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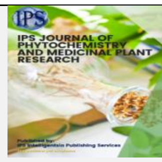

Evaluating the Quality and Composition of Date Palm and Banana Fruit Vinegar: Physicochemical and Nutritional Aspects

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Abstract

The physicochemical and nutritional composition of vinegar is critically dependent on the choice of fermentation substrate. While vinegar is a globally important condiment, the quality attributes of variants produced from underutilized tropical fruits remain inadequately characterized. Specifically, vinegars derived from *Phoenix dactylifera* (date palm) and *Musa paradiscum* (banana), Fruits prized for their high sugar content, dietary fiber, and antioxidant phytochemicals lack a comprehensive scientific evaluation. This study aimed to analyze and compare the quality profiles of vinegar produced from date palm and banana fruit extracts. Yeast (*Saccharomyces cerevisiae* strain SR 128) and acetic acid bacteria (*Acetobacter aceti* strain WI) were isolated and used to ferment the respective fruit musts via submerged fermentation. Key physicochemical and proximate nutritional parameters were determined using standard gravimetric and instrumental techniques. Data were analyzed using Analysis of Variance (ANOVA) and Tukey's post-hoc test at a 95% confidence level. The results showed only slight, statistically non-significant ($p > 0.05$) variations between the two vinegars. The determined compositional ranges were as follows: moisture (98.70–99.55%), ash (0.27–1.11%), protein (0.10–0.12%), and fat (0.06–0.08%). All measured parameters for both vinegar samples conformed to established food quality standards. Therefore, the prepared vinegar samples from MP and PD had physicochemical and nutritive parameters that conformed to the stipulated standard and the sample prepared from PD was slightly better. Therefore, the prepared vinegar samples from MP and PD had physicochemical and nutritive parameters that conformed with the stipulated standard and the sample prepared from PD was slightly better.

Keywords: Physicochemical, Vinegar, *Saccharomyces*, *Acetobacter*, *Malus*, *Phoenix*.

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Introduction

Vinegar is a fermented product produced through the microbial oxidation of ethanol to acetic acid by acetic acid bacteria, primarily of the genera *Acetobacter* and *Komagataeibacter* (Hazzouri *et al.*, 2015; Iheukwumere *et al*., 2025a; Dim *et al*., 2025a). It can be synthesized from a diverse range of alcoholic substrates, including fermented fruit musts, with its organoleptic qualities—such as color, aroma, and flavor—directly derived from the raw material used (Jamaludin *et al*., 2016; Ejike *et al*., 2017; Nwike *et al*., 2017). Historically utilized as a universal condiment and preservative, vinegar is fundamentally a sour liquid produced from the fermentation of natural, food-grade substances rich in fermentable carbohydrates (Bhat *et al*., 2014; Amadi *et al*., 2017; Henke *et al*., 2019). While substrates like grapes, apples, and honey are commonly employed, the essential functional and antimicrobial agent in all vinegar remains acetic acid

(Matthew *et al.*, 2019; Tumane *et al.*, 2018; Iheukumere *et al.*, 2022a).

Beyond its traditional culinary roles, vinegar is increasingly recognized as a functional beverage due to its content of micronutrients and bioactive phytochemicals, which contribute to its purported health benefits (Cusano *et al.*, 2020; Iheukwumere *et al*., 2025b). The nutritional value of fruit-based vinegars, such as those from dates, includes a spectrum of essential minerals and health-promoting polyphenols, linked to antioxidant, hypoglycemic, and cardioprotective effects (Arfaoui, 2021; Tumane *et al.*, 2018; Ekechukwu *et al.*, 2025a). These attributes underscore its growing significance in the nutraceutical and functional food industries.

The quality, stability, and bioactivity of vinegar are critically governed by its physicochemical properties. Key parameters, including pH, total acidity, soluble solids content, and specific density, serve as essential indicators of product integrity, safety, and shelf life (Sengun *et al.*, 2020; Dim *et al.*, 2025b). These characteristics are highly variable and are influenced by a complex interplay of factors, such as the raw material composition, fermentation methodology, microbial consortium, and processing conditions (Budak *et al.*, 2010; Obianom *et al.*, 2024). Consequently, the specific physicochemical profile directly determines the vinegar's sensory acceptance, preservation potential, and physiological impact (Kim *et al.*, 2021).

While extensive research has established general principles regarding vinegar from common fruits (Sengun *et al.*, 2020; Kim *et al.*, 2021; Dim *et al.*, 2025c), a systematic comparative analysis of vinegar produced from *Phoenix dactylifera* (date palm) and *Musa* spp. (banana) remains scarce. These two nutritionally dense and globally significant fruits possess distinct compositional profiles, suggesting their derived vinegars may exhibit unique quality attributes. Therefore, this study aims to systematically evaluate and compare the key physicochemical properties and nutritional composition of vinegar produced from *Phoenix dactylifera* and *Musa* spp. fruit extracts

Materials and Methods

Isolation and Characterization of Saccharomyces species from Spoilt Fruit Samples

Sample collection

Spoilt *Musa paradisicum* (Banana) and *Phoenix datylifera* (Date palm) 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 polyethene 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 shaked, 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%), CaCO3 (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 (commonly known as Date) and *Musa paradisicum* (commonly known as Banana) 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).

Determination of Physicochemical Parameters of the Vinegar

The Physical parameters determined were pH, temperature, acidity, total solid, total dissolved solid, and total suspended solid as described in the study published by Iheukwumere *et al.* (2025h), Idigo *et al*. (2025c), Idigo *et al*. (2025d), Ike *et al.* (2025d).

Determination of pH: The pH of the water samples was determined using a pH meter (PHS-3CU/Mainland, China). The pH meter was first standardized using a phosphate buffer to pH value of 4.0 and 7.0. After that, the electrode was dipped into the sample contained in a beaker and the pH value was taken. This was done in triplicate as described by AOAC (2019), Ezedianafo *et al*. (2025d); Idigo *et al*. (2025d); Idigo *et al*. (2025e).

Total Solid in the Sample: This was carried out using the method of AOAC (2019) Obiefuna *et al*. (2025b); Ike *et al*. (2025d); Idigo *et al*. (2025f).The weight of crucible was taken and recorded, and a known amount of the sample was measured into the crucible, and the weight was also measured and recorded. The crucible and its content were heated in an oven at 105^{0}C to dryness. The total solid was determined as follows:

$$\text{Total Solid (mg/L)} = \frac{\text{Weight Crucible + Dried Sample – Weight of empty crucible}}{\text{Volume of sample used}} \text{ x } 100$$

Total Dissolved Solid (TDS) of the Sample: This was carried out using TDS meter in Mg/L. The sample (100 ml) was measured into 200 ml beaker. A Digital TDS meter was powered and allowed for 30 minutes and the probe was carefully inserted to take the measurement of the TDS of each of the samples. This was done in triplicate (A0AC, 2019; Idigo *et al*., 2025g; Idigo *et al*., 2025h).

Total suspended solids (TSS) determination: The method of AOAC (2019), Idigo *et al*. (2025i); Idigo *et al*. (2025j) was used. The total suspended solids were determined by subtracting the result of total dissolved solids from total solid as follows:
Total solids (TS) – Total dissolved solids (TDS) = Total Suspended solids (TSS)

Determination of acidity

This was carried out using the method of AOAC (2019), Idigo *et al*. (2025k); Idigo *et al*., (2025l). Prepared vinegar sample (10 mL) was added into cleaned and dried 250 mL conical flask (Pyrex). This was titrated with 0.1N standard sodium hydroxide (NaOH) solution using phenolphthalein as an indicator. The titrated volume was observed as soon as the solution turned light purple (end point) and the acidity of the sample was calculated as follows:

$$\text{Acidity (w/v\%)} = \frac{\text{Titre x Factor}}{\text{Volume of Sample}} x100$$

Factor=0.006005 (for acetic acid)

Determination of alcohol content

The alcohol content of prepared vinegar was determined using Alcoholmeter at room temperature (30±2◦C) as described in the study published by Khlin and Thwe (2016).

Specific gravity

The specific gravity of the sample was determined using 25 mL density bottle (S-Pyrex) at 20◦C. The ratio of the weights of equal volume of the sample and water was determined and matched the respective values with specific gravity chart (AOAC, 2019; Idigo *et al*., 2025m; Idigo *et al*., 2025n; Idigo *et al*., 2025o).

Total sugar content

Vinegar samples were first hydrolyzed with HCl at 100◦C for 30 min, and then neutralized with NaOH. The solution was further diluted with water.

Then 3 mL of 3,5 – dinitrosalicyclic acid (DNSA) was added into 1 mL of the hydrolyzed samples or standard glucose solution (0 – 2.0 mg/mL), respectively and heated at 100◦C in water bath for 5 min. After cooling, 10 mL of water was added to the reaction solution and absorbance was measured at 540 nm using UV/visible spectrophotometer (UV – 6100/ China). Total sugar content was quantified by extrapolating the absorbance value from the standard glucose curve (AOAC, 2019; Idigo *et al*., 2025p; Idigo *et al*., 2025q).

Viscosity
Here, 100 mL of the sample was measured into 250 mL beaker (S – Pyrex). A selected spindle in Viscometer was then used to read the viscosity of the sample at 25◦C (AOAC, 2019)

Nutritional Constituents
Moisture content: A crucible was dried and cooled, then initial weight of the crucible was taken as W_1, 10 mL of the sample was transferred into the crucible and the weight of the crucible was taken W_2 .The crucible and its content were then heated in an oven at 105ºC for 4-6 h. After which the final weight of the crucible and its content were taken as W_3. Then the percentage moisture content was calculated as follows:

$$\% \text{ Moisture content } = \frac{W_2 - W_3}{W_2 - W_1} x100$$

Ash Content: A crucible was dried and cooled, then initial weight of the crucible was taken as W_1, 10 mL of the sample was transferred into the crucible and the weight of the crucible was taken W_2 .The crucible and its content were then heated in a furnace at 550ºC for 3-5 h until the content became gray in colour, after which the crucible was removed and allowed to cool. The final weight of the crucible and its content was taken after drying/ashing as W_3. The percentage ash content was then calculated as follows:

$$\% \text{ Ash content } = \frac{W_3 - W_1}{W_2 - W_1} x100$$

Fat content: A soxhlet extractor was used, the soxhlet flask was dried in an oven at 105ºC and allowed to cool, after which the weight of the flask was taken as W_1. Then 10 mL of the sample was taken as W_2 and transferred into the thimble of the extractor, the sample was extracted using 250 ml of hexane for 4-5 h. After 5 h the chaff was emptied properly for the determination of the fibre content and all the solvent were recovered. The flask that contains all the extract were dried in an oven at 105ºC until all the water have been evaporated leaving the oil only, the weight of the flask and oil content was taken as W_3.The percentage fat was calculated as follows:

$$\% \text{ Fat } = \frac{W_3 - W_1 \text{ x } 100}{W_2}$$

Fiber content: The residue was then transferred into a beaker and boiled for another 30 minutes with 200 mL of dilute sodium hydroxide solution and filtered, transferred into an ignited crucible.
The residue was then washed 3 times with 20ml ethanol and 2 times with 10 mL petroleum ether. The residue was dried in an oven and cooled, then weighed (w_2). The dried residue was transferred into a furnace and ignited, cooled and weighed (w_3).

Calculation

$$\text{Percentage Crude Fibre} = \frac{w_2 - w_3}{w_1} \ x \ \frac{100}{1}$$

Protein
A 1.0 mL of the sample was weight and transferred into a digestible flask, 20 mL of sulphuric acid and 0.5g of selenium powder (catalyst) were added, this mixture were heated in a fume cardboard for about 7 h (i.e until a clear or colourless solution is seen). The sample generated was diluted (1:4 dilution was carried out), 5ml of the diluted sample was collected into a distillation flask and 5ml of 40% NaOH was added, then 10 mL of 10 % boric acid was put inside a conical flask, 5 drops of bromocresol green and 1drop of methyl red was also added and was properly mixed. The conical flask was placed under the tip of the condenser and the distillation started, 50 drops of the distillate was allowed to enter into the conical and then the color of the solution was turned blue. A burette was filled with 0.01 HCl and titrated against the content of the flask until the colour was changed to wine red, the titrate value was taken.

% Nitrogen = Titre x molarity of acid used (0.01M) x atomic mass of nitrogen x DF

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.*, 2017b, Idigo *et al*., 2025r; 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 cerevisae* 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 ($P > 0.05$).

Physicochemical Properties of the Vinegars
The study revealed that the studied vinegars had varying pH, total soluble solid (TSS), acidity and total sugar content. There was no alcohol detected in the three samples. The specific gravities and their viscosities were slightly similar. Sample VB recorded the highest values pH, TSS, and acidity but these variations were statistically non-significant ($P > 0.05$) except the level of acidity that showed significant difference ($P < 0.05$) when compared to that of sample VD. The study also revealed that total sugar content was non-significantly ($P > 0.05$) detected most in sample VD but least in sample VB (Table 6).

Nutritional Constituents of the Vinegar
The study revealed that fibre and carbohydrate were not detected in the vinegar samples as shown in Table 7. There were presence

of fat, proteins, and ash, and these occurred in very low amount. The ash and fat contents were slightly detected most in sample VB but this variation was statistically (P > 0.05). The major component of this sample was mainly moisture, and this was slightly and non-significantly (P > 0.05) detected most in sample VD.

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	Saccharomyces cerevisae	Saccharomyces cerevisae

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	*Acetobacter* species	*Acetobacter* species

Table 3: Quality and nature of the extracted nucleic acid

Sample ID	Nucleic acid(µg/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	*Acetobacter aceti* strain W2 (AAW1) 16S rRNA gene partial sequence	*Saccharomyces cerevisiae* strain Ysr128 (SC128) chromosome 1, complement sequence

Table 5: Alcohol tolerance of the test isolate

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

Table 6: Physicochemical properties of the prepared vinegars

Parameter	VB	VD	VS
pH	3.10±0.00	2.70±0.00	3.05±0.00
TSS (%)	4.96±0.11	4.20±0.14	4.05±0.00
Acidity (%)	4.15±0.01	1.80±0.01	2.34±0.00
Alcohol Content (%)	0.00±0.00	0.00±0.00	0.00±0.00
Specific gravity	1.014±0.001	1.011±0.001	1.014±0.00
Total Sugar (%)	9.20±0.14	13.21±0.41	10.80±0.00
Viscosity(cSt)	2.20±0.00	2.40±0.00	2.10±0.00

VB=Vinegar from Banana; VD= Vinegar from Dates; VS= Vinegar from supermarket

Table 7: Nutritional constituents of the vinegars

Parameter	VB	VD	VS
Moisture (%)	98.70±1.89	99.55±1.92	99.54±1.86
Ash (%)	1.11±0.01	0.31±0.01	0.27±0.01
Protein (%)	0.11±0.00	0.11±0.00	0.12±0.00
Fat (%)	0.08±0.00	0.06±0.00	0.07±0.00
Fibre (%)	0.00±0.00	0.00±0.00	0.00±0.00
Carbohydrate (%)	0.00±0.00	0.00±0.00	0.00±0.00

VB=Vinegar from Banana; VD= Vinegar from Dates; VS= Vinegar from supermarket

Discussion

This study investigates the phytochemical composition and *in vitro* antimicrobial efficacy of vinegars derived from *Phoenix dactylifera* (date) and *Musa paradisicum* (banana). Fruit vinegar is a complex fermented product containing organic acids, vitamins, minerals, and bioactive phytochemicals such as phenolics and flavonoids (Hamidalu, 2014). The production of vinegar from these fruit substrates aligns with established research on fruit-based fermentations (Tengberg, 2012; Cantadori *et al.*, 2022; Habiba *et al.*, 2024; Iheukwumere *et al.*, 2025j).

Microbiological analysis confirmed the presence of characteristic fermentative microorganisms. The yeast isolate from date fruit exhibited traits consistent with *Saccharomyces cerevisiae*, matching descriptions by Mohammed *et al.* (2021), Chibi and El Haldi (2019), Atitallah *et al.* (2021), and Ahmad *et al.* (2021). Molecular identification corroborated the presence of strains such as *Saccharomyces cerevisiae* Ysr128, supporting earlier reports by Ahmad *et al.* (2021) and Ugobogu *et al.* (2025). Similarly, the bacterial isolate from banana displayed profiles consistent with *Acetobacter* species, as described by Fatima and Mishra (2015), Prisacaru and Oroian (2018), and Armi *et al.* (2023), and specifically aligned with reports of *Acetobacter aceti* strain w1 (Boonsupa *et al.*, 2019; Iheukwumere *et al*., 2025k).

The acetic acid yield from date fruit vinegar reached 5.2%, a concentration exceeding yields reported for several other fruits. This result is consistent with studies on other high-sugar substrates, such as green apple and mango juice (Klawplyapamornkun *et al.*, 2015; Ouattara *et al.*, 2018; Iheukwumere *et al*., 2025l).

The physicochemical parameters of the vinegar samples correlated with values reported in other studies (Morhtar *et al.*, 2016; Sengun *et al.*, 2020). Specifically, pH and specific gravity aligned with data for apple cider and Nipa vinegars (Morhtar *et al.*, 2016; Iheukwumere *et al.*, 2025m) but diverged from findings by Akarca *et al.* (2020). The low pH and high acidity observed in both vinegars are likely attributable to the high initial sugar content of the fruit must.
Proximate analysis confirmed the presence of moisture, ash, protein, and fat, consistent with the work of Morhtar *et al.* (2016) and Iheukwumere *et al.* (2025n). The absence of detectable carbohydrates indicates the near-complete conversion of fermentable sugars to ethanol and subsequent oxidation to acetic acid during fermentation.

Conclusion

The study has shown that the prepared vinegar samples from *Phoenix dactylifera* (PD/Date) and *Musa paradisicum* (MP/Banana) fruits had physicochemical and nutritive parameters that conformed with the stipulated standard, the sample prepared from PD was slightly better.

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