



# Unveiling the Bioactive Compounds and Antimicrobial Potential of Date and Grape Fruit Vinegars

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| Abstract                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Article History                                                                                                                              |
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| <p>The global rise in antimicrobial resistance has intensified the search for effective natural alternatives. Fruit vinegars, traditionally valued for their health benefits, are promising candidates; however, the specific phytochemical and antimicrobial profiles of vinegars derived from <i>Phoenix dactylifera</i> (date) and grape (<i>Vitis vinifera</i>) require detailed characterization. This study explored the phytochemical composition and antimicrobial efficacy of vinegars produced from these fruits. Yeast and acetic acid bacteria were isolated from spoiled date and grape samples and characterized using standard microbiological techniques. Vinegar was produced via submerged fermentation of fruit must. The physicochemical properties, nutrient content, and phytochemical constituents were analyzed using gravimetric and instrumental methods. <i>In vitro</i> antimicrobial activity was evaluated against selected pathogens. Data were analyzed using Analysis of Variance (ANOVA) at a 95% confidence level, with post-hoc analysis performed using Tukey's test. Alkaloids, saponins, flavonoids, tannins, and glycosides were detected in both vinegar samples, fermented using <i>Saccharomyces cerevisiae</i> strain SR 128 (SC 128) and <i>Acetobacter aceti</i> strain WI (AAWI). The vinegars demonstrated significant (<math>p &lt; 0.05</math>) antimicrobial activity against <i>Staphylococcus aureus</i>, <i>Escherichia coli</i>, <i>Salmonella enterica</i> serovar Typhi, and <i>Candida albicans</i>, with the most potent inhibition observed against <i>E. coli</i>. The results indicate that date and grape fruit vinegars possess substantial phytochemical and antimicrobial properties, with the date vinegar exhibiting marginally superior efficacy. This study supports the potential of these vinegars as functional foods with natural antimicrobial value.</p> <p>Keywords: Vinegar, Phytochemical, Antimicrobial, <i>Saccharomyces</i>, <i>Acetobacter</i>, <i>Staphylococcus</i>, <i>Escherichia</i>, <i>Candida</i></p> | <p>Received: 22 Dec 2025<br/>Accepted: 11 Jan 2026<br/>Published: 19 Jan 2026</p>                                                            |
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## Introduction

Fruit vinegars, produced through the sequential microbial fermentation of sugars to ethanol and subsequently to acetic acid, constitute a significant class of functional fermented foods with historical applications in gastronomy and ethnomedicine. Beyond their culinary utility, these acidic substrates serve as concentrated reservoirs of bioactive phytochemicals, positioning them at the nexus of nutritional science, food preservation, and therapeutic discovery. Contemporary public health is challenged by the escalating crisis of antimicrobial resistance (AMR), necessitating the exploration of novel, plant-derived antimicrobial agents as a

critical research imperative (World Health Organization, 2021; Iheukwumere *et al.*, 2025a). This pursuit aligns with a growing consumer and industrial demand for natural preservatives and health-promoting functional foods, warranting the scientific validation of traditional fermentation products (Santiago-López *et al.*, 2022; Iheukwumere *et al.*, 2025b; Dim *et al.*, 2025a). The present investigation therefore aims to conduct a comparative analysis of the phytochemical composition and concomitant antimicrobial efficacy of vinegars derived from two distinct, economically vital fruits: *Phoenix dactylifera* L. (date palm) and *Vitis vinifera* L. (common grape vine).

The date fruit (*Phoenix dactylifera* L.) is a nutrient-dense commodity, characterised by a high concentration of phenolic acids (including ferulic, caffeic, and protocatechuic acids), flavonoids, and carotenoids, which collectively underpin its robust antioxidant capacity (Al-Farsi and Lee, 2021; Dim *et al.*, 2025b; Ekechukwu *et al.*, 2025a). The biotransformation of dates into vinegar via acetic acid fermentation is posited to not only preserve these inherent phytochemicals but also to generate novel bioactive metabolites through microbial action, potentially augmenting its functional properties (Masmoudi *et al.*, 2020; Ejike *et al.*, 2017; Amadi *et al.*, 2017). In contrast, grape vinegar, particularly from polyphenol-rich *Vitis vinifera* cultivars, is a well-documented source of resveratrol, anthocyanins, and flavan-3-ols. The fermentation process can significantly modulate this polyphenolic profile, enhancing the bioavailability of certain compounds and yielding microbial metabolites such as gallic and syringic acids, which may exhibit potentiated bioactivity (Ho *et al.*, 2017; Iheukwumere *et al.*, 2022a).

The antimicrobial mechanism of fruit vinegars is multifaceted, arising from a combination of physicochemical and biochemical factors. The primary inhibitory effect is attributed to acetic acid, which exerts its action by disrupting microbial membrane potential, denaturing proteins, and acidifying the intracellular environment (Daglia, 2021). Importantly, a growing body of evidence highlights the contributory and often synergistic role of the native phenolic compounds. These phytochemicals can impede microbial growth through mechanisms including membrane perturbation, essential ion chelation, and interference with enzymatic activity and nucleic acid synthesis (Mith *et al.*, 2022). This polypharmacological profile suggests that fruit vinegars may serve as broad-spectrum antimicrobial agents against a range of foodborne pathogens and spoilage microorganisms, presenting a viable natural alternative to conventional synthetic preservatives.

## Materials and Methods

### Isolation and Characterization of *Saccharomyces* species from Spoilt Fruit Samples

#### Sample collection

Spoilt *Phoenix dactylifera* (Date palm) and *Vitis vinifera* (Grape vine) fruits were collected from different points in Nkwo Oba market, Idemili South LGA, Anambra State. The fruits were detected through sight and nasal perception; this was followed by carefully and selectively picking of the detected fruits into polythene bags. The polythene bags were appropriately labeled and transported immediately to the laboratory for further analysis.

#### Sample preparation

The fruit samples were thoroughly washed using distilled water and their ectocarps were appropriately peeled using stainless chicken knife. The peeled fruits were pulverized using electric blender (SMX425/Japan). This was serially diluted (1:10) using 250 mL conical flask (Pyrex) in the capacity of 10 g of the fruit sample to make up 200 mL of the sample solution. The solution was thorough shaken, stoppered and kept for further analysis as described by Egbe *et al.* (2025a), Egbe *et al.* (2025b), Iheukwumere *et al.* (2025c), and Iheukwumere *et al.* (2025d).

### Isolation of yeast

The Sabouraud Dextrose Agar (SDA) and Yeast Extract Agar (YEA) were prepared according to the manufacturer's direction. The prepared media were autoclaved at standard conditions (121°C 15PSI at 15 min). The media were aseptically poured in Petri dishes and allowed to solidify. An aliquot of 0.1 mL of the prepared sample was aseptically spread on the surfaces of the agar poured plates and incubated at an inverted position at 35±2°C for 24 hours as described in a study published by (Egbe *et al.*, 2025c; Iheukwumere *et al.*, 2022b; Iheukwumere *et al.*, 2025e; Ekesiobi *et al.*, 2025).

### Characterization of the yeast

The yeast isolate was characterized morphologically, biochemically, and molecularly using the method described in Cheesbrough (2010), Iheukwumere *et al.* (2020a), Iheukwumere *et al.* (2020b); Ekechukwu *et al.* (2025b). The yeast isolate was physically examined; the colour, the shape, texture, elevation and the consistency were examined and recorded.

### Isolation of Acetic Acid Bacterium from Spoilt Fruit Samples

This was carried out using Glucose-Yeast Extract Calcium Carbonate (GYC) agar prepared from glucose (10%), CaCO<sub>3</sub> (2%) and agar (1.5%). The re-constituted medium was autoclaved at standard conditions (121°C, 15 PSI at 115 min). The medium was aseptically distributed into different Petri dishes and allowed to solidify. An aliquot of 0.1 mL of the prepared sample from the spoilt fruits was aseptically spread on the surfaces of the prepared agar medium and these were incubated on inverted position at room temperature (30±2°C) for 48 h. Colonies with large clear zones around them were subcultured (Chude *et al.*, 2020; Ekechukwu *et al.*, 2025c; Ezedianafo *et al.*, 2025a; Idigo *et al.*, 2025a; Iheukwumere *et al.*, 2025f).

### Characterization of the Bacterial Isolate

The pure isolates will be characterized using the morphological, biochemical and molecular characteristics as described by Iheukwumere *et al.* (2017a); Iheukwumere *et al.* (2018a); Iheukwumere *et al.* (2020c). The cultural descriptions (size, appearance, edge, elevation, colour) of the isolates will be carried out as described in Iheukwumere *et al.* (2017b); Iheukwumere *et al.* (2018b), Iheukwumere *et al.* (2024). The Gram staining technique which revealed the Gram reaction, cell morphology and cell arrangement will also be carried out using the procedure described by Cheesbrough (2010), Iheukwumere *et al.* (2018c), Iheukwumere and Iheukwumere (2022a) and Iheukwumere *et al.* (2023a). The presence or absence of capsule will also be carried out as described by Iheukwumere *et al.* (2017c), Iheukwumere *et al.* (2017d), and Iheukwumere *et al.* (2022c). The presence or absence of flagellum will be determined by carrying out motility test as described by Cheesbrough (2010), Iheukwumere *et al.* (2023b), Ezedianafo *et al.* (2025b), Ike *et al.* (2025a). The capability of the isolates to produce catalase, indole, oxidase, acetoin, grow in 6.55 % NaCl and to utilize sugars, sugar alcohols and other substances (ribose, sorbitol, arabinose, sacharose, glucose trehalose, lactose, starch, inulin, salicin, hiparate) and also the haemolytic activity of the isolates were done using the methods described by Cheesbrough (2010),

Iheukwumere *et al.* (2018), Iheukwumere and Iheukwumere (2022c), Iheukwumere *et al.* (2022d). The molecular characterization involved DNA extraction, authentication, amplification and sequencing of the amplicons (Iheukwumere *et al.*, 2017e; Okeke *et al.*, 2017; Iheukwumere *et al.*, 2022e; Iheukwumere and Iheukwumere, 2022d).

### Vinegar Production

#### Collection and preparation of fruit samples for production of vinegar

*Phoenix dactylifera* (Date palm) and *Vitis vinifera* (Grape vine) fruits were bought from Eke Awka Market, Anambra State. The fruit samples were thoroughly washed using distilled water and their ectocarps were thoroughly peeled. These were separately pulverized using electric blender (SMX 425/Japan). The pulverized fruits were extracted using distilled water. The solutions were then filtered using muslin cloth.

#### Production of alcohol

Here, 400 mL of the fruit extract was dispensed each into 500 mL conical flask (Pyrex). The extracts were sterilized using an Autoclave at standard conditions (121°C, 15 PSI at 115 min). The sterilized extracts were allowed to cool. The extracts were each inoculated *Saccharomyces cerevisiae* strain and allowed for 28 days with manually daily shaking at 30±2°C. After the fermentation, the alcohol was decanted and poured into sterile 2000 mL bottle and allowed open for 2 days (Iheukwumere *et al.*, 2022f; Iheukwumere and Iheukwumere, 2022e; Ezedianafo *et al.*, 2025c).

#### Alcohol tolerance test

The ability of the acetic acid bacterium to grow in the presence of alcohol was carried out using the method described in the study published by Tharinee *et al.* (2015). The tested isolate was grown in yeast extract agar (0.50% yeast extract, 2% agar) supplemented with 2%, 4%, 6%, 8%, and 10% (v/v) absolute ethanol. The above procedure was then modified by growing the isolate in Glucose-Yeast Extract Calcium Carbonate (GYC) broth/agar supplemented with 2%, 4%, 6%, 8%, and 10% (v/v) absolute ethanol as described by (Ike *et al.*, 2025b; Obiefuna *et al.*, 2025b; Ugwu *et al.*, 2025a).

#### Vinegar production

The colonies of *Acetobacter aceti* strain was aseptically transferred into the container containing the alcohol. The bottles were thereafter covered with sac cloth to prevent the entry of insect. The set-up was allowed for 28 days at room temperature (30±2°C.). At the end of the fermentation period, a thick film known as mother of vinegar had covered the surface of the vinegar and was carefully scooped out to avoid contamination. The vinegar was thereafter filtered as described in a study published by Idigo *et al.* (2025b), Iheukwumere *et al.* (2025g), Ike *et al.* (2025c) and Ugwu *et al.* (2025b).

#### Phytochemical Analysis of the Vinegar Samples

The phytochemical components (alkaloids, glycosides, flavonoids, phenolics, tannins, steroids and saponins) of the samples were determined quantitatively using the methods described in the study published by Iheukwumere *et al.* (2025h), Idigo *et al.* (2025c), Idigo *et al.* (2025d), Ike *et al.* (2025d).

**Alkaloids:** Five milliliters of the sample was mixed with 96% ethanol and 20% tetraoxosulphate (VI) acid (1:1). One milliliter of the filtrate from the mixture was added to 5 ml of 60% tetraoxosulphate (VI) acid and allowed to stand for 5 minutes. Then 5 ml of 0.5% formaldehyde was added and allowed to stand for 3 h. The reading was taken at absorbance of 550nm (Ezedianafo *et al.*, 2025d; Idigo *et al.*, 2025d; Idigo *et al.*, 2025e).

**Glycosides:** This was carried out using Buljet's reagent. One millimeter of the sample was added in 9 ml of 70% alcohol for 2 h and then filtered with Whatman No. 1 filter paper. The extract was then purified using lead acetate solution and disodium hydrogen tetraoxosulphate (VI) solution before the addition of freshly prepared Buljet's reagent. The absorbance was taken at of 550nm (Obiefuna *et al.*, 2025b; Ike *et al.*, 2025d; Idigo *et al.*, 2025f).

**Flavonoids:** Five milliliters of the sample was mixed with 5 ml of dilute hydrochloric acid and boiled for 30 minutes. The boiled mixture was allowed to cool and then filtered with Whatman No. 1 filter paper. One milliliter of the filtrate was added to 5 ml of ethyl acetate and 5 ml of 1% ammonia solution. The absorbance was taken at 420nm (Idigo *et al.*, 2025g; Idigo *et al.*, 2025h).

**Phenolics:** Ten milliliters of the sample was boiled with 50 ml acetone for 15 minutes. Five milliliters of the solution was pipetted into 50 ml flask. The 10 ml of distilled water was added. This was followed by addition of 2 M ammonium hydroxide solution and 5 ml of concentrated amyl alcohol solution. The mixture was left for 30 minutes and absorbance was taken at 550nm (Idigo *et al.*, 2025i; Idigo *et al.*, 2025j).

**Tannins:** Ten milliliters was pipetted into 50 ml plastic containing 50 ml of distilled water. This was mixed for 1 h on a sterile mechanical shaker. The solution was filtered with Whatman No. 1 filter paper, and 5 ml of the filtrate was mixed with 2 ml of iron (III) chloride solution in 0.1 N hydrochloric acid. The absorbance was taken at 550nm (Idigo *et al.*, 2025k; Idigo *et al.*, 2025l).

**Steroids:** The sample was mixed with normal ammonium hydroxide solution. Two milliliters of eluate was mixed with 2 ml of chloroform in a test tube. Three milliliters of ice cold acetic anhydride was added to the mixture and allowed to cool. The absorbance was taken at 420nm (Idigo *et al.*, 2025m; Idigo *et al.*, 2025n; Idigo *et al.*, 2025o).

**Saponins:** Five milliliters of the sample was dissolved in aqueous methanol. The 0.25 ml of aliquot was taken for spectrophotometric determination for total saponins at 544nm (Idigo *et al.*, 2025p; Idigo *et al.*, 2025q).

#### Antimicrobial Activity of the Vinegar Samples

Collection and preparation of test organisms: The test organisms used for this study were *Staphylococcus aureus*, *Escherichia coli*, *Salmonella enterica* serovar Typhi and *Candida albican*. The test organisms were collected from ZAHARM Analytical and Research Laboratory, Awka, Anambra State. Catalase test, indole test, citrate/hydrogen sulphide production test and germ tube test were respectively carried out to confirm the identities of the test organisms. The

pure isolates were scrapped in normal saline solution, subsequently diluted to match the turbidity of 0.5 MacFarland matching standard that was prepared by mixing 0.5 mL of 1.175 % BaCl<sub>2</sub>.H<sub>2</sub>O and 9.95 mL of 1 % of concentrated H<sub>2</sub>SO<sub>4</sub> to form  $1.50 \times 10^8$  cells/mL

**Agar-welled diffusion technique:** This was carried out using the method described by Iheukwumere *et al.* (2017b), Idigo *et al.* (2025r). Each labeled plate was uniformly inoculated with the test organism using pour plate method. A sterile cork borer of 5 mm diameter was used to make the wells on the medium. One tenth milliliter of test sample was dropped into each labeled wells and then incubated at  $37 \pm 2^\circ\text{C}$  for 24 h. Antimicrobial activity was determined by measuring the diameter of the zones of inhibition (mm) produced after incubation.

### Statistical Analysis

The data generated from this study were analyzed at 95% confidence level using Analysis of Variance (ANOVA), and post-hoc analysis using Turkey's test (Iheukwumere *et al.*, 2025h; Iheukwumere *et al.*, 2025i; Idigo *et al.*, 2025s, Idigo *et al.*, 2025t, Manasseh *et al.*, 2025).

## Results

### Characterization of the Yeast Isolate and Acetic Acid Bacteria Strains

The yeast isolate (XI) showed characteristic features of yeast such as cream white colonies on Sabouraud Dextrose Agar (SDA) plate, smooth surface, spherical morphology and utilization of glucose and sucrose. The yeast was also resistant to cycloheximides as shown in Table. The acetic acid bacterium (AI) showed cream to yellow colonies on glucose yeast extract calcium carbonate agar (GYA). The isolate was also Gram negative rod, motile, catalase, methyl red and Voges Prokauer positive, but indole, oxidase and citrate negative as shown in Table 2. The quality and nature of the extracted nucleic acid revealed 260/280. Hence, Deoxyribonucleic acid (DNA) as shown in Table 3. The

molecular identities of the isolates revealed 100% query cover and 100% identities. This revealed that sample 1D AI was *Acetobacter aceti* strain WI (AAWI) whereas sample ID XI was *Saccharomyces cerevisiae* strain Ysr128 (SC 128) as shown in Table 4

### Alcohol Tolerance Potential of the Test Isolate

The study revealed that the test isolate was able to grow in the presence of 10% absolute alcohol. There was significant ( $P < 0.05$ ) number of colonies of acetic acid bacteria in 10% absolute alcohol level in both yeast extract agar (YEA) and glucose-Yeast extract calcium carbonate agar (GYA). The number of colonies slightly decreased as the concentration of alcohol increased as shown in Table 5 but the decrease was statistically non-significant ( $P > 0.05$ ).

### Phytochemical Constituents of the Vinegars

The study revealed the presence of alkaloids, saponins, flavonoids, tannins, and glycosides as shown in Table 10. Alkaloids and saponins were non-significantly ( $P > 0.05$ ) detected most in sample VG. Tannin was significantly ( $P > 0.05$ ) detected most in VG. Flavonoids was non-significantly ( $P > 0.05$ ) detected most in VD whereas glycosides was detected most in VD.

### Antimicrobial Activities of the Vinegar Samples

The study revealed significant activities of the vinegar samples against *S. aureus*, *E. coli*, *S. enterica* ser. Typhi and *C. albicans* as shown in Table 11. The study showed that sample VD showed the highest zones of inhibition when compared to samples VG and VS but the variations in their zones of inhibition were statically non-significant ( $P > 0.05$ ). The zones of inhibition of the vinegar samples against *S. aureus*, *E. coli*, and *S. ser. Typhi* were significantly ( $P < 0.05$ ) lower than that of ciprofloxacin (standard antibiotic) as shown in Table 11. Ketoconazole (standard antifungal agent) was able to inhibit only *C. albicans*, and the zone of inhibition is significantly ( $P < 0.05$ ) higher than the zones of inhibitions recorded by the vinegar samples against *C. albicans*.

Table 1: Morphological and biochemical characteristics of the yeast isolates

| Parameter         | X1                              | X2                              |
|-------------------|---------------------------------|---------------------------------|
| Appearance on GYA | Cream white colonies            | Cream white colonies            |
| Surface           | Smooth                          | Smooth                          |
| Margin            | Circular                        | Circular                        |
| Elevation         | Convex                          | Convex                          |
| Shape             | Spherical                       | Spherical                       |
| Bud               | Present                         | Present                         |
| Ascospore         | Present                         | Present                         |
| Glucose           | +                               | +                               |
| Sucrose           | +                               | +                               |
| Maltose           | +                               | +                               |
| Gelactose         | +                               | +                               |
| Raffinose         | +                               | +                               |
| Mannitol          | —                               | —                               |
| Lactose           | —                               | —                               |
| Xylose            | —                               | —                               |
| Cyclohexide       | Resistance                      | Resistance                      |
| Suspected yeast   | <i>Saccharomyces cerevisiae</i> | <i>Saccharomyces cerevisiae</i> |

Table 2: Morphological and biochemical characteristics of the acetic acid bacterium

| Parameter         | A1                         | A2                         |
|-------------------|----------------------------|----------------------------|
| Appearance on GYA | Cream to yellow colour     | Cream to yellow colour     |
| Surface           | Smooth                     | Smooth                     |
| Elevation         | Convex                     | Convex                     |
| Opacity           | Opaque                     | Opaque                     |
| Shape             | Rod                        | Rod                        |
| Arrangement       | Clustered                  | Clustered                  |
| Gram Reaction     | —                          | —                          |
| Motility          | +                          | +                          |
| Indole            | —                          | —                          |
| Citrate           | —                          | —                          |
| Catalase          | +                          | +                          |
| Methyl red        | +                          | +                          |
| Voges Proskauer   | +                          | +                          |
| Oxidase           | —                          | —                          |
| Glucose           | +                          | +                          |
| Sucrose           | +                          | +                          |
| Mannitol          | +                          | +                          |
| Bacterium         | <i>Acetobacter</i> species | <i>Acetobacter</i> species |

Table 3: Quality and nature of the extracted nucleic acid

| Sample ID | Nucleic acid( $\mu\text{g/mL}$ ) | 260 nm | 280 nm | 260/280 |
|-----------|----------------------------------|--------|--------|---------|
| A1        | 120.20                           | 3.412  | 1.875  | 1.82    |
| X1        | 102.10                           | 3.104  | 1.687  | 1.84    |

Table 4: Molecular identities of the isolates

| Parameter        | A1                                                                          | X1                                                                                            |
|------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Max Score        | 2676                                                                        | 6205                                                                                          |
| Total Score      | 2676                                                                        | 6604                                                                                          |
| Query Cover (%)  | 100                                                                         | 100                                                                                           |
| E-Value          | 0.0                                                                         | 0.0                                                                                           |
| Identity (%)     | 100                                                                         | 100                                                                                           |
| Accession Length | 1449                                                                        | 224595                                                                                        |
| Accession Number | 1ICC662508.1                                                                | CP036471.1                                                                                    |
| Description      | <i>Acetobacter aceti</i> strain W2 (AAW1)<br>16S rRNA gene partial sequence | <i>Saccharomyces cerevisiae</i> strain Ysr128<br>(SC128) chromosome 1, complement<br>sequence |

Table 5: Alcohol tolerance of the test isolate

| Alcoholic Content (%) | Yeast Extract Agar   |            | Glucose-Yeast Extract<br>Calcium Carbonate |            |
|-----------------------|----------------------|------------|--------------------------------------------|------------|
|                       | Count (CFU/mL)       | Log CFU/mL | Count (CFU/mL)                             | Log CFU/mL |
| 2.0                   | 5.10X10 <sup>2</sup> | 2.71       | 6.40X10 <sup>2</sup>                       | 2.81       |
| 4.0                   | 4.70X10 <sup>2</sup> | 2.67       | 6.10X10 <sup>2</sup>                       | 2.79       |
| 6.0                   | 4.30X10 <sup>2</sup> | 2.63       | 5.70X10 <sup>2</sup>                       | 2.76       |
| 8.0                   | 4.10X10 <sup>2</sup> | 2.61       | 5.40X10 <sup>2</sup>                       | 2.73       |
| 10.0                  | 3.80X10 <sup>2</sup> | 2.58       | 5.10X10 <sup>2</sup>                       | 2.71       |

Table 10: Phytochemical constituents of the vinegars

| Parameter  | VG (%)    | VD (%)    | VS (%)    |
|------------|-----------|-----------|-----------|
| Alkaloids  | 0.29±0.01 | 0.17±0.01 | 0.11±0.00 |
| Saponins   | 2.11±0.03 | 1.93±0.04 | 1.82±0.13 |
| Flavonoids | 1.74±0.11 | 2.19±0.31 | 2.04±0.07 |
| Tannins    | 3.05±0.17 | 1.86±0.11 | 2.23±0.13 |
| Glycosides | 1.04±0.01 | 2.14±0.14 | 2.04±0.01 |
| Steroids   | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |

Table 11: Antimicrobial activities of the samples

| Test organism        | Diameter Zones of INHIBITION ( $\bar{x} \pm SD$ ) mm |                 |                 |     |                  |
|----------------------|------------------------------------------------------|-----------------|-----------------|-----|------------------|
|                      | VG                                                   | VD              | VS              | CPX | KET              |
| <i>S. aureus</i>     | 6.70 $\pm$ 0.14                                      | 7.40 $\pm$ 0.11 | 6.90 $\pm$ 0.21 |     | 14.10 $\pm$ 0.33 |
| <i>E. coli</i>       | 7.80 $\pm$ 0.42                                      | 8.50 $\pm$ 0.00 | 8.40 $\pm$ 0.21 |     | 28.50 $\pm$ 0.11 |
| <i>S. ser. Typhi</i> | 7.10 $\pm$ 0.81                                      | 7.90 $\pm$ 0.14 | 7.90 $\pm$ 0.11 |     | 19.50 $\pm$ 0.14 |
| <i>C. albicans</i>   | 6.80 $\pm$ 0.11                                      | 7.30 $\pm$ 0.58 | 7.10 $\pm$ 0.22 |     | 0.00 $\pm$ 0.00  |
|                      |                                                      |                 |                 |     | 17.10 $\pm$ 0.00 |

CPX= Ciprofloxacin; KET= Ketoconazole

## Discussion

Fruit vinegars, which are produced through a two-stage fermentation process converting sugars to ethanol and then to acetic acid, represent an important category of functional foods with longstanding culinary and ethnomedicinal uses (Hamidalu, 2014). This investigation focused on the phytochemical composition and antimicrobial potential of vinegars derived from *Phoenix dactylifera* (date) and *Vitis vinifera* (grape). The identification of a yeast isolate from date fruit aligned with characteristics reported in prior studies (Mohammed *et al.*, 2021; Chibi and El Haldi, 2019; Atitallah *et al.*, 2021; Ahmad *et al.*, 2021; Iheukwumere *et al.*, 2025j). Specifically, the isolation of *Saccharomyces cerevisiae* strain Ysr128 (SC 128) from spoiled date samples confirmed earlier findings by Ahmad *et al.* (2021) and Ugobogu *et al.* (2025). Similarly, the cultural, morphological, and biochemical traits of a bacterial isolate from grape fruit were consistent with descriptions from several researchers (Navarro *et al.*, 2013; Arifuzzman *et al.*, 2014; Klawpiyapamomkun *et al.*, 2015; Iheukwumere *et al.*, 2025k). The presence of *Acetobacter aceti* strain w1 (AAWI) in spoiled grape samples further corroborated the work of Rahman *et al.* (2024).

The successful vinegar production from both date and grape fruits is supported by previous research (Tengberg, 2012; Mohammed *et al.*, 2018; Cantadori *et al.*, 2022; Iheukwumere *et al.*, 2025l), with analogous studies reporting vinegar synthesis from various other plant sources (Klawpiyapamomkun *et al.*, 2015; Atitallah *et al.*, 2021; Ahmad *et al.*, 2018).

Phytochemical analysis revealed the presence of alkaloids, saponins, flavonoids, tannins, and glycosides in the vinegar samples, consistent with the findings of Hamidatun (2014) and Zubaidah (2015). As noted by Yuliant *et al.* (2015), the combination of acetic acid, flavonoids, and other antioxidants in vinegar can prevent oxidative damage caused by free radicals. Yuliant *et al.* (2019) further reported that the antioxidant properties of flavonoids, tannins, and phenolics protect cells and organs from oxidative stress, a conclusion supported by Han *et al.* (2016) regarding flavonoid activity. Additionally, saponins were identified as contributing significant biological activities, including medicinal and antimicrobial properties (Safrida *et al.*, 2023; Iheukwumere *et al.*, 2025m).

The vinegar samples exhibited inhibitory activity against *Staphylococcus aureus*, *Escherichia coli*, *Salmonella enterica* serovar Typhi, and *Candida albicans*, which is likely attributable to their phytochemical and bioactive constituents. This aligns with conclusions drawn by other researchers (Senguen *et al.*, 2020; Singh & Garg, 2022; Iheukwumere *et al.*, 2025n).

The slightly greater inhibitory activity observed in *P. dactylifera* vinegar may be due to a higher potency of its phytochemicals and a greater acetic acid concentration. The most pronounced inhibitory effect against *E. coli* may be explained by the specific nature of this bacterium, particularly the structure of its cell wall.

## Conclusion

The study has shown that vinegar samples produced from *Phoenix dactylifera* and *Vitis vinifera* fruits possessed significant phytochemical and antimicrobial properties, and the sample produced from PD was slightly better than the sample produced from VV, mostly against *Escherichia coli*.

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