QUANTIFICATION OF ETHANOL AND ACIDITY IN FERMENTED FRUIT VINEGAR FOR HALAL CERTIFICATION ANALYSIS

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Abstract

Fermented vinegar products are increasingly gaining popularity as natural health supplements. However, the presence of ethanol as a by-product of the fermentation process places vinegar in a critical position in determining its halal status, particularly after the issuance of MUI Fatwa No. 10 of 2018, which stipulates that halal beverages must contain less than 0.5% ethanol (v/v). This study aims to determine the ethanol content and total acidity of various fruit vinegar products available on the market. Eight samples were analyzed using distillation–UV–Vis spectrophotometry to quantify ethanol levels and acid–base titration to determine total acidity. The results demonstrated that all samples—including apple, pineapple, pear, and orange vinegar—contained non-detectable ethanol levels (0.00%) and total acidity values ranging from 1.38% to 7.69%. These findings indicate that the two-stage fermentation process—alcoholic fermentation followed by acetic fermentation—occurred optimally, resulting in complete oxidation of ethanol into acetic acid during product formation. Consequently, all samples met the halal criteria specified in Fatwa MUI 2018, as none exceeded the permissible ethanol threshold and none originated from khamr. This study confirms that fermented fruit vinegar marketed in the community is safe and halal for consumption, while also emphasizing the importance of laboratory-based halal literacy as a scientific foundation for strengthening public awareness of food safety and religious compliance.

Keywords:; Ethanol Content, Fermented Vinegar, Halal Food; MUI Fatwa, Total Acidity

Produk cuka fermentasi semakin populer sebagai suplemen kesehatan alami. Namun, keberadaan etanol sebagai hasil samping proses fermentasi menempatkan cuka pada posisi krusial dalam penetapan status kehalalan, terutama setelah Fatwa MUI No. 10 Tahun 2018 menetapkan batas maksimum etanol yang diperbolehkan untuk produk minuman halal yaitu <0,5% (v/v). Penelitian ini bertujuan untuk menentukan kadar etanol dan total asam pada berbagai produk cuka buah yang beredar di pasaran. Sebanyak delapan sampel dianalisis menggunakan metode distilasi–spektrofotometri UV-Vis untuk penentuan kadar etanol dan titrasi asam–basa untuk kuantifikasi total asam. Hasil penelitian menunjukkan bahwa seluruh sampel—meliputi cuka apel, nanas, pir, dan jeruk—memiliki kadar etanol tidak terdeteksi (0,00%) dan kadar total asam berkisar antara 1,38% hingga 7,69%. Hal ini mengindikasikan bahwa proses fermentasi dua tahap—fermentasi alkohol yang diikuti fermentasi asetat—berlangsung secara optimal sehingga etanol yang terbentuk pada tahap awal sepenuhnya teroksidasi menjadi asam asetat. Dengan demikian, seluruh sampel memenuhi kriteria kehalalan sesuai ketentuan Fatwa MUI 2018, karena tidak melampaui batas etanol yang diperbolehkan dan tidak berasal dari khamr. Studi ini menegaskan bahwa cuka buah fermentasi yang beredar di masyarakat tergolong aman dan halal untuk dikonsumsi, sekaligus menyoroti pentingnya literasi halal berbasis data laboratorium sebagai fondasi ilmiah untuk meningkatkan kesadaran masyarakat terhadap keamanan pangan dan kepatuhan syariat.

Kata kunci: Cuka fermentasi; Kadar etanol; Total asam; Kehalalan pangan; Fatwa MUI.

INTRODUCTION

The consumption of fermented beverages has been known since the time of the Prophet Muhammad

ﷺ, one of which was nabidh—a drink prepared by soaking dates or raisins in water overnight, resulting in a sweet flavor with slight acidity (Tamizi et al., 2014). In the Prophetic era, nabidh was not consumed for intoxicating purposes, but rather valued as a nourishing and health-supporting drink. The narration of Ibn Abbas (r.a.) reports that the Prophet ﷺ prepared nabidh at the beginning of the night and would drink it in the morning, afternoon, and evening, then instructed that any remaining drink be discarded on the third night (Jamilah et al., 2022). This instruction reflects an awareness of the changing characteristics of fermented beverages and confirms that nabidh is permissible as long as it has not transformed into an intoxicating substance due to increasing alcohol content over time.

In addition to nabidh, vinegar was another widely known fermented product during the time of the Prophet ﷺ and one that even received direct praise (Khalifa et al., 2024). In a sahih narration from Jabir ibn Abdullah (r.a.), the Prophet ﷺ said, “The best condiment is vinegar” (Radhiah & Nazirah, 2018). This praise indicates that vinegar is halal, wholesome, and nutritionally beneficial, and thus recommended for consumption. Vinegar has been widely used across the world for thousands of years as an acidic condiment, and growing scientific evidence positions it not only as a culinary ingredient but also as a functional health supplement. Fruit vinegar contains essential nutrients—including amino acids, sugars, vitamins, and minerals—along with bioactive compounds such as organic acids, polyphenols, melanoidins, and tetramethylpyrazine, all of which are associated with valuable physiological effects (Xia et al., 2020). The statement influenced the practices of the Companions, who developed a strong fondness for vinegar. Classical scholars such as Al-Khattabi and Al-Qadhi Ibn Iyadh explained that the hadith encourages the use of vinegar as a simple, inexpensive, and easily accessible food. Ibn Muflih interpreted the hadith as a general commendation of vinegar without restriction to its type or form (*Al-Ādāb al-Sharʿiyyah*, Vol. 3). Jabir (r.a.) stated that he never ceased to love vinegar after hearing the hadith directly from the Prophet ﷺ, and Thalhah ibn Nafi’ reported a similar sentiment after learning it from Jabir ((An-Nawawi, n.d., Vol. 13)

From a scientific perspective, vinegar is produced through two sequential fermentation stages (Mat Isham et al., 2018). The first stage is alcoholic fermentation, during which fruit sugars are converted into ethanol by yeasts such as Saccharomyces cerevisiae. The second stage is acetic fermentation, in which ethanol is oxidized into acetic acid by acetic acid bacteria such as Acetobacter and Gluconobacter. When oxidation proceeds completely, ethanol levels decline to very low or undetectable levels, while acetic acid increases and determines the sensory characteristics and microbiological stability of vinegar (Mar et al., 2021). Thus, the biochemical formation of vinegar inherently eliminates alcohol rather than preserves it, unlike the process occurring in alcoholic beverages (Boasiako et al., 2024).

This biological distinction forms the basis of the jurisprudential discourse regarding the status of alcohol in fermented products. Some scholars maintain that the mere presence of alcohol renders a product impermissible, whereas others assert that the ruling depends on whether the product has intoxicating properties. The majority of scholars from the Shafi‘i, Maliki, and Hanbali schools uphold the principle that any intoxicating substance is prohibited in both large and small amounts (Haider, 2013), based on the sayings of the Prophet ﷺ: “Every intoxicant is khamr, and every khamr is forbidden” ((Muslim, Sahih Muslim, Hadith No. 2003)), and “Whatever intoxicates in large quantities, a small amount of it is also forbidden” (Abu Dawud, Sunan Abi Dawud, Hadis No. 3681). Conversely, the Hanafi school holds that the presence of alcohol does not automatically render a product unlawful as long as it does not reach an intoxicating level and does not originate from beverages produced for intoxication (Winarno, 2018)

The difference in scholarly opinion also extends to the permissibility of vinegar derived from khamr. According to a narration from Abu Dawud (Sunan Abi Dawud, Hadith No. 3675), when Abu Talhah asked the Prophet ﷺ about intentionally converting khamr into vinegar, he replied, “It is not permitted.” On the basis of this narration, the majority of scholars agree that deliberately converting khamr into vinegar is impermissible because it constitutes the utilization of a prohibited substance. However, vinegar that forms naturally without human intervention is unanimously regarded as lawful and pure (Wijayant & Kaukab, 2019)

In the context of the modern food industry, this jurisprudential discussion has been clarified through evidence-based fatwa approaches. Fatwa MUI No. 10 of 2018 affirms that vinegar produced through fermentation—whether natural or assisted by technological processes—is halal as long as it is not derived from khamr and the residual ethanol content in the final product does not exceed 0.5% (v/v) (Majelis Ulama Indonesia., 2018). This aligns with international Codex Alimentarius standards, which set alcohol limits in vinegar to protect consumers and ensure fairness in global food trade (Mukherjee et al., 2022). Codex was jointly developed by FAO and WHO as an international food safety standard (Vojir et al., 2012).

Accordingly, laboratory analysis of ethanol content and total acidity in fermented vinegar products is crucial not only to ensure food safety but also to validate the halal status of the products in accordance with Islamic law. The integration of scientific analysis and jurisprudential interpretation plays an important role in improving halal literacy among the public and preventing extreme attitudes—whether overly strict (tasyaddud) or excessively lenient (tasahhul) (Nandala et al., 2024). The concept of taḥawwul ṣaḥīḥ, the complete conversion of alcohol compounds into a new, non-intoxicating form, is an important basis for determining the halal status of vinegar. Previous research in Malaysia found that most vinegar products met taḥawwul ṣaḥīḥ and were halal, but two products were categorized as non-halal because the conversion process from alcohol to acetic acid was incomplete, resulting in detectable ethanol content (Harahap, et al, 2020).Based on this urgency, the present study was conducted to analyze ethanol levels and total acidity in various fermented fruit vinegars sold in the community and to compare the laboratory results with the criteria established in Fatwa MUI 2018 to determine whether these products comply with halal standards.

METHODOLOGY

This study employed a quantitative research design with a laboratory experimental approach to measure the ethanol content and total acidity of fermented vinegar beverages. A total of eight samples were analyzed, consisting of four commercial fruit vinegar products available on the market and four homemade fruit vinegar products fermented from apples, pineapples, pears, and oranges. Sampling was conducted purposively by considering the availability and popularity of fermented products commonly consumed by the public. All analyses were performed in duplicate to increase data accuracy, minimize experimental variability, and ensure consistency in measurement outcomes. Laboratory examinations were carried out at the Chemix Pratama Laboratory, Bantul, Yogyakarta.

Homemade Fruit Vinegar Preparation

The homemade fruit vinegar samples were produced through natural fermentation (see figure 1). The fruits—apple, pear, pineapple, or orange—were washed thoroughly under cold running water and then cut into small cubes to accelerate the fermentation process. The fruit pieces were placed into glass jars and submerged with water until fully covered. Subsequently, sugar was added at approximately one teaspoon (± 4 grams) per fruit, followed by gentle stirring to ensure complete dissolution and homogeneous mixing. The jars were then covered with thin cloth or clean cotton fabric and secured with rubber bands to keep the containers closed while still allowing air exchange, as limited oxygen exposure is necessary to support natural fermentation and the formation of vinegar. As an alternative procedure, the jar lids may be slightly opened on the second day to ensure an adequate oxygen supply for acetic acid–producing microorganisms

Figure 1. Fruit vinegar samples made from pineapple, pear, apple, and orange.

Alcohol Content Analysis

The ethanol content of fruit vinegar was analyzed using a distillation method followed by a colorimetric test based on the Conway microdiffusion technique, with final absorbance measurement using a UV–Vis spectrophotometer (Sumiyani et al., 2024). Approximately ±1 g of vinegar sample was weighed and diluted to a final volume of 100 mL to ensure that the ethanol concentration fell within the optimal detection range (<0.1%). The diluted sample was then subjected to Conway microdiffusion. In the Conway apparatus, 1 mL of acid dichromate solution was placed in chamber A as the trapping reagent, 1 mL of sample was loaded into chamber B, and 1 mL of saturated potassium carbonate or sodium carbonate was added to chamber C to enhance ethanol volatility, enabling its evaporation and subsequent reaction with dichromate. The Conway unit was tightly sealed, and the joint surface was coated with petroleum jelly to prevent vapor leakage during the diffusion process.

The sealed Conway unit was incubated at 80 °C for two hours with gentle shaking to ensure complete diffusion of evaporated ethanol toward the reagent chamber and allow the chromogenic reaction to progress. After incubation, the reacted dichromate solution from chamber A was removed and diluted to 10 mL in a volumetric flask. The absorbance of this solution was then measured using a UV–Vis spectrophotometer at 470 nm. The ethanol concentration in the sample was determined by comparing the measured absorbance value against a calibration curve generated from ethanol standards of graded concentrations. The final concentration was calculated using the regression equation of the calibration curve and corrected based on the dilution factor. Where necessary, the calculated concentration was converted into percent volume per volume (% v/v). This analytical protocol enables accurate and quantitative determination of ethanol in fermented fruit vinegar in accordance with internationally recognized analytical standards.

Acetic Acid Content Analysis

The acetic acid content of fruit vinegar was determined using an acid–base titration method (acidi–alkalimetry). Approximately 10 g of vinegar sample was weighed into a 250 mL Erlenmeyer flask and diluted with distilled water in a volumetric flask to a final volume of 250 mL. After homogenization, 25 mL of the diluted sample was pipetted into a 100 mL Erlenmeyer flask, followed by the addition of 3–5 drops of phenolphthalein (PP) indicator to allow color change at the titration endpoint. The solution was then titrated with 0.1 N NaOH until a stable light-pink color persisted for several seconds, indicating the completion of the reaction.

The percentage of total acidity was calculated using the following equation:

$$\%\text{Total Acidity} = \frac{\text{Titration Volume} \times \text{NaOH Normality} \times \text{Molecular Weight of Acid}}{\text{Sample Weight (mg)}} \times 100\%$$

The molecular weight (MW) of the acid was selected based on the dominant organic acid present in the sample, as each organic acid contributes differently to titration results. Common molecular weights of organic acids found in fermented products include: acetic acid (60), lactic acid (90), citric acid (70), tartaric acid (150), malic acid (116), and chlorogenic acid (354.31). Accurate selection of the corresponding MW is critical to ensure valid and representative quantification of total acidity. Using this titration approach, total acidity in fermented vinegar can be determined precisely and used as an indicator of product quality, microbiological stability, and sensory characteristics.

RESULT AND DISCUSSION

The determination of ethanol concentration in fruit vinegar using UV–Vis spectrophotometry was carried out through a standard curve–based quantification procedure. First, ethanol standard solutions with a series of graded concentrations were prepared, and the absorbance of each solution was measured using a UV–Vis spectrophotometer. The relationship between concentration (x) and absorbance (y) was then used to construct a calibration curve, yielding a linear regression equation, for example y=−0.6x+0.609 with a coefficient of determination R^2=0.9979 indicating excellent linearity between the variables. This regression equation served as the basis for calculating ethanol concentration in the test samples (See figure 2).

After establishing the calibration curve, fruit vinegar samples were filtered to remove suspended particles and diluted when necessary to ensure that the ethanol concentration fell within the linear detection range of the curve. The samples were then treated identically to the standards and their absorbance was recorded at the same wavelength using a UV–Vis spectrophotometer. The absorbance values obtained were entered into the regression equation of the calibration curve to determine the ethanol concentration in the test solution using the formula $x = \frac{0.609-y}{0.6}$. If dilution was performed during sample preparation, the calculated concentration was multiplied by the dilution factor to obtain the ethanol content in the original undiluted vinegar.

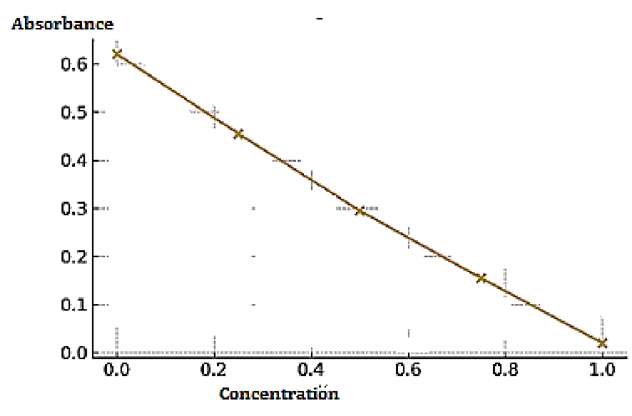

Figure 2. Ethanol quantification in fruit vinegar by UV–Vis calibration curve method.

Absolute ethanol was weighed at 125 mg and subsequently diluted to a final volume of 100 mL to obtain an ethanol stock solution with a concentration of 1 mg/mL. This concentration was derived from the calculation that ethanol, with a specific gravity of 0.8, contains 100 mg of pure ethanol in 125 mg of material; therefore, when dissolved in 100 mL of solvent, it yields an equivalent concentration of 100 mg per 100 mL, or 1 mg/mL.

This stock solution was then used to prepare ethanol standard solutions with graded concentrations, which served as the basis for generating the calibration curve in the quantitative analysis of ethanol (See table 1).

Table 1. Ethanol calibration standards and corresponding absorbance values.

Sample Code	Absorbance	Concentration (mg/mL)
S0	0.620	0.00
S1	0.455	0.25
S2	0.295	0.50
S2	0.155	0.75
S2	0.020	1.00

Laboratory analysis revealed that all eight fruit vinegar samples, both commercial and homemade contained no detectable ethanol, with measured values of 0.00% in every sample (See table 2 and table 3). These findings indicate that the two-stage fermentation process—alcoholic fermentation followed by acetic fermentation—proceeded optimally, resulting in complete oxidation of the ethanol initially produced into acetic acid as the dominant constituent of vinegar. The absence of residual ethanol in the final products confirms that all samples were far below the maximum permissible ethanol threshold stipulated by MUI Fatwa, namely ≤0.5% (v/v). Therefore, from an Islamic law perspective, all fruit vinegar samples tested meet the halal qualification standard.

In addition to ethanol content, total acidity emerged as an important differentiating parameter among the vinegar samples, with values ranging from 1.38% to 7.69%. Acidity is widely recognized as a key indicator of vinegar quality, and premium vinegar typically contains 5–6° of acidity in accordance with international quality standards The highest acidity was recorded in Tahesta Apple Vinegar (7.56–7.69%), while the lowest was observed in homemade orange vinegar (1.38–1.51%). These variations can be attributed to differences in raw material properties—particularly initial sugar content, nutrient availability, and the metabolic performance of acetic acid (Di Vincenzo et al., 2019)–producing microorganisms during fermentation. Samples with acidity levels above 4%, including Nutri Great Apple Vinegar, Tahesta Apple Vinegar, Batu Apple Vinegar, and Makkata Pineapple Vinegar, were characterized by better microbiological stability and stronger natural inhibitory effects against spoilage and pathogenic microorganisms. Conversely, the low acidity found in homemade orange vinegar is likely associated with limited fermentable sugars and suboptimal activity of acetic acid bacteria, resulting in reduced acetic acid production.

Table 2. Commercial fruit vinegar products available on the market

No	Sample Code	Total Acidity (%) Replicate 1	Total Acidity (%) Replicate 2	Ethanol (%) Replicate 1	Ethanol (%) Replicate 2
1	Nutri Great Apple Vinegar	2.7707	2.8967	Negative	Negative
2	Tahesta Apple Vinegar	7.5676	7.6938	Negative	Negative
3	Batu Apple Vinegar	2.5835	2.6465	Negative	Negative

4	Makkata Pineapple Vinegar	4.2851	4.4111	Negative	Negative

Table 3. Homemade fruit vinegar products

No	Sample Code	Total Acidity (%) Replicate 1	Total Acidity (%) Replicate 2	Ethanol (%) Replicate 1	Ethanol (%) Replicate 2
1	Pineapple Vinegar	3.5236	3.4606	Negative	Negative
2	Apple Vinegar	3.5954	3.5323	Negative	Negative
3	Pear Vinegar	3.6371	3.5117	Negative	Negative
4	Orange Vinegar	1.5118	1.3858	Negative	Negative

Further comparison between commercial and homemade fruit vinegars reveals differences not only in acidity magnitude but also in stability and consistency across replicates. Commercial products exhibited smaller variability between replicates, indicating tighter control of fermentation parameters such as oxygen availability, temperature, inoculum concentration, and fermentation duration. Industrial producers typically implement standardized fermentation protocols and controlled aeration systems, enabling high and stable conversion of ethanol into acetic acid, as demonstrated by the consistently high acidity of Tahesta Apple Vinegar. Meanwhile, variations among commercial apple vinegar brands (Nutri Great, Tahesta, and Batu) may reflect differences in fermentation cycle length, microbial strain selection, and oxygenation strategies—including hyperoxygenation, which is known to significantly increase acetic acid yield. In contrast, homemade samples demonstrated greater variation, reflecting the biological uncertainty of spontaneous, non-controlled fermentation. While homemade pineapple, apple, and pear vinegars reached moderate acidity levels (3.46–3.64%), the extremely low acidity of homemade orange vinegar highlights a limitation of domestic fermentation practices.

When both biochemical parameters—ethanol absence and total acidity—are assessed against halal requirements, all tested samples fully comply with the halal criteria set by Fatwa MUI 2018. The undetectable ethanol concentration (0.00%) in every sample confirms the absence of characteristics associated with intoxicating beverages (khamr), while the acceptable acidity range indicates that the biochemical pathways of two-stage fermentation were completed properly. Overall, these findings demonstrate that public concern regarding ethanol residues in fruit vinegar is largely unfounded when fermentation is carried out correctly. At the same time, they emphasize the importance of science-based halal education to improve public awareness of both religious compliance and food safety, while also encouraging better household fermentation practices to enhance vinegar quality, microbial stability, and shelf-life.

CONCLUSION

The results of this study showed that all fermented vinegar samples contained no detectable ethanol (0.00%), placing them far below the <0.5% threshold established by MUI Fatwa 2018 for halal beverages. The total acidity values, which ranged from 1.38% to 7.69%, further indicated that the fermentation process occurred properly and produced vinegar with good microbiological stability and desirable sensory characteristics. Taken together, the absence of ethanol and the acceptable acidity levels confirm that both commercial and homemade vinegar samples are safe and halal for consumption. These findings also address ongoing public concerns about alcohol in fermented products and underscore the need for science-based halal education to promote food safety awareness and more informed consumption within the community.

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