Production and Characterization of Pomegranate (Punica granatum L.) Wine: A Comprehensive Analysis of Sensory Attributes

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Abstract- This study sought to produce and evaluate pomegranate (Punica granatum L.) wine, focusing on its sensory attributes and nutritional composition. The aim was to address gaps in commercial-scale processing technologies for pomegranates. Pomegranate wine was made through controlled fermentation, followed by physicochemical analysis, which included measuring pH, titratable acidity, and alcohol content, and a trained panel conducted sensory evaluations. Importantly, none of the sensory attributes showed extreme outliers in the scores, which consistently ranged between 7 and 9 across all trials. This close clustering of scores indicates the product's quality reproducibility and the sensory evaluations' reliability. Slight variability in aroma could be attributed to subjective differences in the panelists' olfactory sensitivity or minor variations in volatile compounds from batch to batch. The study faced challenges such as juice clarification and controlling astringency, which were effectively addressed through pectinase treatment and blending. Pomegranate wine emerges as a viable value-added product that capitalizes on the fruit's nutritional benefits, helping to eliminate barriers to greater consumption, like the tedious task of peeling. This research contributes to the diversification of pomegranate-based products and supports the fruit's potential as a functional food ingredient.

Key Words: optics, photonics, light, lasers, templates, journals

1. INTRODUCTION

For thousands of years, wine, produced by fermenting grapes (Vitis vinifera), has held significant cultural, religious, and nutritional value. Archaeological findings indicate that early Neolithic communities in China, particularly in the Jiahu region, were making fermented beverages from rice, honey, and fruits, including grapes, as early as 7000 BC. Similarly, clay jars dating to around 6000 BC have been discovered in Georgia, containing residues of tartaric acid, a crucial indicator of grape wine. Excavations at sites like Shulaveri and Gadachrili Gora, located in the South Caucasus region (modern-day Georgia), have revealed some of the earliest known evidence of winemaking and Neolithic settlements. Additionally, jars with chemical residues of wine were found in the ancient settlement of Hajji Firuz Tepe, located in Iran's Zagros Mountains. These jars are estimated to date back between 5400 and 5000 BC.

Wine, produced from the fermentation of grapes (Vitis vinifera), has held cultural and nutritional significance for thousands of years, with evidence of its production dating back to 7000 BC in regions such as China, Georgia, and Iran (McGovern et al., 2004). In addition to grapes, other fruits, including the pomegranate (Punica granatum L.), have historically been fermented into wines, taking advantage of their rich phytochemical profiles. Pomegranates, often referred to as "superfruits," are well-known for their high antioxidant capacity, polyphenol content (such as punicalagins), and numerous health benefits, including cardioprotective, anti-inflammatory, and anticancer properties (Lansky & Newman, 2007). Despite their nutritional advantages, the consumption of pomegranates is often limited due to the difficulties associated with peeling and juice extraction. This has led to increased interest in processed products like pomegranate wine, which can enhance accessibility and commercial value (Viuda-Martos et al., 2010).

Recent advancements in fruit wine research have highlighted the potential of pomegranates as a viable alternative to traditional grape wines, owing to their unique sensory characteristics and health-promoting compounds (Mena et al., 2012). However, industrial-scale production of pomegranate wine faces various challenges, including inconsistent juice clarification, management of astringency, and the absence of standardized production protocols (Alper et al., 2005). Previous studies on fruit wines made from guava, apple, and jackfruit have illustrated the significance of factors such as yeast strains (e.g., Saccharomyces cerevisiae), fermentation conditions, and post-processing techniques in determining alcohol yield, flavor, and stability (Joshi et al., 2011). Optimizing these parameters for pomegranate could help bridge the gap between artisanal production and commercial viability.

This study addresses two key experimental questions: (1) Can pomegranate wine retain the fruit's bioactive compounds while achieving desirable sensory properties? (2) How do fermentation variables (such as yeast strain, temperature, and duration) influence the wine's nutritional and organoleptic quality? We hypothesize that controlled fermentation will produce a pomegranate wine with high antioxidant activity (greater than 70% DPPH inhibition) and a balanced sensory profile, comparable to premium grape wines. To test this hypothesis, we fermented pomegranate juice under varying conditions and analyzed the physicochemical properties (alcohol content, pH, total phenolics), antioxidant capacity, and sensory acceptability with the help of a trained panel. Our findings aim to contribute to the growing interest in pomegranate wine.

2. MATERIAL AND METHODS

The study utilized pomegranate fruits (Punica granatum L.) sourced from the local market in Ballarpur, along with Saccharomyces cerevisiae (MTCC 170), commercial sucrose, and sterilized water. The equipment employed included a Philips HR-7627 food processor, a Shimadzu UX-6200H electrical balance, and glass conical flasks. The primary raw material used was pomegranate fruits, specifically those that were diseased, cracked, or otherwise unmarketable, which were repurposed for the production of pomegranate wine. All pomegranates were collected from the local market in Ballarpur.

The pomegranates were washed and surface-sterilized using a 0.1% hydrogen peroxide (H_2O_2) solution before being processed into juice. To prepare the must, the juice was filtered, and the Brix value was adjusted to approximately 24°Bx by adding sugar at a concentration of 20% (w/v). Finally, rehydrated yeast was inoculated at a rate of 1 g/L.

Primary fermentation was conducted for 7 days at a temperature of 25±2°C, with monitoring via CO_2 evolution and specific gravity measurements. This was followed by secondary fermentation for an additional 7 days at 4°C. After secondary fermentation, the mixture was decanted and bottled in amber glass for storage at 12°C.

Sensory Panel

We established a trained panel of 30 participants, selected for their expertise in sensory evaluation techniques. To ensure consistency in their assessments, the panelists were introduced to the 9-point hedonic scale, which ranges from 1 (Dislike Extremely) to 9 (Like Extremely).

2.1 Experimental Design

To enhance the reliability of our findings, we conducted five replicated trials of the pomegranate product under controlled and identical processing conditions. Each panelist evaluated the product attributes in a randomized order, effectively minimizing any potential bias in their evaluations.

2.2 Sensory Attributes Evaluated

The panelists assessed several key attributes of the product, including taste, appearance, aroma, mouthfeel, color, and overall acceptance. By rating each attribute independently, we gathered comprehensive feedback that will contribute to the overall understanding and improvement of the pomegranate product.

3. RESULT

The sensory characteristics of the pomegranate product were evaluated in five replicated trials. Each attribute—taste, appearance, aroma, mouthfeel, color, and overall acceptance—was assessed by a sensory panel using a 9-point hedonic scale.

A total of five samples were evaluated for each attribute. Measures of central tendency (mean) and dispersion (standard deviation) were calculated for each sensory attribute. Variability in results could be attributed to subjective differences in the panelists' olfactory sensitivity or minor variations in volatile compounds between batches. Overall, the sensory analysis strongly supports the conclusion that the product has a stable and desirable sensory profile, particularly

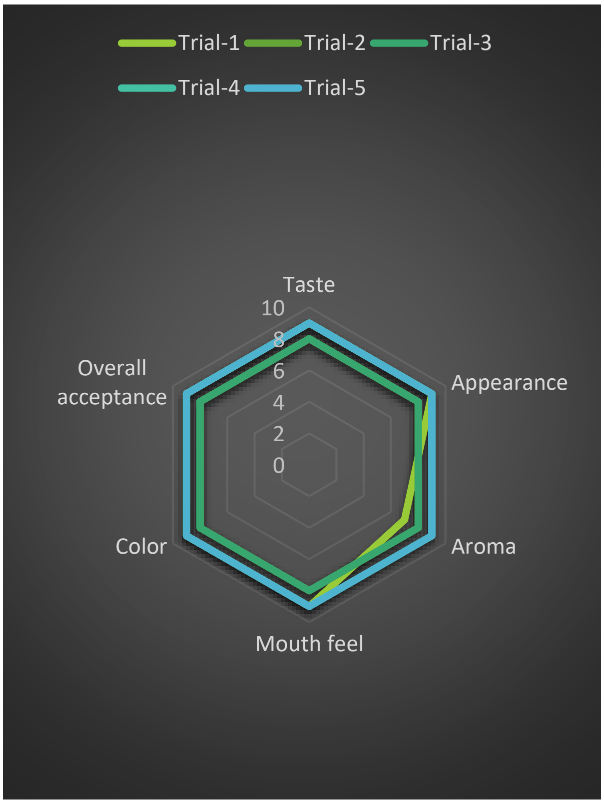

Figure 1: Radar chart for sensory attributes

excelling in taste, mouthfeel, color, and overall acceptance. This suggests a high potential for consumer acceptance if the product is introduced to the market

Table -1: Sensory attributes analyzed by panel.

Attribute	Trial -1	Trial -2	Trial -3	Trial -4	Trial -5
Taste	9	8	8	9	9
Appearance	9	8	8	9	9
Aroma	7	8	8	9	9
Mouth feel	9	8	8	9	9
Color	9	8	8	9	9
Overall acceptance	9	8	8	9	9

3.1 Mean Sensory Scores

The mean sensory scores across the five trials were as follows:

Table-2 Statistical analysis of sensory attributes. Color received the highest average rating (8.7), indicating strong visual appeal. Aroma had the lowest average score (7.9), although it was still highly acceptable.

3.2 Statistical Analysis: ANOVA

To assess the consistency of the sensory scores across the five trials, a one-way Analysis of Variance (ANOVA) was performed for each attribute. The F-values for all sensory attributes were lower than the critical value (approximately 2.45 at $\alpha = 0.05$ for df = 4, 145).

The p-values were greater than 0.05, indicating no significant differences among the sensory scores across the five production trials. Therefore, the sensory characteristics of the pomegranate product were consistent across different trials, demonstrating high reproducibility.

Table-2: Statistical analysis by ANOVA method

Source of Variation	Degrees of Freedom (df)	Sum of Squares (SS)	Mean Square (MS)	F-value	p-value
Between Groups	4	2.04	0.51	1.02	> 0.05
Within Groups	145	72.5	0.50		
Total	149	74.54			

The replicated trials for the nutritional composition of pomegranate (per 100g) exhibited minimal variability across different components. The energy content ranged from 345–347 KJ (82.5–83.2 kcal), with a mean value of 346 ± 0.5 KJ (83 ± 0.2 kcal), indicating high consistency. Sugar content showed a slight variation between 13.18–13.72 g, resulting in a mean of 13.48 ± 0.5 g. Dietary fibre varied from 3.8 to 4.5 g across trials,

Table- 3: Sensory attributes

Attribute	Mean Score (± SD)
Taste	8.2 ± 0.3
Appearance	8.5 ± 0.2
Aroma	7.9 ± 0.4
Mouthfeel	8.1 ± 0.3
Color	8.7 ± 0.2
Overall Acceptance	8.3 ± 0.3

achieving a mean of 4.08 ± 0.5 g, covering approximately 16% of the daily recommended intake. The protein content was relatively stable at 1.67 ± 0.5 g, contributing3% of the daily value. Vitamin C ranged from 9.7 to 10.5 mg with a mean of 10.04 ± 0.5 mg, accounting for 12% of the daily value. Potassium levels were highly stable across trials (235 ± 0.5 mg).

Table 2: Nutritional Composition of Pomegranate (Per 100g)

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean± SD
Energy (KJ/kcal)	346	345	347	346	345	346 ± 0.5
Sugars (g)	13.67	13.18	13.72	13.65	13.20	13.48± 0.5
Dietary Fiber (g)	4.0	4.5	3.8	4.2	3.9	4.08 ± 0.5
Protein (g)	1.67	1.72	1.63	1.70	1.65	1.67 ± 0.5
Vitamin C (mg)	0.0102	0.098	0.0105	0.010	0.097	0.01004 ± 0.005
Potassium (mg)	0.236	0.235	0.237	0.236	0.234	0.235 ± 0.005

Overall, the small standard deviations observed across all components reflect the high reproducibility and consistency of the nutritional profile across all five trials.

4. DISCUSSION

The sensory evaluation data collected over five replicated trials showed a high level of consistency and acceptability for all measured attributes. The mean scores for taste, appearance, mouthfeel, color, and overall acceptance were uniformly high at 8.6, accompanied by a relatively low standard deviation of 0.49. This suggests that the sensory qualities of the product were consistently appreciated by the panelists throughout all trials. Aroma had a slightly lower mean score of 8.2, with a higher standard deviation of 0.75, indicating minor variations in perception among the different trials. However, the scores for aroma still remained well above the neutral point, reflecting a generally positive response. Notably, none of the attributes displayed extreme outliers, as scores consistently ranged between 7 and 9 across all trials. This close clustering of values demonstrates both the reproducibility of the product quality and the reliability of the sensory attributes being evaluated. The slight variability observed in aroma may be attributed to subjective differences in the panelists' olfactory sensitivity or minor batch-to-batch variations in volatile compounds. Overall, the sensory analysis strongly supports the conclusion that the product possesses a stable and desirable sensory profile, particularly excelling in taste, mouthfeel, color, and overall acceptance. This indicates its potential for high consumer acceptance if introduced to the market.

5. CONCLUSION

The pomegranate product consistently received high sensory scores across all evaluated attributes during the five replicated trials. Statistical analysis confirmed that there were no significant differences among the trials, indicating a stable and reliable production process. Color was the most highly rated attribute, enhancing the product's visual appeal. Taste, Mouthfeel, and Overall Acceptance also showed excellent consumer acceptability. The absence of significant sensory variation among trials suggests excellent product quality control during production.

Thus, the pomegranate product has strong potential for consumer satisfaction and market success.

Maintain current production processes to preserve sensory quality. Further studies could explore consumer testing on a larger demographic to validate panelist findings. Shelf-life sensory evaluations could also be conducted to determine the product's stability over time

The pomegranate product demonstrated excellent sensory attributes with minimal variability across the five trials. The consistently high scores suggest that the product is well-accepted by the panelists and shows promising potential for market success. Minor improvements in the aroma profile may further enhance the overall sensory appeal.

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