

## Vacuum evaporation optimization of Bali local honey for quality enhancement

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### Article history:

Received: 13 January 2023

Received in revised form: 11 March 2023

Accepted: 9 April 2024

Available Online: 27

December 2024

### Keywords:

Quality enhancement,

Local honey,

Vacuum evaporation,

Moisture content

### DOI:

[https://doi.org/10.26656/fr.2017.8\(6\).018](https://doi.org/10.26656/fr.2017.8(6).018)

### Abstract

The quality of honey is of great importance to both local and international markets, as it ensures competitive pricing and promotes human health. One crucial factor that affects honey's quality is its moisture content. Therefore, this study aimed to evaluate the effect of temperature and rotation speed of evaporated vacuum on the physicochemical quality of local honey and to determine the most effective vacuum evaporated to improve honey quality. It employed a randomized complete block design comprising of two factors, such as evaporated temperatures of 60°C, 70°C, and 80°C, as well as the rotation speed of the evaporator vacuum at 80 rpm, 100 rpm, and 120 rpm. The results showed that reducing the moisture content of local honey can improve its quality significantly. Furthermore, the quality can be improved by a rotary vacuum evaporator using a temperature of 70°C and a rotary speed of 100 rpm. The physicochemical quality showed a moisture content, ash content, reducing sugar, pH value, L\*, a\*, and b\* of 20.978±0.335%, 0.310±0.006%, 65.460±0.135%, 3.741±0.006, 16.473±0.206, 2.447±0.105, and 1.280±0.040, respectively.

## 1. Introduction

Stingless bee honey is a valuable product known for its higher nutritional and medicinal value than *Apis mellifera* honey (Zhao *et al.*, 2016). However, the production is limited mainly because of the low quantities produced (Chuttong *et al.*, 2016). It has been reported to be beneficial for human health due to its high antioxidant content (Amin *et al.*, 2018), and the price is considerably higher than *Apis mellifera* (Cardona *et al.*, 2019).

Honey is a natural sweet substance produced by honeybees from the nectar of flowers' plant secretion (Codex Alimentarius Commission, 2019; Hernández-Fuentes *et al.*, 2021). It is known for its antioxidant and antimicrobial properties (Tomczyk *et al.*, 2019). Additionally, honey is widely utilized as a food ingredient (Kohsaka *et al.*, 2017), and its natural

medicinal properties have made it a popular choice for healthcare reasons (Rao *et al.*, 2016). The decision of consumers to purchase products is dependent on the quantity and quality level of honey.

Honey quality cannot be uniform after harvest because the physical and chemical characteristics depend on external and internal factors. The external factors are the source of nectar, season, soil or geographic conditions, processing, and storage conditions. Meanwhile, the internal factor is the type of bee (Tomczyk *et al.*, 2019; Damayanti *et al.*, 2019; Sayusti *et al.*, 2020; Evahelda *et al.*, 2021).

Moisture is one of the most important parameters of honey quality. The amount of moisture determines its stability against fermentation and granulation (Singh and Singh, 2018). Honey is closely tied to moisture content,

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resulting in reduced quality, while low moisture content tends to have a longer shelf life. Moisture content is influenced by climate and post-harvest handling (Parihar *et al.*, 2020). According to the Indonesian National Standard (SNI) (Badan Standarisasi Nasional, 2013), good quality honey should have a maximum moisture content of 22%. The high moisture content is caused by harvesting honey earlier, in which the bee hive is not covered with wax properly (Harjo *et al.*, 2015). Furthermore, it is a component of honey that affects viscosity and crystallization properties, as well as flavor, color, and shelf life (Escuredo and Seijo, 2019).

Moisture in honey can vary according to the moisture content of the plant used during the production, the harvest season, and climatic conditions (Da Silva *et al.*, 2016; Gürbüz *et al.*, 2020). According to Saputra *et al.* (2021), the dry air in the dry season may cause the low quality of nectar, resulting in increased sugar content. Honey harvested during this season can produce a lower moisture content than those obtained in the rainy season due to the surrounding dry air. The high moisture content of honey increases the possibility of fermentation due to osmophilic yeast development (Agrib *et al.*, 2017). Many dead yeasts, glycerol, ethanol, and butanediol due to the fermentation of honey result in the deterioration of its taste (Moore *et al.*, 2012). Different management, harvesting, and processing techniques can influence the final quality of honey.

Honey exhibits hygroscopic properties and is capable of absorbing moisture. Therefore, all the processing equipment must be maintained at optimal dryness. Excessive moisture content can lead to fermentation, which should be avoided (Bett, 2017). According to Adnan *et al.* (2015), heating is the most important processing step in honey production due to its direct effects on the quality. The current study showed that processing temperature has a significant effect on moisture content. Honey processed at 60°C had higher moisture of 17.98%, compared to 17.06% and 16.40% at 70 and 80°C, respectively (Singh and Singh, 2018). According to Chua *et al.* (2015), the moisture content of honey can be reduced to less than 20% by heating at 90°C for 30 mins. The study further established that increasing the temperature up to 90°C enhances the kinetics of moisture reduction. However, excessive heating of honey above 90°C can lead to the caramelization of its sugar content (Singh and Singh, 2018). Adalina (2017) noted that harvesting is critical in producing high-quality honey. The study further suggested that honey harvested tends to have a lower moisture content.

Based on a primary study on beekeeper groups in Bali Province, most local honeybees (*Tetragonula*

*laeviceps*) have a lower quality. Hakim *et al.* (2021) reported that stingless bee honey is susceptible to having high moisture content. High moisture content can lead to fermentation and crystallization, decreasing the quality of honey. The study highlighted that one of the major challenges honey producers face in tropical countries is the rapid deterioration in quality resulting from fermentation (Eshete and Eshete, 2019). Honey exhibits a moisture content of over 22%, rendering its color and taste unstable and reducing its shelf-life. Meanwhile, Singh and Singh (2018) highlighted the significance of maintaining high-quality standards in domestic and international markets, ensuring competitive prices, and safeguarding human health. This study enhanced local honey quality and identified the optimal method by reducing its moisture content.

## 2. Materials and methods

The sample used was a local honeybee classified as a stingless bee (*Tetragonula laeviceps*). The honeybee was harvested at the beekeeper group of “Sarining Trigona Pertiwi” in Bongkasa Village, Badung Regency, Bali Province, Indonesia. It has a specific name in Bali known as “kela-kela” and honey was harvested two months after the first harvesting using a local portable suction machine from 1.00 to 2.00 pm. Furthermore, it was transferred to plastic bottles, transported to the Laboratory of Agriculture Faculty at Warmadewa University, and refrigerated before analysis.

The processing equipment and physical-chemicals analysis were used, including a portable suction machine, Rotary vacuum evaporator R-300 BUCHI, and refrigerator. Instruments for chemical and physical analysis consist of UV-Vis Double beam spectrophotometer Libra S 60, Colorimeter CS-280, Viscometer NDJ-8 S, pH meter HI 8424 HANNA, Condenser, Memmert incubator, centrifuge, autoclave, porcelain dish, oven, Soxhlet, desiccator, analytical scale, thermometer, Erlenmeyer, beaker, test tube, and dropper.

This study used a completely randomized design consisting of two factors involving evaporating temperature at 60, 70, and 80°C and the rotation speeds of the vacuum rotary evaporator at 80, 100, and 120 rpm. There are nine treatment combinations that have been replicated three times with a total of 27 sample units.

### 2.1 Preparation of samples (fresh honeybee)

To obtain clean honey, a total of 220 mL was filtered as the sample. Before processing the sample, the rotary evaporator must be activated to increase moisture to a boiling temperature. Once moisture temperature reached

60°C, honey was carefully poured into a glass bottle and placed into the vacuum rotary evaporator machine at 80 rpm for 1 hr. Some moisture was collected during the final process, and the volume was recalculated accordingly. An analysis of the physicochemical quality of honey was conducted according to the recalculation process.

The same procedure was carried out for other honey with different treatments consisting of heating at a temperature of 60°C with a speed of rotary evaporator 100 and 120 rpm. Heating honey should be performed at a temperature of 70°C with evaporated speeds of 80, 100, and 120 rpm. The evaporation process is conducted at 80°C with the rotary speed of 80, 100, and 120 rpm for 1 hr. The temperature of the moisture bath outlet was maintained at 60°C while the honey sample inlet was at 35°C. Meanwhile, the temperature of the moisture bath and honey sample was increased from 70°C to 80°C and 45°C to 55°C, respectively.

## 2.2 Physicochemical analysis procedure of honeybee

The physicochemical quality of local honey was evaluated through moisture content, ash content, reducing sugar, pH, and color intensity ( $L^*$ ), ( $a^*$ ), and ( $b^*$ ).

### 2.2.1 Moisture content

The moisture content of honey was analyzed using the gravimetric method (Kyaw *et al.*, 2020). Firstly, the dish and lid were dried in the oven at 105°C for 3 hrs and then transferred to the desiccator to cool down. They were weighed after the cooling process, and 3 g of the sample was placed in the dish. Furthermore, the dish with the samples was placed in the oven and dried at 105°C for 3 hrs. After drying, the dish, partially covered with a lid, was transferred to the desiccator to cool the temperature down. The dish and sample were re-weighed after cooling, and moisture content was calculated using Equation 1.

$$\% \text{ Moisture} = \frac{W1 - W2}{W1} \times 100 \quad (1)$$

Where  $W1$  = Weight of the sample before drying (g) and  $W2$  = Weight of the sample after drying (g)

### 2.2.2 Ash content

To determine the ash content of honey samples, 3 g of each was weighed in a Chinese crucible and put in an electric furnace at 640°C for 6 hrs. Subsequently, the amount of ash was measured (Namini *et al.*, 2018; Cardona *et al.*, 2019).

### 2.2.3 Reducing sugar

Reducing sugar was analyzed using the Nelson-Somogyi method (Agrib *et al.*, 2017), and 1 mL sample was added to distilled moisture until the final volume was 10 mL. A mixture of both liquids was taken, specifically, 1 mL of the mixture, and then an additional 9 mL of distilled moisture was added. The resulting solution was then combined with 1 mL of Nelson's solution, a mixture of Nelson A and B in a ratio of 25:1 v/v. The solution was heated to 100°C for 20 mins before cooling the sample to room temperature. After cooling, 1 mL of arsenomolybdate solution and 7 mL of distilled moisture were added and shaken. Subsequently, the mixture was put into a cuvette, and the absorption of visible light was measured at a wavelength of 510 nm. The absorbance value was obtained by reducing the blank, and the sample was converted to reducing sugar content (mg/mL) based on the standard solution regression equation. The following formula calculates the reducing sugar content of the sample.

$$X = (y - a)/b \quad (2)$$

Where  $X$  is the reducing sugar concentration,  $y$  is the absorbance of a sample, and  $a$  and  $b$  are constants of a standard curve from equation (3).

$$\% \text{ Reducing sugar} = \frac{(X \text{ mg/mL} \times \text{df})}{\text{mg/mL sample}} \times 100\% \quad (3)$$

Where  $X$  is the reducing sugar (mg/mL) and  $df$  is the dilution factor

### 2.2.4 pH

pH measurements were conducted using a digital pH meter (HI 8424 HANNA), and 10 g of homogenized honey was added to 90 mL of distilled moisture. Subsequently, the pH was read directly from the meter, and the instrument was calibrated with standard buffer solutions of pH 7 and 4 (Parihar *et al.*, 2020).

### 2.2.5 Color intensity ( $L^*$ , $a^*$ , $b^*$ )

The color, mainly the degree of lightness of honey, was analyzed using colorimeter type PCE-CSM 1, represented in the coordinates  $L^*$ ,  $a^*$ , and  $b^*$  (Commission Internationale de l'Éclairage, CIE). About 10 g was put into a small Petri dish for measurement. Lightness ( $L^*$ ) value is 0 – 100 (black-white), the redness to green ( $a^*$ ) value is +100 – (-100), and the yellow to blue ( $b^*$ ) value is +100 – (-100) (Kwak *et al.*, 2018).

## 2.3 Statistical analysis

In the statistical analysis, a completely randomized design was used. Data obtained in the physicochemical analysis was submitted to the analysis of variance

(ANOVA) with a confidence level of 95% (Seder *et al.*, 2021). Furthermore, the analysis was then continued to the DMRT and standard deviation (SD) when the effects of the treatments were significantly observed ( $p < 0.05$ ).

### 3. Results and discussion

The physicochemical quality of the fresh honey before and after processing is shown in Tables 1, 2, and 3. After processing, the honey was analyzed to compare the quality improvement using a vacuum rotary evaporator. The local fresh honey contents had a reducing sugar and moisture content of 59.60% and 30.66%, respectively. This was similar to the moisture content of “kelulut” honey which was above 30% (Hidalgo *et al.*, 2020). Meanwhile, Malaysian stingless bee honey has a moisture content of 21% to 31% (Fatima *et al.*, 2018; Hasali *et al.*, 2018; Sujanto *et al.*, 2021). The moisture content of the fresh honey was 30.66%, which was higher than SNI, a maximum of 22%.

The reduction of moisture content in fresh local honey is essential to improve the quality and safety of honey and increase its shelf-life. The physicochemical quality of local honey after processing with various rotary vacuum evaporator methods is shown in Table 2.

#### 3.1 Moisture content

Moisture content is one attribute used to indicate honey quality. According to SNI-3545-2013 (Badan Standarisasi Nasional, 2013) for honey, the maximum moisture content of honey is 22%. This study showed that the variable varies from all processing methods from 4.681±0.235% to 33.134±0.100% for a different honey. The five methods produced similar results with lower moisture contents against the SNI-3545-2013. The methods were processing honey at 80 rpm:80°C, 100

rpm:80°C, 120 rpm:80°C, 100 rpm:70°C, and 80 rpm:70°C. The results showed moisture content of honey was 4.681±0.235, 10.718±1.244, 17.155±0.577, 20.978±0.335, and 22.054±0.781%, as shown in Table 2. The lowest and highest moisture content of 4.681±0.235% and 33.134±0.100% was obtained from honey vacuum-evaporated at 80 rpm and 120 rpm with the temperature at 80°C and 60°C, respectively. These results concurred with Singh and Singh (2018), where the processing temperature significantly affected moisture content. This can be seen from the results of honey processed at 60°C and 80°C, which had higher moisture of 17.98% and 16.40%, respectively. According to Seder *et al.* (2021), low moisture content provides natural protection against fungal spoilage caused by the action of osmotolerant yeast fermentation during honey storage, which can convert carbohydrates into ethyl alcohols. Adnan *et al.* (2015) reported that less than 20% moisture content is required to reduce the fermentation rate and increase the stability of honey. Meanwhile, the high moisture content is considered disadvantageous for long shelf life during storage.

The increasing temperature in the evaporation process causes a decrease in honey moisture, making it lower in quality. The evaporation process at 80°C in all speed treatments at 80, 100, and 120 rpm resulted in lower moisture content. It showed significant differences in results compared to other treatments, as seen in Figure 1. Therefore, the increase in temperature during the evaporation process had a significant effect compared to the speed of the rotary in the vacuum evaporator on the moisture content of honey. This was similar to the results obtained by Lastriyanto *et al.* (2020), where evaporation with reduced pressure decreased the required time. The method is more time-efficient for reducing the moisture content of honey than the dehumidifier method. Moisture

Table 1. Physicochemical quality of fresh local honey

Physicochemical Quality	Moisture Content (%)	Ash (%)	Reducing sugar (%)	pH
Fresh honey	30.66	0.014	59.60	3.13

Table 2. Physicochemical quality of local honey

Treatment	Moisture content (%)	Ash (%)	Reducing Sugar (%)	pH
80 rpm:60°C	26.213±0.599 <sup>c</sup>	0.162±0.006 <sup>d</sup>	61.187±0.657 <sup>ef</sup>	3.139±0.050 <sup>g</sup>
80 rpm:70°C	22.054±0.781 <sup>e</sup>	0.027±0.002 <sup>e</sup>	65.093±0.268 <sup>d</sup>	3.139±0.036 <sup>g</sup>
80 rpm:80°C	4.681±0.235 <sup>h</sup>	0.014±0.003 <sup>f</sup>	68.423±0.361 <sup>c</sup>	3.185±0.010 <sup>f</sup>
100 rpm:60°C	29.130±0.691 <sup>b</sup>	0.285±0.002 <sup>b</sup>	61.607±0.081 <sup>e</sup>	3.856±0.027 <sup>a</sup>
100 rpm:70°C	20.978±0.335 <sup>e</sup>	0.310±0.006 <sup>a</sup>	65.460±0.135 <sup>d</sup>	3.741±0.006 <sup>c</sup>
100 rpm:80°C	10.718±1.244 <sup>g</sup>	0.264±0.008 <sup>c</sup>	69.230±0.234 <sup>b</sup>	3.809±0.007 <sup>b</sup>
120 rpm:60°C	33.134±0.100 <sup>a</sup>	0.016±0.002 <sup>f</sup>	60.693±0.719 <sup>f</sup>	3.540±0.004 <sup>c</sup>
120 rpm:70°C	24.231±0.121 <sup>d</sup>	0.019±0.002 <sup>ef</sup>	65.790±0.131 <sup>d</sup>	3.644±0.009 <sup>d</sup>
120 rpm:80°C	17.155±0.577 <sup>f</sup>	0.016±0.002 <sup>f</sup>	72.780±0.617 <sup>a</sup>	3.755±0.008 <sup>c</sup>

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ( $P < 0.05$ ).

bath and inside temperatures are 80°C and 45-50°C. Chua *et al.* (2015) reported that the moisture content of honey was reduced to less than 20% after 30 mins of heating at 90°C. The temperature above 90°C resulted in higher kinetic moisture reduction. However, heating honey above 90°C could result in the caramelization of sugar (Singh and Singh, 2018).

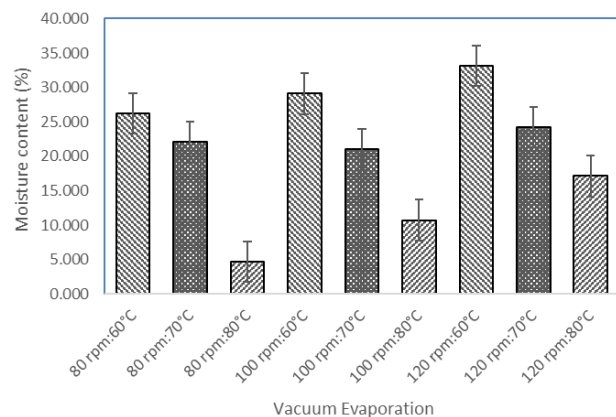


Figure 1. Moisture content (%) of honey in various vacuum evaporation.

### 3.2 Ash content

Ash content in honey indicates the mineral composition due to nectar resources and soil quality. SNI reported that a honey product should have a maximum ash content of 0.5% w/w. Table 2 shows that the ash content of honey after processing with different evaporated methods was between  $0.014 \pm 0.003\%$  to  $0.310 \pm 0.006\%$ . Honey within this range has fulfilled the quality standard set by SNI. The ash content resulting from the evaporation process at 80 rpm:80°C was determined to be  $0.014 \pm 0.003\%$ . Notably, this value was significantly different from the ash content obtained under evaporation conditions at 100 rpm:70°C, which was  $0.310 \pm 0.006\%$ . However, the evaporated methods gave significant differences in the ash content of honey, which increases after the evaporating process but still fulfills the standard quality. This was because reducing moisture content will increase the amount of organic and inorganic matter, such as carbohydrate percentage and mineral content. According to Adnan *et al.* (2015), ash consists of minerals and metals, which are non-labile compounds, and the increased content causes the color amber-brown (Rao *et al.*, 2016). According to Abd Jalil *et al.* (2017), dark honey exhibits a higher mineral content than light honey. It has been observed that the light variant contains approximately 0.20% of colloidal material, while the dark honey type contains 1% of these substances.

### 3.3 Reducing sugar

Honey quality is not decided only by moisture content but also by total sugar, consisting of fructose and glucose (Savitri *et al.*, 2017). The result of reducing sugar from the process taken from local fresh honey of *Tetragonula laeviceps* was 59.60%. This was lower than the quality standard set by SNI, which was a minimum of 65% w/w of glucose content. After processing with the evaporator, the content increased, and all evaporated treatments significantly affected the reduced sugars. Furthermore, the reduced sugar content of honey products after evaporating was around  $60.693 \pm 0.719\%$  to  $72.780 \pm 0.617\%$ . Evaporating honey at 60°C and 80°C with a rotary speed of 120 rpm gave the lowest and highest reducing sugar content of  $60.693 \pm 0.719\%$  and  $72.780 \pm 0.617\%$ . The processes showed a significant difference in the reducing sugars compared to others. However, three evaporated methods resulted in lowering reducing sugar content to  $60.693 \pm 0.719\%$ ,  $61.187 \pm 0.657\%$ , and  $61.607 \pm 0.081\%$  at evaporating speed and temperature of 120 rpm:60°C, 80 rpm:60°C, and 100 rpm:60°C, respectively (Table 2). The other evaporated methods resulted in higher reduced sugar content after evaporating and met the quality standard. According to Savitri *et al.* (2017), the reduced sugar content was affected by the moisture and pH level of honey. The evaporating temperature and the rotation speed increase the reduced sugar content (Figure 2). The evaporating process at 60°C to 80°C and a rotation speed of 80 rpm to 120 rpm can evaporate and decrease moisture content. According to Singh and Singh (2018), the extent of moisture reduction can increase the concentration of reducing and non-reducing sugars. The higher temperature and speed rotation can increase moisture reduction in honey. Tomczyk *et al.* (2019) reported that good quality honey should contain 5 g/100 g sucrose and at least 60 g/100 g reducing sugar.

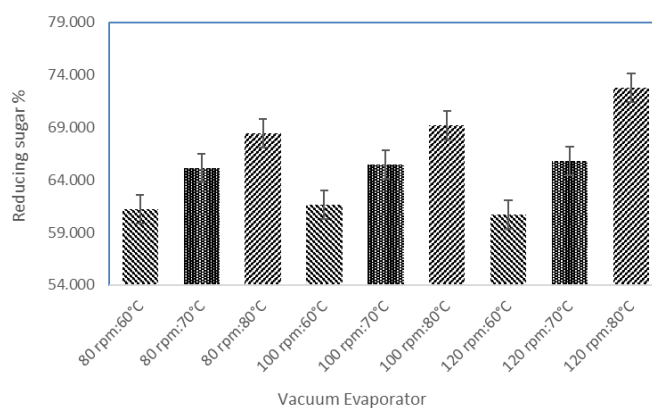


Figure 2. Reducing sugar content (%) of honey in various vacuum evaporation.

### 3.4 pH

Honey pH is determined by hydrogen ions dissociation in an aqueous solution, while most of it contains various minerals, including Ca, Na, and K (Evahelda *et al.*, 2021). The evaporating temperature and rotary speed significantly affected the pH of the honey product ( $p > 0.05$ ). The value was around  $3.139 \pm 0.036$  to  $3.856 \pm 0.027$ , showing a significant difference ( $p > 0.05$ ) among the evaporated methods. The lowest and highest pH of  $3.139 \pm 0.036$  and  $3.856 \pm 0.027$  result was obtained by the evaporation speed and temperature at 80 rpm:70°C. This result showed a significant difference ( $p > 0.05$ ) in pH value (Table 2). It was similar to the results by Gürbüz *et al.* (2020), where the pH value ranges from 3.67 to 6.45 and  $3.77 \pm 0.05$  in Malaysian stingless bee honey (Omar *et al.*, 2019). The evaporating temperature and rotary speed increase with honey pH value. The increase in pH was due to the reduction of the volatile organic acids and moisture in honey that evaporates during processing. The decrease in organic acid content can increase honey pH. On the other hand, the decrease in moisture content can increase the mineral content percentage and pH. The higher mineral content can increase honey pH (Evahelda *et al.*, 2021). Moisture content influences honey pH (Savitri *et al.*, 2017). The sour taste in honey was attributed to a high organic acid content, which lowers the pH level. Tomczyk *et al.* (2019) reported that the pH depends on both the ionized acid and mineral elements. Even though honey with high antioxidant compounds offers health benefits, consumers tend to avoid those with excessive sourness. According to SNI, good quality honey has pH values ranging from 3.4 to 4.3 to avoid microbial contamination (Gürbüz *et al.*, 2020).

### 3.5 Lightness ( $L^*$ )

The honey color is one of its most distinctive characteristics and indicates the presence of phenolic

compounds (Hernández-Fuentes *et al.*, 2021). Singh and Singh (2018) reported that color is an important physical parameter required for consumers' preferences and changes during heating. Lightness can be considered as one of the quality parameters for honey products. The increase in the lightness value denotes that honey possesses a clear and bright appearance, while a decrease signifies a darker coloration. After evaporating, the lightness was between  $9.053 \pm 3.721$  to  $18.463 \pm 0.195$ , as shown in Table 3. The temperature and speed of the rotary evaporator had a significant effect ( $p > 0.05$ ) on the product's lightness. Honey evaporated at 80 rpm:70°C and 100 rpm:80°C resulted in a low and high lightness of  $9.053 \pm 3.721$  and  $18.463 \pm 0.195$ , respectively. The result was not significantly different ( $p < 0.05$ ) when honey was evaporated at 100 rpm:70°C resulting in  $16.473 \pm 0.206$ . The processes of 100 rpm:80°C and 100 rpm:70°C gave a significant difference ( $p > 0.05$ ) with the evaporated process. According to Singh and Singh (2018), the heating of honey causes non-enzymatic browning due to the Maillard reaction of sugars with free amino acids to form brown pigments. Popov-Raljić *et al.* (2015) reported that honey was classified into light and dark colors with a value of  $L^* > 50$  and  $L^* \leq 50$ . Therefore, honey utilized in this study can be classified as light honey.

### 3.6 Color intensity ( $a^*$ )

The temperature and rotation speed of rotary vacuum evaporated methods gave a significant effect ( $p > 0.05$ ) on the color value  $a^*$ . The treatments showed a significant difference ( $p > 0.05$ ) in the color value  $a^*$ . According to Table 3, the color of  $a^*$  gave a positive value for all evaporated methods. It signifies that honey is red, but the negative value indicates green color. However, based on the results, no honey has a negative value, and the color value  $a^*$  ranges from  $1.420 \pm 0.020$  to  $6.673 \pm 2.624$ , slightly red to yellow dark. Rao *et al.* (2016) and Syafrizal *et al.* (2020) reported that the color of stingless

Table 3. The color intensity of local honey in various vacuum evaporation.

Treatment	Color intensity		
	$L^*$	$a^*$	$b^*$
80 rpm:60°C	$10.853 \pm 1.174^{dc}$	$5.810 \pm 0.901^{ab}$	$-1.820 \pm 0.792^{cd}$
80 rpm:70°C	$9.053 \pm 3.721^e$	$6.673 \pm 2.624^a$	$-2.587 \pm 1.929^d$
80 rpm:80°C	$14.850 \pm 1.729^{bc}$	$4.083 \pm 0.428^{bcd}$	$-0.457 \pm 0.599^{bc}$
100 rpm:60°C	$17.553 \pm 0.394^a$	$2.493 \pm 0.204^{dc}$	$1.463 \pm 0.095^a$
100 rpm:70°C	$16.473 \pm 0.206^{ab}$	$2.447 \pm 0.105^{dc}$	$1.280 \pm 0.040^a$
100 rpm:80°C	$18.463 \pm 0.195^a$	$1.420 \pm 0.020^e$	$1.933 \pm 0.253^a$
120 rpm:60°C	$12.287 \pm 0.613^{cd}$	$5.127 \pm 0.392^{abc}$	$-0.457 \pm 1.171^{bc}$
120 rpm:70°C	$13.630 \pm 0.479^{cd}$	$3.547 \pm 0.697^{cd}$	$0.623 \pm 0.122^{ab}$
120 rpm:80°C	$12.050 \pm 0.432^d$	$5.233 \pm 0.202^{abc}$	$-1.167 \pm 0.095^{cd}$

Values are presented as mean  $\pm$  SD. Values with different superscripts within the same column are statistically significantly different ( $P < 0.05$ ).

bee honey is dark amber. The factors affecting the color are ash content, heat, light exposure, duration of storage, enzymatic reaction, and presence of various compounds.

### 3.7 Color intensity ( $b^*$ )

The color intensity of honey is one of the factors for higher pH (Nurfatin *et al.*, 2021). The  $b^*$  value is the color from yellow to blue, where the positive and negative value means yellow and blue. Table 3 showed that the temperature and rotation speed of rotary vacuum evaporated methods gave a significant effect ( $p>0.05$ ) on the color value  $b^*$  ranging from  $-2.587\pm 1.929$  to  $1.933\pm 0.253$ . Several treatments of temperatures and speed evaporated yielded negative color values, while speed rotation at 100 rpm in  $60^\circ\text{C}$ ,  $70^\circ\text{C}$ , and  $80^\circ\text{C}$ , gave positive color values of  $1.463\pm 0.095$ ,  $1.280\pm 0.040$  and  $1.933\pm 0.253$ , respectively. Furthermore, speed rotation at 120 rpm and evaporation at a temperature of  $70^\circ\text{C}$  also affected the color  $b^*$  value. The higher  $b^*$  value positively means the honey color looks more yellow. In general, evaporating local honey with 100 rpm of speed rotation increases the yellowish color by more than 80 rpm and 120 rpm, as shown in Table 3. The evaporating process at 100 rpm was responsible for the yellow color. Based on the rotational speed, a color transition to light and brownish-yellow would occur at 80 and 120 rpm. According to Table 2, when subjected to rotational speeds of 100 rpm and temperatures of  $60^\circ\text{C}$ ,  $70^\circ\text{C}$ , and  $80^\circ\text{C}$ , the color of the substance changes from yellow to brown. This color change was attributed to the ash content of honey, which measures  $0.285\pm 0.002\%$ ,  $0.310\pm 0.006\%$ , and  $0.264\pm 0.008\%$  for each respective temperature. Color values depend on the mineral content and floral origin (Moumeh *et al.*, 2020). Syafrizal *et al.* (2020) reported that the differences in composition, taste, and color in honey were caused by flower source, geography, climate, species, processing, and storage.

## 4. Conclusion

The application of evaporated temperature and rotary speed to honey processing has significant effects on the physicochemical quality of local honey (*Tetragonula laeviceps*). The quality can be improved by evaporating at  $70^\circ\text{C}$  with a 100 rpm rotation speed. Meanwhile, processing with vacuum rotary evaporated can decrease moisture content and increase the reducing sugar, ash content, and pH. Reducing moisture content can increase the intensity of the honey color ( $L^*$ ,  $a^*$ ,  $b^*$ ). After evaporation, honey quality is enhanced to extend the shelf-life.

## Conflicts of interest

The authors declare no conflicts of interest.

## Acknowledgments

The authors would like to express their gratitude to the Beekeepers of Sarining Trigona Pertiwi Group and the local official government of Bongkasa Village for their cooperation in conducting this research. Special thanks to our Rector of Warmadewa University and Head of the Research Institution University of Warmadewa, for supporting the finances of this project, facilities, and supervising. I also thank especially the Presidents and directors of Research Central Bicol State of Agriculture, Philippines, and their teams for the collaboration of research.

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