



# Evaluating the Microbial Safety and Sensory Quality of Date Palm and Cherry Fruit Vinegar: A Consumer Preference Analysis

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Abstract	Article History
<p>The sensory appeal and microbial safety of fruit vinegar are subject to variation based on production methods, raw material quality, and storage conditions. This study evaluated the microbial quality and sensory attributes of vinegar produced from <i>Phoenix dactylifera</i> (date palm) and <i>Prunus avium</i> (cherry), and assessed their implications for consumer preference. Fermentative microorganisms, including <i>Saccharomyces cerevisiae</i> strain SR 128 and <i>Acetobacter aceti</i> strain WI, were isolated from spoiled fruits using standard microbiological techniques and utilized in submerged fermentation of the respective fruit musts. Microbial loads were quantified using the standard plate count method, while sensory evaluation was conducted with a trained panel using a 9-point hedonic scale to assess color, aroma, taste, and overall acceptability. Data were analyzed using Analysis of Variance (ANOVA) and Tukey's post-hoc test. Results indicated that while minor variations in microbial counts were observed, differences between the vinegars were statistically non-significant (<math>p &gt; 0.05</math>), and both samples complied with relevant safety standards. Sensory evaluation yielded consistently favorable ratings across all attributes, reflecting high consumer acceptance. In conclusion, vinegars derived from date palm and cherry exhibit compliant microbial safety and desirable sensory profiles. The date palm vinegar demonstrated marginally superior overall quality, suggesting a subtle yet notable preference advantage.</p> <p>Keywords: Vinegar, Microbial, Sensory, <i>Saccharomyces</i>, <i>Acetobacter</i></p>	<p>Received: 05 Jan 2026 Accepted: 13 Feb 2026 Published: 17 Feb 2026</p>  <p>Scan QR code to view*</p> <p>License: CC BY 4.0*</p>  <p>Open Access article.</p>
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## Introduction

Vinegar is a globally utilized fermented condiment synthesized through a two-stage microbial process involving the alcoholic fermentation of carbohydrates into ethanol, followed by the acetous fermentation of ethanol into acetic acid (Budak *et al.*, 2014; Iheukwumere *et al.*, 2025a; Dim *et al.*, 2025a). This transformation, primarily mediated by *Saccharomyces cerevisiae* and *Acetobacter acetii*, can utilize a diverse range of carbohydrate-rich substrates, including fruits, grains, and honey (Hutchinson *et al.*, 2019; Ekechukwu *et al.*, 2025a; Obianom *et al.*, 2024). Historically recognized for its therapeutic applications, vinegar has been

employed to address ailments such as obesity and gastrointestinal discomfort since the 18th century (Bray, 2014). In contemporary food systems, it serves as a critical functional ingredient for pickling, seasoning, and preservation across a wide array of products, from condiments to dressings (Saha and Benerjee, 2013; Iheukwumere *et al.*, 2025b; Dim *et al.*, 2025b).

The sensory profile and preservative efficacy of vinegar are predominantly dictated by its acetic acid content, which imparts characteristic sourness and antimicrobial properties, thereby lowering pH and inhibiting spoilage microorganisms

(Alboronoz, 2012; Amadi *et al.*, 2017; Ejike *et al.*, 2017; Nwike *et al.*, 2017). Consequently, sensory evaluation is integral to determining consumer acceptability and product success (Sharma *et al.*, 2018). Microbiologically, the acidic environment of vinegar restricts the survival of pathogenic bacteria, with the resident microbiota typically comprising acetic acid bacteria that require specialized culture media, such as Glucose Yeast Extract Calcium Carbonate (GYC) agar, for isolation (Sharma *et al.*, 2018; Iheukwumere *et al.*, 2022a; Dim *et al.*, 2025c).

While extensive research has documented the quality attributes of vinegars derived from common fruits such as apples and grapes, there remains a significant gap in the evaluation of vinegars produced from *Phoenix dactylifera* (date palm) and cherry fruits. Given their distinct biochemical compositions and growing interest as value-added fermented products, a systematic assessment of their microbial safety and sensory characteristics is warranted. This study therefore aims to evaluate the microbial quality and sensory attributes of vinegar produced from date palm and cherry fruits, with implications for product standardization, safety assurance, and consumer preference.

## Materials and Methods

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

#### Sample collection

Spoilt *Phoenix dactylifera* (Date palm) and *Prunus avium* (Cherry) 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 careful and selective 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, saccharose, 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 *Prunus avium* (commonly known as cherry) 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 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 ( $P > 0.05$ ).

### 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 (VC) and dates (VD) non-significantly ( $P > 0.05$ ) showed slight variations in their TMABC as shown in Table 7. There was also slight variations in TABC of VC 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 ( $P > 0.05$ ) the most in VC. 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 VC 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 8. 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	<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	11CC662508.1	CP036471.1
Description	<i>Acetobacter acetii</i> strain W2 (AAW1) 16S rRNA gene partial sequence	<i>Saccharomyces cerevisiae</i> 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/mL)	Log CFU/mL
2.0	$5.10 \times 10^2$	2.71	$6.40 \times 10^2$	2.81
4.0	$4.70 \times 10^2$	2.67	$6.10 \times 10^2$	2.79
6.0	$4.30 \times 10^2$	2.63	$5.70 \times 10^2$	2.76
8.0	$4.10 \times 10^2$	2.61	$5.40 \times 10^2$	2.73
10.0	$3.80 \times 10^2$	2.58	$5.10 \times 10^2$	2.71

Table 7: Microbial qualities of the vinegar samples

Count	VC	VD	VS
TMABC (CFU/mL/LogCFU/mL)	$5.40 \times 10^2$ (2.73)	$5.10 \times 10^2$ (2.71)	$9.20 \times 10^2$ (2.96)
TBCC(CFU/mL/LogCFU/mL)	0(0)	(0)	$0.60 \times 10^2$ (1.78)
TSC (CFU/mL/LogCFU/mL)	0(0)	0(0)	$2.20 \times 10^2$
TABC(CFU/mL/LogCFU/mL)	$7.60 \times 10^2$ (2.88)	$7.90 \times 10^2$ (2.90)	$6.80 \times 10^2$ (2.83)
TLBC(CFU/mL/LogCFU/mL)	0(0)	0(0)	$1.20 \times 10^2$ (2.08)
TYC(CFU/mL/LogCFU/mL)	$2.60 \times 10^2$ (2.41)	$2.10 \times 10^2$ (2.32)	$6.80 \times 10^2$ (2.226)
TMC(CFU/mL/LogCFU/mL)	0(0)	0(0)	$0.30 \times 10^2$ (1.48)

Table 8: Sensory parameters and acceptability of the vinegar samples

Parameter	VC	VD	VS
Colour	$0.74 \pm 0.01$	$0.71 \pm 0.01$	$0.76 \pm 0.01$
Taste	$0.51 \pm 0.001$	$0.52 \pm 0.01$	$0.56 \pm 0.01$
Odour	$0.64 \pm 0.01$	$0.62 \pm 0.01$	$0.61 \pm 0.01$
General Acceptability	$0.82 \pm 0.01$	$0.84 \pm 0.01$	$0.84 \pm 0.1$

## Discussion

This study provides a comprehensive evaluation of the microbial quality and sensory attributes of vinegar produced from *Phoenix dactylifera* (date) and *Prunus avium* (cherry). 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 cherry displayed profiles characteristic of *Acetobacter* species, as described in research on berry fermentations by De Roos and De Vuyst (2019), Solieri *et al.* (2020), and Pérez *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 (TABAC), 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), Jones *et al.* (2019), and 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 cherry 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 *Prunus avium* (PA/Cherry) and *Phoenix dactylifera* (PD/Date) fruits had microbial qualities that conformed with the stipulated standard, preferred and acceptable, and the sample prepared from PD was slightly better.

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**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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