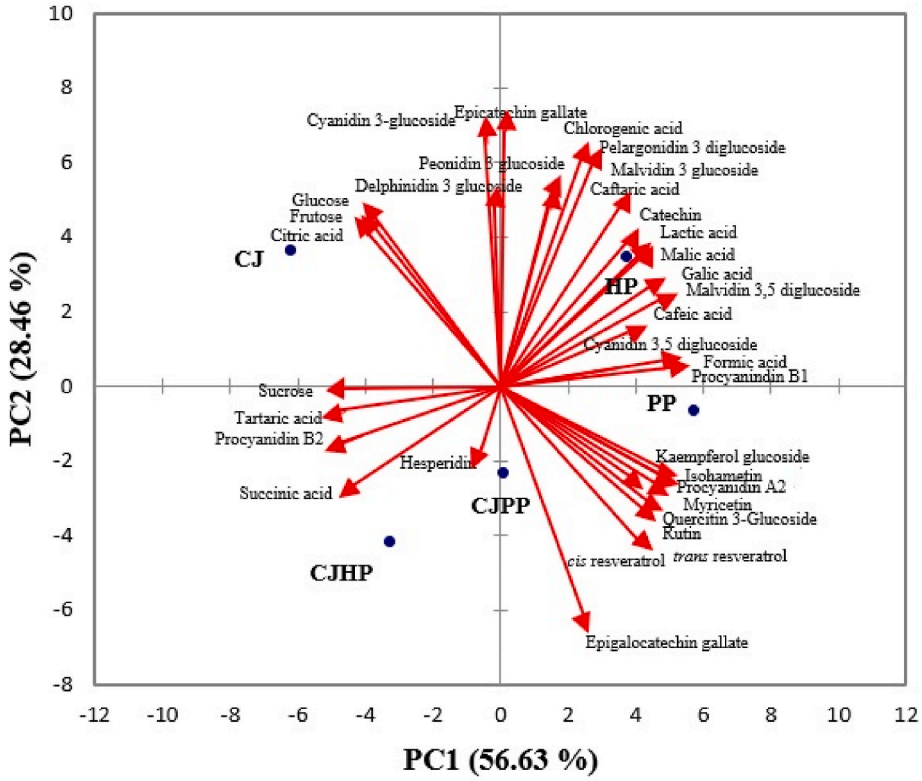

Fig. 1. Principal Component Analysis (PCA) constructed with the primary and secondary metabolites quantified in the whole grape juices obtained without and with grape pomace pressing.

Table 3
Sensory profile of juices obtained with and without pressing the grape pomace, using 100 judges and RATA data*.

Descriptors	Grape juices				
	CJ	HP	PP	CJHP	CJPP
Appearance					
Violet color	4.3^{ab}	4.1^{b}	4.4^{a}	4.1^{b}	4.2^{ab}
Limpidity	2.4^{a}	2.5^{a}	2.5^{a}	2.5^{a}	2.4^{a}
Aroma					
Aromatic intensity	3.2^{a}	2.8^{ab}	2.7^{b}	3.1^{ab}	3.1^{ab}
Sweet aroma	2.9^{a}	2.5^{a}	2.6^{a}	2.7^{a}	2.7^{a}
Cooked aroma	1.2^{a}	1.5^{a}	1.3^{a}	1.3^{a}	1.4^{a}
Grape juice aroma	3.5^{a}	3.1^{ab}	2.9^{b}	3.3^{ab}	3.4^{a}
Flavor					
Sweet taste	3.0^{ab}	2.7^{b}	2.7^{b}	3.2^{a}	3.2^{a}
Acidity taste	2.3^{a}	2.2^{a}	2.2^{a}	1.8^{b}	1.9^{ab}
Grape juice flavor	3.8^{a}	3.2^{c}	3.3^{bc}	3.7^{ab}	3.6^{ab}
Cooked flavor	1.3^{a}	1.5^{a}	1.3^{a}	1.2^{a}	1.2^{a}
Mouthfeel Sensations					
Refreshment	2.5^{ab}	2.2^{b}	2.4^{ab}	2.5^{ab}	2.6^{a}
Astringency	1.4^{a}	1.5^{a}	1.5^{a}	1.2^{a}	1.3^{a}

*Means followed by equal letters, in lines, do not differ among themselves by the Tukey test at 5% of error probability. Scale used to assess the intensity of descriptors by the sensory method. RATA scale used: 1 = very little; 2 = little; 3 = medium; 4 = much; 5 = very much. CJ: Control juice (without pressing the grape pomace); HP: 100% hydraulic press juice; PP: 100% pneumatic press juice; CJHP: Blend of 87% control juice + 13% hydraulic press juice, and CJPP: Blend of 87 % control juice + 13% pneumatic press juice.

among the samples ($p \leq 0.05$). On the other hand, for the attributes as aromatic intensity and grape juice aroma and flavor, the control juice (CJ) showed the highest mean intensities, which only differed significantly ($p \leq 0.05$) from juices obtained 100% from pressing grape pomace, PP (to aromatic intensity, grape juice aroma, and grape juice flavor), and HP (to grape juice flavor). Among the volatile compounds responsible for the aroma of grape juice, methyl anthranilate, 2′-aminoacetophenone, and 4-hydroxy-2,5-dimethyl-3 (2H)-furanone (furaneol) are prominent. Furaneol was associated with the aromatic typicity of grape juices produced in the same region as that in this study by Dutra, de Souza, et al. (2018). In summary, volatiles were extracted during the maceration stage of grape juice production. The incorporation of juice obtained by pressing grape pomace at a proportion of 13% did not significantly reduce the olfactory potential of these compounds, as it did not significantly decrease the intensity of attributes such as aromatic intensity, grape juice aroma, or grape juice flavor.

The preference of consumers regarding the grape juice samples and the influence of sensory descriptors on the overall acceptability average can be observed in the Extended Internal Preference Map (EPM), presented in Fig. 2. CJ, CJHP, and CJPP were preferred by the majority of consumers ($n = 100$) and were associated with a higher intensity of attributes, such as refreshment, grape juice flavor and aroma, sweet taste and aroma, and aromatic intensity. Few consumers preferred PP juice, which was associated with a violet color, and HP juice, which stood out for cooked flavor and aroma. Supplementary Fig. 4 shows that the attributes of sweet taste and grape juice flavor can be considered as the preferred drivers for grape juice acceptability by consumers. These attributes showed a significant positive correlation ($p < 0.05$) with overall acceptability according to the Partial Least Squares regression model (Biasoto et al., 2014).

Table 4 presents the responses for appearance, aroma, flavor, and overall acceptability, along with the percentages of acceptance and rejection in the purchase intention test. The grape juice samples did not differ in terms of appearance acceptance, although HP and PP juices exhibited higher color intensity (Table 1). However, for aroma, flavor, and overall acceptability, HP juice obtained the lowest scores, possibly because of the higher intensities of cooked flavor and aroma in this sample (Fig. 2). Zemanek et al. (2019) emphasized that the pressing process of grapes using a hydraulic press is more rustic and less careful than pressing in a pneumatic press, with the advantage of a lower cost.

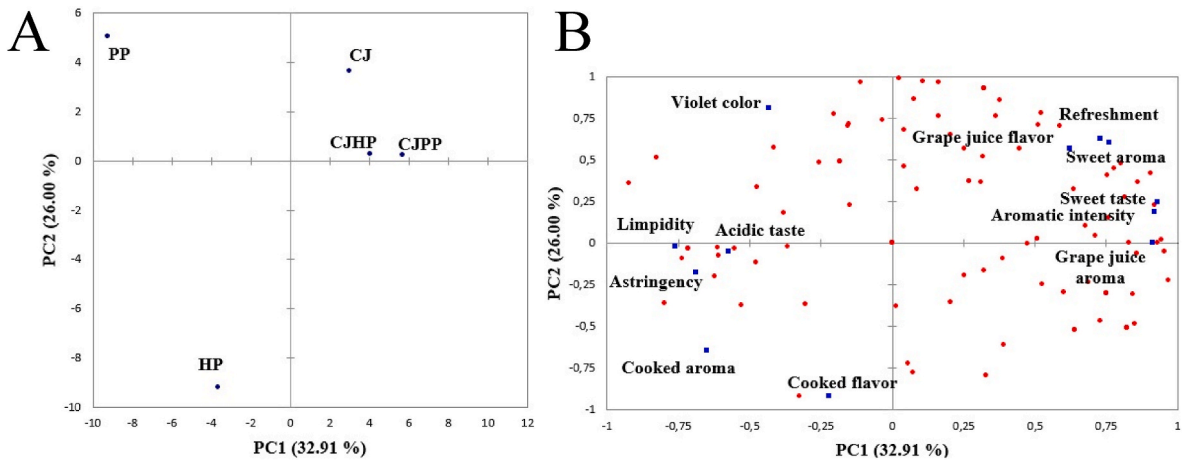

Fig. 2. Extended Internal Preference Map (EPM) for the overall acceptability and sensory descriptive profile data showing the configuration of the grapes juices (A), EPM (B) for the overall acceptability and sensory descriptive profile data showing the configuration of the consumers ($n = 100$) and the sensory descriptors ($n = 12$).

Table 4
Sensory acceptability and buy intention of the juices obtained with and without pressing grape pomace, using 100 consumers*.

	Grape juices				
	CJ	HP	PP	CJHP	CJPP
Acceptance test					
Appearance	7.6^{a}	7.4^{a}	7.5^{a}	7.7^{a}	7.5^{a}
Aroma	6.9^{a}	6.1^{b}	6.6^{ab}	6.7^{ab}	6.7^{ab}
Flavor	7.0^{ab}	6.1^{c}	6.5^{bc}	7.2^{a}	7.1^{ab}
Overall acceptability	7.3^{a}	6.4^{c}	6.7^{bc}	7.0^{ab}	7.2^{ab}
Buy intention test[3]					
Acceptance notes	69%	48%	50%	67%	67%
Rejection notes	16%	32%	30%	17%	13%

*Means followed by equal letters, in lines, do not differ among themselves by the Tukey test at 5% of error probability. Hybrid hedonic scale used: 1 = disliked extremely; 5 = neither liked nor disliked; 9 = liked extremely. Acceptance notes = ∑ certainly would buy + possibly would buy; Rejection notes = ∑ certainly would not buy + possibly would not buy. CJ: Control juice (without pressing the grape pomace); HP: 100% hydraulic press juice; PP: 100% pneumatic press juice; CJHP: Blend of 87% control juice + 13% hydraulic press juice, and CJPP: Blend of 87 % control juice + 13% pneumatic press juice.

The overall acceptability decreased in the following order: CJ > CJPP > CJHP > PP > HP. In the purchasing intention test, more than 60% of consumers indicated that they would buy CJ, CJPP, and CJHP juices if they were available for sale, whereas 48% would buy HP juice. Nevertheless, all juices obtained satisfactory acceptance from consumers who did not perceive differences between the sensory characteristics of the control juice and the juices with 13% pressed grape pomace (CJPP and CJHP). This demonstrates that pressing the residual grape pomace from the maceration stage, followed by the incorporation of the pressed juice, is an excellent option for optimizing the production of whole grape juice. This increases the process yield and maintains the sensory quality expected by grape juice consumers.

The findings presented in this study are important not only for the projection of production on an industrial scale, but also for understanding the factors that affect the product due to reincorporating pressed grape juice on aspects of the product's quality, antioxidant, and sensory properties, based on the profile of the phenolic compounds, sugars, and organic acids. Both hydraulic and pneumatic processes offer promising avenues for processing grape juice. However, shelf-life studies should be performed to evaluate the effect of reincorporating pressed grape juice in the long term.

4. Conclusions

Incorporation juice from pressing grape pomace collected during the maceration stage positively influenced the product's chemical composition without altering its sensory profile or negatively affecting its acceptance by consumers. Adding the pressing stage to the production of whole grape juice increased the process yield, reduced the amount of industrial waste generated, and enhanced the concentration of phytochemicals such as flavanols, flavonols, and stilbenes. Therefore, this study recommends the tested proportion of 13% incorporation for industrial-scale production of whole grape juice. Juices obtained from 100% grape pomace pressing had the lowest consumer acceptance scores (HP < PP), possibly because of lower aromatic intensity, grape juice aroma and flavor notes, sweet aroma and taste, and higher concentrations of malic acid. Nevertheless, these juices still received satisfactory acceptability ratings and contained high concentrations of bioactive compounds, making them suitable for commercialization at a lower cost. This study demonstrated that recovering pressed juice from grape pomace is an excellent alternative for improving grape juice production, reducing losses, minimizing environmental impacts, and producing high-quality products, particularly when using pneumatic presses.

CRediT authorship contribution statement

Maria da Conceição Prudêncio Dutra: Writing – original draft, Validation, Methodology, Investigation, Conceptualization. **Tainara Araújo Amorim:** Formal analysis. **Ana Júlia Araújo de Brito:** Visualization, Formal analysis. **Ederlan de Souza Ferreira:** Writing – review & editing, Writing – original draft, Visualization, Resources, Funding acquisition. **Marcos dos Santos Lima:** Writing – review & editing, Writing – original draft, Supervision, Funding acquisition, Conceptualization. **Aline Camarão Telles Biasoto:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of generative AI and AIassisted technologies in the writing process

Generative AI is not an author. The author(s) take(s) full responsibility for the content of the publication.

Declaration of competing interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.lwt.2025.117372.

Data availability

No data was used for the research described in the article.

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