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'RESEARCH ARTICLE

Fermenting Dragon Fruit: Elevating Homemade Wine through Sensory and Microbiological Insights

Elvie O. Tomas*

College of Teacher Education, *Nueva Vizcaya State University, Philippines*

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***Corresponding Author**

etomas@nvsu.edu.ph

ABSTRACT

Dragon fruit is well-known for its abundance of health advantages, boasting elevated levels of antioxidants, vitamins, and minerals. Thus, this study explored the utilization of dragon fruit in the production of homemade wine, focusing on sensory evaluation and microbiological analysis. A total of 150 liquor enthusiasts were randomly selected to serve as participants. The quality of wine produced during the fermentation period was assessed for microbiological content and physico-chemical characteristics to ensure its suitability for human consumption. Acceptability and sensory evaluation of the wine were rated using a nine-point Hedonic scale. The Analysis of Variance was employed to identify significant differences between variables. Four treatments of dragon fruit wine were used during fermentation, labeled as Treatment 1, Treatment 2, Treatment 3, and Treatment 4. Through comprehensive assessment, the dragon fruit wine showcased commendable sensory attributes encompassing appearance, color, flavor, texture, and taste, while maintaining acceptable pH levels and alcohol content. Minimal mold and yeast counts underscored the quality of the fermented wine. The evaluation of sensory attributes across the four dragon fruit wine treatments highlighted discernible differences in appearance, color, flavor, texture, and taste. These variations signify varying degrees of acceptability among treatments, underscoring the influential role of fermentation duration and other processing factors on the sensory profile of dragon fruit wine.

INTRODUCTION

In a competitive wine market, diversification and innovation are crucial for attracting consumers and staying relevant. Introducing dragon fruit wine allows producers to differentiate their product offerings, meeting the growing demand for wines that offer something unique and exotic [1]. With the increasing popularity of exotic fruits and flavors in the beverage industry, dragon fruit wine provides a new and exciting option for consumers, potentially leading to increased market share and profitability [2], [3].

Dragon fruit, also known as pitaya, offers a distinct flavor profile that combines sweetness with subtle tanginess. This unique taste can add complexity to wine blends, appealing to consumers looking for novel and exotic flavors in their wines [4], [5]. Dragon fruit is renowned for its numerous health benefits, including high levels of antioxidants, vitamins, and minerals. By incorporating dragon fruit into wine production, producers can market their wines as not only flavorful but also health-conscious options, appealing to health-conscious consumers [6], [3] [7].

Dragon fruit's vibrant color and versatile flavor profile make it an ideal ingredient for creating visually striking wines with unique taste profiles [8]. This versatility not only allows winemakers to

experiment with various styles, including still, sparkling, and fortified wines but also enables them to cater to different consumer preferences and market segments, enhancing their potential for attracting attention on store shelves and expanding their customer base [9].

Dragon fruit cultivation is relatively environmentally friendly, requiring minimal water and pesticides compared to some other fruit crops. By utilizing dragon fruit in wine production, producers can align themselves with sustainable practices, appealing to environmentally conscious consumers [10], [11}. Dragon fruit is deeply rooted in various cultures, particularly in Asian countries where it is native. Incorporating dragon fruit into wine production can appeal to consumers with cultural ties to these regions, providing them with a unique and nostalgic drinking experience [12], [13].

The consumption of dragon fruit in wine production suggests chances to address multiple SDGs simultaneously by promoting sustainable agriculture, supporting economic development, fostering innovation, and contributing to improved health and well-being [14], [15], [16], [17]. In particular, **d**ragon fruit cultivation can contribute to food security and sustainable agriculture, which is central to SDG 2. By utilizing dragon fruit in wine production, farmers have an additional revenue stream, potentially improving their economic well-being and food security. Additionally, promoting sustainable agricultural practices in dragon fruit cultivation can help ensure long-term food availability [14],[18].

Further, dragon fruit is rich in vitamins, minerals, and antioxidants, contributing to good health and well-being. By incorporating dragon fruit into wine production, producers can create wines with added health benefits, aligning with SDG 3's objective of promoting healthy lifestyles and well-being. Furthermore, **u**tilizing dragon fruit in wine production promotes responsible consumption and production practices. Dragon fruit cultivation typically requires fewer pesticides and water compared to other fruit crops, contributing to sustainable agricultural practices [19]. Furthermore, by diversifying product offerings and utilizing locally sourced ingredients like dragon fruit, wineries can reduce their environmental footprint and promote sustainable consumption patterns. Additionally, dragon fruit cultivation can be relatively resilient to climate change and requires minimal water compared to other crops. By incorporating dragon fruit into wine production, producers can support climate-resilient agriculture and contribute to SDG 13's goal of combating climate change and its impacts [20], [21].

Moreover, **i**ntroducing dragon fruit wine production creates employment opportunities along the value chain, from farming to processing and marketing. By generating income for farmers and workers involved in dragon fruit cultivation and wine production, this initiative contributes to SDG 8's objective of promoting inclusive and sustainable economic growth [22]. Finally, **i**ncorporating dragon fruit into wine production fosters innovation within the agricultural and beverage industries. By exploring new uses for dragon fruit and developing innovative winemaking techniques, producers can contribute to SDG 9's goal of promoting sustainable industrialization and fostering innovation [23], [24}.

The utilization of dragon fruit in homemade wine production presents an intriguing opportunity for innovation within the beverage industry. However, several critical questions remain unanswered, prompting the need for focused inquiry such as a) the impact of different fermentation durations on the sensory attributes and overall acceptability of dragon fruit wine, b) the variations in dragon fruit wine treatments affecting microbiological content and physico-chemical characteristics during the production process, c) the implications of incorporating dragon fruit into homemade wine production for technology and livelihood education (TLE) curriculum, business enterprises, waste management, and the standard operational procedures that can be adapted to ensure consistent quality and market viability of dragon fruit wine. Addressing these issues will provide valuable insights into optimizing the production and marketability of dragon fruit wine, thereby contributing to the advancement of homemade wine crafting practices and sustainable utilization of agricultural resources.

This study aimed to assess the feasibility and viability of incorporating dragon fruit as a key ingredient in wine production, evaluating factors such as sensory attributes and microbiological considerations.

Specifically, this study sought to achieve the following objectives:

a) to determine the formulation and fermentation process of dragon fruit into wine;

b) to determine the characteristics of dragon fruit wine as to sensory attributes (appearance, color, flavor, texture, taste); physico-chemical analysis (*pH* level, alcohol content), and microbial content (molds, yeast); and,

c) to compare the sensory attributes of the four dragon fruit wine treatments in terms of appearance, color, flavor, texture, and taste.

MATERIALS AND METHODS

Research Design

This study employed the experimental design to investigate the integration of dragon fruit in wine production. Four distinct treatments were formulated and fermented, each varying in duration and composition. Subsequently, the resulting wines underwent rigorous sensory evaluation by research participants. The findings from these evaluations served as primary data sources, facilitating the fulfillment of the study's objectives.

Participants of the Study

Profile: The participants were predominantly male and primarily individuals in their late teens to early twenties. Particularly, few of the participants were in their fifties. In terms of marital status, there were more single than married participants. Most participants were employed, with government employees being the most common occupation, while students constituted those without employment.

Drinking Preferences: The majority (56.67%) of participants were occasional drinkers, with 24% *drinking* weekly and 19.33% daily. Most consume one or fewer bottles per day (55.33%), while 44.67% consume 2 to 3 bottles daily. Major drinking occasions include "all occasions" (75.33%), Christmas (16%), and birthdays (8.67%). Home is the preferred drinking venue (62.67%), followed by friend or relative's house and bars (37.33%). Friends (51.33%) are the primary drinking companions, followed by relatives (48.67%). Taste is the most important factor (62.57%), followed by alcoholic content (28.09%), and low price (8.67%).

Ingredients and Materials

1. *Dragon Fruit*: selected and peeled, totaling five kilograms.

2. *Sugar*: Five kilograms for fermentation.

3. *Yeast*: One hundred grams of Bruggeman brand yeast.

4. *Water*: Purified water added as needed to the must.

5. *Utensils and Equipment*: Various utensils, including knives, stainless spoons, basins, mixing bowls, trays, casserole dishes, weighing scales, measuring cups/spoons, beakers, plastic bottles, water barrels, hoses, cheesecloth, coffee filters, and plastic funnels.

6. *Airlock*: Employed to prevent air infiltration during fermentation, using molding clay for sealing.

Experimental Procedure

In wine making, sanitation is paramount. All equipment and materials were thoroughly washed with clean water and liquid soap, then steamed for 15 minutes for sterilization. The researcher selected high-quality dragon fruit and followed the experimental procedure outlined as follows:

1. Wash, peel, and mash the dragon fruit, transferring it to a clean tray.
2. Properly measure all required raw materials using a weighing scale, measuring cups, and spoons.
3. Weigh five kilograms of dragon fruit (excluding peelings), five kilograms of white sugar, and 100 grams of yeast.
4. In a clean stainless casserole, pour 10 liters of purified water, mix the sugar and dragon fruit, and cook for 20 minutes before setting aside.
5. Strain the mixture to separate the liquid from the mash.
6. Add yeast to each mixture in bottles.
7. Seal the bottles with cork plugs and airlock devices to prevent air exposure, crucial for successful fermentation.
8. Store the mixtures in a water barrel container for three months. After fermentation, filter the wine and pasteurize at 60 degrees Celsius for 20 minutes to remove undesired matters. Allow the wine to settle for one week to remove remaining sediments.

The sealed musts were stored undisturbed in a cool, dark place for the entire fermentation duration. Four treatments of fermentation were conducted: T1 (2 weeks), T2 (4 weeks), T3 (8 weeks), and T4 (12 weeks, complete fermentation). Complete fermentation was determined when no more air bubbles were observed in the fermentation bottle. Subsequently, the four treatments underwent testing and evaluation by 150 participants, who tasted the wine and recorded their assessments on scorecards. After fermentation completion, the wine was aged for two months before bottling.

Data Gathering

Data for the study were collected through a questionnaire designed to address the objectives of this study. Adapted from previous beverage product testing studies, the questionnaire underwent modifications and revisions to enhance validity. Additionally, personal interviews were conducted with respondents to verify information. Research participants were invited to participate in wine testing and evaluation activities. Following the tasting sessions, participants were asked to complete scorecards to record their assessments of the wine. The scorecards included questions evaluating the physical characteristics of the wine preparation and participants' preferences in purchasing dragon fruit wine.

Sensory Evaluation: Dragon fruit wine underwent consumer product testing using the Nine-Point Hedonic Scale to assess its acceptability. The Nine-Point Hedonic Scale, ranging from "dislike extremely" to "like extremely," was utilized to gauge participants' feelings about the wine. This scale, frequently employed in consumer preference tests, provides reliable results when administered to similar groups. Each panelist was served a 20 ml wine sample and provided with finger foods and water afterward.

Physico-chemical Properties: The physico-chemical properties of the wine were assessed to ensure standard *pH* levels and alcohol content. The *pH* level, indicating acidity, ideally falls between 2.9 – 4.0 for wine. Alcohol content was analyzed using sophisticated equipment. Samples were sent to the

Department of Science and Technology (DOST) Regional Office, Tuguegarao City, Philippines for analysis.

Microbial Attributes: To determine microbial content in the wine mixture, samples were submitted to the DOST Regional Office for mold and yeast analysis. This assessment is crucial for determining beverage potability, shelf life, and quality. Laboratory procedures necessitated 250-500 ml of sample for testing.

Statistical Treatment of Data

The collected data underwent statistical analysis using percentage, mean, and Analysis of Variance (ANOVA). All treatments were evaluated by 150 panelists using the Nine Point Hedonic Scale to assess appearance, color, flavor, texture, and taste of the wine.

RESULTS AND DISCUSSION

A. Formulation and Fermentation Process of Dragon Fruit Wine

The formulation and fermentation process of dragon fruit wine underwent multiple trials and a year of experimentation before achieving the final product. Initial research involved extensive study of standard wine production processes. Dragon fruit, meticulously selected and prepared, served as the primary ingredient, along with sugar and purified water.

In the initial trial, wine production failed due to using inadequate equipment—a one-liter soda glass bottle. Despite fermentation occurring and generating alcohol and carbon dioxide, the sealed bottle couldn't contain the pressure. Within two days, the carbon dioxide pressure exceeded the bottle's capacity, causing the cap to fly off, releasing some of the mixture. This incident highlighted the unsuitability of soda bottles for wine fermentation.

In the second trial, the researcher devised an improvised airlock system using basic materials: a one-inch cork, a 26-inch plastic hose, 4 inches of aluminum tubing, and a plastic bottle filled with water. This airlock facilitated carbon dioxide release during fermentation while preventing air ingress, crucial for preserving wine quality. Despite these adjustments, the resulting wine exhibited low alcohol content after three months, likely due to bacterial presence, compromising product quality.

The final trial adhered to standard guidelines and procedures, with sanitized equipment and sterilized fermentation containers. Yeast and sugar were added to facilitate fermentation, which lasted three months, followed by a week of aging (racking) to clarify the solution.

Dragon fruit wine preparation involved the following steps:

1. Wash, peel, and mash dragon fruit on a clean tray.
2. Measure ingredients accurately using weighing scales and measuring utensils.
3. Weigh 5000 grams of dragon fruit (excluding peelings), 5000 grams of white sugar, and 100 grams of yeast.
4. In a clean stainless casserole, mix 10,000 milliliters of purified water, sugar, and dragon fruit, cooking for 20 minutes, then set aside.
5. Strain the mixture to separate liquid from mash.
6. Add yeast to each mixture in bottles.
7. Cover bottles with a cork plug and airlock device to permit carbon dioxide release while preventing outside air entry.

Fermentation Period:

1. Treatment 1: 2 weeks.
2. Treatment 2: 4 weeks.
3. Treatment 3: 8 weeks.
4. Treatment 4: 12 weeks.

Ratio of Ingredients: The researcher strictly adhered to ingredient ratios for optimal wine quality: 5000 grams of dragon fruit (excluding peelings), 100 grams of yeast, 5000 grams of sugar, and 10,000 milliliters of purified water.

Fermentation: Fermentation, catalyzed by yeast, converts sugar into alcohol and carbon dioxide. *Yeast*, a one-celled fungi, has been used historically for fermenting various substances, including alcoholic beverages.

Filtration: After cooking, the dragon fruit mixture underwent filtration using cheesecloth and *coffee* filters to remove solid impurities.

Pasteurization: The wine was pasteurized at 60 degrees Celsius for 30 minutes to eliminate remaining bacteria while preserving its composition and aroma.

Storage/Aging: The wine was stored in clear bottles with cork stoppers to observe its characteristics post-pasteurization. Proper storage at ambient temperature (25 degrees Celsius) prevents degradation of volatile compounds, ensuring quality over time. Sediments that may form during aging do not indicate spoilage.

B. Characteristics of Dragon Fruit Wine During Fermentation

B.1 *Sensory Attributes*: Sensory analysis was conducted among 150 participants to assess the appearance, color, flavor, texture, and taste of dragon fruit wine. Results are reflected in Table 1.

Table 1. Mean scores of the four treatments in terms of the sensory attributes of the homemade Dragon fruit wine (appearance, color, flavor, texture, and taste) as evaluated by the participants

Treatments	Appearance	Color	Flavor	Texture	Taste
T1	1.71	1.85	1.91	1.95	1.79
T2	2.60	2.94	3.29	2.64	2.47
T3	4.97	4.56	5.64	5.72	5.89
T4	8.17	8.35	8.47	8.03	7.78

Legend:

Mean Scores	Verbal Description
8.50 – 9.00	Like extremely
7.50 – 8.49	Like very much
6.50 – 7.49	Like moderately
5.50 – 6.49	Like slightly
4.50 – 5.49	Neither like nor dislike
3.50 – 4.49	Dislike slightly
2.50 – 3.49	Dislike moderately
1.50 – 2.49	Dislike very much
1.00 – 1.49	Dislike extremely

Appearance: Treatment 4 (T4) had the highest mean score of 8.17, indicating that participants "liked very much" the appearance of the Dragon Fruit wine after 12 weeks of fermentation. As fermentation duration increased, there was a noticeable improvement in appearance ratings, with T1 having the lowest score of 1.71, indicating that participants "disliked very much" its appearance after 2 weeks of fermentation. The higher ratings for appearance in wines subjected to longer fermentation periods suggest that extended fermentation enhances the visual appeal of Dragon Fruit wine. Winemakers should consider allowing sufficient time for fermentation to achieve desirable appearance characteristics, which can enhance consumer perception and appeal.

Color: Similar to appearance, T4 received the highest mean score of 8.35, indicating a strong preference for the color after 12 weeks of fermentation. Again, as fermentation duration increased, color ratings improved gradually, with T1 having the lowest score of 1.85, indicating strong dislike for its color after 2 weeks. Similar to appearance, the improved color ratings in wines with longer fermentation durations indicate that extended fermentation positively influences the color development of Dragon Fruit wine. Winemakers should recognize the importance of fermentation duration in achieving vibrant and attractive color in the final product, which can influence consumer preferences and purchase decisions.

Flavor: T4 had the highest mean score of 8.47, suggesting that participants "liked very much" the flavor of the Dragon Fruit wine after 12 weeks of fermentation. Similarly, there was a consistent improvement in flavor ratings with longer fermentation periods, with T1 having the lowest score of 1.91, indicating strong dislike for its flavor after 2 weeks. The higher ratings for flavor in wines with longer fermentation periods highlight the significant impact of fermentation duration on flavor development. Winemakers should focus on allowing adequate fermentation time to develop desirable flavor profiles, ensuring a more enjoyable and satisfying drinking experience for consumers.

Texture: T4 also had the highest mean score of 8.03 for texture, indicating a strong preference for its texture after 12 weeks of fermentation. Like the other sensory attributes, texture ratings showed improvement as fermentation duration increased, with T1 having the lowest score of 1.95, indicating a strong dislike for its texture after 2 weeks. The preference for texture in wines with longer fermentation durations suggests that extended fermentation contributes to improved mouthfeel and texture. Winemakers should recognize the role of fermentation duration in enhancing the overall texture of Dragon Fruit wine, aiming for smoother and more enjoyable drinking experiences for consumers.

Taste: T4 received the highest mean score of 7.78, indicating a strong preference for its taste after 12 weeks of fermentation. Once again, taste ratings improved progressively with longer fermentation durations, with T1 having the lowest score of 1.79, indicating a strong dislike for its taste after 2 weeks. The preference for taste in wines subjected to longer fermentation underscores the importance of fermentation duration in shaping the overall taste profile of Dragon Fruit wine. Winemakers should prioritize longer fermentation periods to achieve balanced and pleasant taste characteristics, which can contribute to consumer satisfaction and repeat purchases.

Overall, the data suggests that longer fermentation periods result in Dragon Fruit wine with more favorable sensory attributes, including appearance, color, flavor, taste, and texture. Participants consistently preferred wines that underwent longer fermentation, indicating the importance of fermentation duration in achieving desirable sensory characteristics. Additionally, the results imply that fermentation duration significantly influences the sensory attributes of Dragon Fruit wine. By understanding and optimizing fermentation processes, winemakers can produce wines with superior appearance, color, flavor, taste, and texture, ultimately enhancing consumer satisfaction and market competitiveness.

B.2 *Physico-Chemical Properties*: In this experimental study, the physical and chemical properties of wine derived from dragon fruit were meticulously examined utilizing advanced analytical tools. Specifically, the investigation focused on quantifying the pH levels and alcohol content present in the dragon fruit wine. Results are reflected in Tables 2 and 3.

Table 2. pH level of the Dragon fruit wine

Treatment	pH Level
Dragon fruit wine	3.4

The *pH level* of the dragon fruit wine measured 3.4. This value falls within the typical range for wine, indicating moderate acidity. A *pH* of 3.4 suggests a balanced acidity level, contributing to the wine's flavor profile and stability. Findings indicate that the moderate acidity can enhance the wine's flavor profile, providing a pleasant tartness and crispness. This pH level suggests sufficient acidity to preserve the wine and inhibit microbial growth, contributing to its stability and shelf life. Maintaining the *pH* within an optimal range is crucial for ensuring the quality and consistency of the wine. This analysis helps in monitoring and maintaining the desired acidity levels for producing high-quality dragon fruit wine. The titratable acidity of fruit serves as a pivotal indicator of fruit maturity and potential wine flavor. In Yu et al.'s [9] study, they emphasized the significance of achieving an optimal acid and pH balance by acidifying the must prior to fermentation. Tartaric acid was selected for titratable acidity adjustment due to its exceptional microbiological stability among naturally occurring carboxylic acids present in fruit. Additionally, it serves to mitigate the catalyzation of wine oxidation by *Fe*, as highlighted by Danilewicz [25], and finds widespread application as an additive in the food and beverage industries [26].

Table 3. Alcohol content of Dragon fruit wine

Treatment	Alcohol Content
Dragon fruit wine	15.6 %

The *alcohol content* of the dragon fruit wine was measured at 15.6%. This percentage represents the volume of ethanol present in the wine, indicating its alcoholic strength. Results imply that a higher alcohol content, such as 15.6%, suggests that the dragon fruit wine has a robust alcoholic profile. This can contribute to its perceived quality and character. The alcohol content significantly influences the wine's flavor and aroma profile. A higher alcohol content may result in a fuller-bodied wine with more pronounced flavors and aromas. Understanding the alcohol content allows producers to cater to consumer preferences. Some consumers may prefer wines with higher alcohol content for their perceived richness and complexity. Monitoring alcohol content is essential for regulatory compliance. This ensures that the wine meets legal requirements and labeling standards, providing transparency to consumers.

B.3 *Microbial Content*: Microbial testing assesses the microbial composition in wine, crucial for ensuring quality. *Yeast*, vital for fermentation, must be controlled to prevent post-bottling issues. *Molds*, if present, can spoil the wine post-fermentation. Dragon fruit wine meets standards for unfortified wines, indicating its quality. Results are reflected in Tables 4.

Table 4. Molds and yeast counts of the homemade Dragon fruit wine

Treatment	Mold and Yeast Count
Dragon fruit wine	$<1.0 \times 10^{1}$* CFU/mL

The table indicates that the homemade dragon fruit wine has a mold and yeast count of less than 1.0×10^{1} colony-forming units per milliliter (CFU/mL). This suggests a low microbial presence, which is desirable for maintaining the wine's quality and preventing spoilage. The implication is that the wine

meets microbial safety standards, ensuring its suitability for consumption and storage without significant risk of contamination or deterioration. Suranska and associates [27] stated that the fermentation of fruits into wine is a multifaceted ecological process, intricately influenced by various factors, with yeasts serving as pivotal actors in this transformation. While studies have yet to isolate a specific yeast strain from local dragon fruit for wine fermentation, the systematic selection of indigenous yeasts remains an ongoing endeavor even in the realm of grape winemaking, highlighting the importance of harnessing local microbial diversity [9].

C. Comparison in the Sensory Attributes of the Four Dragon Fruit Wine Treatments in terms of Appearance, Color, Flavor, Texture, and Taste

Appearance: Table 5 reflects the results of the test of difference in the acceptability of the homemade Dragon fruit wine in terms of its appearance.

Table 5. Test of difference in the acceptability of homemade Dragon fruit wine in terms of appearance

Sensory Attribute		Sum of Squares	df	Mean Square	F	Sig.
Appearance	Between Groups	3751.793	3	1250.598	2.160E3	.000
	Within Groups	345.000	596	.579		
	Total	4096.793	599			

The table presents the results of a one-way ANOVA test analyzing the acceptability of dragon fruit wine based on its appearance. The significant F-value of 2.160E3 ($p < 0.05$) suggests a substantial difference in acceptability among the treatment groups. This indicates that the appearance of the wine significantly influences its overall acceptability. The implication is that factors affecting the appearance of the wine, such as color, clarity, and presentation, may be carefully considered and optimized to enhance consumer satisfaction and perception [28]. Additionally, further investigation into the specific attributes contributing to appearance preferences can guide improvements in wine production and marketing strategies. The significant difference in acceptability based on appearance suggests that consumers place considerable importance on visual attributes when evaluating dragon fruit wine. Winemakers may prioritize enhancing the visual appeal of their products through factors such as color consistency, clarity, and packaging aesthetics [29]. Investing in methods to improve appearance, such as refining filtration processes or selecting dragon fruit varieties with vibrant pigmentation, could lead to increased consumer satisfaction and loyalty. Additionally, marketing efforts may highlight the visually appealing aspects of the wine to capitalize on consumer preferences and differentiate the product in a competitive market.

Table 6. Post hoc-Scheffe Test-Multiple comparison in the acceptability of homemade Dragon fruit wine in terms of appearance

(1) Treatment (J) Treatment	Mean Difference (l-J)	Sig.
T1 T2	-.8867*	.000
T1 T3	-3.25333*	.000
T1 T4	-6.46000*	.000
T2 T3	-2.36667*	.000
T2 T4	-5.57333*	.000
T3 T4	-3.20667*	.000

Results in Table 6 indicate significant mean differences in the acceptability of dragon fruit wine based on appearance between various treatments. Specifically, Treatment 4 (T4) consistently demonstrated the highest acceptability compared to other treatments (T1, T2, and T3), with mean differences ranging from -0.8867 to -6.46000. These findings suggest that wines subjected to longer fermentation periods (T4) are perceived more favorably in terms of appearance. Winemakers should consider extending fermentation durations to enhance the visual appeal of dragon fruit wine, potentially increasing consumer satisfaction and market competitiveness.

Flavor: Table 7 reflects the results of the test of difference in the acceptability of the homemade Dragon fruit wine in terms of its flavor.

Table 7. Test of difference in the acceptability of homemade Dragon fruit wine in terms of flavor

Sensory Attribute		Sum of Squares	df	Mean Square	F	Sig.
Flavor	Between Groups	3712.458	3	1237.486	2.357E3	.000
	Within Groups	312.860	596	.525		
	Total	4025.318	599			

Finding in Table 7 reveals significant differences in the acceptability of dragon fruit wine concerning flavor across various treatments. The considerable F-value (2.357E3) and associated p-value (.000) indicate that the variations in flavor acceptability among treatments are unlikely due to chance. These findings suggest that different fermentation durations or processing methods significantly impact the flavor profile of dragon fruit wine. Winemakers may explore optimizing fermentation techniques or ingredient compositions to enhance flavor consistency and appeal, thereby improving consumer satisfaction and market acceptance of their products [30].

Table 8. Post hoc-Scheffe Test-Multiple comparison in the acceptability of homemade Dragon fruit wine in terms of flavor

(1) Treatment (J) Treatment	Mean Difference (l-J)	Sig.
T1 T2	-1.38000*	.000
T1 T3	-3.72667*	.000
T1 T4	-6.55333*	.000
T2 T3	-2.34667*	.000
T2 T4	-5.17333*	.000
T3 T4	-2.82667*	.000

Results in Table 8 reveal significant mean differences in the acceptability of homemade dragon fruit wine regarding flavor among different treatments. All pairwise comparisons between treatments demonstrate statistically significant differences with p-values less than .001. This suggests that the flavor acceptability of the wine varies significantly depending on the fermentation duration or other treatment factors. Adjustments in fermentation techniques or ingredients may be necessary to standardize and optimize flavor characteristics, enhancing consumer satisfaction and market competitiveness of the product [31].

Color: Table 9 reflects the results of the test of difference in the acceptability of the homemade Dragon fruit wine in terms of its color.

Table 9. Test of difference in the acceptability of homemade Dragon fruit wine in terms of color

Sensory Attribute		Sum of Squares	df	Mean Square	F	Sig.
Color	Between Groups	2491.573	3	830.524	1.649E3	.000
	Within Groups	300.187	596	.504		
	Total	2791.760	599			

The table presents the results of the test of difference in the acceptability of homemade Dragon fruit wine concerning color. The analysis shows significant variability in color acceptability across different treatments, as indicated by the high F-value (1.649E3) and a p-value of .000, suggesting that the differences observed are unlikely due to chance. This implies that the duration of fermentation or other treatment factors significantly influence the perception of color in the wine. Adjustments in processing techniques, such as fermentation duration or fruit preparation methods, may be necessary to achieve a consistent and desirable color profile. Additionally, enhancing color stability through additives or processing methods could improve consumer appeal and marketability.

Table 10. Post hoc-Scheffe Test-Multiple comparison in the acceptability of homemade Dragon fruit wine in terms of color

(1) Treatment (J) Treatment	Mean Difference (l-J)	Sig.
T1 T2	-1.33333*	.000
T1 T3	-2.65333*	.000
T1 T4	-5.50667*	.000
T2 T3	-1.32000*	.000
T2 T4	-4.17333*	.000
T3 T4	-2.85333*	.000

The table illustrates the results of the Post hoc-Scheffe Test, indicating multiple comparisons in the acceptability of homemade Dragon fruit wine concerning color between different treatments. The significant mean differences (l-J) and p-values of .000 across all treatment pairs suggest notable distinctions in color acceptability. Specifically, Treatment 4 consistently exhibits the highest mean difference compared to other treatments, implying that wines subjected to longer fermentation durations possess more desirable color attributes. Conversely, Treatment 1 consistently demonstrates the lowest mean difference, suggesting inferior color quality relative to other treatments. These findings highlight the importance of fermentation duration in influencing color acceptability, emphasizing the need for optimization to ensure consistent color profiles and enhance consumer satisfaction. *Texture:* Table 11 reflects the results of the test of difference in the acceptability of the homemade Dragon fruit wine in terms of its texture.

Table 11. Test of difference in the acceptability of homemade Dragon fruit wine in terms of texture

Sensory Attribute		Sum of Squares	df	Mean Square	F	Sig.
Texture	Between Groups	3581.567	3	1193.856	2.913E3	.000
	Within Groups	244.267	596	.410		
	Total	3825.833	599			

The table presents the results of the Test of Difference in the acceptability of homemade Dragon fruit wine concerning texture. The analysis reveals a significant difference in texture acceptability among different treatment groups, as indicated by a high F-value of 2.913E3 and a p-value of .000, suggesting a statistically significant effect. The considerable sum of squares between groups compared to within groups underscores the substantial variability in texture acceptability attributed to different treatment conditions. These findings underscore the importance of treatment variations, such as fermentation duration or processing techniques, in influencing the texture profile of Dragon fruit wine, emphasizing the need for meticulous optimization to enhance overall consumer satisfaction.

Table 12. Post hoc-Scheffe Test-Multiple comparison in the acceptability of homemade Dragon fruit wine in terms of texture

(1) Treatment (J) Treatment	Mean Difference (l-J)	Sig.
T1 T2	-.69333*	.000
T1 T3	-3.77333*	.000
T1 T4	-6.08000*	.000
T2 T3	-3.08000*	.000
T2 T4	-5.38667*	.000
T3 T4	-2.30667*	.000

The table displays the results of the Post hoc-Scheffe Test, examining multiple comparisons in the acceptability of homemade Dragon fruit wine concerning texture. Significant mean differences are observed across all treatment pairs, denoted by asterisks (*) and supported by p-values less than .001. These findings suggest distinct variations in texture acceptability between different treatment groups. Specifically, treatments T1 and T2 exhibit a mean difference of -.69333, while T1 and T3 show a mean difference of -3.77333, indicating pronounced disparities in texture satisfaction. Similarly, significant differences are observed between T1 and T4, T2 and T3, T2 and T4, and T3 and T4, further emphasizing the influence of treatment variations on the texture profile of Dragon fruit wine.

Taste: Table 13 reflects the results of the test of difference in the acceptability of the homemade Dragon fruit wine in terms of its taste.

Table 13. Test of difference in the acceptability of homemade Dragon fruit wine in terms of taste

Sensory Attribute		Sum of Squares	df	Mean Square	F	Sig.
Taste	Between Groups	3629.258	3	1209.753	3.457E3	.000
	Within Groups	2.08.540	596	.350		
	Total	3837.798	599			

The table presents the results of the test of difference in the acceptability of homemade Dragon fruit wine concerning taste. Significant differences are observed between treatment groups, as evidenced by the F-statistic of 3.457E3 and a p-value less than .001. This indicates that variations in treatment significantly influence the taste acceptability of the wine. The large sum of squares between groups compared to within groups suggests that the treatment conditions have a substantial impact on taste perception. Consequently, it is crucial to consider these treatment differences when optimizing the taste profile of Dragon fruit wine for consumer satisfaction.

Table 14. Post hoc-Scheffe Test-Multiple comparison in the acceptability of homemade Dragon fruit wine in terms of taste

(1) Treatment (J) Treatment	Mean Difference (l-J)	Sig.
T1 T2	-.68000*	.000
T1 T3	-4.10667*	.000
T1 T4	-5.99333*	.000
T2 T3	-3.42667*	.000
T2 T4	-5.31333*	.000
T3 T4	-3.42667*	.000

In Table 14, the Post hoc-Scheffe Test examines multiple comparisons of the acceptability of homemade Dragon fruit wine concerning taste. Each row compares two treatments (T1, T2, T3, T4), evaluating the mean difference and significance level (Sig.) between them. Significant differences are observed between all treatments ($p < 0.001$). T1 shows lower mean differences compared to T2, T3, and T4, indicating it is less favored in taste. T2 exhibits higher mean differences compared to T3 and T4, suggesting a gradual improvement in taste from T1 to T4. Overall, T4 demonstrates the highest mean differences, indicating it is the most preferred in taste among all treatments.

CONCLUSIONS

The formulation and fermentation process of dragon fruit into wine were successfully determined through a series of trials, resulting in the development of a standardized procedure for dragon fruit wine production. The characteristics of dragon fruit wine were comprehensively assessed, revealing satisfactory sensory attributes in terms of appearance, color, flavor, texture, and taste. Additionally, the pH level and alcohol content of the homemade Dragon fruit wine are within acceptable ranges. Moreover, minimal mold and yeast counts affirmed the quality of the wine. The analysis of sensory attributes among the four treatments of dragon fruit wine revealed notable distinctions in appearance, color, flavor, texture, and taste. These variations indicate differing levels of acceptability across treatments, suggesting that factors such as fermentation duration and other processing variables significantly impact the sensory characteristics of dragon fruit wine.

Data Availability Statement

The data that support the findings of this study are available upon reasonable request from the author. Restrictions apply to the availability of these data, which were used under license for this study and are not publicly available. However, data may be available from the author upon reasonable request and with permission from the relevant institutional ethics committee.

Disclosure Statement

The author declares no conflicts of interest or financial disclosures related to this research. This study was conducted in accordance with ethical standards and guidelines and received no external funding.

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