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Dragon Fruit (*Hylocereus polyrhizus*) Wine: Physical, Biochemical, and Organoleptic Preferences

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Abstract

Dragon fruits (*Hylocereus polyrhizus*) are considered as one of the nutritious exotic fruits in Asian countries. Juice extracted from these fruits has been processed into wine by spontaneous fermentation. Fermentation was carried out for 21 days, and then wine aging was continued for 3 months. The biochemical properties (tartaric acid, alcoholic content, total soluble solids, reducing sugar content, color, and antioxidant activity) were determined using standard scientific procedures of food characteristics. The results after 3 months of wine aging show that a pH value of 3.51, a tartaric acid of 8.06%, an alcoholic content of 13%, a total soluble solid of 3° brix, a total reducing sugar content of 0.28 g/100 mL, a DPPH activity of 75.79%, and a chroma test score of 13.73. Sensory evaluation showed no differences in flavor, taste, aroma, and overall acceptability between the processed wine and a reference wine. The dragon fruit wine was generally accepted. Therefore, this study requires further comprehensive investigation into the substantial contents of functional compounds such as organic volatile groups and bioactive compounds.

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Introduction

Dragon fruit is an exotic cactus fruit, genera of *Selenicereus* and *Hylocereus*. It is well-grown in tropical Asian countries, including Indonesia (Jalgaonkar et al, 2022). There are several species of dragon fruits, however, the species of *H. polyrhizus* is the most common type which is cultivated in Indonesia. The flesh is red, scattered with small black seeds, and has a soft texture, sweet and slightly sour (Jalgaonkar, 2020). Red dragon fruits have been reported to contain vitamins, minerals (potassium, magnesium, and calcium), dietary fiber, and reducing sugars such as fructose (0.4 – 2.0g/100 g) and glucose (3.0 – 5.5g/100g) (Tran et al., 2015; Hossain et al., 2021). They are also higher in antioxidants than white dragon fruits (Sekar et al., 2016). Recently, due to its medicinal benefits, the identification of the phytochemical and bioactive compounds present in dragon fruit has been increasing. Betalains, flavonoids, polyphenols, terpenoids, steroids, saponins, alkaloids, tannins, and carotenoids can be extracted from all the parts of the fruits (Luu et al, 2021). Flesh and peel are rich in betacyanin, which is beneficial as a colorant and antioxidant to free radicals (Manihuruk et al., 2017; Hossain et al., 2021). Their extracts also contain anti-cancer, anti-lipidemic, anti-inflammatory, anti-spasmodic, and antimicrobial effects (Joshi and Prabhakar, 2020). In addition, consuming dragon fruits can help reduce the total amount of cholesterol, triglycerides, and LDL-cholesterol while increasing HDL-cholesterol levels (Harahap et al. 2020; Fadlilah et al. 2021). On the other hand, in terms of shelf stability, dragon fruit cannot be stored and it is only consumed fresh or processed into juice or puree with a short shelf life (Rodeo et al. 2018; Muhialdin et al. 2020), therefore, further processing is needed (e.g., making into syrup, jam or candies, etc) to maintain nutritional content, extend shelf life and reduce losses (Dartsch et al. 2009; Jalgaonkar et al. 2022). In addition, red dragon fruit (*Hylocereus polyrhizus*) has great potential to be utilized for the processing of alcoholic beverages such as wine due to the attractive red pigment of the juice makes it similar to grape juice (Jalgaonkar et al. 2022).

In the wine-making process, the addition of sugar and the concentration of the starter affect the characteristics of the resulting wine. Huan et al. (2020) reported red dragon fruit has a sugar content of between 16-20°Brix. This value is dissimilar to the sugar content in grapes (*Vitis vinifera* L.), which is above 20°Brix. Sugar added to fruit juice provides nutrients that support microbes to carry out their activities. In addition, the composition of added sugar also aims to obtain the desired alcohol content as well as functional effects such as the flavour, taste, and sensory attributes of wine (Velic et al. 2018). Research highlights the diverse physicochemical profiles of fruit wines. For instance, sugarcane-watermelon wine exhibited 9.6% (v/v) alcohol, 14.2 °Brix total soluble solids, 0.92% titratable acidity, and 11.98% total reducing sugar (Soibam et al., 2016). Similarly, a study on pineapple wine (Boondaeng et al., 2021) across juice-water ratios (2:1, 1:2, and 1:3) yielded alcohol contents of 10.71%, 9.61%, and 8.535% (v/v), respectively. This pineapple wine also presented pH values ranging from 3.56 to 3.82, titratable acidity from 0.384% to 0.448%, acetic acid content from 0.0013% to 0.0016%, and total soluble solids from 9.7 to 13 °Brix. Furthermore, it demonstrated a total antioxidant activity of 0.91 mmol/L TE (DPPH) and a total phenolic content of 365.80 mg/L GAE. Other analysis of the sugarcane-sweet melon wine reported by Tatah and Abah (2024) showed specific physicochemical properties: 3.2% alcohol, a pH of 4.60, and a temperature of 28.1°C. Its composition was notable for a high moisture content (96.73%) and lower amounts of ash (0.17%), fat (0.5%), total carbohydrates (0.07%), fibre (0.3%), and protein (0.12%). The wine also contained several essential amino acids, namely methionine (6.179 µL), phenylalanine (60.055 µL), and leucine (234.281 µL), alongside the nonessential amino acids such as asparagine (82.357 µL), proline (87.365 µL), glutamic acid (225.686 µL), cysteine (52.923 µL), and glutamine (167.338 µL).

This study was aimed at determining the potential of dragon fruits (*H. polyrhizus*) in wine fermentation, based on the analyses of physicochemical properties (pH, colour, % TDS, % alcohol), and antioxidant (DPPH) activity during fermentation at ambient temperature. Publications on the determination of physicochemical, DPPH activity changes as well as sensory evaluations of the dragon fruit wine are required to develop an understanding of how the process of fermentation and aging time affects functional attributes in dragon fruit wine. Therefore, this study has the potential to produce commercial wine from dragon fruit juice.

Materials and Methods

Preparation of juice and wine processing

Mature, fully ripe, and healthy red dragon (*Hylocereus polyrhizus)* fruits used in this current study were purchased from a local market in Kupang city-East Nusa Tenggara, Indonesia. The fruits had an average weight of 535.0 ± 39.9 g (range 500.0 to 600.0 g) and a diameter of 8.9 ± 0.4 cm (range from 8.0 to 10.0 cm). Only fresh and un-damaged fruits were used, as the quality of fruits can be a crucial consideration that could influence wine's final product (e.g. taste, color, and aroma) (Boss et al. 2015). The peels of the selected fruits were removed, then the flesh was sliced into small pieces and pulped. The pulp was mixed with water (1:1, w/v ratio) to get extracted juice. Then the juice was mixed with water (1:3, v/v ratio), boiled, and kept to 70°C for 15 min. Crystal cane sugar (20%), lemon juice (3%), and grape essence (2%) are also added to the mixtures. Fermentation was done at room temperature for 7 days then solid matters were removed using a sterilized cloth and the fermentation process was continued for 3 weeks. Aging was carried out for a month, 2 months, and 3 months after fermentation.

Measurements of pH and titratable acidity (TA)

The measurements of the pH value was done using a pH meter (Lab Bench pH AMT20). About fifty (50) ml of wine was made up to a 100 mL volume with distilled water. An aliquot of the solution was then titrated against 0.01 N sodium hydroxide using phenolphthalein (1%) until the colour changed to light pink. The titratable acidity (TA) was calculated using the formula reported by Arivalagan et al. (2021) and was expressed as a percentage of tartaric acid (MW = 150.087 g/mol).

$$\%\ \mathrm{TA} = \frac{\mathrm{V_{NaOH}} \times \mathrm{N_{NaOH}} \times \mathrm{MW\ tartaric\ acid}}{\mathrm{Sample\ weight\ (g)\ x\ Aliqout\ sample\ (mL)\ x\ 1000}} \times 100$$

Soluble solid (sugar) analysis

The total soluble sugar concentration was estimated using a Refractometer (ATC, range: 0-32º, China). Briefly, one drop of the samples was placed on the prism and left for 1 min to allow for temperature adjustment before the reading was taken. The values were recorded as total soluble sugars (TSS) of dragon fruit wine.

Measurement of alcoholic content

The alcoholic by volume (% ABV) of wine was carried out using an ethyl alcohol refractometer (ATC, range: 0 – 80%, v/v, China) by placing a drop of liquid sample on the prism and a light blue boundary was shown as a result value of %ABV.

Determination of total reducing sugars

The total reducing sugar content was determined using Nelson-Somogy procedure (Shao and Lin 2018). Briefly, one milliliter of the dilute wine was transferred to a clean tube and 1 mL of the Nelson reagent was added. Measured standard solution tubes were placed together on a single rack and immersed in a boiling water bath for 20 minutes. After heating, the tubes are quickly cooled in running water and the mixtures are added with 1 mL of the arsenomolybdate reagent. The mixtures of the tubes are vortexed and diluted with 7 mL of deionized water. The mixture samples and standard solution then were placed in the cuvettes for reading via a spectrophotometer. The spectrophotometer was adjusted to a wavelength of 540 nm and the absorbance of the solutions obtained from the spectrophotometer was recorded. The zero setting on the spectrophotometer is made through a reagent blank tube run like the samples.

Colour evaluation

Colour measurement was done using a colorimeter reader (CHNSpec CS-10, China). The colorimetric values (L*, a*, and b*) representing lightness, redness/greenness, and yellowness/blueness, respectively were recorded. The instrument was calibrated using a standard black tile and a whiteboard supplied by the manufacturer. The wine samples were poured into plastic cups and three readings were taken. The average values were recorded. Chroma [C*=(a*2+b*2)1/2] was then calculated from CIE a* and b* (Bunga et al. 2021).

Antioxidant activity

DPPH scavenging activity was determined according to the method reported by (Mitrevska et al. 2020) with slight modifications. Briefly, 4 mg of DPPH (2,2-Diphenyl-1-Picrylhydrazyl) in 100 mL of 96% EtOH (w/v) was prepared and the absorbance (used as control) was measured using a spectrophotometer (SP-UV1000-DLAB), read at 517 nm. Then, wine samples were diluted 1:10 (v/v) with dH2O, and 2 mL of diluted wines were added to 2 mL of DPPH solution in 96% ethanol (w/v) and vortexed for 5 sec. The absorbance was measured at 517 nm after samples were incubated in the dark for 30 min at ambient temperature. The inhibition percentage of DPPH at the steady state was determined using the following equation:

$$\%\ \text{inhibition} = 1 - \frac{\text{Abs}_{\text{sample}}}{\text{Abs}_{\text{control}}} \times 100$$

Consumer acceptance testing

Sixteen untrained consumers (students, staff, and lecturers from agriculture-related departments with wine consumption experience) evaluated the taste, aroma, and color/appearance of the wine samples. A 5-point Hedonic scale (1 = strongly dislike to 5 = strongly like) was used for this consumer acceptance test, conducted as part of the initial product development and optimization. Dragon fruit wine and a selected commercial grape wine (Hatten wine, Bali) were presented for comparison. Samples were served in labeled (3-digit random numbers) plastic transparent shot glasses (single shot), and participants were provided with questionnaires and water for palate cleansing between tastings. To minimize misinterpretation, the attributes were explained to the consumers before they began their evaluation.

Statistical Analysis

All experiments were carried out in three replicates. Assessments were analysed using a one-way ANOVA, expressed as the mean ± standard deviation (SD).

Results and Discussion

Titratable acidity and pH value

The pH and acidity are important values and contribute to the freshness and acidity of the wine. Titratable acidity (Table 1) represented as acid acetate and tartaric acids ranged between 3.73 – 6.51% and 4.84 – 8.06%, respectively. The pH value of the wine was acidic throughout the aging period, reduced from 5.77 to 3.51 after 3 months of aging. This result is consistent with that reported on mango wine (Ogodo et al. 2018), and fermentation of starfruit – mango wine (Muotolu and Mbaeyi-Nwaoha, 2020), which reported the pH was 3.7 and 2.4 – 4.20, respectively. According to Tsegay and Lemma (2020), total acidity, titrable acidity, and volatile acidity of a fruit wine originate from the types of organic acid present. Furthermore, low pH and high acidity inhibited the growth of spoilage microbes however created a conducive and competitive advantage environment for the growth of desirable microbes (Mathew et al. 2017). The pH value and acidity influence the tastes of wines by imparting sour tastes to the end product (Ogodo et al. 2015).

Alcoholic content (% ABV), total soluble solid (TSS), and reducing sugar content

Generally, all alcoholic beverages contain less than 15% ethanol. Pinto et al. (2022) summarized that fermented fruit juices with the fermentation and aging period will have alcoholic content between 5% and 13%. The higher the alcohol content, the more resistant the beverages to bacterial infection. This recent study reported the alcoholic content of the dragon fruit wines was relatively stable during 3 months of aging, which is recorded at 13% (Table 2). The noticeable acetic acid aroma in the wine from this study indicates the presence of acetic acid spoilage, a common defect in winemaking. This spoilage is primarily caused by the aerobic activity of *Acetobacter* species, which convert ethanol into acetic acid. While the fermentation in this study was spontaneous, *Acetobacter* are ubiquitous in the environment and are often present on fruit surfaces and equipment.

The conditions within the fermenting wine, specifically the 13% Alcohol by Volume (ABV) and a concurrent decrease in Total Soluble Solids (TSS), were conducive to the proliferation of these bacteria. *Acetobacter* preferentially utilize ethanol as a substrate, converting it to acetic acid in the presence of oxygen. As noted by Cendrowski, Królak, and Kalisz (2021), exposure to air, even during early fermentation stages, can lead to acetic acid formation. The high ethanol content in the final product (13% ABV) would have provided an abundant substrate for *Acetobacter* once oxygen became available, contributing to the strong acetic acid aroma observed. This observation is further

Table 1. Biochemical characteristics of dragon fruit wine

Parameter	Aging time (months)			
	0	1	2	3
pH	5.77^{a}	3.81^{a}	3.67^{b}	3.51^{c}
Acid acetate (%)	3.73 ± 0.51^{a}	3.92 ± 0.19^{a}	4.70 ± 0.90^{a}	6.51 ± 0.90^{a}
Tartaric acid (%)	4.84 ± 0.68^{c}	5.53 ± 1.07^{b}	5.53 ± 1.07^{b}	8.06 ± 1.13^{a}
% ABV	0^{b}	13^{a}	13^{a}	13^{a}
TSS (°Brix)	11^{a}	3^{b}	3^{b}	3^{b}
Total reducing sugar (g/100mL)	13.52 ± 3.15^{a}	0.41 ± 0.05^{b}	0.38 ± 0.03^{b}	0.28 ± 0.01^{b}
DPPH activity (% inhibition)	66.60 ± 0.40^{c}	72.72 ± 0.10^{b}	72.92 ± 0.26^{b}	75.79 ± 0.45^{a}

Value was presented as mean ± SD.

$^{a-c}$ Values with different superscript letters in the same row are significantly different ($p < 0.05$).

Table 2. Colour evaluation of dragon fruit wine

Colour parameter	Aging time (months)			
	0	1	2	3
L*	3.89 ± 0.66[c]	6.07 ± 0.27[b]	6.97 ± 0.35[b]	10.38 ± 0.34[a]
a*	-3.66 ± 1.28[c]	-2.67 ± 1.62[b]	-2.18 ± 0.11[b]	-1.78 ± 1.66[a]
b*	5.22 ± 0.87[c]	5.40 ± 1.16[c]	10.08 ± 3.33[b]	13.55 ± 0.06[a]
C*	5.94 ±1.43[c]	6.64 ± 0.75[c]	10.32 ± 3.26[b]	13.73 ± 0.24[a]

Value was presented as mean ± SD.
[a-c] Values with different superscript letters in the same row are significantly different ($p < 0.05$).

supported by research from Boondaeng et al. (2021), which highlights that *Acetobacter* strains are well-adapted to conditions with significant alcohol content. The result of the total soluble solids (TSS) decreased with increasing aging time from 11°Brix to 3°Brix. While the total reducing sugar content (g/100 mL) decreased from an initial value of 13.52 ± 3.15 to 0.28 ± 0.01. Aside from that, the content of tartaric acid increased from 4.48% ± 0.68 to 8.06% ± 1.13. The increase in tartaric acid content during fermentation and aging time is similar to the study in grape juice wine performed by Wu et al. (2021). Other substances such as acetic acid, glycerol, and higher alcohols, were produced during alcoholic fermentation, resulting in a lower pH and higher TA (Boondaeng et al. 2021).

Figure 1. Dragon fruits used for wine processing

Antioxidant (DPPH) activity

The antioxidant activity (% inhibition) in the present study (Table 2) was measured in wine by the free radical scavenging with the DPPH method, and elimination of the reactive oxygen species (ROS) by hydrogen peroxide (H_2O_2). The wine showed antioxidant activity with % inhibition (DPPH) values of 66.70 - 1.23 % and decreased to 56.94 - 0.71 % after 3 month-aging time. The antioxidant activity of wine against DPPH radicals is due to the presence of hydrogen atoms, leading to the termination of the chain reaction (Boondaeng et al. 2022). However, this result depends on the type of fruits and acid value during the process of fermentation.

Colour Evaluation

Colour can attract the consumers' preferences to a product and can support the marketing of the product (Velic et al. 2018). Colour parameters characterized as lightness (L*), redness (a*), yellowness (b*), and chroma (C*) for dragon fruit-palmyra neera wines are shown in Table 3. During 3 months of aging time after fermentation, the wine changed colour from violet-pink (month 0) to light-brown (after 3 months of aging). The a* value changed from a (-3.66 ± 1.28) at month 0 to a (-1.78 ± 1.66) at month 3, respectively. The b* value increased from a 5.22 ± 0.87 (at month 0) to 13.55 ± 0.06 (at month 3) as well as the L* value increased with the progression of aging periods up to month 3 from an average of 3.89 ± 0.66 to 10.38 ± 0.34. Then, followed by the rising of the chroma (C*) value from 5.94 ± 1.43 (at month 0) to 13.73 ± 0.24 at the end of aging time.

Organoleptic Evaluation

This preliminary study involved 16 panellists to gather initial qualitative sensory feedback on a new product concept. While a larger consumer panel (typically 40 to 100 individuals) is generally recommended for robust consumer acceptance data, our findings, based on this smaller group, provide valuable early indicators for further product development. Table 3 presents the organoleptic acceptance results for our Dragon Fruit Wine (DFW) alongside a reference (REF) wine. Panellists exhibited varied preferences across colour, aroma, and taste. Notably, the DFW received a significantly higher sensory rating for colour (81.25%) when panellists evaluated it on a "like to strongly like" scale, outperforming the reference wine. Regarding taste on the same scale, both DFW and the reference wine were generally well-received, with approximately 50% to 68.75% of panellists expressing a liking for both. However, only 25% of respondents favoured the DFW based on its aroma. This lower preference for aroma might be attributed to its acidity, as high acidity in

Table 3. Panellist's acceptance of dragon fruit wine (DFW) vs the reference (REF) wine

Preferences	Colour		Aroma		Taste	
	DFW	REF	DFW	REF	DFW	REF
Strongly dislike – dislike	6.25	18.75	25.0	6.25	18.57	6.25
Neutral	12.5	37.5	50	37.5	12.5	43.75
Like – strongly like	81.75	43.75	25.0	56.25	68.75	50.0

Value was presented as percentage (%) of mean.

fermented fruit juice can sometimes make a product unpleasant for consumers, as noted by Pinto et al. (2022). Despite this, the dragon fruit wine was generally accepted by consumers in this initial evaluation.

Conclusion

Dragon fruits, though not commonly utilized in the wine industry, present a compelling opportunity for commercially promising fermented beverages due to their abundant availability in tropical regions and their inherent beneficial compounds, including significant antioxidant activity and other desirable biochemical attributes. A recent study focused on the spontaneous fermentation of dragon fruit juices aimed to characterize their physical, biochemical, and sensory properties, thereby identifying optimal aromatic, acidic, and volatile functional groups in the developed wine. The findings revealed that while one month of aging is highly effective for achieving primary wine characteristics such as maximum alcohol content, substantial sugar reduction, and an initial drop in pH, extending the aging period to three months proves most advantageous for enhancing antioxidant properties and further reducing pH. Specifically, DPPH activity continues to increase significantly, and pH reaches its lowest point by three months, with a continued rise in tartaric acid contributing to the wine's overall complexity and a more developed flavour profile. Therefore, while core fermentation is largely complete within the first month, a three-month aging period yields a more well-rounded dragon fruit wine with superior antioxidant capacity and improved stability. Consequently, the study's outcomes suggest that further research is warranted to optimize the functional compound content in dragon fruit wine and, in turn, mitigate any astringent flavours.

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