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Pumpkin and Beetroot Wine: Production and Quality Analysis

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ABSTRACT

In this study, a novel approach was undertaken to formulate a unique vegetable-based wine by blending pumpkin and beetroot juices. Pumpkin is a powerhouse of beta-carotene, vitamins, and minerals, particularly Vitamin A, while beetroot is celebrated for its high levels of betalains, nitrates, and dietary fiber, which contribute to cardiovascular health, antioxidant defense, and digestive well-being. The preparation of this vegetable wine involved a series of processing steps, starting with the cleaning, peeling, and crushing of the pumpkin and beetroot to extract their juices. These juices were then subjected to fermentation, a critical phase where *Saccharomyces cerevisiae* yeast was employed at a controlled temperature of 20°C. The resulting wine displayed a visually appealing deep red color, indicative of the pigments inherent in pumpkin and beetroot. The alcohol content was found to be between 11% and 13%, a range that aligns with typical wine standards. One of the significant findings of this study was that the bioactive constituents of the original vegetables, such as beta-carotene from pumpkin and betalains from beetroot, remained largely intact throughout the fermentation process. This is crucial as it suggests that the therapeutic properties of these vegetables, including their antioxidant and anti-inflammatory effects, are preserved in the final product. Sensory evaluation revealed that the vegetable-based wine possessed a pleasant and palatable taste, with a flavor profile that was well-received by evaluators. This indicates its potential as a functional beverage that not only offers enjoyment but also contributes to health.

Keywords: *Antioxidants, Bioactive compounds, Beetroot, Functional beverage, S. cerevisiae, Pumpkin, Sensory evaluation.*

INTRODUCTION

Wine, a timeless beverage primarily made from fermented grapes, is celebrated for its diverse range of flavors, from the crisp acidity of white wines to the deep, tannic richness of reds (Feinberg, 2020). The process of winemaking, or vinification, involves the careful fermentation of grape juice, during which yeast converts the sugars into alcohol, creating a complex interplay of flavors and aromas (Joshi, and Ray, 2021). The aging process further enhances the wine's characteristics, allowing for the development of depth and subtlety that connoisseurs highly prize. Different grape varieties, terroirs, and winemaking techniques result in a vast array of wine styles, each with its unique profile, making wine an integral part of culinary traditions worldwide. (Fazio et al. 2023)

Vegetable wine, while less conventional, offers a fascinating twist on this ancient craft. Instead of grapes, vegetables such as carrots, beets, pumpkins, and tomatoes are fermented to create wines with distinctive flavors that reflect the earthy, sweet, or savory notes of the vegetables used. The process is similar to traditional winemaking but requires careful adjustment of sugar levels and acidity to achieve a balanced flavor. These wines often carry the vibrant colors and unique nutritional benefits of their vegetable origins, making them both visually striking and potentially healthier options. Vegetable wines are gaining attention among adventurous wine enthusiasts and those looking for new, innovative ways to enjoy the art of fermentation, providing a fresh and diverse alternative to the classic grape wine experience. (Liang et al., 2021; Andreo-Martínez et al., 2020; Vilela et al., 2020)

Pumpkin (*Cucurbita moschata*) is a highly nutritious vegetable known for its vibrant color, which is primarily due to its rich content of beta-carotene, a potent antioxidant and precursor to vitamin A. In addition to beta-carotene, pumpkin contains a variety of other beneficial compounds, including vitamins C and E, potassium, fiber, and polysaccharides. These chemical constituents contribute to pumpkin's diverse therapeutic effects. Beta-carotene and vitamin A support eye health, immune function, and skin health, while the high fiber content promotes digestive health and helps regulate blood sugar levels. The antioxidants in pumpkin, such as beta-carotene and vitamins C and E, help combat oxidative stress, potentially reducing the risk of chronic diseases such as heart disease and cancer. Moreover, pumpkin's anti-inflammatory properties have been linked to improved cardiovascular health and reduced risk of metabolic syndrome. Its seeds are also valued for their high content of magnesium, zinc, and healthy fats, which contribute to overall cardiovascular and prostate health. Due to its rich nutrient profile and therapeutic benefits, pumpkin is widely regarded as a valuable component of a healthy diet. (Dotto, and Chacha, (2020; Kaur et al., 2020; Hussain et al., 2022)

Beetroot (*Beta vulgaris*) is a nutrient-rich vegetable known for its deep red color and earthy flavor, commonly consumed for its various health benefits. The vibrant hue of beetroot is due to the presence of betalains, which are powerful antioxidants with anti-inflammatory properties. Additionally, beetroot is rich in nitrates, which are converted into nitric oxide in the body, a compound that helps relax blood vessels, improving blood flow and lowering blood pressure. Beetroot also contains vitamins A, C, and several B-complex vitamins, as well as essential minerals like potassium, magnesium, and iron. The high fiber content in beetroot supports digestive health, while its antioxidant properties help protect against oxidative stress. Therapeutically, beetroot has been studied for its potential in improving cardiovascular health, enhancing exercise performance, and supporting liver function. Its natural compounds also contribute to its potential anticancer effects, making beetroot a valuable addition to a healthy diet. (Ceclu et al., 2020; Thiruvengadam et al., 2024)

Given the aforementioned health characteristics of both veggies, a wine was made by combining them. The objective of this work was to establish a methodical procedure for manufacturing vegetable wine via a variety of pumpkin and beetroot mixes. The current study examined the macronutritive characteristics of pumpkin and beetroot. It is possible to transform these substrates into durable products, such as wine, which may be preserved for prolonged durations. This enables purchasers to take advantage of these qualities when they are not easily accessible. Hence, integrating value-added features might augment the market potential and raise the economic worth.

1. METHODOLOGY

The current study was conducted in the Department of Biotechnology, affiliated with Government College, Hisar.

2.1 Substrate

Acquired from the local market of Hisar (Haryana), the fresh and mature beetroot and pumpkin were used for the preparation of wine.

2.2 Inoculum preparation

The pure strain Saccharomyces cerevisiae MTCC 178 was obtained from the Institute of Microbial Technology in Chandigarh, India. The cultures were sustained using YEPD growing media specifically designed for yeast cultivation. Symbiotic yeast (S. cerevisiae) inoculum was prepared using sterilized grape juice. One teaspoon of 24-hour-old yeast cultivated on agar slant was aseptically transferred to 10 ml of grape juice and left to develop for 24 hours at 30 degrees Celsius. The entire contents of the tube were transferred to 100 ml of sterilized grape juice and immersed in a mild shaking environment for 24 hours at 30°C. This mixture was then utilized as the inoculum for wine production.

2.3 Extraction of juice from pumpkin and beetroot

Pumpkin and Beetroot that had reached full ripeness were thoroughly washed with running water, and the mash (pulp) were prepared in Blender. The juices were then manually squeezed through muslin cloth.

2.4 Preparation of wine from pumpkin and beetroot

The juices were combined for the purpose of winemaking. The ratio of pumpkin and beetroot juices was taken to be 3:1. After sterilizing the final mixture of juices, several parameters such as pH, specific gravity, and TSS were determined. The must was then partitioned into three distinct sets: SET I (PB1), SET II (PB2), and SET III (PB3). The sets were calibrated to brix values of 22, 24, and 26 degrees. The Brix adjustment and flavour improvement were achieved by the addition of orange juice and sugar. Next, these sets were inoculated with S. cerevisiae yeast for anaerobic fermentation at a temperature of 20°C. Anaerobic fermentation persisted for a duration of seven days, during which the advancement of fermentation was tracked by quantifying the decrease in Total Suspended Solids (TSS). Following the completion of wine formation, the process of filtering, clarifying, and racking began. To conduct chemical analysis, samples were collected at consistent time intervals. Measurements of alcohol concentration, pH, specific gravity, TSS, titrable acidity, and other parameters were conducted.

2.5 Analysis of wine

Analysis of the wine was conducted during the storage period, and biochemical changes were documented at various time points. The specific gravity of wine samples was determined using a hydrometer in a measuring cylinder containing 50 ml of sample, with the appropriate temperature correlation factor defined as 20^{o} C. The specific gravity of wine is a quantitative assessment of its density in relation to water, employed for the purpose of monitoring fermentation and approximating the alcohol concentration. Previous to fermentation, the specific gravity of grape juice (must) usually falls within the range of 1.070 to 1.100, which serves as an indicator of the sugar content. As the process of fermentation advances, the specific gravity of sugar drops due to its conversion into alcohol. Analysis of fresh wine made from various mixes was conducted using the following physicochemical parameters.

2.5.1 Detection of Ethanol Before measuring wine's ethanol content with chromic acid, a precise volume is made and diluted. To make fresh chromic acid reagent, dissolve chromium trioxide (CrO_3) in concentrated sulfuric acid. After mixing the wine sample with the chromic acid reagent, ethanol is oxidized to acetic acid and chromic acid is reduced from orange-red to green chromium ions. This reaction is allowed at room temperature for a specified time. Spectrophotometers monitor color change at 600 nm. The wine's ethanol concentration is calculated by comparing the absorbance value to a calibration curve using known-concentration standard ethanol solutions. (Tupe et al., 2018; Caputi et al., 1968)

2.5.2 Detection of pH The Eutech Cyberscan pH meter was utilized. Rinsed electrode with distilled water. The instrument was calibrated with buffer solutions. The probe was dipped in 50ml wine. Records were kept of stable reading.

2.5.3 Detection of Vitamin C Vitamin C was measured via iodine titration. Measured 2 g KI and 1.3 g I_2 exactly. Shaking completely dissolved them in a little water. A 1L volumetric flask was filled with iodine solution, rinsed with purified water, and filled to the mark. A 0.5% starch indicator solution was made by adding 0.25 grams of soluble starch to a 100 mL conical flask or beaker with 50 mL of distilled water. Heated the solution at 79°C for 5 minutes while stirring. In a 250 ml conical flask, added 20 ml wine sample solution, 150 mL distilled water, and 1 mL starch indicator solution. The samples were titrated with 0.005 mol L^{-1} iodine solution. Starch-iodine gives the first dark blue-black titration endpoint trace. Additional sample solution aliquots were titrated until values were within 0.1 mL.

Vitamin C (mg)= [Volume of Iodine Solution (L) x Molarity of iodine Solution (mol/L) x Molar mass of Vitamin C (g/mol) x1000]/ Volume of sample (ml)

Where:

- **Volume of iodine solution (L)**: The volume of iodine solution used in the titration (in liters).
- **Molarity of iodine solution (mol/L)**: The concentration of the iodine solution used.
- **Molar mass of Vitamin C (g/mol)**: The molar mass of ascorbic acid, which is 176.12 g/mol.
- **Volume of sample (mL)**: The volume of the sample solution titrated. (Sathpathy, 2021)

2.5.4 Detection of Reducing Sugar DNS method was used to quantify decreasing sugar concentration (Khatri, 2020) with certain modifications. One gram of 3,5-dinitrosalicylic acid (DNSA) and 30 grams of sodium-potassium tartaric acid were dissolved in 80 millilitres of 0.5 N NaOH at 45 degrees Celsius. After reaching room temperature, 100 ml of distilled water was added to prepare the solution. The sample (0.1) was diluted with 10 ml distilled water and transferred 0.5 ml to a 2.5-mL test tube. DNSA reagent (3ml) was heated in boiling water for 5 minutes. The absorbance was measured at 540 nm with a spectrophotometer. Using a standard D-glucose solution calibration curve, the reducing sugar concentration was calculated. Milligrammes of D-glucose per millilitre of sample were reported. (Miller 1959)

2.5.5 Detection of titrable acidity The hot plate was heated to maximum. A 100 mL glass beaker received 10.0 mL of wine by pipette. A few boiling granules were added. The sample was then cooked on a hot plate until boiling, then quickly removed. The wine was refrigerated before titration. Wine was blended with filtered, heated, cooled water. The solution was then titrated with 0.1M NaOH until it reached pH 8.2 or until phenolphthalein showed the first long-lasting pale pink tint (Tsegay ,2020). Titrable acidity was estimated using the formula.

Titrable Acidity (g/l) = [(molarity of NaOH) × {mLs NaOH (sample titration) – mLs NaOH (blank titration)}] × 75/ mLs of sample

2.5.6 Detection of Antioxidant activity The DPPH method is based on the ability of antioxidants to scavenge the stable DPPH free radical, causing a color change from purple to yellow, which can be measured spectrophotometrically. The use of the DPPH assay provides an easy and rapid way to evaluate antioxidants by spectrophotometry. 4mg of DPPH was added to 100 ml of methanol. 2.5mg of ascorbic acid was taken and added to 2.5 ml of distilled water. Methanol was taken as blank. For negative control 100µl methanol and 2900 µl of DPPH were taken.

Then 100 µl wine sample was taken and 2900 µl of DPPH was added to it. Now this solution was incubated for 30 min in dark at 37^0C and the reading was taken at 517nm.
To calculate the percentage radical-scavenging activity (%SA), used the formula:

$$\%SA = 100 \times (A_{control} - A_{sample}) / A_{control},$$

where Acontrol represents the absorbance of a solution containing only DPPH and ethanol, and Asample represents the absorbance of the DPPH solution in the presence of the wine fractions. (Romanet et al., 2021)

2.5.7 Measurement of °Brix The Erma Inc. refractometer was retrieved and calibrated using distilled water. After cleaning it, we placed a wine sample and carefully recorded the measurement.
2.5.8. Sensory/ Organoleptic Analysis The 9-point hedonic scale is used in sensory analysis, notably wine analysis, to determine consumer preferences. This scale enables wine drinkers assess their preferences from "dislike extremely" to "like extremely." For consistency, wine samples were served at the same temperature and in the same glassware before analysis. Then, numerous volunteers were picked to offer different perspectives. Each participant used the 9-point hedonic scale to rate a wine sample's smell, flavor, mouthfeel, and acceptability. After analyzing participant responses for each attribute, average scores were generated. Data indicates consumers' favorite and least liked attributes. This analysis aids product development, marketing, and quality. Winemakers can measure consumer preferences with the 9-point hedonic scale to improve their products and client satisfaction. (Lesschaeve, and Noble, 2022)

RESULT AND DISCUSSION

Vegetable wine is an intriguing alternative to regular fruit wines since it offers a variety of benefits that make it an appealing choice. It presents uncommon, earthy flavors that are distinct from the conventional fruity profiles, so offering wine aficionados a distinctive experience that they will not find anywhere else. The nutritional benefits of the vegetables that were used in the production of these wines are preserved, including vitamins, minerals, and antioxidants. As a result, these wines may provide possible health benefits, such as enhanced digestion and support for the cardiovascular system. In addition, vegetable wines are diverse in terms of their applications in the kitchen, with the ability to complement a wide range of recipes, particularly those that are savory and robust. There is a vast variety of vegetables that can be used in the production of wine, which enables a wide variety of flavors and styles to be created, which can accommodate a variety of preferences about diet and taste. In addition, vegetable wines typically have a lower sugar level, which makes them an excellent alternative for individuals who are looking for a beverage that is either less sweet or lower in calories. When taken as a whole, vegetable wines are an example of a creative and unique approach to the production of wine. They are appealing to consumers who are seeking for beverages that are either environmentally friendly or those that are produced locally. As a result, the purpose of this endeavor was to create a vegetable wine by utilizing two particular edible plants, namely pumpkin and beetroot. In order to compensate for the relatively low sugar content that is present in the majority of juices and pulp, sucrose is frequently utilized to increase the amount of sugar that is present in the juice. The Brix of the pumpkin must considered most suitable by Pali and his colleagues was 24 degrees, and they raised the brix level by using sugar.

According to the findings of the current experiment, the three wine blends all had the same amount of pumpkin and beetroot, but their brix index levels were different from one another. 22^{o} is the Brix index for blend 1, also known as PB1, which has been increased to 24^{o} for blend PB2 and 26^{o} for formulation PB3. In addition, the fermentation process was carried out at a temperature of 25 degrees Brix using only pure pumpkin and beetroot juice (Table 1). While the mashes were being made, a yeast culture was added to them at a concentration of one gram per liter. According to the findings reached by Prescott and Dunn, the best inoculum level for the production of wine is somewhere in the region of four to six percent. It was indicated by Sterehaina and colleagues that a concentration of inoculum at 10.0% (v/v) is sufficient for industrial fermentation. This was done with the intention of reducing the likelihood of contamination occurring in the fermentation medium. The total soluble solids (TSS) contained in the wine that Singh et al., 2021 made from beetroot was 6.55Brix. According to Mo et al.'s research (2020), the degree Brix for beetroot wine decreased from 21.84 to 6.22 during fermentation.

When conducting the chromic acid method, which is a traditional wine ethanol test, a solution of chromium trioxide in sulfuric acid is utilized to oxidize ethanol to acetic acid during the process. A spectrophotometric measurement is performed at a wavelength of 600 nm in order to determine the degree of color shift that occurs as a result of the reduction of orange-red chromic acid to green chromium ions. This color change is determined by the concentration of ethanol in the wine. Based on the findings of the current research, the amount of alcohol discovered was somewhere between 11 and 13%. Based on the findings that Hailu and Mekonnen acquired in 2017, it was found that beetroot wine contained 13% ethanol by volume. According to Mo et al.'s 2020 research, beetroot wine had an alcohol content of 7.2% volume/volume.

According to De Souza et al.'s research from 2020, the pH scale is a numerical method that is utilized in the winemaking industry to evaluate the acidity of juice or wine by quantifying the acidity or alkalinity of a solution that contains water. The total acidity of a solution is a measurement of the overall concentration of acids in the solution, whereas the pH of a solution is a numerical representation of the relative strength of acids, considering the fact that not all acids have the same strength (Sun and Berg, 2003). According to Botezatu et al. (2021), the pH levels of juice and wine will normally fall around between 3 and 4. Because of the high acidity level, a wine with a low pH will have a sour flavor. This is because of the wine's low pH. According to Terblanche (2019), a wine that has a high pH level would have a flavor that is devoid of vitality and will lack the freshness that is characteristic of most wines. When making wine, it is extremely important to maintain a pH level that is under control because this has a direct impact on the stability of microorganisms and the risk of decay (Seo et al., 2020).

According to Lee et al.'s research from 2022, the pH and acidity of the mashes that were produced were purposefully altered in order to prevent the growth of microbes that were not desired in the fermentation process. As a result of the current investigation, the pumpkin beetroot wine has a pH that falls somewhere between 4.11 and 4.42, which indicates that it has a sour taste. Using beetroot as the primary ingredient, Singh et al., 2021 produced a wine with a pH of 3.96. The pH of the beetroot wine was found to be 3.49, according to the findings that Hailu and

Mekonnen acquired in 2017. Mo et al., 2020 demonstrated that the pH of beetroot wine dropped from 4.7 to 3.9 over the course of the study.

According to the most recent findings, the best range for titrable acidity for winemaking is between 4.0 and 4.3, depending on the specifics of the situation. 0.35 percent titratable acidity was the maximum that was found in the wine that Singh *et al*. (2021) made from beetroot. The findings that were obtained by Hailu and Mekonnen in 2017 indicated that beetroot wine had a TA value of 0.65% volume/volume. According to Mo et al.'s research from 2020, the total titratable acidity of beetroot wine was 0.31-0.34%.

According to the findings of the research that Kempraj and Dasgupta carried out, the amount of reducing sugars that are present in wine can be used as a reference point to determine the quality of these food products. On top of that, it has been demonstrated that the total marketing quality may be improved by monitoring the reduction of sugar levels throughout the production process of food, (2018) according to Jangra and colleagues. According to the findings of this research, the pumpkin beetroot wine had reducing sugar level of 0.64, which indicates that plenty of fermentation had taken place. One study conducted by Singh et al. in 2021 found that wine made from beetroot had a lowering sugar content of 26.75 lg ml-1.

In addition, temperature has a wide range of effects, in addition to the direct influence it has on the activity and growth of yeast. According to Shenbagamuthuraman et al.'s research from 2022, higher temperatures result in the depletion of aromatic components and alcohol, as well as the production of more alcohol and other secondary chemicals. Between 20 and 28 degrees Celsius is the temperature range that is considered to be optimal for the fermentation of alcoholic beverages. In the current investigation, the fermentation process was carried out at a temperature of 20 degrees Celsius for around seven days.

Table 3 contains a presentation of the enological features of wine that were determined during this research. Upon completion of the fermentation process, the wines did not display any discernable pattern in their final specific gravities. The findings that were obtained by Hailu and Mekonnen in 2017 indicated that beetroot wine had an SG value of 0.99. According to Mo et al.'s research from 2020, the specific gravity of beetroot wine ranged from 1.092 to 1.021. As a result of the findings of Chaudhari et al. (2013), the specific gravity of red pumpkin was determined to be 1.0853 by weight, whereas the specific gravity of beetroot was 1.0743. This indicates that wine contains between 11 and 14 percent alcohol and is sweet. According to the findings of the prior investigations, the current findings were consistent.

According to Zia and Alibas (2021), vitamin C is a highly significant quality indication that makes food more effective in its ability to offer antioxidant protection. According to the findings of the current experiment, the levels of vitamin C ranged from 5.03 to 5.88 mg/100 ml, which indicates that the antioxidant activity was at a satisfactory level. The concentration of DPPH inhibition was measured in order to carry out the process of determining the level of antioxidant activity present in wines. According to the findings of Somesh et al. (2018), wines made with pumpkin had the highest antioxidant activity. Sharma et al., 2021 demonstrated that the wine that was made with Zingiber officinale and G. glabra (GM4) had the highest scavenging activity value for the DPPH radical, which was 84%. It is possible to draw the conclusion that using pumpkin as a base vegetable, has the potential to be used in the production of high-quality pumpkin table wine that can be supplemented with herbs. The most recent findings from our investigation have shown that the pumpkin beetroot mixtures PB1, PB2, and PB3 have an exceptional level of antioxidant activity. As a result of the fact that pumpkin and beetroot are vegetables that have been scientifically proven to exhibit anti-inflammatory parameters and considerable amounts of free radical scavenging activity, it can be concluded that these vegetables have medical benefits.

The °Brix is a rigorous quantitative evaluation of the total concentration of dissolved soluble solids in 100 milliliters of juice. This evaluation takes into account the pigments, acids, glycerol, and sugar (Bezus et al., 2022). Because of this, °Brix can be utilized for the purpose of estimating the concentrations of sugar sources. According to the findings of the current inquiry, the °Brix value fluctuated between 20 and 2 over the course of the first few days. The fact that the value of the parameter decreased as the number of days of fermentation increased is indicative of the fact that sugar was converted with more efficiency at this particular time. The ultimate brix value reached a value of zero after a period of seven days, which indicates that there was no more sugar conversion in the wine. According to Chen and Darriet (2021), the evaluation of wine is based on the perception of the flavors and aromas. The procedure of evaluating wine was first carried out throughout the production process, but it was not until the fourteenth century that it became more formalized. According to Malfeito-Ferreira et al. (2021), esteemed wine oenologists frequently make use of vocabulary in order to explain the flavors, aromas, and characteristics of wine. These evaluations determine the complexity, profile, and appeal of a wine, as well as any flaws that may be present. Every aspect of our vegetable wines, including their complexity, inherent traits, potential, and flaws, was evaluated using the same set of criteria. Table 4 provides a presentation of the sensory evaluation that was carried out by many panelists consisting of students, professors, and staff members from the Government College in Hisar.

The study conducted by Otegbayo et al. in 2020 revealed that there were notable variations ($p < 0.05$) in the taste, flavor, and general acceptability of beetroot wines that were fermented for seven days, fourteen days, and twenty-one days. Furthermore, in terms of taste, aroma, flavor, and general acceptability, beetroot wine that had been fermented for 14 days was seen as superior to those that had been fermented for 7 and 21 days separately. In their study from 2014, Thakur and colleagues discovered that pumpkin wine possessed a number of desired qualities, including a higher percentage of alcohol, higher sensory scores, and improved qualities such as acidity, sugars, and other qualities. The treatment of pumpkin with Ocimum sanctum (basil leaves) at a concentration of one percent was determined to be the most effective by Sharma et al. in 2021. A high concentration of esters and phenols, as well as a low degree of volatile acidity, were among the many favorable qualities that the wine possessed among its numerous qualities. The results of the sensory evaluations also showed that the herbal wine that contained basil leaves had a high level of acceptability.

According to the findings of the current experiment, pumpkin beetroot wine had a significant level of desirability among tasters. The color of the wine was a vibrant deep red. Undoubtedly, there were no particles that were insoluble. There was a pleasant scent that pervaded the beverage. A powerful and distinctive bouquet of beetroot was present in the wine, and it closed with a subtle undertone of pumpkin, which indicated that there was a wine that was well-balanced and somewhat sweet on the table. The wine had a delightfully delicate trace of alcohol, which complemented the wine's already delightfully sweet degree of sweetness. When consumed, the wine that was produced from pumpkin beetroot had the impression of being a rich and sweet liquid. When tasting, almost all wines follow a regular pattern that is based on data that is not acquired through the senses. After comparing the three sets, it was determined that PB2 received the highest amount of favorable feedback overall.

According to Lucini et al. (2021), wines that are produced utilizing substrates such as pumpkin and beetroot are thought to be good to one's health due to the polynutrients that are present in both of these vegetables. This is because pumpkin and beetroot contain different types of nutrients. Furthermore, this wine is full of antioxidants and phytochemicals, both of which contribute to the health of heart and digestive tract. This wine contains antioxidants such as vitamin C, which will be of great aid to the health of the skin, hair, and overall immune system due to the fact that they will help build up immunity. For the objective of providing a comprehensive overview of the entire process of manufacturing vegetable wine, the purpose of this study is to make use of substrates such as pumpkin and beetroot. Utilizing this information, food manufacturers and processors are able to create value-added wines that not only capture the distinctive phytochemical profiles of a wide variety of vegetables but also maintain and maybe enhance the bioactive chemicals that are present in these vegetables. This makes it possible to manufacture functional beverages that are in line with the need of consumers for products that are high in nutritional density. As a result, the ability to include the health-promoting qualities of vegetables into a refined wine that has been scientifically formulated is made possible.

CONCLUSION

The future scope of pumpkin and beetroot wine is promising, particularly as the market increasingly values functional and health-oriented beverages. These wines, rich in antioxidants, vitamins, and bioactive compounds like beta-carotene from pumpkin and betalains from beetroot, are well-suited to appeal to health-conscious consumers seeking alternatives to traditional fruit wines. Beyond their health benefits, these wines offer unique flavors and vibrant colors that could inspire culinary innovation, making them attractive for gourmet cooking and food pairings. Additionally, as sustainability and local production gain importance, pumpkin and beetroot wines present an opportunity to promote environmentally friendly, locally sourced beverages. Continued research and development could further enhance their nutritional profile and sensory appeal, solidifying their place in the evolving landscape of functional and artisanal wines.

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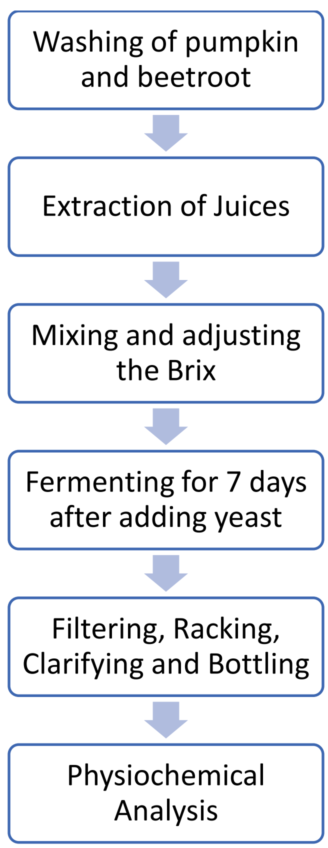

Figure 1: Flow Chart Depicting Pumpkin Beetroot Wine Preparation

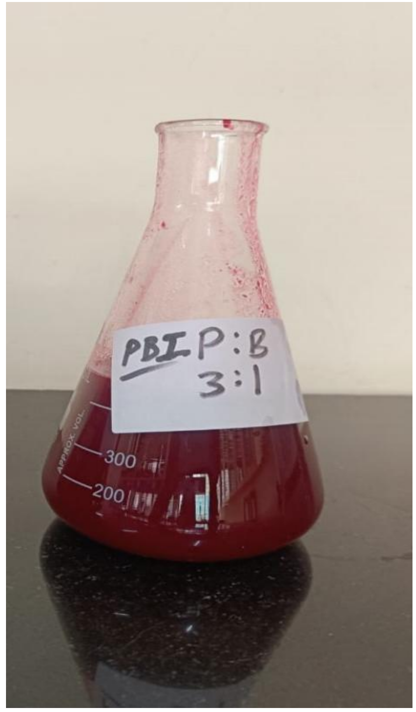

Figure 2: Pumpkin Beetroot Blend Before Fermentation

Figure 3: Pumpkin Beetroot Blends after Fermentation on 7th day

Figure 4: Fermentation at 20°C

Table 1: 9-point hedonic scale

Range	Point	Range	Point
Extremely liked	9	Neither liked or disliked	5
Very Much Liked	8	Slightly disliked	4
Moderately Liked	7	Moderately disliked	3
Slightly Liked	6	Very Much disliked	2
		Extremely disliked	1

Table 2: Physiochemical analysis of different wine samples at a fermentation temperature of 20°C

	Samples		
Physiochemical Parameters	**SET I (PB1)**	**SET II (PB 2)**	**SET III (PB 3)**
Initial TSS (Brix)	22	24	26
Final TSS (Brix)	0	0	0
Titrable Acidity (g/l)	4.0	4.3	4.0

Alcohol Content (%)	11.21	12.01	13.54
pH	4.11	4.42	4.37

Table 3: Oenological properties of Pumpkin-beetroot wine

	Samples		
Properties	**SET I (PB1)**	**SET II (PB 2)**	**SET III (PB 3)**
Specific Gravity (Initial)	1.091	1.104	1.087
Specific Gravity (Final)	0.998	0.999	0.998
Reducing Sugar (g/100ml)	0.61	0.64	0.62
Antioxidant Activity (%)	93	97	94
Vitamin C (mg/100ml)	5.03	5.88	5.09

Table 4: Table illustrating Sensory evaluation of Pumpkin-Beetroot wine samples

	Preparations		
Attributes	**SET I (PB1)**	**SET II (PB 2)**	**SET III (PB 3)**
Appearance	8	9	8
Aroma	7	8	8
Taste	9	9	8.9
Flavor	8.7	8.9	8.2
Overall Acceptance	8.17	8.725	8.275

Table 5: Table illustrating Non- Sensory evaluation of Pumpkin-beetroot wine samples

	Preparations		
Attributes	**SET I (PB1)**	**SET II (PB 2)**	**SET III (PB 3)**
Color	Deep Red	Deep Red	Deep Red
Alcohol Content	Natural	Natural	Natural
Relative sweetness	Sweet and astringent	Sweet and astringent	Sweet and astringent
pH	Acidic	Acidic	Acidic

Attributes	Red and clear	Red and clear	Red and clear