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Utilization of sugarcane (Saccharum officinarum L.) byproducts for functional food development: A novel process optimization study

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INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a perennial grass of the Poaceae family, cultivated in over 102 countries across 24 million hectares for its economic and medicinal value [1]. It is a rich source of carbohydrates and can be consumed as stem pieces or juice. Sugarcane juice contains about 15% natural sugar, providing 39 calories and 9 g carbohydrates per 100 ml. It is rich in minerals like phosphorus, potassium, calcium, and iron, along with vitamins A, B-complex, C, and vitamin E [2]. The sugarcane juice helps rehydrate the body, boosts immunity, and offers instant energy. Globally, about 1.9 billion tons are produced annually, mainly by Brazil, followed by India, China, and others (Fig 1) [3].

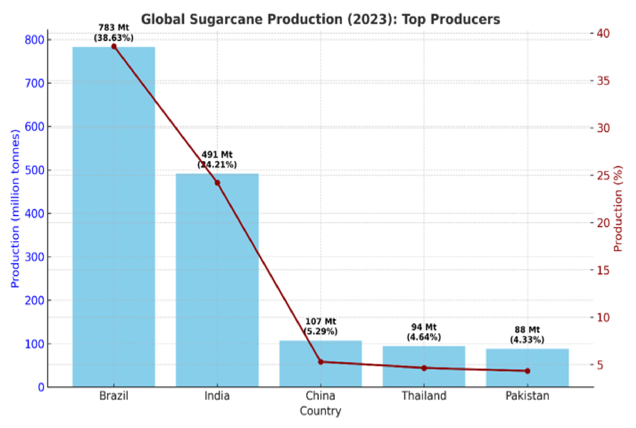


Figure 1. This figure demonstrates both sugarcane production (in million tons) and percentage of global production for the top five producers in 2023 according to (FAO 2023).

OBJECTIVES

This study aimed to utilize a sugarcane byproduct for vinegar production using a two-step process involving *Saccharomyces cerevisiae* for ethanol formation and *Acetobacter* for acetic acid conversion, and to evaluate the optimization of the acidification process. The developed value-added product will not only generate income for producers but also promote the industrial processing of sugarcane

MATERIALS AND METHODS

- Good quality sugarcane were brought from Sugarcane Crop Research Institute, Changsha, China. Chemicals used in this study were brought from the local market.
- Pre-Processing. The sugarcane were first washed with tape water to eliminate dust and dirt. Juice were extracted through cane juice extractor Machine. The juice was first filter and then pasteurized at 80 °C for 15 to 30 min before further study. The complete process of sugarcane vinegar development is shown in figure 2.
- Yeast Starter. *Saccharomyces cerevisiae* was used for alcoholic fermentation. The yeast was activated by adding 20 g to a 0.1% salt solution, then mixed with a 20 °Brix sugar solution. The mixture was incubated at 30°C for 10 minutes to activate the yeast.
- Treatment preparation. Sugarcane juice was split into different treatment and placed at different environmental condition according to the mentioned study plan in (table).

Treatment	Juice	Yeast starter	Storage Environment
To	1 Lit	5ml	**Room Temperature (Uncontrolled Temperature)**
T1	1 Lit	5ml	**Dehydrator (25°)**
T2	1 Lit	5ml	**Incubator (30°)**
T3	1 Lit	5ml	**Open sun (Uncontrolled Temperature)**

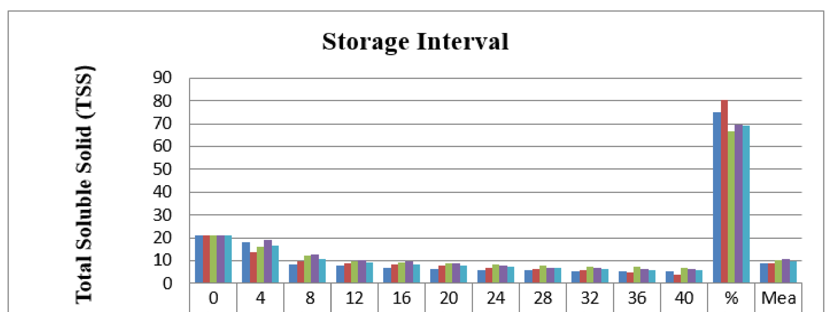
Table. This table presents the plan for treatment preparation.

- The physiochemical properties of Sugarcane cider, including % acidity, total soluble solids (TSS), alcohol content, and pH, were analyzed. TSS was measured as % Brix using a portable digital refractometer, while pH was determined with a HANNA pH meter following AOAC standards. Titratable acidity was measured by the AOAC method (942.15) using 0.1N NaOH. Alcohol content was assessed with an ebulliometer based on differences in boiling points.

Figure 2. This diagram shows the schematic representation of sugarcane vinegar production process.

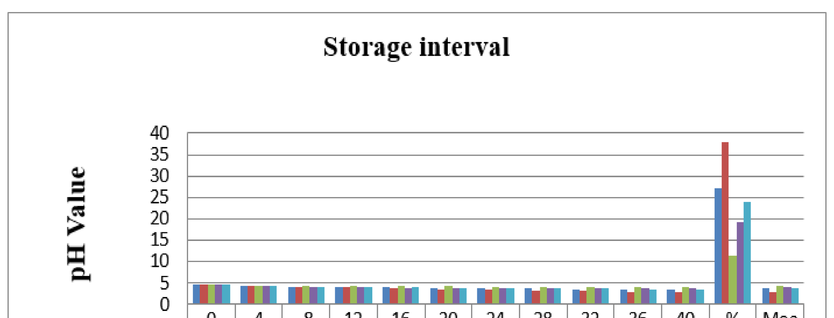
RESULTS AND DISCUSSIONS

The Total soluble solid (TSS) of sugarcane cider vinegar decreased from 21% to 5.3%, 4.1%, 7.0%, and 6.4% in all treatments To-T3, repectively, with the higher decrease was observed in T1 (Dehydrator) (80.47%) and lower in T2 (incubator) (66.66%) as shown in (figure 3). The initial decline during the first two weeks was due to yeast converting sugars into alcohol, while the later decrease resulted from acetic fermentation. Similar findings have been reported by Thuong ND & Hang NT. [4] and Sinclair [5]. The pH of sugarcane cider vinegar decreased from 4.52 to 3.3, 2.8, 4.01, 3.65 in all treatments To-T3, respectively, as demonstrated in (figure 4). In all treatments the higher decrease was observed in T1 (Dehydrator) (38.05%) and lower in T2 (incubator) (11.28%). The decline in pH across treatments resulted from increased acetic acid formation during fermentation, consistent with Giang, N. T. N et al. [6] results. The alcohol content of sugarcane cider vinegar decreased from 5.5, 6, 5, and 5.5 to 2.6, 0.75, 4.5, and 4.35 in T0–T3, respectively, with the highest reduction in T1 (Dehydrator) (87.5%) and the lowest in T2 (Incubator) (10%) as shown in (figure 5). Alcohol initially increased due to yeast fermentation but decreased during acetic fermentation, aligning with Maal et al. [7] findings. The titratable acidity of sugarcane cider vinegar increased from 0.282 to 3.3, 4.1, 1.88, and 2.65 in T0–T3, respectively, with the highest rise in T1 (Dehydrator) (93.13%) and lowest in T2 (Incubator) (85.02%) as shown in (figure 6). The rise in acid content was a result of alcohol consumption by acetic acid bacteria under different environmental conditions and storage periods, consistent with Dias, D. R et al. [8] results.



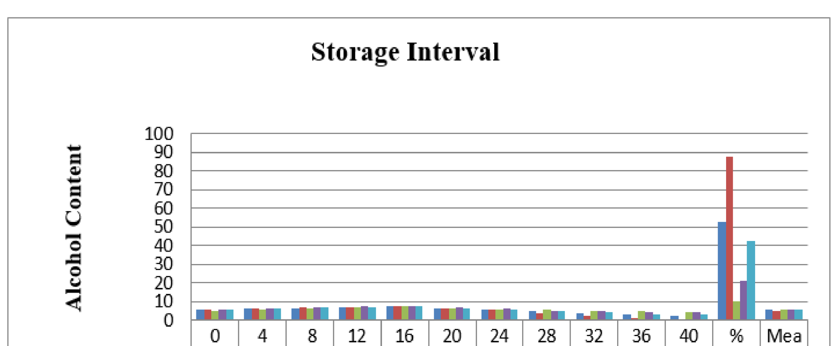
	0 day	4 day	8 day	12 day	16 day	20 day	24 day	28 day	32 day	36 day	40 day	% dec	Mean
Room Temp. To	21	17.9	8.4	7.9	6.8	6.1	5.9	5.6	5.5	5.3	5.3	74.76	8.7
Dehydrator T1	21	13.8	9.8	9	8.2	7.7	6.9	6.2	5.6	4.9	4.1	80.47	8.83
Incubator T2	21	15.9	12.2	9.7	9.4	8.7	8.5	7.8	7.5	7.2	7	66.66	10.44
Open Sun T3	21	19.2	12.7	10.1	9.5	8.9	7.6	7	6.7	6.3	6.4	69.52	10.49
Mean	21	16.7	10.7	9.17	8.47	7.85	7.22	6.65	6.32	5.92	5.7	69.01	9.61

Figure 3. Effect of different environmental condition and storage interval on TSS of Sugarcane vinegar. The mean data showed that the total soluble content continuously decreased from 21 Brix to 5.7 Brix during total period of storage.



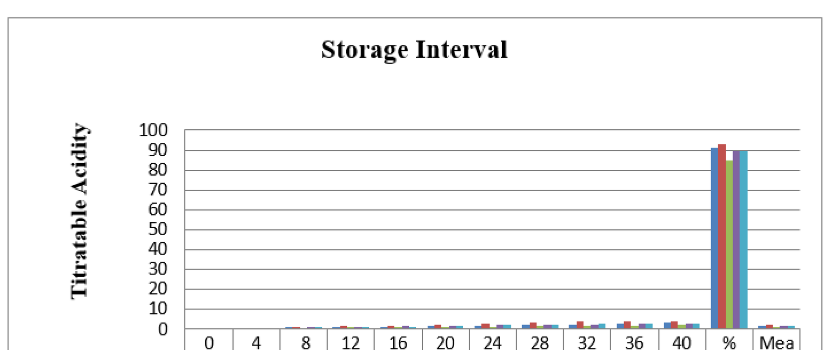
	0 day	4 day	8 day	12 day	16 day	20 day	24 day	28 day	32 day	36 day	40 day	% dec	Mean
Room Temp To	4.52	4.19	3.92	3.92	3.9	3.86	3.71	3.64	3.5	3.39	3.3	26.99	3.8
Dehydrator T1	4.52	4.37	4.08	3.92	3.82	3.49	3.29	3.11	3.07	2.93	2.8	38.05	2.78
Incubator T2	4.52	4.44	4.36	4.21	4.2	4.17	4.15	4.08	4.03	4.03	4.01	11.28	4.2
Open Sun T3	4.52	4.27	3.98	3.89	3.85	3.77	3.72	3.72	3.68	3.65	3.65	19.24	3.88
Mean	4.52	4.31	4.08	3.98	3.96	3.82	3.71	3.63	3.57	3.5	3.44	23.89	3.66

Figure 4. Effect of different environmental condition and storage interval on pH of Sugarcane vinegar. The results showed that the pH value decreased in all the treatments.



	0 day	4 day	8 day	12 day	16 day	20 day	24 day	28 day	32 day	36 day	40 day	% Dec	Mean
Room Temp. To	5.5	6.25	6.55	7.1	7.45	6.4	5.8	5.2	4.1	3.4	2.6	52.72	5.48
Dehydrator T1	6	6.6	7.1	7.25	7.6	6.5	5.7	3.9	2.7	1.2	0.75	87.5	5.02
Incubator T2	5	5.8	6.65	7	7.5	6.3	5.9	5.55	5.1	4.8	4.5	10	5.82
Open Sun T3	5.5	6.05	6.7	7.5	7.85	6.9	6.35	5.2	4.85	4.5	4.35	20.9	5.97
Mean	5.5	6.17	6.75	7.21	7.6	6.52	5.93	4.96	4.18	3.4	3.05	42.78	5.57

Figure 5. Effect of different environmental condition and storage interval on alcohol content of Sugarcane vinegar.



	0 day	4 day	8 day	12 day	16 day	20 day	24 day	28 day	32 day	36 day	40 day	% Inc	Mean
Room Temp.To	0.282	0.371	0.763	0.938	1.184	1.384	1.722	1.925	2.311	2.782	3.3	91.46	1.542
Dehydrator T1	0.282	0.506	0.831	1.323	1.804	2.323	2.885	3.284	3.634	3.982	4.1	93.13	2.268
Incubator T2	0.282	0.416	0.48	0.657	0.689	0.693	1.102	1.314	1.511	1.733	1.88	85.02	0.978
Open Sun T3	0.282	0.346	0.659	0.696	1.247	1.522	1.902	2.211	2.403	2.652	2.65	89.2	1.265
Mean	0.282	0.41	0.683	0.903	1.231	1.48	1.903	2.183	2.464	2.787	2.983	89.7	1.513

Figure 6. Effect of different environmental condition and storage interval on titratable acidity of Sugarcane vinegar.

CONCLUSIONS

The purpose of this research work was to utilize sugarcane byproduct for the production of a novel variety of vinegar and to evaluate the optimization of the acidification process. A two-step process was used for vinegar production. In the first step, yeast (Saccharomyces cerevisiae) was applied for the production of ethanol from the carbohydrates present in the raw material. In the second step, acetic acid bacteria (Acetobacter) oxidized ethanol to acetic acid. On the basis of results It was concluded that the dehydrator treatment is the most effective and rapid method for acetic acid fermentation due to the consistent temperature and fresh air promoting bacterial growth. This research introduces an innovative method for handling sugarcane byproducts, supporting both value-added production and sustainable utilization of byproducts.

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