Productivity, Quality, and Consumer Preference Assessments of Wild Honeybee from Bangeris trees (*Koompassia exselsa*) in East Kalimantan

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ABSTRACT

Assessment of honeybee productivity of beekeeping has been widely researched,but there was no data about honey productivity of wild honeybees. This research aimed to determine honey productivity and quality of wild and beekeeping honeybees as human healthy subjects. Honey quality assessment tested were relative density, sugar content, water content, viscosity, and color parameters, i.e. L*, a*, and b*. Further, consumer sensory tests were conducted for adequate commercial needs including color, taste, aroma, and appearance. The results of the study showed that wild honeybees were found in 19 Banggeris trees and 17 trees had beehives that had produced honeycombs. Wild honeybees produced the highest honey production of 160 liter/tree, with an average of 41.70 liter/honeycomb. This study recommended the optimum honeycomb in the same tree was three honeycombs to avoid honey productivity decreased. Whereas honey quality from wild honeybees was determined relative density of 1.35, sugar content of 75.55 Brix, water content of 30.86 %, and viscosity of 581 mm^2/s. Wild honeybees produce more honey than beekeeping. There were significant differences between them in pH, viscosity, and soluble sugar parameters. Consumer sensitivity levels also differ between the two products; consumers tend to be more sensitive to the wild honeybees' taste, color, aroma, and appearance, respectively.

1. Introduction

According to [1] and [2], honey can be defined as a natural sweet substance produced by honeybees from nectar, plant secretions, or insect excretions, which is processed and matured in the hive. Its significance in various medicinal, spiritual, and culinary applications is universally recognized. Humans obtain honey in three ways: harvesting from wild beehives, keeping wild bees by simply building hives, and sustainably farming using artificial hives [1]. [3] specifically explain in their research that the quality characteristics of honey are determined by the nectar source and the type of bee producing it. This is supported by Chirsanova et al., [4], who state that the selling value of honey is determined by its flavor characteristics, sweetness level, and distinctive aroma. These characteristics are closely related to the plant's botanical source, which is influenced by the geographic location of the honey production area and the purity of the pollen collected by the bees.

Honey obtained from wild beehives generally has a highwater content because it often consists of a mixture of mature and immature honey. Difficult harvesting conditions, such as high-mounted hives and nighttime harvesting, are key factors influencing the characteristics of honey harvested by wild bees [1]. In Indonesia, traditional forest honey harvesting practices are still widely practiced, particularly from hives in tall trees, which can reach heights of approximately 50 meters and have trunk diameters of approximately 2 meters. The honey harvesting and processing process is carried

out conventionally, involving climbing the tree, fumigating to repel bees, and then extracting the honey by draining directly from the hive [5]. Meanwhile, honey beekeeping harvesting can be done by adjusting the harvest time, specifically when the honey is ripe and ready to be harvested, which has been shown to significantly increase yields and honey quality compared to traditional methods [6]. Therefore, the quality of honey harvested from the cultivation method produces better results physically, chemically, and microbiologically, while minimizing contamination, unlike traditional methods that can damage colonies or kill bees during harvest [7]. This cultivation approach, which utilizes cultivation management and technology, allows honey harvesting without destroying colonies or hives, thus maintaining the health of bee colonies and contributing to the sustainability of cultivation and the pollination ecosystem [8].

Research on the characteristics of Apis dorsata forest honey in Indonesia indicates that honey produced from tropical forest ecosystems can meet national quality standards. A study conducted in Berau, East Kalimantan, reported that forest honey quality parameters, including moisture content, ash content, hydroxymethylfurfural (HMF), acidity, and reducing sugars, met the requirements of SNI 8664-2018, thus reflecting good physicochemical quality [9]. Furthermore, [10] in another study revealed that forest honey from various regions in East Kalimantan possesses distinctive bioactive properties, such as antibacterial and antioxidant activity, which are important characteristics of tropical forest honey. Honey quality can be determined through sensory testing [11] in addition to laboratory testing, to determine whether the honey is acceptable to consumers. [12].

This study aimed to compare the productivity and quality of honey from two different sources: wild bees and cultivated bees in East Kalimantan. Quality assessments were conducted by measuring the relative density, sugar content, water content, viscosity, and color of the honey. Wild honey came from Panaan Village, Berau Regency, harvested directly from Banggeris trees (Koompassia excelsa), while cultivated honey came from Karang Joang Village, Balikpapan Regency. Then, organoleptic tests were carried out to assess sensory characteristics so that the research results could provide relevant information regarding consumer preferences and acceptance of the two types of honey.

2. Method

Wild honey samples were obtained from Banggeris (*Koompassia excelsa*) trees in the PT Utama Damai Indah Timber (UDIT) area, in Panaan Village, Berau District, East Kalimantan. Branch-free height (BFH) was measured using a suunto-clinometer, followed by counting the number of beehives on each tree. Information on the honey harvest was collected based on production data from each hive, collected by the tree owner, who collects the honey. Wild honey samples were randomly collected for quality analysis. Meanwhile, cultivated honey (*Apis sp*.) samples were collected from Karang Joang Village, Balikpapan District, East Kalimantan.

Honey quality analysis was conducted for density, viscosity, pH, sugar content, and water content. Density was measured using a pycnometer, while viscosity was determined according to ASTM D4212 standard procedures using a Zahn cup. The pH was determined using a pH meter, and the sugar content was analyzed using a hand-held refractometer, using refractive index readings as the basis for determining sugar concentration. Moisture content was determined using an oven drying method at a controlled temperature until a constant weight was achieved. Meanwhile, honey color was analyzed using computer vision analysis techniques based on the method of [13]. Statistical analysis of the data was performed using descriptive statistics and an independent sample T-test.

This study involved 40 semi-trained panelists grouped by age: 20 individuals aged 20–40 years and 20 individuals aged 41–60 years. Organoleptic testing was conducted on samples of wild honey and cultivated honey, which were alternately presented to the panelists. Assessments were conducted using a five-level hedonic scale: very dislike (1), dislike (2), neutral (3), like (4), and very like (5). Panelists assessed the sensory attributes of the honey, including color, taste, aroma, and appearance, while also determining their preferences for the samples tested. The data obtained were then analyzed descriptively using Microsoft Excel and presented graphically for visualization.

3. Results and Discussion

3.1. Honeycomb and Honey Production

Differences in beekeeping systems between Karang Joang Village and Panaan Village result in significantly distinct hive characteristics and honey production. The characteristics of managed bee colonies in Karang Joang Village, Balikpapan, are strongly influenced by the design of the hive boxes used. The hives are maintained in wooden boxes with a maximum dimension of 20 × 30 × 40 cm, which are generally placed around residential areas adjacent to forested landscapes. This setting enables the bees to access forage resources from surrounding forest vegetation. Based on interviews with local beekeepers, honey production from this cultivation system ranges from 2–4 liters per hive, with an estimated total annual production of approximately 300–400 liters.

In contrast, wild honeybee nests in Panaan Village develop naturally on Banggeris trees (*Koompassia excelsa*) without size limitations. These nests can grow to approximately 2 × 3 m and are suspended on tree branches at various heights. The nesting heights range from 13 to 20 m, with the highest concentration of nests found at 19 m. However, despite the greater number of nests at this height, the highest honey yield was obtained from nests located at approximately 15 m, with an average production of 41.7 liters per branch. Meanwhile, the lowest average honey production, amounting to 15.0 liters per branch, was recorded at a height of 19 m. A more detailed distribution of nest heights and honey yields from Banggeris trees is presented in Table 1.

Table 1. Total of wild honeybee in Panaan village, Berau District.

Banggeris Tree number	Branch Free Height (m)	Total Beecombs each tree	Honey each tree (L)	Average honey each Beecombs (L)
1	15	3	75	25.0
2	13	1	35	35.0
3	15	1	25	25.0
4	17	3	90	30.0
5	13	2	65	32.5
6	17	3	105	35.0
7	15	3	125	41.7
8	15	2	55	27.5
9	20	6	160	26.7
10	17	2	60	30.0
11	15	2	55	27.5
12	19	8	120	15.0
13	13	2	55	27.5
14	15	2	60	30.0
15	13	1	30	30.0
16	17	3	95	31.7
17	17	2	60	30.0
		46	**1,270**	**29.4**

The height of the honeycomb does not always show a positive correlation with honey production volume, indicating that environmental factors and forage availability also play crucial roles in determining the productivity of wild honeybees. Bees regulate their foraging effort in response to nectar availability and concentration, as well as the distance between the honeycomb and food sources. Numerous studies have demonstrated that landscape fragmentation and forest habitat isolation negatively affect ecological interactions between flowers and pollinating insects [14]. The findings of this study indicate that honey production declines markedly as the distance between the honeycomb and forage resources increases.

3.2. Honey quality

The quality comparison between honey of wild honeybee from Panaan village and honey from Karang Joang village, East Kalimantan can be seen in table 2.

Table 2. Quality comparison between honey of wild honeybee from Panaan village and honey from Karang Joang village, East Kalimantan.

Honey quality	Honey from Panaan village	Honey from Karang Joang village	Significance
Moisture content (%)	30.86+1.26	26.95+0.64	0.210^{ns}
pH	3.77+0.01	3.93+0.01	0.040*
Viscosity (mm^2/s)	581.00+25.46	1525.25+70.36	0.021*
Specific gravity	1.35+0.01	1.36+0.02	0.874^{ns}
Soluble sugar (brix)	75.55+0.07	78.75+0.21	0.040*
Color			
L*	22.2+3.50	40.2+3.63	0.004*
a*	29.2+2.50	38.2+2.17	0.008*
b*	23.2+1.64	43.6+5.32	0.001*

Remarks : * = t-test had significant value; ^{ns} = t-test had no significant value

The moisture content of honey from Panaan Village was 30.86%, higher than that of cultivated honey, which was 26.95%. Despite this difference in mean values, the paired t-test results indicated no significant difference in moisture content between the two types of honey (Table 2). Moisture content is one of the primary indicators of honey quality, as it determines product stability during storage [15]. High moisture content can trigger fermentation and granulation in honey and may also promote the growth of osmotolerant yeasts that produce ethyl alcohol and carbon dioxide during storage [16]. Field observations revealed that honey from Panaan Village produced more foam when the bottle was opened, suggesting a relatively higher moisture content. Therefore, it is recommended that honey from Panaan Village be stored by filling bottles only to approximately 60–75% of their total volume in order to minimize the risk of fermentation.

The average pH value of honey from Panaan Village was 3.77, lower than that of cultivated honey, which had an average pH of 3.93. The paired t-test results showed that this difference was statistically significant, indicating a distinct pH characteristic between wild and cultivated honey. The pH values obtained in this study fall within the range reported in previous studies. Several types of honey in Malaysia have been reported to exhibit pH values between 3.10 and 4.30[17], while honey from the rain-shadow region of Brazil showed a pH range of 3.20–4.20 (Costa et al., 2013). In addition, multifloral honey from Palestine had an average pH of 3.44 [18]. Another study by [19] reported average pH values of 3.77 and 4.09 for honey samples collected from Kasr Khiar and Garaboli in western Libya, respectively. These comparisons demonstrate that the pH value of honey from Panaan Village remains within the normal global range for honey characteristics.

The average viscosity of honey from Panaan Village was 581 mm^2/s, equivalent to 7.84 Pa.s, which is considerably lower than that of cultivated honey at 1525.25 mm^2/s or 20.74 Pa.s. Paired t-test analysis indicated a significant difference in viscosity between wild and cultivated honey. The viscosity values obtained in this study are comparable with those reported in other countries, such as Australia (34.40 Pa.s), China (8.03 Pa.s), and Brazil (3.12 Pa.s). Furthermore, the viscosity of wildflower honey from Jordan has been reported to range from 33–43 Pa.s at 28°C [20]. In general, honey viscosity is inversely related to moisture content, whereby honey with lower moisture content tends to exhibit higher viscosity [21]. This relationship explains the relatively low viscosity of honey from Panaan Village, which has a higher moisture content.

The specific gravity of wild honey from Panaan Village was 1.35, slightly lower than that of cultivated honey at 1.36. Based on the paired t-test results, no significant difference was observed in specific gravity between the two honey types. These values are consistent with findings from previous studies. The specific gravity of wildflower honey from Jordan has been reported to range

between 1.246 and 1.330 [20], while [19] reported average specific gravity values of 1.37 and 1.36 for honey samples from Kasr Khiar and Garaboli in western Libya. Additionally, [22] stated that honey samples with lower specific gravity generally possess higher moisture content. Thus, the slightly lower specific gravity of honey from Panaan Village is consistent with its relatively higher moisture level.

The Brix value of wild honey from Panaan Village was 75.55°Brix, lower than that of cultivated honey, which reached 78.75°Brix. The paired t-test results indicated a significant difference in soluble sugar content between the two honey types. The Brix values obtained in this study are relatively lower than those reported in previous studies, such as honey from Zambia, which ranged from 81.60–83.40°Brix [23], and honey from Romania, which ranged from 80.30–81.60°Brix [24]. The lower Brix value of honey from Panaan Village is likely associated with its higher moisture content, which results in a lower concentration of dissolved sugars.

The t-test results for all honey color parameters showed significant differences between wild and cultivated honey. Based on lightness (L*) values, honey with L* ≤ 50 is classified as dark-colored honey [25]. Honey from Panaan Village had an L* value of 22.2, while honey from Karang Joang Village had an L* value of 40.2, indicating that honey from Panaan Village is darker in color. In terms of a* values, honey from Panaan Village had a value of 29.2, whereas honey from Karang Joang Village had a value of 38.2, suggesting that honey from Karang Joang exhibits a stronger reddish hue. Meanwhile, the b* value of honey from Panaan Village was 23.2, compared to 43.6 for honey from Karang Joang, indicating that honey from Karang Joang tends to have a more pronounced yellow coloration. These differences in color characteristics reflect variations in nectar sources and the chemical composition of the respective honey types.

3.3. Organoleptic test for honey colour

Based on the results of the color preference test, consumers showed a greater preference for honey from Panaan Village, with 20% expressing "strongly like" and 65% expressing "like." Honey from Panaan Village exhibits a darker color compared to honey from Balikpapan. Color is recognized as an important parameter in the assessment of honey quality [26]. According to the color parameters presented in Figure 1, the two honey products demonstrated statistically significant differences. Nevertheless, consumer preference for honey color is not solely influenced by the physical characteristics of the product but is also shaped by prior habits and experiences in honey consumption.

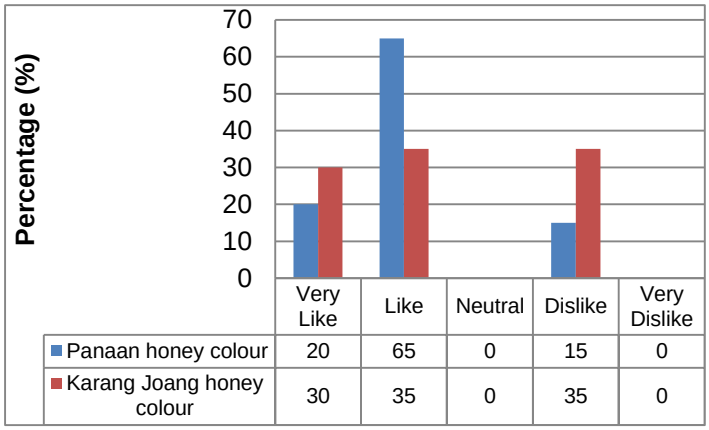

Figure 1. Percentage of organoleptic test for honey colour origin from Panaan and Karang Joang Villages, East Kalimantan.

Based on sensory characteristics, particularly color and appearance, honey can be classified into light-colored and dark-colored categories [25]. Consumer preferences toward honey color are influenced by age-related factors. Younger consumers tend to prefer light-colored honey with lower viscosity, whereas older consumers are more inclined to favor dark-colored honey [26]. In general, dark-colored honey contains higher mineral content than light-colored honey [27]. Furthermore, the darker color of honey is associated with the presence of bioactive compounds such as carotenoids, flavonoids, tannins, and polyphenols, which function as antioxidants [25].

3.4. Organoleptic test for honey taste

Organoleptic test for the taste of two honey products showed that there are different perceptions of consumers, both for honey products originating from Panaan and Karang Joang. This can be seen clearly in the following figure 2. Based on the taste preference test conducted in this study, consumers demonstrated a greater preference for honey from Panaan, with 20% indicatingstrongly like and 65% indicating like. Honey from Panaan is characterized by a flavor profile that combines sweetness with a slight acidity, as reflected by a soluble sugar content of 75.55°Brix and a pH value of 3.77. In contrast, honey from Balikpapan is more dominated by sweetness, with a higher sugar content (78.75°Brix) and lower acidity (pH 3.93), as presented in Table 2. This difference in the balance between sweet and acidic taste components is presumed to influence consumer preference for the two types of honey.

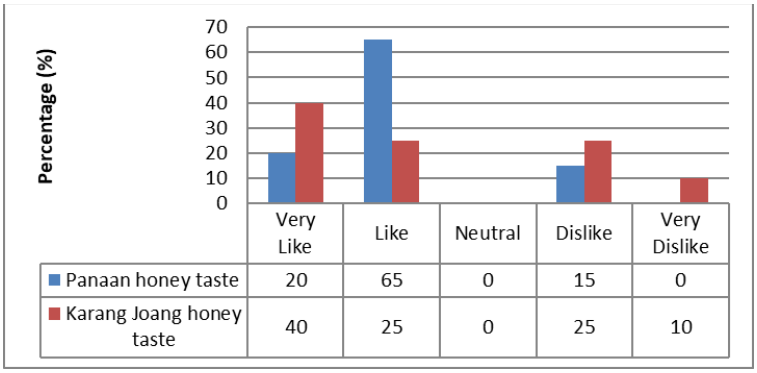

Figure 2. Percentage of organoleptic test for honey taste origin from Panaan and Karang Joang Villages, East Kalimantan.

3.5. Organoleptic test for honey aroma

Each sample was given a random perception and presented in a different order for each consumer sample was evaluated in graphic form, in which five classifications were presented in this following figure 3. Based on the preference test results in this study, consumers demonstrated a greater preference for the aroma of honey from Balikpapan, with 45% of respondents indicating strongly like and 25% indicating like.

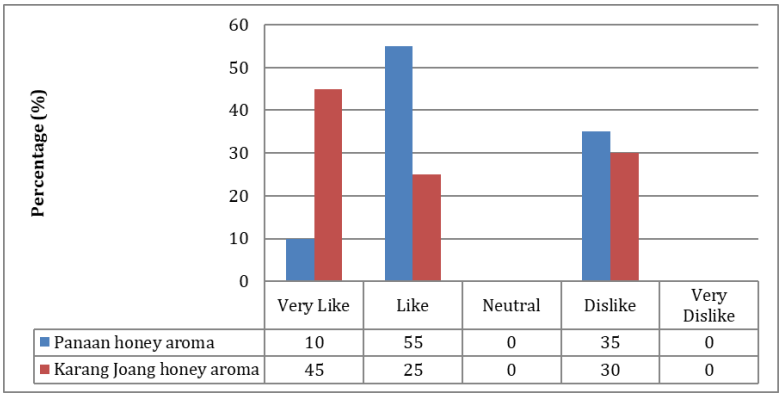

Figure 3. Percentage of organoleptic test for honey aroma origin from Panaan and Karang Joang Villages, East Kalimantan.

This difference in aroma is presumed to be associated with the soluble sugar content of the honey, which has been reported to influence aroma perception [28]. Honey from Balikpapan contains a higher level of soluble sugars, reaching 78.75°Brix, compared to honey from Panaan, which has a value of 75.55°Brix. The main sugar components in honey, namely the monosaccharides fructose and glucose, play an important role in shaping the overall flavor and aroma profile.

3.6. Organoleptic test for honey appearence

In the present study, honey sensory description for appearance test was conducted including five hedonic classifications as can be seen in this figure 4. Based on the appearance preference test, consumers showed a greater preference for honey from Panaan Village, with 30% of respondents indicating "strongly like" and 55% indicating "like." One of the main factors influencing the visual perception of honey is its viscosity. Honey with high viscosity tends to have greater surface tension [29], making it more difficult to pour. This condition is generally less favored by consumers, as honey that is difficult to dispense from the bottle is considered less practical to use. Consumers tend to prefer honey that is easy to handle and can be poured smoothly both into and out of the container [30].

The results of this study indicate that honey from Panaan Village has a lower viscosity, at 581 mm²/s, compared to honey from Balikpapan, which reached 1525.25 mm²/s. This difference in viscosity is presumed to be one of the main reasons for the higher level of consumer preference for honey from Panaan. Viscosity itself is an important parameter in assessing honey quality [31]. Several factors significantly influence honey viscosity, including temperature and moisture content [32]. Honey with higher moisture content generally exhibits lower viscosity, making it easier to pour and more favorable in terms of physical appearance.

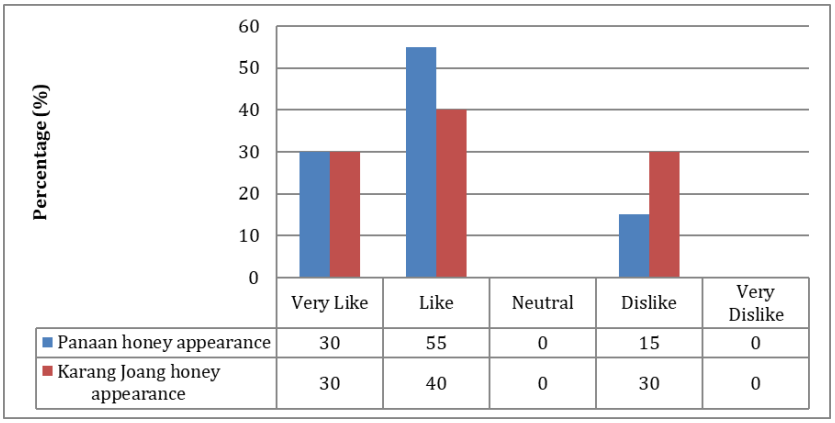

Figure 4. Percentage of organoleptic test for honey appearance origin from Panaan and Karang Joang Villages, East Kalimantan.

5. Conclusion

The Banggeris tree (Koompassia excelsa) serves as an ideal habitat for natural honey production in Panaan Village, where it thrives within the local customary forest area. Honey processing in this region is still based on traditional local knowledge; however, the honey produced has provided significant economic benefits to the surrounding forest community.

Organoleptic analysis revealed that consumers showed a greater preference for honey from Panaan Village compared to honey from Balikpapan in terms of color, taste, aroma, and overall evaluation. Quality assessment of Panaan honey demonstrated favorable characteristics as a tropical honey, with moisture content, pH, viscosity, and sugar content falling within acceptable ranges. Statistical analysis indicated significant differences between the two honey types in pH, viscosity, and soluble sugar content, while no significant differences were observed in moisture content and specific gravity.

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Data and Software Availability Statements

The study was based on primary field data and laboratory analyses. No publicly archived datasets or custom software were generated. All relevant data are included in the article and can be obtained from the authors upon reasonable request. Data analysis was conducted using Microsoft Windows and Microsoft Office licensed by the Indonesian National Research and Innovation Agency (BRIN).

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