Vol. 14, No. 6 (2025): 2131 - 2144 http://dx.doi.org/10.23960/jtepl.v14i6.2131-2144

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

# Improvement of the Conditioning Process to Enhance the Quality of Vanilla (*Vanilla planifolia*)

Andi Ulfa Hardianty Syahrullah[1,✉], I Wayan Budiastra[1], Sutrisno Mardjan[1]

[1] Department of Mechanical and Biosystem Engineering, IPB University, Bogor, INDONESIA.

**Article History:**

Received : 23 July 2025
Revised : 19 September 2025
Accepted : 29 September 2025

**Keywords:**

*Conditioning, Microbial, Postharvest, Temperature, Vanillin.*

Corresponding Author:
✉ andiulfa0205@gmail.com
(Andi Ulfa Hardianty Syahrullah)

**ABSTRACT**

*The quality of national vanilla still does not fully meet national and international standards, one reason is the suboptimal conditioning process, namely, the final storage stage to stabilize quality. This study aims to examine the effect of packaging type, combined with temperature and conditioning duration, on vanilla's physical, chemical, sensory, and microbiological quality, and determine the best treatment combination in producing vanilla quality that meets SNI. Factorial Completely Randomized Design (CRD) was used in this experiment with three factors namely different material packaging (wax paper and HDPE plastic), various temperatures storage (25 °C, 30 °C, 35 °C), and conditioning durations (1, 1.5, and 2 months). Results showed that temperature, type of packaging, and conditioning duration significantly affect most of the physical, chemical, and microbiological quality parameters of vanilla, except for ash content and organoleptic aroma, which are not significantly different. The best treatment combination was obtained using HDPE packaging with a temperature of 35 °C for 1.5 months of conditioning, producing quality according to SNI 01-0010-2002 with high vanillin content and stable color. However, the total microbial count (TPC) in this treatment still exceeded the limits set by FAO.*

## 1. INTRODUCTION

Indonesia is one of the world largest vanilla producers. According to data from the Food and Agriculture Organization (FAO, 2023), Indonesia ranks second after Madagascar, with total production reaching 7,166 tons during the 2020–2023 period. Vanilla production centers are spread across various regions, including East Java, Lampung, Central Java, West Java, North Sumatra, East Nusa Tenggara, Yogyakarta, Papua, and several areas in Sulawesi. Approximately 110 types of vanilla grown in tropical regions, three are widely known: *Vanilla planifolia* Andrews, *Vanilla pompona* Schiede, and *Vanilla tahitensis* J.W. Moore (Samadi, 2021). *Vanilla planifolia* is the variety most widely cultivated by Indonesian farmers due to its high quality potential and economic value.

The quality of Indonesian vanilla, however, generally falls short of international standards. One important quality indicator is vanillin content. The FAO (2009) recommends an ideal vanillin content between 1.5–2.5% of the dry weight. Meanwhile, the Indonesian National Standard (SNI 01-0010-2002) classifies vanilla into four quality grades, with the best vanillin content of 2.25% and lower grades having vanillin content of 1.0–1.5% (BSN, 2002). However, low vanillin content (< 1.5%) is still common (Trubus, 2021a), and the resulting aroma is less intense (Trubus, 2021b).

Several processing stages determine the final quality of vanilla, one of the most crucial being conditioning. Conditioning is the final stage in post-harvest vanilla processing, aimed to stabilize the moisture content and maximize the development of the distinctive aroma. This process is carried out after the vanilla has gone through the withering, curing, and drying stages. According to Xu *et al*. (2020), the traditional vanilla curing process involves four main stages, including blanching, sweating, drying, and conditioning. The vanilla is stored in a sealed container for several months

until its distinctive aroma of vanilla develops. The conditioning stage is crucial because it contributes to the development of the final flavor and maintains the quality of the vanilla.

Wongsheree *et al*. (2013) reported that conditioning for one month at room temperature (24−36 °C) produced the highest vanillin content. Longer conditioning durations can degrade aromatic compounds and a drastic decrease in water content. Yeh *et al*. (2024) showed that storing post-curing vanilla at −20 °C for 6 months was able to maintain the highest vanillin content and color stability, but storage at high temperatures (25−35 °C) for ≥12 months caused degradation of volatile compounds and significant color changes, which negatively impacted aroma and visual quality. Previous studies showed that conditioning temperature and duration determine the final quality of vanilla. There have been no studies on the effect of packaging type on vanilla quality during the conditioning process. Therefore, this study examines the impact of packaging type, combined with temperature and conditioning duration, on physical, chemical, microbiological, and sensory quality of vanilla, and determines the best treatment combination to produce vanilla quality that meets the SNI. Results of this study are expected to provide a technical reference for farmers and industries to enhance vanilla quality to meet SNI and FAO standards. It also supports the development efficient postharvest technologies to boost competitiveness of vanilla export and offers a foundation for future research on microbial control and aroma optimization.

## 2. MATERIALS AND METHODS

### 2.1. Research Location and Time

This research was conducted from July to November 2024. Tests for moisture content, ash content, color, and vanillin content were conducted at the Integrated Chemical Engineering Laboratory, Ujung Pandang State Polytechnic, Makassar. Storage (conditioning) was conducted at three locations: the Integrated Chemical Engineering Laboratory, Ujung Pandang State Polytechnic, Makassar; the Fish Parasites and Diseases Laboratory, Faculty of Marine Sciences and Fisheries, Hasanuddin University, Makassar; and the PKP Laboratory, Hasanuddin University, Makassar. Microbiological tests were conducted at the Microbiology Laboratory, Center for Health Laboratories (BBLK) Makassar. Organoleptic tests were conducted at the Analytical Chemistry Laboratory, Food Quality Control, Food Science and Technology Study Program, Faculty of Agriculture, Hasanuddin University.

### 2.2. Tools and Materials

The tool in this study included a wooden box with dimensions of 18×11×10 cm, an oven (Memmert), chromameter (Konica Minolta), desiccator (Iwaki), vortex (Labinco L46), spectrophotometer (B-One), micropipette (Eppendorf), stomacher (Seward), analytical balance (Sartorius), incubator (30 °C and 35 °C) (Faithful with a capacity of 30L), hotplate stirrer (Heidolph), water bath (Series 180), a cup (Iwaki), glassware (Iwaki), black cotton cloth, plastic tray, artificial conditioning chamber for a temperature of 25 °C, styrofoam box (storage room), DC fan, and temperature control module (digital display).

The main material was vanilla pods from Bulukumba, South Sulawesi, with a maximum harvest age of 8−9 months and length of at least 15 cm. Other materials included wax paper, HDPE plastic, distilled water, and PCA media (Merck).

### 2.3. Research Procedures

The curing process consisted of four stages, namely wilting, curing, drying, and conditioning. First, vanilla pods wer sorted based on length (15 cm), rotten and broken pods were separated. The blanching stage was conducted by soaking the pods in hot water at 65 °C, followed by curing in wooden boxes and drying for 5–7 days until the moisture content reached ≤ 35%. Subsequently, the samples were conditioned under various combinations of temperature (25, 30, and 35 °C), packaging type (HDPE and wax paper), and conditioning duration (1, 1.5, and 2 months).

### 2.4. Experimental Design

The research was arranged in a Completely Randomized Design (CRD) with three factors and three replications. The first factor was temperature, namely B0 (25 °C), B1 (30 °C), and B2 (35 °C), the second factor was packaging material including A0 (Wax paper), and A1 (HDPE plastic), and the third factor was conditioning duration consisting C1 (1

month), C2 (1.5 months), and C3 (2 months). Data analysis was carried out using ANOVA and Duncan's multiple range test (DMRT) when significant differences were detected using SPSS version 29 software.

### 2.5. Chemical Quality Observation

#### 2.5.1. Water Content

Water content was determined according to procedure outlined in SNI 01-2891-1992. Empty cups and lids were dried in an oven at 105 ºC for 15 min, then cooled in a desiccator. The dried cups were weighed. The vanilla samples were cut into smaller pieces and weighed around 5 g in each cup. They were then dried in an oven at 105 ºC for 3 h, cooled again in a desiccator, and then weighed. The drying and weighing process were repeated until the sample weight was constant (difference ≤ 0.0005 g). Water content (WC) was calculated using Equation (1).

$$\text{WC (\% wb)} = \left(\frac{(W_1 - W_2)}{W_1}\right) \times 100 \quad (1)$$

where $W_1$ and $W_2$ is respectively weight of fresh sample and dry sample (both in g).

#### 2.5.2. Ash Content

The steps for testing ash content followed the AOAC (2005) method. A porcelain crucible containing 2 grams of sample was weighed, then the sample was placed in a furnace at 700 °C for 6 h. The crucible was then placed in a desiccator to cool for 20 min. Next, the ash-filled cup was weighed, and the ash content was calculated using Equation (2).

$$\text{Ash Content (\%)} = \frac{\text{Ash weight}}{\text{Dry sample weight}} \times 100\% \quad (2)$$

#### 2.5.3. Vanillin Content

Vanillin content was determined using the spectrophotometric method (AOAC, 1981).

1. *Sample preparation.* Five grams of vanilla were weighed, chopped, and placed in an Erlenmeyer flask containing 10 mL of 60% ethanol. The sample was soaked for 2 days (soaking I), then filtered. The filtrate was collected in a 100 mL volumetric flask and washed with 5 mL ethanol. The residue from the first soaking was crushed and then soaked again in 10 mL of 50% ethanol for 1 day (soaking II). The filtrate from the second soaking was filtered and mixed with the filtrate from the first. The residue was then rewashed with 60% alcohol. All filtrates were combined and diluted to a total volume of 100 mL, resulting in a sample solution.

2. *Preparing a standard curve.* Pure vanillin was weighed at 0.100 g, dissolved in 5 mL of 95% alcohol, and diluted with distilled water to a total volume of 100 mL. The solutions were then pipetted with 2 mL, 4 mL, 5 mL, 8 mL, 10 mL, and 12 mL, respectively. They were then diluted with distilled water to 250 mL and shaken until homogeneous (coded 1-6). A 10 mL volume of each solution was pipetted, 2 mL of 0.1 N NaOH was added, and the final volume was diluted again with distilled water to 100 mL. A neutral solution was used as a reference for the wavelength of the sample solutions. The absorbance of the solution was measured at a wavelength of 348 nm using a neutral solution as a blank. A standard curve was constructed by plotting the concentration against the absorbance value (Figure 1).

3. *Determination of sample solution absorbance.* A 10 mL sample solution was diluted with distilled water to 100 mL. 2 mL was pipetted into 100 mL volumetric flasks (B1 and B2). Solution B1 was diluted to the mark with distilled water and used as a blank. 2 mL of 0.1 N NaOH was added to solution B2, followed by additional distilled water. The absorbance of solution B2 was measured using B1 as a blank at a wavelength of 348 nm (Fitriani *et al*., 2024). The spectrophotometric results were entered into the formula in Equation (3).

$$\text{Vanillin content (\%)} = \frac{X \times Fp}{M \times 100} \times 100 \quad (3)$$

where $X$ is sample concentration (ppm), $Fp$ is dilution factor (2,500), and $M$ is mass of dried sample (mg).

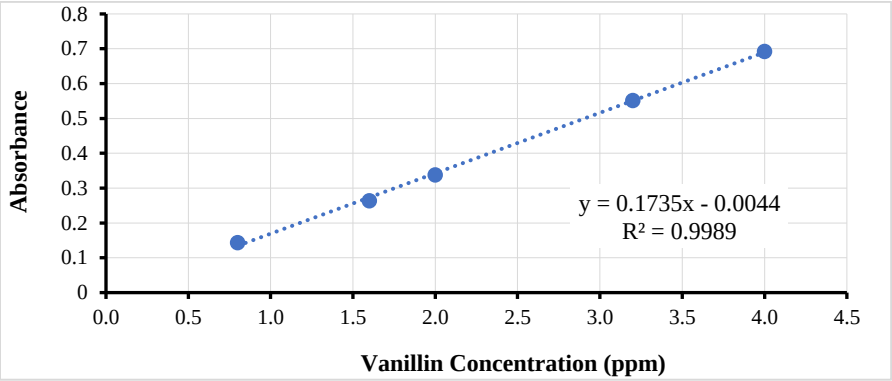


Figure 1. Standard curve of absorbance versus vanillin concentration (ppm)

### 2.6. Physical Quality

#### 2.6.1. Color

Color was measured using a chromameter which displayed the *L**, *a**, *b** values, where *L** indicates brightness from 0 (dark/black) to 100 (bright/white), *a** indicates green (*a** negative) to red (*a** positive), and *b** indicates blue (*b** negative) to yellow (*b** positive). Analysis was performed by cutting the sample into several pieces, arranging them in a sample container with the appropriate chromameter area, and then examining them three times. Before this, the chromameter was calibrated with the instrument's standard white color.

#### 2.6.2. Organoleptic (Color and Aroma)

Organoleptic testing followed the method used by Qamariah *et al*. (2022) and was conducted by 25 semi-trained panelists. Panelists ticked a check mark on a sheet containing assessments based on color and aroma. Before assessment, each vanilla sample was placed in a transparent container and assigned a random three-digit code. Panelists received a set of equipment consisting of an assessment form, a pen, mineral water to neutralize the taste and aroma, and the sample to be assessed. Panelists were given instructions on the assessment procedure and asked to evaluate each sample based on two attributes (color and aroma). The evaluation process was approximately 15 minutes. The panelists involved were individuals with a scientific background in the food industry, thus possessing basic skills in conducting organoleptic testing. Each attribute for organoleptic testing was rated according to the panelists' level of preference using a hedonic scale, namely 5 = very much like, 4 = like, 3 = neutral, 2 = dislike, 1 = very much dislike.

#### 2.6.3. Microbiological Quality

Microbiological testing for total plate count used the conventional FDA BAM, Chapter 3-2001 method. Twenty-five grams of vanilla pods were crushed and placed in a sterile plastic bag. 225 mL of Butterfield's phosphate-buffered solution is added to achieve a 10:1 dilution and homogenized in a stomacher for 2 minutes. A series of dilutions was then made with Butterfield's phosphate-buffered solution up to 10-3. To perform a 10-fold dilution, mix 1 mL of the previous dilution with 9 mL of the diluent solution. All dilutions must be homogeneous.

Aseptically take 1 mL of the prepared sample from each dilution in a petri dish, then pour 15 mL of PCA media into the dish. Spread the sample by shaking the dish until homogeneous. Do this in duplicate. Do the preparation work until the sample analysis does not exceed 20 minutes to avoid contamination with air. Next, incubate the dish at 35°C for 2 days. Do not stack the petri dishes higher than three, and do not turn them upside down. Colonies in the dish are counted after 2 days of incubation. Bacterial colonies are counted using a colony counter, the number of colonies per petri dish containing 25-250 colonies, and the results are recorded at each dilution level.

Table 1. Summary of ANOVA on the water content, ash content, and color of vanilla

| | Water Content | | Ash Content | | Vanillin Content | | Total Microbes | |
|---|---|---|---|---|---|---|---|---|
| | SS | Sig* | SS | Sig* | SS | Sig* | SS | Sig* |
| Corrected Model | 2637.64[a] | 0.000 | 60.91[a] | 0.462 | 29.952[a] | 0.007 | 385.029[a] | 0.036 |
| Intercept | 19114.35 | 0.000 | 1472.88 | 0.000 | 369.421 | 0.000 | 1,705.670 | 0.000 |
| Factor A | 2307.05 | 0.000 | .000 | 1.000 | 5.947 | 0.005 | 111.830 | 0.003 |
| Factor B | 21.12 | 0.033 | .517 | 0.929 | .657 | 0.612 | 4.330 | 0.824 |
| Factor C | 95.91 | 0.000 | 19.724 | 0.074 | 14.098 | 0.000 | 42.216 | 0.164 |
| Factor A * Factor B | 122.77 | 0.000 | 10.742 | 0.231 | 2.818 | 0.133 | 117.591 | 0.010 |
| Factor A * Factor C | 23.91 | 0.022 | .168 | 0.976 | 3.205 | 0.103 | 40.775 | 0.174 |
| Factor B * Factor C | 20.92 | 0.140 | 20.709 | 0.231 | 1.103 | 0.795 | 22.102 | 0.738 |
| Factor A * Factor B * Factor C | 45.95 | 0.008 | 9.053 | 0.635 | 2.124 | 0.531 | 46.185 | 0.401 |
| Error | 101.69 | | 126.566 | | 23.773 | | 400.227 | |
| Total | 21853.67 | | 1660.354 | | 423.146 | | 2,490.927 | |
| Corrected Total | 2739.33 | | 187.479 | | 53.725 | | 785.256 | |

Treatment or treatment combination is statistically significant if Sig value is less than 0.05 (shaded values).

Table 2. Summary of ANOVA on the vanillin content, total microbes, and hedonic score.

| | *L** | | *a** | | *b** | | Hedonic Color | | Hedonic Aroma | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SS | Sig* | SS (x$10^{12}$) | Sig* | SS | Sig* | SS | Sig* | SS | Sig* |
| Corrected Model | 50.45[a] | 0.000 | 17.62[a] | 0.000 | 37.27[a] | 0.000 | 3.885[a] | 0.001 | 0.845[a] | 0.029 |
| Intercept | 18786.52 | 0.000 | 786.84 | 0.000 | 337.35 | 0.000 | 661.500 | 0.000 | 649.237 | 0.000 |
| Factor A | 13.07 | 0.000 | 0.06 | 0.520 | 0.072 | 0.581 | 0.007 | 0.747 | 0.004 | 0.698 |
| Factor B | 6.86 | 0.003 | 3.57 | 0.000 | 6.15 | 0.000 | 0.533 | 0.023 | 0.013 | 0.767 |
| Factor C | 3.09 | 0.060 | 4.79 | 0.000 | 4.97 | 0.000 | 0.689 | 0.009 | 0.417 | 0.001 |
| Factor A * Factor B | 1.48 | 0.246 | 1.01 | 0.039 | 2.64 | 0.007 | 0.151 | 0.315 | 0.037 | 0.458 |
| Factor A * Factor C | 12.62 | 0.000 | 4.50 | 0.000 | 10.95 | 0.000 | 1.310 | 0.000 | 0.028 | 0.554 |
| Factor B * Factor C | 5.91 | 0.035 | 0.79 | 0.252 | 5.33 | 0.001 | 0.408 | 0.192 | 0.108 | 0.348 |
| Factor A * Factor B * Factor C | 7.42 | 0.013 | 2.90 | 0.002 | 7.16 | 0.000 | 0.788 | 0.027 | 0.239 | 0.056 |
| Error | 18.26 | | 5.07 | | 8.34 | | 2.274 | | 0.844 | |
| Total | 18855.23 | | 809.53 | | 382.96 | | 667.659 | | 650.926 | |
| Corrected Total | 68.71 | | 22.69 | | 45.61 | | 6.159 | | 1.689 | |

Treatment or treatment combination is statistically significant if Sig value is less than 0.05 (shaded values).

## 3. RESULTS AND DISCUSSION

This chapter will systematically discuss the research results based on the observed parameters. The discussion focuses on the significance of the treatment effects on each parameter, then links it to relevant theory and previous research findings to provide a deeper understanding of vanilla post-harvest processing and its implications for final product quality. Table 1 and Table 2 summarize results of ANOVA of three factors towards observed parameters, including water content, ash content, vanillin content, vanilla color, and hedonic of color and aroma.

### 3.1. Water Content

Water content is an important parameter that determines the quality, shelf life, and stability of agricultural products. Based on the ANOVA analysis, the combination of packaging type, temperature, and conditioning duration significantly affected the water content with a *p*-value of < 0.001. Results of DMRT (Figure 2) showed that the highest water content was obtained in the control treatment at 35.77%, The A0B2C2 treatment showed the lowest value at 9.35%. The control, A1B1C1, A1B2C1, A1B2C2, A1B0C3, and A1B2C3 treatment met the FAO (2009) quality standards (grade 1) and SNI 01-0010-2002 (grade 1).

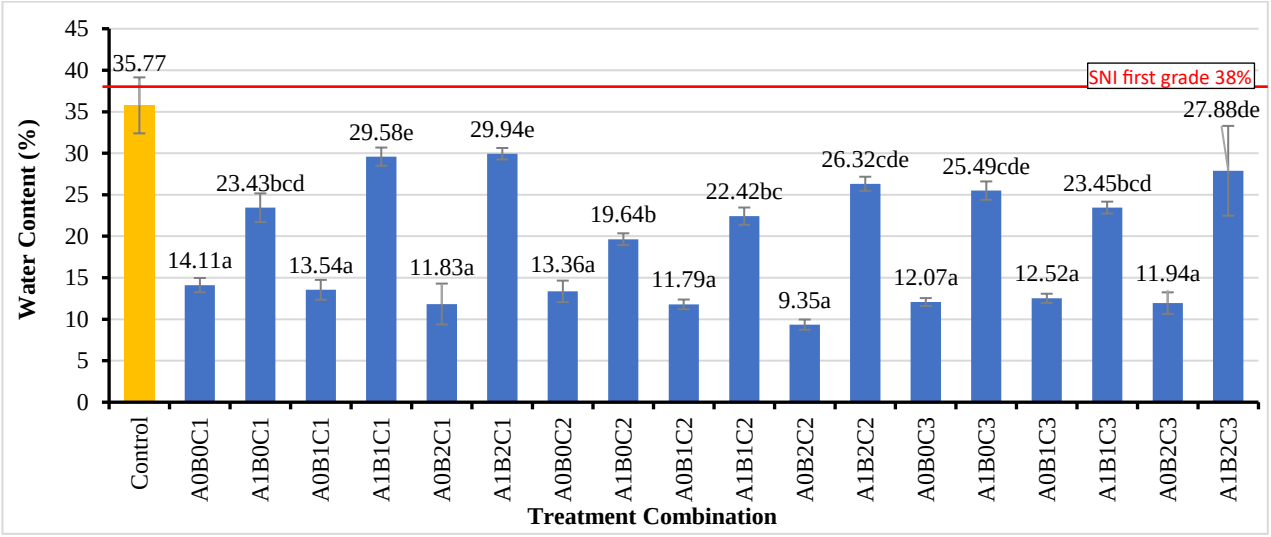


Figure 2. Effect of treatment combinations (temperature, type of packaging, conditioning duration) on water content of vanilla. [Desc: A0: Wax paper; A1: HDPE; B0: 25 °C; B1: 30◦C; B2: 35◦C; C1: 1 Month; C2: 1.5 Month; C3: 2 Month. Different letters following mean values indicate significant different based on DMRT at 5% level]

HDPE packaging dominated the treatments that met SNI and FAO quality standards due to its low water vapor permeability, which helps maintain pod moisture. As an ethylene polymer with low permeability, HDPE limits the diffusion of water and gases, thereby stabilizing humidity (Sucipta *et al*., 2017). In contrast, wax paper, although hydrophobic, remains permeable to small water vapor molecules that can penetrate microscopic pores, leading to significant moisture loss during conditioning (Nowacka *et al*., 2018; Jahangiri *et al*., 2025). High temperatures (30–35 °C) also supported quality retention, as the hygroscopic nature of vanilla pods promotes water reabsorption under humid conditions. The Clausius–Clapeyron equation further explains that higher temperatures increase saturated vapor pressure, facilitating water evaporation (Knözinger, 2013). However, storage at low relative humidity accelerates water loss, whereas humid conditions enable reabsorption (Gidado *et al*., 2024). Additionally, compounds formed during conditioning contribute to water vapor reabsorption in vanilla pods (Brunschwig *et al*., 2016).

### 3.2. Ash Content

Ash content is an important parameter used to determine the total inorganic mineral content remaining after combustion of organic components. Ash content is generally determined using a combustion method in a muffle furnace at 550 °C

for 2.5 h (Pangestuti & Darmawan, 2021). Based on the ANOVA results (Table 1), all three factors (packaging type, temperature, and conditioning duration) as well as their interactions did not significantly affect the ash content with a *p*-value > 0.05. The highest ash content was obtained in treatment A1B1C1 at 7.11%, while the lowest value occurred in treatment A0B0C2 at 3.41%. Figure 3 shows that all treatments met the FAO (2009) grade 1 (7%, max) and SNI 01-0010-2002 grade 1 (8%, max). Compared to the initial ash content of the material of 4.55±0.41, the ash content value during the conditioning process showed fluctuations, although the resulting difference was not statistically significant. In theory, ash content is a parameter to indicate the total inorganic mineral content in a material. Minerals are generally stable and do not easily change due to physical treatments such as heating, drying, or storage. Inorganic minerals are not easily evaporating and degraded by temperature. According to Ndumuye *et al*. (2022), the ash content obtained from ashing shows organic minerals that are not easily affected by high temperatures. These minerals remain stable and do not evaporate nor degrade by temperature, and the minerals are stable to physical treatments such as heating.

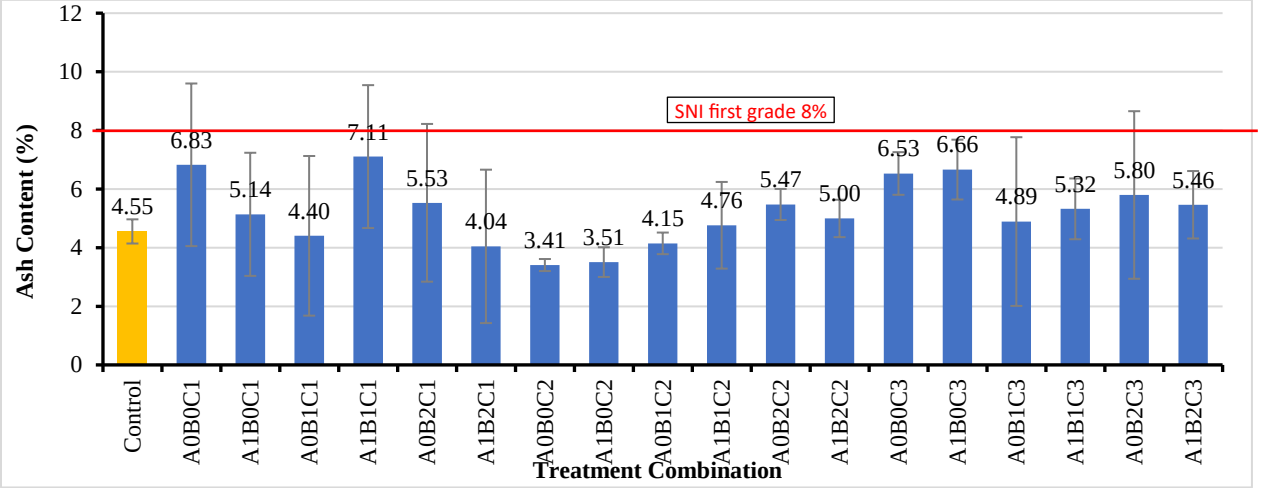


Figure 3. Effect of treatment combinations (temperature, type of packaging, conditioning duration) on ash content of vanilla [Desc: A0: Wax paper; A1: HDPE; B0: 25 °C; B1: 30◦C; B2: 35◦C; C1: 1 Month; C2: 1.5 Month; C3: 2 Month].

### 3.3. Vanillin Content

Vanillin content is one of the main parameters determining vanilla products' quality and selling value. The initial vanillin content of vanilla used in this research (2.46±0.085)% was higher than the FAO standard of first grade quality with minimum 1.0%, but lower than the SNI standard of 2.983%. The highest increase in vanillin content occurred in treatment A1B2C2 (HDPE, 35 °C, conditioning time 1.5 months) with a vanillin content reaching 4.19%, whereas treatment A1B2C1 (HDPE, 35 °C, conditioning time 1.0 months) resulted the lowest with 1.43%. Based on the ANOVA analysis (Table 1), factor A (packaging type) and factor C (conditioning duration) are significant on the vanillin content with p-value of 0.005 and 0.000, respectively. Factor B and all interactions of the tree factors are not significant (*p*-values > 0.05). Figure 4 shows post hoc test for effect of factor A and factor C on the vanillin content.

Figure 4a shows that packaging using HDPE is able to keep the vanillin content at a percentage of 2.95±1.12, very close to the SNI standard, and significantly higher than that of wax paper with vanillin percentage content of 2.28±0.76. Studies have shown that HDPE packaging maintains the stability of vanillin content. HDPE's impermeability to oxygen and water vapor allows for moisture retention and minimizes the volatility of aromatic compounds. Conversely, wax paper's semi-permeability allows for greater gas and water vapor exchange, accelerating the evaporation of volatile compounds and the degradation of aroma components, including vanillin. Yeh *et al*. (2024) found that the main volatile compounds of vanilla, including vanillin, are highly susceptible to oxidation when exposed to air.

Figure 4b shows the effect of conditioning time on the vanillin content. Conditioning time of 1.5 month resulted in the highest percentage of vanillin content of 3.26±0.96, significantly higher than those conditioning for 1.0 month and 1.5 month. These results indicate that 1.5 months of conditioning achieved optimum conditions for the activity of the β-

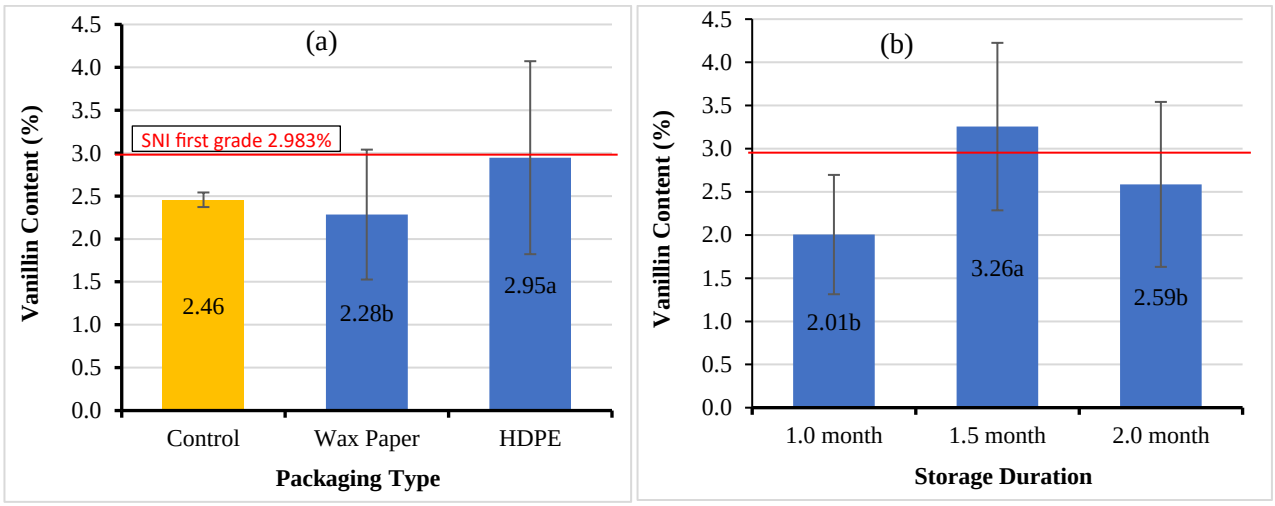


Figure 4. Effect of treatment factors on vanillin content of vanilla: (a) Packaging types; and (b) Conditioning duration. [Different letters following mean values indicate significant different based on DMRT at 5% level]

glucosidase enzyme, the primary enzyme involved in forming vanillin from the precursor glucovanillin. Several factors influence vanillin formation. The correct conditioning time allows for optimal enzymatic reaction, but too long can potentially reduce vanillin levels due to degradation. These results align with the findings of Matsuzawa *et al*. (2024), who found that the enzymatic activity that forms vanillin has a specific timeframe for optimal operation. Extending the time beyond this optimum point can decrease vanillin production efficiency due to degradation.

### 3.4. Total Microbiology TPC (Total Plate Count)

Total microbial count is critical to food safety and product shelf life. Conditions such as high humidity and unstable storage temperatures support the growth of microorganisms (Mathot *et al*., 2021). Based on the ANOVA analysis, the interaction of the three factors (packaging type, temperature, and conditioning duration) was not significant on the TPC value with a *p*-value of 0.401 ($p > 0.05$). Factor A and its interaction with factor B are significant with p-value of 0.003 and 0.10, respectively.

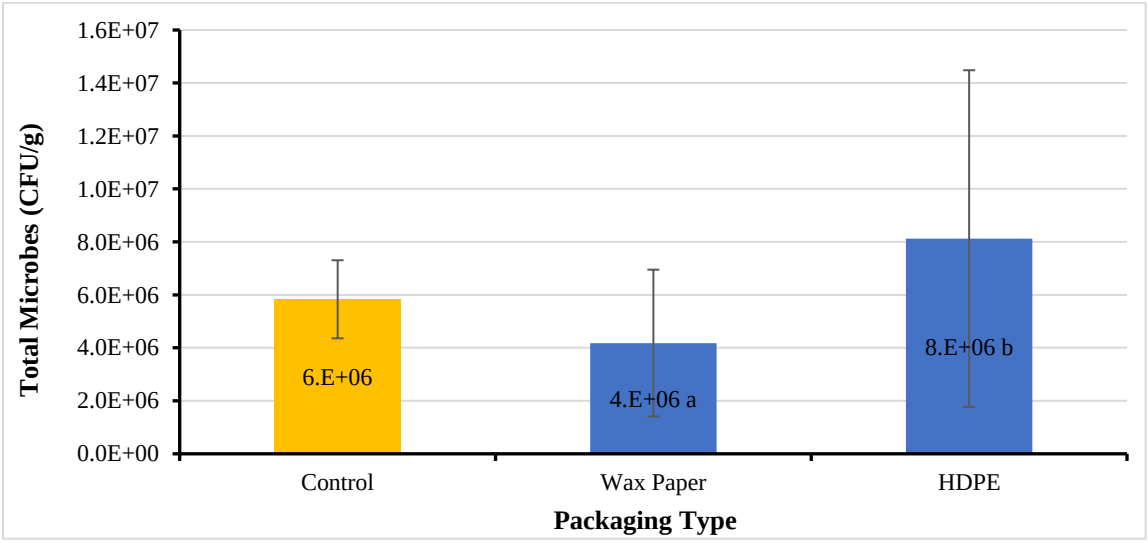


Figure 4. Effect of packaging types on the total microbes of vanilla. [Different letters following mean values indicate significant different based on DMRT at 5% level]

Treatment A1B2 yielded the highest total microbial count at $1.1 \times 10^7$ CFU/g, whereas treatment A0B2 yielded the lowest at $2.8 \times 10^6$ CFU/g. Figure 9 shows none of the treatments met the FAO (2009) standard. In wax paper packaging, the total microbial count decreased as temperature increased. The semi-permeable structure allowed water vapor to escape, reducing humidity and creating an environment less conducive to microbial growth. In contrast, HDPE packaging retained water vapor at high temperatures, which created humid conditions that supported microbial proliferation. The processing temperatures likely fell within the optimal growth range for mesophilic microorganisms, as the storage conditions matched their preferred range. Kumar *et al*. (2019) reported that mesophilic groups, including coliform bacteria, *Salmonella*, and fecal *Streptococci*, grow optimally at 20–40 °C and serve as widely recognized indicators of microbiological contamination in food. Furthermore, Mafe *et al*. (2024) stated that water is an important factor influencing microbial growth. Furthermore, optimal temperature can accelerate microbial growth, meaning these two factors can accelerate microbial growth. Furthermore, according to Xu *et al*. (2020), no specific sterilization steps exist in the curing process. Vanilla beans are always in contact with the external environment. Therefore, microbial growth occurs in vanilla beans during the curing process.

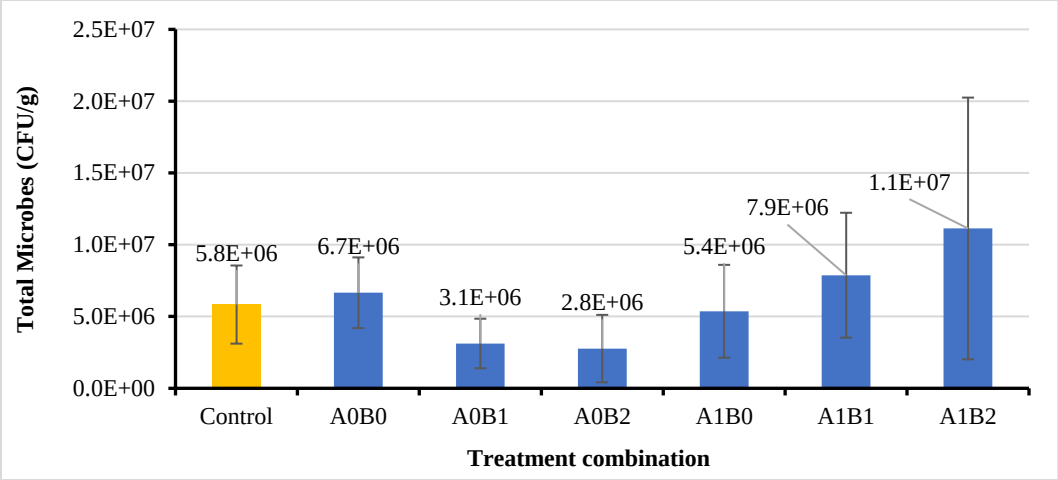


Figure 9. Effect of interaction factor A (packaging type) and factor B (temperature) on total microbes of vanilla [Different letters following mean values indicate significant different based on DMRT at 5% level]

### 3.5. Color Lightness (*L**)

Color is an important visual parameter for assessing the quality of agricultural products. Color differences can indicate the level of ripeness, processing stage, and potential degradation of product quality. Based on the ANOVA analysis, the interaction treatment of the three factors (packaging type, temperature, and conditioning duration) had a significant effect on the values of color components ($L^*$, $a^*$, and $b^*$) with a $p$-value < 0.05, specifically is 0.013 for $L^*$, 0.002 for $a^*$, and 0.000 for $b^*$ (Table 2).

Figure 5 shows that the $L^*$ values for all treatments ranged from 16.71 to 21.02. A low $L^*$ value indicates a darker color. Compared to the control, all treatments experienced a decrease in $L^*$ values, indicating a darkening of the color during the conditioning process. Furthermore, all treatments met SNI 01-0010-2002, a shiny black-brown to brown. High temperatures during conditioning likely decrease the $L^*$ value by inducing non-enzymatic browning (Maillard reaction). These results are consistent with the statement by Buitimea-Cantúa *et al*. (2023), that color changes are also related to non-enzymatic browning.

Furthermore, the use of packaging likely influences the $L^*$ value by affecting the enzymatic browning reaction, in which polyphenol oxidase oxidizes phenolic compounds. According to Singh *et al*. (2018), enzymatic browning will be active in the presence of oxygen and water. However, controlling both factors decreases enzyme activity and better maintains the color. Meanwhile, non-enzymatic reactions continue to take place but their rates are highly dependent on temperature, humidity, and substrate availability.

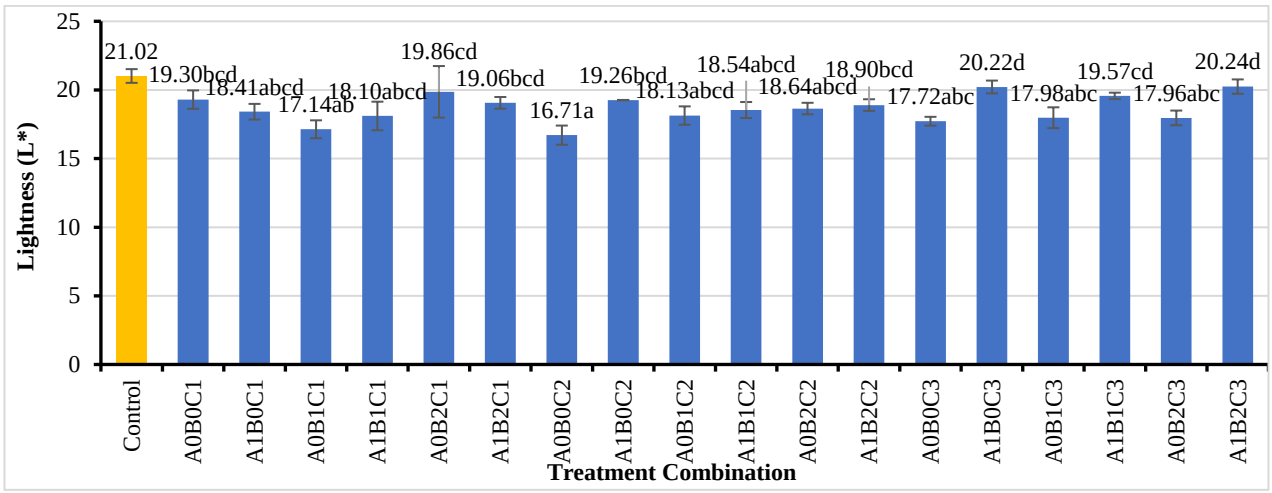


Figure 5. Effect of treatment combinations (temperature, type of packaging, conditioning duration) on lightness ($L^*$) value of vanilla [A0: Wax paper; A1: HDPE; B0: 25 °C; B1: 30◦C; B2: 35◦C; C1: 1 Month; C2: 1.5 Month; C3: 2 Month. Different letters following mean values indicate significant different based on DMRT at 5% level]

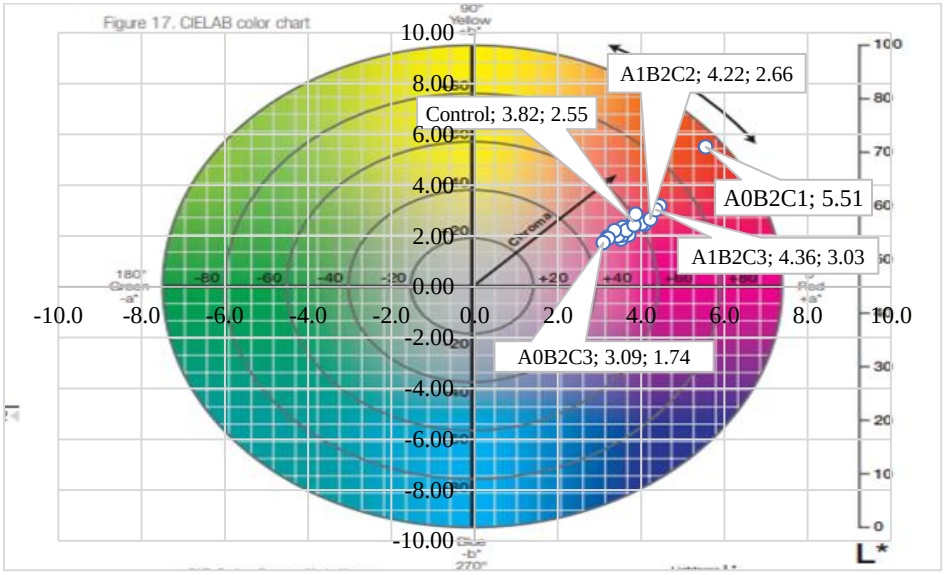


Figure 6. Color diagram for vanilla

The color measurement results show that all sample points are in the upper right quadrant of the diagram (Figure 6), indicating a positive $a^*$ value (tending to reddish) and $a^*$ positive $b^*$ value (tending to yellowish). The sample position consistently reflects $a^*$ hue dominated by a combination of red and yellow, forming a brown spectrum. The relatively short distance of the points from the center of coordinates (0,0), which represents the chroma value, indicates low color intensity or saturation, resulting in a dull and dark brown hue. Such a hue corresponds to the desired color characteristics according to SNI 01-0010-2002 shiny brownish black to brown. Treatments that meet SNI standards include A1B1C2 (HDPE, 30°C, 1.5 months), A1B1C3 (HDPE, 30°C, 2 months), A1B2C2 (HDPE, 35°C, 1.5 months), and A1B2C3 (HDPE, 35°C, 2 months). Treatment of HDPE packaging at medium-high temperatures for 1.5–2 months resulted in a low $L^*$ value, with $a^*$ and $b^*$ remaining positive but approaching neutral, resulting in a less saturated dark chocolate.

Conditioning duration decreased the $a^*$ value, particularly in wax paper packaging, because its permeability to air and water vapor accelerated enzymatic browning and phenolic compound oxidation. A temperature of 35°C accelerates

oxidative and Maillard reactions, especially when air and water vapor are triggered. Conversely, HPDE packaging is thought to maintain a more stable *a** value due to its impermeable nature, thus preventing color pigment degradation. According to Buitimea-Cantúa *et al*. (2023), the phenolic compounds in vanilla pods are highly susceptible to oxidation, either by the enzymes polyphenoloxidase (PPO) or peroxidase (POD), or non-enzymatically when oxygen and water are present. This process causes a decrease in the *a** value, as the red color changes to a dark brown pigment.

The *b** value also decreased with the wax paper treatment at 35 °C as conditioning time increased, presumably due to the degradation of the yellow pigment triggered by further oxidation. In contrast, HDPE packaging retained moisture and limited oxygen exposure, slowing pigment degradation. This result is consistent with the statement by Yeh *et al*. (2024), who stated that compounds such as 2-acetylpyrrole and 5-hydroxymethylfurfural, formed during the Maillard reaction, are known to contribute to the development of yellow to light brown color in vanilla pods during the early stages of conditioning. However, prolonged exposure to high temperatures and oxygen can trigger further reactions such as oxidation and polymerization, forming darker pigments.

### 3.6. Organoleptic Testing (Color & Aroma)

The researchers performed organoleptic testing to assess panelists' evaluations of the aroma and color of vanilla products Ismanto (2023). The results, presented in Figures 7 and 8, illustrate the panelists' preferences regarding the sensory attributes of vanilla pods. Based on the ANOVA analysis (Table 2), the treatment of packaging type, temperature, and conditioning duration significantly affected the organoleptic value of color with a *p*-value of 0.001 ($p < 0.05$). Figure 7 shows that the sample using wax paper at a temperature of 35ºC and stored for 2 months (A0B2C3) obtained the highest color score of (3.95±0.96) and the lowest in the sample using wax paper packaging at a temperature of 30ºC and stored for 1 month (A0B1C1) of (2.99±0.83). In wax paper packaging at 25, 30, and 35 ºC, color scores increased with longer conditioning durations. A significant increase occurred at 35 ºC, indicating that the panelists preferred this treatment. The semi-permeable nature of the packaging allows water vapor and air exchange, which facilitates the degradation of phenolic compounds and promotes the Maillard reaction, thereby explaining the panelists' preference. In HDPE packaging at 25 ºC, the color score initially decreased until 1.5 months of conditioning and then increased again. The score increased at 30 ºC and 35 ºC but declined after 2 months of conditioning. HDPE is airtight and moisture-resistant properties likely restricted air and water vapor entry, thereby slowing oxidation and browning reactions. The pigment formation reaction may be faster at high temperatures, but limited oxygen can inhibit optimal color development. Yeh *et al*. (2024) stated that 5-HMF and 2-acetylpyrrole, which form through the Maillard reaction, give vanilla a yellow to

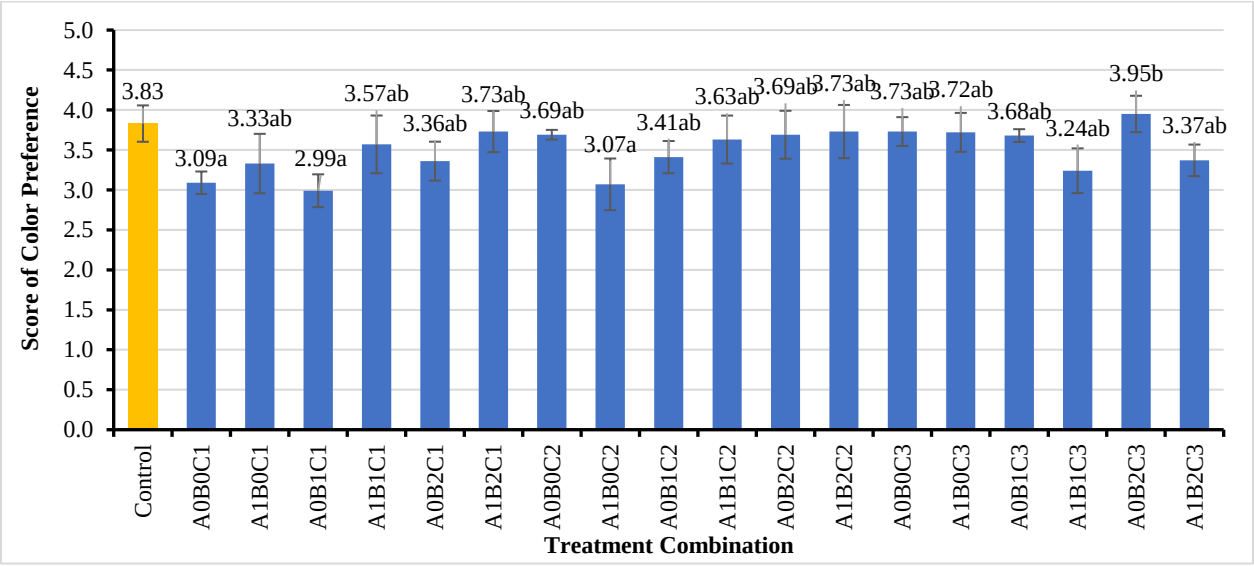


Figure 7. Effect of treatment combinations (temperature, type of packaging, conditioning duration) on lightness (*L**) value of vanilla [A0: Wax paper; A1: HDPE; B0: 25 °C; B1: 30◦C; B2: 35◦C; C1: 1 Month; C2: 1.5 Month; C3: 2 Month. Different letters following mean values indicate significant different based on DMRT at 5% level]

light brown color during the early processing stages. Prolonged exposure of vanilla to high temperatures and excessive oxygen can further transform these compounds, producing dark pigments. As a result, the color of vanilla can become too dark or uneven, which reduces the product's visual quality and appeal. Therefore, combining storage temperature, packaging type, and conditioning duration significantly influences color development in vanilla products through oxidation and Maillard reactions. Selecting the right storage conditions can produce a color that panelists more prefer.

Based on the ANOVA analysis (Table 2), all interactions of the three factors was not significant effect on the preference score for aroma of the vanilla with p-value > 0.05. Treatment factor C (storage duration) is the only factor significant on the aroma preference of the vanilla with *p*-value of 0.001. Figure 8 shows the effect of storage duration on the panelists' acceptance score of vanilla aroma. Longer storage duration improve the aroma of vanilla with the highest score of 3.58±0.17 was found after storage for 2 month. Higher values indicate a strong and preferred aroma. The increase in aroma during the conditioning stage indicates that the biochemical process of forming vanilla volatile compounds is still ongoing, so this stage plays an important role in developing the distinctive vanilla aroma. The degradation of volatile compounds likely causes the decrease in aroma, as these compounds readily evaporate. In addition, vanilla pods also emit slightly sour, woody, sweet, and other additional aromas. Yeh *et al*. (2024) reported that the quality of vanilla aroma changes during the conditioning process, beginning with an increase in aroma, followed by a decrease in quality due to compound degradation, and later a further increase in complexity as new compounds form. Brunschwig *et al*. (2016) similarly stated that phenolic compounds in vanilla pods generally contribute to strong woody and smoky aromas.

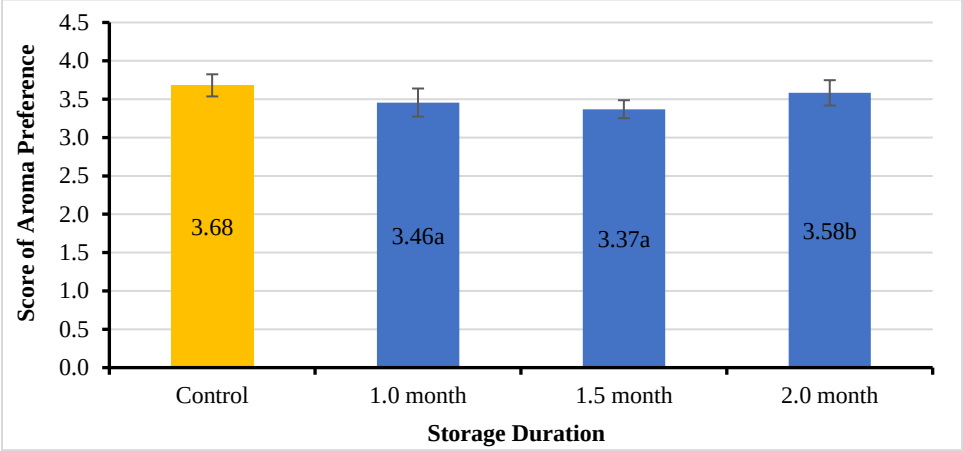


Figure 8. Effect of storage duration factor on the organoleptic score for aroma of vanilla

## 4. CONCLUSION

This study examined This study proves that temperature, type of packaging, and conditioning duration significantly affect most of the physical, chemical, and microbiological quality parameters of vanilla, except for ash content and organoleptic aroma, which are not significantly different. The best treatment combination was obtained using HDPE packaging with a temperature of 35 °C for 1.5 months of conditioning, producing quality according to SNI 01-0010-2002 with high vanillin content and stable color. However, the total microbial count (TPC) in this treatment still exceeded the limits set by FAO.

## REFERENCES

AOAC (Association of Official Analytical Chemists). (1981). Official Methods of Analysis. In *Association of Official Analytical Chemists* (13th ed.).

AOAC (Association of Official Analytical Chemists). (2005). Official Methods of Analysis. In *Official Methods of Analysis of Association of Official Analytical Chemists* (18th ed.).

Brunschwig, C., Rochard, S., Pierrat, A., Rouger, A., Senger-Emonnot, P., George, G., & Raharivelomanana, P. (2016). Volatile composition and sensory properties of Vanilla ×tahitensis bring new insights for vanilla quality control. *Journal of the Science of Food and Agriculture*, ***96***(3), 848–858. https://doi.org/10.1002/jsfa.7157

BSN (Badan Standarisasi Nasional). (2002). *Persyaratan Mutu Panili. SNI-1-0010-2002*. Badan Standarisasi Nasional, Jakarta.

Buitimea-Cantúa, G.V., Chávez-Leal, V., Soto-Caballero, M.C., Tellez-Medina, D.I., Welti-Chanes, J., & Escobedo-Avellaneda, Z. (2023). Enzymatic activity and its relationships with the total phenolic content and color change in the high hydrostatic pressure-assisted curing of vanilla bean (*Vanilla planifolia*). *Molecules*, ***28***(22). https://doi.org/10.3390/molecules28227606

FAO (Food and Agriculture Organization). (2009). *Vanilla Post-harvest Operations-Post-harvest Compendium Vanilla*. Food and Agriculture Organization of the United Nations. http://www.fao.org/3/a-ax447e.pdf

FAO (Food and Agriculture Organization). (2023). *Production Quantities of Vanilla*. Food and Agriculture Organization of the United Nations. https://www.fao.org/faostat/en/#data/QCL/visualize

Fitriani, A., Budiastra, I.W., Mardjan, S., & Nurfadila, N. (2024). Effects of curing method on quality of vanilla pod using a greenhouse effect dryer. *Food Research*, ***8***(5), 380–384.

Gidado, M.J., Gunny, A.A.N., Gopinath, S.C.B., Ali, A., Wongs-Aree, C., & Salleh, N.H.M. (2024). Challenges of postharvest water loss in fruits: Mechanisms, influencing factors, and effective control strategies – A comprehensive review. *Journal of Agriculture and Food Research*, ***17***, 101249. https://doi.org/10.1016/j.jafr.2024.101249

Ismanto, H. (2023). Uji organoleptik keripik udang (L. *vannamei*) hasil penggorengan vakum. *Jurnal AgroSainTa: Widyaiswara Mandiri Membangun Bangsa*, ***6***(2), 53–58. https://doi.org/10.51589/ags.v6i2.3137

Jahangiri, F., Mohanty, A., Pal, A.K., Clemmer, R., Gregori, S., & Misra, M. (2025). Wax coatings for paper packaging applications: Study of the coating effect on surface, mechanical, and barrier properties. *ACS Environmental Au*, ***5***(2), 165–182. https://doi.org/10.1021/acsenvironau.4c00055

Knözinger, H. (2013). Clausius-Clapeyron equation. *Catalysis from A to Z: A Concise Encyclopedia, 4 Volume Set*, *1–4*(3), 521–522.

Kumar, P., Jyoti, B., Kumar, A., & Paliwal, A. (2019). Biotechnological and microbial standpoint cahoot in bioremediation. In *Smart bioremediation technologies: Microbial enzymes* (pp. 137–158). Elsevier. https://doi.org/10.1016/B978-0-12-818307-6.00008-1

Mafe, A.N., Edo, G.I., Makia, R.S., Joshua, O.A., Akpoghelie, P.O., Gaaz, T.S., Jikah, A.N., Yousif, E., Isoje, E.F., Igbuku, U.A., Ahmed, D.S., Essaghah, A.E.A., & Umar, H. (2024). A review on food spoilage mechanisms, food borne diseases and commercial aspects of food preservation and processing. *Food Chemistry Advances*, ***5***, 100852. https://doi.org/10.1016/j.focha.2024.100852

Mathot, A.G., Postollec, F., & Leguerinel, I. (2021). Bacterial spores in spices and dried herbs: The risks for processed food. *Comprehensive Reviews in Food Science and Food Safety*, ***20***(1), 840–862. https://doi.org/10.1111/1541-4337.12690

Matsuzawa, M., Ito, J., Danjo, K., & Fukui, K. (2024). Vanillin production by *Corynebacterium glutamicum* using heterologous aromatic carboxylic acid reductases. *Biotechnology for Biofuels and Bioproducts*, ***17***(1), 1–11. https://doi.org/10.1186/s13068-024-02507-3

Ndumuye, E., Langi, T.M., & Taroreh, M.I.R. (2022). Chemical characteristics of muate flour (*Pteridophyta filicinae*) as traditional food for the community of Kimaam Island. *Jurnal Agroekoteknologi Terapan*, ***3***(2), 261–268. https://doi.org/10.35791/jat.v3i2.44440

Nowacka, M., Rybak, K., Wiktor, A., Mika, A., Boruszewski, P., Woch, J., Przybysz, K., & Witrowa-Rajchert, D. (2018). The quality and safety of food contact materials – paper and cardboard coated with paraffin emulsion. *Food Control*, ***93***, 183–190. https://doi.org/10.1016/j.foodcont.2018.06.011

Pangestuti, E.K., & Darmawan, P. (2021). Analysis of ash contents in wheat flour by the gravimetric method. *Jurnal Kimia dan Rekayasa*, ***2***(1), 16–21. https://doi.org/10.31001/jkireka.v2i1.22

Qamariah, N., Handayani, R., & Mahendar, A. I. (2022). Uji hedonik dan daya simpan sediaan salep ekstrak etanol umbi hati tanah. *Jurnal Surya Medika*, *7*(2), 124–131. https://doi.org/10.33084/jsm.v7i2.3213

Samadi, B. (2021). *Budidaya Vanili*. Angkasa Bandung.

Singh, B., Suri, K., Shevkani, K., Kaur, A., Kaur, A., & Singh, N. (2018). Enzymatic browning of fruit and vegetables: A review. *Enzymes in Food Technology: Improvements and Innovations*, 63–78. https://doi.org/10.1007/978-981-13-1933-4_4

Sucipta, I.N., Suriasih, K., & Kencana, P.K.D. (2017). *Pengemasan Pangan Kajian Pengemasan yang aman, Nyaman, Efektif dan Efisien*. Udayana University Press.

Trubus, R. (2021a). *Kebangkitan Vanili*. Trubus Swadaya, Jakarta.

Trubus, R. (2021b). *Olah Vanili*. Trubus Swadaya, Jakarta.

Wongsheree, T., Wongs-Aree, C., Srilaong, V., & Jitareerat, P. (2013). Vanilla cultivation and curing in Thailand. *Acta Horticulturae*, ***1011***, 213–218. https://doi.org/10.17660/ActaHortic.2013.1011.25

Xu, F., Chen, Y., Cai, Y., Gu, F., & An, K. (2020). Distinct roles for bacterial and fungal communities during the curing of vanilla. *Frontiers in Microbiology*, ***11***(September). https://doi.org/10.3389/fmicb.2020.552388

Yeh, C.-H., Chou, C.-Y., Yang, K.-M., Wu, C.-S., Chu, L.-P., Hsu, Y.-L., & Chen, H.-C. (2024). Effects of storage time and temperature on the aroma quality and color of vanilla beans (*Vanilla planifolia*) from Taiwan. *Food Chemistry: X*, ***24***, 101761. https://doi.org/10.1016/j.fochx.2024.101761