



# Bioscene

**Bioscene**

**Volume- 22 Number- 03**

**ISSN: 1539-2422 (P) 2055-1583 (O)**

**[www.explorebioscene.com](http://www.explorebioscene.com)**

## Optimization and Characterization of Alcohol Production from Agro-Wastes by Indigenous *Candida tropicalis* Strain IDRI000028827 and Commercial *Saccharomyces cerevisiae*

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**Abstract:** Alcohol is widely used in Nigeria across different industries, but its production is costly because it depends on commercial yeast (*Saccharomyces cerevisiae*) and refined substrates. This study investigated the use of agro-wastes for alcohol production using an indigenous yeast strain, *Candida tropicalis* IDRI000028827, and compared its performance with *S. cerevisiae* under similar conditions. Agro-waste substrates were prepared from date palm, corn, sugarcane, pineapple, and banana (carbon sources), and from defatted groundnut, bambara nut waste, crayfish by-products, eggshell, and snail shell (nitrogen sources). The materials were dried, powdered, and subjected to fermentation under varying temperatures (15–40 °C) and pH values (4.0–7.0). Alcohol was distilled, quantified, and analyzed by Gas Chromatography–Mass Spectrometry (GC–MS). Antibacterial activity of the alcohol was tested against *Staphylococcus aureus* OPD001-1, *Bacillus* sp. FFOS, and *Salmonella enterica* strains 2011k-1440 and CFSANO27396. Results showed that *S. cerevisiae* produced higher yields (116.7%) under refined substrates, while *C. tropicalis* performed better on agro-wastes. Optimal yields were obtained from sugarcane bagasse (3.3% w/v) and bambara nut waste (3.1% w/v) at 25 °C and pH 5.5. Alcohol yield from *C. tropicalis* with agro waste (66.7% w/v) was significantly higher than from *S. cerevisiae* (15.3% w/v) ( $p < 0.05$ ). GC–MS confirmed that *C. tropicalis* generated higher levels of methanol (5.63 ppm), ethanol (4.40 ppm), and propanol (3.15 ppm), compared with *S. cerevisiae*. The alcohol from *C. tropicalis* also showed stronger antibacterial activity (80–92%) than that from *S. cerevisiae* (35–58%). This study highlights *C. tropicalis* IDRI000028827 as a promising low-cost alternative for bio-alcohol production, with sugarcane bagasse and bambara nut waste serving as efficient, sustainable substrates.

**Key words:** Agro-wastes, Optimization, Alcohol production, Characterization, *Candida tropicalis* IDRI000028827, *Saccharomyces cerevisiae*

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## Introduction

Over the centuries, fossil fuels along with synthetic alcohols derived from them have served as major sources of energy. Yet, their adverse environmental effects have intensified the global search for greener alternatives. Increasingly, researchers are exploring biological processes as sustainable options. In West Africa, particularly Nigeria, *Saccharomyces cerevisiae* has traditionally been the primary yeast used in alcohol production, often relying on refined and costly substrates (Onyema et al., 2023). However, the reliance on expensive inocula and imported substrates worsened because of the fluctuating currency exchange rates which pose serious economic challenges for local industries. Moreover, diverting edible crops to fermentation as a substitute raises the risk of food insecurity, adding further pressure to already vulnerable populations (Ahamefule et al., 2024). An attractive alternative lies in the use of rich food wastes, which are abundant, affordable, and environmentally friendly (Shah et al., 2025; Ngando-Same et al., 2024). Unfortunately, conventional *S. cerevisiae* strains have limited ability to hydrolyze such complex wastes effectively (Li et al., 2022), restricting alcohol yield and productivity. This highlights the need for alternative microorganism with greater hydrolytic capacity and tolerance to osmotic and fermentation stresses. Non-conventional yeasts such as *Candida tropicalis* have recently gained attention for their versatility in fermenting carbohydrate-based wastes into diverse metabolites. Unlike *S. cerevisiae*, *C. tropicalis* can utilize both hexose and pentose sugars while withstanding toxic by-products generated during fermentation (Ayepa et al., 2024). Its potential in processing agricultural residues has been documented in several studies (Sorour et al., 2023; Shariq and Sohail, 2019; Hermansyah et al., 2015). However, limited research has focused on its efficiency in converting locally available agro-wastes into alcohols relative to commercial *S. cerevisiae* strains under optimized fermentation conditions, or on assessing its alcohol for antimicrobial properties. This study therefore set out to address that gap by optimizing and evaluating alcohol production from agro-wastes using an indigenous strain, *C. tropicalis* IDRI000028827, and benchmarking its performance against commercial *S. cerevisiae*. The outcomes are expected to support the use of this local strain for cost-effective alcohol fermentation, offering scalable solutions particularly suited for resource-limited economic countries such as Nigeria.

## Materials and Methods

### Microorganism

The test organism used in this study was *C. tropicalis* strain IDRI000028827, previously reported to possess alcohol tolerance (Onyia et al., 2025). The strain was obtained from the Culture Collection Laboratory of the Department of Microbiology, Enugu State University of Science and Technology. Its stock culture was maintained

in glycerol stock on Potato Dextrose agar (PDA) at 4 °C until when required for experimentation.

### **Substrate Collection and Preparation**

Carbon sources including date palm waste, corn waste, sugarcane bagasse, pineapple peels, and banana peels were collected from different processing sites within Enugu metropolis. Nitrogen sources such as defatted groundnut, bambara nut waste, crayfish processing by-products, eggshells, and snail shells were also sourced locally. All collected substrates were rinsed thoroughly with sterile water to remove dirt and impurities. The materials were then sun-dried at ambient temperature, ground into powder using a manual home blender (Corona), and sieved through muslin cloth to obtain uniform particle size suitable for fermentation.

### **Activation of *C. tropicalis* IDRI00028827 Culture**

The yeast preserved in glycerol stock was first streaked onto Potato Dextrose Agar (PDA) plates and incubated at 30 °C for 48 hours to obtain actively growing colonies. The resulting biomass was used as inoculum for fermentation experiments.

### **Preliminary Alcohol Fermentation Using Refined Substrates**

The preliminary alcohol production by *C. tropicalis* and *S.cerevisiae* was carried out with refined substrates in 500 ml Erlenmeyer flasks containing sterile Mineral Salt medium composed of glucose (2.5% w/v), yeast extract (1.5 % w/v),  $\text{NH}_4\text{SO}_4$  (0.5 % w/v),  $\text{KH}_2\text{PO}_4$  (0.1% w/v), and  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$  (0.05% w/v) prior to optimization studies. The medium was sterilized at 121 °C for 15 min prior to inoculation. The activated yeast inoculum (0.3% w/v) was introduced aseptically into the fermentation medium, and incubation was performed at 30 °C for 7 days under stationary (anaerobic) conditions (Eeomet al., 2018).

### **Distillation of the Alcohol**

The harvested fermented broth was centrifuged (Eppendorf, Germany) at 1000rpm and later subjected to distillation using a laboratory distiller (Spaqlabs, India) to recover the alcohol. The alcohol content was then quantified using a refractometer following the procedure of Gerogiannaki-Christopoulou et al. (2003). Prior to measurement, the refractometer was calibrated to 0% alcohol at room temperature. A drop of the distilled sample was placed on the prism surface, and the reading was recorded. The percentage alcohol content was calculated using the following formula:

Alcohol content (%) =

$$\frac{\text{Refractive index of test alcohol} - \text{Refractive index of water}}{\text{Refractive index of pure alcohol (Control)} - \text{Refractive index of water}} \times 100$$

Where

Refractive index of water =0 and

Refractive index of pure alcohol (ethanol) =3

### **Optimization Study with Indigenous Agro-Wastes**

#### **i. Substrate Screening**

The one-factor-at-a-time (OFAT) approach, as adopted by George-Okafor and Mike-Anosike (2012), was used for substrate screening. In this method, each carbon source (2.5% w/v) was used to replace glucose in earlier outlined fermentation medium, with an inoculum concentration of 0.3%. Anaerobic static fermentation was performed at 30 °C for 7 days, following the procedure of Eeomet al. (2018). The same procedure was applied for nitrogen sources, where yeast extract was replaced with each test nitrogen substrate at a concentration of 1.5% (w/v). The carbon and nitrogen sources that produced the highest alcohol yields were selected for further analysis. Their concentration ranges were tested from 0.9% to 3.7% for carbon substrates and from 0.7% to 3.9% for nitrogen substrates to determine optimal concentrations. The concentrations that resulted in the highest alcohol production were chosen for subsequent optimization experiments.

#### **ii. Fermentation Condition Profile**

The effect of temperature on alcohol production was evaluated by carrying out anaerobic fermentation with the selected substrates at temperatures between 15 °C and 40 °C for 7 days. Similarly, the influence of pH was assessed by adjusting the fermentation medium within a range of pH 4.0–7.0 under anaerobic conditions at the previously optimized temperature for 7 days. All optimization experiments were also conducted with a commercial strain of *S. cerevisiae*, which served as the control.

### **Optimal Alcohol Production Using Agro-Wastes**

Both the test organism (*C. tropicalis* Strain IDRI000028827 and *S. cerevisiae*) were subjected to a larger scale alcohol fermentation (2.5 litres) by inoculating 0.3% biomass into fermentation medium composed of sugarcane bagasse (3.3%) bambara nut waste (3.1%),  $\text{NH}_4\text{SO}_4$  (0.5%),  $\text{KH}_2\text{PO}_4$  (0.1%), and  $\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$  (0.05%) fermentation under optimized condition at pH of 5.5, and temp of 25°C for 7 days. The produced crude alcohol was distilled as earlier described.

### **Characterization of Distilled Alcohol**

The type, quantity, and antibacterial properties of alcohol produced by *C. tropicalis* strain IDRI000028827 and *S. cerevisiae* were determined and compared.

### **Alcohol Profiling and Quantification**

The quantification of the type of alcohol produced was carried out using the Gas Chromatography–Mass Spectrometry (GC–MS) technique described by Saito (1996).

For each sample, 1.5 ml of alcohol was filtered into vials using 0.45 µm cellulose acetate microfilters. A solution of 5 ml acetonitrile was transferred into a graduated vial and diluted to 10 ml with the filtered sample. The acetonitrile layer was concentrated to 1 ml, and 100 µL was injected into the GC-FID. The analysis was performed using an Agilent 6590 gas chromatograph fitted with a polyethylene glycol TPA-modified column (ZB-FFAP, 30 m × 0.32 mm. × 0.25 µm; Chrompak, Middleburg, Netherlands) and a flame ionization detector. A split/splitless injector was employed, with both injection and detection temperatures maintained at 300 °C. Nitrogen served as the carrier gas at a flow rate of 2 ml/min. Then the initial column temperature was set at 35 °C and held for 3 min. The temperature was then ramped to: 40 °C at 2.5 °C min<sup>-1</sup> and held for 2 min; 80 °C at 20 °C min<sup>-1</sup> and held for 4 min; 140 °C at 20 °C min<sup>-1</sup> and held for 5 min; 220 °C at 20 °C min<sup>-1</sup> with a final hold of 1 min. The total run time was 26 min. Calibration curves were generated from peak area ratios of known standards at different concentrations compared to an internal standard. Working standards were prepared by serial dilutions (0.5–2.0 µg/dl) in 40% acetonitrile. Unknown compounds in the samples were identified by matching their retention times with those of the standards.

#### **Antibacterial Evaluation of the Agro-Waste- Alcohol**

The antibacterial activity of alcohol generated by *C. tropicalis* strain IDRI000028827 was tested against four bacterial pathogens: *Salmonella enterica* 2011k-1440, *S. enterica* serovar CFSAN027396, *Staphylococcus aureus* OPD001-1, and *Bacillus subtilis* FFOS. Each strain was prepared in sterile saline and adjusted to McFarland's standard to obtain a final concentration of  $\sim 1.0 \times 10^8$  CFU/ml. For the assay, 3 ml of bacterial suspension was combined with 3 ml of test alcohol (70% v/v) in sterile tubes and kept at room temperature for 30 minutes without agitation. The mixtures were then transferred into sterile beakers and gently agitated in a water bath at 37 °C to remove residual alcohol. Subsequently, 1 ml of each treated sample was plated using the pour plate method. Selective media were used: *Salmonella-Shigella* agar for *Salmonella*, Mannitol Salt Agar for *S. aureus*, and Nutrient Agar for *B. subtilis*. The same procedure was repeated using agro-waste-alcohol produced by *S. cerevisiae*. Ethanol from refined substrates served as a positive control, while samples without alcohol served as the negative control. Plates were incubated at 37 °C for 24 h, and colonies were counted using a digital colony counter (Equitron model 0671M (GMP/desk-top digital model, India). Antibacterial activity was expressed as percentage inhibition, calculated from survival values relative to the negative control using the formula:

$$\% \text{ survival} = \frac{\text{Colony Forming Unit in Treated Samples}}{\text{Colony Forming Unit in Negative control}} \times 100\%$$

Colony Forming Unit in Negative control

Then % Inhibition = 100% - % survival

Where 100% represented plate without any growth

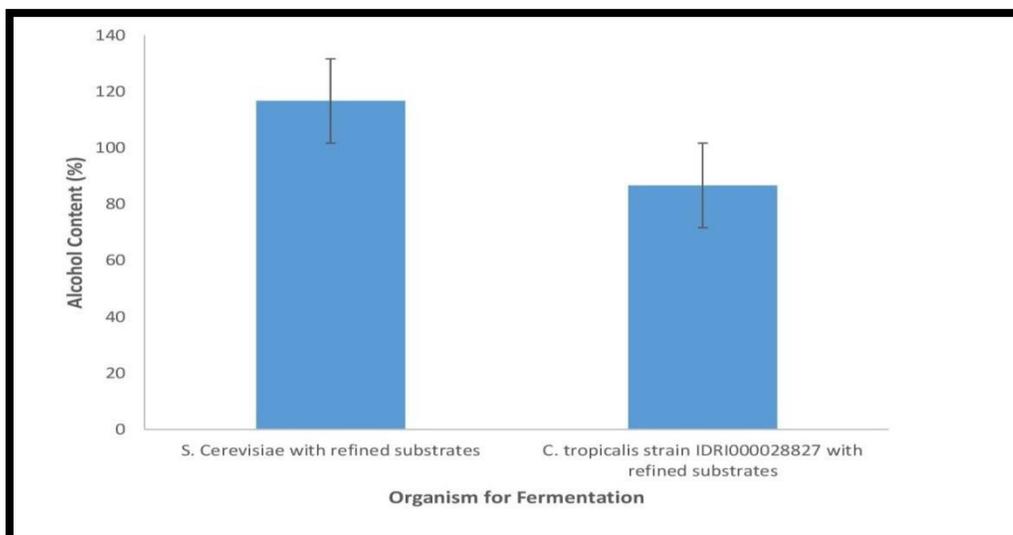
### Statistical Analysis

All experimental data were analyzed using IBM SPSS Statistics software, version 18. Results were expressed as mean  $\pm$  standard deviation. One-way analysis of variance (A One-way analysis of variance (ANOVA) followed by Dunnett's test for multiple comparisons was applied to assess differences across groups. A probability value of  $p < 0.05$  was considered statistically significant for both within- and between-group comparisons.

### Results and Discussion

#### Alcohol Yields from Refined Fermentation Medium

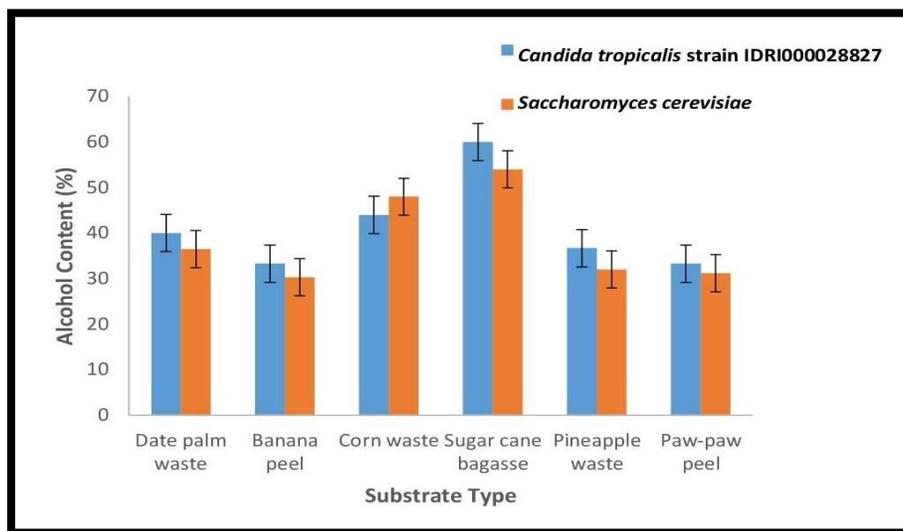
The preliminary alcohol production carried out with refined substrates revealed that *S. cerevisiae* produced 116.7% alcohol, while *C. tropicalis* produced only 86.7% alcohol. This can be explained with the fact that most refined substrates are hexoses sugar (e.g., glucose, sucrose) which *S. cerevisiae* preferentially metabolized than pentoses even under unfavourable condition. *S. cerevisiae* is known to possess highly active enzymes such as alcohol dehydrogenase and pyruvate decarboxylase that convert glucose to ethanol more efficiently than in most non-Saccharomyces yeasts (Walker, 2011) It can also continue fermenting even when alcohol levels become toxic to other microorganisms. In contrast, *C. tropicalis* sugar metabolism slows down, under anaerobic condition and part of it becomes converted into by-products like organic acids and glycerol instead of ethanol (Barnett, 2003). Generally, the difference in alcohol yield also reflects variations in substrate utilization and cellular adaptation.



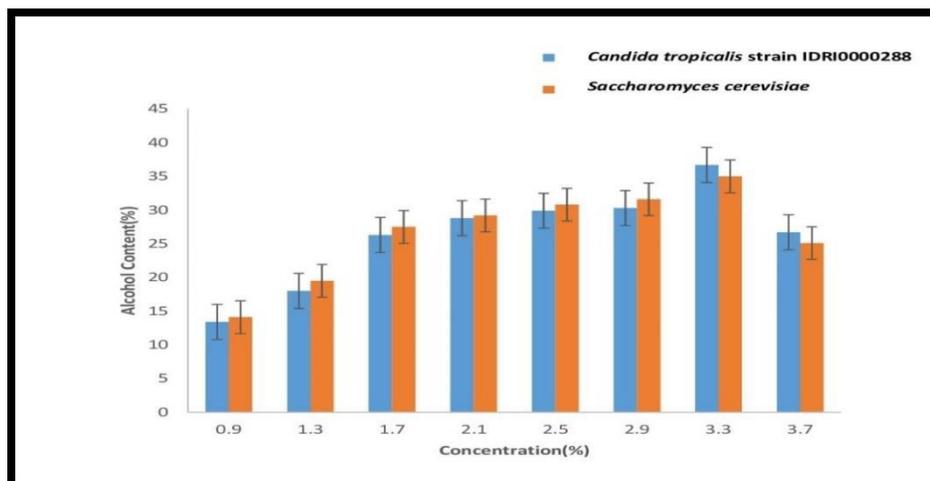
**Fig 1. Alcohol yield of *Candida tropicalis* and *Saccharomyces cerevisiae* on refined substrates**

### Carbon Substrate Profile

Sugarcane bagasse supported the highest alcohol yield (66.7% w/v) at an optimum concentration of 3.3% (Fig. 2a–b). This agrees with previous reports highlighting sugarcane bagasse as an efficient substrate for proteolytic enzyme and bioethanol production (George-Okafor and Mike-Anosike, 2012; Jeyaram et al., 2024). Its effectiveness is likely due to its fermentable carbohydrate content, which drives glycolysis and alcohol formation. Although You et al. (2017) reported optimal yields at 5% pretreated bagasse, the lower concentration observed in this study may reflect the absence of pretreatment, which otherwise enhances substrate accessibility and minimizes fermentation inhibition (Sun et al., 2016).



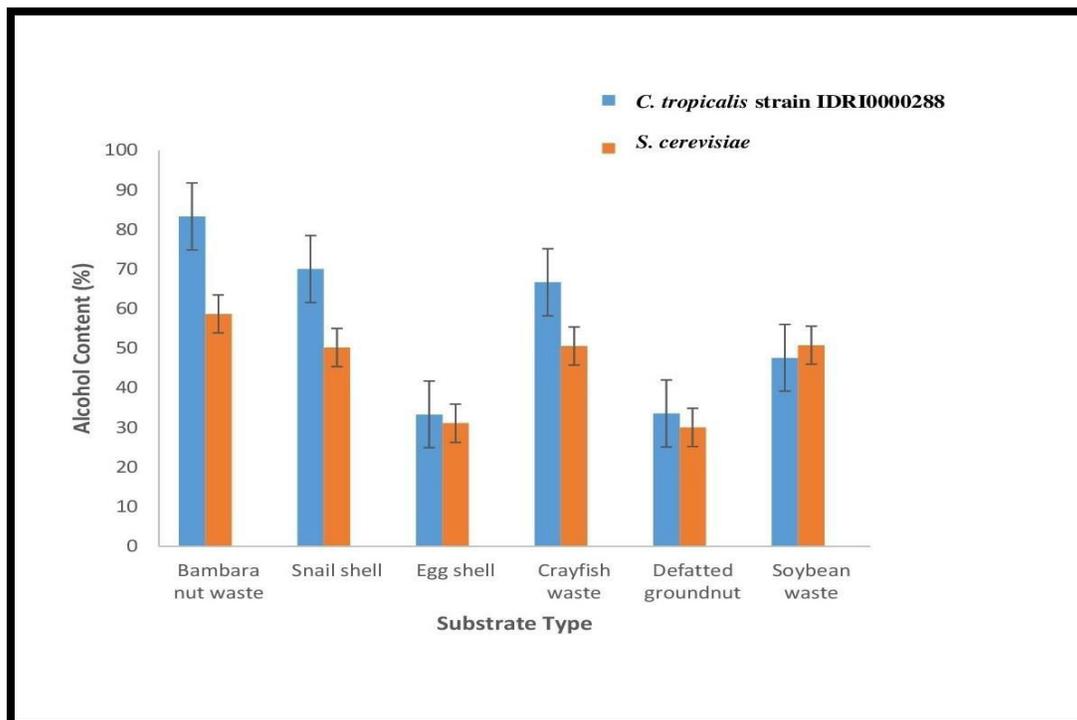
**Figure 2a: Effect of agro-wastes carbon on alcohol production by *C. tropicalis* strain IDRI000028827 and commercial *Saccharomyces cerevisiae***



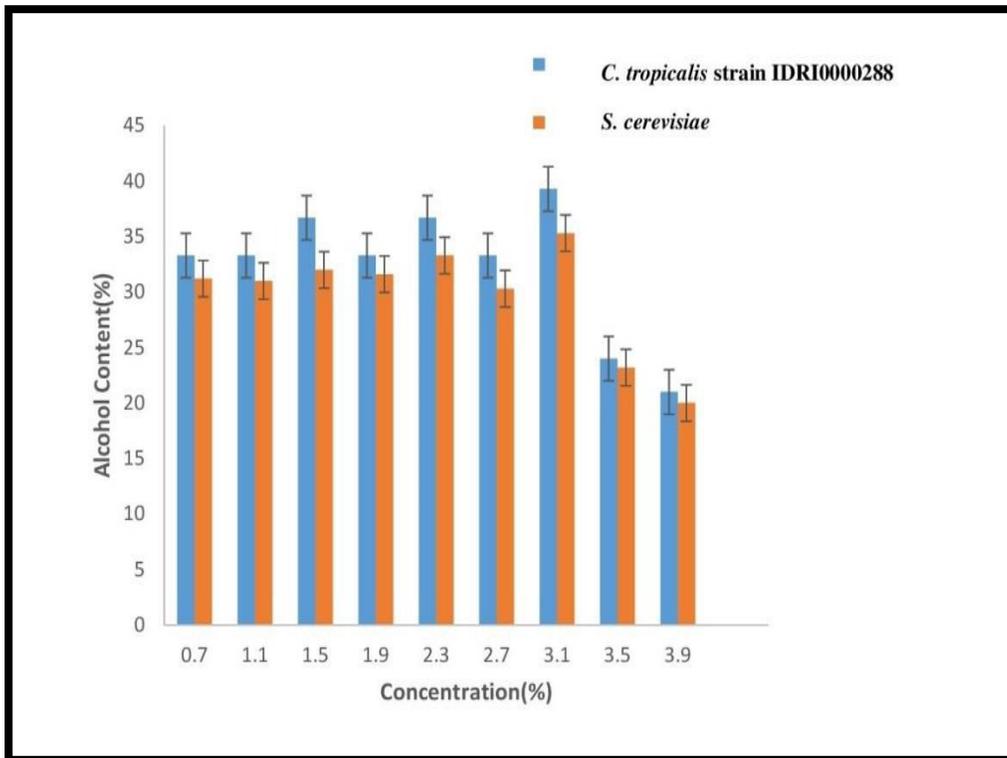
**Figure 2b: Effect of concentration of sugarcane bagasse on alcohol yield by *C. tropicalis* strain IDRI0000288 and *S. cerevisiae***

### Nitrogen Source

For *C. tropicalis*, the highest alcohol production was observed with bambara nut waste (83.3%), followed by snail shell (70%) and crayfish waste (66.7%) (Fig. 3a). This observation is consistent with earlier reports highlighting the value of bambara nut residues in industrial fermentations (Lungaho et al., 2025). The improved yield compared with the initial level (66.3%, Fig. 2a) can be attributed to the typical carbon-to-nitrogen balance, where limited nitrogen availability promotes alcohol formation, whereas excess nitrogen generally enhances cell growth. At higher substrate concentrations (3.5–3.9%, Fig. 3b), yields dropped sharply, most likely as a result of substrate inhibition, osmotic stress, or the accumulation of toxic metabolites; this reduction was more severe in *S. cerevisiae*. Conversely, at lower substrate levels (0.7–1.9%), both yeasts produced only moderate alcohol levels, indicating possible restriction by fermentable sugar or nutrient availability. Overall, the results suggest that while both organisms are capable of fermenting bambara nut waste, *C. tropicalis* demonstrated a slight advantage in both alcohol yield and tolerance at elevated substrate levels. However, the heterogeneous nature of bambara nut waste could have limited sugar accessibility and introduced inhibitory factors that compromised yeast performance (Sun et al., 2016).



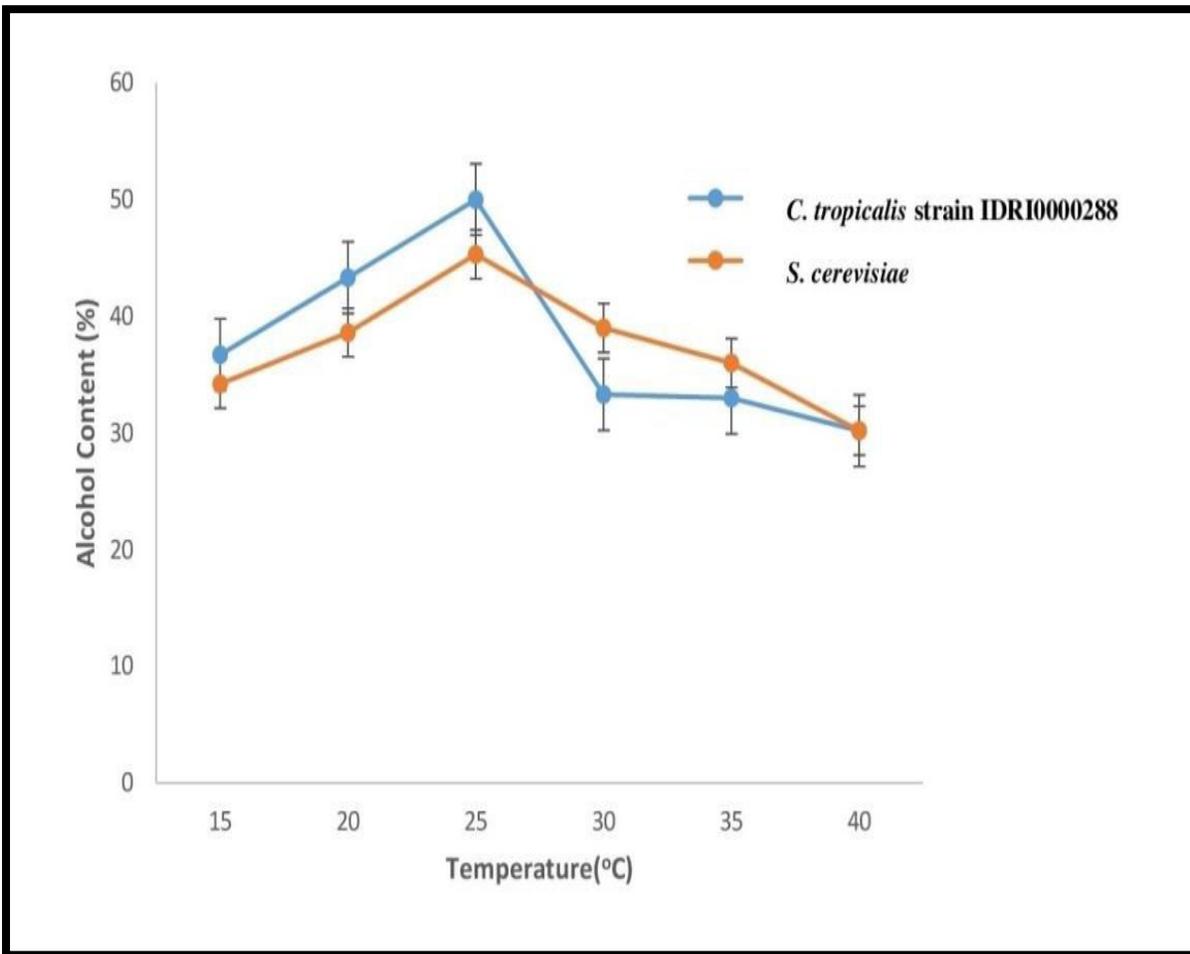
**Figure 3a: Effect of agro waste nitrogen content on alcohol production by *Candida tropicalis* strain IDRI000028827 and *S. cerevisiae***



**Figure 3b: Concentration profile of bambara nut waste on alcohol yield by *Candida tropicalis* strain IDRI000028827 and *S. cerevisiae***

### Temperature Profile

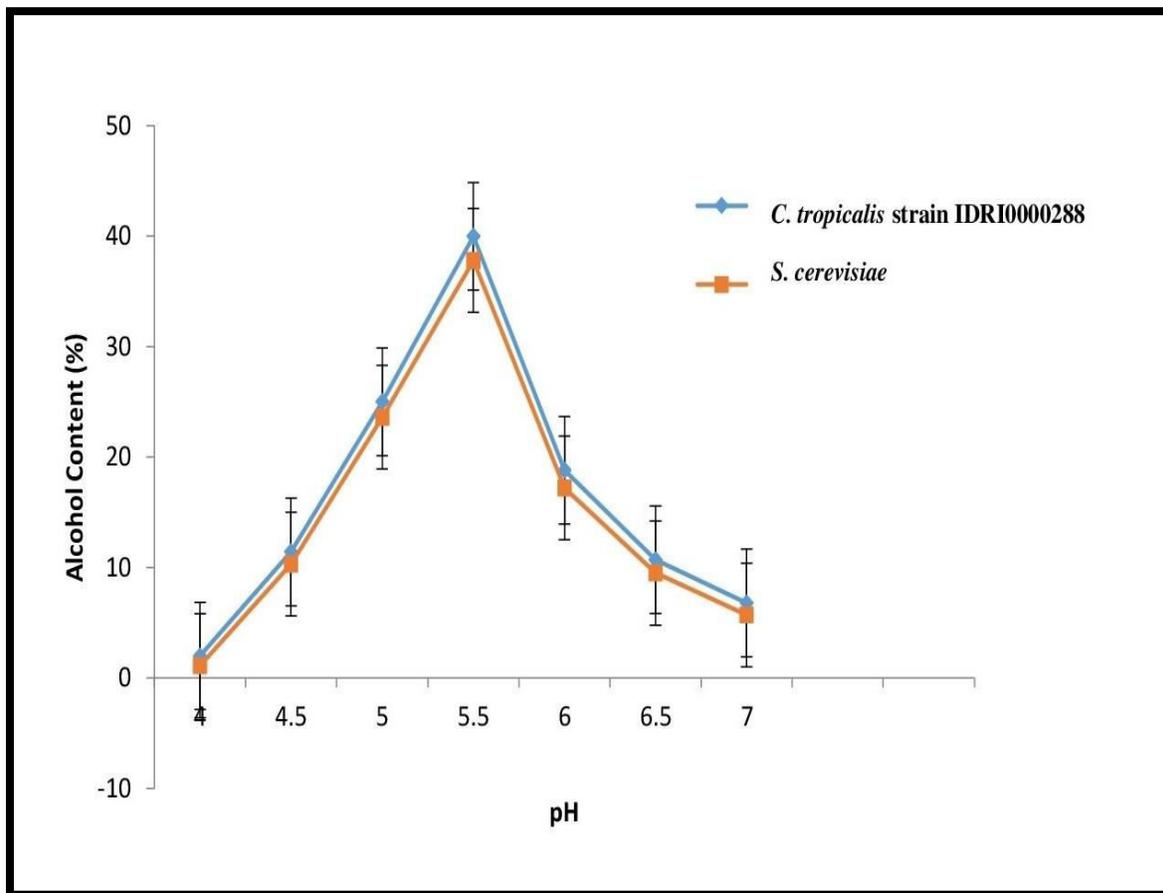
*C. tropicalis* strain IDRI000028827 produced maximum alcohol at 25 °C (Fig. 4). This optimum temperature is consistent with earlier findings reporting peak alcohol production by *C. tropicalis*(YMEC14) at 25 °C (Jamai et al., 2001), but differs from the 30 °C optimum reported by Zulfikar et al. (2019) for *C. tropicalis*(JCB1-24). In general, yeasts, including the conventional *S. cerevisiae*, achieved maximum alcohol production within the mesophilic range (20–40 °C), where enzyme activity, membrane stability, cell growth, and ethanol tolerance are often enhanced (Liszkowska and Berlowska , 2021).



**Fig. 4: Effect of temperature on alcohol production by *C. tropicalis* strain IDRI000028827 and *S. cerevisiae***

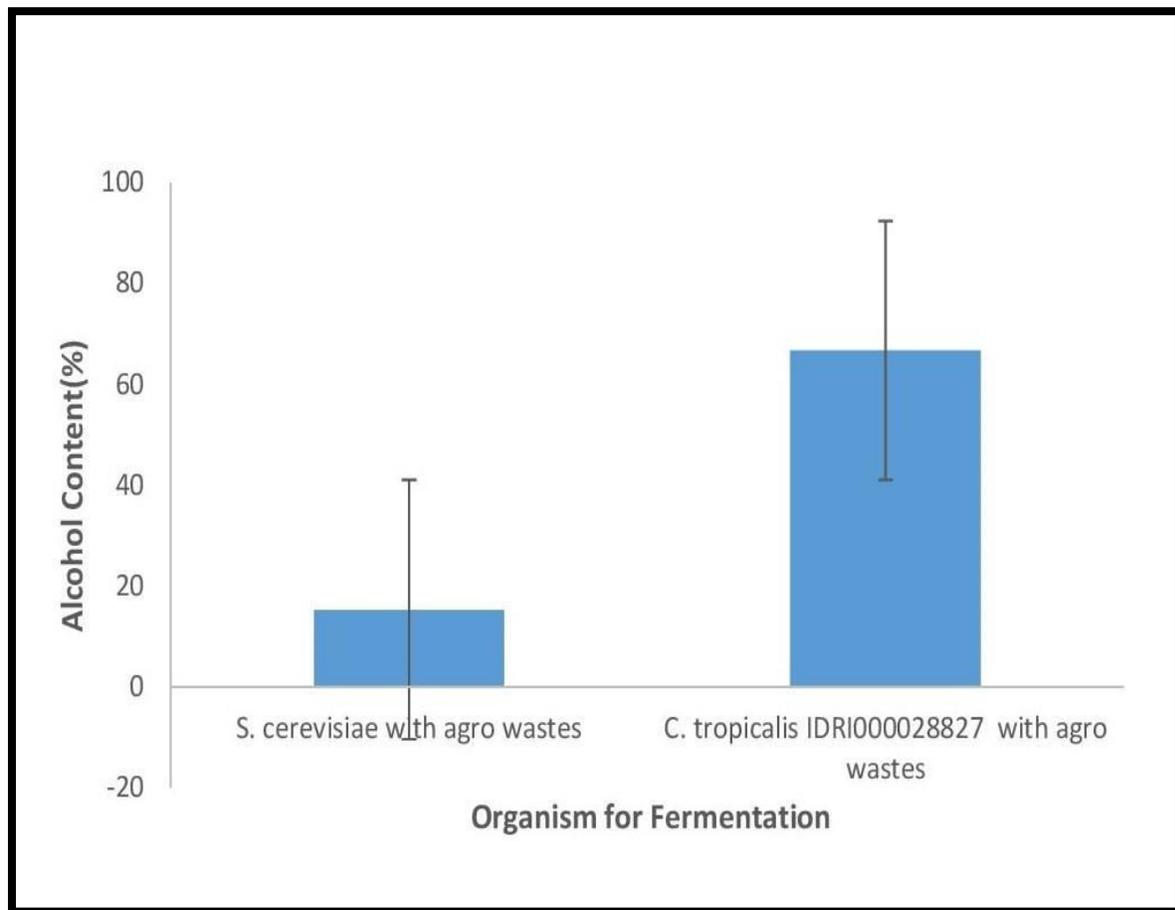
#### **pH Profile**

Maximum alcohol production was achieved at pH 5.5 by *C. tropicalis* strain IDRI000028827 (40%) and *S. cerevisiae* (37.8%) while yields declined with increasing pH, reaching 10% at pH 7 (Fig. 5). This finding is consistent with previous reports indicating that most yeasts produce alcohol optimally within pH 4.5–5.5 (Sopandi and Wardah, 2017). Similarly, agro-waste fermentations have been shown to support higher yields in this range (Hashem et al., 2021). The observed optimum of pH 5.5 for *C. tropicalis* strain IDRI000028827 and *S. cerevisiae* therefore aligns with established patterns, as yeast enzymes are more metabolically active under these conditions, while the slightly acidic environment also minimizes microbial contamination.



**Fig. 5: Effect of pH on alcohol production by *Candida tropicalis* strain IDRI000028827 and *S. cerevisiae***

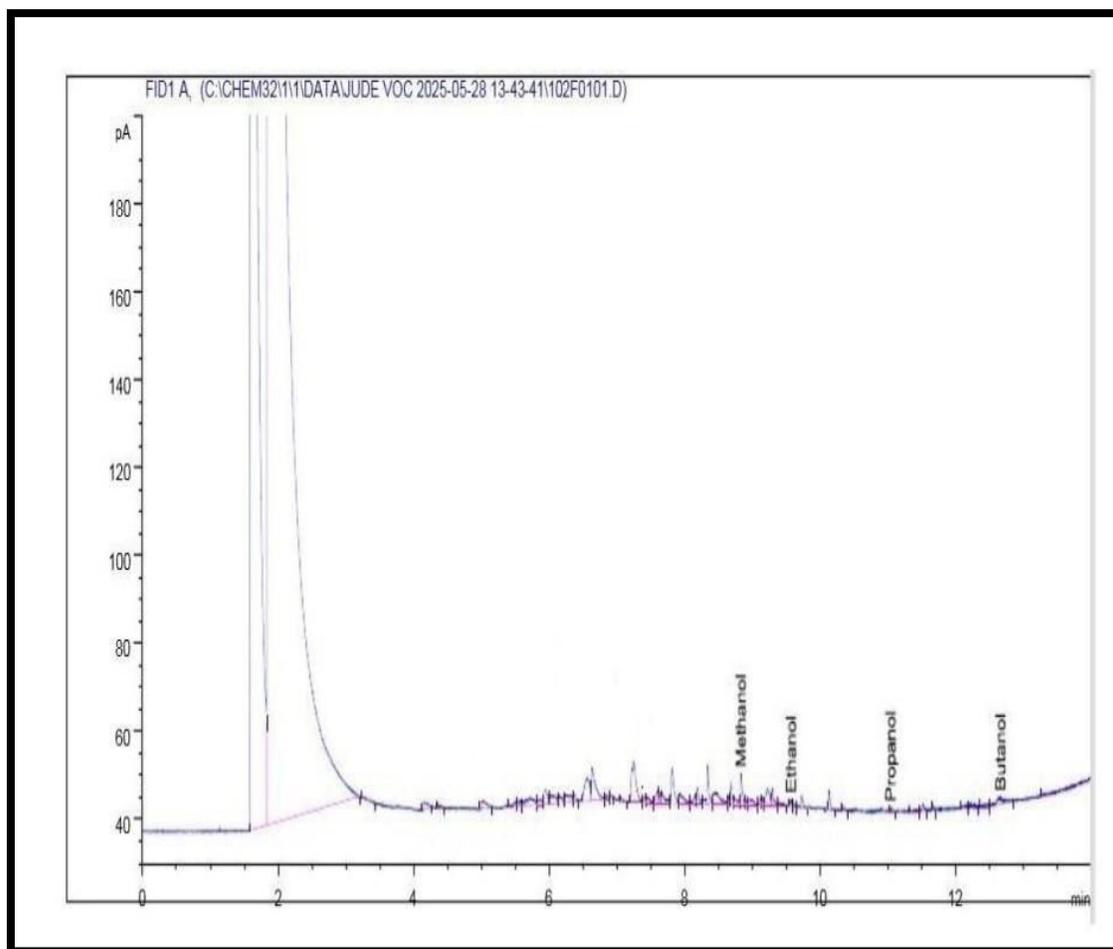
**Alcohol Yields with Agro-Wastes Under Optimized Conditions**  
 Scale-up production (2.5litres) under optimized condition (3.3% sugarcane bagasse, Bambara nut wastes, at 25 °C, pH 5.5, for 7 days), *Ctropicalis* strain IDRI000028827 produced 66.7% alcohol, compared with 15.3% by the commercial *S. cerevisiae* (Fig. 6). This disparity highlights the limited efficiency of commercial *S. cerevisiae* in fermenting complex agro-waste substrates. Previous studies have linked such limitations to its restricted ability to metabolize pentose sugars, lower tolerance to inhibitory compounds, reduced stress resilience, and narrower substrate utilization range (Maltam et al., 2016; Jamaluddin et al., 2023). Furthermore, its relatively poor performance may also reflect slower adaptation to indigenous waste materials, in contrast to *C. tropicalis* strain IDRI000028827, which was locally isolated from orange juice and could therefore possessed higher adaptability to native substrates (Onyia et al., 2025).



**Fig. 6: Alcohol produced with agrowastes by *C.tropicalis* strain IDRI000028827 and *S. cerevisiae* under optimized condition**

#### **Alcohol Identification and Quantification**

Gas Chromatography–Mass Spectrometry (GC–MS) analysis confirmed the presence of methanol, ethanol, propanol and butanol in the fermented broth of both the test and standard yeast strains (Figs. 7a–b). *Candida tropicalis* strain IDRI000028827 produced a significantly higher amount of ethanol (4.40 ppm,  $P < 0.05$ ) compared with *S. cerevisiae* (1.72 ppm) for fermentation with agrowastes. Ethanol production by *C. tropicalis* has previously been documented for strains ATCC 750 and 4kr27 (Liu et al., 2019; Zulfikar et al., 2019). The detection of propanol in this study is also consistent with findings by Singh et al. (2023), who reported its production alongside ethanol when *C. tropicalis* (K21D) was cultivated on different carbon sources. The comparatively higher production of multiple alcohol types by strain IDRI000028827, relative to commercial *S. cerevisiae* under the same conditions, indicates its potential for utilization. This capacity suggests promising applications in waste-to-biofuel conversion and highlights the need for additional optimization and waste treatment studies to maximize yield.

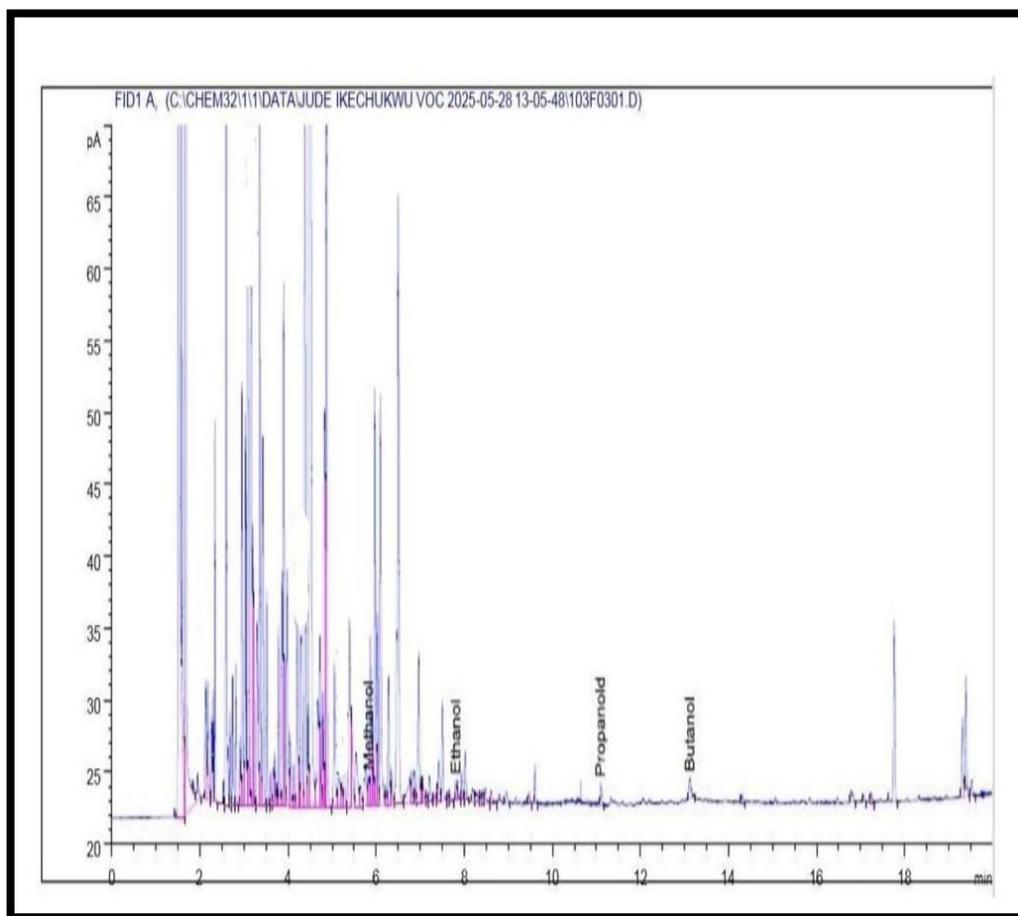


**Fig. 7a: Chromatogram of agrowaste-alcohol produced by *C. tropicalis* strain IDRI000028827.**

**Key:**

**Name:** *Candida tropicalis* strain IDRI000028827

RetTime [min]	Type	Area [pA*s]	Amt/Area	Amount [ppm]	Grp	Name
9.433	BB	20.13767	7.76010e-1	5.62704	1	Methanol
13.178	VV	5.70060	7.72667e-1	4.40466	1	Ethanol
14.434	VV	68.42715	7.76764e-1	3.15172	1	Propanol
14.584	VB	13.65857	7.75237e-1	0.58862	1	Butanol



**Fig.7b: Chromatogram of agrowaste-alcohol types produced by *S. cerevisiae***

**Key:**

**Sample Name:** *Saccharomyces cerevisiae*

RetTime [min]	Type	Area [pA*s]	Amt/Area	Amount [ppm]	Grp	Name
5.835	VV	4.31365	7.71514e-1	3.32804	1	Methanol
7.821	BV	2.25051	7.65632e-1	1.72306	1	Ethanol
11.112	BB	2.81797	7.67891e-1	2.16389	1	Propanol
13.132	BB	4.91858	7.71807e-1	3.79619	1	Butanol

### Antibacterial Efficacy of Produced Alcohol

The antimicrobial performance of alcohol produced by *C. tropicalis* and *S. cerevisiae* on agro-waste substrates was evaluated against a refined-substrate alcohol (control). As expected, ethanol obtained from *S. cerevisiae* cultivated on refined substrates demonstrated the highest activity, completely inhibiting both strains of *Salmonella enterica* and *Staphylococcus aureus*, and nearly eliminating *Bacillus subtilis*. This aligns with earlier reports attributing the strong antimicrobial effect of pure ethanol to its ability to denature proteins and disrupt microbial membranes (Mathew, 2024; Kampf, 2018). A marked reduction in inhibition was observed with *S. cerevisiae* agro-waste alcohol, with activity ranging between 35% and 58%. This decline suggests reduced ethanol yield and purity, possibly due to limited fermentable sugars in the waste material or the presence of inhibitory fermentation by-products (Demiray et al., 2018). The relatively stronger activity against *S. aureus* compared to *Salmonella* reflects the higher susceptibility of Gram-positive organisms to alcohol, consistent with differences in cell wall architecture (Russell, 2003). Generally, agro-waste alcohol derived from *C. tropicalis* retained substantially higher activity, with inhibition values of 80–92% across all pathogens. Its performance against *B. subtilis* (92%) and *S. aureus* (90%) approached that of the control, while inhibition of *Salmonella* strains (80–90%) also remained high. Comparatively, agro-waste-alcohol from *C. tropicalis* IDR1000028827 significantly inhibited all the assayed test organisms more than *S. cerevisiae* with agro-waste at  $p < 0.01$ . This positions *C. tropicalis* alcohol as a strong bio-disinfectant and preservative, alternative to synthetic ethanol for application.

**Table 4.3: Percentage Inhibition of the Produced Alcohol against Test Pathogens**

#### % Alcohol Inhibition From

Test Organism	<i>S. cerevisiae</i> with Refined Substrates (Control)	<i>S. cerevisiae</i> with Agro-waste (Test)	<i>C. tropicalis</i> IDR1000028827 with Agro-waste (Test)
<i>Salmonella enterica</i> 2011k-1440	*100	35	90
<i>Salmonella enteric</i> subsp. <i>enterica</i> serovar CFSANO27396	100	49	80
<i>Staphylococcus aureus</i> OPD001-1	100	58	90
<i>Bacillus subtilis</i> FFOS	98	55	92

\*100% was assigned to plates without organisms after treatment and used to calculate the inhibition rate of the test alcohol.

## Conclusion

The findings of this study highlight the efficiency of *C. tropicalis* strain IDRI000028827 in converting agro-wastes such as sugarcane bagasse and bambara nut residues into alcohol. Compared with commercial *S. cerevisiae*, the strain produced higher alcohol yields, generated a wider range of alcohols, and showed stronger antibacterial effects. These results suggest its promise as a sustainable and cost-effective option for industrial alcohol production, reducing dependence on refined substrates and imported yeast.

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