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Effect of Prolonged Dehumidification on the Chemical Properties of Crassiacarpa and Mangium Honey

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Abstract

Honey is a natural substance bees produce from nectar, flower sap, or liquid collected from living plant parts. The honey undergoes bee modification and binding before being stored in hexagonal combs. Effective dehumidification is crucial for enhancing honey quality and extending its shelf life. This study aimed to evaluate the effects of prolonged dehumidification time, honey type, and their interaction on the quality of Crassiacarpa and Mangium honey and to determine the optimal dehumidification treatment to meet the SNI 8664-2018 standard. A factorial Completely Randomized Design (CRD) with three replications was employed. Two liters each of Crassiacarpa and Mangium honey were placed in trays with a thickness of ±2 cm and dehumidified at 25°C and 40% humidity for 24, 48, 72, and 96 hours. Following dehumidification, the honey was analyzed for moisture content, total acidity, pH, and sensory attributes (taste, color, aroma, texture). Data were analyzed descriptively. The results demonstrated that dehumidification time significantly impacted moisture content, total acidity, and pH. Honey type significantly affected moisture content and pH. The interaction between dehumidification time and honey type significantly affected pH. The optimal treatment for both honey types was dehumidification for 96 hours, which resulted in honey that met the SNI 8664-2018 standard.

Keywords: Crassiacarpa; dehumidification; honey; Mangium.

INTRODUCTION

Indonesia, as an archipelagic nation rich in tropical forests and diverse flora and fauna, hosts a wide variety of honeybee species, including *Apis cerana, Apis mellifera, Apis koschevnikovi, Apis dorsata, Apis nigrocincta*, and *Apis andreniformis*. These species play a vital role in honey production, valued for their sweetness and nutritional benefits derived from the nectar of various plants, which contains a carbohydrate-rich secretion (30-50%) (Pribadi et al., 2019).

According to the Indonesian Central Bureau of Statistics (BPS, 2020), honey production in Indonesia has shown significant fluctuations from 2016 to 2020. In 2016, national honey production peaked at 362.2 thousand litres but sharply declined to 51.3 thousand litres by 2020. Java emerged as the largest producer, with 1.6 thousand litres, constituting 81.06% of the total output. Sumatra followed with 4.01 thousand litres (7.81% of the total), while Kalimantan and Sulawesi produced 3,000 and 500 litres, respectively. These figures highlight the regional disparities in honey production, which are influenced by various factors such as climate, flora availability, and beekeeping practices. Approximately 80% to 90% of honey originates from wild bees across various regions of Indonesia, showcasing the significant role of wild bees in the country's honey production landscape.

Honey, as defined by the Indonesian National Standard (SNI) 01-3545-1994 (BSN, 1994), is a natural liquid characterized by its sweetness, produced by bees from the nectar of flowers or other plant parts. The consumption of honey in Indonesia is steadily increasing, evidenced by the growing number of honey brands and honey-based products in the market. Post-harvest handling plays a crucial role in determining honey quality. Nanda et al. (2014) observed that honey harvested at later stages tends to have lower water content than younger honey. Proper handling and processing are essential for maintaining honey quality, while improper practices can degrade quality and reduce shelf life. For instance, excessive heating during processing can reduce the nutritional value and alter the physical properties of honey. As a hygroscopic substance, honey absorbs moisture from the air, making its water content susceptible to environmental humidity (Sarwono, 2007).

The Indonesian National Standard (SNI) 8664-2018 stipulates that honey should contain no more than 22% water content (BSN, 2018). However, a common

challenge producers face is that freshly harvested honey often exceeds this standard, leading to fermentation. High water content facilitates fermentation, which degrades honey quality, shortens its shelf life, and can even cause packaging to break. Therefore, reducing water content is crucial to maintaining honey quality. Effective moisture control is imperative to prevent fermentation and ensure the longevity of honey's shelf life. Factors influencing honey's water content include climate, harvesting practices, and the types of nectar bees collect (Savitri et al., 2017). The longer honey is left in the hive or improperly stored post-harvest, the more water evaporates (Minarti et al., 2016). However, improper storage conditions can lead to reabsorption of moisture, complicating the quality control process. This issue can be mitigated by using a dehumidifier, which effectively removes water vapour from honey through dehumidification.

To ensure compliance with quality standards, honey producers employ various methods to reduce water content, such as heating to speed up evaporation using direct and indirect heating methods with vacuum dehydrators. Another effective method is dehumidification using a water dehumidifier to absorb moisture from honey. Honey producer located in Bandar Lampung Indonesia, utilizes dehumidification processes to lower water content and maintain honey quality. This method was chosen due to its practicality and proven effectiveness in previous studies. Apriantini (2022) reported that dehumidification using an air dehumidifier at 30^{o}C for 4 and 8 hours did not reduce the physical properties quality and yielded improved other properties such as pH, viscosity, color intensity, and antioxidant activity on rubber and rambutan honey. In this study, we extend the dehumidification duration to Crassiacarpa and Mangium honey types produced by *Apis mellifera* bees. This study aims to investigate the effect of the prolonged dehumidification process on the chemical properties of Crassiacarpa and Mangium honey.

MATERIALS AND METHODS

Honey Samples

Two types of honey samples, Crassiacarpa and Mangium, produced by *Apis mellifera* bees, were harvested from the local honey bee farm in Bandar Lampung, Indonesia.

Experimental Design

This study employs a factorial Completely Randomized Block Design (CRBD). The first factor is the type of honey (P), consisting of two levels: Crassiacarpa (P1) and Mangium (P2). The second factor is the dehumidification duration (T), consisting of four treatment levels: 24 hours (T1), 48 hours (T2), 72 hours (T3), and 96 hours (T4), with each treatment being repeated three times. Observed parameters on dehumidified honey included water content, acidity, and pH. The data were statistically analyzed using analysis of variance (ANOVA) and processed further using the Least Significant Difference (LSD) test at the 5% significance level. The best treatment was determined by the adherence to those parameters with the international honey standard (CAC, 2001). The best treatment samples were then tested using the duo-trio method to detect differences in color, aroma, taste, and texture compared to the control (non-dehumidified honey).

Dehumidification Process

The harvested honey is received in bulk at the raw material reception section. The honey is then filtered to remove impurities. Subsequently, the honey is poured into trays to a thickness of approximately ± 2 cm. The dehumidification room (25^{o}C) humidity was set at a humidity level of 40% using a dehumidifier (Kris, Indonesia) in a tightly sealed condition. The duration of dehumidification is 24, 48, 72, and 96 hours. After the dehumidification process, the honey is packaged in a translucent HDPE jerry can and transported to the laboratory. It is then kept in the refrigerator (4°C, RH 75%) for 4 hours before being analyzed further.

Water Content, Acidity, and pH Analysis

The measurement of water content using a refractometer (RHB-92ATC, China). Technically, a refractometer measures the refractive index of a substance. To measure the water content of honey, a sample of honey is placed on the tip of the refractometer. Once the sample is placed, the water content can be directly observed from the refractive index displayed by the refractometer. The percentage of water content is indicated by the highest boundary of the light blue color on the metric scale.

Total acidity tests were conducted using the volumetric method described by Balos et al. (2018). A 10 g sample of honey is weighed and then placed into a 250 mL Erlenmeyer flask. It is dissolved with 75 mL of distilled water, and 4-5 drops of phenolphthalein indicator are added. The solution is then titrated with 0.1 N NaOH solution while swirling the Erlenmeyer flask until a permanent color change is observed for 10 seconds. The volume of 0.1 N NaOH required for the titration is recorded. The acidity value (in mL N NaOH/kg) is calculated by multiplying the volume of NaOH used in the titration (in mL) by the normality of NaOH (0.1 N), divided by the sample weight (in g) and then multiplied by 1000.

The pH was measured using the potentiometric method, following Chakir et al. (2016). The pH meter (Lutron PH222, Taiwan) is calibrated using a pH seven buffer solution. Once the pH meter is standardized, it is immersed in the honey sample container, and the pH measurement result is displayed on the device. The same procedure is followed for each treatment.

Duo-trio Sensory Evaluation

The duo-trio test was performed to determine whether there was a significant difference between the control honey sample (non-dehumidified) and the dehumidified honey sample from the best treatment based on sensorial attributes (texture, color, aroma, and taste). The sensory evaluation was conducted by 20 trained panellists. Samples were placed in small glasses, each containing two teaspoons of honey. Samples were labelled with three random-digit codes and presented on a tray with a spoon, pen, and questionnaire form. The presenter provided the test sample set and explained how to complete the questionnaire. The panellists were then asked to provide their responses to the questionnaire. The collected data were analyzed and matched with the duo-trio table following ISO 10399:2017 (ISO, 2017) with a significance level of 5%.

RESULTS AND DISCUSSION

Water Content

The research results show that the moisture content of two types of honey, Crassiacarpa (P1) and Mangium (P2), ranges between 17–23%. The moisture content of Crassiacarpa honey (P1) ranges from 18.5–23%, while Mangium honey (P2) ranges from 17.3–20.6%. The variance analysis (Table 15) indicates that the dehumidification time (T) and the type of honey (P) significantly affect the moisture content, but their interaction does not have a significant effect. The results of the 5% LSD test indicate that dehumidification time (T) and type of honey (P) significantly affect the moisture content of the honey, as shown in Figures 1 and 2.

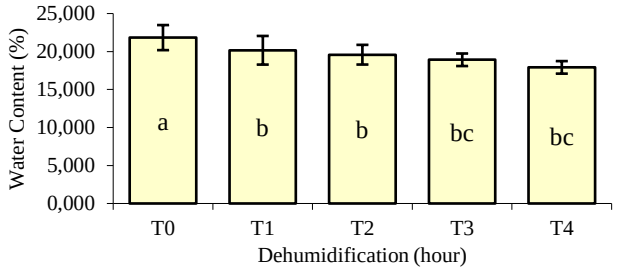

Figure 1. Water content of dehumidified honey at different duration. (T0: 0 hour, T1: 24 hour, T2: 48 hour, T3: 72 hour, T4: 96 hour).

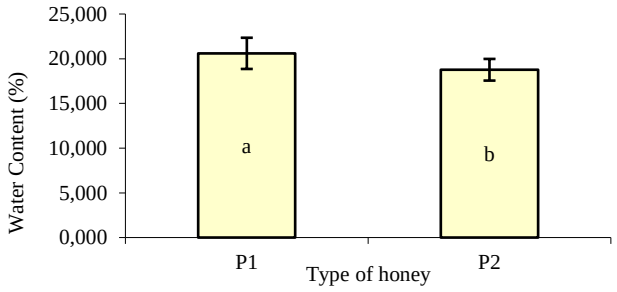

Figure 2. Water content of Crassiacarpa (P1) and Mangium (P2) honey.

Figure 1 shows that the moisture content of honey dehumidified at T0 (0 hours) differs significantly from T1 (24 hours), T2 (48 hours), T3 (72 hours), and T4 (96 hours), while T1 (24 hours) does not differ significantly from T2 (48 hours) and T3 (72 hours) but differs significantly from T4 (96 hours). High-quality honey contains a maximum moisture content of 22% (BSN, 2018). In this study, the lowest moisture content was achieved at dehumidification time T4 (96 hours). The longer the dehumidification time, the lower the moisture content due to the increased evaporation of water from the honey during the dehumidification process, which is absorbed by the dehumidifier. This is consistent with the study by Apriantini (2022), which found that 4 and 8 hours dehumidification times reduced the moisture content in kapok and rambutan honey.

In Figure 2, the moisture content of Crassiacarpa and Mangium honey after dehumidification shows a significant difference. The moisture content of Crassiacarpa honey is higher than that of Mangium honey. This is likely because the initial moisture content of Crassiacarpa honey before dehumidification was higher (23%) than Mangium honey (20%). The viscosity of honey before treatment determines the rate of moisture reduction. The more viscous the honey sample, the longer it takes to reduce its moisture content, whereas less viscous honey reduces its moisture content more easily. This explains why Crassiacarpa honey has a higher moisture content than Mangium honey. The results of the 5% LSD test show that the type of honey (P) significantly affects the moisture content of the honey, as shown in Figure 2.

Moisture content is the first component measured to determine the quality of honey. Low moisture content in honey can inhibit microbial activity and reduce the natural fermentation rate of the honey (Yap et al., 2019). Chayati (2008) stated that reducing the moisture content of honey increases the percentage of other nutrients contained in the honey. High-quality honey has a sufficiently low moisture content, or a maximum of 22%. According to BSN (2018), the maximum moisture content for forest honey is 22%, for stinging bee honey is 22%, and for stingless bee honey is 27.5%. The research results for Crassiacarpa and Mangium honey show that both types meet the standards set by SNI 8664-2018 (BSN, 2018). The difference in the rate of moisture reduction between Crassiacarpa (P1) and Mangium (P2) honey can be influenced by several factors, including the initial water content of the honey, the viscosity of the honey, and the physicochemical properties of the two types of honey.

Total Acidity

The results show that the total acidity of Crassiacarpa (P1) and Mangium (P2) honey, measured at various dehumidification times (24, 48, 72, and 96 hours), ranges between 12.138 to 15.406 ml NaOH/kg. Specifically, the total acidity of Crassiacarpa honey is between 12.138 and

15.406 ml NaOH/kg, while Mangium honey ranges from 12.138 to 14.939 ml NaOH/kg. Variance analysis indicates that dehumidification time (T) significantly affects total acidity, but there is no significant interaction between dehumidification time and honey type (P). The results of the 5% LSD test confirm that dehumidification time significantly influences the total acidity of honey, as shown in Figure 3.

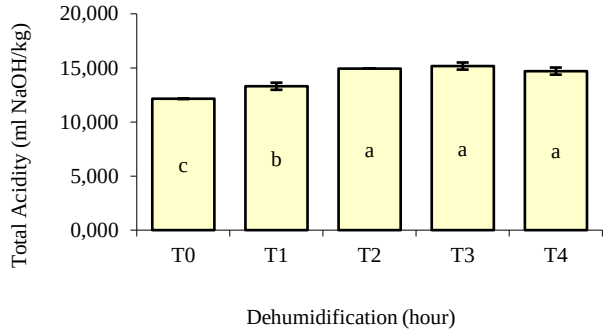

Figure 3. Total acidity of dehumidified honey at different duration. (T0: 0 hour, T1: 24 hour, T2: 48 hour, T3: 72 hour, T4: 96 hour)

The results of the 5% LSD test also revealed that both types of honey (Crassiacarpa and Mangium) dehumidified at T0 (0 hours) and T1 (24 hours) show significantly lower total acidity compared to those dehumidified at T2 (48 hours), T3 (72 hours), and T4 (96 hours). However, no significant differences were observed between T2 (48 hours), T3 (72 hours), and T4 (96 hours). The lowest total acidity occurred at T0 (0 hours), which is associated with the higher moisture content in the honey at this time point, leading to a lower concentration of acids. As the dehumidification time increases, a more significant reduction in moisture content is observed (Figure 1), increasing total acidity. Despite the increase in total acidity, the dehumidification process, conducted at a low temperature of 30°C, does not damage the acids present in the honey.

The acidity of honey is primarily due to the presence of organic acids, including gluconic acid, pyruvic acid, malic acid, and citric acid, along with inorganic ions such as phosphate, sulfate, and chloride (Terrab et al., 2003). Acidity plays a crucial role in determining honey quality, as it contributes to the stability of honey during storage, helps detect fermentation caused by osmophilic yeasts such as Zygosaccharomyces, and affects the texture and taste of honey (Terrab et al., 2003). Organic acids naturally occur in honey from 0.17% to 1.17%, with an average concentration of 0.57% of the total honey composition. These acids can also range in concentration from 8.7 to 46.8 ml NaOH/kg, with an average of 29.1 ml NaOH/kg. The source of these acids can be attributed to the nectar from the flowers that bees feed on, although a significant portion is produced by the bees themselves through the action of the enzyme glucose oxidase. This enzyme catalyzes the oxidation of glucose in honey to produce gluconic acid (Olaitan, 2007). According to the SNI 8664-2018 standards (BSN, 2018), high-quality stinging bee honey should have a total acidity of no more than 50 ml NaOH/kg, while stingless bee honey is allowed a higher limit of up to 200 ml NaOH/kg. In this study, both Crassiacarpa and Mangium honey samples meet the quality standards for total acidity, with values significantly below the maximum allowable limit of 50 ml NaOH/kg.

pH

The pH values obtained for Crassiacarpa (P1) and Mangium (P2) honey samples ranged from 3.39 to 3.67, indicating good honey quality. The analysis of variance (Table 25) reveals that both the type of honey and the dehumidification time significantly affect the pH values. The results of the 5% LSD test demonstrate that the interaction between honey type (P) and dehumidification time (T) has a significant effect on the pH of honey during the moisture reduction process, as illustrated in Figure 4.

Figure 4 shows that the pH of Crassiacarpa honey at P1T0 (0 hours of dehumidification) differs significantly from P1T2 (48 hours) and P1T4 (96 hours), but no significant differences were observed between P1T0 and P1T1 (24 hours) or P1T3 (72 hours). For Mangium honey, no significant differences in pH were found between the different dehumidification times, and the pH was consistently lower than that of Crassiacarpa honey across all dehumidification periods (24, 48, 72, and 96 hours). The interaction between honey type and dehumidification time reveals that P1T0 (0 hours) does not differ significantly from any of the Mangium honey treatments (P2T0, P2T1, P2T2, P2T3, P2T4), but P1T1 (24 hours) and P1T3 (72 hours) show significant differences when compared to Mangium honey across all dehumidification times (P2T1, P2T2, P2T3, P2T4). In contrast, P1T2 (48 hours) and P1T4 (96 hours) differ significantly from all Mangium honey treatments.

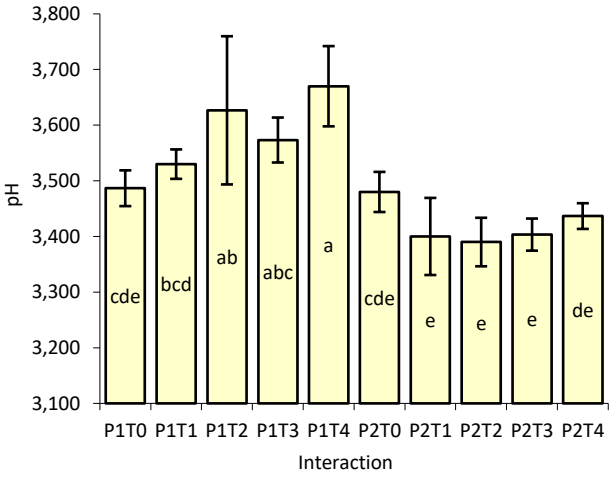

Figure 4. pH value of honey from various dehumidification duration (T) and type of honey (P). (T0: 0 hour, T1: 24 hour, T2: 48 hour, T3: 72 hour, T4: 96 hour; P1: Crassiacarpa, P2: Mangium)

The higher pH values observed in Crassiacarpa honey at P1T4 (96 hours) are likely due to the decrease in moisture content during dehumidification, which leads to the concentration of compounds that influence pH. This difference in pH values between Crassiacarpa and Mangium honey could also be attributed to differences in mineral and acid content, as suggested by Gulfraz et al. (2010). The mineral content of honey is influenced by factors such as soil composition, geographical location, and the climate of the region where the nectar-producing plants grow (Buba et al., 2013). Importantly, the dehumidification process used in this study, which occurs at a low temperature of 30°C, does not degrade the organic acid content of the honey. The lower pH observed in Mangium honey after longer dehumidification may be due to its lower moisture content, which results in higher total acidity (Figure 8), possibly because of reduced enzymatic and microbial activity.

According to Saepudin et al. (2014), the pH of pure honey typically ranges from 3.2 to 4.5, with an average of 3.91, whereas fake or adulterated honey tends to have a pH between 2.4 and 3.3. If the pH falls outside this range, honey quality may be compromised, as the acidity helps to protect the honey from microbial contamination, which could otherwise lead to rapid spoilage. The low pH values found in honey are mainly due to the presence of organic acids such as syringic acid (3,5-dimethoxy-4-hydroxybenzoic acid), methyl syringate (3,4,5-trimethoxybenzoic acid), and 2-hydroxy-3-phenylpropionic acid, as reported by Puspita (2007). Ratiu et al. (2020) further emphasize the relationship between honey pH and microbial activity, noting that lower moisture content and pH are associated with reduced microbial contamination. In their study, honey samples with pH values ranging from 3.20 ± 0.01 to 4.49 ± 0.01 showed no bacterial presence. These findings align with the pH results obtained in this study, where values ranged from 3.39 ± 0.41 to 3.67 ± 0.07, all within the acceptable range for maintaining honey freshness and aroma. Additionally, Adalina (2017) highlighted that organic acids play a significant role in determining honey's taste, aroma, and resistance to microbial growth.

In conclusion, the pH values of Crassiacarpa and Mangium honey in this study fall within the acceptable range for high-quality honey, as outlined by SNI 8664-2018 (BSN, 2018), which specifies a pH range of 3.2 to 4.5. This acidic environment helps to inhibit bacterial growth and prolong the shelf life of honey. Although Crassiacarpa honey showed some fluctuations in pH at different dehumidification times, the pH remained within the desirable range, ensuring that the honey maintained its quality throughout the dehumidification process. Meanwhile, Mangium honey exhibited no significant pH changes with increasing dehumidification time, confirming its stability and good quality.

Best Treatment Selection

Based on the analysis of moisture content, pH, and total acidity for both Crassicarpa and Mangium honey, summarized in Tables 1 and 2, the optimal dehumidification times were identified. For Crassicarpa honey, lower moisture content and higher pH values were observed at 48–96 hours of dehumidification, with no significant differences in total acidity between 24 and 96 hours. Similarly, for Mangium honey, the moisture content remained low between 24 and 96 hours, consistent pH values across 0–96 hours, and no significant variation in total acidity between 48 and 96 hours. Compared with the Indonesian National Standard (SNI) 8664:2018, all treatments for both honey types met the required parameters for moisture content, pH, and total acidity. However, to minimize the risk of fermentation associated with higher moisture levels, a dehumidification period of 96 hours was selected as the most suitable treatment for both honey types.

Table 1. Determination of best treatment for Crassiacarpa honey.

P1	T0 (0 hour)	T1 (24 hours)	T2 (48 hours)	T3 (72 hours)	T4 (96 hours)	Standard
Water content	23^{a}	$21{,}5^{ab}$	20^{bcd}	$19{,}5^{bcde}$	$18{,}5^{cde}$	22%
pH	$3{,}48^{cde*}$	$3{,}53^{bcd*}$	$3{,}62^{ab}$	$3{,}57^{abc*}$	$3{,}67^{a*}$	3,2- 4,5
Total acidity	$12{,}13^{c*}$	$13{,}53^{abc*}$	$14{,}93^{ab*}$	$15{,}4^{a*}$	$14{,}93^{ab*}$	Max 50

Table 2. Determination of best treatment for Mangium honey.

P1	T0 (0 hour)	T1 (24 hours)	T2 (48 hours)	T3 (72 hours)	T4 (96 hours)	Standard
Water content	$20{,}67^{bc}$	$18{,}83^{cde}$	$18{,}66^{cde}$	$18{,}33^{de}$	$17{,}33^{e*}$	22%
pH	$3{,}48^{cde*}$	$3{,}4^{e*}$	$3{,}39^{e*}$	$3{,}40^{e*}$	$3{,}43^{e*}$	3,2- 4,5
Total acidity	$12{,}13^{c*}$	$13{,}07^{bc*}$	$14{,}93^{ab*}$	$15{,}4^{a*}$	$14{,}47^{ab*}$	Max 50

Duo-Trio Test

The duo-trio test in this study, involving 20 panellists from the Department of Agricultural Product Technology, asked panellists to differentiate between honey dehumidified for 96 hours and untreated honey (R) based on aroma, taste, viscosity, and color. According to the binomial distribution table, significant differences were observed in all parameters—aroma, taste, viscosity, and color—at the 5% significance level (Tables 3 and 4). The results indicate that both Crassicarpa and Mangium honey dehumidified for 96 hours exhibited distinct sensory characteristics compared to untreated honey in terms of texture, taste, aroma, and color. This suggests that honey dehumidified for 96 hours can be easily distinguished from untreated honey by general consumers.

Table 3. Duo trio test results on the Crassiacarpa honey at best treatment (dehumidification 96 hours).

Parameter	Number of panelists noted the difference	Number of panelist required (Binomial table 0,05 %, with 20 panelists)	Remarks
Texture	17	15	R*
Color	15	15	R*
Aroma	16	15	R*
Taste	15	15	R*

Note: R* = different with control sample

Table 4. Duo trio test results on the Mangium honey at best treatment (dehumidification 96 hours).

Parameter	Number of panelists noted the difference	Number of panelist required (Binomial table 0,05 %, with 20 panelists)	Remarks
Texture	15	15	R*
Color	17	15	R*
Aroma	16	15	R*
Taste	15	15	R*

Note: R* = different with control sample

CONCLUSION

Dehumidification time significantly affected the honey's moisture content, pH, and acidity. Additionally, the type of honey had a notable influence on the moisture content and pH. The interaction between dehumidification time and honey type significantly impacted the pH values, with a dehumidification time of 96 hours being the optimal treatment for both honey types. This resulted in honey that met the standards set by SNI 8664:2018.

Authors' Contributions: Depri Mubarik, Otik Nawansih, Esa Ghanim Fadhallah, and Fibra Nurainy designed the study and wrote the manuscript in Bahasa. Depri Mubarik conducted the research. Otik Nawansih, Esa Ghanim Fadhallah, and Fibra Nurainy supervised the research. Esa Ghanim Fadhallah translates to English and proofreads the manuscript. All authors read and approved the final version of the manuscript.

Competing Interests: The authors declare that there are no competing interests.

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