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Prototype Development of a Wine-Based Flavored Beverage with Freeze-Dried Strawberry Extract

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Abstract

The aim of this study was to develop and characterize a wine-based flavored beverage produced from single-varietal white Moscatel wine with the incorporation of freeze-dried strawberry extract (cv. Fortuna Original®), and to evaluate its physicochemical, chromatic, and short-term sensory stability over 20 days. Five formulations (0, 4, 6, 8, and 12 g extract per 500 mL) were analyzed after 10 and 20 days of storage. The incorporation of strawberry extract led to increased total acidity and slight dilution of alcohol content (from ≈7.1% to 6.9% v/v), while pH and density remained stable, indicating the preservation of the physicochemical structure of the wine matrix. Chromatic parameters showed modulation associated with strawberry-derived pigments, with reduced variability over time, suggesting short-term color stabilization. Analytical results demonstrated low coefficients of variation for most parameters after 20 days, indicating system consistency during storage. Sensory evaluation revealed that the formulation containing 6 g of extract exhibited a higher aromatic intensity and enhanced red fruit perception compared to the control wine. Overall, the results demonstrate that the incorporation of freeze-dried strawberry extract into a white wine matrix is technologically feasible and enables the controlled modulation of physicochemical and sensory properties without compromising short-term stability.

Keywords: flavored beverage; freeze-dried strawberry extract; physicochemical characterization; sensory characterization; white wine

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1. Introduction

In recent years, wine consumption habits have followed global trends in the beverage industry, with growing demand for wine-based flavored beverages and ready-to-drink products. This evolution reflects the wine sector's adaptation to new consumer preferences, which value convenience, innovation, sensory diversity, and concerns related to health and well-being, as well as the increasing demand for beverages with lower or no alcohol content [1]. In the context of stagnant wine consumption and increased competition from other beverage categories, alongside quality and product differentiation, these beverages play a central role in the competitiveness of the wine industry [2].

Consumer preferences have evolved toward fresher wines with lower alcohol content and reduced oak influence, favoring fruitier sensory profiles aligned with sustainability principles [3]. At the same time, there is growing appreciation for healthier, practical, and accessible options, driving the development of new formulations, particularly wine-based

beverages with moderate alcohol content [4]. In this context, ready-to-drink beverages stand out for their practicality, versatility, and diversity, encouraging producers to invest in innovation, incorporate flavors derived from traditional ingredients, and adopt new production and presentation approaches. The development of new wine-based beverages may therefore represent a relevant strategy for product differentiation, strengthening the competitiveness of wine companies and enhancing their position in national and international markets [5].

Wine is defined as the product obtained exclusively from the total or partial alcoholic fermentation of fresh grapes, whether crushed or not, or of grape must (Regulation (EC) No 479/2008; Regulation (EU) No 1308/2013). Alcoholic fermentation is mainly carried out by yeasts and may, under certain conditions, also involve lactic acid bacteria, influencing the chemical and sensory profile of the final product [6,7]. In winemaking, quality results from the interaction of several factors, namely the winemaker, the grape variety, grape quality, and the adopted vinification method [8]. To obtain high-quality wines, grapes must present an adequate balance between sugars, acids, and phenolic compounds, be free from microbiological damage, and reflect the origin, variety, and technical expertise of both the viticulturist and the winemaker [7]. Moreover, each type of wine follows a specific vinification process, whose stages directly influence the physicochemical parameters and organoleptic characteristics of the final product. In red winemaking, fermentation occurs in contact with the skins, allowing the extraction of anthocyanins, tannins, and aromatic compounds, followed by pressing, maturation—often in wood—and bottling [8]. In white winemaking, however, pressing precedes alcoholic fermentation, and there is no maceration of the solid parts, resulting in wines with greater freshness and lightness. Rosé wines combine the characteristics of both styles and may be produced either by direct pressing or partial maceration, leading to limited extraction of phenolic compounds [6,7]. In addition to traditional wines, several beverages can be obtained from wine or must through the addition of other raw materials, with the aim of modifying or intensifying aromas and flavors. These products are legally classified into the categories of aromatized wine, wine-based aromatized beverages, and aromatized cocktails of wine products, distinguished by the proportion of wine and alcohol content (Regulation (EC) No 251/2014; Regulation (EU) 2017/670; Regulation (EU) 2024/585). Products such as vermouth and sangria fall within these categories and are subject to specific legal requirements.

The aromatization of wines and wine products can be achieved through the addition of natural or artificial flavoring ingredients or through wood aging. The direct incorporation of ingredients allows for more precise control of the sensory profile, while barrel aging promotes significant changes in the color, structure, and aroma of the wine, resulting from interactions between wood phenolic compounds and wine constituents, although it requires longer production times [7,8].

Despite the broad context of market trends and product innovation outlined above, there is still limited scientific information regarding the short-term physicochemical and sensory stability of wine-based flavored beverages, particularly when fruit-derived ingredients are incorporated into low-phenolic matrices such as white wines. Recent studies have highlighted that the stability of such beverages is strongly influenced by matrix composition, storage conditions, and interactions between added bioactive compounds and wine constituents, yet short-term evolution remains poorly documented [7,9,10]. In this context, the behavior of freeze-dried fruit extracts remains insufficiently characterized, especially considering the structural modifications induced by dehydration processes and their impact on solubility, compositional homogeneity, and interaction with wine systems [11–13]. Moreover, the incorporation of strawberry-derived compounds, notably anthocyanins and organic acids, into a white wine matrix raises important questions regarding pigment be-

havior, chromatic modulation, and system stability. Anthocyanins are known to be highly sensitive to pH, sulfur dioxide, and copigmentation phenomena, which are significantly less pronounced in white wines due to their low phenolic content [9,14–16]. Consequently, pigment stabilization mechanisms may be limited, affecting both color expression and its evolution over time. Additionally, interactions between organic acids, ethanol, and volatile compounds may further influence sensory perception and overall product balance [7,17]. Therefore, this study aims to address these gaps by developing a wine-based flavored beverage using freeze-dried strawberry extract and evaluating its physicochemical, chromatic, and sensory characteristics over a short storage period, with particular emphasis on system stability, pigment-related changes, and their implications for product development.

2. Materials and Methods

2.1. Strawberry Extract Production

The production of the strawberry extract was carried out in four sequential stages: raw material selection, sanitization, processing, and freeze drying.

The fruits used belonged to the cultivar Fortuna Original® (FL 01 116), sourced from the Ribatejo region, Portugal. The selection was based on visual and qualitative criteria, including the homogeneous coloration characteristic of the cultivar, surface brightness, and absence of lesions or necrotic spots. Additionally, the condition of the peduncle and calyx was assessed, prioritizing samples with an intense green color and fresh appearance, indicative of appropriate ripeness and physiological integrity.

Sanitization was performed using a sodium hypochlorite-based disinfectant solution (Clean Essence®, Wearebond Lda, Lisbon, Portugal) to ensure reduction in the surface microbial load. The procedure was carried out as indicated on the label: 10 mL of the Clean Essence solution per 2 L of water. The strawberries were soaked for 10 min and, after this period, rinsed thoroughly with potable water. After sanitization, the non-edible parts were removed, and the pulp was processed without the addition of water, preservatives, or other technological adjuvants.

Grinding was performed using a blender (SilverCrest SSME 250, Lidl, Portugal) operating at a nominal power of 250 W for 2 min, until a homogeneous extract was obtained. The resulting extract was subsequently subjected to freeze drying using a freeze dryer (Biobase, model BK-FD, Jinan, Shandong, China). The process included an initial freezing step at −60 °C for 4 h, followed by sublimation drying under a pressure of 110 kPa for 24 h, aiming at water removal by sublimation and preservation of the physicochemical characteristics of the product. The extraction yield was determined based on the ratio between the fresh fruit mass and the corresponding freeze-dried extract obtained after processing. On average, the process yielded approximately 10 g of freeze-dried extract per 100 g of fresh strawberries, corresponding to a dehydration yield consistent with the high initial moisture content of the fruit (≈90%). The fruit-to-extract ratio was therefore approximately 10:1 (fresh weight basis). Residual moisture of the freeze-dried extract was estimated based on constant weight after the drying cycle and was assumed to be below 5%, in accordance with typical values reported for freeze-dried fruit products under similar conditions. The attainment of constant mass after 24 h of freeze-drying indicates effective water removal and contributes to the physicochemical stability of the extract.

2.2. White Wine Production

For white wine production, Moscatel grapes from the Palmela region (Portugal) were used. Vinification was conducted according to the protocol described by [18], with adaptations to laboratory conditions. After destemming and pressing, the must was treated with sulfur dioxide at the standard dosage of 36 mL per 100 kg. Following a 24 h settling

period, SpringArom (nutrient) was added to the vat at the standard rate of 36 g/100 kg. The yeast was rehydrated in water at 37 °C (1:10 ratio) and added to the must at the standard inoculation rate of 30 g/hL. After 20 min of hydration, the yeast suspension was transferred to the vat and the mixture was homogenized. Fermentation lasted 9 days, with temperatures ranging between 15.9 and 17.9 °C, and progress was monitored through regular measurements of temperature and density. PVPP/Polyvinylpolypyrrolidone (Divergan F) was applied at the standard rate of 24 g/100 kg once the density reached 1060 g/cm^3. Diammonium phosphate (DAP) was added at the standard rate of 24 g/100 kg at the fermentation peak, corresponding to a density of 1030–1040 g/cm^3. When the density dropped to 1000 g/cm^3, sulfur dioxide was added at the standard rate of 5 mL/hL to halt fermentation. The wine was subsequently filtered and bottled.

During the enological process, specific technological preparations were applied: the enzyme Enozym Extra Arome to enhance the release of varietal aromatic compounds; sulfur dioxide (SULPHUR) as an antioxidant and antimicrobial agent; selected yeast SafŒno™ to conduct alcoholic fermentation; and the enological nutrient SpringArom to ensure adequate availability of assimilable nitrogen for yeast metabolism.

Additionally, diammonium phosphate (DAP) was incorporated as a supplementary source of inorganic nitrogen to optimize fermentation kinetics, and the fining agent PVPP (Divergan F) was applied for phenolic stabilization and improvement of the organoleptic characteristics of the obtained wine.

2.3. Production of the Wine-Based Aromatized Beverage

In order to determine the optimal proportion between wine and freeze-dried strawberry extract, aiming to obtain a product with distinctive organoleptic characteristics, four different wine-based aromatized beverages formulations were developed (Table 1).

Table 1. Percentage ratio between strawberry extract and wine per formulation.

Formulation (g)	Wine Volume (mL)	Extract (%)
A1–0	500	0.0
A2–4		0.80
A3–6		1.20
A4–8		1.60
A5–12		2.40

The definition of the proportions was established based on preliminary sensory criteria, considering parameters such as aroma, taste profile, and color intensity/hue, and the quantities tested ranged from 4 g upward, doubling progressively to 12 g in order to evaluate differences.

The freeze-dried strawberry extract was directly added to the base wine without prior rehydration. Homogenization was performed through controlled manual agitation for approximately 1–2 min to ensure the adequate dispersion of solid particles while minimizing oxygen incorporation. No subsequent filtration or clarification step was applied after incorporation in order to preserve the full particulate and soluble fraction of the extract within the wine matrix. Due to the limited solubility of certain extract components and the presence of insoluble or partially soluble particles resulting from the freeze-drying process, complete dissolution was not achieved. This condition likely contributed to the turbidity observed in some formulations during sensory evaluation, particularly at higher extract concentrations. Sensory evaluations were conducted at these two time intervals to determine the impact of strawberry extract addition on the organoleptic characteristics of the product, particularly in terms of aroma, flavor, and color. Bottling was performed in 500 mL

amber glass bottles, selected to reduce light exposure and consequently minimize potential oxidative reactions that could compromise the stability and quality of the beverage.

2.4. Physicochemical Analyses of Strawberries and Their Extract

After the sanitization process, the total soluble solids content (TSS, expressed in °Brix) was determined in fresh strawberries (n = 4; analytical replicates) and in the corresponding extract (n = 6; analytical replicates) using an analog refractometer (Atago; model Master, Tokyo, Japan), previously calibrated with distilled water.

The pH of the strawberries (n = 4; analytical replicates) was measured using a calibrated potentiometer specific for food matrices (Hanna Wireless Foodcare pH Meter, model FC2022 HALO, Póvoa de Varzim, Portugal). Fruits' firmness (n = 4; analytical replicates) was evaluated using a Bellevue-type penetrometer (Konica Minolta, Inc., Tokyo, Japan)equipped with an 11 mm diameter tip (0.5 cm^2) and a penetration depth of 1 cm, with the results expressed in kg.

The fresh and dry weight (n = 4; analytical replicates) of the samples were determined using a precision balance (Bauer; model KS36, Empfingen, Germany). Strawberry samples were dried for 24 h at 65 °C until constant weight was achieved. Electrical conductivity (n = 4; analytical replicates) was measured in fresh strawberries using a multiparameter potentiometer (Consort; model C6030, Halle, Belgium) equipped with SK20T electrodes. After drying and subsequent grinding (n = 4; analytical replicates), the mineral content was quantified by X-ray fluorescence using a Thermo Scientific analyzer (Thermo Fisher Scientific Inc. model Niton XL3t 950 He GOLDD+, Waltham, MA, USA).

Sugar quantification in strawberry extracts (n = 6; analytical replicates) was performed according to [19]. Samples were previously filtered (nylon filter; 0.45 µm) and analyzed using a high-performance liquid chromatography system (HPLC; Waters, Milford, MA, USA) coupled to a refractive index detector (Waters 2414). The system was equipped with a SugarPak I column (Waters; 6.5 × 300 mm) and corresponding pre-column (Wat 088141) packed with SugarPak II (Wat 015209). The mobile phase consisted of ultrapure water containing 50 ppm EDTA-Ca, at a flow rate of 0.5 mL min^{-1}, with an injection volume of 40 µL per sample. Quantification was carried out using Empower 3 software, based on external calibration curves.

The total fat content in strawberry extracts (n = 6; analytical replicates) was determined using the Soxhlet method [20] with a SER 148 Series—Solvent Extractors system (VELP, Usmate, Italy). Adaptations were made to the extraction times and temperatures of phases I, W, and R to adjust the procedure to the specific characteristics of the analyzed matrix.

The colorimetric parameters of the samples (n = 4; analytical replicates), evaluated on the external and internal parts of the fruits as well as in the concentrated extract, were determined according to [19], considering the CIELab coordinate system (L*, a*, and b*). Measurements were performed using a Minolta CR-300 colorimeter(Konica Minolta, Tokyo, Japan) with standard illuminant C. Scanning colorimetric spectrophotometry was carried out using an Agrosta Roxane Colorimeter (Agrosta Instruments, Geispolsheim, France), as described by [19].

2.5. Physicochemical Analyses of Grapes, Wine, and the Aromatized Beverage

After sanitization, the total soluble solids (TSS) content of Moscatel grapes (n = 9; analytical replicates) was determined using an analog refractometer (Atago; model Master), with results expressed in °Brix.

In white wine samples (A1—without addition of strawberry extract) and in the wine-based aromatized beverage formulations (A2, A3, A4, and A5), prepared from 500 mL of wine with the incorporation of 4, 6, 8, and 12 g of strawberry extract, physicochemical

parameters (n = 4; analytical replicates) were quantified after 10 and 20 days of storage. The evaluated parameters included pH, Baumé degree, density (using a density meter—Anton Paar, model DMA 35N, Graz, Austria), and TSS.

In the white wine (A1) and in the aromatized beverage containing 6 g of extract (A3), additional determinations (n = 4; analytical replicates) were carried out 10 days after storage using Fourier Transform Infrared Spectroscopy (FTIR), with a Foss Analytics instrument (FOSS Analytical A/S, Hørsholm, Denmark). The following parameters were measured: alcohol content, glucose and fructose concentration, malic acid, volatile and total acidity, and pH.

The free and total SO_2 were determined by titration using a sulfur titrator (TDI; model ENO 20/Mais, Cherry Hill, NJ, USA), with diluted sulfuric acid (1/3) and 5 N sodium hydroxide as reagents. For free SO_2 determination, 20 mL of sample and 2 mL of diluted sulfuric acid (1/3) were used. For total SO_2 determination, 2 mL of 5 N sodium hydroxide was added to 20 mL of sample; after 10 min of rest, 4 mL of diluted sulfuric acid (1/3) was added, followed by titration.

The alcoholic strength by volume was also determined by ebulliometry, based on measuring the boiling temperature of the samples using an ebulliometer, thermometer, and corresponding conversion disk.

The colorimetric parameters of the grapes (n = 4; analytical replicates) were evaluated according to the CIELab system (L*, a*, and b*) using a Minolta CR-300 colorimeter with standard illuminant C. Spectrophotometric scanning colorimetric analysis was performed using an Agrosta Roxane Colorimeter, as described by [19].

2.6. Sensory Analyses

The sensory analysis was conducted using untrained panelists (n = 17; nine male and eight female participants), reflecting a consumer-oriented exploratory approach rather than a formal descriptive sensory evaluation. All participants were regular consumers of wine and provided informed consent prior to participation, in accordance with standard ethical practices for voluntary sensory studies. Following a preliminary screening of formulations A2–A5, formulation A3 (6 g of strawberry extract per 500 mL of wine) was selected for detailed sensory comparison, as it presented the most balanced combination of sensory impact (aroma and flavor) and physicochemical stability. Therefore, the sensory analysis focused on comparing the control wine (A1) and formulation A3. The evaluation was conducted using a structured tasting sheet, including descriptors organized into three sensory categories: visual, olfactory, and gustatory attributes (Table 2). The intensity of each descriptor was rated using a five-point ordinal scale (1–5), corresponding to increasing perception intensity. For data treatment and comparative purposes, scores were normalized to a scale ranging from 0.20 (minimum perception) to 1.00 (maximum perception), maintaining proportional relationships between categories. The results of the visual analysis were expressed as percentages, while the results of the olfactory and gustatory analyses were expressed as the mean of the values obtained (minimum value of 0.20 and maximum of 1.00) for each criterion.

Table 2. Tasting sheet including visual, olfactory, and gustatory sensory descriptors.

Sensory Analysis Form		
Type of Analysis	**Criterion**	**Score**
Visual I—Clarity	Clear	
	Cloudy	

Table 2. *Cont.*

Sensory Analysis Form		
Type of Analysis	**Criterion**	**Score**
Visual II—Color	Lemon	
	Straw	
	Golden	
Olfactory I	Intensity	
Olfactory II—Fruity	Citrus	
	Tropical	
	Red fruits	
Olfactory III—Floral	White flowers	
	Violet	
	Lavender	
Olfactory IV—Vegetal	Herbs	
	Vegetables	
	Tobacco	
Olfactory V—Wood	Wood	
	Coffee	
	Spices	
Gustatory I	Sweetness	
	Acidity	
	Astringency	
	Body	
Gustatory II	Fruity	
	Floral	
	Vegetal	
	Wood	

2.7. Statistical Analysis

The statistical analysis of the data was performed using Minitab® software, version 20.3 (64-bit), considering a significance level of $p \leq 0.05$. Prior to the analysis of variance (ANOVA), the assumptions of normality and homogeneity of variances were evaluated using the Anderson–Darling test and Levene's test, respectively. A one-way ANOVA was applied to assess differences among formulations for each physicochemical parameter. A two-way ANOVA was used to evaluate the effects of formulation and storage time, as well as their interaction, on the analyzed variables. For sensory data, scores were obtained using an ordinal scale and subsequently normalized to facilitate comparison. Given the exploratory and consumer-oriented nature of the sensory evaluation, an ANOVA test was applied as an approximate method to identify general differences between samples. Nevertheless, these results should be interpreted with caution, as the data originate from untrained panelists and do not meet the strict assumptions of parametric analysis. When significant differences were detected, Tukey's post hoc test was used to identify pairwise differences between means, with a 95% confidence interval.

3. Results

3.1. Physicochemical Characterization of Fresh Strawberry and Its Extract

Fresh strawberries showed (Table 3) a total soluble solids (TSS) content of 8.1 ± 0.3 °Brix, corresponding to a coefficient of variation (CV) of 3.83%, indicating uniformity in the concentration of soluble solutes. The pH value (Table 3) was 3.6 ± 0.1, with a CV of 1.65%, demonstrating the high stability among the analyzed samples.

Table 3. Physicochemical characterization of fresh strawberries and their extract (mean, standard deviation—SD—and coefficient of variation—CV). Data consistency was assessed through the coefficient of variation (CV), allowing for the evaluation of experimental precision and sample homogeneity.

Samples	Physicochemical Parameters		Mean	SD	CV (%)
Fresh Strawberry (n = 4)	TSS (°Brix)		8.1	0.3	3.83
	pH		3.6	0.1	1.65
	Firmness (kg/cm^2)		2.4	0.1	5.09
	Mass (g)		15.1	0.1	0.86
	Moisture (%)		90.3	1.3	1.45
	Electrical conductivity (µS/cm)		12.2	0.6	5.25
	Mineral content (mg/kg)	K	226.5	2.3	1.02
		P	82.0	1.3	1.59
		Ca	49.3	0.7	1.46
		Fe	3.5	0.4	1.28
		Mn	23.5	0.4	1.62
		Cu	15.0	0.1	0.80
		Zn	4.3	0.0	0.71
Strawberry extract (n = 6)	TSS (°Brix)		12.7	0.2	1.42
	Density (g/cm^3)		0.9	0.0	0.65
	Sugar content (mg/100 mg)	Glucose	3.0	0.4	11.71
		Fructose	3.7	0.5	12.40
	Total fat (mg/g)		1.6	0.0	1.25

Firmness (Table 3) presented a mean value of 2.4 ± 0.1 kg/cm^2, with a CV of 5.09%, being the physical parameter with the highest relative variability in the fruit, possibly associated with natural structural differences between sample units. The average mass (Table 3) was 15.1 ± 0.1 g, with a CV of 0.86%, demonstrating high homogeneity in fruit size.

The moisture content was 90.3 ± 1.3%, with a CV of 1.45%, confirming the high water content characteristic of strawberries and indicating low dispersion between determinations (Table 3). Electrical conductivity showed a value of 12.2 ± 0.6 µS/cm, with a CV of 5.25% (Table 3), revealing some variation in dissolved ion concentration, though still within low variability limits.

Regarding the mineral profile (Table 3), potassium (K) was the predominant element (226.5 ± 2.3 mg/kg; CV = 1.02%), followed by phosphorus (P) (82.0 ± 1.3 mg/kg; CV = 1.59%) and calcium (Ca) (49.3 ± 0.7 mg/kg; CV = 1.46%). Among micronutrients, values of 34.5 ± 0.4 mg/kg for Fe (CV = 1.28%), 23.5 ± 0.4 mg/kg for Mn (CV = 1.62%), 15.0 ± 0.1 mg/kg for Cu (CV = 0.80%), and 4.3 ± 0.0 mg/kg for Zn (CV = 0.71%) were observed. The low relative variation for all minerals (CV < 2%) demonstrates high an-

alytical precision and indicates that the mineral composition of the analyzed batch was highly homogeneous.

The strawberry extract showed (Table 3) a total soluble solids (TSS) content of 12.7 ± 0.2 °Brix, with a CV of 1.42%, a value higher than that of the fresh fruit, reflecting the concentration of soluble compounds during the extraction process. Density was 0.9 ± 0.0 g/cm^3, with a CV of 0.65%, demonstrating the high physicochemical stability of the obtained extract (Table 3).

Regarding sugar content (mg/100 mg), glucose presented 3.0 ± 0.4 (CV = 11.71%) and fructose 3.7 ± 0.5 (CV = 12.40%) (Table 3). These were the parameters with the highest relative variability among all analyses, possibly associated with variations in extraction yield, differential sugar solubilization, or intrinsic matrix heterogeneity. Total fat content (Table 3) was relatively low (1.6 ± 0.0 mg/g), as expected for fruit-derived products, with a CV of 1.25%, indicating high precision in quantification.

Overall, the physicochemical parameters of fresh strawberries presented coefficients of variation predominantly below 5%, while in the extract most parameters showed CV values below 2%, except for sugars. Additionally, the extraction process increased the total soluble solids content while maintaining low variability in structural physicochemical parameters (density and fat), suggesting the stability of the obtained extract. The greater dispersion observed in sugars indicates that these compounds are more sensitive to processing or sampling variations.

Colorimetric analysis (Table 4), using the CIELab scale, showed that in the interior of the strawberries the L* parameter presented a value of 37.73 ± 2.22 (CV = 5.88%), indicating moderate variability. The a* parameter was 29.78 ± 3.01 (CV = 10.11%), being the most variable among the three coordinates. The b* value was 25.25 ± 3.88, with a CV of 15.37%, revealing greater relative dispersion in the yellow component. The presence of distinct letters in the interior column confirms significant differences among some parameters, reflecting structural differences in the relative contribution of luminosity and chromatic components. On the exterior of the strawberries, L* showed a value of 52.13 ± 2.70 (CV = 5.18%), demonstrating good homogeneity of surface luminosity. The a* parameter was 22.19 ± 1.71 (CV = 7.71%) and b* was 25.55 ± 1.64 (CV = 6.42%), both presenting moderate variability. Statistical analysis indicates significant differences among parameters within the same sample, revealing the predominance of luminosity relative to chromatic components on the fruit surface. Regarding the strawberry extract, the L* parameter indicated intermediate luminosity, reflecting a moderately dark tone consistent with the presence of natural pigments extracted from the fruit. The low coefficient of variation associated with this parameter (CV = 1.91%) demonstrates high homogeneity in terms of luminosity. The positive a* value confirms the predominance of the red component in the extract, characteristic of anthocyanin presence. However, the magnitude of this parameter was lower than that observed in the fresh fruit, suggesting the possible dilution or modification of red color intensity during the extraction process. The coefficient of variation was 10.63%, indicating moderate variability in this chromatic component. For the b* parameter, the positive value indicates the presence of yellow tones, although with lower intensity compared to the red component. The CV of 13.56% reveals greater relative dispersion in this coordinate, possibly associated with pigment sensitivity to processing conditions such as oxidation or pH variations. Overall, the strawberry extract exhibited predominantly red coloration, with stable luminosity and greater variability in chromatic components. These results indicate that the extraction process preserves the characteristic chromatic identity of strawberries, although with a relative reduction in color intensity and increased dispersion associated with pigments.

Table 4. Colorimetric parameters (CIELab scale and scanning spectrophotometry) of strawberry samples (interior and exterior) and the respective extract. Results are expressed as mean ± standard deviation (n = 4). Different letters in the same column (for CIELab scale or spectrophotometric scanning) indicate statistically significant differences ($p < 0.05$). Relative variability was assessed through the coefficient of variation (CV).

Colorimetric Parameters		Strawberry Interior			Strawberry Exterior			Strawberry Extract		
		Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)
CIElab Scale	L*	37.73 B	2.22	5.88	52.13 A	2.70	5.18	39.75 B	0.76	1.91
	a*	29.78 AB	3.01	10.11	22.19 A	1.71	7.71	16.18 B	1.72	10.63
	b*	25.25 A	3.88	15.37	25.55 A	1.64	6.42	10.92 B	1.48	13.56
Colorimetric Scanning Spectrophotometry (nm)	450	678.80 B	10.80	1.59	502.25 C	6.36	1.27	763.30 A	22.70	2.97
	500	625.00 B	11.20	1.79	447.00 C	5.21	1.17	702.80 A	22.70	3.23
	550	1143.50 A	6.60	1.45	748.00 C	2.48	0.33	964.50 B	19.40	2.01
	570	904.80 A	16.70	1.85	499.75 C	2.69	0.54	736.00 B	17.90	2.43
	600	1343.80A	23.60	1.76	817.80 C	13.00	1.59	980.00 B	15.60	1.59
	650	1634.80 A	33.60	2.06	1215.80 B	48.50	3.99	1204.80 B	18.30	1.52

Scanning spectrophotometry (Table 4) revealed, in the strawberry interior, a progressive increase in absorbance with wavelength. Values ranged from 678.80 ± 10.80 (CV = 1.59%) at 450 nm to 1634.80 ± 33.60 (CV = 2.06%) at 650 nm. CV values remained low at all wavelengths (between 1.45% and 2.06%), indicating high experimental precision. Statistical differences confirmed that higher wavelengths presented significantly greater absorbance, revealing a stronger presence of absorbing compounds in the red region. On the exterior of the strawberries, values also increased with wavelength, ranging from 502.25 ± 6.36 (CV = 1.27%) at 450 nm to 1215.80 ± 48.50 (CV = 3.99%) at 650 nm. Although the increasing trend was similar to that observed in the interior, the absolute values were lower, indicating lower overall absorption intensity. CV values remained below 4%, demonstrating good analytical reproducibility. In the strawberry extract, absorbance values were higher at 450 nm (763.30 ± 22.70; CV = 2.97%) and 500 nm (702.80 ± 22.70; CV = 3.23%), decreased at intermediate wavelengths, and increased slightly again at 650 nm (1204.80 ± 18.30; CV = 1.52%). The coefficients of variation ranged between 1.52% and 3.23%, indicating experimental stability. The statistical differences observed among wavelengths reveal that the spectral profile of the extract differs from that of the fresh fruit, with relatively greater intensity in the lower wavelength region.

Overall, the results demonstrate low experimental variability, with CV values generally below 6% in scanning spectrophotometry and below 16% in colorimetry. Greater chromatic heterogeneity was observed in the fruit interior, particularly in the b* component. Distinct spectral profiles between interior, exterior, and strawberry extract indicate that the structural matrix of the fruit significantly influences optical behavior. The combined analysis of CIELab parameters and spectrophotometric data shows that processing alters chromatic balance and absorption patterns, reflecting modifications in the distribution and/or stability of the compounds responsible for strawberry coloration. These parameters were used to ensure compositional homogeneity and suitability of the raw material for processing, thereby supporting the reproducibility of the extraction procedure.

3.2. Physicochemical Characterization of Grapes, Wine, and the Wine-Based Aromatized Beverage

The Moscatel grapes used in the winemaking process showed a TSS content of 19.25 ± 0.52 °Brix. Strawberry extract was then added to the produced wine (Table 5). After 10 days (T1), the control wine presented a pH of 4.09 ± 0.23 (CV = 5.62%). The

extract-containing formulations ranged from 3.92 ± 0.14 (CV = 3.57%, 8 g) to 4.16 ± 0.02 K (CV = 0.43%, 4 g). Lowercase letters indicate significant differences between some formulations, suggesting that extract concentration slightly influenced pH. After 20 days, the control showed a pH of 3.92 ± 0.00 (CV = 0.10%), while the remaining formulations ranged from 3.89 ± 0.03 (CV = 0.77%, 12 g) to 4.05 ± 0.11 (CV = 2.81%, 8 g). In general, CV values decreased at 20 days, indicating greater system stability during storage. Uppercase letters show that some formulations exhibited significant differences between 10 and 20 days, although the magnitude of variation was small.

Table 5. Physicochemical parameters of control wine (A1) and wine-based aromatized beverage with strawberry extract (A2, A3, A4, and A5, corresponding to the addition of 4, 6, 8, and 12 g of extract per 500 mL of wine, respectively), evaluated after 10 days (T1) and 20 days (T2) of storage. Results are expressed as mean ± standard deviation, including coefficient of variation (CV%). Statistical analysis was performed using analysis of variance (ANOVA), followed by multiple comparison testing ($p < 0.05$). For pH, Baumé degree, and density, different lowercase letters (a, b) indicate significant differences among formulations (0, 4, 6, 8, and 12 g) at the same storage time, while different uppercase letters (A, B) indicate significant differences between storage times (10 and 20 days) for the same formulation. For total soluble solids (TSS), the letter A indicates absence of significant differences among samples ($p < 0.05$).

Analytical Parameters	Time	Formulations														
		A1			A2			A3			A4			A5		
		Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)
pH	T1	4.09 aA	0.23	5.62	4.16 aA	0.02	0.43	4.10 aA	0.07	1.71	3.92 bA	0.14	3.57	3.93 bA	0.00	0.10
	T2	3.92 aB	0.00	0.10	3.92 aB	0.00	0.05	3.91 aB	0.00	0.05	4.05 aA	0.11	2.81	3.89 aA	0.03	0.77
Baumé degree (° Bé)	T1	0.63 aA	0.06	9.92	0.70 aA	0.04	5.71	0.68 aA	0.05	6.96	0.70 aA	0.04	5.71	0.83 aA	0.05	5.70
	T2	0.25 bB	0.03	11.20	0.40 abB	0.04	10.00	0.33 bB	0.05	14.46	0.38 abB	0.05	12.53	0.53 aB	0.03	4.76
Density (g/cm^3)	T1	0.999 aA	0.002	0.20	0.999 aA	0.001	0.10	1.000 aA	0.003	0.30	0.999 aA	0.001	0.01	1.001 aA	0.001	0.10
	T2	0.998 bA	0.000	0.00	0.998 bB	0.000	0.00	0.999 abA	0.000	0.00	0.999 abA	0.001	0.10	1.000 aB	0.000	0.00
TSS (°Brix)		4.65 A	0.45	9.68	4.60 A	0.18	3.91	4.10 A	0.05	1.22	3.80 A	0.08	2.11	4.10 A	0.12	2.93

Baumé degree showed a direct influence of extract addition (Table 5). After 10 days, the control presented 0.63 ± 0.06 (CV = 9.92%), while the 12 g treatment reached 0.83 ± 0.05 (CV = 5.70%). Intermediate formulations presented CV values between 5.71% and 6.96%. Significant differences between formulations (lowercase letters) confirm an increase in °Bé with extract incorporation. After 20 days, a general reduction in values was observed: the control showed 0.25 ± 0.03 (CV = 11.20%), while aromatized formulations ranged from 0.33 ± 0.05 (CV = 14.46%, 6 g) to 0.53 ± 0.03 (CV = 4.76%, 12 g). CV values were higher than those observed after 10 days, particularly in intermediate formulations, indicating greater variability after storage. Uppercase letters indicate significant differences between times for most treatments.

Density remained close to 1.000 g/cm^3 in all formulations (Table 5). After 10 days, values ranged between 0.999 ± 0.001 and 1.001 ± 0.001, with CV between 0.10% and 0.30%. After 20 days, values ranged between 0.998 and 1.000 g/cm^3, with CV values equal to or below 0.10%, including several cases of 0.00%. No significant differences were observed between formulations (lowercase letters) or between storage times (uppercase letters), demonstrating high structural stability of the wine after extract addition.

Total soluble solids (TSS) were globally evaluated in the formulations (Table 5). The control presented 4.65 ± 0.45 °Brix (CV = 9.68%). Formulations with extract ranged between 3.80 ± 0.08 (CV = 2.11%, 8 g) and 4.60 ± 0.18 (CV = 3.91%, 4 g), while the remaining treatments showed CV values of 1.22% (6 g) and 2.93% (12 g). Compared to the control, extract-containing treatments presented lower relative variability, indicating greater homogeneity in aromatized formulations. Lowercase letters indicate significant differences among some formulations, suggesting that extract concentration influenced the soluble solids content. A perfectly linear relationship between extract concentration and TSS was

not observed, although higher extract concentrations tended to present intermediate to higher values.

Comparative analysis between 10 and 20 days revealed that pH remained relatively stable during storage, with reduced variability after 20 days. The Baumé degree decreased after 20 days and exhibited greater relative variability at this time point. Density remained practically unchanged, demonstrating high physicochemical stability. TSS showed moderate variability, lower in extract-containing formulations compared to the control.

Overall, the incorporation of freeze-dried strawberry extract resulted in relevant compositional and technological modifications of the wine matrix. In particular, an increase in total and volatile acidity was observed, reflecting the contribution of organic acids from the fruit. A slight reduction in alcohol content was also detected, likely associated with a dilution effect. In addition, chromatic parameters indicated modulation of color due to the presence of strawberry-derived pigments. These changes were accompanied by low analytical variability after 20 days, indicating short-term system stabilization.

Comparative analysis of the white wine (A1) and the aromatized beverage with 6 g of strawberry extract (A3), using FTIR (Table 5), showed that density presented very similar mean values between samples (0.995 g/cm^3 for A1 and 0.996 g/cm^3 for A3), with CV values below 0.5%, demonstrating high instrumental repeatability. Volatile acidity was higher in the aromatized beverage (1.19 g/dm^3) compared to the white wine (0.89 g/cm^3), while maintaining high analytical precision (CV = 0.34% in both). Likewise, total acidity increased from 4.20 g/dm^3 (A1) to 5.10 g/dm^3 (A3), revealing the acidic contribution of the strawberry extract. CV values remained below 1%, confirming the robustness of the method. pH values were practically identical (4.38 in A1 and 4.37 in A3), with very low CV values ($\leq$0.23%), indicating high matrix stability after extract incorporation. Regarding glucose + fructose content, both formulations presented 3.90 g/L (CV = 0.51%), demonstrating that extract addition did not significantly alter the overall content of these sugars as quantified by FTIR. Malic acid showed a slight reduction in the aromatized beverage (0.59 g/dm^3) compared to the white wine (0.68 g/dm^3), with CV values below 0.5%. Overall, the parameters evaluated by FTIR showed coefficients of variation below 1%, indicating the high analytical precision and excellent repeatability of the method. Titration analysis of A1 and A3 (Table 6) revealed that free SO_2 increased from 21.00 mg/dm^3 (A1) to 28.00 mg/dm^3 (A3), possibly associated with technological adjustments following extract incorporation. Total SO_2 followed a similar trend (86.00 mg/dm^3 in A1 and 94.00 mg/dm^3 in A3). The coefficients of variation ranged between 1.10% and 1.95%, indicating good analytical precision, although were slightly lower than that observed for FTIR, as expected for volumetric methods. Ebulliometric analysis of alcoholic strength revealed a mean value of 7.10% (v/v) for the white wine and 6.90% (v/v) for the aromatized beverage (Table 6). This slight reduction may be associated with a dilution effect resulting from extract addition. CV values were low (1.27% and 1.01%), confirming adequate repeatability. Density values measured by aerometry at 25 °C and corrected to 20 °C showed minimal variation between formulations. The coefficients of variation ranged from 0.60% to 0.70%, indicating the high consistency of results. Overall, most parameters presented CV values below 2%, demonstrating high analytical precision and methodological robustness. The incorporation of 6 g of strawberry extract mainly resulted in increased volatile and total acidity and higher SO_2 content, as well as a slight reduction in alcoholic strength, without significant changes in density or pH. The low coefficients of variation reinforce the reliability of the applied methods and the homogeneity of the analyzed samples, supporting the comparative validity between the base white wine and the developed aromatized beverage.

Table 6. Analytical parameters determined (n = 4) in control wine (A1) and in the aromatized beverage with 6 g of strawberry extract (A3), after 10 days of storage. Results are expressed as mean ± standard deviation, including coefficient of variation (CV%). Determinations were performed by Fourier Transform Infrared Spectroscopy (FTIR and FOSS), titration, ebulliometry, and aerometry, according to the analyzed parameter.

Analytical Parameters	Formulations					
	A1			A3		
	Mean	SD	CV (%)	Mean	SD	CV (%)
	Method—FTIR (FOSS)					
Density—g/cm^3	0.995	0.004	0.40	0.996	0.003	0.30
Volatile acidity—g/dm^3	0.89	0.00	0.34	1.19	0.00	0.34
Total acidity—g/dm^3	4.20	0.03	0.71	5.10	0.04	0.78
pH	4.38	0.01	0.23	4.37	0.00	0.00
Glucose + Fructose—g/L	3.90	0.02	0.51	3.90	0.02	0.51
Malic acid—g/dm^3	0.68	0.00	0.44	0.59	0.00	0.34
	Method—Titration					
Free SO_2—mg/dm^3	21.00	0.41	1.95	28.00	0.53	1.89
Total SO_2—mg/dm^3	86.00	0.95	1.10	94.00	1.50	1.60
	Method—Ebulliometry					
Degree—% Volume	7.10	0.09	1.27	6.90	0.07	1.01
	Density—Hidrometry					
Measure—g/cm^3—Temp. 25 °C	0.995	0.007	0.70	0.995	0.007	0.70
Corrected—g/cm^3—Temp. 20 °C	0.996	0.006	0.60	0.997	0.007	0.70

Colorimetric parameter analysis after 10 days of storage, according to the CIELab scale (Table 7), revealed luminosity (L*) values ranging from 54.73 (A3) to 62.70 (A1). The a* parameter ranged between −1.89 (A1) and −1.24 (A5), while the b* parameter varied from 6.46 (A4) to 8.37 (A3). The coefficients of variation for L* ranged from 0.28% (A4) to 4.08% (A1). For a*, CV values ranged from 3.35% (A3) to 8.59% (A2), and for b* from 1.06% (A5) to 8.60% (A3). In the colorimetric analysis using scanning spectrophotometry (450–650 nm), mean values (Table 7) ranged from 1171.80 to 2050.80 absorbance units, depending on the formulation and wavelength. In A1, CV values reached 43.31% and 43.60% at 450 nm and 500 nm, respectively. In the remaining formulations, the coefficients of variation were below 5% at most wavelengths, with A4 and A5 showing particularly low values, generally below 1%. After 20 days of storage (Table 7), L* values ranged between 50.53 (A5) and 65.86 (A1). The a* parameter varied from −1.37 (A3) to −1.01 (A5), while b* ranged from 5.35 (A5) to 6.34 (A3). The coefficients of variation for CIELab parameters were below 1% in most formulations, with minimum values of 0.08% for L* (A1) and maximum values of 0.93% for b* (A5). In scanning spectrophotometry (Table 7), mean values ranged from 1189.50 to 2096.30 units depending on wavelength and formulation. The coefficients of variation were generally between 1% and 5%. Formulation A4 presented slightly higher values, reaching 6.08% at 570 nm.

Table 7. Colorimetric parameters, determined using the CIELab scale and scanning spectrophotometry, of the control wine (A1) and wine-based aromatized beverage with strawberry extract (A2, A3, A4, and A5, corresponding to the addition of 4, 6, 8, and 12 g of extract per 500 mL of wine, respectively), evaluated after 10 days (T1) and 20 days (T2) of storage (n = 4). Results are expressed as mean ± standard deviation, including coefficient of variation (CV%).

Colorimetric Parameters	Formulations														
	A1			A2			A3			A4			A5		
	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)	Mean	SD	CV (%)
T1 (10 dias after storage)															
CIElab Scale															
L*	62.70	2.56	4.08	58.97	2.21	3.75	54.73	1.69	3.09	58.08	0.16	0.28	57.63	2.12	3.68
a*	−1.89	0.12	6.35	−1.63	0.14	8.59	−1.79	0.06	3.35	−1.40	0.05	3.57	−1.24	0.06	4.84
b*	8.040	0.27	3.33	8.01	0.21	2.62	8.37	0.72	8.60	6.46	0.39	6.04	5.68	0.06	1.06
Colorimetric Scanning Spectrophotometry (nm)															
450	130.00	56.30	43.31	1232.00	24.70	2.00	1186.30	43.80	3.69	1406.00	9.26	0.66	1171.80	4.71	0.40
500	1458.30	63.70	43.60	1329.00	31.10	2.34	1284.50	45.40	3.53	1483.30	7.74	0.52	1197.50	5.01	0.42
550	2034.80	84.30	4.14	1856.50	55.40	2.98	1785.50	53.30	2.98	2050.80	5.65	0.28	1614.80	2.36	0.15
570	1502.30	69.80	4.65	1367.80	37.60	2.75	1319.00	47.40	3.59	1513.30	6.55	0.43	1197.50	4.44	0.37
600	1612.30	70.00	4.34	1475.50	41.00	2.78	1415.00	44.20	3.12	1611.00	4.42	0.27	1289.00	3.58	0.28
650	1679.80	65.30	3.89	1563.80	34.00	2.17	1516.00	42.40	2.80	1675.80	7.56	0.45	1406.80	4.87	0.35
T2 (20 dias after storage)															
CIElab Scale															
L*	65.86	0.05	0.08	58.62	0.05	0.09	57.84	0.10	0.17	65.09	0.07	0.11	50.53	0.41	0.81
a*	−1.28	0.00	0.23	−1.33	0.01	0.68	−1.37	0.01	0.73	−1.27	0.01	0.71	−1.01	0.00	0.20
b*	5.36	0.01	0.15	5.780	0.02	0.35	6.34	0.02	0.38	5.75	0.02	0.26	5.35	0.05	0.93
Colorimetric Scanning Spectrophotometry (nm)															
450	1435.30	74.20	5.15	1291.80	27.70	2.14	1189.50	33.50	2.82	1235.80	63.60	5.15	1218.00	25.20	2.07
500	1525.30	72.60	4.76	1365.00	26.70	1.96	1275.00	30.00	2.35	1306.30	75.20	5.76	1278.50	28.30	2.21
550	2096.30	51.20	2.44	1878.50	14.50	0.77	1804.80	18.60	1.03	1801.00	101.00	5.61	1771.30	38.30	2.16
570	1543.30	69.80	4.52	1379.80	22.80	1.65	1294.00	29.90	2.31	1329.50	80.86	6.08	1300.80	32.70	2.51
600	1637.00	56.60	3.46	1479.00	15.90	1.08	1399.50	24.50	1.75	1430.00	77.40	5.41	1404.30	31.40	2.24
650	1710.80	66.90	3.91	1568.80	24.90	1.59	1481.50	27.10	1.83	1524.30	71.20	4.67	1496.30	29.60	1.98

3.3. Sensory Analysis

Preliminary sensory evaluation results (Table 8) indicate that, at the visual level, parameter "Clarity", sample A1 was predominantly classified as "Clear" (76%), whereas sample A3 was mainly described as "Cloudy" (82%). Regarding color, A1 was primarily classified as "Lemon" (71%), while A3 was mostly described as "Straw" (53%). In the olfactory analysis (Table 8), concerning intensity, sample A1 presented a mean score of 0.63, while sample A3 obtained a higher mean of 0.74, indicating greater perceived aromatic intensity in the aromatized beverage. For fruity characteristics, sample A1 achieved a higher mean value for citrus notes (0.60), whereas sample A3 recorded the highest mean (0.72) for red fruit aroma, reflecting the influence of strawberry extract incorporation. In the floral criterion, the highest value in sample A1 was 0.24 for violet notes, while in sample A3 the highest value reached 0.30 for white flower aroma. Regarding the vegetal criterion (Table 8), sample A1 showed the highest score (0.24) for herbal notes, while sample A3 registered a slightly higher value (0.28), also in the herbal category. In the evaluation of Wood-related attributes, both samples received minimal scores, indicating negligible perception of Wood-derived aromas. Concerning gustatory analysis (Table 8), sample A3 was perceived as sweeter and more acidic compared to sample A1, while attributes such as body and astringency showed low relevance in both samples. In Gustatory Analysis II, both samples demonstrated a stronger tendency toward a fruity flavor. This pattern

may be associated either with an intrinsic characteristic of Moscatel white wine or with the incorporation of strawberry extract. The sensory results indicate that the incorporation of strawberry extract enhanced the perception of red fruit attributes and increased the overall aromatic intensity, supporting its contribution to sensory differentiation of the beverage. Nevertheless, these results should be interpreted as indicative of consumer perception trends rather than as a formal descriptive sensory characterization. In addition, due to the ordinal nature of the sensory data and the use of untrained panelists, the statistical results should be interpreted as indicative trends rather than definitive differences.

Table 8. Sensory analysis conducted with untrained panelists (n = 17; nine male and eight female participants) of control wine (A1) and the aromatized beverage with strawberry extract (A3), considering visual, olfactory, and gustatory descriptors. Different letters indicate statistically significant differences at a 95% confidence level. Lowercase letters (a, b) correspond to comparisons between different types of criteria within the same analysis and sample. Uppercase letters (A, B) correspond to comparisons of the same criterion between samples (A1 and A3).

Type of Sensory Analysis	**Visual Analysis**		
	Criterion	**Sample A_1**	**Sample A_3**
Visual I—Clarity	Clear	76%	18%
	Cloudy	24%	82%
Visual II—Color	Lemon	71%	12%
	Straw	29%	53%
	Golden	0%	35%
	OlfactoryOlfactory Analysis		
Olfactory I	Intensity	0.63 ± 0.03 a	0.74 ± 0.08 a
Olfactory II—Fruity	Citrus	0.60 ± 0.04 aA	0.25 ± 0.02 bB
	Tropical	0.36 ± 0.03 bA	0.32 ± 0.03 bB
	Red fruits	0.22 ± 0.01 bB	0.72 ± 0.05 aA
Olfactory III—Floral	White flowers	0.20 ± 0.00 aB	0.30 ± 0.03 aA
	Violet	0.24 ± 0.00 aA	0.25 ± 0.02 abA
	Lavender	0.20 ± 0.00 aA	0.20 ± 0.00 bA
Olfactory IV—Vegetal	Herbs	0.24 ± 0.03 aA	0.28 ± 0.02 aA
	Vegetables	0.20 ± 0.00 aB	0.25 ± 0.02 abA
	Tobacco	0.20 ± 0.00 aA	0.20 ± 0.00 bA
Olfactory V—Wood	Wood	0.20 ± 0.00 aA	0.20 ± 0.00 bA
	Coffee	0.20 ± 0.00 aA	0.20 ± 0.00 bA
	Spices	0.22 ± 0.01 aA	0.24 ± 0.02 aA
	Gustatory Analysis		
Gustatory I	Sweetness	0.47 ± 0.03 aB	0.58 ± 0.04 aA
	Acidity	0.55 ± 0.03 aA	0.64 ± 0.03 aA
	Astringency	0.28 ± 0.03 bA	0.31 ± 0.03 bA
	Body	0.34 ± 0.02 bA	0.30 ± 0.02 bA
Gustatory II	Fruity	0.55 ± 0.03 aB	0.69 ± 0.04 aA
	Floral	0.25 ± 0.02 bA	0.29 ± 0.03 bA
	Vegetal	0.27 ± 0.02 bA	0.25 ± 0.02 bA
	Wood	0.20 ± 0.00 bA	0.00 bA

4. Discussion

The TSS values (≈8 °Brix) observed in fresh strawberries fall within the lower to intermediate range reported for mature commercial cultivars (7–12 °Brix), depending on variety and edaphoclimatic conditions [11,21]. Compared to studies conducted on Mediterranean cultivars, where values may exceed 9–10 °Brix, the results obtained here suggest adequate but not excessive technological maturity. This condition may be advantageous from an industrial perspective, as it avoids over-ripening, which often compromises structural integrity and postharvest stability [22]. The recorded pH (≈3.6) is also consistent with values described for strawberries (3.3–3.8) [23]. This range is particularly relevant for anthocyanin stability, as the flavylium form is favored under acidic conditions [14]. Comparative studies indicate that small pH variations may cause significant changes in color intensity, especially after thermal or mechanical processing [15]. Thus, the observed pH constitutes a positive factor for maintaining chromatic quality in the extract. Firmness showed moderate variability. Compared with literature reporting high textural heterogeneity in manually harvested fruits [22], the present results indicate relative physiological uniformity, although pectin degradation may influence subsequent turbidity and sedimentation.

The increase in TSS in the extract confirms the concentration of soluble compounds, a phenomenon widely described in fruit maceration and grinding processes [12]. However, the relatively high variability observed in sugars (CV ≈ 12%) contrasts with studies where controlled extractions present CV values below 5% [22], suggesting matrix heterogeneity. From a biochemical perspective, cellular disruption promotes interaction between oxidative enzymes and phenolic substrates. Although oxidation markers (e.g., browning index or total phenols) were not measured, the modification of the chromatic profile suggests possible polyphenol oxidase activity [24]. Compared with studies employing antioxidant treatments or atmospheric control, the absence of specific oxidative control measures may represent a technological limitation. Nevertheless, the stability of density and lipid fraction indicates absence of significant colloidal instability, suggesting that the process did not induce relevant macromolecular aggregation.

Considering that anthocyanins are highly sensitive to pH, temperature, and SO_2 presence [8,14], the incorporation of the extract into the wine matrix resulted in changes in the spectral profile, suggesting the structural reorganization of pigments. In red wines, copigmentation with flavonols and tannins can enhance color intensity and stability [9,15]. However, the base matrix here is white wine, which is poor in anthocyanins. Therefore, interaction between strawberry pigments and wine phenolic compounds may have been limited, potentially explaining the relative reduction in red intensity. Compared to beverages aromatized with anthocyanin-rich extracts (e.g., berries), where sustained increases in color intensity are observed [16], the present results suggest moderate chromatic modulation, without significantly altering the visual identity of the white wine.

The increase in total acidity after extract addition aligns with the introduction of organic acids from strawberries, mainly citric and malic acids. Comparative studies in aromatized beverages report similar behavior, with increases proportional to extract concentration [25]. However, the relative stability of pH following extract incorporation suggests a buffering capacity of the wine matrix [8]. This effect can be attributed to the presence of potassium salts, particularly potassium bitartrate, which participate in acid–base equilibria and contribute to pH regulation. In addition, organic acids in wine exist in dissociated and undissociated forms, and their equilibrium shifts in response to compositional changes, mitigating abrupt pH variations. Although white wines such as Moscatel contain lower concentrations of phenolic compounds compared to red wines, these compounds may still contribute to buffering through weak acid–base interactions. Consequently, the addition

of strawberry-derived organic acids increased total acidity without inducing proportional changes in pH, reflecting the intrinsic buffering behavior of the wine system.

The slight reduction in alcoholic strength is consistent with a dilution effect associated with the incorporation of freeze-dried strawberry extract. Although the extract is added in solid form, its dissolution contributes to non-volatile components (e.g., sugars, organic acids, and other soluble solids), effectively increasing the total mass of the system and reducing the relative proportion of ethanol. This effect is proportional to the amount of extract incorporated and was more evident at higher concentrations. In addition, small variations in ethanol content may influence the solubility and partitioning of aromatic compounds, particularly esters, which are sensitive to ethanol concentration. A reduction in ethanol can decrease ester solubility in the liquid phase and promote their release into the headspace, potentially enhancing the perception of fruity aromas observed in the sensory analysis [25]. Sensory studies demonstrate that small variations in alcohol content can alter perception of body and aromatic intensity [17].

The increase in total and free SO_2 is technologically justified as an antioxidant strategy. However, free SO_2 is also known to interact with anthocyanins, leading to the formation of colorless anthocyanin–bisulfite adducts. This reversible reaction reduces the concentration of the flavylium cation form responsible for red coloration, thereby decreasing color intensity. In the present study, the increase in free SO_2 following extract incorporation may have contributed to the observed attenuation of red chromatic components (Table 7), despite the presence of strawberry-derived pigments [8]. This effect is particularly relevant in white wine matrices, where the limited availability of copigmentation cofactors may further reduce pigment stabilization.

The reduction in analytical variability at 20 days suggests system stabilization. In wine systems, phenolic polymerization and controlled oxidation reactions contribute to chromatic stabilization [9]. However, compared to accelerated aging studies, where progressive increases in color intensity and polymeric pigment formation are observed, the 20-day period is relatively short, which may explain the moderate changes detected.

Overall, the observed preliminary physicochemical stability suggests that the aromatized beverage presents short-term oxidative stability.

The sensory results confirm greater fruity intensity in the aromatized beverage, consistent with the incorporation of volatile compounds from strawberries. Studies on Moscatel wines report the presence of terpenes (e.g., linalool and geraniol) contributing to floral profiles [25]. The interaction between these compounds and strawberry esters may generate a synergistic aromatic effect. Compared to commercial aromatized beverages, which often show acid–sweet imbalance or excessive turbidity, the preliminary structural stability observed here constitutes a positive indicator of technological quality.

When compared to other aromatized wine-based beverages, such as sangria or vermouth, the system evaluated in this study presents distinct physicochemical behavior. Sangria typically involves the addition of fresh fruit or fruit juices, which can introduce higher variability in sugar content, microbial load, and turbidity, often leading to less stable systems over short storage periods. Vermouth, on the other hand, is produced through the addition of botanical extracts and often includes fortification, resulting in higher alcohol content and greater oxidative stability. In contrast, the use of freeze-dried strawberry extract in a white wine matrix allows for a more controlled incorporation of fruit-derived compounds, with limited impact on structural parameters such as pH and density, while still enabling modulation of acidity, color, and aroma. This controlled behavior may contribute to improved short-term stability and reproducibility compared to more heterogeneous aromatized wine products.

5. Limitations

This study acknowledges certain limitations, including the relatively short storage period (20 days), the absence of microbiological analyses, and the limited size and untrained nature of the sensory panel. Additionally, more specific compositional analyses related to pigment behavior and oxidative stability—such as total anthocyanin content, total phenolics, antioxidant capacity, and browning index—were not performed. These parameters would provide a more comprehensive understanding of pigment-related mechanisms and their interaction with the wine matrix. As a result, the interpretation of chromatic evolution and pigment-related interactions is based on indirect evidence derived from colorimetric and physicochemical data. While the observed trends are consistent with known mechanisms in wine systems, the absence of direct measurements limits a more detailed mechanistic interpretation of these processes. Furthermore, some analyses conducted on the raw material, including mineral composition, electrical conductivity, and total fat, were primarily intended to assess compositional uniformity and technological suitability of the fruit matrix, rather than to directly address the central research question. Additionally, the sensory analysis was based on a limited number of untrained panelists and should therefore be interpreted as a preliminary consumer-oriented assessment rather than a comprehensive descriptive evaluation.

6. Conclusions

The results of this study demonstrate that the incorporation of freeze-dried strawberry extract into a white wine matrix is a feasible approach for developing a wine-based flavored beverage with modified physicochemical and sensory properties. The addition of the extract led to increased total and volatile acidity, a slight reduction in alcohol content, and measurable chromatic modulation associated with strawberry-derived pigments, without compromising the short-term physicochemical stability of the system. The analytical results indicated low variability for most parameters after 20 days of storage, suggesting the consistency of the beverage under the tested conditions. Sensory evaluation, conducted as a preliminary consumer-oriented assessment, showed enhanced aromatic intensity and increased perception of red-fruit attributes in the formulation containing 6 g of extract. Overall, the findings support the potential of freeze-dried fruit extracts as ingredients supporting the diversification of wine-based beverages, enabling the controlled modulation of their composition and sensory profile within a short storage period. Future work should address longer-term stability, including turbidity evolution and sedimentation behavior, as well as detailed phenolic and anthocyanin characterization, oxidative stability, and the use of trained sensory panels to provide a more robust evaluation of sensory attributes.

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Institutional Review Board Statement: According to the provisions of Decree-Law No. 80/2018, Law No. 21/2014, and Law No. 58/201, ethical approval is required for clinical trials with medicinal products, clinical studies involving medical devices, medical experiments or interventions, psychological or behavioral studies involving participants, and trials involving new therapies or clinical techniques. The sensory assessment does not fall within any of these categories; it is non-invasive and poses minimal risk. Therefore, ethical approval is waived.

Informed Consent Statement: Verbal informed consent was obtained from the participants. Verbal consent was obtained rather than written because, as stated before the sensory assessment does not fall within any health or other risk for humans.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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