RESEARCH ARTICLE

Journal of Public Health, Policy, and Society (JPHPS)
DOI: https://doi.org/10.54117/mwht3691

3(1): 62-73 (2026)

Consumer Preference and Microbial Safety of Date Palm and Banana Fruit Vinegar: A Sensory Evaluation

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Received: *29 Dec 2025* ***Accepted:*** *28 Jan 2026* ***Published:*** *12 Feb 2026*

ABSTRACT

The sensory characteristics and microbiological safety of fruit vinegar are influenced by factors such as raw material quality, production methods, and storage conditions. This study evaluated the microbial quality and sensory profile of vinegar produced from *Phoenix dactylifera* (date palm) and *Musa* spp. (banana) and assessed their implications for consumer acceptance. Using standard microbiological techniques, fermentative microorganisms, including *Saccharomyces cerevisiae* strain SR 128 and *Acetobacter aceti* strain WI, were isolated from spoiled fruits and utilized in submerged fermentation of fruit musts. Microbial quality was assessed using standard plate counting, while sensory evaluation was conducted with a trained panel using a 9-point hedonic scale to measure color, aroma, taste, and overall acceptability. Statistical analysis was performed using Analysis of Variance (ANOVA) and Tukey's post-hoc test. Results indicated that although variations in microbial loads were observed, differences between the two vinegars were statistically non-significant ($p > 0.05$), with both complying with established safety standards. Sensory evaluation yielded favorable ratings across all attributes, indicating high consumer acceptability. In conclusion, vinegar derived from date palm and banana exhibits compliant microbial safety and favorable sensory qualities, supporting its suitability for consumer use. The date palm vinegar demonstrated marginally superior overall quality, suggesting a subtle preference advantage.

How to cite this article
Obianom, A. O., Iheukwumere, I. H., Iheukwumere, C. M., Mere, C. A., Nnagbo, P. A., Ike, V. E., Ezendianefo, J. N., Okongwu, D. J., & Abba, O. (2026). Consumer preference and microbial safety of date palm and banana fruit vinegar: A sensory evaluation. *Journal of Public Health, Policy, and Society*, *3*(1), 62–73. https://doi.org/10.54117/mwht3691

Keywords
Vinegar, Microbial, Sensory, *Saccharomyces*, *Acetobacter*

INTRODUCTION

Vinegar is a globally recognized fermented condiment produced through a sequential two-stage biochemical process. This involves an initial alcoholic fermentation, where yeasts such as *Saccharomyces cerevisiae* convert sugars to ethanol, followed by an acetous fermentation, in which acetic acid bacteria (AAB) like *Acetobacter aceti* oxidize the ethanol to acetic acid under aerobic conditions (Budak *et al.*, 2014; Hutchinson *et al.*, 2019; Iheukwumere *et al*., 2025a; Dim *et al*., 2025a). A diverse array of carbohydrate-rich substrates, including fruits, grains, and honey, can serve as feedstocks for its production (Chen *et al.*, 2016; Ekechukwu *et al*., 2025a; Dim *et al*., 2025b). Beyond its culinary roles, vinegar has a long history of ethnomedicinal use, valued since the 18th century for its purported therapeutic benefits in treating various ailments (Bray, 2014; Ejike *et al*., 2017; Amadi *et al*., 2017; Nwike *et al*., 2017). In modern food technology, it fulfills multiple functional roles as a critical acidulant, preservative, and flavoring agent in products ranging from pickles to condiments (Saha & Banerjee, 2013; Obianom *et al*., 2024; Iheukwumere *et al*., 2025b).

The preservative efficacy and defining sensory character of vinegar are primarily attributed to its acetic acid content. This compound lowers pH, creating an antimicrobial environment that inhibits pathogenic and spoilage microorganisms, thereby extending food shelf-life (Alboronoz, 2012; Dim *et al*., 2025c; Iheukwumere *et al*., 2025b). Consequently, the sensory profile, encompassing acidity, aroma, and flavor—is a paramount determinant of consumer acceptance and commercial viability (Sharma *et al.*, 2018). The same antimicrobial properties shape the product's microbial ecology; a properly fermented vinegar typically hosts a microbiome dominated by AAB, with pathogens being scarce. The fastidious nature of these AAB often necessitates specialized media like Glucose Yeast extract Calcium carbonate (GYC) agar for their cultivation and study (Sharma *et al.*, 2018).

Journal of Public Health, Policy, and Society (JPHPS)
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While the sensory and microbiological profiles of vinegars from common fruits like apples (*Malus sylvestris*) and grapes are well-documented, significant research gaps exist for vinegars derived from many tropical fruits. Specifically, comprehensive quality assessments of vinegar produced from *Phoenix dactylifera* (date palm) and *Musa* spp. (banana) are lacking. These fruits possess distinct sugar compositions and phytochemical profiles, suggesting the potential for unique fermentation dynamics and final product characteristics. Therefore, this study aims to evaluate the microbial quality and sensory attributes of vinegar produced from date palm and banana fruits.

MATERIALS AND METHODS

Isolation and Characterization of Saccharomyces species from Spoilt Fruit Samples

Sample collection

Spoilt *Phoenix dactylifera* (date palm) and *Musa paradisicum* (banana) 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).

Microbial Analyses of the Vinegar

The microbial analyses of the vinegar were carried out using the standard plate count technique as described in Cheesbrough (2010), Iheukwumere *et al.* (2025h), Idigo *et al*. (2025c), Idigo *et al*. (2025d), and Ike *et al*. (2025d) with slight modification in the choice of media used. The total spore counts were carried out by growing the heated samples on Nutrient Agar (BIOTECH) at 35±2◦C for 24 h. The total Bacillus cereus counts were carried out by growing the heated samples on Mannitol Nutrient Agar (MNA) at 35±2◦C for 24 – 48 h as described by Ezedianafo *et al*. (2025d), Idigo *et al*. (2025d), Idigo *et al*. (2025e). The total mesophilic aerobic bacterial counts were carried out by growing the samples on nutrient agar (BIOTEC H) at 35±2◦C for 24 h. The total acetic acid bacterial count was carried out by growing the samples at GYC agar at room temperature (30±2◦C) for 24 h. The total lactic acid bacterial counts were carried out by growing the samples on Demann Rogosa Sharpe (MRS) agar at 30±2◦C for 48 h. The total yeast and mold counts were carried out by growing the samples on Sabouraud Dextrose Agar (SDA) at 35±2◦C and 30±2◦C, respectively, for 24 hours and 5 days respectively as described by Obiefuna *et al*. (2025b); Ike *et al*. (2025d); Idigo *et al*. (2025f) Idigo *et al*. (2025g), Idigo *et al*. (2025h).

Sensory Evaluation of the Prepared Vinegar

Sensory Evaluation: In house consumer-oriented test was conducted to determine product acceptability using scoring test with the aid of 9-points hedonic scale with little modification in the studies published by Adedokun *et al.* (2013), Piotrowska *et al*. (2015) and Enidiok *et al*. (2017), Idigo *et al*. (2025i); Idigo *et al*. (2025j), Idigo *et al*. (2025k); Idigo *et al*., (2025l) . The sensory characteristics of the vinegar samples such as colour, odour, taste and general acceptability was examined by the team of twenty (20) validated panelists which was drawn from microbiology students of Chukwemeka Odumegwu Ojukwu University, Uli. The panelists were validated in such a way that they were able to detect little perceptible changes in the sensory attributes mentioned. Each panelist was asked to score each coded sample based on a nine point hedonic scale (like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much, dislike extremely) as described by Idigo *et al*., 2025m; Idigo *et al*., 2025n; Idigo *et al*., 2025o.

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.

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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 (Table 5). 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 ($P > 0.05$).

Microbial Qualities of the Vinegar Samples

The study revealed count values for total mesophilic aerobic bacterial counts (TMABC), total acetic acid bacterial counts (TABC) and total yeast counts (TYC) for the three vinegar samples. The TMABC was significantly ($P < 0.05$) higher in vinegar bought from the supermarket (VS) whereas the vinegar prepared from apples (VB) and dates (VD) non-significantly ($P > 0.05$) showed slight variations in their TMABC as shown in Table 6. There was also slight variations in TABC of VB and VD and these were non-significantly ($P > 0.05$) higher than that of VS.

There were variations in TYC, and this was non-significantly ($P > 0.05$) most in VB. There was no total spore counts (TSC), total *Bacillus cereus* counts (TBCC), total lactic acid bacterial counts (TLBC) and total mold counts (TMC) detected in VB and VD; TSC, TBC, TLBC, and TMB were within the stipulation limit of National Industrial Standard (NIS).

Sensory Evaluation and Acceptability of the Vinegar Samples

The study on the sensory evaluation and acceptability of the vinegar samples are shown in Table 7. The study revealed that the colour of the vinegar samples were like moderately in the 9-point hedonic scale. The taste of the vinegar samples were within neither like nor dislike points, and the odour was within like slightly in the point scale. The general acceptability of the vinegar samples was seen within like very much in the 9-point hedonic scale.

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

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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: Microbial qualities of the vinegar samples

Count	**VB**	**VD**	**VS**
TMABC (CFU/mL/LogCFU/mL)	$5.40X10^2$ (2.73)	$5.10X10^2$ (2.71)	$9.20X10^2$ (2.96)
TBCC(CFU/mL/LogCFU/mL	0(0)	(0)	$0.60X10^2$ (1.78)
TSC (CFU/mL/LogCFU/mL	0(0)	0(0)	$2.20X10^2$
TABC(CFU/mL/LogCFU/mL	$7.60X10^2$ (2.88)	$7.90X10^2$ (2.90)	$6.80X10^2$ (2.83)
TLBC(CFU/mL/LogCFU/mL	0(0)	0(0)	$1.20X10^2$ (2.08)
TYC(CFU/mL/LogCFU/mL	$2.60X10^2$ (2.41)	$2.10X10^2$ (2.32)	$6.80X10^2$ (2.226)
TMC(CFU/mL/LogCFU/mL	0(0)	0(0)	$0.30X10^2$ (1.48)

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Table 7: Sensory parameters and acceptability of the vinegar samples

Parameter	VB	VD	VS
Colour	0.74±0.01	0.71±0.01	0.76±0.01
Taste	0.51±0.001	0.52±0.01	0.56±0.01
Odour	0.64±0.01	0.62±0.01	0.61±0.01
General Acceptability	0.82±0.01	0.84±0.01	0.84±0.1

DISCUSSION

This study provides a comprehensive evaluation of the microbial quality and sensory attributes of vinegar produced from *Phoenix dactylifera* (date) and *Musa paradisicum* (banana). As a complex fermented product, fruit vinegar serves as a valuable source of organic acids, vitamins, minerals, and bioactive phytochemicals such as phenolics and flavonoids, which contribute to its functional properties (Hamidalu, 2014; Iheukwumere *et al*., 2025j). The successful production of vinegar from these substrates confirms their viability as feedstocks, aligning with established methodologies for fruit-based fermentations (Tengberg, 2012; Cantadori *et al.*, 2022; Habiba *et al.*, 2024; Iheukwumere *et al.*, 2025k).

Microbiological characterization identified the essential fermentative consortia. The yeast isolate from date fruit exhibited traits consistent with *Saccharomyces cerevisiae*, corroborating findings from multiple studies on date fermentation (Mohammed *et al.*, 2021; Chibi & El Haldi, 2019; Atitallah *et al.*, 2021; Ahmad *et al.*, 2021). Molecular identification further substantiated the presence of specific strains, such as *Saccharomyces cerevisiae* Ysr128, supporting earlier reports (Ahmad *et al.*, 2021; Ugobogu *et al.*, 2025). Similarly, the bacterial isolate from banana displayed profiles characteristic of *Acetobacter* species, as described by Fatima & Mishra (2015), Prisacaru & Oroian (2018), and Armi *et al.* (2023), with specific alignment to *Acetobacter aceti* strain w1 (Boonsupa *et al.*, 2019).

The fermentation process proved particularly efficient for date vinegar, which achieved an acetic acid yield of 5.2%. This concentration surpasses yields reported for many other fruits and is consistent with the high productivity observed in studies of other sugar-rich substrates, such as green apple and mango juice (Klawplyapamornkun *et al.*, 2015; Ouattara *et al.*, 2018; Iheukwumere *et al.*, 2025l). This result underscores the robust fermentative potential of date must.

Assessment of microbial safety revealed that total mesophilic aerobic bacterial counts (TMABC), total acetic acid bacterial counts (TABC), and total yeast counts (TYC) for both vinegars were within permissible limits as stipulated by the National Industrial Standard (NIS). Crucially, no detectable counts of *Bacillus cereus* (TBCC), lactic acid bacteria (TLBC), or molds (TMC) were recorded. This absence of common spoilage and pathogenic organisms indicates excellent production hygiene and effective process control. This finding, however, contrasts with reports by Ruth *et al.* (2014), Li *et al.* (2015), and Jones *et al.* (2019), Iheukwumere *et al.* (2025m) who isolated such microbiota in other vinegar samples. The discrepancy likely stems from variations in raw material quality, fermentation parameters, or sanitation protocols, highlighting the critical influence of standardized production practices on final product safety.

Sensory quality is a paramount determinant of overall product acceptability and serves as an indirect indicator of safety and production consistency. The favourable sensory profiles obtained for both date and banana vinegars affirm their good quality and safety. These results align with positive sensory evaluations reported for other fruit-derived vinegars (Adebayo-Oyetoro *et al.*, 2017; Chen *et al.*, 2025; Iheukwumere *et al.*, 2025n), supporting their strong potential for consumer acceptance.

CONCLUSION

The study has shown that the prepared vinegar samples from *Musa paradisicum* (MP/Banana) and *Phoenix dactylifera* (PD/Date) fruits had microbial qualities that conformed to the stipulated standard, preferred and acceptable. The sample prepared from PD was slightly better.

Acknowledgment: We are grateful to all our study participants who join the study voluntarily. We are grateful to ZAHARM Analytical and Research Laboratory, Amawbia, Awka Anambra State, Nigeria for providing enabling environment, resources and techniques for this study. We really salute their wonderful efforts.

Conflict of interests: The authors declare no conflict of interests.

Funding: This research did not receive specific grant from any funding agencies.

Ethical approval: Not applicable

Authors Contributions: All contributed towards the study design, experiment execution, data analysis, and manuscript drafting.

Availability of Data and Materials: All datasets analyzed and described during the present study are available from the corresponding author upon reasonable request.

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