eISSN 1981-1829

Ciência e Agrotecnologia
Science and Agrotechnology

Alternative yeasts as microbial agents for wines produced from non-*Vitis vinifera* grapes: A sensometric approach. Part I: BRS Núbia

Leveduras alternativas como agentes microbianos para vinhos produzidos a partir de uvas não-*Vitis vinifera*: Uma abordagem sensométrica. Parte 1: BRS Núbia

Danieli Cristina Alves[1*], Vanildo Luiz Del Bianchi[1], Maurício Bonatto Machado de Castilhos[2]

ABSTRACT

Wines are produced from *Vitis vinifera* or American/hybrid grapes as a result of alcoholic fermentation and this bioprocess is modulated by yeasts of the *Saccharomyces* or non-*Saccharomyces* species. This study aimed at characterizing the chemical and sensory acceptance profiles of wines produced from BRS Núbia hybrid grapes with the classic yeast *Saccharomyces cerevisiae* (SC), and alternative yeasts *Saccharomyces bayanus* (SB) and *Saccharomyces uvarum* (SU). The wines produced using the same winemaking protocol were evaluated using the physicochemical parameters of total acidity, volatile acidity, total dry extract, reducing sugars, alcohol content, total phenolic content, color indices and the sensory acceptance method. All the physicochemical parameters evaluated were in accordance with the legislation. The SC wine sample showed greater acceptance of appearance and body due to its high color intensity, reducing sugar and total phenolic content. The SU wine sample was related to the physicochemical parameters of acidity (total and volatile), alcohol content, dry extract and CIELab parameters, showing higher acceptance for aroma, flavor, overall acceptance and purchase intention. The SB wine showed no relationship with any physicochemical property or sensory acceptance attribute. The SU yeast showed potential in producing wines with great acceptance by Brazilian consumers, considered an alternative yeast that can be used for the production of hybrid grape wines.

Index terms: *Saccharomyces bayanus; Saccharomyces uvarum;* hybrid grape; sensory profile; red wine.

RESUMO

Os vinhos são produzidos a partir de uvas *Vitis vinifera* ou americanas/híbridas como resultado da fermentação alcoólica e esse bioprocesso é modulado por leveduras das espécies *Saccharomyces* ou não-*Saccharomyces*. Este estudo teve como objetivo caracterizar os perfis químicos e de aceitação sensorial dos vinhos produzidos a partir de uvas híbridas BRS Núbia com a levedura clássica *Saccharomyces cerevisiae* (SC) e as leveduras alternativas *Saccharomyces bayanus* (SB) e *Saccharomyces uvarum* (SU). Os vinhos produzidos usando o mesmo protocolo de vinificação foram avaliados usando os parâmetros físico-químicos de acidez total, acidez volátil, extrato seco total, açúcares redutores, teor alcoólico, teor de fenólicos totais, índices de cor e o método de aceitação sensorial. Todos os parâmetros físico-químicos avaliados estavam de acordo com a legislação. A amostra de vinho SC apresentou maior aceitação de aparência e corpo devido à sua alta intensidade de cor, açúcar redutor e conteúdo fenólico total. A amostra de vinho SU foi relacionada aos parâmetros físico-químicos de acidez (total e volátil), teor alcoólico, extrato seco e parâmetros do CIELab, mostrando maior aceitação para aroma, sabor, aceitação geral e intenção de compra. O vinho SB não apresentou relação com nenhuma propriedade físico-química ou atributo de aceitação sensorial. A levedura SU mostrou potencial na produção de vinhos com grande aceitação pelos consumidores brasileiros, sendo considerada uma levedura alternativa que pode ser usada para a produção de vinhos de uvas híbridas.

Palavras-chave: *Saccharomyces bayanus; Saccharomyces uvarum*; uva híbrida; perfil sensorial; vinho tinto.

Food Science and Technology

Ciênc. Agrotec., 48:e010824, 2024
http://dx.doi.org/10.1590/1413-7054202448010824

Editor: Renato Paiva

[1]Universidade Estadual Paulista/ Unesp, Departamento de Engenharia e Tecnologia de Alimentos, São José do Rio Preto, SP, Brasil
[2]Universidade do Estado de Minas Gerais/UEMG, Departamento de Ciências Agrárias e Biológicas, Frutal, MG, Brasil

Corresponding author: danielicris2023@gmail.com

Received in May 16, 2024 and approved in August 13, 2024

Introduction

Wine is an alcoholic beverage obtained from the alcoholic fermentation of healthy, fresh and ripe grapes, and the grape juice resulted from this processing is fermented with indigenous or selected yeasts. During fermentation, several substances are formed to provide wine uniqueness and singularity, such as: ethyl alcohol, glycerol, acetic acid, carbon dioxide, among others (Venturini Filho, 2010; Brasil, 2023). Different grape cultivars play a relevant role in influencing the chemical and, consequently, the sensory profile of the wine. Moreno-Olivares et al. (2020) reported that wines produced from a crossing between Monastrell and Cabernet Sauvignon grape cultivars showed a predominance of esters, providing a fruity aroma; however, the varietal wines of each grape cultivar presented a higher concentration of alcohols, acids, and terpenes.

The inoculation of yeasts in winemaking is the key for obtaining quality wines. Among them, the yeast *Saccharomyces* *bayanus* has been studied in the production of wines and fermented beverages, which when used improves the taste of the beverages, can increase the production capacity of glycerol, malic acid, acetate and ethyl ester (Jackson, 2020; Gamero et al., 2011; Liu et al., 2022). Another yeast that has been studied is *Saccharomyces uvarum*, used in wine fermentation due to its aromatic features. This yeast is suitable for wines that are produced from fermentations at low temperatures, improving the yield of by-products, producing relevant volatile compounds such as 2-phenylethyl acetate, which is responsible for a pleasant floral aroma (Minebois, Pérez-Torrado, & Querol, 2020; Tapia et al., 2022).

Álvarez-Barragán et al. (2023) studied the influence of spontaneous, "pied de cuve" and commercial dry active yeasts fermentation on Pinot Noir and Chardonnay wine molecular composition and sensory profile. They reported that the wines produced with "pied de cuve" presented were described as vinegar, glue/solvent aroma with higher odor intensities due to the presence of acetic acid and ethyl acetate. However, the wines produced from spontaneous fermentation and using the dry active yeasts provided fruity aromas due to the presence of ethyl butyrate and isoamyl acetate. Varela et al. (2017) studied the sensory and volatile profile of Merlot wines produced from SU and they have reported that these wines presented a higher concentration of higher alcohols, and they were sensory described as barnyard and meat. These findings showed the importance of the grape cultivar and the yeast used in alcoholic fermentation to obtain wines with differences in chemical and sensory features.

The chemical and sensory profile is influenced by the grapes and yeasts involved in the fermentation process, which define the quality of the wines. During fermentation, several substances are formed, either extracted from the grapes or released during the process. The sensory profile indicates the evaluation of aroma, mouthfeel, taste and appearance, while the chemical profile quantifies phenolic compounds, total and volatile acidity, pH, color index, dry extract, reducing sugars, volatile compounds and many other substances present in wines (Hranilovic et al., 2018; Merkytė et al., 2020; Diez-Ozaeta, Lavilla, & Amarita 2021, Lin et al., 2022).

Thus, the application of alternative yeasts in the winemaking process results in significant or non-significant changes in the physicochemical properties of the wines. These chemical changes affect the wine sensory profile and can bring positive or negative impacts.

The *Vitis vinifera* has been considered the principal grape cultivar for winemaking; however, other grape cultivars such as *Vitis labrusca*, *Vitis bourquina* and their hybrids are gaining notoriety in some countries. Some of these hybrid grape cultivars in Brazil stand out in production, such as the Isabel, Bordô, and the BRS grape type (Camargo, Maia, & Ritschel, 2015).

The BRS grape type is a result of the genetic improvement program developed by the Brazilian Agricultural Research Corporation (Embrapa Uva e Vinho), and these grapes are used in alcoholic fermentation aiming at improving some wine features such as aroma, color and flavor. These grapes present high concentrations of phenolics, bioactive compounds, flavonoids, anthocyanins and volatile compounds responsible for their unique aroma. The aromatic composition can vary according to the region of production and the climate, giving it aromas of green notes and strawberry aroma (Castilhos et al., 2016; Soldateli et al., 2023).

Among them, the BRS Núbia stand out, and they present potential to produce table grape wines, juices or grape derivatives with features that are appreciated by the Brazilian consumers. The BRS Núbia grape cultivar is a result of the cross between 'Michele Palieri' and 'Arkansas 2095' grape cultivars and presents berries with 24 mm diameter and 34 mm length with an intense and strong violet color. This grape cultivar can achieve 16 to 20 ºBrix in its maturity stage (Maia et al., 2013).

In this context, this study aimed at producing wines with the Brazilian hybrid grape BRS Núbia analyzing the application of alternative yeasts, SB and SU in the winemaking process, evaluating their activity on physicochemical and sensory profiles in comparison to wines produced with the classic yeast SC.

Material and Methods

Material

The BRS Núbia grapes were obtained from the producer in the city of Jales (20º 16' 7" South and 50º 32' 58" West), São Paulo - Brazil. The grapes presented, at the beginning of alcoholic fermentation, soluble solids content (ºBrix) around 17.1±0.5 for SC treatment, 16.6±0.0 for SB treatment, and 16.9±0.5 for SU treatment. The grapes also presented pH of 3.3±0.0. Around 20 Kg were processed in 5 L non-toxic plastic fermentation reactors. The yeasts inoculated in the fermentation process, presenting 10^8 CFU/g, were the classic yeast *Saccharomyces cerevisiae* (SC) (SACCCE and two alternative yeasts: *Saccharomyces bayanus* (SB) (SACCBJ) and *Saccharomyces uvarum* (SU) (SACCBJ) (European and Mediterranean Plant Protection Organisation - EPPO, 2024). Also, potassium metabisulphite was used as antimicrobial selective agent. All these materials, including the yeasts,were obtained from Amazon Group®.

Winemaking procedure

All the treatments followed the standard winemaking procedure described by Castilhos et al. (2019). The BRS Núbia grapes were weighed, destemmed and crushed for obtaining the fermentation juice, which was placed in non-toxic plastic fermentation reactors with a volume of 5 L and treated with the addition of potassium metabisulfite at a rate of 10 grams per 100 kilograms of grapes to preserve quality and avoid inappropriate contamination. The active dry yeasts (SC, SB and SU) were inoculated into each must in the fermenters at a ratio of 20 g of yeast per 100 L of grape must. The fermentation was carried out at 30 to 35 ºC. All the musts were chaptalized using 18 g/L of crystal sugar to reach 1.0 % (volume/volume) of alcohol, according to Brazilian legislation (Brasil, 2018). The crystal sugar added for each treatment was as follows: 114.2±20.8 g for SC wine; 133.3±2.5 g for SB wine; and 124.8±22.2 g for SU wine. The end of CO_2 production, the Brix level around 3 ºBrix and the density of the wine, around 1.010 g/cm^3, determined the end of alcoholic fermentation.

After 7 days, the wines were dejuiced and immediately stored in fermentation flasks. After the alcoholic fermentation, the wines were racked three times at 10-day intervals, allowing vacuum filtration between the second and third racking. After 10 days, the last racking was carried out and the wines were then bottled in 750 mL amber glass bottles and horizontally stored in a clean and dry place, 50% relative humidity, away from light at 18 ºC. The wines were produced in two repetitions.

Enological parameters

The following enological parameters were measured: total and volatile acidities (TAC and VAC, as gL^{-1} tartaric acid and acetic acid, respectively) using titration apparatus and NaOH 0.1 mol/L and pH (Association of Official Analytical Chemists - AOAC, 2005) using pHmeter; total dry extract (EXT) (gL^{-1}) using porcelain capsules and thermostatic bath at 100 ºC (AOAC, 2005); reducing sugars (RSG) (gL^{-1}) by the Lane-Eynon method (AOAC, 2005), alcoholic content (ALC) (% volume/volume) (AOAC, 2005) by distillation using electrodes using Super DEE Distiller and hydrostatic balance from Gibertini® , total phenolic content (PHEN) using gallic acid as standard in an absorbance spectrophotometer at 765 nm (Slinkard & Singleton, 1977) and color indices using CIELab space parameters as follows: Luminosity (L*), Chroma (C*), hue angle (h*), red-greenish coordinate (a*), blue-yellowish coordinate (b*), color intensity (INT) and tonality (TON), determined by MSCV 7.1® software using absorbances at 450 nm, 520 nm, 570 nm, and 630 nm (Ayala, Echavarri, & Negueruela, 2012).

Sensory analysis

The analysis was carried out at the Sensory Analysis Laboratory of the Institute of Biosciences, Letters and Exact Sciences (Ibilce) in São José do Rio Preto, São Paulo. The Ethics in Research Committee of the Institute of Biosciences, Humanities, and Exact Sciences, São Paulo State University approved the ethical Issues regarding the sensory analysis (protocol n. 69960423.2.0000.5466).

The sensory acceptance test rated the attributes of appearance, aroma, body, flavor and overall acceptance, using a nine-point structured scale, (1) extremely dislike; (5) neither like nor dislike; (9) extremely like (Castilhos et al., 2013; Taladrid et al., 2020). Also, the purchase intention attribute was assessed using a five-point hedonic scale (1 = certainly would not buy, 5 = certainly would buy).

The sensory descriptors used for the RATA (Rate-All-That-Apply) technique were red color, fruity aroma, vegetal aroma, floral aroma, sweet taste, bitter taste, sour taste, fruity taste, body and persistence. This technique consists of assessing how applicable the attributes are and whether they are related to the sample presented, by evaluating the intensity of the attributes using an unstructured 9 cm scale (Sabino et al., 2023).

The wine samples were presented in 30 mL glasses containing 10 mL of the sample at 18 ºC in individual booths under white light at room temperature, 23 ºC. A glass of water was given to the panelists for mouth rinsing (Meilgaard, Civille & Carr, 2015). All the samples were presented in a monadic way, i.e. one sample at a time, in a randomized order, coded with three random digits to avoid carry-over effects. A complete block design was used, i.e., all the panelists tasted all the six samples (three treatments in two repetitions).

Data analysis

Data from wine chemical characterization and sensory analysis were treated using One-way Analysis of Variance (ANOVA) followed by Tukey's posthoc test (when $P<0.05$). Principal Component Analysis (PCA) multivariate statistical tool determined the relationship between the chemical properties and the sensory acceptance attributes. All the statistical tests were applied at a significance level of 0.05 using the Minitab 17 (Minitab Inc.) and Statistica 10 software (StatSoft, Inc.,2013).

Results and Discussion

Enological parameters

In the pH analyses, the samples showed significant differences when compared to each other ($P<0.001$). The pH range for red wines should be between 3.2 and 3.4, and all samples were within this range (Ribéreau-Gayon et al., 2006). The SU wine had the lowest pH when compared to the SC and SB wines. A similar result was found by Englezos et al. (2019), who studied the yeast *S. cerevisiae* with mixed fermentation of *Starm. bacillaris* and pure *S. cerevisiae* resulting in higher pH. The wines studied by Álvarez-Barragán et al. (2023) also presented pH between 3.15 and 3.24 with the "pied de cuve" wine with the lowest pH when compared to spontaneous fermentation and induced fermentation using active dry yeasts.

There were significant differences among the wines' alcohol content, and all the samples were in accordance with the range values recommended by Brazilian legislation, 8.6 to 14% v/v, i.e., the chaptalization was effective in achieving the desired alcohol content (Brasil, 2018). The wine SB produced the highest alcohol content with 11.13% v/v, followed by SU with 10.98% v/v and SC with 10.62% v/v. A similar result was observed by Lin et al. (2020), who reported that red pitaya wine produced with SB presented the highest ethanol content (10.8 % v/v) in comparison with the wines produced with *Metschnikowia agaves* and by co-inoculation of both yeasts (Lin et al., 2020). The use of alternative yeasts in winemaking might influence the alcohol content, especially with the SB yeast presenting a high alcohol tolerance condition that could result in a slow loss of viability, producing wines with a high alcohol content (Jackson, 2020).

The SU wine showed significant higher results for total acidity, 8.36 g/L, when compared with the wines produced from SC and SB yeasts, both with 7.55 g/L. This mentioned result was expected since the SU yeast can increase the total acidity of wines as reported by Wei et al. (2019), who showed that yeast metabolism contributes to the production of acids, increasing the total acidity of wines.

According to the Brazilian legislation, the wine volatile acidity must be below 1.2 g/L (Brasil, 2018) equivalents in acetic acid, which comprises wines free of contamination and safe for sensory analysis. All the wine samples studied presented volatile acidity below 1.2 g/L, as follows: 0.19 g/L for SC, 0.25 g/L for SB and 0.26 g/L for SU, showing significant differences ($P<0.05$). The yeasts SU, SB and the inoculation of non-*Saccharomyces* yeasts with SC have developed low volatile acidity in wines. A similar result was shown in the production of ciders, the authors reported that *S. cerevisiae* yeast obtained lower volatile acidity values when compared to the *S. pombe* yeast (Shi et al., 2019; Jackson, 2020; He et al., 2022). Liu et al. (2020) also showed that fermented kiwi beverages produced from the yeasts SB and SU presented lower volatile acidity compared to beverages produced from SC.

The wines were classified as light-bodied, with dry extract values around 20 g/L (Zoecklein et al., 1994; Jackson, 2020). There were no significant differences in the dry extract when the wine samples were compared. According to the legislation, wines can be classified as dry when the reducing sugar is up to 4 g/L, demi-sec from 4 g/L to 25 g/L and sweet above 25 g/L (Brasil, 2018). The results for reducing sugars were lower than 4 g/L; therefore, all the samples were considered dry wines, and they presented no significant differences ($P>0.05$).

Phenolic compounds are closely related to wine color, bitterness and astringency and their concentration varies according to grape cultivar, maturity, climatic conditions (*terroir*), production area, vine management, and winemaking procedures (Moreno-Arribas & Polo, 2009; Castilhos et al., 2016). The results for this parameter in wines were 941.37 mg/L for SC, 936.90 mg/L for SB and 925.94 mg/L for SU, showing no significant differences in the comparison of the wines. This result indicates that the yeast did not significantly influence the concentration of phenolic compounds. He et al. (2022) reported that the yeast SC and *S. pombe* in the production of cider did not significantly affect the phenolic compounds; however, some compounds such as catechin and procyanidins showed higher concentrations in the cider produced with *S. pombe* (He et al., 2022).

The SU yeast gave a lower color intensity for its respective wine, which is probably related to the yeast behavior. Moreno-Arribas and Polo (2009) reported that the anthocyanins, which is a group of chemical compounds responsible for wine color, can be adsorbed by the yeast cell walls since it has a great affinity for anthocyanins. Despite this, the SU wine showed higher values in the color indices L* (luminosity), C* (chroma), h* (hue angle), a* (red-green color component), b* (yellow-blue color component), and hue, and there were significant differences when compared to the SC and SB wines ($P<0.05$). The color intensity of the wine produced from SB yeast presented a lower value when compared to SC. This same result was shown in the study of kiwi fermented beverages, which the color intensity of the beverage produced with SB yeast was lower when compared to that produced with SC. Thus, it is assumed that this result is linked to the adsorption of anthocyanins by the yeasts, i.e., the amount of anthocyanins that the yeasts adsorb consequently influences the wines' color intensity, improving or decreasing its intensity (Echeverrigaray et al., 2020; Liu et al., 2020).

Mannoproteins, glucans and mannans are the primary components of yeast cell walls and they present a strong affinity to anthocyanins, allowing their adsorption. The amount of anthocyanin adsorbed depends on ethanol concentration, pH, SO_2 and pigment chemical structure. In this case, we can assume that SU has a higher adsorption potential, presenting a higher affinity to the anthocyanins, decreasing the color intensity of the wine due to its higher adsorption phenomenon (Moreno-Arribas, Polo, 2009).

The result found for SC wine was revealed in another study, which observed its ability to produce wines with higher pigment concentrations and a higher degree of opacity, consequently increasing color intensity and decreasing luminosity, indicating that the yeast adsorbs the grape pigment at a lesser extent that the other yeasts only at the end of the fermentation (Echeverrigaray et al., 2020; Tofalo, Suzzi, & Perpetuini, 2021). The SB wine showed a decrease in hue and the SU wine showed an increase for this parameter, and this fact showed the contribution of yeasts in the hue variation in red wines.

The results showed significant differences in the a* and b* color components, with the SU sample showing significantly higher values in both parameters than the SC and SB samples. The hue angles of the SC, SB and SU samples are up to 90º, so they are assigned to the first quadrant of the CIELab space, and they are identified by both positive a* and b* coordinates, highlighting the reddish hue according to the color distribution. The association of the reddish hue with the yellow hue was observed in the SU wine (Table 1).

Table 1: Enological parameters (mean ± standard deviation) of BRS Núbia wines according to the alternative yeasts used in winemaking procedure.

	Wines[2]			
Enological parameters[3]	SC	SB	SU	P-value[1]
pH	3.29±0.02[a]	3.26±0.01[a]	3.20±0.03[b]	<0.001
Alcohol content (ALC)	10.62±0.10[b]	11.13±0.11[a]	10.98±0.29[a]	0.001
Total acidity (TAC) (g/L)	7,55±0,10[b]	7,55±0,12[b]	8,36±0,13[a]	<0.001
Volatile acidity (VAC) (g/L)	0,19±0.00[b]	0,25±0.00[a]	0,26±0.02[a]	<0.001
Dry extract (EXT) (g/L)	18.62±2.04[a]	19.77±1.67[a]	20.00±0.55[a]	0.285
Reducing sugar (RSG) (g/L)	1.66±0.24[a]	1.66±0.10[a]	1.50±0.13[a]	0.208
Total phenolic content (PHEN) (mg/L)	941.37±19.32[a]	936.90±32.80[a]	925.90±9.03[a]	0.493
L*	10.82±2.78[b]	17.67±5.38[b]	42.72±14.97[a]	<0.001
C*	28.58±2.50[b]	45.10±13.11[b]	89.70±25.90[a]	<0.001
h*	40.19±8.77[b]	41.84±2.65[b]	53.20±5.02[a]	0.004
a*	21.42±0.97[c]	33.48±9.47[b]	52.05±9.31[a]	<0.001
b*	18.50±4.92[b]	30.16±9.27[b]	72.70±25.30[a]	<0.001
Color intensity (INT)	10.30±1.29[a]	8.78±0.26[b]	7.57±0.65[b]	<0.001
Tonality (TON)	1.70±0.27[ab]	1.46±0.04[b]	1.81±0.13[a]	0.010

[1]Different letters in the same line indicate significant differences according to Analysis of Variance (ANOVA) with Tukey post-hoc test (P<0.05). [2]SC: *S. cerevisiae*, SB: *S. bayanus*, SU: *S. uvarum*. [3]L*: Luminosity, C*: Chroma, h*: hue angle, a*: red-greenish coordinate, b*: blue-yellowish coordinate.

Sensory analysis

The sensory analysis was carried out with 87 consumers (44 women - 50.57%) aged between 18 and 67 years old. Of the total number of consumers who evaluated the wine samples, 28 (32%) reported a very low consumption of red wine, 19 (22%) reported a low consumption, 13 (15%) reported a moderate consumption, 17 (20%) reported a high consumption, and 10 (11%) reported a very high consumption of wine per month.

There were no significant differences in the sensory acceptance attributes (Table 2) (P>0.05), showing that the use of the alternative yeasts did not influence the sensory attributes.

A similar result was found by Quincozes et al. (2020) in the production of wines with alternative yeasts and the *Saccharomyces* genus, showing no significant differences in the aromatic profile scores, but it was evident that the SC yeast obtained better aromatic scores, except for the floral aroma.

In terms of overall acceptance, the wines obtained average scores above 5.0, indicating that the samples were well accepted by consumers and the SC wine showed a higher purchase intention when compared to the other wines, despite the absence of significant differences.

In view of the results presented, the univariate approach provided no significant information regarding the sensory profile of the assessed wines produced from BRS Núbia by the yeasts SC, SB, and SU. This fact can be explained by the untrained panel used for the acceptance sensory test, i.e. in this case the judges presented no experience in sensory testing and it is expected that the variation of the data will be high, making it difficult the occurrence of significant differences between the wine samples when they are compared. Therefore, a sensometric approach was applied using Principal Component Analysis (PCA) aiming at improving the relationship between the chemical parameters and the sensory attributes of acceptance.

Sensometric Approach

According to the results of the Principal Component Analysis (Figure 1), Principal Component 1 (PC1) explained 67.18% of the total variance of the results and Principal Component 2 (PC2) explained 32.82%, totaling 100% of the total variation in the data.

Two groups of variables explained PC1 (positive axis): pH, reducing sugars (RSG), total phenolic content (PHEN), color intensity (INT), and the acceptance attributes of appearance and body. The second group (negative axis) was made up of the following attributes: alcohol content (ALC), total acidity (TAC), volatile acidity (VAC), dry extract (EXT), luminosity (L*), Chroma (C*), hue angle (h*), red-greenish component (a*), and blue-yellowish component (b*).

One groups of variables explain PC2 (negative axis) composed by tonality (TON), and the acceptance attributes of aroma, taste, overall acceptance, and purchase intention.

Table 2: Sensory acceptance results (mean ± standard deviation) for BRS Núbia wines.

Sensory acceptance attributes[1]	Wines[2]			P-value
	SC	SB	SU	
Appearance	7.62±1.12[a]	7.29±1.28[a]	7.16±1.47[a]	0.057
Aroma	6.82±1,47[a]	6.43±1.72[a]	6.78±1.42[a]	0.182
Body	6.31±1.60[a]	6.06±1.70[a]	6.05±1.61[a]	0.486
Flavor	5.61±1.99[a]	5.17±2.08[a]	5.45±1.99[a]	0.355
Overall acceptance	6.20±1.67[a]	5.72±1.90[a]	5.97±1.76[a]	0.219
Purchase intention[3]	3.00±1.13[a]	2.90±1.14[a]	2.97±1.09[a]	0.826

[1]Different letters in the same line indicate significant differences according to Analysis of Variance (ANOVA) with Tukey post-hoc test (P<0.05). [2]SC: *S. cerevisiae*, SB: *S. bayanus*, SU: *S. uvarum*. [3]5-point structured scale.

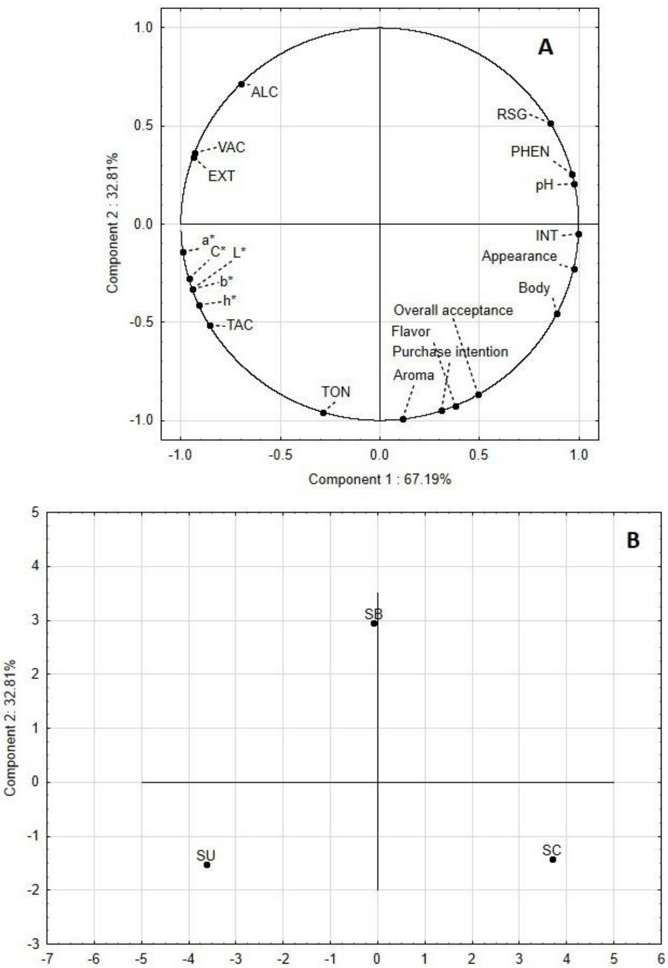

Figure 1: Projection of the chemical and sensory profiles (A) and BRS Núbia wine samples (B) using PCA. Abbreviation: TAC: total acidity, VAC: volatile acidity, EXT: dry extract, RSG: reducing sugar, ALC: alcohol content, PHEN: total phenolic content, L*: luminosity, C*: Chroma, h*: hue angle, a*: red-green color component, b*: blue-yellow color component, INT: color intensity, TON: tonality. SC: *Saccharomyces cerevisiae*, SB: *Saccharomyces bayanus*, SU: *Saccharomyces uvarum*.

According to Figure 1, the SC wine sample was correlated with the variables located in the positive axis of PC1 and the negative axis of PC2. The variables of negative axis of the PC1 and negative axis of PC2 were also related with the SU wine sample. The SB wine sample was in the positive axis of PC2, presenting no relationship with physicochemical and sensory variables. The wine produced from the SC yeast was related to the sensory acceptance attributes of appearance and body, from PC1, and aroma, flavor, overall acceptance, and purchase intention from PC2, and the physicochemical parameters linked to this sample were: pH, reducing sugars, total phenolic content, and color intensity.

The SC sample showed a direct relationship with all the sensory acceptance attributes, when we analyze both PCs, and this result is probably due to the combination of the physicochemical properties of reducing sugars, color intensity, and phenolic content, primarily for body and appearance acceptance. The high color intensity, combined with the high content of total phenolics, was responsible for determining an attractive color for this sample, promoting greater acceptance by consumers.

Phenolic compounds have relevant effects for wines, as they play an important role in determining color through anthocyanins and in determining bitterness and astringency, primarily because of the presence of flavan-3-ols and tannins, which are considered mouthfeel sensations that influence the wine body (Saénz-Navajas et al., 2016; Jackson, 2017; Jackson, 2020). Thus, the high acceptance for appearance and body may justify its relationship with high total phenolic content of the SC sample, since these wines presented the higher concentration of phenolic compounds, despite the absence of significant differences (P>0.05). In addition, this result is also supported by the fact that the SC sample has a high color intensity, highlighting its red color compared to the other samples, justifying the high acceptance of appearance.

The reducing sugar plays an essential role in determining the wine's body and sweet taste since it comprises the sugar that has not been metabolized by the yeast and it is responsible for determining the sweetness of the beverage.Castilhos et al. (2013)

reported that wines produced from the BRS Violeta grape using the traditional winemaking protocol presented a high acceptance of body due to their higher content of reducing sugars. The result corroborates the findings of this study.

The wine produced from SU yeast showed a relationship with the variables of PC1 from de negative axis: alcohol content, total acidity, volatile acidity, dry extract, and color indices in the CIELab space, except for color intensity. The SU wine also was related with the variables from the negative axis of PC2, as follows: tonality, acceptance of aroma, flavor, overall acceptance and purchase intention.

The higher acceptance for SU sample aroma and flavor was related with the physicochemical properties of alcohol content, acidity (total and volatile), dry extract and color indices. The alcohol content and the volatile acidity were chemical properties that have strong influence on wine aroma and flavor. Castilhos et al. (2013) reported the influence on volatile acidity on the Brazilian red wines aroma acceptance produced from American grapes Bordô and Isabel. Biasoto et al. (2014) also reported that volatile acidity was a sensory driver for aromas in wines produced from hybrid grapes. Some studies also reported the intense relationship between the alcohol content and wine aroma (Escudero et al., 2007; Le Berre et al., 2007). The alcohol content also has influence on wine flavor as stated by Meillon et al. (2010). Furthermore, other contextual factors such as color intensity and other visual clues can influence the aroma perception and acceptance as reported by Sakai et al. (2005) and Castilhos et al. (2016).

The wine acidity plays an important role in wine aroma and flavor since the low pH enhances the release of volatile compounds due to the hydrolysis of their glycosidic compounds (Mira de Orduña, 2010). Also, Meillon et al. (2010) studied the impact of partial alcohol reduction in Syrah wine on perceived sensations linking it with preference and they have reported that the alcohol content was responsible for enhancing the acceptance of flavor, corroborating the results obtained in this study.

Overall acceptance was related to the interaction of acidity, alcohol content, reducing sugars and dry extract, phenolic compounds and color indices since these physicochemical properties were related to odor and flavor, body and appearance, respectively. Castilhos et al. (2013) studied the response of alternative winemaking on physicochemical and sensory profiles of wines produced from non-*Vitis vinifera* grapes and they have stated that the overall acceptance of a wine is a result of the interaction of all the physicochemical properties that lead to a sample with high acceptance by the judges.

The descriptors of luminosity (L*), hue angle (h*), yellow-blue color component (b*), chroma (C*), red-green color component (a*) showed a significant relationship, i.e. higher scores for SU sample, and these parameters were also responsible for determining the greater acceptance of this sample appearance.

Varela et al. (2017) in their study of sensory profile and volatile aroma composition of reduced alcohol in Merlot wines produced from SU reported that the SU wines showed a sensory profile dominated by unusual and negative sensory attributes such as brown tint, barnyard and meat aromas. These results mentioned showed that the wines produced from SU presented no positive sensory effects; however, the study showed the higher acceptance of the BRS Núbia wines produced with SU, showing that this yeast can be used as an alternative to produce hybrid grape wines with sensory quality and high acceptance.

Conclusions

SC wine was related to pH, reducing sugars, total phenolic content and color intensity, providing strong relationship with appearance and body acceptance. SC wine also presented high acceptance for aroma, flavor, overall acceptance and purchase intention. SU sample presented high relationship with alcohol content, acidity, dry extract, and CIELab parameters, influencing on the higher acceptance of aroma, flavor, overall acceptance and purchase intention. SB sample presented no relationship with chemical properties or sensory attributes.

Author Contribution

Conceptual idea: Alves, D.C.; Del Bianchi, V. L.; Castilhos, M. B. M.; Methodology design: Alves, D.C.; Del Bianchi, V. L.; Castilhos, M. B. M.; Data collection: Alves, D.C.; Castilhos, M. B. M.; Data analysis and interpretation: Alves, D.C.; Del Bianchi, V. L.; Castilhos, M. B. M.; Writing and editing: Alves, D.C.; Del Bianchi, V. L.; Castilhos, M. B. M.

Acknowledgements

The authors would also like to acknowledge the grape producers in Jales (Brazil) that provided the grape cultivars for this project.

References

Álvarez-Barragán, J. et al. (2023). Influence of spontaneous, “pied de cuve” and commercial dry yeast fermentation strategies on wine molecular composition and sensory properties. *Food Research International*, *174*:113648.

Association of Official Analytical Chemists - AOAC. (2005). *Official methods of analysis of the AOAC International*. Washington: AOAC International. 1141p.

Ayala, F., Echavarri, J. F., & Negueruela, A. I. (2012). *MSCV version 7.1 software*.

Biasoto, A. C. T. et al. (2014). Acceptability and preference drivers of red wines produced from *Vitis labrusca* and hybrid grapes. *Food Research International*, *62*:456-466.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. (2018). Instrução Normativa nº 14 de 8 de fevereiro de 2018. Brasília. *Diário Oficial*: República Federativa do Brasil: seção 1, n. 47, p. 4-6.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. (2023). *Consolidação das normas de bebidas fermentado acético, vinho e derivados da uva e do vinho: Anexo à norma interna DIPOV nº 01/2019 - Cartilhão de bebidas- coordenação geral de vinhos e bebidas*. 2 ed., Brasília. 1769p.

Camargo, U. A., Maia, J. D. G., & Ritschel, P. S. (2015). Cultivares de videira para processamento. Produção integrada de uva para o processamento: Implantação do vinhedo, cultivares e manejo da planta. S. V. da. Silveira., A. Hoffmann., & L. da. R. Garrido. (Ed.). *Produção integrada de uva para processamento: Implantação do vinhedo, cultivares e manejo da planta Brasília.* DF: Embrapa, v. 3, cap. 2, (pp. 25-40).

Castilhos, M. B. et al. (2016). Sensory acceptance drivers of pre-fermentation dehydration and submerged cap red wines produced from *Vitis labrusca* hybrid grapes. *LWT-Food Science and Technology*, *69*:82-90.

Castilhos, M. B. M. et al. (2013). Influence of two different vinification procedures on the physicochemical and sensory properties of Brazilian non-*Vitis vinifera* red wines. *LWT-Food Science and Technology*, *54*(2):360-366.

Castilhos, M. B. M. et al. (2019). Sensory descriptive and comprehensive GC–MS as suitable tools to characterize the effects of alternative winemaking procedures on wine aroma. Part I: BRS Carmem and BRS Violeta. *Food chemistry*, *272*:462-470.

Diez-Ozaeta, I., Lavilla, M., & Amarita, F. (2021). Wine aroma profile modification by *Oenococcus oeni* strains from Rioja Alavesa region: Selection of potential malolactic starters. *International journal of food microbiology*, *356*:109324.

Echeverrigaray, S. et al. (2020). Anthocyanin adsorption by *Saccharomyces cerevisiae* during wine fermentation is associated to the loss of yeast cell wall/membrane integrity. *International Journal of Food Microbiology*, *314*:108383.

Englezos, V. et al. (2019). *Saccharomyces cerevisiae-Starmerella bacillaris* strains interaction modulates chemical and volatile profile in red wine mixed fermentations. *Food Research Tnternational*, *122*:392-401.

Escudero, A. et al. (2007). Analytical characterization of the aroma of five premium red wines. Insights into the role of odor families and the concept of fruitiness of wines. *Journal of the Agricultural and Food Chemistry*, *55*:4501-4510.

European and Mediterranean Plant Protection Organisation - EPPO. (2024). *EPPO global database*. Available in: <https://www.eppo.int/>.

Gamero, A. et al. (2011). Monoterpene alcohols release and bioconversion by *Saccharomyces* species and hybrids. *International Journal of Food Microbiology*, 145(1):92-97.

He, W. et al. (2022). Phenolic compound profiles in Finnish apple (*Malus× domestica Borkh*.) juices and ciders fermented with *Saccharomyces cerevisiae* and *Schizosaccharomyces pombe* strains. *Food Chemistry*, *373*:131437.

Hranilovic, A. et al. (2018). Chemical and sensory profiling of shiraz wines co-fermented with commercial *non-Saccharomyces* inocula. *Australian Journal of Grape and Wine Research*, *24*(2):166-180.

Jackson, R. S. (2017). *Wine tasting: A professional handbook*. 3rd Edition. Academic Press, San Diego. 430p.

Jackson, R. S. (2020). *Wine science: Principles and applications*. 5th edition. Academic Press, San Diego. 1030p.

Le Berre, E. et al. (2007). Impact of ethanol on the perception of wine odorants mixtures. *Food Quality and Preference*, *18*(6):901-908.

Lin, M. M. H. et al. (2022). Influence of *Kazachstania spp*. on the chemical and sensory profile of red wines. *International Journal of Food Microbiology, 362*:*109496.*

Lin, X. et al. (2020). Improved flavor profiles of red pitaya (*Hylocereus lemairei*) wine by controlling the inoculations *of Saccharomyces bayanus* and *Metschnikowia agaves* and the fermentation temperature. *Journal of Food Science and Technology*, *57*:4469-4480.

Liu, J. et al. (2020). Characterization of major properties and aroma profile of kiwi wine co-cultured by *Saccharomyces* yeast (*S. cerevisiae, S. bayanus, S. uvarum*) and *T. delbrueckii*. *European Food Research and Technology*, *246*:807-820.

Liu, J. et al. (2022). Ethyl esters enhancement of Jinchuan pear wine studied by *coculturing Saccharomyces bayanus* with *Torulaspora delbrueckii* and their community and interaction characteristics. *Food Bioscience*, *46*:101605.

Maia, J. D. G. et al. (2013). *BRS Núbia: Nova cultivar de uva de mesa com sementes e coloração preta uniforme*. Bento Gonçalves: Embrapa Uva e Vinho, 12 p. Comunicado Técnico Embrapa Uva e Vinho, 139.

Meilgaard, M. C., Civille, G. V., & Carr, B. T. (2015). *Sensory evaluation techniques*. 5th. CRC press. 600p.

Meillon, S. et al. (2010). Impact of partial alcohol reduction in syrah wine on perceived complexity and temporality of sensations and link with preference. *Food Quality and Preference*, *21*(7):732-740.

Merkytė, V. et al. (2020). Phenolic compounds as markers of wine quality and authenticity. *Foods*, *9*(12):1785.

Minebois, R., Pérez-Torrado, R., & Querol, A. (2020). A time course metabolism comparison among *Saccharomyces cerevisiae*, *S. uvarum* and *S. kudriavzevii* species in wine fermentation. *Food Microbiology*, *90*:103484.

Mira de Orduña, R. (2010). Climate change associated effects on grape and wine quality and production. *Food Research International*, *43*(7):1844-1855.

Moreno-Arribas, M. V., & Polo, M. C. (2009). *Wine chemistry and biochemistry*. Springer, New York. 735p.

Moreno-Olivares, J. D. et al. (2020). Study of aromatic profile of different crosses of Monastrell white wines. *Journal of the Science of Food and Agriculture*, *100*(1):38-49.

Quincozes, L. et al. (2020). Physicochemical, aromatic, and sensory properties of the 'Riesling Italico' wines fermented with *Saccharomyces* and *non-Saccharomyces* yeasts. *Ciência Rural*, *50*(6):e20190622.

Ribéreau-Gayon, P. et al. (2006). *Handbook of enology: The chemistry of wine stabilization and treatments*. Nova Jersey, EUA: John Wiley & Sons. 441p.

Sabino, L. L. et al. (2023). Production of fermented beverage using pineapple residue as an alcoholic fermentation substrate: A physicochemical and sensory approach. *European Food Research and Technology*, *249*(2):387-396.

Saénz-Navajas, M. et al. (2016). Undesrtanding quality judgments of red wines by experts: Effect of evaluation condition. *Food Quality and Preference*, *48*:216-227.

Sakai, N. et al. (2005). The effect of visual images on perception of odors. *Chemical Sciences*, *30*:244-245.

Shi, W. K. et al. (2019). Effect of *Issatchenkia terricola* and *Pichia kudriavzevii* on wine flavor and quality through simultaneous and sequential co-fermentation with *Saccharomyces cerevisiae*. *LWT*, *116*:108477.

Slinkard, K., & Singleton, V. L. (1977). Total phenol analysis: Automation and comparison with manual methods. *American Journal of Enology and Viticulture*, *28*:49-55.

Soldateli, F. J. et al. (2023). Overall quality, phenolic compounds, and volatile profile of a *Vitis Vinifera* L. variety and hybrids 'BRS Isis' and 'BRS Nubia' table grapes in two terroirs. *Erwerbs-Obstbau*, *65*:2095-2108.

StatSoft, Inc.. (2013). *Statistica version 12*. StatSoft, Inc.

Taladrid, D. et al. (2020). Sensory acceptability of winery by-products as seasonings for salt replacement. *European Food Research and Technology*, *246*:2359-2369.

Tapia, S. M. et al. (2022). Functional divergence in the proteins encoded by ARO80 from S. uvarum, S. kudriavzevii and S. cerevisiae explain differences in the aroma production during wine fermentation. *Microbial Biotechnology*, *15*(8):2281-2291.

Tofalo, R., Suzzi, G., & Perpetuini, G. (2021). Discovering the influence of microorganisms on wine color. *Frontiers in Microbiology*, *12*:790935.

Varela, C. et al. (2017). Sensory profile and volatile aroma composition of reduced alcohol merlot wines fermented with *Metschnikowia pulcherrima* and *Saccharomyces uvarum*. *International Journal of Food Microbiology*, *252*:1-9.

Venturini Filho, W. G. (2010). *Bebidas alcoólicas: Ciência e tecnologia*. São Paulo: Editora Blucher. 492p.

Wei, J. et al. (2019). Characteristic fruit wine production via reciprocal selection of juice and *non-Saccharomyces* species. *Food Microbiology*, *79*:66-74.

Zoecklein, B. W. et al. (1994). *Wine analysis and production*. Chapman & Hall, New York. 621p.