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Influence of peel inclusion and enzymatic extraction on the composition and quality of banana wine

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Abstract
The study was conducted to evaluate the impact of enzyme-based extraction on the physico- chemical characteristics of banana wine prepared with and without peel using pectinase, cellulase, and their combination control without enzymes. Treatments significantly influenced physico-chemical characters such as total soluble solids (TSS), pH, titratable acidity (TA), ascorbic acid content, alcohol content, and clarity. The lowest TSS (7.85 °Brix) and pH (3.0) were observed in the combination enzyme treatment (P_1E_3) with peel, indicating enhanced fermentation efficiency and higher organic acid release. The same treatment exhibited the highest alcohol content (10.45%) and titratable acidity, suggesting that enzymatic hydrolysis promoted sugar conversion and acid liberation from the peel. Furthermore, wines prepared with combination enzymes retained higher ascorbic acid (4.2 mg/100 mL), while maximum clarity (85%) was achieved in wines without peel treated with enzymes. Hence results demonstrate that the synergistic use of pectinase and cellulase improves wine extraction, fermentation efficiency, and overall quality of banana wine, highlighting its potential for commercial-scale fruit wine production.

Keywords: Banana wine, enzymatic extraction, pectinase, cellulose, physico-chemical characteristics, alcohol content, titratable acidity, ascorbic acid, clarity

Introduction
The banana (*Musa* sp.) is a tropical fruit of great economic and nutritional importance, ranking first as the most widely produced fruit globally and cultivated in over 125 countries. India leads in banana production, contributing 19.37% to global output, with about 993 thousand hectares producing 37,378 thousand metric tons in 2023-24 (NHB, 2023–24). Despite being the 20th largest exporter, India exports only 0.3% of its bananas due to high domestic demand, with exports worth ₹1,472 crores (USD 176 million) in 2022-23 (APEDA). Hence produced bananas can be utlised by making into value added products.

Sugandhalu (Sugandi) is notable for its sweet fruits, with bunches weighing 10-12 kg, each containing 7-10 hands of medium-sized fruits (90-100 g), which are cream-pulped, very sweet, and have good shelf life (Devi et al., 2013) [11].

Fruit wines are valued worldwide for their fresh flavors, storability, and nutritive properties. With 8-12% alcohol, 2-3% sugar, and 70-90 kcal/100 mL, wines retain many nutrients from the original juice, further enriched by amino acids and compounds released by yeast. Their composition-including water, alcohol, esters, pigments, acids, tannins, and minerals, gives them therapeutic benefits (Patil et al., 2005) [6]. Fruit wines, commonly made from grapes, can also be produced from bananas, plums, peaches, apricots, and other fruits, offering nutritive value and mild stimulatory effects.

Enzymes are widely used in food industries like juice production, winemaking, and brewing, as they catalyze processes that improve product yield and quality. Pectinases break down pectic substances, boosting juice recovery, filtration speed, and clarity, while cellulases degrade cellulose in fruit cell walls, reducing viscosity and releasing sugars, flavors, proteins, and polysaccharides.

Traditional methods of wine extraction are limited by the presence of cellulose, pectin, and hemicellulose, but enzyme application overcomes these barriers. The present study aims to improve banana wine production through enzymatic treatment to enhance quality and ensure better stability.

Material and methods Materials

Procurement of raw material

The Research was conducted in the Department Laboratory of Postharvest Management in the College of Horticulture, Anantharajupeta, Annamayya District of Andhra Pradesh. To conduct the research investigation, mature and well-ripened banana fruits of Sugandhalu variety were procured from the local market in Railway Koduru, along with sugar. A pure yeast culture was collected from IIHR Bangalore.

Enzymes Pectinase ex. *Aspergillus niger*, 3000 IU/g powder, Cellulase (Meicellase) ex. *Aspergillus niger*, 0.3 U/mg powder, from Sisco Research Laboratories Pvt. Ltd., were procured.

Preparation of enzyme-based banana wine

Fully ripened banana fruits were thoroughly washed and cleaned. The peels were manually removed, and the pulp was prepared separately for treatments with and without peel. For each treatment, 150 grams of pulp (with or without peel) was mixed with 150 ml of distilled water in a 1:1 ratio. The prepared pulp mixtures were then ameliorated with ground cane sugar to raise their total soluble solids (TSS) to 22 °Brix.

Pectinase and cellulase enzymes (0.3%) were added as per the treatments to the banana pulp and incubated in a shaking incubator at 40 °C and 110 rpm for 2 hours to improve juice extraction. The pulp was then pasteurized in sterilized bottles at 70 °C for 15 minutes, cooled under aseptic conditions, and inoculated with 5% starter culture. The inoculated pulp was kept in sterilized conical flasks covered with cotton plugs and aluminium foil, and fermentation was carried out at room temperature until no further decrease in TSS was observed for two consecutive days. After fermentation, the wine was siphoned, filtered through sterilized muslin cloth, and kept for settling before siphoning again. The clear supernatant was transferred into fresh sterilized bottles, corked, and pasteurized at 80 °C for 15 minutes to ensure safe storage.

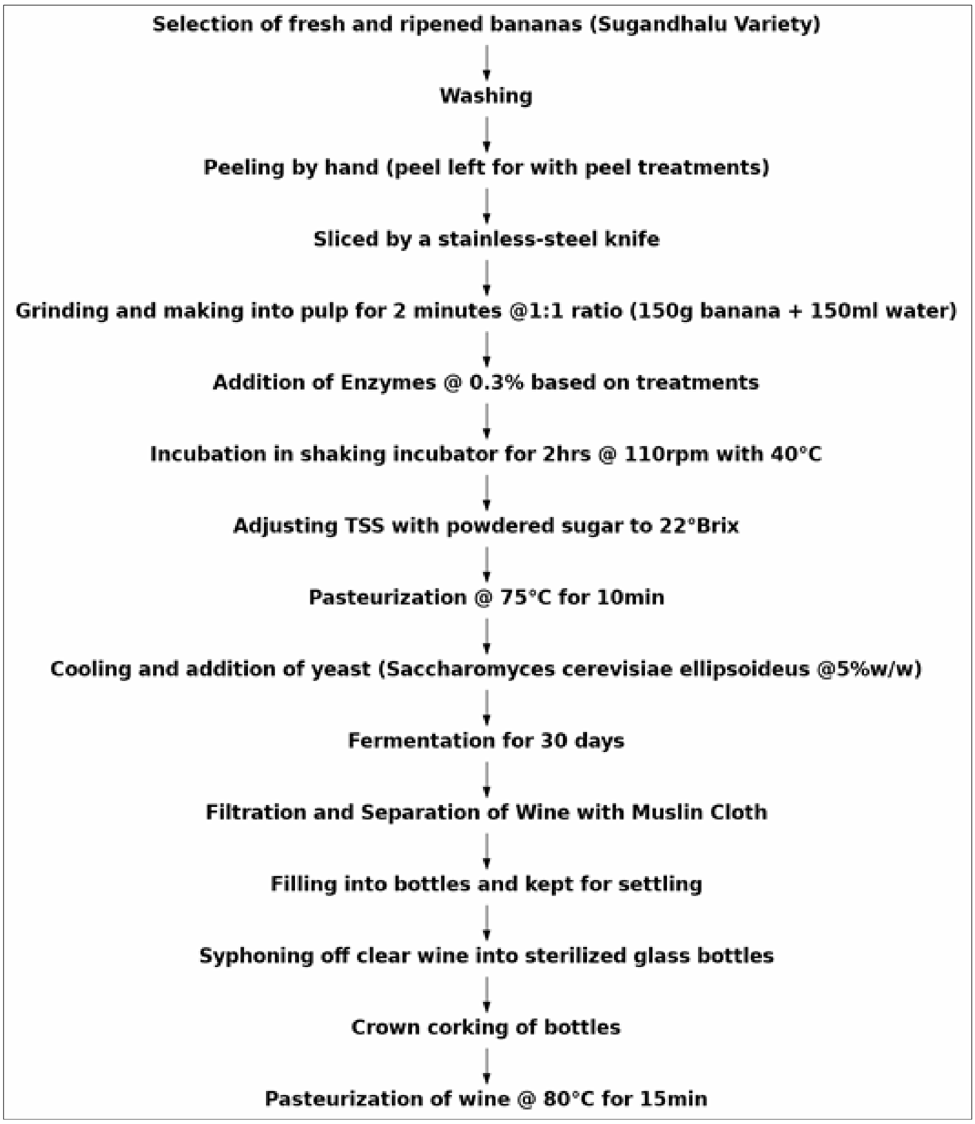

Fig 1: Flow sheet for the preparation of enzyme-based banana wine

Treatment Details

Factor – 1 Peel	Factor – 2 Enzymes
P1 - With peel	E1 - Pectinase @ 0.3%
P2 - Without peel	E2 - Cellulase @ 0.3%
	E3 - Pectinase @ 0.3% + Cellulase @ 0.3%
	E4 - Without enzymes

Treatment combinations

P_1E_1	P_1E_2	P_1E_3	P_1E_4	P_2E_1	P_2E_2	P_2E_3	P_2E_4

Physico – chemical Analysis

Clarity (%) was measured by UV-spectrophotometer (UV-1800, Shimadzu) at 660 nm using water as blank to record transmittance. Total Soluble Solids (°Brix) were directly read using a digital refractometer (Atago RX1000) at room temperature, expressed in °Brix. pH was measured with a digital pH meter (ELICO LI-127). Alcohol content (%) was estimated by Caputi's (1968) [3] dichromate oxidation method and absorbance read at 600 nm against ethanol standard curve. Titratable Acidity (%) was determined by diluting the sample and titrating with 0.1 N NaOH using phenolphthalein indicator, and acidity was calculated by formula. Ascorbic Acid (mg/100g) was determined by titration with 2, 6-dichlorophenol indophenol dye (Sadasivam & Manickam, 1992) [8].

Results and Discussion

Data related to physico–chemical parameters which include TSS, pH alcohol content, titratable acidity, ascorbic acid content and clarity were presented in Table 1&2.

TSS

The lowest TSS was observed in (P1) treatment with peel 7.9 compared to without peel 8.75 and in enzymes (E3) combination of enzymes pectinase + cellulase @ 0.3% gave less TSS 7.85 on par with (E1) pectinase, compared to other treatments. In interaction, tss gave non- significant changes after fermentation.

The synergistic action of pectinase and cellulase on both banana pulp and peel ensures that more sugars are liberated and consequently fermented, resulting in a wine with less TSS at the end of the fermentation this shows that combination enzymes helped in extraction of polysaccharides from peel and improved fermentation of withpeel treatment. Dowerah *et al.* (2023) [12] found the similar result that juice treated with enzyme pectinase recorded the highest TSS later in fermentation converted to alcohol. Scutarasu *et al*. (2019) [9] also found that enzyme treated winegrape wine contains less TSS.

pH

The lowest pH was observed in (P1) 3.32 compared to (P2) without peel 3.59 and in enzymes (E3) combination enzymes recorded the less pH with 3.25. In interaction (P_1E_3) recorded the less pH of 3 it may be due to increase of titratable acidity of wine may be due to release of organic acids from the peel during enzymatic hydrolysis. Aneh *et. al* (2023) [2] also reported that enzyme treated *Dacryodes macrophylla* wine had less pH compared to control.

Alcohol content

The interaction treatment with peel and combination enzymes (P_1E_3) showed the highest alcohol content of 10.45% than (P_2E_4) without peel and without enzymes, 6.1%. this is may be due to extraction of polysaccharides from the peel and converting them into alcohol. Dowerah et al. (2023) [12] and Aneh *et. al* (2023) [2] also stated that enzymatically treated wine has more alcohol content.

Titratable acidity

Highest titratable acidity was recorded in the (P_1E_3) treatment with peel and pectinase + cellulase @ 0.3% compared to (P_2E_4) treatment without peel and without enzymes. This may be due to the release of bound organic acids from the peel during enzymatic hydrolysis. Entonu et al. (2025) [4] also showed that titratable acidity was increased after fermentation.

Ascorbic acid

The highest ascorbic acid content was recorded in the interaction treatment of (P_1E_3) compared to control with (P_2E_4). With 4.2 mg/100ml of ascorbic acid. Thanh, T.H. and Lieu, N (2021) [10] also reported that dragon fruit wine with peel showed more vitamin c than control**.**

Clarity

The treatment combination without peel and combination enzymes performed more clarity 85% than withpeel and without enzymes treatment (P_1E_4) 75% It may due to enzymatic hydrolysis of suspended solids. Similar findings was observed by Dowerah *et al.* (2023) [12] where enzymatic treated wine wine showed clear wine than control in banana. Scutarasu *et al*., (2019) [9] also reported that pectinase and cellulase treated wine showed more clarity in whit grape

Table 1: Physiochemical parameters of enzyme-based banana wine

	TSS(°Brix) after fermentation					pH after fermentation				
	E_1	E_2	E_3	E_4	Mean (P)	E_1	E_2	E_3	E_4	Mean (P)
P_1	7.50	7.9	7.2	9	7.90	3.2	3.4	3	3.67	3.32
P_2	8.3	8.7	8.49	9.5	8.75	3.45	3.6	3.5	3.83	3.59
Mean	7.90	8.3	7.85	9.25		3.32	3.5	3.25	3.75	
Factor	SE (m)±		CD at 5%			SE (m)±		CD at 5%		
P	0.08		0.23			0.03		0.08		
E	0.11		0.32			0.04		0.11		
P×E	0.15		NS			0.06		0.16		

Table 2: Physicochemical parameters of enzyme-based banana wine

	Alcohol content (%) after fermentation					Titratable acidity (%) after fermentation					Ascorbic acid (mg/100ml) after fermentation					Clarity (%) after fermentation				
	E1	E2	E3	E4	Mean	E1	E2	E3	E4	Mean	E1	E2	E3	E4	Mean	E1	E2	E3	E4	Mean
P_1	9.17	8.85	10.45	6.49	8.74	1.38	1.21	1.50	0.7	1.2	5.8	5	6	4.45	5.31	75	71	77	65	72
P_2	8.08	7.64	8.06	6.1	7.47	1.1	0.85	0.9	0.6	0.86	4.85	4.60	5.15	4.2	4.70	82	79	85	68	78.5
Mean	8.63	8.24	9.25	6.29		1.24	1.03	1.20	0.65		5.32	4.80	5.57	4.32		78.5	75	81	66.5	
Factor	SE (m)±		CD at 5%			SE (m)±		CD at 5%			SE (m)±		CD at 5%			SE (m)±		CD at 5%		
P	0.064		0.19			0.01		0.03			0.03		0.09			0.43		1.30		
E	0.09		0.27			0.01		0.04			0.04		0.12			0.61		1.83		
P×E	0.13		0.38			0.02		0.06			0.06		0.17			0.86		2.59		

Conclusion
The study concluded that enzyme-based extraction significantly improved the fermentation efficiency and quality attributes of banana wine. Among all treatments, the combination of pectinase and cellulase (P_1E_3) with peel produced superior results, characterized by higher alcohol content, titratable acidity, and ascorbic acid, along with reduced TSS and pH. The enzymatic hydrolysis enhanced the release of fermentable sugars and organic acids from banana peel, leading to improved wine characteristics. Wines without peel showed greater clarity, likely due to the absence of suspended solids. Overall, the application of pectinase and cellulase in combination proved to be an effective strategy for enhancing the physicochemical properties of banana wine, suggesting its suitability for commercial utilization and value addition of banana fruit and peel.

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