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Development of Functional Dragon Fruit Wine and Assessment of its Physiochemical Characteristics During Fermentation.

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Abstract

Dragon fruit (Hylocereus spp.) is an emerging tropical fruit recognized for its rich nutritional composition and bioactive compounds, including betalains, phenolics, and antioxidants. The present study was undertaken to develop dragon fruit wine and evaluate the effect of fermentation on key quality parameters such as total soluble solids, acidity and ethanol content. Fresh dragon fruits were processed into juice, adjusted with sugar and water, and fermented using Saccharomyces cerevisiae under controlled conditions for a period of 90 days. Proximate analysis was carried out at different fermentation intervals. The results indicated a progressive decrease in total soluble solids from 22% to 5 %, confirming the utilization of sugars during fermentation. Acidity showed a gradual increase from 0.53% to 0.75%, reflecting the formation of organic acids. Ethanol production was confirmed qualitatively through the potassium dichromate method. The study demonstrates that dragon fruit can be effectively utilized for wine production, yielding a product with desirable physicochemical properties and potential functional benefits. The research highlights the scope of dragon fruit as a value added product in the functional beverage industry.

Keywords: Dragon fruit; Hylocereus spp.; Fruit wine; Saccharomyces cerevisiae; Functional wine.

1. Introduction

Dragon fruit is a perennial climbing vine cactus plant belonging to the family Cactaceae (9). It is world-renowned for its large, beautiful, night-blooming flowers, which have earned it nicknames such as "Moonlight Cactus," "Noble Woman," or "Queen of the Night" (14). The fruit is highly valued for its nutritional and medicinal properties, being rich in minerals, glucose, dietary fiber, vitamins, and antioxidants like betalains. It is considered a "super fruit" due to its ability to strengthen the immune system and its potential use in treating diabetes and heart diseases (5). In recent years, it has become a major horticultural crop in countries like China and Vietnam, and it is gaining significant popularity in India as a remunerative "future fruit" (24) Some of the countries considered this plant as an ornamental plant and some as commercial fruit crop. Dragon fruit is considered very popular in Asian countries

because of its colour, attractive feature, nutritional values like vitamins, fibre, phosphorus, calcium, magnesium, phytochemicals and antioxidants (11).

1.1.Objectives

- To develop wine from dragon fruit.
- To analyse the impact of fermentation on alcohol content
- To determine physicochemical characteristics of the wine: Total Soluble solids, Acidity.

2. Review of Literature

2.1.Origin of Dragon fruit

Dragon fruit is native to the tropical and subtropical forest regions of Mexico, Central America, and Northern South America. In these regions, it occurs naturally in warm, humid environments, often climbing on tree trunks or rocks (9). From its center of origin, the fruit was dispersed by birds and humans (5). In the sixteenth century, the Spanish introduced it to the Philippines, and it was brought to Indochina, Vietnam, Laos, and Cambodia) by a French priest in the mid-nineteenth century. It has since spread widely across Southeast Asia, Australia, Israel, and the United States (24).

2.1.2. Types of Dragon fruit grown in India:

Dragon fruit varieties are primarily classified based on their skin and pulp color: White Flesh with Pink/Red Skin, this is the most common commercial species. It has oblong fruits with pink peel and white flesh, covered in long, green, hard scales. Red/Violet-Red Flesh with Pink/Red Skin (S. costaricensis or S. monacanthus): These types have dark magenta or crimson peel with violet-red or deep red flesh. They are often covered in soft, short scales. (* White Flesh with Yellow Skin (S. megalanthus / Hylocereus megalanthus): Also known as the yellow pitaya, this type features yellow peel and white, transparent flesh. Unlike other types, the skin is tuberculate and covered with thorns instead of scales (9). Red Flesh with Yellow Skin A less common variety featuring yellow peel and red pulp (24). Among these white and pink colour flesh fruits are widely used in India.

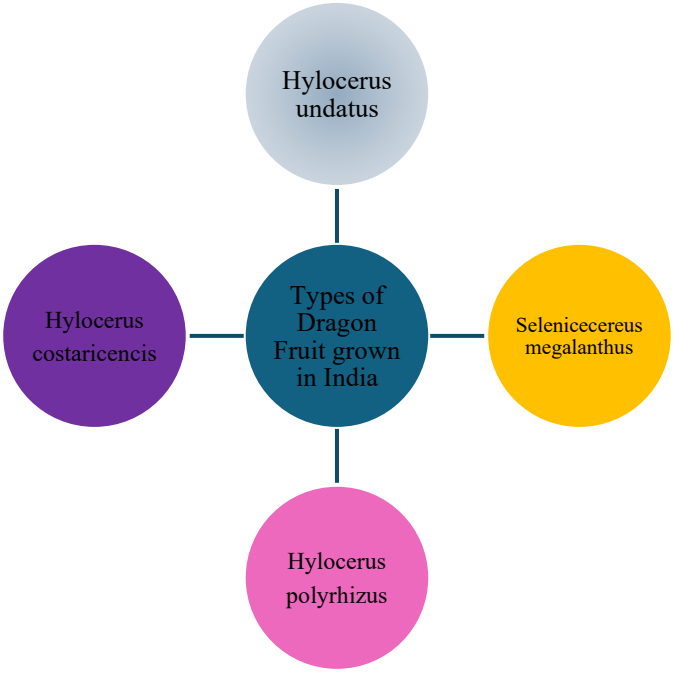

Fig No: 2.2. Types of Dragon Fruit grown in India

2.1.3. Taxonomy and Botanical Description (9,14).

Kingdom	Plantae
Sub kingdom	Tracheobionta
Super division	Spermatophyta
Division	Mangnoliophyata
Class	Mangnoliopsida
Order	Carophyllales
Family	Cactaceae
Subfamily	Cactoideae
Tribe	Hylocereae
Genus	Selenicereus
Common species	S. undatus, S. costaricensis, S. monacanthus, S.megalanthus

Table No 2.1.3. Taxonomy and Botanical description of Dragon fruit.

2.1.4. Health benefits of Dragon fruit:

Dragon fruit (Hylocereus spp.) is a nutritionally rich tropical fruit containing diverse bioactive compounds such as betalains, phenolic compounds, flavonoids, vitamins, and essential fatty acids**.** These compounds contribute to several health benefits including antioxidant, antidiabetic, antimicrobial, anticancer, hepatoprotective, and cardiovascular protective activities**.** Additionally, its prebiotic oligosaccharides and dietary fiber promote digestive health, while high vitamin C and antioxidant levels support immune function and anti-aging effects. These properties highlight dragon fruit as a functional food with significant.

Health Benefit	Bioactive Compounds Responsible	Mechanism of action
Antioxidant activity	Betalains (betacyanin, betaxanthin), vitamin c, polyphenols, flavonoids	Neutralizes free radicals and reduces oxidative stress by inhibiting lipid peroxidation and protecting cellular components
Antidiabetic activity	phenolic compounds , dietary fiber, betalains	Enhances insulin sensitivity, increases glucose uptake, and slows carbohydrate absorption in the intestine
Cardiovascular protection	Polyunsaturated fatty acids (omega-3 and omega-6), phytosterols, flavonoids	Reduces triglycerides and cholesterol levels and improves lipid metabolism
Anticancer activity	Betacyanin, flavonoids, polyphenols, lycopene	Induces apoptosis in cancer cells, inhibits tumor cell proliferation, and reduces oxidative stress
Antimicrobial activity	Flavonoids, phenolic acids, tannins, terpenes	Disrupts bacterial cell membranes and inhibits microbolism

Hepatoprotective activity	Polyphenols, betacyanin, flavonoids	Protects liver cells from oxidative damage and enhances antioxidant enzyme activity
Wound healing activity	Vitamin C, betalains, collagen-related proteins	Stimulates collagen synthesis, fibroblast migration, and tissue regeneration
Prebiotic and digestive health	Oligosaccharides (fructooligosaccharides), dietary fiber	Promotes growth of beneficial gut microbiota and improves intestinal health
Anti-inflammatory effects	Betalains, phenolic acids, flavonoids	Reduces inflammatory mediators and oxidative damage
Anti-aging effects	vitamin c, betalains, antioxidants	Protects skin cells from oxidative damage and supports collagen synthesis
Weight management and metabolic health	Dietary fiber, low calorie content, antioxidants	Enhances satiety, improve metabolic balance, and reduces fat accumulations
Immune system support	Vitamin c, minerals, antioxidants	Strengthens immune response and protects against infections

Table No: 2.1.4. Health Benefits of Dragon Fruit

Additional benefits:

Antioxidant efficacy

It is rich in antioxidants, which play a vital role in protecting the body from reducing inflammation and oxidative stress. The primary antioxidants betacyanin's, flavonoids, phenolic acids, and vitamins C and E found in dragon fruit (1). Betacyanin's, have been shown to reduce oxidative damage and possess anti-inflammatory and anticancer properties which responsible for the fruit's vibrant red colour (3) Flavonoids come up with reducing the risk of cardiovascular diseases and heart health by improving blood circulation. Free radicals, which can damage cells and lead to chronic diseases such as cancer neutralize through Phenolic acids (18)

Anti-diabetic intent

Firstly, it exhibits anti-diabetic properties due to its high fibre content and bioactive compounds i.e. betacyanin's and flavonoids. It helps in slow absorption of sugars, leading to better glycaemic control and reduced blood sugar spikes after meals. Furthermore, pitaya's low glycaemic index ensures gradual glucose release into the bloodstream. Studies advise that its bioactive compounds may improve insulin

sensitivity, promoting better glucose utilization cells. The antioxidants present in dragon fruit, protect pancreatic βcells from oxidative stress, preserving their role in insulin production

Anti-microbial properties

Dragon fruit has antimicrobial properties due to its bioactive compounds, flavonoids, phenolic acids, and betacyanin's etc. They have ability to inhibit the growth of numerous pathogenic bacteria and fungi (4) Studies have shown that pitaya extracts are potent against bacterial strains such as Escherichia coli and Staphylococcus aureus, as well as somewhat fungal species Dragon fruit a potential natural alternative to promoting its use in food preservation and therapeutic applications for combating infections (13)

Anti-cancer properties

Dragon fruit shows anticancer activity due to its rich content of antioxidants like betacyanin's, flavonoids, and phenolic acids. phenolic acids and Flavonoids giving contribution by reducing inflammation, a feature closely associated with tumour development. (21). Investigations have shown that dragon fruit extracts can reduce the growth of various cancer cells, for instance breast and colon cancer cells (18).

Anti-anaemia actions

Dragon fruit's anti-anaemia characters are primarily due to its iron availability, which maintains red blood cell production and enhances haemoglobin synthesis and it is crucial for oxygen transport in the body (10). Dragon fruit helps to fight iron deficiency which reduces the risk of anaemia (2) Studies point tells that regular intake of pitaya can improve haemoglobin in levels and lessen symptoms such as fatigue and weakness associated with anaemia, making it a valuable dietary addition (17).

Hepato-protective actions

As it is rich in antioxidants it includes betacyanin's, flavonoids, and phenolic acids, Dragon fruit exhibits hepatoprotective activity. It helps to neutralize free radicals, reducing oxidative stress in liver cells which is a key factor in liver damage (8). Betacyanin's, protect against lipid peroxidation in liver tissues and preventing cell injury (6)

Anti-hyper lipidemic properties

Due to its antioxidants, fibre and bioactive compounds like flavonoids and betacyanin's, Pitaya shows antihyperlipidemic properties. The high fibre content assist to reduce cholesterol absorption in the gut, minimizing total cholesterol and low-density lipoprotein bad cholesterol levels (19). Investigations have shown that consumption of dragon fruit can improve lipid profiles, lowering triglycerides and low-density lipoprotein levels while increasing high-density lipoprotein (good cholesterol) (22,12).

2.2.WINE

2.2.1. Origin of wine

Wine is an alcoholic beverage typically made from fermented grape juice, though it can be crafted from various tropical fruits. Dragon fruit wine is produced by fermenting the crushed pulp and juice of the Hylocereus species using specialized yeast strains. The primary species involved in this fermentation is Saccharomyces cerevisiae, arguably the most significant fungus in the history of global wine making. It is un-distilled alcoholic beverage mainly prepared from fruit juice. The process of preparation of wine is known as vinification and the branch of science that deals with study of wine is known as enology (American) or oenology (British). There are different types of wine on different fundamental principles. Besides fruit and berries, non-toxic plants (flowers) etc. can also be used for wine production. Since, basic constituent of wine is alcohol, other substrates are also added in it. It contains 3-22% of alcohol. (23).

This yeast is responsible for producing ethanol; it effectively converts the glucose and fructose found in dragon fruit into energy and alcohol. S. cerevisiae is uniquely adapted to thrive in the nutrient-rich must of dragon fruit, breaking down sugars through both aerobic respiration and, crucially, anaerobic fermentation (7).

2.2.2. Classification of wine

The classification of dragon fruit wine depends on several factors: the cultivar used (Red-flesh vs. White-flesh), the ripening stage, the chemical composition of the juice (specifically its pH and brix level), and the specific vinification techniques employed. Depending on the alcohol and sugar content, these wines are classified into two main categories: Natural Dragon Fruit Wines (9–14% alcohol): These include Dry and Sweet Table varieties. Red dragon fruit is often used to create wines comparable to a light red or a soft Merlot due to its deep betalain pigments. Dessert and Appetizer Wines (15–21% alcohol): These are often fortified or have higher residual sugars, including styles similar to British wine. White-flesh dragon fruit typically yields a crisp, clear white wine, while the red-flesh variety produces a "legendary" vibrant red or pink color. (3)

Feature	Red Wine	White Wine
Raw material	Made from red or black grapes	Made from green or golden grapes or selected juice of red grapes
Colour	Red to deep purple colour	Yellow, gold, or straw coloured
Source of colour	Colour comes from anthocyanin pigments present in the grape skin	Produced mainly from non-coloured pulp, so no red pigments
Fermentation process	Fermented with grape skins	Usually fermented without skins
Taste	Rich, strong and complex flavour	Light, crisp and refreshing flavour
Aroma	May include aromas of oak, eucalyptus, chocolate, mint etc.	Generally fresh, fruity and delicate aroma
Food pairing	Usually served with red meats and strong dishes	Usually served with white meats, fish and light foods
Popularity by season	Often preferred in cooler weather	Often preferred in warmer months
Appearance	Darker and opaque	Clear and transparent

Table No: 2.2.2. Classification of Wine (23).

2.1.2. Current status of wine

Over the past decade, the global wine industry has seen a flow in innovative approaches to diversifying wine sources beyond traditional grapes. Significantly, dragon fruit (Hylocereus spp.), a vibrant and nutrient-rich fruit, has entered the scene as a novel ingredient for wine production. Dragon fruit is valued not only for its rich content of vitamins, minerals, and antioxidants, but also for its potential uses in creating high-value products such as wine. The launch of red dragon fruit wine over a decade ago was a crucial moment in the beverage industry. This not only diversified the wine market but also attracted consumers with its vibrant colour and distinctive taste. The market for fruit wines is expanding, especially among millennials and health-conscious consumers. The unique colour and taste of dragon fruit wine position it well for premium branding (7).

2.1.3. Fermentation:

Fermentation describes the process of creating a product using a controlled culture of microorganisms. In

dragon fruit winemaking, the term traces back to the Latin fervere, meaning "to boil," referring to the natural carbon dioxide bubbles that escape as yeast reacts with the fruit's sugars.

In the mid-19th century, Louis Pasteur identified yeast as the catalyst for this transformation. For dragon fruit specifically, the fermentation process is a delicate balance; the yeast acts as a middle person in a progression of reactions that convert fruit sugars into alcohol. Early 20th-century discoveries further clarified how complex chemical processes—such as the breakdown of betacyanins and organic acids—influence the final flavour, colour, and stability of the wine.

Conversion of Glucose to Ethanol

The sugar glucose in dragon fruit is broken down anaerobically by yeast

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{Energy}$$

Reactant:

Glucose ($C_6H_{12}O_6$) - a simple sugar

Products:

Ethanol (C_2H_5OH) - Alcohol

Carbon dioxide (CO_2) - Gas

Energy- released in small amounts

2.1.4. Health benefits of Wine (25,26).

Health Benefits	Explanation	Key compounds involved
Antioxidant protection	Wine contains antioxidants that neutralizes free radicals and reduces oxidative stress, protecting cells and tissues from damage and lowering the risk of chronic diseases.	Polyphenols, flavonoids, resveratrol
Improved cardiovascular health	Moderate wine consumption may improve blood vessel function, support healthy circulation and help maintain proper lipid metabolism, which benefits heart health.	Polyphenols, phenolic compounds
Reduced risk of heart diseases	Wine compounds help prevent oxidation of LDL cholesterol, reduce plaque formation in arteries and decrease platelet aggregation, lowering the risk of heart attacks and strokes.	Polyphenols, resveratrol
Anti-inflammatory effects	Polyphenols in wine help regulate inflammatory responses and support immune function which may reduce inflammation related diseases.	Polyphenols, flavonoids
Anti-ageing and cellular protection	Resveratrol protects cells from oxidative damage and may influence cellular pathways related to longevity and tissue repair	Antioxidants, resveratrol
Support for digestive health	Organic acids and certain compounds in wine stimulate digestive enzymes, improve gastric secretion and help maintain balance of gut microorganisms	Organic acids and polyphenols
Improve blood lipid profile	Moderate wine consumption may increase HDL and reduce harmful cholesterol effects	polyphenols
Neuroprotective effects	Some compounds in wine may help protect nerve cells and reduce the risk of neurodegenerative diseases.	Resveratrol, flavonoids

Improves blood circulation	Polyphenols help maintain elasticity of blood vessels, improving blood flow throughout the body	Polyphenols
Antimicrobial properties	Certain compounds in wine can inhibit the growth of harmful bacteria and support gut microbial balance.	Phenolic compounds
Blood pressure regulation	Wine polyphenols may help improve endothelial function which contributes to maintaining normal blood pressure.	Resveratrol, polyphenols
Metabolic support	Bioactive compounds in wine may influence glucose metabolism and improve insulin sensitivity in some cases	Polyphenols, resveratrol

Table No: 2.1.4. Health benefits of Wine

2.1.5. Scope of Dragon fruit wine:

Choosing dragon fruit for winemaking is a smart move that blends science with sustainability. Because the red-fleshed fruit is full of natural antioxidants called betacyanins, the wine keeps most of its health benefits even after it is processed. its moderate Brix levels are easily processed by Saccharomyces cerevisiae, while its naturally low tannin and acidity levels allow for precise control over the final mouthfeel through calculated adjustments of tartaric or citric acid. The resulting wine offers a subtle, exotic flavour profile making it an ideal candidate for a crisp, specialty summer beverage (2).

3. Materials and Methodology

3.1. Procurement of Raw Material

The dragon fruits are freshly collected from the local market. They are cleaned and cut into pieces. The pulp of the fruit is extracted. Saccharomyces cerevisiae is used at low initial sugar levels; the yeast assumes optimum condition for their activity without any inhibition due to very fast conversion rate of sugar to alcohol as a result of very high initial sugar content. At this condition the yeasts can effectively and completely convert the low initial sugar content into alcohol. The resulting wine should, therefore, contain high alcohol and negligible residual sugar which are the properties of dry wines.

Raw materials	**Quantity**
Dragon fruit	500gm
Sugar	132gm
Yeast	10ml
water	500ml

Table No: 3.1. Quantity of raw materials taken for Dragon fruit wine processing.

3.2. Pre-treatment process of Dragon Fruit

Washing of dragon fruits

↓

Removal of peel

↓

cut into small pieces

Blending

Collecting juice in a blow

Flow Chart No: 3.2. Pre-treatment process of Dragon fruit.

Freshly harvested dragon fruits are collected from the market, washed under a running tap and wiped with the cloth to remove moisture and remove the peel of fruit, cut into small pieces, blend and collect the juice.

3.3. Processing of Wine:

collection of Dragon fruits

Washing & Removal of debris and other foreign matter

Peel off the skin of fruit

Cut into small pieces and blend into juice

Add water to the fruit juice in 1:1 ratio

Add required amount of sugar

Mix thoroughly till the sugar gets dissolved

Stir the mixture with wooden ladle for few minutes

Add Saccharomyces cerevisiae (dry yeast)

Close the mouth of the container with lid

Allow it to ferment (21 to 28 days)

Filtration

Bottling

Storage

Flow Chart No: 3.3. Processing of dragon fruit Wine

Fresh dragon fruits were procured from the local market and used for the preparation of wine. The fruits were first washed thoroughly under running tap water to remove adhering dust, debris, and other foreign materials. After washing, the fruits were wiped with a clean cloth to remove excess surface moisture. The

outer peel of the fruits was carefully removed, and the edible pulp was cut into small pieces. The chopped fruit pieces were then blended using a blender to obtain fresh fruit juice. water was added to the fruit juice in a 1:1 ratio and mixed thoroughly. A required amount of sugar was added to the mixture to increase the fermentable sugar content, and the solution was stirred continuously with a wooden ladle until the sugar was completely dissolved. The prepared must was then inoculated with dry yeast (Saccharomyces cerevisiae) as the fermenting microorganism. The fermentation mixture was transferred into a clean fermentation container, and the mouth of the container was tightly closed with a lid to prevent contamination. The mixture was allowed to undergo fermentation for a period of 85-90 days (3 months) placed in dak place at room temperature. During this period, the yeast converted the sugars present in the must into ethanol and carbon dioxide. After completion of the fermentation process, the fermented mixture was filtered to remove suspended particles and residual fruit pulp, resulting in a clear wine. The clarified wine was then transferred into sterilized bottles, sealed properly, and stored under appropriate conditions for further analysis and maturation.

3.4. Proximate analysis

Various tests had been performed to check the quality of wine:

3.3.1. Test for Total suspended solids

Association of official analytical chemistry methods was used to determine the percentage of sugar of the wine (AOAC,2012)

The total sugar content of the sample was determined using a digital/hand refractometer. Initially, the refractometer prism was cleaned with distilled water and wiped dry with tissue paper. A few drops of the well-mixed sample were placed on the prism surface, and the cover plate was gently closed to spread the sample evenly. The refractometer was then held towards a light source, and the reading was observed through the eyepiece. The value obtained was recorded in degrees Brix (°Brix), which represents the percentage of soluble solids present in the sample, mainly sugars. The measurement was carried out at room temperature, and the refractometer was calibrated with distilled water before analysis. The total sugar content was expressed as °Brix.

3.3.2. Test for acidity

Acidity is determined by neutralizing acids present in the sample using a standard alkali solution (NaOH). The endpoint is detected using phenolphthalein indicator and the result is expressed as % of a predominant acid (e.g., citric acid, lactic acid, tartaric acid).

3.3.3. Test for ethanol

Ethanol content in the fermented product was quantitatively determined by the potassium dichromate method. In this 1ml sample is taken in a conical flask and add 3ml potassium dichloride and add 3 to 4 drops of conc. H2SO4 mix the contents thoroughly and place on the hot plate stir continuously until the end point as green colour.

4. Result and Discussion

4.1. Total Soluble Solids:

The decreasing sugar concentration over time shows active consumption or reaction of sugar, typical of fermentation. The rapid drop initially, followed by a slower decline, indicates progressive substrate use that slows as sugar becomes limited.

Time period (in days)	Sugar Concentration
1st day	22%
45th day	12.5%
90th day	5%

Table No: 4.1. Changes in the soluble solids concentration during fermentation of Dragon fruit wine.

4.2 Test for Acidity:

The results indicate that acid content in the sample is increasing with time, which is typical in fermentation or ripening processes. The decrease in NaOH volume is due to less sample volume or concentration change, but overall acidity percentage rises, confirming ongoing acid production.

Time period (in days)	Initial reading (0.1 N NaOH)	Final reading (0.1N NaOH)	Volume used (0.1N NaOH)	Acidity (%) of citric acid
1st day	0	3.2ml	3.2ml	0.53
45th day	0	2.1ml	2.1ml	0.67
90th day	0	1ml	1ml	0.75

Table No: 4.2. Changes in the acidity level in the dragon fruit wine during fermentation.

4.3 Test for Ethanol:

Colour change to green confirms that ethanol is present.

Fig. No: 4.3. colour change in the sample (Dragon fruit wine) determining the presence of Ethanol

Conclusion:

The present study successfully demonstrated the feasibility of producing wine from dragon fruit using saccharomyces cerevisiae. The fermentation process resulted in significant biochemical changes, including a reduction in sugar concentrattion, an increase in acidity, and the formation of ethanol, indicating efficient fermentation. The observed trends in total soluble solids and acidity confirm the active metabolic role of yeast in converting fermentable sugars into alcohol and organic acids. The final product exhibited acceptable physiochemical characteristics, suggesting its potential as novel fruit-based alcoholic beverage. Furthermore, the inherent presence of bioactive compounds in dragon fruit enhances the functional and nutritional value of the wine. Therefore, dragon fruit wine production represents a

promising approach for the value addition, diversification of fruit processing industries, and development of functional beverages with potential health benefit.

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