Development of Rose Wine and Evaluation of Its Physicochemical Properties and Bioactive Profile Using FTIR Spectroscopy

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***Abstract*—The present study investigates the quality characteristics and functional group composition of rose wine prepared using fresh rose petals, sugar, water, and Saccharomyces cerevisiae as the fermenting agent. Fermentation was carried out under controlled conditions, and the resulting wine was analyzed using Fourier Transform Infrared (FTIR) spectroscopy to identify major biochemical constituents and evaluate the chemical changes occurring during fermentation. The FTIR spectrum displayed characteristic absorption bands corresponding to O–H stretching (3265 cm^{-1}), C–O stretching of alcohols and esters (1058–1256 cm^{-1}), C=C stretching of phenolic compounds (1636 cm^{-1}), and C–H bending and aromatic ring vibrations (1345–1423 cm^{-1}). These peaks confirm the presence of ethanol, phenolic antioxidants, organic acids, esters, and residual sugars in the final wine product. The spectral profile highlights the successful conversion of sugars into ethanol while retaining essential bioactive compounds from rose petals. Overall, the findings demonstrate that FTIR is an effective tool for characterizing fermentation-derived chemical changes and assessing the quality and functional properties of rose wine.**

***Index Terms*—Rose wine; Fermentation; Saccharomyces cerevisiae; FTIR spectroscopy; Phenolic compounds; Functional groups.**

I. INTRODUCTION

Fruit and floral wines represent an emerging segment in the beverage industry due to increasing consumer demand for novel, functional, and antioxidant-rich alcoholic drinks. Among floral substrates, rose petals (Rosa spp.) are of particular interest because of their pleasant aroma, high phenolic content, and reported health-promoting properties such as antioxidant, anti-inflammatory, and antimicrobial activities. Traditionally used in perfumery, herbal medicine, and culinary preparations, rose petals have recently gained attention as a promising raw material for value-added fermented beverages [1].

Wine fermentation is a complex biochemical process involving the conversion of fermentable sugars into ethanol and carbon dioxide by yeast, accompanied by the formation of secondary metabolites such as organic acids, esters, higher alcohols, and phenolic derivatives [2]. These compounds significantly influence the sensory quality, stability, and functional attributes of wine. Therefore, comprehensive characterization of the chemical composition of novel wines is essential to assess their quality and potential health benefits.

Fourier Transform Infrared (FTIR) spectroscopy is a rapid, non-destructive, and cost-effective analytical technique widely used for qualitative and semi-quantitative analysis of food and beverage matrices [3]. FTIR provides information on functional groups and molecular interactions, making it suitable for monitoring fermentation progress and identifying major constituents such as alcohols, acids, sugars, and phenolic compounds [4]. Compared to conventional chromatographic techniques, FTIR offers simplicity and minimal sample preparation while delivering reliable compositional insights.

The present study aims to develop rose wine using fresh rose petals and to evaluate its chemical characteristics using FTIR spectroscopy. The work focuses on identifying key functional groups formed during fermentation and assessing the retention of bioactive compounds from rose petals in the final wine product.

II. MATERIALS AND METHODS

A. Materials

Fresh rose petals (Rosa spp.) were collected from fully bloomed, pesticide-free flowers grown under natural conditions. The petals were manually separated from the calyx and thoroughly washed with distilled water to remove surface dust and adhering impurities. Analytical-grade sucrose was used as the fermentable carbohydrate source. Active dry yeast (Saccharomyces cerevisiae) was procured commercially and used as the fermenting microorganism. Distilled water was used throughout the experiment. All chemicals and reagents employed in the study were of analytical grade.

B. Preparation of Rose Petal Extract

Approximately 200 g of fresh rose petals were finely chopped and mixed with 1 L of distilled water in a stainless-steel vessel. The mixture was gently heated at 60–65 C for 20 min to enhance the extraction of pigments, aroma compounds, and phenolic constituents from the petals. After extraction, the mixture was allowed to cool to room temperature and filtered through muslin cloth to remove solid residues. Sucrose was added to the filtrate to adjust the total soluble solids to 20–22 Brix, measured using a hand refractometer. The prepared rose must be transferred into a sterilized fermentation flask for further processing.

C. Yeast Inoculation and Fermentation

Active dry yeast (Saccharomyces cerevisiae) was activated by suspending 1 g of yeast in 50 mL of lukewarm distilled water (35–37 C) containing a small amount of sucrose and allowed to stand for 15 min. The activated yeast culture was then inoculated into the rose must at a concentration of 0.1% (w/v) [5].

Fermentation was carried out under anaerobic conditions at 28 ± 2 C for 10–12 days. The fermentation vessel was fitted with an airlock to allow the release of carbon dioxide while preventing external contamination. The progress of fermentation was monitored daily by observing CO_2 evolution and periodic measurement of Brix. Fermentation was considered complete when no further decrease in Brix was observed.

D. Clarification and Stabilization of Wine

Upon completion of fermentation, the fermented rose wine was filtered using Whatman No. 1 filter paper to remove yeast cells and suspended solids. The clarified wine was allowed to stabilize at 4 C for 48 h to facilitate sedimentation of fine particulates. The clear supernatant was carefully decanted and stored in airtight glass bottles under refrigeration until further analysis.

E. Physicochemical Analysis

The pH of the rose wine was measured using a calibrated digital pH meter. Total soluble solids (Brix) were determined using a refractometer. The alcohol content was estimated using standard distillation and hydrometry methods. These parameters were used to assess the quality and fermentation efficiency of the rose wine

F. FTIR Spectroscopic Analysis

Fourier Transform Infrared (FTIR) spectroscopy was employed to characterize the functional groups and chemical constituents present in the rose wine. FTIR analysis was performed using an FT-IR spectrometer (Cary 630 FTIR with Diamond ATR from Agilent Technologies, USA) operating in the mid-infrared region of 4000–600 cm^{-1}.

Prior to analysis, the wine sample was brought to room temperature and homogenized gently. A small aliquot of the sample was placed directly on the ATR crystal/sample holder, and spectra were recorded at room temperature with an appropriate number of scans to improve signal-to-noise ratio. The obtained spectra were analyzed to identify characteristic absorption bands corresponding to alcohols, phenolic compounds, organic acids, esters, and residual sugars.

III. RESULTS AND DISCUSSION

A. Physicochemical Characteristics of Rose Wine

The physicochemical properties of the fermented rose wine were analyzed to evaluate fermentation efficiency, chemical stability, and overall product quality. The key parameters assessed included pH, total soluble solids (Brix), alcohol content, and titratable acidity, as summarized in Table 1.

The pH of the fermented rose wine was recorded as 3.62 ± 0.04, indicating a mildly acidic nature. Such acidity is desirable in wine as it enhances microbial

stability, inhibits spoilage organisms, and contributes to a balanced sensory profile. The obtained pH value falls within the typical range reported for fruit and floral wines, confirming appropriate acid development during fermentation [6].

The total soluble solids (TSS) of the rose must initially adjust to 21.0 ± 0.3 Brix decreased significantly to 6.2 ± 0.2 Brix after fermentation. This substantial reduction in Brix confirms the effective utilization of fermentable sugars by Saccharomyces cerevisiae and indicates efficient conversion of sugars into ethanol and carbon dioxide. The residual Brix may be attributed to non-fermentable sugars and soluble phenolic compounds extracted from rose petals [7].

The alcohol content of the final rose wine was determined to be 9.1 ± 0.3% (v/v). This alcohol level is characteristic of low-to-moderate alcoholic floral wines and is sufficient to impart desirable sensory attributes while ensuring product stability [8]. The alcohol concentration correlates well with the prominent O–H and C–O stretching vibrations observed in the FTIR spectrum, confirming successful alcoholic fermentation.

The titratable acidity, expressed as tartaric acid equivalents, was measured as 0.68 ± 0.02% (w/v). Balanced acidity is crucial for the freshness, taste, and overall acceptability of wine. The observed acidity level contributes to a pleasant sensory profile without excessive sourness and supports the stability of the fermented product [8].

Table 1 Physicochemical Properties of Rose Wine

Parameter	Value
pH	3.62 ± 0.04
Initial TSS (Brix)	21.0 ± 0.3
Final TSS (Brix)	6.2 ± 0.2
Alcohol content (% v/v)	9.1 ± 0.3
Titratable acidity (% w/v, as tartaric acid)	0.68 ± 0.02

B. FTIR Spectral Interpretation of Rose Wine

The FTIR spectrum of the fermented rose wine as shown in Figure 1, reveals distinct absorption bands corresponding to alcohols, phenolic compounds, organic acids, esters, and residual sugars, confirming the successful biochemical transformation during fermentation.

A broad and intense absorption band observed at 3265 cm^{-1} is attributed to O–H stretching vibrations, which arise from ethanol, water, and hydroxyl groups of phenolic compounds. The broadness of this band indicates strong hydrogen bonding interactions, typical of fermented alcoholic beverages. The pronounced intensity confirms effective sugar-to-ethanol conversion by Saccharomyces cerevisiae.

Weak absorption bands appearing at 2340 cm^{-1} and 2109 cm^{-1} are associated with CO_2-related stretching vibrations, suggesting dissolved carbon dioxide or residual fermentation gases entrapped within the wine matrix. These peaks are commonly reported in freshly fermented beverages.

A strong absorption peak at 1636 cm^{-1} corresponds to C=C stretching vibrations of aromatic rings and phenolic compounds, as well as possible contributions from C=O stretching of organic acids. This peak confirms the presence and retention of phenolic antioxidants extracted from rose petals during fermentation, contributing to the functional and nutraceutical value of the wine.

The bands observed at 1423 cm^{-1} and 1349 cm^{-1} are assigned to C–H bending vibrations and aromatic ring modes, further supporting the presence of complex organic molecules derived from both floral constituents and fermentation metabolites.

A distinct absorption peak at 1039 cm^{-1} is attributed to C–O stretching vibrations of alcohols, esters, and residual carbohydrates [9]. This region is characteristic of ethanol and ester compounds formed during fermentation and plays a critical role in defining the aroma and flavor profile of wine.

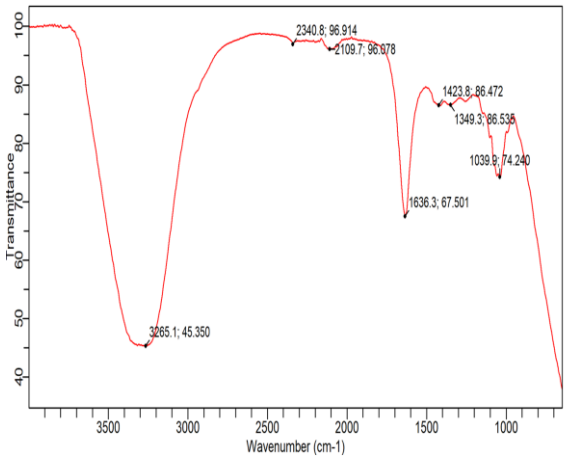

Fig. 1 FTIR Graph of Rose Wine

C. Total Phenolic Content of Rose Wine

The total phenolic content (TPC) of the fermented rose wine was determined using the Folin–Ciocalteu

method and expressed as gallic acid equivalents (GAE). The TPC of the rose wine was found to be 412 ± 15 mg GAE/L, indicating a substantial retention of phenolic compounds derived from rose petals.

Phenolic compounds are primarily responsible for the antioxidant potential, color stability, and health-promoting properties of wines. The obtained TPC value is higher than those reported for jasmine wine (180–250 mg GAE/L) and comparable to hibiscus wine (350–500 mg GAE/L), which is well known for its rich phenolic composition. This elevated phenolic content highlights the effectiveness of rose petals as a functional substrate for wine production [10].

The presence of phenolic compounds is further corroborated by the FTIR absorption band observed at 1636 cm^{-1}, corresponding to C=C stretching vibrations of aromatic rings. This agreement between chemical quantification and spectroscopic evidence strengthens the reliability of the results.

The relatively high phenolic content suggests that rose wine possesses significant antioxidant potential, positioning it as a value-added functional alcoholic beverage. Preservation of phenolics during fermentation may be attributed to controlled fermentation conditions and moderate ethanol concentration, which minimize oxidative degradation of bioactive compounds.

IV. COMPARISION WITH OTHER FLORAL WINES

The physicochemical characteristics of the developed rose wine were compared with those reported for other floral wines such as hibiscus, jasmine, dandelion, and marigold wines to evaluate its relative quality and fermentation performance. Floral wines typically exhibit moderate alcohol content, mild acidity, and appreciable phenolic composition due to the extraction of bioactive compounds from floral substrates.

The pH value of the rose wine (3.62 ± 0.04) is comparable to hibiscus wine (pH 3.2–3.6) and jasmine wine (pH 3.5–3.8), indicating a desirable acidic environment that enhances microbial stability and sensory balance. The observed pH confirms that rose petals provide sufficient organic acids to maintain appropriate wine acidity without external acidification.

The alcohol content of 9.1 ± 0.3% (v/v) is within the range reported for floral wines such as dandelion wine (8–10% v/v) and marigold wine (7–9% v/v). This moderate alcohol level suggests efficient sugar utilization by Saccharomyces cerevisiae while preserving delicate floral aromas that may otherwise be lost at higher ethanol concentrations.

The titratable acidity of 0.68 ± 0.02% (w/v) compares favorably with hibiscus and rose-based fermented beverages, which typically exhibit acidity in the range of 0.6–0.9%. Balanced acidity contributes to freshness, flavor complexity, and overall acceptability of floral wines. The residual total soluble solids (6.2 ± 0.2 Brix) observed after fermentation are consistent with reports on jasmine and lavender wines, where non-fermentable sugars and phenolic compounds contribute to mouthfeel and body.

Table 2 Comparison with other floral wine

Wine Type	pH	Alcohol (% v/v)	Titratable Acidity (%)	TPC (mg GAE/L)
Rose wine (present study)	3.62	9.1	0.68	412
Hibiscus wine [11]	3.2–3.6	9–11	0.7–0.9	350–500
Jasmine wine [12]	3.5–3.8	6–8	0.5–0.7	180–250
Dandelion wine [13]	3.6–4.0	8–10	0.4–0.6	150–300
Marigold wine [14]	3.4–3.9	7–9	0.5–0.8	200–350

V. CONCLUSIONS

The study successfully developed rose petal wine using Saccharomyces cerevisiae and demonstrated its quality through physicochemical and FTIR analyses. Efficient fermentation resulted in a balanced wine with moderate alcohol content, desirable acidity, and significant reduction in sugars. FTIR spectroscopy confirmed the presence of ethanol, esters, organic acids, and phenolic compounds, while the high total phenolic content indicated notable antioxidant potential. Overall, the findings establish rose petals as a promising substrate for producing value-added, functional fermented beverages and highlight FTIR as a rapid tool for wine quality assessment.

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