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Exploring Sweet Sorghum (CSV-34) as a Sustainable Substrate for Wine Fermentation

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ABSTRACT

Sweet sorghum (Sorghum bicolor L.) is a versatile crop widely utilized for stalk-based ethanol production; however, its immature green grains remain largely unexplored. The present study investigates the feasibility of wine production using green grains of the CSV-34 variety, sourced from Panjabrao Deshmukh Krushi Vidyapeeth (PDKV), Akola, by utilizing their carbohydrate-rich composition as a fermentable substrate.
The grains were subjected to enzymatic treatment to convert complex starch into fermentable sugars, followed by fermentation using Saccharomyces cerevisiae under controlled anaerobic conditions.
The progression of fermentation was evaluated through physicochemical parameters such as pH, titratable acidity (TA), ethanol concentration, and sugar content. Advanced analytical techniques including Gas Chromatography (GC), High-Performance Liquid Chromatography (HPLC), Mass Spectrometry (MS), and Nuclear Magnetic Resonance (NMR) spectroscopy were employed to characterize volatile and non-volatile compounds contributing to aroma and flavour. Potassium metabisulphite was incorporated to enhance microbial stability and prevent contamination.
The results indicated efficient sugar conversion, stable ethanol production, and controlled acidity. The developed wine exhibited a mild yet distinct aroma profile enriched with esters and higher alcohols. These findings highlight the potential of CSV-34 green grains as a sustainable and innovative substrate for wine production.

1. INTRODUCTION

Wine production traditionally depends on fruits rich in fermentable sugars, which ensure optimal ethanol yield, acidity balance, and desirable sensory attributes. However, increasing demand for sustainable and cost-effective production has encouraged the exploration of alternative substrates.
Sweet sorghum (*Sorghum bicolor L.*) is a fast-growing and multipurpose crop known for its high carbohydrate content, short cultivation period, and adaptability to diverse climatic conditions. While its stalk has been extensively utilized for ethanol production, the immature grains, particularly of the CSV-34 variety collected from Panjabrao Deshmukh Krushi Vidyapeeth (PDKV), Akola, remain largely unexplored despite their significant fermentation potential.
These immature grains contain starch, reducing sugars, proteins, and organic acids, which can be converted into fermentable sugars through enzymatic hydrolysis. Under anaerobic conditions, *Saccharomyces cerevisiae* efficiently converts these sugars into ethanol while producing aroma-enhancing compounds such as esters and higher alcohols.
To evaluate the quality of the produced wine, both physicochemical and advanced analytical techniques were employed. Parameters such as pH and titratable acidity were monitored to assess stability, while ethanol content indicated fermentation efficiency. Techniques like GC, HPLC, MS, and NMR provided detailed insight into chemical composition and flavour development.
This study demonstrates the feasibility of producing wine from green grains of **CSV-34**, highlighting its potential as a sustainable alternative in modern fermentation technology.

2. EXPERIMENTAL METHODOLOGY

A systematic experimental procedure was followed to produce wine from green grains of sweet sorghum (CSV-34), ensuring reproducibility and process control.

Sample Collection and Pre-Treatment

Fresh immature grains of CSV-34 were collected from Panjab Rao Deshmukh Krushi Vidyapeeth (PDKV), Akola, ensuring authenticity and varietal purity. The grains were thoroughly washed with hot water to remove dust, soil, and impurities. This step also helped in reducing the surface microbial load, ensuring a clean substrate for fermentation.

Acid Treatment
The cleaned grains were subjected to controlled acid treatment under sterile conditions to improve extractability and inhibit unwanted microbial growth. After treatment, the grains were washed with distilled water to remove residual acid and restore neutrality.

Crushing
The treated grains were crushed using sterile equipment to obtain a uniform paste. This process increased surface area and facilitated the release of fermentable components.

Must Preparation
The crushed grain paste was mixed with warm distilled water and sugar in a sterilized airtight container. The mixture was thoroughly stirred to ensure uniformity and then sealed to prevent contamination and oxygen exposure.

Yeast Inoculation
After cooling, *Saccharomyces cerevisiae* (Lalvin EC-1118) was inoculated into the must. This yeast was selected due to its high ethanol tolerance and efficient fermentation capability.

Fermentation
Fermentation was carried out under anaerobic conditions using an air-lock system. The process was maintained at controlled temperature, with periodic stirring to ensure uniform fermentation. Carbon dioxide evolution was monitored as an indicator of fermentation activity.

Clarification
After completion of fermentation, the clear liquid was separated from sediments through siphoning. This step improved clarity, flavour, and overall stability of the wine.

3. ANALYTICAL EVALUATION

The produced wine was analysed using various physicochemical and sensory parameters.

pH Measurement: Measured using a digital pH meter to monitor acid development.

Specific Gravity: Measured using a hydrometer to track sugar conversion into ethanol.

Total Soluble Solids (Brix): Measured using a refractometer to evaluate sugar consumption.

Ethanol Content: determined using distillation or chemical methods to assess fermentation efficiency.

Colour and Clarity: Visually observed and optionally confirmed using UV–Visible spectroscopy.

Aroma Profile: Evaluated through sensory analysis and supported by GC analysis.

Comparative Analysis

Parameter	Sorghum Wine (CSV-34)	Grape Wine	Observation
pH	3.5–3.7	3.0–3.5	Slightly milder
TA	Moderate	Higher	Less acidic
Ethanol (%)	8–12	10–13	Comparable
Aroma	Mild, earthy	Fruity	Distinct
Colour	Pale golden	Yellow–red	Lighter

Storage: The final wine was stored in airtight glass bottles at 4–8°C. An additional 75–100 ppm of potassium metabisulfite was added to extend shelf life and maintain microbial stability.

4. OBSERVATIONS

The fermentation process of sweet sorghum grains was closely monitored by evaluating pH, reducing sugars, titratable acidity, ethanol content, and aroma profile. The following results were observed:

Parameter	Initial	Final	Interpretation
pH	3.4–3.6	3.1–3.2	Acid formation
Sugars	18–20 g/L	1–2 g/L	Sugar depletion
TA	0.25%	0.38%	Acid increase
Ethanol	0%	9–11%	Successful fermentation

5. CONCLUSION

The present study successfully demonstrates that immature green grains of sweet sorghum (CSV-34), collected from Panjabrao Deshmukh Krushi Vidyapeeth (PDKV), Akola, can be effectively utilized as a non-conventional substrate for wine production under controlled anaerobic fermentation conditions. The experimental results clearly indicate efficient conversion of fermentable sugars into ethanol, accompanied by a gradual decrease in pH and a controlled increase in titratable acidity, confirming stable fermentation kinetics.

The produced wine exhibited ethanol content within an acceptable range, along with a balanced acidity profile and satisfactory clarity. The development of characteristic aroma compounds, particularly esters and higher alcohols, contributed to a mild yet pleasant sensory profile. These findings validate the suitability of *Saccharomyces cerevisiae* for fermenting sorghum-based substrates and highlight its role in enhancing both biochemical transformation and flavour development.

The use of the CSV-34 variety is particularly significant due to its high carbohydrate content, adaptability to semi-arid climatic conditions, and low agricultural input requirements. Unlike traditional grape-based wine production, which depends on specific climatic and soil conditions, sweet sorghum offers greater flexibility and resilience, making it a viable alternative for regions with limited resources. This contributes to the diversification of raw materials in fermentation industries and reduces dependency on conventional substrates.

From an economic perspective, the utilization of sorghum grains for wine production presents an opportunity for value addition to an underutilized agricultural resource. It has the potential to enhance farmer income, promote rural agro-based industries, and support small-scale fermentation enterprises. Additionally, the process can be optimized further for large-scale production, ensuring commercial feasibility.

Environmentally, the adoption of sweet sorghum as a fermentation substrate supports sustainable agricultural practices. The crop requires less water, grows efficiently in marginal soils, and produces multiple outputs such as grains, stalk, and fodder, ensuring maximum resource utilization. The fermentation process itself generates minimal waste and offers scope for by-product recovery, further enhancing sustainability.

In conclusion, this study establishes that green grains of sweet sorghum (CSV-34) are a promising, sustainable, and economically viable substrate for wine production. The integration of controlled fermentation techniques with comprehensive analytical evaluation provides a strong foundation for future research and industrial application. Further studies focusing on process optimization, sensory enhancement, and large-scale feasibility can contribute to the development of innovative and climate-resilient fermentation technologies.

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