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FORTIFICATION OF WHEAT FLOUR TYPE 000 WITH GRAPE POMACE POWDER. CHEMICAL AND SENSORY ASPECTS

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ABSTRACT

The most promising and high-value-added direction for winery by-products is their reintegration into food matrices intended for human consumption as powders.
The study of the behavior of the composite made of wheat flour type 000 and grape pomace powder, a by-product of the Cabernet Sauvignon grape variety, is both important and complex in the food industry. Type 000 flour is a refined white flour that is nutritionally poor due to the removal of the grain's outer bran layers during milling. The addition of grape pomace powder at different concentrations (5, 10, 15, and 20 %) fortifies the flour composite by enriching it with polyphenolic compounds (total polyphenols and anthocyanins) with a proven role in human health. Qualitative parameters (moisture, acidity) that can influence the technological and sensory aspects of the composite are also studied.

INTRODUCTION

Processing 1,000 kg of Cabernet Sauvignon grapes yields approximately 750 L of wine and 130 kg of grape pomace, representing 20-25% of the total grape mass (Oliveira et al., 2016; Yang et al., 2022).

From a chemical standpoint, grape pomace is an extremely complex matrix. It contains substantial amounts of insoluble (cellulose, hemicellulose) and soluble (pectins) dietary fibres, proteins, mineral salts, and, in particular, phenolic compounds (Almanza-Oliveros et al., 2024; Căpruciu et al., 2026). In the case of red grapes, such as Cabernet Sauvignon, the pomace retains substantial amounts of pigmented anthocyanins, hydroxycinnamic acids, flavonols, and catechins that were not fully extracted during the maceration-fermentation phase (Delić et al., 2024, Castro et al., 2025).

Grape pomace, a by-product of the wine industry, is increasingly used as a functional and sustainable ingredient in the food and nutraceutical industries due to its high fiber and polyphenol content (Baldan et al., 2023; Costa-Pérez et al., 2024; García-Lomillo & González-San José, 2025). It enhances the nutritional profile and quality of various food products, transforming them into functional foods with antioxidant and anti-inflammatory properties, despite challenges associated with sensory modification of the final products (Ozcan et al., 2024; Santos et al., 2024).

Concentrated extracts obtained from red grape pomace provide a safe and sustainable alternative to artificial colorants. Anthocyanins extracted from the skins

yield stable red-violet shades in food environments with controlled acidity and simultaneously act as natural preservative agents by inhibiting free radicals and reducing oxidative degradation (Giugea et al., 2019; Muntean & Pîrnă, 2025, Martin & Silva, 2025).

Cabernet Sauvignon pomace delivers a massive contribution of phenolic compounds, particularly condensed tannins. These compounds chemically interact with the gluten in type 000 flour through hydrogen bonds and hydrophobic interactions (Arfaoui, 2021, Lou et al.,2021, Cichi et al., 2024).

Incorporating grape pomace powder into refined flours (such as type 000 flour) represents an effective strategy to remedy the fiber and antioxidant deficiency in the modern diet (Santos et al., 2024).

The purpose of this study is to observe, through a qualitative analysis, the behavior of grape pomace powder in contact with flour, as well as how the proportioned addition of grape pomace powder influences the chemical and sensory quality of the final composite.

MATERIAL AND METHODS

Material

The grape pomace used in this study was obtained from the vinification of Cabernet Sauvignon grapes (2025 harvest) at the winery of the Banu Mărăcine Didactic Station, Dolj, Romania. The commercial white wheat flour type 000 was purchased from the local market.

To prepare the laboratory samples, the grape pomace powder and the composite flour samples—consisting of type 000 flour blended with different percentages of grape pomace powder (5, 10, 15, and 20 %)—were prepared as follows: T_{CS} - control grape pomace sample; F_{000} - control flour sample; FT_5 - composite flour sample with 5 % grape pomace addition (5 % grape pomace + 95 % flour); FT_{10} - composite flour sample with 10% grape pomace addition (10% grape pomace + 90 % flour); FT_{15} - composite flour sample with 15 % grape pomace addition (15 % grape pomace + 85 % flour); FT_{20} - composite flour sample with 20 % grape pomace addition (20 % grape pomace + 80 % flour) (Figure 1.3).

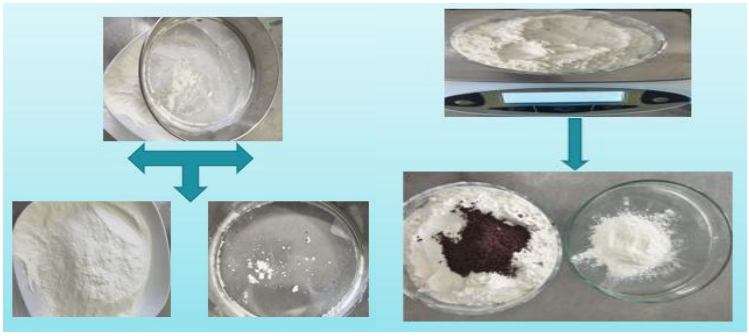
The production of the Cabernet Sauvignon grape pomace powder was carried out according to the following stages:

- Stalk fragments and leaves were removed to prevent the development of a harsh astringent or herbaceous taste.
- The primary objective was to reduce the moisture content from over 60% down to 8 %, enabling the milling of the pomace into powder and ensuring its shelf-life stability.
- The dried pomace was cooled to room temperature without separating its components; seeds were retained to enhance the nutritional value of the type 000 flour, in addition to its sensory attributes.
- The dried grape pomace was processed in a disc mill until a small particle size (fine powder) was achieved.
- The fine grape pomace powder was passed through a stainless-steel sieve to ensure sample uniformity. This process yielded a fine, deep purple powder (characteristic of the Cabernet Sauvignon variety), with a distinctive wild-berry and wine aroma and a slightly sour, astringent taste.
- The powder was immediately packed into opaque, airtight containers and stored in a cool, dry place (Figure 1.1).



Figure 1.1 Drying of grape pomace and production of grape pomace powder (T_{CS})

To prepare the composite flour samples, the control flour sample was first weighed (Figure 1.2 a), from which a predetermined percentage of wheat flour was replaced with grape pomace powder (Figure 1.2 b), resulting in composite flour samples with 5, 10, 15, and 20 % addition (Figure 1.3).



a b

Figure 1.2 Procedure for preparing the control flour sample (F_{000}) - a and the composite flour sample – b



FT_5 FT_{10} FT_{15} FT_{20}

Figure 1.3 Composite flour samples

Methods

Total polyphenol content (TPC)

The total phenolic content (TPC) was determined using the Folin–Ciocalteu colorimetric method (Pascoal et al., 2022). The samples were incubated in the dark at room temperature for 60 minutes, after which the absorbance was measured at 765 nm using a UV-Vis spectrophotometer (T70+ UV/VIS Spectrophotometer). The phenolic content was calculated as gallic acid equivalents (GAE), and quantification

was performed using a standard calibration curve derived from diluted gallic acid solutions ranging from 0 to 5 mg/L.

Total Anthocyanin Content (TAC)

The total anthocyanin content (TAC) of the composite flour samples was estimated using a method adapted from Yang & Kilmartin (2025). The samples were prepared according to the analytical protocol and filtered prior to measuring the absorbance at 540 nm using a UV-Vis spectrophotometer (T70+ UV/VIS Spectrophotometer), against a blank (acidified ethanol). The total anthocyanin content (TA), expressed in mg/100g of GP, was calculated using the following equation:

$TA = A \times D \times 16.17$, where: A= sample absorbance, D= dilution factor, and 16.17 = conversion factor corresponding to malvidin equivalents.

Moisture and Total Acidity

Moisture content and dry matter were determined by oven-drying the samples at 103 °C until a constant weight was reached, thereby removing water by thermal heating. The determination of total acidity was carried out using the titrimetric method in the presence of phenolphthalein as an indicator, with the results expressed as a percentage of citric acid (%).

Sensory Evaluation

Sensory profiling (covering overall appearance, taste, color, and odor) was conducted on the four composite flour samples prepared by substituting wheat flour with finely ground grape pomace powder at substitution levels of 5 %, 10 %, 15 %, and 20 %, respectively. The sensory evaluation was carried out by a panel of 10 pre-trained and selected assessors (students aged between 20 and 30 years). Testing was performed under standardised laboratory conditions in accordance with current methodological guidelines, following a comprehensive briefing of the panel regarding the evaluation protocol. A 9-point hedonic scale (ranging from 1 = 'dislike extremely' to 9 = 'like extremely') was employed to determine the acceptability of the selected attributes. For data visualization and graphical analysis, the mean scores obtained for each sample were utilized.

Statistical Analysis

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The data used in the statistical evaluation (simple linear regression) were obtained through analytical replication, which consisted of measuring the moisture content and acidity three times from the same sample.

RESULTS AND DISCUSSIONS

Following the chemical analysis of the control samples (T_{CS} and F_{000}) and the composite samples (FT_5, FT_{10}, FT_{15}, FT_{20}), the values obtained are presented in Figure 1.4 and Table 1.1.

It can be observed that the partial replacement of white wheat flour with grape pomace powder directly influences the chemical properties of the composite blends. Consequently, the moisture content of the composite flours decreases as the percentage of added grape pomace increases, leading to a gradual reduction in overall moisture. A similar conclusion was reached by Marcos et al. (2023), who evaluated different substitution levels of grape pomace powder (5 %, 10 %, and 15

% of the flour mass). To assess the effect of this addition, they analysed the physical properties, nutritional composition, and sensory acceptability of the products.

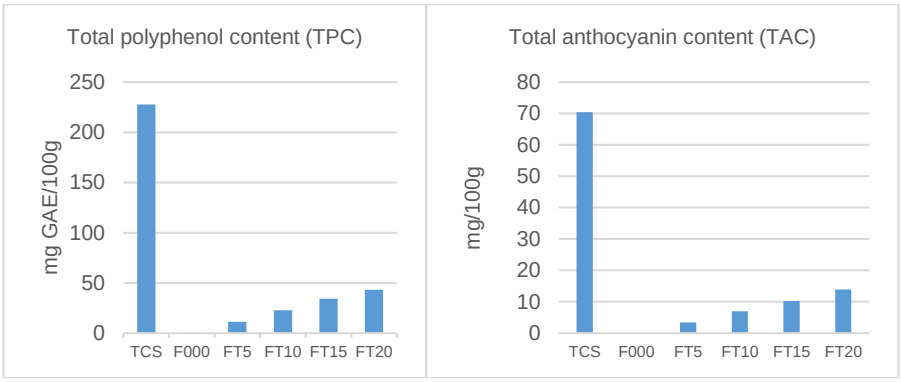


Figure 1.4 Total Polyphenol and anthocyanin content

Table 1.1

Chemical characteristics of grape pomace, flour, and composite samples

Chemical characteristics	Samples					
	T_{CS}	F_{000}*	FT_5	FT_{10}	FT_{15}	FT_{20}
Moisture content (%)	7.51	12.20	10.03	9.94	9.34	9.20
Total acidity (%)	3.80	2.10	2.25	2.40	2.55	2.70

**Note: Flour acidity is expressed in degrees of acidity (°), representing the number of millilitres of 0.1 N sodium hydroxide (NaOH) solution required to neutralise the acids in 100 g of product.*

The linear regression analysis (Figure 1.4) reveals a negative (inversely proportional) correlation between moisture content and acidity, which is directly influenced by the increasing proportion of added pomace (from the control F000 to the 20 % pomace addition FT20).

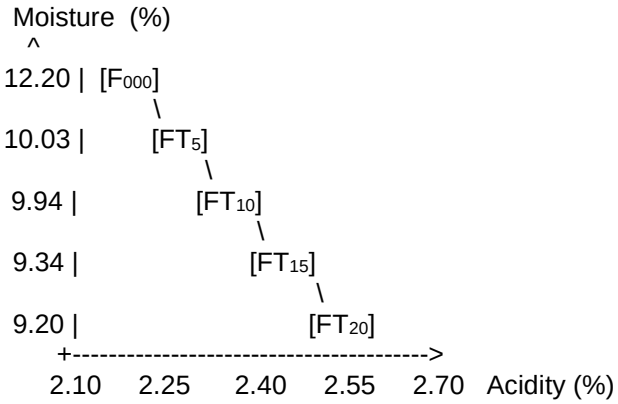


Figure 1.4 Regression line established between moisture content and acidity

A progressive decrease in moisture content is observed as the pomace concentration increases, from a maximum of 12.20 % (F000) to a minimum of 9.20 % (FT20), a decrease linearly correlated with an increase in acidity from 2.10° to 2.70°. The resulting regression line shows that the variation in moisture can be directly explained by the dynamics of acidity resulting from the addition of pomace powder, leading to the conclusion that adding pomace significantly and controllably modifies certain properties of the final product.*Sensory Analysis of Type 000 Wheat Flour Enriched with Cabernet Sauvignon Grape Pomace*

To accurately evaluate the impact of adding grape pomace (5 %, 10 %, 15 %, and 20 %) on the sensory profile of the composite flours, a rigorous protocol is necessary. In this regard, the taste intensity, aroma, and color of samples FT_5, FT_{10}, FT_{15}, and FT_{20} were determined in comparison with the control (F_{000}). Finally, the overall acceptability of the new composite product was evaluated by consumers.

Regarding color, a progressive score increase was observed, ranging from 6 (F_{000}) up to 9 (FT_{20}). This indicates that the panellists appreciated the reddish shades imparted by the natural pigments in grape pomace (anthocyanins), which give the flour an attractive visual appearance (Figure 1.5). Similarly, the aroma scores evolved from 8 to 9 for the higher concentrations (FT_{15}, FT_{20}). The grape pomace adds pleasant, fruity aromatic notes characteristic of grapes, which enrich the plain olfactory profile of standard white flour. The conclusion for this parameter is that the composite's aroma improves with increasing grape pomace content. Conversely, a different evaluation pattern was observed among the samples regarding taste and astringency. While FT_5 and FT_{10} received a score of 8 for taste, the score decreased to 6 for FT_{15} and reached 5 for FT_{20}. This decline confirms that the accumulation of organic acids and tannins at doses exceeding 15% produces a sour taste and a drying sensation (astringency) in the mouth, which by some panellists find more difficult to tolerate.



Figure 1.5 Sensory analysis of composite flour samples compared to the control sample

Although sample FT_{15} exhibited a decrease in its taste score (to 6), its overall acceptability remained constant at 8, identical to both the control sample and those with lower addition levels. This demonstrates that the improvements in color and aroma partially compensates for the sour note perceived in terms of taste.

Furthermore, at a 20% addition level, overall acceptability dropped to 7. Although this remains a favourable score on most hedonic scales, the decline is driven by a score of 5 for taste, indicating that the 20 % grape pomace threshold alters the overall sensory balance of the composite flour.

CONCLUSIONS

The addition of grape pomace powder to type 000 flour leads to a progressive, linear decrease in the moisture content of the composite mixtures. Concurrently, as the percentage of grape pomace in the flour replacement increases, the acidity levels of the composite samples rise steadily.

The grape pomace powder in the flour composite serves as a direct vector for enriching the flour with bioactive compounds.

From a sensory perspective, sample FT_{10} exhibits the best hedonic balance for color, enhancing the appearance of the composite without negatively affecting taste or overall acceptability. Sample FT_{15} can be utilised when a higher nutritional intake of antioxidants is targeted. High concentrations (such as FT_{20}) develop sensory defects related to astringency and acidity.

The utilisation of grape pomace-blended flour is an innovative and effective strategy for the modern food industry, successfully combining consumer demand for functional foods rich in antioxidants with global circular-economy requirements.

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