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Optimization of Banana Peel Vinegar Production: Effect of Vinegar Starter Concentration on Organoleptic Properties

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***Abstract*— Banana peels, a part of the fruit with numerous benefits, have not been fully utilized, leading to significant organic waste. Banana peel vinegar is a product derived from the acetic acid fermentation of banana peels. This study examined the effects of varying vinegar starter concentrations on the organoleptic characteristics of vinegar made from *kepok* banana peels (*Musa acuminata* Colla). The research employed an experimental method with a laboratory experiment approach, incorporating both qualitative and quantitative analyses. The study involved five trained panelists and 25 untrained panelists. Data were analyzed using variance analysis and were tested using *Berat Nyata Jujur* (BNJ) or Tukey's Honestly Significant Difference (HSD) test. The concentration of the vinegar starter influenced the color, aroma, and taste of banana peel vinegar. Among the four treatments, the 15% vinegar starter concentration was the most preferred by both trained and untrained panelists. The study concludes that a 15% vinegar starter concentration is optimal for producing banana peel vinegar with the most favorable organoleptic properties, making it a promising approach for reducing organic waste. Likewise, the results of this study can serve as a reference for the production of vinegar from *kepok* banana peels.**

***Keywords*— Acetic acid fermentation; banana peel vinegar; organoleptic characteristics; waste reduction**

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I. INTRODUCTION

The *kepok* banana (*Musa acuminata* Colla) is a notable variety characterized by its flattened, square-shaped fruit. It grows to about 3 meters in height, with fruit clusters ranging from 30 to 60 cm in length, and each cluster containing 10-20 bananas. These bananas, typically 10-12 cm long and weighing 80-120 g, have a thick greenish-yellow peel and a shelf life of up to 21 days at room temperature. Plants grow in various soil topographies, especially in flat lands below 500 meters above sea level with optimal soil pH levels of 4.5–7.5 and daily temperatures between 25°C and 28°C [1] [2] [3].

Globally, bananas are a crucial food crop, with production increasing from 70 million tons in 1999 to approximately 117 million tons in 2019, making them one of the most widely consumed fruits in tropical and subtropical regions. In Indonesia, the Central Statistics Agency (*Badan Pusat Statistics* or BPS) reported a production of 9.24 million tons of bananas in 2022, with East Java as the leading producer. Banana cultivation results in significant agricultural waste, with banana peels alone accounting for 35%-50% of the total fruit mass, highlighting the importance of utilizing these by-products effectively [4] [5].

Banana peels, traditionally considered waste, have been identified as valuable functional food ingredients owing to their rich content of nutrients and bioactive compounds. Studies have shown that both ripe and unripe banana peels enhance the nutritional qualities of various food products, such as bread, noodles, and meat products [6] [7]. Peels are rich in dietary fiber, polyunsaturated fatty acids, and essential minerals, making them highly beneficial for health. Moreover, banana peels contain antioxidant, antimicrobial, and anticancer properties, offering significant potential for application in the food and pharmaceutical industries [8] [9] [10].

Moreover, vinegar, derived from the French words "*vin*" (wine) and "*aigre*" (sour), is an acidic liquid produced through the natural fermentation of organic materials such as fruits and grains. Since ancient times, it has been used for various purposes, including food preservation, medicine, and hygiene, due to its antimicrobial and antioxidant properties [11] [12]. Vinegar from *kepok* banana peels (*Musa acuminata* Colla) is produced through a fermentation process that involves converting alcohol into acetic acid using bacteria like *A. aceti*, which gives vinegar its characteristic sour taste [13] [14].

The production of vinegar from *kepok* banana peels involves two stages of fermentation: alcohol fermentation using yeast (*Saccharomyces cerevisiae*) and acetic acid fermentation with *A. aceti*. Alcohol fermentation occurs under anaerobic conditions, in which yeast convert sugars to ethanol. The ethanol is then oxidized into acetic acid by *A. aceti* in the presence of oxygen, which is crucial for the growth and successful production of vinegar [15] [16] [17]. The result is a vinegar rich in organic acids, which contribute to its therapeutic properties.

Banana peel vinegar is a promising product with multiple health benefits, largely due to the bioactive compounds found in banana peels, such as carotenoids, polyphenols, and dietary fiber [18] [19]. These compounds have antioxidant, anti-inflammatory, and anticancer properties, making banana peel vinegar a valuable ingredient in health and nutrition. Additionally, the acetic acid in vinegar enhances the absorption of essential minerals like calcium and iron, supports digestive health, and offers potential prebiotic benefits by promoting the growth of beneficial gut bacteria [20] [21].

Furthermore, organoleptic testing is a sensory evaluation method used to assess food materials based on user preferences, utilizing the human senses to determine the quality and acceptability of a product [22] [23]. This testing involves panelists who provide feedback on sensory properties such as visual appearance, aroma, texture, taste, and overall impression, which are crucial in determining whether a product meets consumer expectations. The process includes stages like material acceptance, recognition, and a detailed description of sensory attributes to ensure the product's quality, safety, and consumer acceptance [24].

The characteristics of organoleptic testing include evaluating food products through the human senses, assessing product samples, and analyzing various sensory attributes by trained and untrained panelists. This method plays a critical role in understanding consumer perceptions and ensuring that products are suitable for consumption and successful in the market [25]. Through this comprehensive evaluation, organoleptic testing minimizes risks in decision-making related to food product development and marketing.

Research conducted by Nurismanto [26], using varying concentrations of *A. acetic* inoculum in the production of vinegar from the peels of *kepok* banana (*Musa acuminata* Colla) and *melinjo* (*Gnetum*) leaves, yielded an acetic acid content of 4.325%, a pH of 3.350, alcohol content of 0.380%, total sugar of 0.255%, and total dissolved solids of 4.650 Brix. This demonstrates satisfactory production with a total *A. acetic* inoculum concentration of 15% and a fermentation period of 10 days. Another study by Wusnah [27] found that a 10-day fermentation period with the addition of 40 milliliters (10%) of *A. acetic* starter produced the highest acetic acid concentration in arabica coffee liquid, reaching 65.25 grams per liter. The differences in approach between the studies of Nurismanto [26] and Wusnah [27] regarding the concentration of *A. acetic* inoculum and fermentation time provide valuable information on the acetic acid content in vinegar made from the peels of *kepok* bananas, *melinjo* leaves, and arabica coffee liquid [28] [29].

This present study offers significant novelty by focusing on the exploration of the potential of *kepok* banana peels (*Musa acuminata* Colla) as raw material in the production of vinegar. Although banana peels are often considered organic waste, this study highlights the added value of this material by producing vinegar that could offer potential benefits. The variation in the vinegar starter concentrations used in this study identified the organoleptic characteristics of banana peel vinegar. Through this approach, the study not only contributes to sustainable banana waste management but also opens new opportunities for the development of banana peel-based products that could enhance economic value and public health. By incorporating organoleptic characteristics, this research provides a comprehensive view of the consumer acceptance of banana peel vinegar, which could serve as a foundation for future sustainable product development.

II. MATERIAL AND METHODS

A. Materials

This study employed a laboratory experiment approach, using both qualitative and quantitative methods [30]. The research design was completely randomized design (CRD) with four treatments and five replicates per treatment, resulting in 20 experimental units [31]. The treatments included a control using commercial vinegar and three variations of vinegar concentrate, following a modified method from Nurismanto [26] with concentrations of 5%, 10%, and 15%, and fermentation periods of 7 days with *Saccharomyces cerevisiae* and 10 days with vinegar concentrate. The treatments are described as follows:

- P1: Commercial vinegar (Apple Vinegar)
- P2: 7-day fermentation with *Saccharomyces cerevisiae* + 5% vinegar concentrate, followed by fermentation for 10 days.
- P3: 7-day fermentation with *Saccharomyces cerevisiae* + 10% vinegar concentrate, fermented for 10 days.
- P4: 7-day fermentation with *Saccharomyces cerevisiae* + 15% vinegar concentrate, followed by fermentation for 10 days.

The equipment used include a blender (AMB GF400), digital scale (SF 400), sieve (12 cm diameter), measuring glass (1 liter), Erlenmeyer flask (250 ml), beaker glass (1 liter), glass stirrer (20 cm), aluminum foil (3 meters), and incubator (IN55).

B. Methods

The banana peels were sourced from Neusu Aceh, Banda Aceh, Aceh Province, Indonesia. 250 g of young green peels were boiled for 15 min, blended, and filtered to obtain the filtrate. This was mixed with 750 ml of water and 50 g of sugar, pasteurized it at 65°C for 15 min, and then 2.5 grams of *Saccharomyces cerevisiae* (1% of the total weight) was added. The mixture was fermented anaerobically at room temperature for 7 days, then divided into three portions, and 5%, 10%, and 15% vinegar concentrates were added. The mixture was further fermented aerobically for 10 days. After fermentation, the solution was pasteurized in an incubator at 65°C for 30 min, filtered, and stored in sterile bottles at 4°C [32].

The testing of the vinegar was conducted at the Chemistry Education Laboratory, Faculty of Teacher Training and Educaiton, Universitas Syiah Kuala, Indonesia, adhering to national standards (SNI 01-4371, 1996) which stipulate a pH of 3-4 and alcohol content not exceeding 10%. The pH was measured using a pH meter, the acetic acid content was analyzed by alkalimetric titration with NaOH, and the alcohol content was determined using Gas Chromatography-Mass Spectrometry (GC-MS) [33].

The procedure for the organoleptic testing of *kepok* banana peel vinegar started with the acceptability test involving 25 untrained panelists from the faculty and 5 trained panelists from the Family Welfare Education Study Program at Universitas Syiah Kuala. The untrained panelists were briefed on the scoring This research was conducted at the Biology Education Laboratory and Chemistry Education Laboratory of the faculty at Universitas Syiah Kuala. The vinegar were based on taste, aroma, color, and overall acceptability, following the parameters outlined by Aryani et al [7].

Research Parameters: The parameters observed in this study include the acetic acid content, pH level, alcohol content, and organoleptic attributes (color, aroma, taste, and acceptability) of the *kepok* banana peel vinegar.

Data Collection Technique: Data on panelists' preferences were collected using a hedonic scale questionnaire and divided into descriptive and preference tests. Panelists evaluated four vinegar samples: commercial vinegar (apple vinegar) and kepok banana peel vinegar with 5%, 10%, and 15% concentrations of vinegar. The questionnaire was adapted to the hedonic scale and organoleptic test table as per SNI 2729:2013 (BSN, 2013).

Data Analysis Technique: Organoleptic data (color, aroma, taste, and acceptability) were analyzed using Analysis of Variance (ANOVA) at a 1% significance level for CRD. The general ANOVA formula was used as per Hanafiah [34], and the research hypothesis was tested by comparing F-values to determine significant differences. If significant differences were found, further tests were conducted using Duncan's multiple range test (DMRT), Least Significant Difference (LSD), or Honest Significant Difference (HSD), depending on the coefficient of variation (CV).

III. Results and Discussion

Based on the conducted research, variations in the addition of vinegar starter to *kepok* banana peel vinegar affect its organoleptic characteristics. The effect of adding vinegar starter on organoleptic properties, including color, aroma, taste, and overall acceptability, is described below.

A. Color Evaluation of Kepok Banana Peel Vinegar

The highest average descriptive score for the color of *kepok* banana peel vinegar was obtained in the P3 treatment (*kepok* banana peel vinegar with 10% vinegar starter concentration) with an average score of 7.58. Other descriptive color evaluations of *kepok* banana peel vinegar showed that P1 (commercial/apple vinegar) had an average score of 4.23, P2 (*kepok* banana peel vinegar with 5% vinegar starter concentration) had an average score of 7.07, and P4 (*kepok* banana peel vinegar with 15% vinegar starter concentration) had an average score of 7.50. The average descriptive color scores are presented in Figure 1.

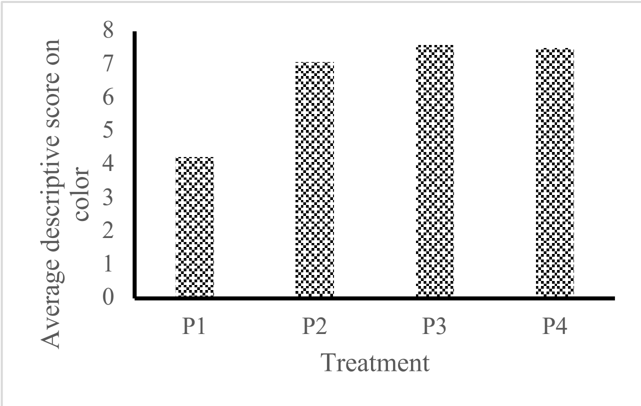

Fig. 1 Average descriptive scores for the color of *kepok* banana peel vinegar. Key: P1 (commercial/apple vinegar), P2 (*kepok* banana peel vinegar with 5% vinegar starter concentration), P3 (*kepok* banana peel vinegar with 10% vinegar starter concentration), and P4 (*kepok* banana peel vinegar with 15% vinegar starter concentration)

The ANOVA results show that $F_{calculated} > F_{table}$, i.e., 3184.33 > 3.24. This indicates that the vinegar starter concentration influences the color of *kepok* banana peel vinegar.

The post hoc test was the Honest Significant Difference (HSD) test (CI = 0.95%). The HSD test results are presented in Table 1. Based on Table 1, the HSD test results for the descriptive color analysis of *kepok* banana peel vinegar show that P1 differs significantly from P2, P3, and P4. P2 differed significantly from P1, P3, and P4. P3 differed significantly from P1 and P2 but did not differ significantly from P4. P4 differed significantly from P1 and P2 but did not differ significantly from P3. The lowest average descriptive score for color was found in the P1 treatment, whereas the highest was found in the P3 treatment.

TABLE 1

HSD TEST RESULTS FOR DESCRIPTIVE COLOR ANALYSIS OF *KEPOK* BANANA PEEL VINEGAR

Treatment	Average	Std Dev.	Notation
P1	4.23	0,10	a
P2	7.07	0,03	b
P4	7.50	0,05	c
P3	7.58	0,04	c

The highest average preference score for color was found in the P1 treatment with an average score of 6.58. The highest average preference score for the color of *kepok* banana peel vinegar was obtained for P2, with an average score of 6.04. Other preference evaluations for the color of *kepok* banana peel vinegar showed that P3 had an average score of 6.02, and P4 had an average score of 5.65. The average preference scores for color are presented in Figure 2.

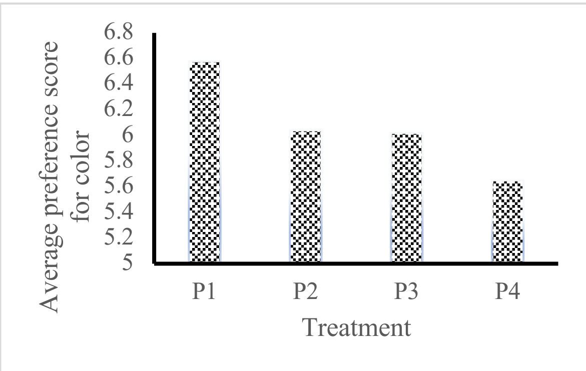

Fig. 2 Average preference scores for the color of kepok banana peel vinegar

The ANOVA results show that $F_{calculated} > F_{table}$, i.e., 360.59 > 3.24. This indicates that varying the vinegar starter concentration influences the preference for *kepok* banana peel vinegar color.

The post hoc test was the Honest Significant Difference (HSD) test (CI = 0.74%). The HSD test results are presented in Table 2. Based on Table 2, the HSD test results for the color preference analysis of *kepok* banana peel vinegar show that P1 differs significantly from P2, P3, and P4. P2 differed significantly from P1 and P4 but did not differ significantly from P3. P3 differed significantly from P1 and P4 but did not differ significantly from P2. P4 differed significantly from P1, P2, and P3. The lowest average preference score for color was found in the P4 treatment, whereas the highest score was found in the P1 treatment.

TABLE 2

HSD TEST RESULTS FOR COLOR PREFERENCE ANALYSIS OF *KEPOK* BANANA PEEL VINEGAR

Treatment	Average	Std Dev.	Notation
P4	5.65	0,07	a
P3	6.02	0,03	b
P2	6.04	0,04	b
P1	6.58	0,01	c

B. Aroma Evaluation of Kepok Banana Peel Vinegar

The highest average descriptive score for aroma was found in the P1 treatment with an average score of 7.51. The highest average descriptive score for the aroma of *kepok* banana peel vinegar was obtained for P4, with an average score of 6.37. Other descriptive aroma evaluations of *kepok* banana peel vinegar showed that P2 had an average score of 5.56, and P3 had an average score of 6.18. The average descriptive scores for aroma are presented in Figure 3.

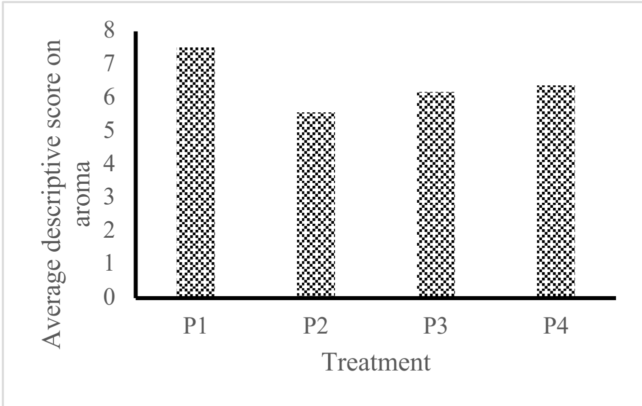

Fig. 3 Average descriptive scores for the aroma of *kepok* banana peel vinegar

The ANOVA results show that $F_{calculated} > F_{table}$, i.e., 1668.36 > 3.24. This indicates that the vinegar starter concentration influences the aroma of *kepok* banana peel vinegar.

The follow-up test was the Honest Significant Difference (HSD) test (KK = 0.68%). The results of the HSD test are presented in Table 3. Based on Table 3, the HSD test results for the descriptive aroma of *kepok* banana peel vinegar indicate that P1 significantly differed from P2, P3, and P4. P2 differed significantly from P1, P3, and P4. P3 differed significantly from P1, P2, and P4. P4 significantly differed from P1, P2, and P3. The lowest average descriptive aroma rating for *kepok* banana peel vinegar was found in treatment P2, while the highest average rating was found in treatment P1.

TABLE 3

THE HONEST SIGNIFICANT DIFFERENCE (HSD) TEST OF THE DESCRIPTIVE AROMA OF *KEPOK* BANANA PEEL VINEGAR

Treatment	Average	Std Dev.	Notation
P2	5.29	0,02	a
P3	5.76	0,06	b
P4	6.41	0,05	c
P1	7.96	0,04	d

The highest mean preference score for the aroma of *kepok* banana peel vinegar was obtained for P2, with a mean score of 5.72. Other preference scores for the aroma of *kepok* banana peel vinegar were as follows: P1, with a mean score of 4.13; P3, with a mean score of 5.38; and P4, with a mean score of 5.68. The average preference scores for aroma are shown in Figure 4.

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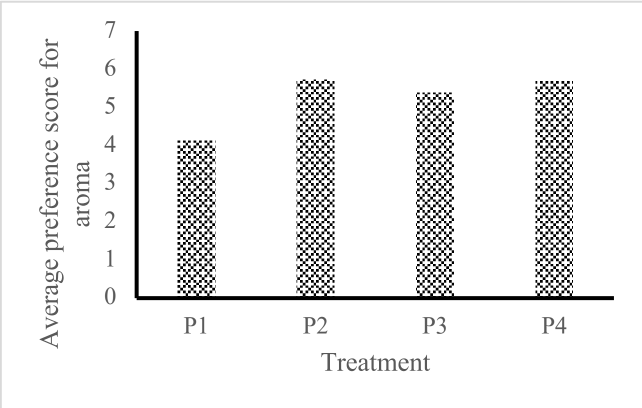

Fig. 4 Average preference scores for the aroma of *kepok* banana peel vinegar

The ANOVA results indicate that the calculated F-value exceeds the F-table value, specifically, 1795.70 > 3.24. This indicates that the addition of varying concentrations of the vinegar mother to *kepok* banana peel vinegar significantly affects the aroma.

The follow-up test was the Honest Significant Difference (HSD) test (KK = 0.75%). The results of the HSD test are presented in Table 4. Based on Table 4, the HSD test results for the aroma preference of *kepok* banana peel vinegar indicate that P1 significantly differed from P2, P3, and P4. P2 significantly differed from P1 and P3, but did not significantly differ from P4. P3 differed significantly from P1, P2, and P4. P4 significantly differed from P1 and P3 but did not significantly differ from P2. The lowest average preference rating for *kepok* banana peel vinegar was found in P1 treatment, while the highest average rating was found in P2 treatment.

TABLE 4

THE HONEST SIGNIFICANT DIFFERENCE (HSD) TEST OF THE AROMA PREFERENCE OF *KEPOK* BANANA PEEL VINEGAR

Treatment	Average	Std Dev.	Notation
P1	4.13	0,02	a
P3	5.38	0,04	b
P4	5.68	0,04	c
P2	5.72	0,04	c

C. Flavor Evaluation of Kepok Banana Peel Vinegar

The highest mean descriptive rating for flavor was found for treatment P1, with a mean score of 7.96. The highest mean descriptive rating for the flavor of *kepok* banana peel vinegar was found in treatment P4, with a mean score of 6.41. Other descriptive ratings for the flavor of *kepok* banana peel vinegar were as follows: P2 with a mean score of 5.29, and P3 with a mean score of 5.76. The average descriptive scores for flavor are shown in Figure 5.

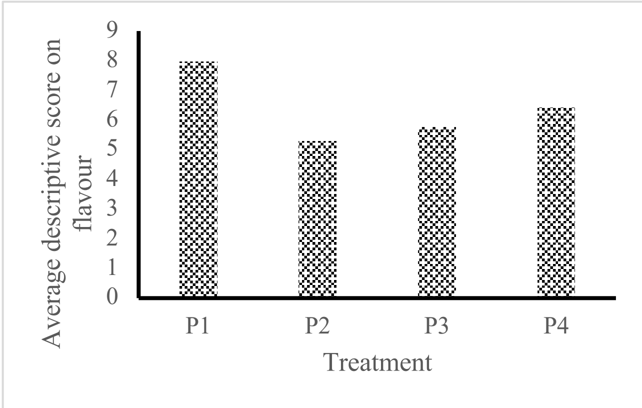

Fig. 5 Average descriptive scores for the flavor of *Kepok* banana peel vinegar

The ANOVA results indicate that the calculated F-value exceeds the F-table value, specifically, 3594.18 > 3.24. This indicates that the addition of varying concentrations of vinegar mother to *kepok* banana peel vinegar significantly affects the flavor.

The follow-up test was the Honest Significant Difference (HSD) test (KK = 0.68%). The results of the HSD test are presented in Table 5. Based on Table 5, the HSD test results for the descriptive flavor of *kepok* banana peel vinegar indicate that P1 significantly differed from P2, P3, and P4. P2 differed significantly from P1, P3, and P4. P3 differed significantly from P1, P2, and P4. P4 significantly differed from P1, P2, and P3. The lowest average descriptive flavor rating for *kepok* banana peel vinegar was found in P2 treatment, while the highest average rating was found in P1 treatment.

TABLE 5

THE RESULTS OF THE HONEST SIGNIFICANT DIFFERENCE (HSD) TEST FOR THE DESCRIPTIVE FLAVOR OF *KEPOK* BANANA PEEL VINEGAR

Treatment	Average	Std Dev.	Notation
P2	5.29	0,04	a
P3	5.76	0,04	b
P4	6.41	0,05	c
P1	7.96	0,05	d

The average preference score for the flavor of *kepok* banana peel vinegar was highest for P4, with an average score of 5.52. Other preference scores for the flavor of *kepok* banana peel vinegar are as follows: P1, with an average score of 4.43; P2, with an average score of 5.15; and P3, with an average score of 5.21. The average preference scores for flavor are shown in Figure 6.

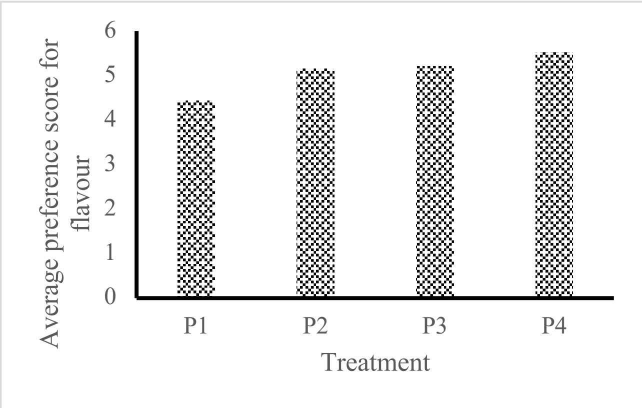

Fig. 6 Average preference scores for the flavor of *kepok* banana peel vinegar

The ANOVA results indicate that the F-value (221.81) is greater than the F-table value (3.24), which suggests a significant effect of varying concentrations of mother vinegar on the flavor of *kepok* banana peel vinegar.

Post hoc testing using Honest Significant Difference (HSD) test (KK = 0.68%) results are presented in Table 6. According to Table 6, the HSD test revealed significant differences in flavor preference between P1 and P2, P3, and P4. P2 significantly differed from P1 and P4, but not from P3. P3 significantly differed from P1 and P4, but not from P2. P4 differed significantly from P1, P2, and P3. The lowest average flavor preference score is for P1, while the highest average score is for P4.

TABLE 6

HONEST SIGNIFICANT DIFFERENCE (HSD) TEST RESULTS OF FLAVOR PREFERENCE IN *KEPOK* BANANA PEEL VINEGAR

Treatment	Average	Std Dev.	Notation
P1	4.43	0,07	a
P2	5.15	0,05	b
P3	5.21	0,08	b
P4	5.52	0,07	c

D. Acceptance Assessment of Kepok Banana Peel Vinegar

The highest average acceptance score for *kepok* banana peel vinegar was recorded for P4, with an average score of 6.00. The other acceptance scores for *kepok* banana peel vinegar were as follows: P1, with an average score of 5.03; P2, with an average score of 5.61; and P3, with an average score of 5.29. The descriptive average acceptance scores are illustrated in Figure 7.

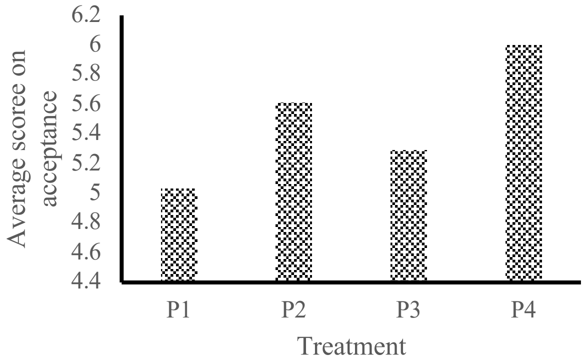

Fig. 7 Average acceptance scores of *kepok* banana peel vinegar

The ANOVA results show that the F-value (458.27) is greater than the F-table value (3.24), indicating a significant effect of varying concentrations of mother vinegar on the acceptance of *kepok* banana peel vinegar.

Post hoc testing using the Honest Significant Difference (HSD) test (KK = 0.79%) results are presented in Table 7. According to Table 7, the HSD test revealed significant differences in acceptance between P1 and P2, P3, and P4. P2 differed significantly from P1, P3, and P4. P3 differed significantly from P1, P2, and P4. P4 differed significantly from P1, P2, and P3. The lowest average acceptance score is for P1, while the highest average score is for P4.

TABLE 7

HONEST SIGNIFICANT DIFFERENCE (HSD) TEST RESULTS OF *KEPOK* BANANA PEEL VINEGAR ACCEPTANCE

Treatment	Average	Std Dev.	Notation
P1	5.03	0,05	a
P3	5.29	0,03	b
P2	5.61	0,04	c
P4	6.00	0,05	d

E. Acetic Acid Content, pH Level, and Alcohol Content of Kepok Banana Peel Vinegar

The acetic acid content in *kepok* banana peel vinegar for treatment P2 was 3.98%, with a pH level of 5.3 and an alcohol content of 5.45%. For treatment with P3, the acetic acid content was 10.12%, the pH was 5.1, and the alcohol content was 8.31%. For treatment with P4, the acetic acid content was 9.69%, the pH was 4.5, and the alcohol content was 5.12%.

F. Discussion

The present study found that varying the concentration of mother vinegar during the production of *kepok* banana peel vinegar affects its organoleptic characteristics, including color, aroma, taste, and overall acceptance.

Panel assessments of the color of *kepok* banana peel vinegar were categorized into descriptive and preference tests. The descriptive evaluation ranged from deep cream to pale brown. The descriptive organoleptic test yielded a score of 6.59 (brownish cream). The average score for P1 (commercial/apple vinegar) as the control was 4.32 (pale brown cream), while the average scores for *kepok* banana peel vinegar with varying concentrations of mother vinegar were 7.38 (pale cream) for treatments P2, P3, and P4. The color of *kepok* banana peel vinegar and commercial vinegar showed distinct gradients, with commercial vinegar being darker due to the use of apples in its production.

In the preference test, ranging from 'very much liked' to 'very much disliked', the average score for *kepok* banana peel vinegar was 6.07 ('somewhat liked'). The control (P1, commercial/apple vinegar) had an average score of 6.58 ('somewhat liked'), while the average scores for *kepok* banana peel vinegar treatments P2, P3, and P4 were 5.90 ('neutral').

Aroma assessments were also divided into descriptive and preference tests. The descriptive evaluation ranged from highly characteristic of acetic acid to not characteristic at all. The descriptive organoleptic score for aroma was 6.40 ('somewhat characteristic of acetic acid'). The average score for P1 as the control was 7.51 ('characteristic of acetic acid'), whereas *kepok* banana peel vinegar treatments P2, P3, and P4 had an average score of 6.03 ('somewhat characteristic of acetic acid'). The aroma of *kepok* banana peel vinegar differed from that of commercial vinegar, with the latter exhibiting a more pronounced acetic acid scent due to its higher pH level. In the aroma preference test, ranging from 'very much liked' to 'very much disliked', the average score was 5.23 ('neutral'). For P1, the score was 4.13 ('somewhat disliked'), while treatments P2, P3, and P4 had an average score of 5.59 ('neutral').

Taste assessments were categorized into descriptive and preference tests. The descriptive evaluation ranged from very acidic to not acidic at all. The descriptive organoleptic score for taste was 6.35 ('somewhat acidic'). The average score for P1 as the control was 7.96 ('acidic'), while the average score for *kepok* banana peel vinegar with varying concentrations were 5.82 ('neutral'). Commercial vinegar had a higher acidity compared to *kepok* banana peel vinegar. In the taste preference test, ranging from very much liked to 'very much disliked', the average score was 5.08 ('neutral'). For P1, the score was 4.43 ('somewhat disliked'), while treatments P2, P3, and P4 had an average score of 5.29 ('neutral').

Overall acceptance assessments ranged from 'very much liked' to 'very much disliked'. The average organoleptic score for acceptance was 5.48 ('neutral'). The control (P1) had an average score of 5.03 ('neutral'), while treatments P2, P3, and P4 had an average score of 5.63 ('neutral'). The highest acceptance score among the *kepok* banana peel vinegars was for P4, with an average score of 6.00 ('somewhat liked').

Nevertheless, fruit vinegars are best consumed after three months of production to optimize nutrition and flavor. After three months of storage, the pH level in vinegar may increase, making it more acidic [35]. Davies et al. [36] recommend storing vinegar in glass bottles or containers due to its high acidity, which can react with plastic or metal. Glass is a non-reactive material that does not alter the quality and content of vinegar. Antoniewicz et al. [37] found that fruit vinegar should be stored in a dark place, away from sunlight, at room temperature (24°C) or in the refrigerator (4°C). These measures help maintain stable pH levels and prevent mold or microorganism growth [38,39]. Lower acidity levels in vinegar increase the likelihood of mold formation on the liquid surface

IV. CONCLUSION

This study demonstrated that varying the concentration of mother vinegar during the production of *kepok* banana peel vinegar significantly affects its organoleptic properties, including color, aroma, taste, and overall acceptance. The highest acceptance and preference were observed for a 15% mother vinegar concentration, which achieved better sensory scores compared to lower concentrations of and commercial vinegar. These findings emphasize the potential of *kepok* banana peel vinegar as a viable alternative to commercial apple vinegar, with notable sensory qualities that can be optimized by adjusting the mother vinegar concentration.

CONFLICT OF INTEREST

Authors declare no conflict of interest to disclose.

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