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# Development and Quality Evaluation of a Functional Blended Dragon Fruit (*Hylocereus polyrhizus*) and Pomegranate (*Punica granatum* L.) Wine: Physicochemical, Fermentation and Sensory Characteristics.

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## ABSTRACT

Dragon fruit (*Hylocereus polyrhizus*) and pomegranate (*Punica granatum* L.) are rich sources of betalains, anthocyanins, polyphenols, vitamins, and other bioactive compounds with well-established antioxidant and functional properties. Their high perishability and seasonal availability necessitate value-added processing approaches to reduce post-harvest losses while enhancing market potential. The present study aimed to develop and standardize a functional blended dragon fruit–pomegranate wine through controlled fermentation using *Saccharomyces cerevisiae* and to evaluate its fermentation kinetics, physicochemical characteristics, and sensory quality. A standardized formulation comprising equal proportions of dragon fruit and pomegranate pulp was fermented under controlled conditions for 90 days. Fermentation progress was monitored through changes in total soluble solids (TSS), titratable acidity, ethanol formation, and sensory attributes. The results demonstrated a continuous decline in TSS from 22.0 to 5.8 °Brix, indicating efficient utilization of fermentable sugars by yeast. Titratable acidity increased from 1.12% to 1.33%, reflecting progressive organic acid formation during fermentation. Ethanol production was confirmed qualitatively using the potassium dichromate oxidation method. Sensory evaluation by semi-trained panelists revealed that the blended wine achieved superior colour and appearance (7.8/9) and marginally higher overall acceptability (5.58/9) than dragon fruit wine, indicating improved consumer preference. The synergistic incorporation of pomegranate enhanced the physicochemical stability and sensory appeal of the beverage while retaining the functional attributes associated with both fruits. The findings demonstrate that blended dragon fruit–pomegranate wine represents a promising functional fermented beverage with considerable commercial potential for value addition and utilization of underexploited tropical fruits.

**Keywords:** Dragon fruit; Pomegranate; Functional fruit wine; Mixed fruit wine; *Saccharomyces cerevisiae*; Fermentation kinetics; Physicochemical properties; Sensory evaluation.

## INTRODUCTION

Dragon fruit is a perennial climbing vine cactus plant belonging to the family Cactaceae (14). 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" (20). 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 (9).

Pomegranate fruit short shurb beloning to the Lythraceae family, producing globose fruits typically weighing between 200 to 650g. contains a high concentration of polyphenolic compunds like ellagitannins, ellagic acids, catechin, epicatechin, and anthocyanins, which are up to 10 higher than those found in standard grape based wine (32).

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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"(30). Some countries consider this plant as an ornamental plant and some as a commercial fruit crop. Dragon fruit is considered very popular in Asian countries because of its color, attractive features, nutritional values like vitamins, fiber, phosphorus, calcium, magnesium, phytochemicals, and antioxidants (16).

**Fig. No. 1.a** Dragon fruit

**Fig. No. 1.b** Pomegranate

Despite the excellent nutritional and agronomic profile of Hylocereus spp. and chemical profile of Punica granatum L., post-harvest management presents a critical challenge for growers. Due to its high moisture content, delicate outer peel, and rapid respiration rates in tropical conditions, fresh dragon fruit is highly susceptible to mechanical bruising, rapid fungal spoilage, and quality deterioration immediately after harvest. During peak harvesting seasons, local markets often experience severe gluts, leading to substantial economic losses for farmers and a drop in commercial value.(30)

At the same time, the global commercial beverage sector faces an era of shifting consumer demands. Traditional grape-based wines dominate the landscape, yet modern consumers particularly millennials and health-conscious buyers are consistently seeking out innovative flavor experiences, exotic ingredients, and products that offer functional health benefits beyond recreational alcohol consumption. This has left a clear market gap for fruit-based alcoholic beverages that retain the bioactive profile of their raw materials.

Developing a functional dragon fruit wine directly addresses both of these challenges. By converting perishable surpluses into an un-distilled alcoholic beverage with an extended shelf life, vinification acts as an effective preservation strategy. This approach minimizes post-harvest waste, stabilizes agricultural revenue, and introduces a high-value product to the beverage industry.

The primary challenge lies in establishing a standardized processing protocol. Because dragon fruit naturally possesses lower tannin levels and moderate starting acidities compared to traditional wine grapes, it requires precise adjustments to achieve a balanced flavor profile and ensure long-term stability. Investigating how fermentation affects the fruit's physical and chemical properties is essential for creating a reliable framework for large-scale production.(9,20)

Choosing dragon fruit and Pomegranate fruit for wine making is a smart move that blends science with sustainability. Because the red-fleshed fruit is full of natural antioxidants called betalains, and every part of the pomegranate plant including the bark, leaves, rind, flowers, arils, and peel possesses a dense concentration of polyphenolic compounds, 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 flavor profile, making it an ideal candidate for a crisp, specialty summer beverage.

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**Objective**

To develop and standardize a functional blended dragon fruit and pomegranate wine through controlled yeast fermentation and assess its fermentation kinetics, physicochemical quality characteristics, and sensory acceptability to establish its suitability as a value-added fermented beverage.

## REVIEW OF LITERATURE

### Origin and Global Dispersal of Dragon Fruit and Pomegranate 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 (14). From its center of origin, the fruit was dispersed by birds and humans (9). 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.(30) Botanical and historical consensus places the native origin of the pomegranate in Central Asia and the Near East, specifically spanning a region from modern-day Iran and the Caucasus (Transcaucasia) eastward through Turkmenistan, Afghanistan, Pakistan, and northern India. Wild pomegranates naturally thrive in these areas, demonstrating a high tolerance for arid and semi-arid climates characterized by hot summers and mild winters.

### Taxonomy and Botanical Profiles

The systematic classification of dragon fruit establishes its position within the succulent family Cactaceae, cataloging its evolutionary adaptations to tropical climbing habits.

| Taxonomical Hierarchy | Botanical Identification |
|---|---|
| Kingdom | Plantae |
| Sub kingdom | Tracheobionta |
| Super division | Spermatophyta |
| Division | Magnoliophyta |
| Class | Magnoliopsida |
| Order | Caryophyllales |
| Family | Cactaceae |
| Subfamily | Cactoideae |
| Tribe | Hylocereae |
| Genus | Selenicereus (formerly Hylocereus) |
| Common Species | S. undatus, S. costaricensis, S. monacanthus |

**Table. No. 2.2.1:** Taxonomy and Botanical Profile of Dragon fruit (13)(18).

| Taxonomical Hierarchy | Botanical Identification |
|---|---|
| Kingdom | Plantae |

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| | |
|---|---|
| Sub kingdom | Tracheobionta |
| Super division | Spermatophyta |
| Division | Magnoliophyta |
| Class | Magnoliopsida |
| Order | Mytales |
| Family | Lythraceae |
| Genus | Punica L. |
| Common Species | Punica granatum L. |

**Table. No. 2.2.2:** Taxonomy and botanical Profile of Pomegranate

**Varietal Classifications Cultivated in India:**

Dragon fruit is classified into four major types based on the color of its skin and flesh. White flesh with pink/red skin (*Hylocereus undatus*) is the most common commercial variety, characterized by oblong fruits with a bright pink peel, white flesh, and long, green, hard scales. Red or violet-red flesh with pink/red skin (*Hylocereus costaricensis*/*Hylocereus polyrhizus*) has a dark magenta or crimson peel with deep red or violet-red flesh and is typically covered with soft, short scales. White flesh with yellow skin (*Selenicereus megalanthus*), commonly known as yellow pitaya, features a yellow peel and white, translucent flesh; unlike the other varieties, its skin is tuberculate and covered with thorns instead of scales. A red-fleshed variety with yellow skin is also available, although it is comparatively rare. Among these different types, the white-fleshed and pink/red-fleshed dragon fruits are the most widely cultivated and utilized in India. For the present study on the development of functional dragon fruit and pomegranate blended wine, the red-fleshed dragon fruit with pink/red skin (*Hylocereus costaricensis*/*Hylocereus polyrhizus*) was selected because of its high betalain pigment content, attractive natural color, superior antioxidant properties, and suitability for producing a nutritionally enriched and visually appealing wine.

**Fig. No. 2.3.1** Dragon fruit (Red flesh with red skin)

**Pharmacological and Health Properties of Raw -Dragon Fruit and Pomegranate**

| **Health Benefit / Pharmacological Property** | **Dragon Fruit (*Hylocereus polyrhizus)*** | **Pomegranate (*Punica granatum L.*)** | **Major Bioactive Compounds** | **Mechanism of Action** | **Key References** |
|---|---|---|---|---|---|

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| | | | | | |
|---|---|---|---|---|---|
| **Antioxidant Activity** | Rich in betalains, vitamin C, flavonoids and polyphenols that neutralize free radicals and reduce oxidative stress. | Extremely rich in ellagitannins, punicalagins, anthocyanins and ellagic acid with exceptionally high antioxidant capacity. | Betacyanins, betaxanthins, vitamin C, punicalagins, ellagic acid, anthocyanins, flavonoids | Scavenges ROS, inhibits lipid peroxidation, enhances SOD, CAT and GPx activity | Arivalagan et al. (2021); Rebecca et al. (2010); Viuda-Martos et al. (2010); Ismail et al. (2012) |
| **Antidiabetic Activity** | Improves insulin sensitivity and delays intestinal glucose absorption through dietary fibre and betalains. | Polyphenols improve insulin secretion, glucose metabolism and reduce insulin resistance. | Dietary fibre, betalains, phenolics, punicalagins, ellagic acid | Enhances glucose uptake, protects β-cells and suppresses oxidative stress | Omidizadeh et al. (2014); Medjakovic & Jungbauer (2013) |
| **Cardioprotective Activity** | Reduces LDL cholesterol and triglycerides while improving HDL levels. | Lowers blood pressure, prevents LDL oxidation and improves endothelial function. | Omega-3 & 6 fatty acids, phytosterols, punicalagins, anthocyanins | Improves lipid metabolism, reduces oxidative damage and vascular inflammation | Le Bellec et al. (2006); Aviram & Rosenblat (2012) |
| **Anticancer Activity** | Betacyanins inhibit proliferation of breast and colon cancer cells by inducing apoptosis. | Punicalagins and ellagic acid inhibit tumour growth, angiogenesis and metastasis in prostate, breast and colon cancers. | Betacyanins, flavonoids, ellagic acid, punicalagins | Cell-cycle arrest, apoptosis induction and inhibition of inflammatory signalling | Wu et al. (2006); Lansky & Newman (2007) |
| **Anti-inflammatory Activity** | Betalains suppress inflammatory cytokines and oxidative injury. | Punicalagins inhibit NF-κB activation and inflammatory mediators. | Betalains, phenolic acids, flavonoids, ellagitannins | Reduces TNF-α, IL-6, COX-2 and oxidative stress | Rebecca et al. (2010); Ismail et al. (2012) |
| **Antimicrobial Activity** | Effective against *Escherichia coli*, *Staphylococcus aureus* and several fungi. | Peel extract exhibits strong antibacterial and antifungal activity against | Phenolic acids, flavonoids, tannins, punicalagins | Disrupts microbial cell membranes and inhibits | Choo et al. (2018); Duman et al. (2009) |

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| | | | | | |
|---|---|---|---|---|---|
| | | foodborne pathogens. | | enzyme activity | |
| **Hepatoprotective Activity** | Prevents oxidative liver damage and lipid peroxidation. | Protects liver tissues by reducing oxidative stress and inflammatory damage. | Betacyanins, polyphenols, punicalagins, ellagic acid | Enhances antioxidant enzymes and prevents hepatocyte injury | Song et al. (2016); Faria & Calhau (2011) |
| **Gastrointestinal and Prebiotic Activity** | Fructooligosaccharides and fibre promote beneficial gut microbiota. | Polyphenols are metabolized into urolithins that improve gut microbial diversity and intestinal health. | Dietary fibre, fructooligosaccharides, ellagitannins | Stimulates beneficial bacteria and improves intestinal function | Arivalagan et al. (2021); Espín et al. (2013) |
| **Immune System Support** | Vitamin C and antioxidants enhance immune response and reduce oxidative stress. | Polyphenols strengthen immune function and regulate inflammatory responses. | Vitamin C, minerals, punicalagins, flavonoids | Enhances leukocyte activity and immune modulation | Wu et al. (2006); Viuda-Martos et al. (2010) |
| **Wound Healing Activity** | Vitamin C promotes collagen synthesis and tissue regeneration. | Ellagic acid and tannins accelerate tissue repair and reduce microbial infection. | Vitamin C, betalains, collagen-promoting compounds, tannins | Stimulates fibroblast proliferation and collagen formation | Rebecca et al. (2010); Hayouni et al. (2011) |
| **Anti-aging Activity** | Antioxidants reduce skin oxidative damage and preserve collagen. | Polyphenols protect against UV-induced oxidative stress and skin ageing. | Vitamin C, betalains, anthocyanins, ellagic acid | Prevents collagen degradation and oxidative damage | Esquivel et al. (2007); Fischer et al. (2011) |
| **Weight Management** | Low calorie content and high dietary fibre improve satiety and metabolic health. | Polyphenols improve lipid metabolism and reduce adipogenesis. | Dietary fibre, flavonoids, ellagitannins | Enhances satiety, regulates lipid metabolism and decreases fat accumulation | Nurliyana et al. (2010); Basu & Penugonda (2009) |
| **Anti-anemia Activity** | Iron and vitamin C improve | Vitamin C enhances iron | Iron, vitamin C, polyphenols | Improves erythropoies | Jaafar et al. (2009); |

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|---|---|---|---|---|---|
| | haemoglobin synthesis and iron absorption. | absorption, while polyphenols protect erythrocytes from oxidative damage. | | is and iron utilization | Jurenka (2008) |
| **Neuroprotective Activity** | Betalains reduce oxidative stress in neuronal tissues. | Punicalagins and ellagic acid reduce neuroinflammation and amyloid toxicity. | Betalains, ellagitannins, anthocyanins | Protects neurons against oxidative damage and inflammation | Arivalagan et al. (2021); Hartman et al. (2006) |

**Table. No. 2.4.1:** Pharmacological and Health Properties of Raw Fruit

**Fundamentals of Oenology and Vinification**

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 "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 winemaking. It is an un-distilled alcoholic beverage prepared from fruit juice.

The process of preparation of wine is known as vinification, and the branch of science that deals with the study of wine is known as enology (American) or oenology (British). There are different types of wine classified on different fundamental principles. Besides fruit and berries, non-toxic plants (flowers) can also be used for wine production. Since the basic constituent of wine is alcohol, other substrates are also added to it, and it typically contains 3% to 22% of alcohol(29).

**Wine Characteristics**

Wine is an alcoholic beverage produced through the controlled fermentation of fruit sugars by yeast, primarily **Saccharomyces cerevisiae**, under anaerobic conditions. Although grapes (*Vitis vinifera*) are the traditional raw material for wine production, wines can also be produced from several fruits such as dragon fruit, pomegranate, apple, mango, berries, and plum. During fermentation, the naturally occurring sugars (glucose and fructose) are converted into ethanol, carbon dioxide, and a wide range of secondary metabolites that contribute to the wine's aroma, flavour, colour, and mouthfeel.

According to the **International Organisation of Vine and Wine (OIV)**, wine is defined as *"the beverage resulting exclusively from the complete or partial alcoholic fermentation of fresh grapes, whether crushed or not, or of grape must."* Fruit wines produced from non-grape fruits follow the same fermentation principles but are identified by the name of the fruit used, such as dragon fruit wine or pomegranate wine. Recent advances in food science have expanded the concept of wine beyond a recreational beverage to include functional fruit wines, which retain significant amounts of bioactive compounds including polyphenols, flavonoids, anthocyanins, betalains, vitamins, and organic acids. These compounds contribute to both sensory quality and potential health-promoting properties, making fruit wines an emerging segment of the functional beverage industry.

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| S.No | Characteristics | Description |
|---|---|---|
| 1 | Appearance | Wine should possess a clear, bright appearance without turbidity or sediment. Colour varies from pale yellow to deep ruby depending on the fruit source and pigment composition. |
| 2 | Colour | Determined by natural pigments such as anthocyanins in grapes and betalains in red dragon fruit. Colour intensity changes during fermentation and ageing. |
| 3 | Aroma (Bouquet) | Produced by volatile esters, alcohols, aldehydes, terpenes and higher alcohols formed during fermentation and maturation. |
| 4 | Taste | A balanced combination of sweetness, acidity, bitterness, tannins and alcohol that determines overall flavour quality. |
| 5 | Alcohol Content | Generally ranges between 9–15% (v/v) for table wines and 15–21% (v/v) for fortified or dessert wines. |
| 6 | Acidity | Mainly due to tartaric, malic, citric and lactic acids, contributing to freshness, microbial stability and flavour balance. |
| 7 | Residual Sugar | Determines whether wine is classified as dry, semi-dry or sweet. |
| 8 | Body | Refers to the mouthfeel created by alcohol, glycerol, sugars and phenolic compounds. |
| 9 | Phenolic Composition | Includes flavonoids, tannins, anthocyanins or betalains, which influence colour, antioxidant activity and astringency. |
| 10 | Shelf Stability | Depends on alcohol concentration, acidity, sulphur dioxide level, storage conditions and microbial stability. |

**Table. No. 2.6.1:** Characteristics of Wine

**Biochemical Mechanisms of Fermentation**

Fermentation describes the process of creating a product using a controlled culture of microorganisms. In dragon fruit and Pomegranate 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.

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 flavor, color, and stability of the wine.

The sugar glucose in the fruits is broken down anaerobically by yeast according to the classic Gay-Lussac metabolic equation:During this catabolic sequence, one mole of glucose ($C_6H_{12}O_6$) is converted by glycolysis under anaerobic conditions into two moles of ethanol ($C_2H_5OH$) and two moles of carbon dioxide ($CO_2$) gas, releasing small amounts of metabolic energy for the yeast population. ‘Saccharomyces 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.

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# METHODS AND METHODOLOGY

## Raw Material Formulation

Fresh dragon fruits (Hylocereus spp.) and Pomegranate (Punica granatum L.) weighing 500 grams were procured directly from local agricultural markets. The raw material formulation was structured with precise ingredient masses and volumes to maintain optimal conditions for yeast metabolic pathways.

## Procurement of Raw Materials

| Ingredients | Quantities |
|---|---|
| Fresh Dragon fruit pulp | 250g |
| Fresh Pomegranate fruit pulp | 250g |
| Granulated sucrose (sugar) | 132g |
| Yeast inoculum (S. cerevisiae) | 10ml (liquid suspension) |
| Purified water solvent | 500ml |

**Table. No. 3.1.1 :** Raw Material Formulation of mixed fruit wine.

Saccharomyces cerevisiae is applied at low initial sugar levels; the yeast assumes optimum conditions for its activity without any inhibition due to a very fast conversion rate of sugar to alcohol, which can occur at very high initial sugar contents.

Under these conditions, the yeasts can effectively and completely convert the initial sugar content into alcohol. The resulting wine should, therefore, contain high alcohol and negligible residual sugar, which are characteristic properties of dry wines.

## Pre-Treatment Process

The fresh, fully ripened red-fleshed dragon fruits (*Hylocereus polyrhizus*) and Pomegranate (*Punica granatum* L.) were first carefully selected based on their uniform size, bright colour, and freedom from physical damage, insect infestation, or microbial spoilage.

The selected fruits were thoroughly washed under running potable water to remove adhering dirt, dust, pesticide residues, and surface microorganisms, thereby ensuring hygienic processing. After washing, the fruits were peeled manually using a sterile stainless-steel knife to remove the outer peel while minimizing the loss of edible pulp.

The peeled fruits were then cut into small, uniform pieces to facilitate efficient blending. During this step, the seeds were carefully separated from the pulp as required for the experimental procedure to obtain a smoother juice consistency. The prepared fruits were subsequently blended in a sanitized laboratory blender until a homogeneous pulp was obtained.

Finally, the freshly prepared juice was collected in a clean, sterilized bowl for further physicochemical adjustments and subsequent fermentation during wine production. Proper hygienic practices were maintained throughout the entire process to preserve the nutritional quality, natural colour, flavour, and bioactive compounds of the dragon fruit juice while minimizing microbial contamination.

**Fig. No. 3.2.1.a** Sliced Dragon fruit **Fig. No. 3.2.1.b** Pomegranate seeds

**Vinification and Fermentation Operations**

The transformation of raw dragon and Pomegranate fruit juice into a clarified functional wine follows a rigorous sequential process:

The fresh fruit juice was adjusted with water in a 1:1 ratio and mixed thoroughly. Granulated sugar (132g) was added to achieve the target initial fermentable sugar level, and the solution was stirred continuously with a wooden ladle until the sugar crystals dissolved completely. This must was then inoculated with 10mL of active Saccharomyces cerevisiae culture.

The inoculation mixture was transferred into a clean fermentation vessel and sealed tightly with a fitted lid to establish strict anaerobic conditions and prevent contamination. The container was placed in a dark storage room maintained at ambient room temperature to ferment for 85 to 90 days. During this extended incubation, the yeast steadily metabolized the sugars into ethanol and carbon dioxide. Following the 90-day fermentation period, the mixture was filtered through a fine mesh filter to separate suspended solids and residual pulp. The clarified wine was filled into sterile glass bottles, sealed securely, and stored under stable conditions for maturation and subsequent quality analysis.

**Processing of wine**

collection of Dragon fruit and Pomegranate
↓
Washing & Removal of debris and other foreign matter
↓
Pre-treatment process of fruits
↓
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)

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↓
Filtration
↓
Bottling
↓
Storage

**Flowchart. No. 3.3.1.** Processing of Dragon Fruit (*Hylocereus polyrhizus*) and Pomegranate (*Punica granatum* L.) Wine.

**Fig. No. 3.3.1.a** Wine filtration

**Fig. No. 3.3.1.b** Bottled wine

**Physicochemical and Proximate Analytical Techniques**

| **Parameter** | **Analytical Technique / Instrument** | **Principle** | **Importance in Wine Quality** | **Standard Method / Reference** |
|---|---|---|---|---|
| **Total Soluble Solids (°Brix)** | Digital Handheld Refractometer | Measures the refractive index of wine, which is proportional to dissolved sugars. | Determines initial sugar concentration, fermentation progress and residual sugar. | AOAC (2019); OIV (2023); |
| **Titratable Acidity (TA)** | Acid-base titration using 0.1 N NaOH and phenolphthalein | Organic acids are neutralized with standard alkali until the endpoint. | Indicates acidity, taste balance and fermentation quality. | AOAC (2019); OIV (2023); |
| **Qualitative Ethanol Test** | Potassium Dichromate Test | Ethanol reduces orange potassium dichromate to green chromium (III) ions. | Confirms alcohol production during fermentation. | AOAC (2019); |
| **Sensory Evaluation** | 9-Point Hedonic Scale | Panelists evaluate appearance, aroma, | Determines consumer acceptance and product quality. | Stone & Sidel (2004); |

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| | | | | |
|---|---|---|---|---|
| | | taste, mouthfeel and overall acceptability. | | |

**Table. No. 3.4:** Physicochemical and Proximate Analytical Techniques

## RESULTS AND DISCUSSION

### Evaluation of Total Soluble Solids (°Brix)

The concentration of total soluble solids dropped substantially during the 90-day monitoring period, indicating active sugar consumption by the yeast population.

| Fermentation- interval | TSS of Mixed fruit wine (°brix) |
|---|---|
| Day 01 (initial) | 22 |
| Day 45 (mid-interval) | 10.5 |
| Day 90 (terminal wine) | 5.8 |

**Table. No. 4.1** Total soluble solids

This decreasing sugar concentration over time shows active consumption and conversion of sugar, which is typical of fermentation. The rapid drop initially, followed by a slower decline, indicates progressive substrate use that slows as sugar becomes limited within the medium. This confirms that Saccharomyces cerevisiae efficiently metabolized the sucrose and native fruit sugars into ethanol.

### Evaluation of Total Titratable Acidity

Titration monitoring revealed a steady upward trend in total acid concentrations as fermentation progressed, which is typical for fruit wine configurations.

Fermentation Phase Initial Burette Mark Final Burette Mark Total Volume of 0.1N NaOH Used Calculated Acidity (% Citric Acid)

| Fermentation phase | Calculated acidity(%Citric Acid) Of Mixed Fruit wine |
|---|---|
| Day 01 | 1.12% |
| Day 45 | 1.24% |
| Day 90 | 1.33% |

**Table. No. 4.2:** Titratable acidity

The results indicate that the acid content in the sample increases over time, which is typical in fermentation or ripening processes. The decrease in the volume of NaOH solution required per titration across the timeline reflects modifications in sample dilution or concentration factors, while the overall calculated acidity percentage

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rises, confirming ongoing organic acid production. This accumulation of organic acids is due to secondary yeast metabolic actions and small amounts of bacterial acid synthesis, which helps preserve the beverage and balances the sensory profile of the final wine.

**Formula of Titratable Acidity % =**

$$\frac{\text{volume of base x Normality of NaoH x Equivalent weight x 100}}{\text{Sample weight}}$$

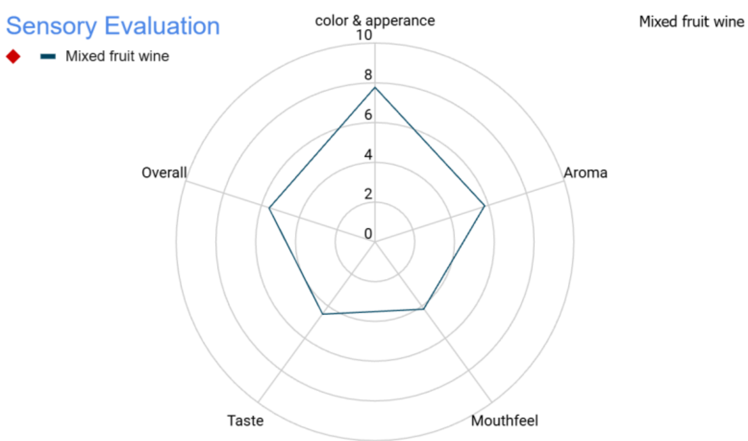
**Evaluation of Ethanol Generation**

The qualitative evaluation of ethanol using the potassium dichromate oxidation method yielded distinct visual results. Adding concentrated sulfuric acid to the mixture of wine must and potassium dichromate caused a clear color transition, shifting from the bright orange of the unreacted dichromate reagent to a deep green hue. This color change to green confirms that ethanol is present in the final product.

The chemical mechanism driving this color change involves the reduction of hexavalent chromium (Cr6, orange) to trivalent chromium (Cr3, green) as it oxidizes the ethanol molecules into acetic acid. This clear color change verifies successful alcohol production from the fruit sugars.

**Fig. No. 4.3:** Evaluation of Ethanol

**Sensory Evaluation of Wine**




**Graph. No. 4.4:** Sensory Evaluation of Dragon Fruit (*Hylocereus polyrhizus*) and Pomegranate (*Punica granatum* L.) Wine

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A panel of 20 semi-trained judges (consisting of faculty and students from the Department of Food Technology and Management) evaluated the terminal 90-day dragon fruit wine. The samples were served at a chilled temperature of 12°C in clear wine glasses. Panelists evaluated the wine across five primary sensory attributes using a 9-Point Hedonic Scale (where 9 = Like Extremely, 5 = Neither Like nor Dislike, and 1 = Dislike Extremely).

**Summary**

The present investigation successfully developed and standardized a functional blended wine using dragon fruit (*Hylocereus polyrhizus*) and pomegranate (*Punica granatum* L.) through controlled fermentation with *Saccharomyces cerevisiae*. The standardized formulation provided suitable conditions for yeast growth and efficient alcoholic fermentation. Throughout the 90-day fermentation period, progressive biochemical changes were observed, including a marked reduction in total soluble solids and a gradual increase in titratable acidity, confirming active sugar metabolism and organic acid production. Ethanol formation was qualitatively verified, demonstrating successful conversion of fermentable sugars into alcohol.

Sensory evaluation indicated that blending dragon fruit with pomegranate improved colour, visual appeal, and overall acceptability. The incorporation of pomegranate contributed additional phenolic compounds and natural pigments that enhanced the functional and aesthetic qualities of the final product. Overall, the study establishes the feasibility of producing a stable and consumer-acceptable functional fruit wine from tropical fruits while promoting value addition and reducing post-harvest losses.

## CONCLUSION

The present study demonstrated that dragon fruit and pomegranate can be effectively utilized for the production of a functional blended wine through controlled fermentation using *Saccharomyces cerevisiae*. The standardized formulation supported efficient fermentation, as evidenced by the substantial reduction in total soluble solids, progressive increase in titratable acidity, and successful ethanol production during the 90-day fermentation period. These changes confirm normal yeast metabolic activity and the development of a stable fermented beverage.

The blended wine exhibited superior colour and appearance. The combination of betalains from dragon fruit and polyphenolic compounds from pomegranate offers additional nutritional and functional value, making the beverage a promising alternative within the growing functional alcoholic beverage market.

Beyond its technological feasibility, the study highlights the potential of blending underutilized tropical fruits to create innovative, value-added products that can minimize post-harvest losses, diversify fruit utilization, and enhance income opportunities for fruit growers and processors. The developed wine therefore represents a viable functional beverage with potential for commercial production following further optimization and industrial validation.

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