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Fermentation Time-Dependent Changes in Bioactive Compounds and Physicochemical Properties of Starfruit (*Averrhoa carambola* L.) Kombucha

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Abstract

Background: *The rising prevalence of hypertension drives the development of local functional beverages. Starfruit (Averrhoa carambola L.) is a potential kombucha raw material due to its vitamin C and antioxidants, which increase through fermentation. This study analyzes the rarely researched effect of fermentation duration on starfruit kombucha's biochemical traits.* **Methodology:** *An experimental Completely Randomized Design (CRD) evaluated 4, 6, and 8-day fermentation durations with two replications. Fermentation occurred at room temperature (20-27°C) using SCOBY (Symbiotic Culture of Bacteria and Yeast). Tested parameters included vitamin C (iodometric titration), antioxidant activity (DPPH), alcohol content (alcoholmeter), and pH. Data were analyzed using descriptive quantitative methods.* **Findings:** *Longer fermentation increased vitamin C, antioxidant activity, and alcohol content, but decreased pH due to rising acidity. The 8-day fermentation yielded optimal bioactivity: 167.405 mg/100g vitamin C, 80.630% antioxidant activity, and the lowest pH (4.470). However, its alcohol content reached 0.584%, slightly exceeding the 0.5% non-alcoholic limit. Thus, fermentation duration significantly alters the biochemical profile of starfruit kombucha. While an 8-day fermentation maximizes bioactive compounds, process optimization is needed to reduce alcohol levels to meet food safety standards.* **Contribution:** *The novelty of this research lies in assessing starfruit kombucha's biochemical characteristics across varying fermentation durations, an area rarely reported previously.*

Keywords: *Antioxidant; Fermentation; Functional Beverage; Starfruit Kombucha; Vitamin C*

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INTRODUCTION

Increasing public awareness of a healthy lifestyle has driven a rise in the consumption of functional foods, particularly fermented beverages that serve as a preventive measure and a source of nutrition. As reported by the Basic Health Survey conducted by Ministry Health of the Republic Indonesia (2023), the prevalence of hypertension in Indonesia is estimated to be between 34.1% and 36%. This finding highlights the necessity for nutritional interventions. Manongga et al., (2024) further corroborate this by asserting that the intake of functional beverages may positively influence cardiovascular and metabolic health. One of the fermented beverages with potential as a functional drink is kombucha. Through the activity of bacteria and yeast during the fermentation process, kombucha is enriched with B vitamins, organic acids, and various bioactive compounds (Riswanto & Rezaldi, 2021). The bioactive compounds produced from kombucha fermentation have the ability to regulate blood pressure, thereby showing potential as a preventive agent in reducing the prevalence of hypertension (Anantachoke et al., 2023). The content of these bioactive compounds makes kombucha a prospective fermented beverage with health benefits and a favorable level of acceptability among the public (Cardoso et al., 2020).

Kombucha is traditionally produced through the fermentation of tea using a symbiotic consortium of microorganisms consisting of bacteria and yeast, known as the Symbiotic Culture of Bacteria and Yeast (SCOBY). This culture acts as the primary inoculum, where the symbiotic activity and substrate biotransformation among the microbes produce a distinct metabolic profile that imparts a specific sour taste and aroma (Rezaldi et al., 2021). The complex microbial community within SCOBY facilitates a series of biochemical reactions that gradually transform the liquid substrate (Antolak et al., 2021).

The functional characteristics of kombucha are supported by its abundant profile of bioactive compounds, particularly the phenolic group, which significantly contributes to antioxidant activity (Putri et al., 2023). Antioxidant activity can be optimized through the addition of fruit, which not only promotes an increased accumulation of essential metabolites, such as total phenols and organic acids, but also enriches the sensory characteristics and functional value of the beverage (Suciati et al., 2025). Furthermore, the increase in antioxidant activity is associated with the biosynthesis of derivative compounds during the fermentation process, including organic acids and vitamin C, which play a crucial role as natural free radical-scavenging compounds (Wahyuningtias et al., 2023).

Starfruit (*Averrhoa carambola*) is a tropical fruit rich in micronutrients, including vitamin A, vitamin C, oxalic acid, and potassium (Sumiasih & Nurainani, 2023). The potassium content in starfruit (*Averrhoa carambola* L.) plays a role in lowering blood pressure, which can help prevent hypertension (Legi et al., 2020). In addition, starfruit (*Averrhoa carambola* L.) contains various types of phytochemical compounds that play important roles, such as flavonoids, terpenoids, and saponins. This group of phytochemical compounds exhibits significant antioxidant activity, playing a crucial role in neutralizing free radicals to prevent oxidative stress. Based on various studies, this oxidative imbalance has been identified as a major trigger in the

pathogenesis of non-communicable degenerative diseases, including hypertension (Yuniar et al., 2025).

The kombucha fermentation process involves the bioconversion of substrates into various secondary metabolites, primarily ethanol and organic acids such as lactic acid (Nasution & Nasution, 2022). The main carbon source conventionally used as a substrate in this process is sucrose (Rezaldi et al., 2022). As a substitute for sucrose, various alternative sweeteners such as palm sugar, stevia, and coconut sugar (gula jawa) can be utilized (Rodhiyah et al., 2024). Coconut sugar, obtained from the sap of male coconut flower clusters, not only functions as an energy source for microbial activity but also imparts distinctive sensory characteristics to the final product (Fadhilah et al., 2023). Sugar concentration, tea intensity, the amount of starter, and fermentation duration are among the critical variables that influence the changes in physical and chemical properties during the fermentation process (Puspaningrum et al., 2022).

The fermentation duration affects physicochemical characteristics, including pellicle biomass, viscosity, pH value, total titratable acidity, and ethanol content. An excessively long fermentation can lead to the conversion of alcohol into acetic acid (Sulistiawaty & Solihat, 2022). During the fermentation process, the enzymatic activity of microorganisms can increase the accumulation of bioactive compounds such as phenolics and vitamins. A fermentation that is too short can result in the suboptimal synthesis of bioactive metabolites, whereas a fermentation that is too long potentially degrades organoleptic quality due to an increase in acidity and a decrease in the levels of bioactive compounds (Sarmila & Romadhan, 2025). Research by Li et al., (2022) indicates that fermentation duration affects the antioxidant activity, phenolic content, and quality of tea- and fruit-based kombucha. The best results were obtained in kombucha fermented for 6 to 7 days at a temperature of 25–30 °C.

Research regarding the quality parameters of starfruit (*Averrhoa carambola* L.) kombucha treated with variations in fermentation duration remains limited. Previous studies on starfruit kombucha have focused more on introducing the benefits and nutritional content of starfruit, as well as increasing public knowledge regarding its potential to help boost immunity and support the community's economy in Ponggok Village (Juwita et al., 2025). Meanwhile, the utilization of starfruit in the community is still relatively limited, as it is generally only consumed directly as fresh fruit. Therefore, this study was conducted to determine the effect of variations in fermentation duration on the quality of starfruit (*Averrhoa carambola* L.) kombucha, as an effort to optimize the utilization of local harvests into functional beverages.

METHOD

Research Design

This study is an experimental research utilizing a single-factor Completely Randomized Design (CRD) based on fermentation duration (4, 6, and 8 days) with two replications. The sample used in this study was starfruit (*Averrhoa carambola* L.) kombucha subjected to treatments of varying fermentation durations. The observed parameters included antioxidant content, vitamin C, pH value, and alcohol content. This research was conducted from December 2025. The preparation of the starfruit

kombucha and the measurement of pH values were carried out at the Microbiology Laboratory of the Faculty of Teacher Training and Education, Universitas Muhammadiyah Surakarta. Fermentation was conducted in a glass cabinet at room temperature, ranging from 20 °C to 27 °C, to serve as an environmental control during the fermentation process. Tests for vitamin C content, antioxidant activity, and alcohol content were performed at the Chem-Mix Pratama Laboratory, Yogyakarta.

Tools and Materials

The equipment used included an oven, filter bags, basins, a digital balance, measuring cylinders, glass jars, knives, aluminum foil, spatulas, pipettes, Erlenmeyer flasks, volumetric flasks, a centrifuge, test tubes, and an alcoholmeter. Meanwhile, the materials used in this study were starfruits, green tea, boiling water, coconut sugar (*gula jawa*), SCOBY starter, SCOBY culture, 0.01 N standard iodine solution, distilled water, 1% starch, ethanol, stock solution, 1,1-diphenyl-2-picrylhydrazyl (DPPH) solution, and methanol.

Procedure

Sterilization of Tools and Materials

Equipment sterilization was carried out using boiling water as a simple sterilization method. All instruments used in the study were submerged in boiling water and left for approximately 4 minutes to ensure their cleanliness and to minimize the potential for microbial contamination that could affect the fermentation process and test results (Fitri & Ambarwati, 2024). The use of boiling water was chosen because it is more practical and efficient for sterilizing a large quantity of research equipment compared to using an autoclave, which requires more time and has a limited sterilization capacity.

Starfruit Drying

The starfruits were thoroughly washed and then cut into several pieces. Next, the starfruit slices were arranged on an oven tray lined with aluminum foil and dried in an oven at 60 °C for 72 hours (Wardani & Handrianto, 2019).

Making Starfruit Kombucha

A volume of 3 liters of water was poured into a pot and brought to a boil. Then, 15 grams of green tea and 15 grams of dried starfruit, which had been placed inside a 13 x 18 cm filter bag, were added. Following this, 300 grams of coconut sugar (*gula jawa*) were added to the boiling mixture. The solution was allowed to cool to room temperature, reaching an initial pH of 5, and then 250 mL of the solution was transferred into glass jars. The sugar concentration used was 10% (w/v). This study applied treatments varying in fermentation duration, namely 4, 6, and 8 days, with each treatment performed in duplicate, resulting in a total of 6 treatment units. Next, 3 grams of SCOBY and approximately 1 mL of SCOBY starter were added to each fermentation jar. The ratio of SCOBY to the volume of the fermentation solution was 1.2 % (w/v). The fermentation vessels were then placed in a glass cabinet and

fermented at room temperature (20 °C – 27 °C) according to the respective fermentation duration of each treatment.

Vitamin C Content Testing

The sample, which had been homogenized using a blender, was weighed at 5–10 grams and placed into a 100 mL Erlenmeyer flask. Next, distilled water (*aquadest*) was added using a volumetric flask until the volume reached 100 mL. The sample was then filtered using filter paper, and a 25 mL aliquot of the clear filtrate was collected, followed by the addition of 2 mL of 1% starch indicator. The solution was titrated against a 0.01 N standard iodine solution until a color change to blue occurred, and the titration volume obtained was recorded (Putra et al., 2021). Prior to use, the iodine solution was standardized using a standard sodium thiosulfate solution to ensure that the concentration of the solution conformed to the designated value. Method validation was performed through replicate titrations to obtain consistent and accurate results. The percentage of vitamin C content was calculated using the formula (Rahayuningsih et al., 2022).

$$\text{Vitamin C content (mg/100g)} = \frac{ml\ iod\ x\ 0.88\ x\ fp}{Ws\ (gram)}\ x\ 100\% \quad \text{..... (1)}$$

Antioxidant Level Testing

A total of 1 gram of the sample was weighed and then dissolved in ethanol at a specific concentration. Subsequently, 1 mL of this stock solution was transferred into a test tube, to which 1 mL of DPPH solution at a concentration of 200 µg/mL was added. The mixture was then diluted with methanol to a final volume of 5 mL and incubated for 30 minutes in the dark. A blank was also prepared (1 mL of DPPH solution + 4 mL of methanol). After incubation, the absorbance was measured at a wavelength of 517 nm. The absorbance data were analyzed to determine the percentage of free radical inhibition as an indicator of antioxidant activity using the following formula (Rindiani & Suryani, 2023).

$$\text{Antioxidant Activity (\%)} = \frac{\text{OD Blank} - \text{OD Sample}}{\text{OD Blank}}\ \text{X}\ 100\ \% \quad \text{..... (2)}$$

Alcohol Content Testing

Alcohol content was analyzed using an alcoholmeter. The sample was first transferred into a 100 ml graduated cylinder (Gustishio et al., 2023). The alcoholmeter was then immersed into the distillate until it reached the appropriate immersion level relative to the liquid surface. Subsequently, the alcohol content value indicated on the alcoholmeter scale was observed and recorded as the measurement result of the tested sample (Mbeo et al., 2022).

pH Value Measurement

The pH measurement was conducted using a pH meter with a 5 mL sample. The pH meter was turned on by pressing the power button, and the probe of the pH meter was immersed into the container holding the sample. The display was monitored

until the reading stabilized, and the result was then recorded. Prior to each measurement, the probe of the pH meter was rinsed with distilled water (*aquades*) and dried before use (Salsabilla et al., 2025).

Data Analysis

Quantitative data, including vitamin C content, antioxidant activity, alcohol content, and pH, were analyzed using a descriptive quantitative approach by calculating the mean and standard deviation. Furthermore, the data were analyzed using a One-Way ANOVA (Analysis of Variance) test based on a single-factor completely randomized design (CRD). The ANOVA test was employed to determine the presence or absence of the effect of variations in fermentation duration on the observed parameters. If the ANOVA results indicated a significant difference, the analysis was proceeded with Duncan's post-hoc test to identify significantly different variations among the treatments. The results of the analysis were then presented in tabular form to facilitate interpretation and comparison between treatments.

RESULT AND DISCUSSION

Vitamin C Content Test Results

The results of the vitamin C content analysis at various fermentation periods are presented in Table 1. Based on the data in Table 1, the results indicated that the highest vitamin C content was found in the starfruit kombucha treatment with an 8-day fermentation period, reaching 167.405 mg/100g. Meanwhile, the lowest vitamin C level was observed at a 4-day fermentation period, at 155.185 mg/100g.

Table 1. Vitamin C content of Starfruit Kombucha (*Averrhoa carambola* L.)

No.	Treatment	Vitamin C (mg/100g)
1	Starfruit kombucha 4 days	1.477 ± 155.185[a]
2	Starfruit kombucha 6 days	5.536 ± 157.755[a]
3	Starfruit kombucha 8 days	1.506 ± 167.405[b]

**Values represent mean ± standard deviation*
**Different notation letters (a,b, and c) indicate significant differences at the P<0,05 level*
**Values sharing the same letter are not significantly different; Values with different letters are significantly different*

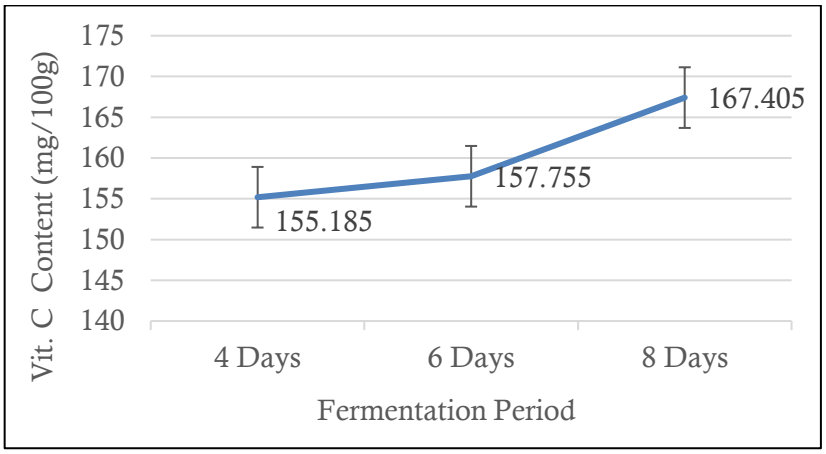

Figure 1. Vitamin C Content of Starfruit Kombucha (*Averrhoa carambola* L.)

Antioxidant Activity Test Results

The results of the antioxidant activity analysis at various fermentation periods are presented in Table 2. Based on the data in Table 2, the results indicated that the highest antioxidant level was found in the starfruit kombucha treatment with an 8-day fermentation period, reaching 80.630%. Meanwhile, the lowest antioxidant level was obtained at a 4-day fermentation period, at 78.835%.

Table 2. Antioxidant Activity of Starfruit Kombucha(*Averrhoa carambola* L.)

No.	Treatment	Antioxidant Activity (%)
1	Starfruit kombucha 4 days	0.120 ± 78.835[a]
2	Starfruit kombucha 6 days	0.120 ± 79.325[b]
3	Starfruit kombucha 8 days	0.113 ± 80.630[c]

**Values represent mean ± standard deviation*
**Different notation letters (a,b, and c) indicate significant differences at the P<0,05 level*
**Values sharing the same letter are not significantly different; Values with different letters are significantly different*

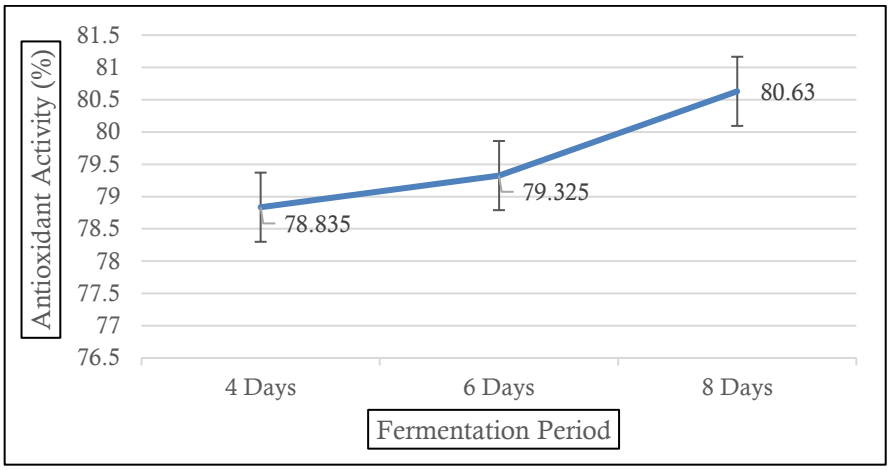

Figure 2. Antioxidant Activity of Starfruit Kombucha(*Averrhoa carambola* L.)

Alcohol Content Test Results

The results of the alcohol content analysis at various fermentation periods are presented in Table 3. Based on the data in Table 3, the results indicated that the highest alcohol content was found in the starfruit kombucha treatment with an 8-day fermentation period, reaching 0.584%. Meanwhile, the lowest alcohol level was obtained at a 4-day fermentation period, at 0.512%.

Table 3. Alcohol Content of Starfruit Kombucha(*Averrhoa carambola* L.)

No.	Treatment	Alkohol Content (%)
1	Starfruit kombucha 4 days	0.001 ± 0.512[a]
2	Starfruit kombucha 6 days	0.001 ± 0.530[b]
3	Starfruit kombucha 8 days	0.002 ± 0.584[c]

**Values represent mean ± standard deviation*
**Different notation letters (a,b, and c) indicate significant differences at the P<0,05 level*
**Values sharing the same letter are not significantly different; Values with different letters are significantly different*

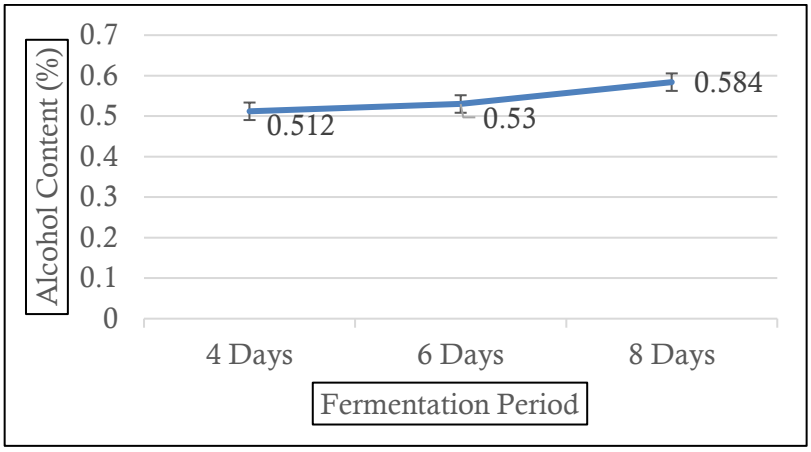

Figure 3. Alcohol Content of Starfruit Kombucha(*Averrhoa carambola* L.)

pH Measurement Results

The pH measurement results at various fermentation periods are presented in Table 4. Based on the data in Table 4, the results indicated that the highest pH value was found in the starfruit kombucha treatment with a 4-day fermentation period, reaching 4.980. Meanwhile, the lowest pH value was obtained at an 8-day fermentation period, at 4.470.

Table 4. pH Values of Starfruit Kombucha(*Averrhoa carambola* L.)

No.	Treatment	pH value
1	Starfruit kombucha 4 days	0.042 ± 4.980[b]
2	Starfruit kombucha 6 days	0.148 ± 4.785[b]
3	Starfruit kombucha 8 days	0.084 ± 4.470[a]

**Values represent mean ± standard deviation*
**Different notation letters (a,b, and c) indicate significant differences at the P<0,05 level*
**Values sharing the same letter are not significantly different; Values with different letters are significantly different*

Discussion

Vitamin C Content of Starfruit Kombucha (*Averrhoa carambola* L.)

Vitamin C functions primarily as a coenzyme or cofactor in various biochemical reactions. This compound is also known as ascorbic acid due to its strong reducing capacity and its role as an antioxidant in hydroxylation processes. Furthermore, vitamin C contributes to lowering blood pressure, cholesterol levels, and the risk of heart disease (Leo & Daulay, 2022). The vitamin C synthesized during kombucha fermentation is an essential element that facilitates the strengthening of the body's immune defense mechanisms (Qutrunnadakhairunnisa et al., 2024).

The results of the vitamin C content analysis using the iodometric titration method are presented in Table 1. The vitamin C content at a 4-day fermentation period was 155.185 mg/100 g, which increased to 157.755 mg/100 g at a 6-day fermentation period, representing a 1.65% increase. Subsequently, the vitamin C content at an 8-day fermentation period reached 167.405 mg/100 g, an increase of 6.12%. Based on these results, the vitamin C content in starfruit (*Averrhoa carambola* L.) kombucha tends to increase with longer fermentation periods.

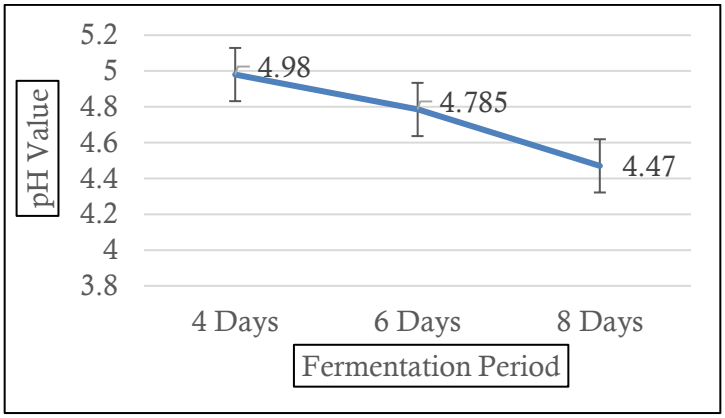

Figure 4. PH Values of Starfruit Kombucha(*Averrhoa carambola* L.)

This increase in vitamin C content occurs due to the transformation of D-glucose, which undergoes reduction into D-sorbitol. The transformation of D-sorbitol into L-sorbose initiates the fermentation stage via enzyme catalysts secreted by *Acetobacter xylinum*. This reaction involves the oxidation of the alcohol group in sugar compounds under oxygen exposure, producing L-sorbose, which gradually diffuses into vitamin C in the subsequent fermentation stage (Darmawan et al., 2018). The ascorbic acid synthesis mechanism is also supported by *Saccharomyces cerevisiae*, which oxidizes sucrose into CO_2 and water that can bind to form ascorbic acid. In the terminal stage of vitamin C biosynthesis, a crucial conversion occurs from L-gulonolactone to 2-keto-L-gulonolactone, a specific reaction catalyzed by bacterial-derived L-gulonolactone oxidase (Wati & Ninggar, 2023).

Antioxidant Activity of Starfruit Kombucha(*Averrhoa carambola* L.)

Antioxidants in kombucha tea function in the prevention of hypertension through the mechanism of reducing oxidative stress in the body (Salsabilah & Handayani, 2024). Antioxidants are compounds that have the ability to neutralize or inhibit the effects of free radicals by donating electrons, thereby stabilizing the free radicals and preventing the formation of chain reactions that can potentially damage cells (Wahdaniah et al., 2020).

The antioxidant activity test results using the DPPH method are presented in Table 2. Based on these results, the antioxidant activity at a 4-day fermentation period of 78.835% increased to 79.325% at a 6-day fermentation period, representing a 0.62% increase. Furthermore, the antioxidant activity at an 8-day fermentation period reached 80.630%, showing an increase of 1.64%. These results indicate an increase in antioxidant activity along with the longer fermentation period, specifically from 4 days to 6 days, and up to 8 days of fermentation.

The increase in antioxidant activity during the fermentation process is closely related to biochemical changes. In the initial stage, yeast plays a role in hydrolyzing sucrose into glucose and fructose, which are then converted into ethanol through the fermentation process. Subsequently, acetic acid bacteria in the SCOBY oxidize ethanol and glucose, thereby producing various organic acid compounds, including acetic acid, gluconic acid, and glucuronic acid. These organic acid compounds are reductive, thus directly contributing to the increase in antioxidant activity (Andry et al., 2025).

The antioxidant activity in kombucha products is determined by the bioactive compound profile and the free radical scavenging capacity of the initial substrate used in the fermentation process (Guspratiwi et al., 2025). Starfruit (*Averrhoa carambola* L.) has a high natural antioxidant content (Hasanah et al., 2023). n addition, antioxidant activity is also influenced by the fermentation duration. This is because a longer fermentation duration allows for an increase in the levels of polyphenol compounds contained in the resulting kombucha (Sejati et al., 2025).

Alcohol Content of Starfruit Kombucha(*Averrhoa carambola* L.)

Alcohol is a transparent compound formed through the fermentation of carbohydrates by yeast. This compound is volatile and soluble in water, chloroform, and ether (Alami et al., 2023). As a fermentation product, the formation of alcohol in kombucha is a process that cannot be entirely avoided. During the fermentation process, the alcohol content produced in kombucha ranges from 0.6% to 5%, depending on the duration of fermentation (Riswanto & Rezaldi, 2021).

The results of the alcohol content testing using an alcoholmeter are shown in Table 3. Based on these results, the alcohol content on day 4 of fermentation was 0.512%, which increased to 0.530% on day 6, reflecting a 3.51% increase. Furthermore, the alcohol content on day 8 of fermentation reached 0.584%, demonstrating an increase of 10.19%. These results indicate that the alcohol content of starfruit kombucha increases along with the fermentation duration. Prolonged storage time can cause the alcohol to gradually transform into organic acids due to bacterial activity, leading to an increase in acidity that contributes to the characteristic sour taste of kombucha (Majidah et al., 2022).

The increase in alcohol content to 0.58% is closely related to the activity of microorganisms in the kombucha culture, particularly the yeast *Saccharomyces cerevisiae* and *Acetobacter* bacteria. In the early phase of fermentation, yeast converts glucose into ethanol, which is then further oxidized into acetic acid by *Acetobacter* (Sulistiawaty & Solihat, 2022). Although an alcohol content of 0.584% is still considered low, this figure slightly exceeds the halal limit for consumption. Legally, non-alcoholic beverages must not exceed the 0.5% ABV limit. Common efforts made to reduce alcohol content include dilution, heat pasteurization, microfiltration to remove alcohol-producing yeast strains, and the partial distillation of alcohol from the product (Kim & Adhikari, 2020).

pH Values of Starfruit Kombucha(*Averrhoa carambola* L.)

The pH value is an important parameter that plays a role in influencing the growth and metabolic activity of lactic acid bacteria. Lactic acid bacteria can survive within a pH range of 3.2 to 9.6 (Meilina et al., 2022). pH acts as a key determining factor in kombucha fermentation because it specifically facilitates the selective growth of microorganisms, regulates their activity, and modifies their metabolic pathways (Chong et al., 2024). The pH of kombucha tends to decrease as the fermentation duration increases. This decrease in pH is caused by the microbial metabolism of sugars, which produces various types of organic acids. Therefore, the longer

the fermentation duration, the greater the accumulation of organic acids formed (Zahra et al., 2022).

The pH values measured using a pH meter are presented in Table 4. The pH value on day 4 of fermentation was 4.980, which decreased to 4.785 on day 6, reflecting a 3.96% decrease. Furthermore, the pH value on day 8 of fermentation reached 4.470, demonstrating a decrease of 6.58%. The pH value continued to decrease as the fermentation duration increased from 4 to 8 days. These results indicate that the fermentation duration influences the resulting pH value. This condition is caused by the formation and accumulation of acidic compounds during the fermentation process, which are the metabolic products of acetic acid bacteria. The accumulation of these acids contributes to the decline of the pH value in kombucha (Hafsari et al., 2021).

CONCLUSION

The results of the analysis indicate that variations in fermentation duration affect the vitamin C content, antioxidant activity, alcohol content, and pH values of starfruit (*Averrhoa carambola* L.) kombucha. The vitamin C content, antioxidant activity, and alcohol content tended to increase as the fermentation duration extended, whereas the pH value decreased during the fermentation process. The enhancement of vitamin C content and antioxidant activity demonstrates the potential of starfruit (*Averrhoa carambola* L.) kombucha as a functional beverage based on local food resources. This research contributes to the advancement of food science and biology, particularly regarding the impact of fermentation duration on the biochemical characteristics of kombucha. The novelty of this study lies in the evaluation of starfruit kombucha quality based on variations in fermentation duration, a subject that has rarely been investigated in previous studies.

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