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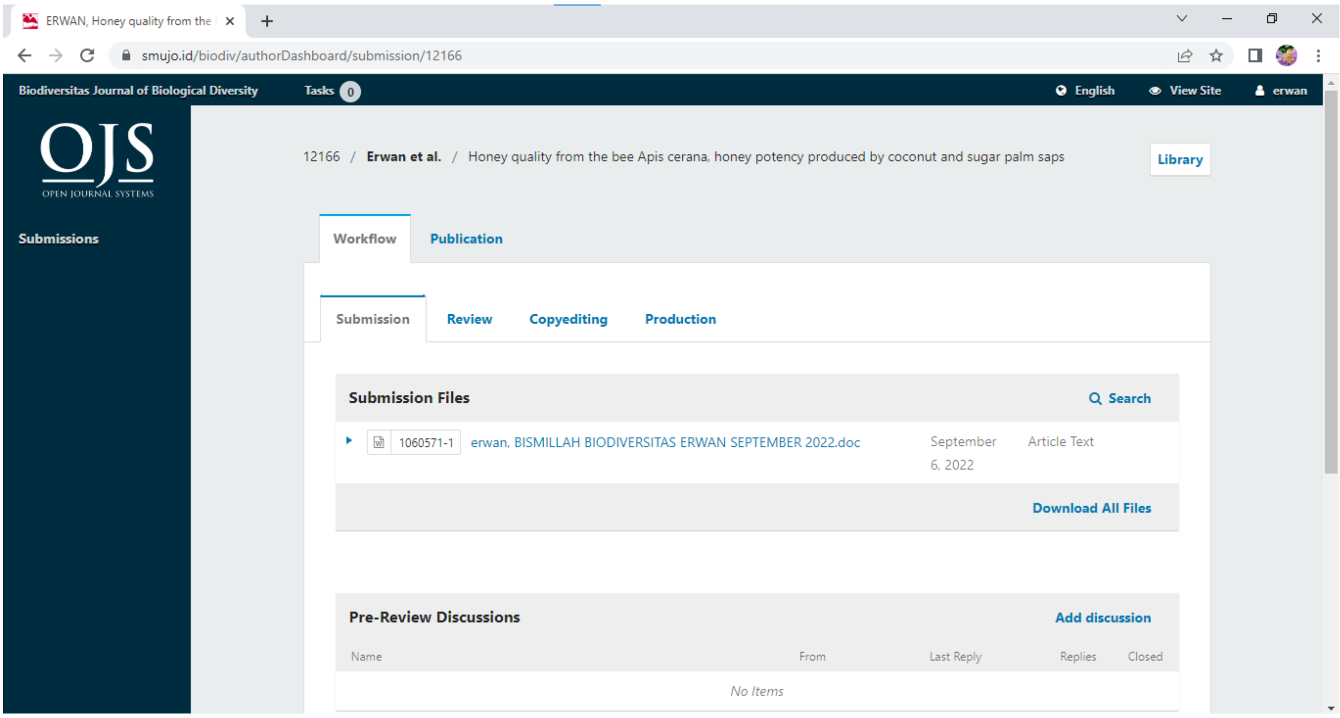

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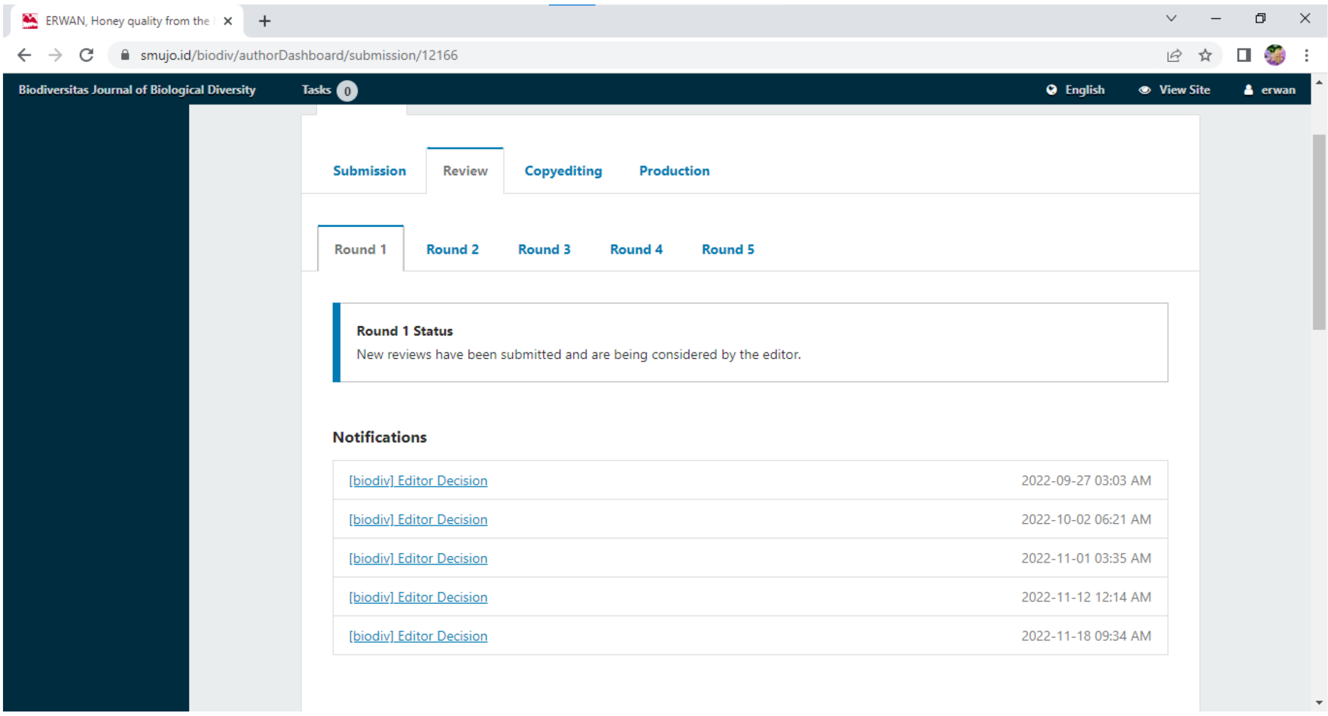

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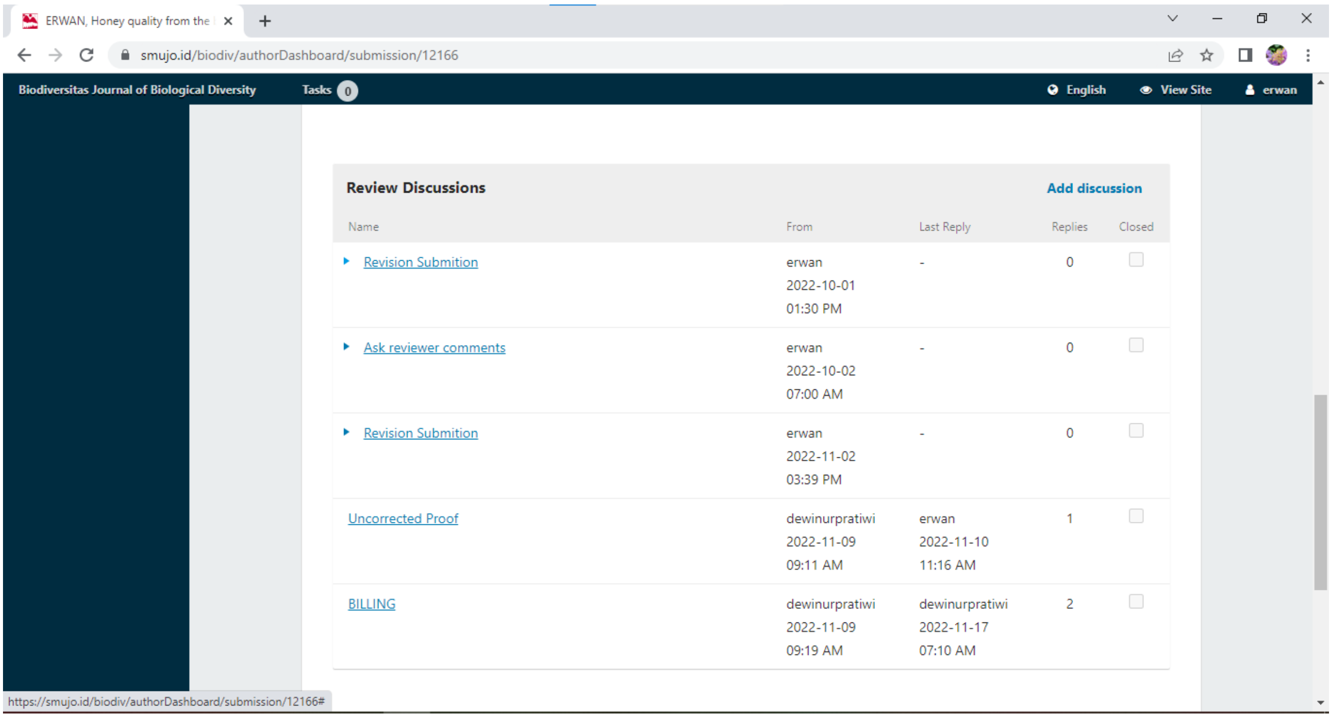

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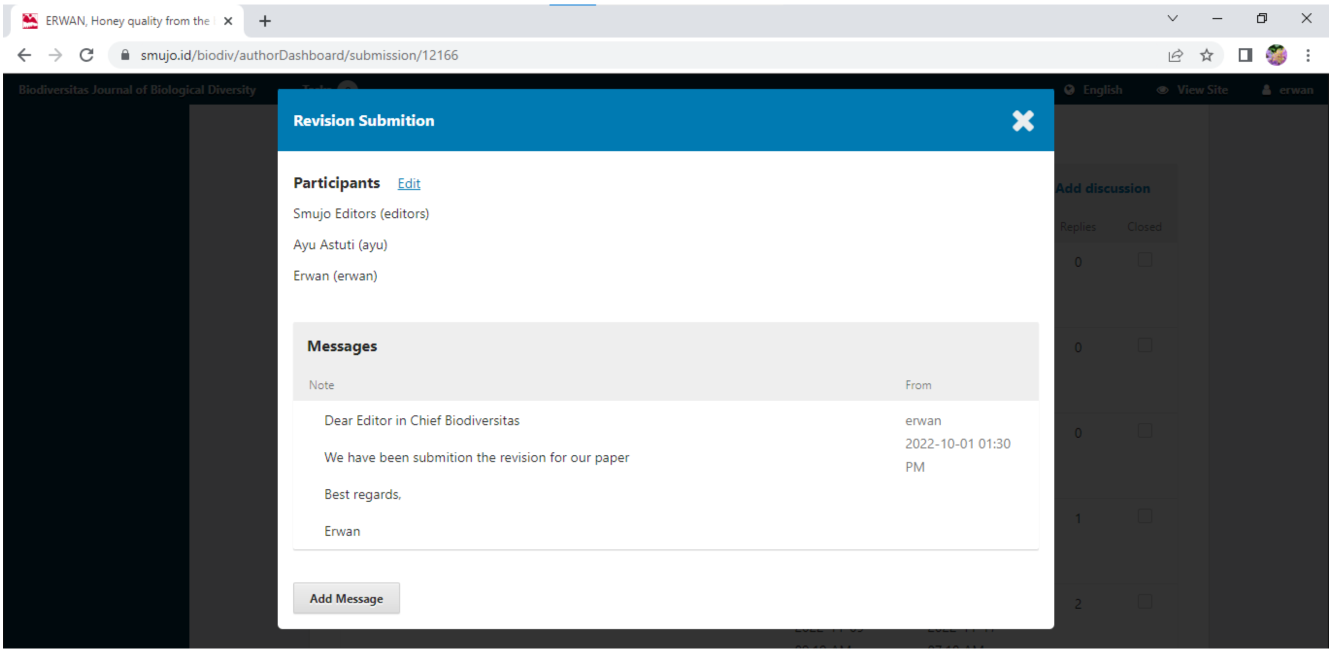

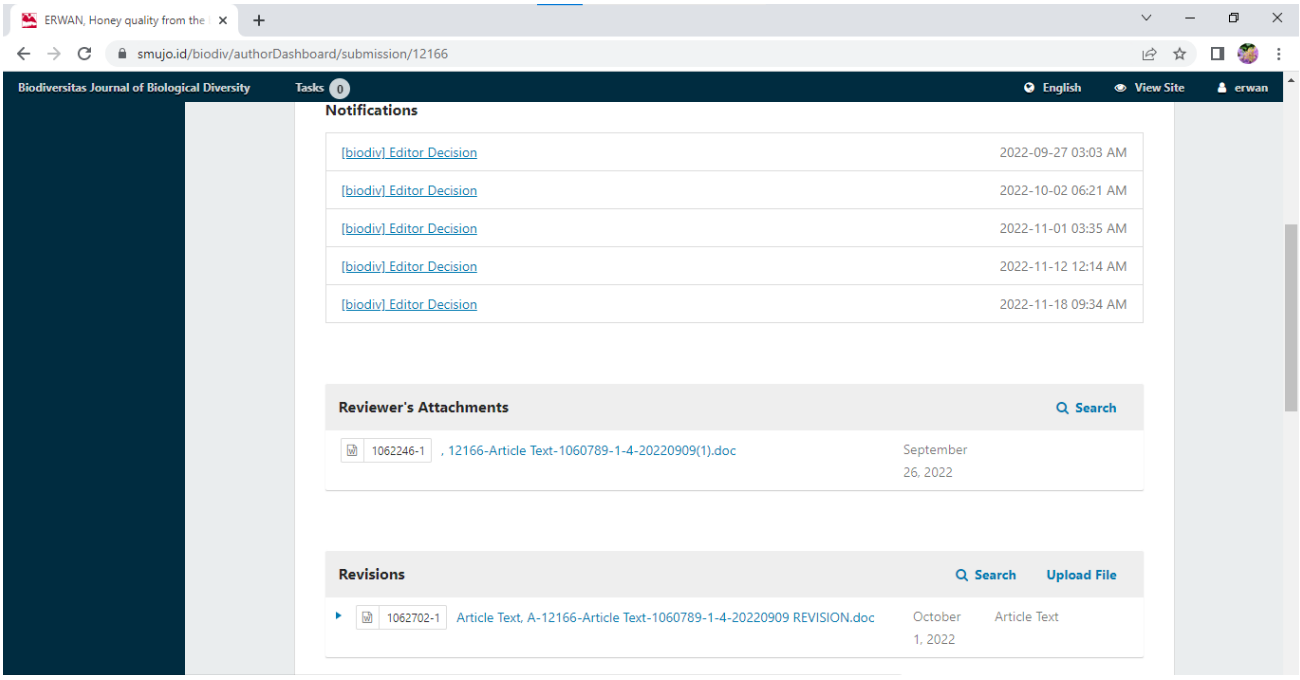

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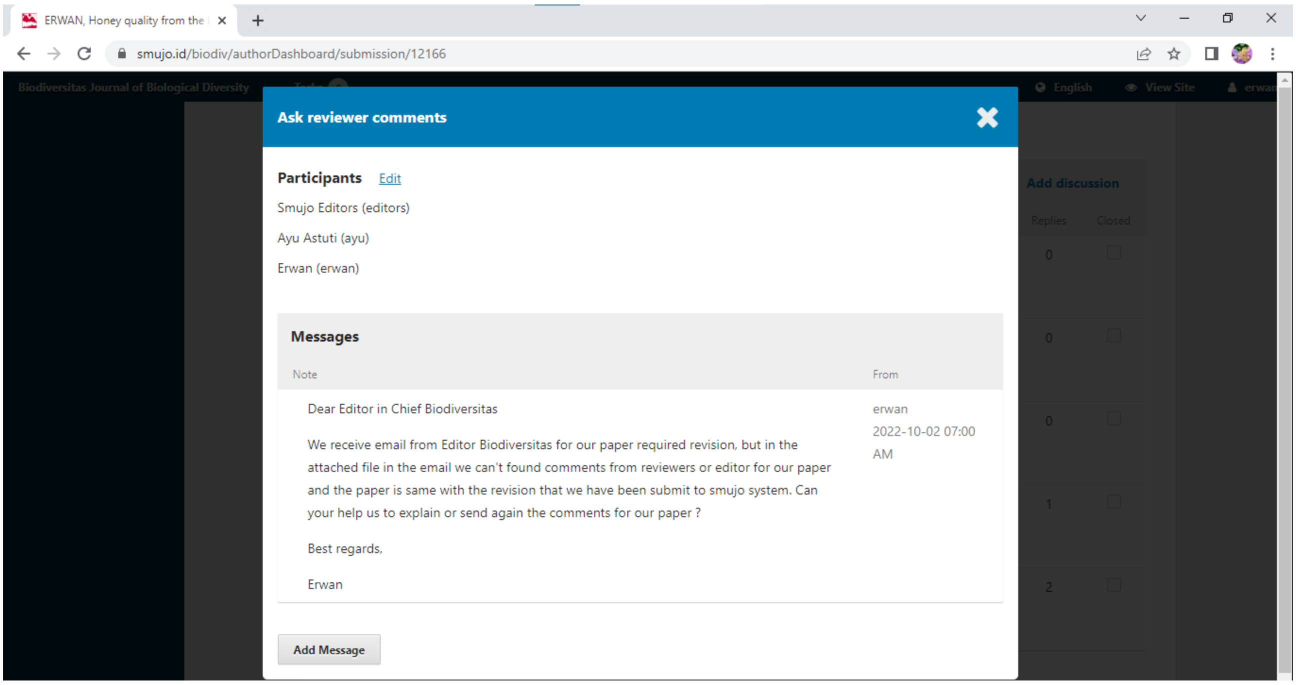

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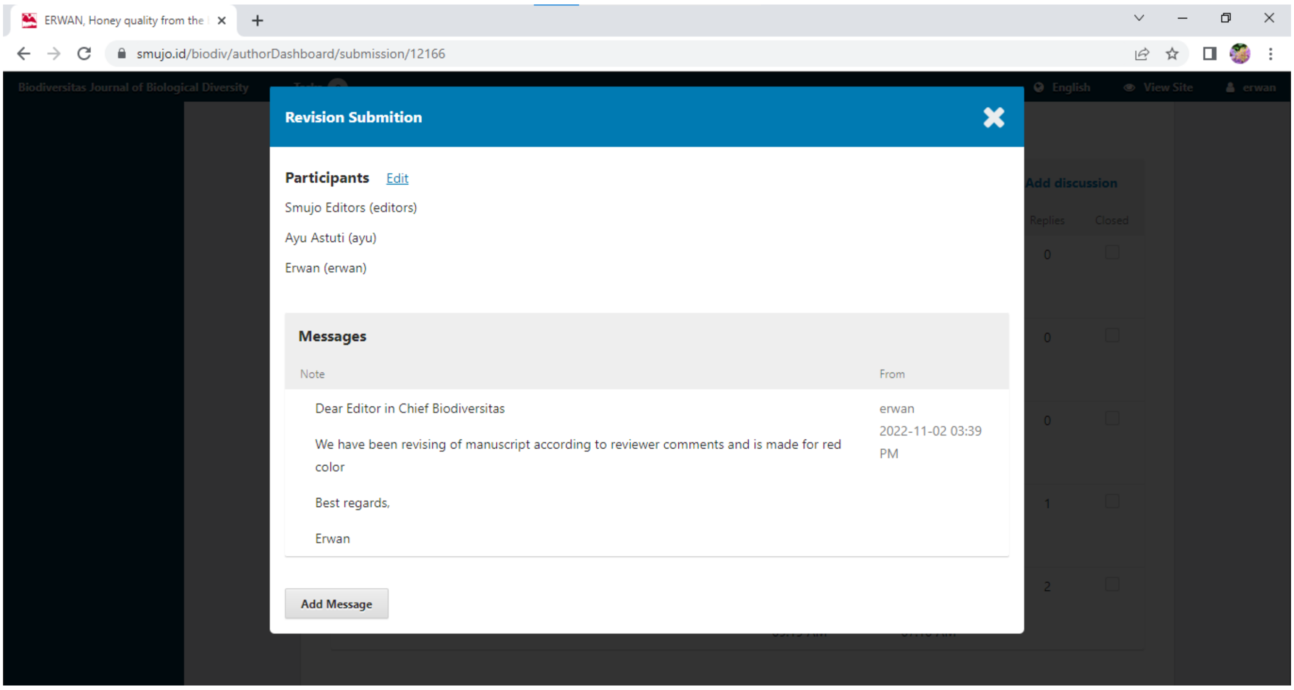

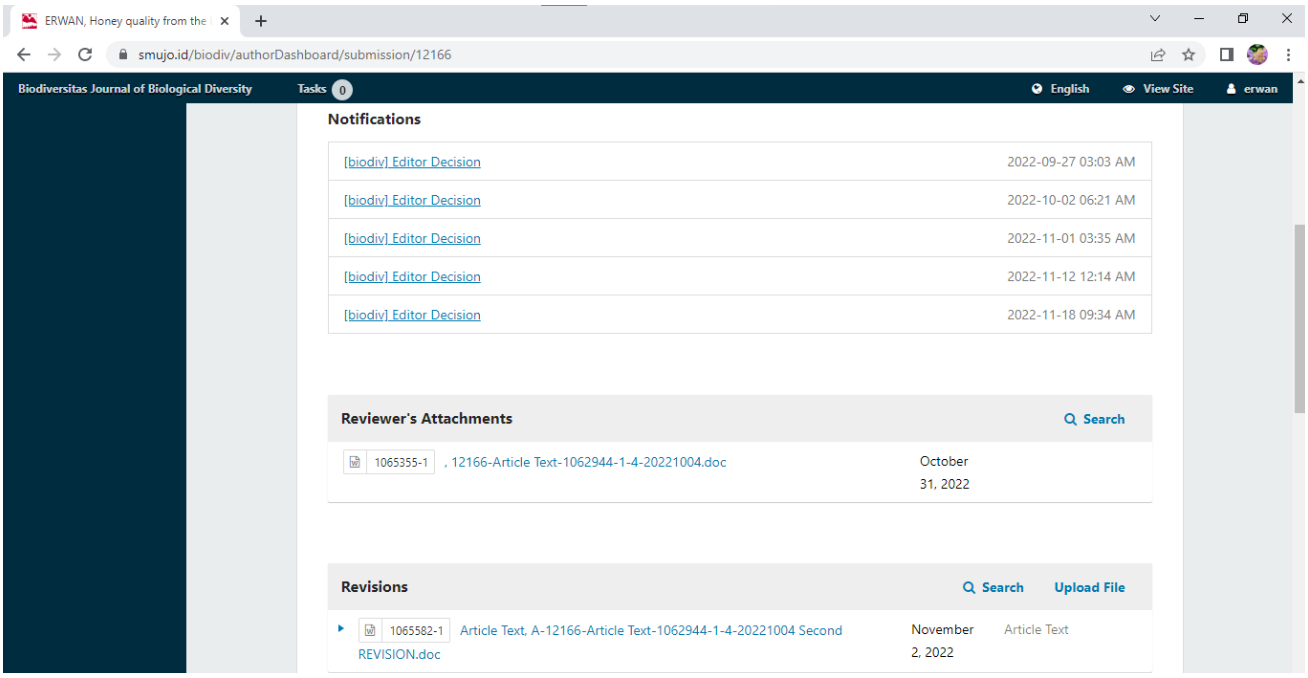

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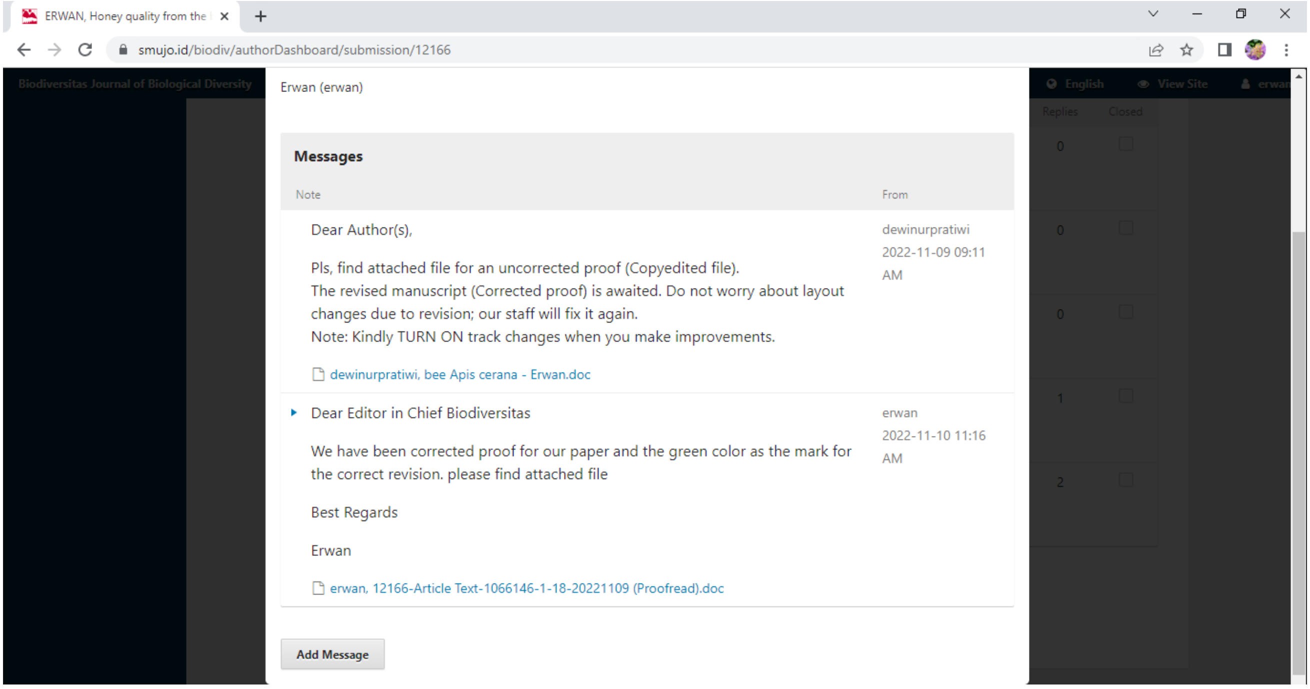

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[biodiv] Submission Acknowledgement

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Dear Editor in Chief Biodiversitas

Thanks very much for the information and we hope our paper can be accepted and published in Biodiversitas
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Best Regards,

Dr. Ir. Erwan, M.Si.
Faculty of Animal Science, University of Mataram, Indonesia

COVERING LETTER

Dear **Editor-in-Chief,**

I herewith enclosed a research article,

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Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

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Erwan and Agussalim

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Novelty:

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The novelty of our study was the honey quality produced by the bee *Apis cerana* and the honey potency which are produced by sugar palm and coconut saps which have not studied by another researcher especially in Indonesia. Therefore, this manuscript is very informative for the beekeepers, researchers or scientist, and honey consumers.

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Sincerely yours,

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Dr. Ir. Erwan, M.Si.

Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

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Manuscript received: DD MM 2016 (Date of abstract/manuscript submission). Revision accepted: .... 2016. (8 pt)

Abstract. One of the big problems when keeping of honeybees is the limited of sustainable feed, especially in the rain season. The objectives of this study were to evaluate the honey quality from the bee *A. cerana* based on the chemical composition, honey potency produced by the coconut and sugar palm saps. This study using thirty colonies of the bee *A. cerana* were divided into six treatments consists of sugar palm sap without sugar palm pollen; coconut sap without sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% without sugar palm pollen; sugar palm sap was added by sugar palm pollen; coconut sap was added by sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen. The chemical composition of honey from the *A. cerana* were moisture (20.76 to 21.80%), reducing sugar (62.78 to 68.37%), sucrose (1.44 to 3.42%), diastase enzyme activity (5.17 to 9.04 DN), hydroxymethylfurfural (2.24 to 5.81 mg/kg), and acidity (26.00 to 36.35 ml NaOH/kg). Honey potency produced by the coconut and sugar palm saps in 100 hectares area produces honey was 1,542.857 tons/year and 1,150 tons/year, respectively. It can be concluded that honey quality is produced by sugar palm and coconut saps, and potential as the bee feed.

Key words: *Arenga pinnata*, beekeeping, *Cocos nucifera* L., extrafloral nectar, multifloral nectar

Running title: Honey quality of *Apis cerana* produced by sugar palm and coconut saps

INTRODUCTION

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Honeybee of *A. cerana* is one of the bees from the *Apis* genus which is include the local bee which is spread in some regions in Indonesia are Kalimantan, Sumatera, Java, Bali, Lombok, Sumbawa, Sulawesi, Papua, and Seram (Radloff et al. 2011; Hepburn and Radloff 2011). In Indonesia, beekeeping of the bee *A. cerana* has been practiced by the beekeepers using a traditional hives (for example using a coconut log hive) and semi modern hive (box hive without nest frame). Furthermore, several regions have been practices the beekeeping of the bee *A. cerana* has been reported by Schouten et al. (2019) are Riau, North Sumatera, Lampung, Banten, Java, Yogyakarta region, Bali, and Lombok.

One of the problems faced by the beekeepers in Indonesia is the limited of feed sustainability as the raw material to produce honey, bee bread, and royal jelly. The limitation feed is the very serious problem have been faced by the beekeepers because they have not area which is used to planted several plants which are used the feed source to produce the honeybees products. Honeybees feeds is divided into two types namely nectar and pollen, where nectar is obtained by the foragers from the plant flowers (nectar floral) and nectar extrafloral which is obtained by the foragers from stalk and leaf of plants (Agussalim et al. 2018, 2017). Pollen is obtained by the foragers from plant flowers which is collected by using all body part and then deposited in the corbicula (Agussalim et al. 2018, 2017; Erwan et al. 2021a). When collecting nectar and pollen from the plant flowers, the foragers is role as the pollinator agent by transporting pollen from the anther to pistil so that the pollination process occurs. This process continuously done by the foragers until the honey stomach is full by a nectar and their corbicula has been deposited by the pollen. This pollination which is impacts on the increasing the plants productivity (; Pohorecka et al. 2014).

One of the strategies to produce the sustainability honey from the bee *A. cerana* by using a sap from the plants such as sugar palm and coconut. Several studies have been conducted by using a sugar palm and coconut saps as the *A. cerana* feed. Erwan et al. (2021b) reported that the feed combination of coconut sap and sugar palm pollen as the *A. cerana* feed can enhancing the production of honey cells and bee bread cells. Furthermore, Erwan et al. (2022) was also reported that the use of sugar palm and coconut saps which each added by sugar palm pollen can improving the bee *A. cerana* productivity such as increase the honey production, brood cells number, and colony weight. In addition, the study use of extrafloral nectar namely sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera* L.) saps as the *A. mellifera* bee feed which is resulting the honey chemical composition which are acceptable by Indonesian national standard and international standard has been regulated by Codex Alimentarius (Erwan et al. 2020). However, the studied about the chemical composition of honey from the bee *A. cerana* which are produced from the sugar palm sap, coconut sap and their honey potency production from both sap sugar palm and coconut have not been studied. Therefore, the objectives of this study were to evaluate the honey quality based on the chemical composition from the bee *A. cerana*, honey potency produced by the coconut and sugar palm saps.

MATERIALS AND METHODS

Study area

This research has been conducted in the North Duman Village (8º32'10"S 116º09'32"E), Lingsar Sub-district, West Lombok (West Nusa Tenggara Province, Indonesia). In this research, we used thirty of *A. cerana* colonies were divided into six treatments and each five colonies per treatment as the replication. The saps were used in our study were obtained from coconut (*Cocos nucifera* L.) and sugar palm (*Arenga pinnata*). The treatments in our study were sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

The technique was used to given sugar palm and coconut saps and sugar palm pollen was according to previously method has been reported by Erwan et al. (2022, 2021b) briefly as follows: fresh coconut and sugar palm saps were given to the bee *A. cerana* by using a plastic plate and split bamboo were completed by 4 to 5 twigs for foragers perch. The plastic plate and split bamboo were placed one meter of the box hives, while the sugar palm pollen was hung besides and above of the box hives. The distance of 600 meters to place colony to avoid the foragers to collect pollen and sap from the other treatments.

Proceduress

Honey quality

Honey from the *A. cerana* was harvested after beekeeping for three months by using a coconut and sugar palm saps. Honey from the five hives in one treatment group was composited into one honey sample and then used to analysis of their chemical composition. Honey quality from the *A. cerana* were evaluated based on the chemical composition consists of moisture, reducing sugar, sucrose, diastase enzyme activity, hydroxymethylfurfural (HMF), and acidity. The moisture content was analyzed by using a proximate analysis based on the method from Association of Official Agricultural Chemists (AOAC) (AOAC 2005). Reducing sugar was analyzed by using a Layne-Enyon method and sucrose content was analyzed by a Luff Schoorl method were described by AOAC (2005). Diastase enzyme activity, hydroxymethylfurfural (HMF), and free acidity were analyzed based on the harmonised methods of the international honey commission (Bogdanovs 2009).

Honey production from sugar palm and coconut saps

Sugar palm and coconut saps each ten liters were used to measuring the honey production from the bee *A. cerana* for three months of beekeeping. The sugar palm and coconut saps were placed in the plastic plate in front of the box hives at the distance of one meter. In addition, the honey production without using of sugar palm and coconut saps were measured for one year of the beekeeping which is used to calculate the contribution of sugar palm and coconut saps in honey production.

Production of saps from coconut and sugar palm

The production of sap from coconut was measured for a year, while the sugar palm sap based on the previously studied was used to calculate the production per hectare area and was also obtained from the deep interview with the farmers. The production of coconut and sugar palm saps per hectare which was calculated from the sap production per hectare multiplied by the tress number in one hectare area. After three months of beekeeping, honey from both treatments sugar palm and coconut saps were harvested to measure the honey production from the use of ten litters sap and then honey production was measured by cylinder glass

Data analysis

The data of honey quality, production potency of honey from sugar palm and coconut saps, honey production, and production of saps were analyzed by using a descriptive analysis (Steel et al. 1997).

RESULTS AND DISCUSSION

Moisture content of honey

Honey is composed by water as the second largest of honey constituent and its ranging from 15 to 21 g/100 g, depending on the plant types as the nectar source which is affected by the botanical origin. Furthermore, honey moisture is also affected by honey maturity level, processing postharvest, and storage condition (Da Silva et al. 2016). The honey moisture is affecting the physical properties such as crystallization, viscosity, flavor, color, taste, solubility, specific gravity, and conservation (Da Silva et al. 2016; Escuredo et al. 2013). In addition, honey moisture is also affected by the temperature and humidity or depending on the season (rain and dry seasons) and honey moisture can increase during the postharvest processing such as storage condition because honey is hygroscopic that can absorbs the moisture in the air (Da Silva et al. 2016; Karabagias et al. 2014).

The recent study showed that the honey moisture from the bee *A. cerana* which was produced by sugar palm and coconut saps and their combination was ranging from 20.76 to 21.80% (Table 1). This honey moisture content is accepted by Indonesian national standard (SNI) where the moisture for beekeeping honey including the bee *A. cerana* and *A. mellifera* is not exceed 22% (National Standardization Agency of Indonesia 2018) and higher compared to international standard which is regulated by Codex Alimentarius is not exceed 20% (Bogdanov et al. 1999; Thrasyvoulou et al. 2018). The variation of honey moisture of the bee *A. cerana* in our study may be caused by the different moisture content of both saps from sugar palm and coconut, however in our study has not measured. The higher moisture content is requiring the long time to ripening of honey and process decreasing of honey moisture have been started by the bees when they are taken a nectar from plant flowers or saps as the raw material to produce honey. Furthermore, small portion of moisture content has been evaporated in the honey sack before transferred to the other bee which is working in the hive. This transfer is rapid depending on the temperature, colony strength, and nectar availability (Winston 1987).

Table 1. The moisture, reducing sugar, and sucrose contents of honey from the bee *A. cerana*

Treatments	Moisture (%)	Reducing sugar (%)	Sucrose (%)
SP0	21.60	65.24	2.86
CP0	20.76	68.37	1.96
SCP0	21.40	64.55	2.51
SP1	21.80	62.78	3.42
CP1	21.58	65.37	1.72
SCP1	20.98	67.33	1.44

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Honey production process is started from the foragers collecting a nectar from the plant flowers or extrafloral nectar and then stored in honey stomach. After that, the foragers will be transferring a nectar has been collected to the other bees whom working to processing a nectar into honey in their mouth, then put in honey stomach and then is transferred to other bees for several times until honey is ripening. A considerable of water amount will be evaporated in this process and this continues with the help of wing fans that can regulate the air humidity for about 15 to 20 minutes (Winston 1987). The honey moisture content in our study was differed to reported by Wang et al. (2021) that honey moisture from the bee *A. cerana* which is collected from 42 different honeycombs from China is ranging from 17.03 to 18.44%, 18.65% for *A. cerana cerana* from Hainan province, China (Wu et al. 2020), and 16.99% for *A. cerana* from Borneo (Malaysian honey) (Moniruzzaman et al. 2013). Furthermore, Erwan et al. (2020) was also reported that the honey moisture was produced by the *A. mellifera* bee by using a sugar palm and coconut saps is ranging from 19.34 to 20.94%. The different honey moisture content has been reported are affected by the different geographical origins which is impact on the different plant types can be growth each region, different environmental condition (temperature and humidity), and also different bee species which is impact on the different ability to evaporate water in the honey.

Reducing sugar and sucrose contents of honey

Sugars in honey are composed by monosaccharides for about 75%, disaccharides are 10 to 15%, and other sugars in small amounts. Honey sugars are responsible as the energy source, hygroscopic, viscosity, and granulation (Da Silva et al. 2016; Kamal and Klein 2011). Several sugars in honey have been reported such as glucose, fructose, sucrose, trehalose, rhamnose, isomaltose, nigerobiose, maltotriose, maltotetraose, melezitose, melibiose, maltulose, nigerose, raffinose, palatinose, erlose and others (Da Silva et al. 2016; De La Fuente et al. 2011).

The recent study showed that the honey s reducing sugar from the bee *A. cerana* were beekeeping by using a sugar palm and coconut saps and their combination as the nectar source to produce honey is ranging from 62.78 to 68.37 % (Table 1). This honey reducing sugar is acceptable by the SNI for treatments SP0, CP0, CP1, and SCP1, but not acceptable for treatments SCP0, SP1 (Table 1), where the minimum reducing sugar is 65% (National Standardization Agency of Indonesia 2018). This sugar is produced by the mechanism of invertase enzyme activity that change the sap sucrose into simple sugars. It is known that this enzyme is responsible for the conversion of sucrose into glucose and fructose. These sugars are included in reducing sugar group and as the main component present in honey. In honey maturity process, the sucrose is break down by the invertase enzyme into simple sugars simultaneously and water will be evaporated so that it will be increasing the reducing sugar content. In addition, enzymes secreted by the worker bees are also can break down the carbohydrate into simple sugars. Furthermore, other enzyme present in honey is diastase enzyme that role to break down starch into simple sugars (Da Silva et al. 2016; Sihombing 2005). The honey reducing sugar in our study (Table 1) was differed to reported by Erwan et al. (2020) that honey reducing sugar from the bee *A. mellifera* which was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 60.15 to 73.69%. The different reducing sugar may be affected by the different bee species which is impact on the different their ability to evaporate water present in honey especially when they are convert the complex sugars into simple sugars and different season when done the study which are related to temperature and humidity environmental.

The honey sucrose content from the bee *A. cerana* in our study is ranging from 1.44 to 3.42% (Table 1) and acceptable by SNI is not exceed 5% for the beekeeping honey including *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also accepted by the International standard has been regulated by Codex Alimentarius is not exceed 5% for blossom and honeydew honeys (Bogdanov et al. 1999; Thrasyvoulou et al. 2018). Naturally, sucrose present in honey in our study is originated from sugar palm and coconut saps. The low of honey sucrose content in our study is caused the honey which is harvested in mature condition that characterized by honey cells have been covered by the wax. Furthermore, the invertase enzyme which is produced by the worker bees is actively break down of sucrose from saps into simple sugars. There are two types of invertase enzymes which are produced by the worker bees, namely glucoinvertase which is converts sucrose into glucose and fructoinvertase which is converts sucrose into fructose. White (1992) explained these enzymes are mostly derived from the bee's secretion and only a small portion from the nectar, while the honeydew from the insect's secretion is mostly contain invertase enzyme. The honey sucrose content in our study (Table 1) was differed to reported by Erwan et al. (2020) that honey sucrose content from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 4.21 to 4.40%%.

The honey sucrose content is a very important parameter to evaluate the maturity of honey to identifying manipulation, where the high levels may be indicated adulterations by adding the several sweeteners such cane sugar or refined beet sugar. In addition, also indicating the early of harvest, where sucrose is not completed transformed into fructose and glucose, the bees feeding artificial in prolonged time by using a sucrose syrup (Da Silva et al. 2016; Puscas et al. 2013; Escuredo et al. 2013; Tornuk et al. 2013). Honey is sugar solution that is supersaturated and unstable so it's easy to crystallize. The honey crystallization is affected by concentration of glucose, fructose, and water. Fructose is the dominant sugar present in honey from *A. mellifera* was produced by several plants as the nectar source which is used by workers to produce honey such as eucalyptus, acacia, bramble, lime, chestnut, sunflower, and from honeydew, except in rape honey was produced by *Brassica napus*. Rape honey is higher in glucose and lower in fructose which is impact on the rapidly crystallization (Escuredo et al. 2014). The sugars content present in honey is dependent on the geographical origins which is impact on the different plant types can growth in each region and impact on the different sugars content from the nectar which is produced by the nectary gland of plant flowers (Agus et al. 2021; Agussalim et al. 2019; Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013). Furthermore, sugars content in honey is influenced by climate (season, temperature, and humidity), processing (heating process), and storage time (Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013).

Diastase enzyme activity and hydroxymethylfurfural of honey

The recent study showed that the diastase enzyme activity from the bee *A. cerana* honey was produced by the sugar palm and coconut saps was ranging from 5.17 to 9.04 DN (Table 2). This enzyme activity is acceptable by SNI with the minimum of 3 DN for the beekeeping honey including the bee *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also acceptable by international standard has been regulated by Codex Alimentarius with the minimum 3 DN (Bogdanov et al. 1999; Thrasyvoulou et al. 2018). One of the honey characteristics is contain enzymes which is originate from the bees, pollen, and nectar from plant flowers, but the mostly enzymes are added by the bees when they are convert nectar into honey (Bogdanov et al. 1999; Da Silva et al. 2016; Thrasyvoulou et al. 2018). The honey diastase enzyme activity in our study (Table 2) was differed to reported by Erwan et al. (2020) that the diastase enzyme activity of honey from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 16.48 to 17.12 Schade unit.

Diastases is divided into α- and β-amylases which are the natural enzymes present in honey. The α-amylase is separate the starch chain randomly in the central to produce dextrin, while the β-amylase to separate the maltose in the end chain. Diastase enzyme content in honey is influenced by nectar source (floral and extrafloral nectars) to produce honey and honey geographical origins which are impact on the different chemical composition of the nectar can be produced by the plants which is impact on the honey chemical composition especially diastase enzyme activity. In addition, the bee species is also influencing the activity diastase because it's related to the distance and the flowers plant numbers can be visited by the foragers when they are collecting nectar and pollen were using to produce honey and bee bread (Da Silva et al. 2016).

Generally, diastase enzyme is role to break down the complex sugars into simple sugars. This enzyme is role to digest of starch into maltose (disaccharide) and maltotriose (trisaccharide) which are sensitive to heat or thermolabile. Thus, this condition can be used to evaluate of overheating and preservation degree of honey (Da Silva et al. 2016). Furthermore, the diastase activity is also used to evaluate honey age which is related to storage time and the temperature because the diastase activity may be reducing when heating above 60ºC and longtime storage (Da Silva et al. 2016; Yücel and Sultanoğlu 2013). The honey diastase activity from the bee *A. cerana* in our study (Table 2) was differed to reported by Wu et al. (2020) for multifloral honey produced by the *A. cerana cerana* from Hainan province (China) was 6.70 Göthe. Furthermore, also was differed to reported by Wang et al. (2021) that the diastase activity of *A. cerana* honey from Qinling Mountains (China) is ranging from 22.05 to 35.67 Göthe. The different diastase activity of honey from *A. cerana* were reported by previously researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Furthermore, the HMF of *A. cerana* honey was produced by the sugar palm and coconut saps in our study was ranging from 2.24 to 5.81 mg/kg (Table 2). This HMF indicate that honey from our study in fresh condition and acceptable by SNI for the beekeeping honey including from *A. cerana* and *A. mellifera* is not exceed 40 mg/kg (National Standardization Agency of Indonesia 2018) and also acceptable by the international standard has been regulated by Codex Alimentarius is not exceed 40 mg/kg for blossom and honeydew honeys (Bogdanov et al. 1999; Thrasyvoulou et al. 2018). The fresh honey after harvested is generally contain the low of HMF is ranging from 0.06 to 0.2 mg/100 g of honey (White 1992). Hydroxymethylfurfural is resulted from the degradation of honey monosaccharide especially fructose and glucose under acid condition and accelerated by the heating. This reaction is producing levulinic and formic acids (Da Silva et al. 2016; White 1992).

Table 2. The diastase enzyme activity, hydroxymethylfurfural, and acidity of honey from the bee *A. cerana*

Treatments	Diastase enzyme activity (DN)	Hydroxymethylfurfural (mg/kg)	Acidity (ml NaOH/kg)
SP0	7.57	5.78	36.33
CP0	5.17	5.04	26.00
SCP0	9.04	4.75	28.60
SP1	6.86	4.77	29.68
CP1	8.51	5.81	28.26
SCP1	6.85	2.24	30.61

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Hydroxymethyfurfural is formed after honey removed from the comb or when the wax covers was opened and the advanced processing like heating process. The increasing of the HMF content is occur in honey with the high acidity and accelerated by the heating process. However, the HMF content also influenced by several factors such as sugars content, organic acids presence, pH, moisture content, water activity, and the plant types as the nectar source (floral source). In addition, HMF is also can be formed at the low temperatures, acidic condition, and sugars dehydration reactions. Therefore, the higher of HMF content is impact on the honey color is darker (Da Silva et al. 2016; Tornuk et al. 2013). Karabournioti and Zervalaki (2001) reported that the heating process increasing the HMF content and decreasing the diastase enzyme activity. The HMF of honey from the *A. cerana* in our study (Table 2) was differed to previously reported by Wu et al. (2020) for multifloral honey of *A. cerana cerana* from China is 3.80 mg/kg and 1.69 mg/kg for *A. cerana* honey from Qinling Mountains, China is 1.69 mg/kg. The different HMF content of honey from *A. cerana* were reported by previously researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Acidity of honey

Free acidity is one of an important parameter to evaluate the honey deterioration which is characterized by the organic acids presence in equilibrium with internal esters, lactone and several inorganic ions such as sulfates, chlorides, and phosphates (Da Silva et al. 2016; Moreira et al. 2007). The recent study showed that the honey acidity from *A. cerana* was produced by the sugar palm and coconut saps was ranging from 26.00 to 36.33 ml NaOH/kg (Table 2). The acidity of *A. cerana* honey in our study is acceptable by SNI is not exceed 50 ml NaOH/kg for the beekeeping honey including *A. cerana* and *A. mellifera*. Furthermore, is also acceptable of the international standard has been regulated by the Codex Alimentarius is not exceed 50 meq/kg for blossom and honeydew honeys (Bogdanov et al. 1999; Thrasyvoulou et al. 2018).

The sour taste of honey originated from the several of organic and inorganic acids, where the dominant of organic acid present in honey is gluconic acid (Da Silva et al. 2016; White 1992). This organic acid is produced by the enzyme activity of glucose-oxidase which is added by the bees when they are convert a nectar into honey, so can protecting a nectar until honey maturity. This protecting mechanism is occurred by the inhibit of microorganisms activity present in honey (Da Silva et al. 2016; White 1992). This inhibit mechanism includes the combination several factors such as low moisture and presence hydrogen peroxide which is produced by the enzyme glucose-oxidase can inhibit the metabolism activity in the microbe cell through the destruction of cell wall resulting in change in cytoplasmic membrane permeability (Molan 1992; Nainu et al. 2021; Pasias et al. 2018).

The acidity total content in honey is small quantity, but the present in honey is very important because can influencing the honey stability on the microorganisms, taste or flavor, and aroma of honey. The high acidity is indicating the fermentation process had been occurred when some reducing sugar is break down into acetic acid. Ghazali et al. (1994) explained that honey acidity content is related to the yeast number where them is break down some reducing sugar into ethanol and if it's reaction with the oxygen is formed the acetic acid which is increasing the honey acidity. Da Silva et al. (2016) explained that the values higher of acidity may be indicating the fermentation process of sugars into organic acids. The honey acidity is affected by several factors such as different content of organic acids, different geographical origin and the seasonal when honey harvested (Da Silva et al. 2016; Tornuk et al. 2013). The honey acidity from the bee *A. cerana* in our study (Table 2) was differed to previously studied by Wu et al. (2020) for *A. cerana cerana* honey is 0.80 mol/kg and Guerzou et al. (2021) is ranging 11 to 47 meq/kg for Algerian honey. Furthermore, is differed to reported by Erwan et al. (2020) that honey acidity from the bee *A. mellifera* were produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 22.00 to 43.00 ml NaOH/kg. The different acidity has been reported previously with our studied is affected by the different plant types as the nectar source to produce honey, honey pH, geographical origin, and organic acids compound, however in our study has not measured the organic acid compound and honey pH.

Honey production potency from the sugar palm and coconut saps

Coconut and sugar palm plants have a good prospect to be developed because almost part of the plants can be utilized which can contributing for communities' income. Generally, the main production from the coconut (*Cocos nucifera* L.) was harvested is coconut fruit to advanced process into coconut oil and copra. Theses commodities have a high price, but if just to producing coconut oil and copra are high risk for the farmers because they are just preparing in the raw material. Therefore, the utilizing of the sap can be produced by the coconut and sugar palm were also potency feed for the bees was used as the nectar source to produce honey. Sugar palm and coconut saps are the feed potential which is studied by Erwan et al. (2021b) that the coconut and sugar palm saps can increasing the number of honey cell and bee bread cell of the bee *A. cerana*. Furthermore, is also reported that sugar palm and coconut are improving the productivity of the bee *A. cerana* such as increase the brood cells number, colony weight, and the honey production (Erwan et al. 2022). In addition, the saps from coconut and sugar palm are usually used by the farmers to produce sugar by using a traditional process.

The coconut plants can produce of 12 stalks in a year and in one of stalk can produce sap of 90 liters, thus, in one coconut plant can produce of 1,080 liters of sap. Furthermore, if the farmers have one hectare of the land which are planted by 100 coconut plants (distance 10 m × 10 m), so can be produced for about 108,000 liters of coconut sap. To produce 1 kg of honey is required coconut sap for about 7 liters and in a year is required 84 liters to produce 12 kg of honey. Thus, honey potency in a year from 100 hectares of the land can be calculated as follows: 10,800,000 liters of sap divided by 84 liters of sap and multiplied by 12 kg of honey and obtained 1,542,857,14 kg/year (1,542.857 tons/year) or equivalent with 128.571 tons/month in 100 hectares of the land. Based on the sap production showing that the coconut plants have a big potency to produce honey. This potency was also supported by the harvest area of coconut in West Lombok (Nusa Tenggara Province, Indonesia) was 10,629.36 hectares (Department of Agricultural and Plantations 2021).

Sugar palm plant can be tapped to collect sap for about 5 to 6 months in one stalk, but generally can be tapping not exceed of 4 months. Wahyuni et al. (2021) reported that the production of sugar palm sap per plant is ranging from 8 to 22 liters/plant or 300 to 400 liters/season (3 to 4 months) or 800 to 1,500 liters/plant/year (average is 1,150 liters/plant/year). Furthermore, if in one hectare of plantation we have 100 sugar palm plants with the distance for planted is 10 m × 10 m, so can be obtained of sap for 115,000 liters.

Based on the field investigation showed that to produce 1 kg of honey from the sugar palm sap is required for about 10 liters and in a year is required for about 120 liters to produce 12 kg of honey. Thus, the honey potency from the sugar palm sap in a year from the 100 hectares of the sugar palm field is 11,500,000 liters which was divided by 120 liters and multiplied by 12 kg, so is obtained 1,150,000 kg of honey per year (1,150 tons of honey) or equivalent with 95.833 tons/month in 100 hectares area. This potency indicate that the sugar palm sap has a big potency to produce honey which is supported by the report data from the Department of Agricultural and Plantations (2021) that the sap production, sap productivity, and harvest area for sugar palm plants in West Lombok (West Nusa Tenggara Province, Indonesia) are 57.46 tones, 304.80 quintals/hectare, and 188.52, respectively, in the year of 2021. It can be concluded that Honey is produced by the bee *A. cerana* from sugar palm and coconut saps as the feed have the quality which is acceptable by Indonesian national standard and international standard has been regulated by the Codex Alimentarius. Honey potency production from the coconut sap in 100 hectares area can produce honey of 1,542.857 tons/year or equivalent with 128.571 tons/month, while in sugar palm can produce honey of 1,150 tons/year or equivalent with 95.833 tons/month.

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Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

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Abstract. One of the big problems when keeping of honeybees is the limited of sustainable feed, especially in the rain season. The objectives of this study were to evaluate the honey quality from the bee *A. cerana* based on the chemical composition, honey potency produced by the coconut and sugar palm saps. This study using thirty colonies of the bee *A. cerana* were divided into six treatments consists of sugar palm sap without sugar palm pollen; coconut sap without sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% without sugar palm pollen; sugar palm sap was added by sugar palm pollen; coconut sap was added by sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen. The chemical composition of honey from the *A. cerana* were moisture (20.76 to 21.80%), reducing sugar (62.78 to 68.37%), sucrose (1.44 to 3.42%), diastase enzyme activity (5.17 to 9.04 DN), hydroxymethylfurfural (2.24 to 5.81 mg/kg), and acidity (26.00 to 36.35 ml NaOH/kg). Honey potency produced by the coconut and sugar palm saps in 100 hectares area produces honey was 1,542.857 tons/year and 1,150 tons/year, respectively. It can be concluded that honey quality is produced by sugar palm and coconut saps, and potential as the bee feed.

Key words: *Arenga pinnata*, beekeeping, *Cocos nucifera* L., extrafloral nectar, multifloral nectar

Running title: Honey quality of *Apis cerana* produced by sugar palm and coconut saps

INTRODUCTION

Honeybee of *A. cerana* is one of the bees from the *Apis* genus which is include the local bee which is spread in some regions in Indonesia are Kalimantan, Sumatera, Java, Bali, Lombok, Sumbawa, Sulawesi, Papua, and Seram (Radloff et al. 2011; Hepburn and Radloff 2011). In Indonesia, beekeeping of the bee *A. cerana* has been practiced by the beekeepers using a traditional hives (for example using a coconut log hive) and semi modern hive (box hive without nest frame) to produce honey. Furthermore, several regions have been practices the beekeeping of the bee *A. cerana* has been reported by Schouten et al. (2019) are Riau, North Sumatera, Lampung, Banten, Java, Yogyakarta region, Bali, and Lombok. However, the beekeeping of *A. cerana* is mostly using traditional hives although using a box hives because is not completed by the honey frame like a beekeeping of *A. mellifera*. The bee *A. cerana* can produce honey, bee bread, royal jelly, and propolis, however their production is lower compared to the bee *A. mellifera*.

One of the problems faced by the beekeepers in Indonesia is the limited of feed sustainability as the raw material to produce honey, bee bread, and royal jelly. The limitation feed is the very serious problem have been faced by the beekeepers because they have not area which is used to planted several plants which are used the feed source to produce the honeybees products. Honeybees feeds is divided into two types namely nectar and pollen, where nectar is obtained by the foragers from the plant flowers (nectar floral) and nectar extrafloral which is obtained by the foragers from stalk and leaf of plants (Agussalim et al. 2018, 2017). Pollen is obtained by the foragers from plant flowers which is collected by using all body part and then deposited in the corbicula (Agussalim et al. 2018, 2017; Erwan et al. 2021a). When collecting nectar and pollen from the plant flowers, the foragers is role as the pollinator agent by transporting pollen from the anther to pistil so that the pollination process occurs. This process is continuously done by the foragers until their honey stomach is full by a nectar and their corbicula has been deposited by the pollen. This pollination which is impacts on the increasing the plants productivity (Pohorecka et al., 2014; Supeno et al., 2021).

One of the strategies to produce the sustainability honey from the bee *A. cerana* by using a sap from the plants such as sugar palm and coconut. Several studies have been conducted by using a sugar palm and coconut saps as the *A. cerana* feed. Erwan et al. (2021b) reported that the feed combination of coconut sap and sugar palm pollen as the *A. cerana* feed can enhancing the production of honey cells and bee bread cells. However, the use each of sap from coconut and sugar palm can increasing the honey and bee bread cells compared to control group without sap as the feed (multifloral nectar). Furthermore, Erwan et al. (2022) was also reported that the use of sugar palm and coconut saps which each added by sugar palm pollen can improving the bee *A. cerana* productivity such as increase the honey production, brood cells number, and colony weight. In addition, in other study showed that the use of extrafloral nectar namely sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera* L.) saps as the *A. mellifera* bee feed which is resulting the honey chemical composition (reducing sugar, sucrose, acidity, moisture, and diastase enzyme activity) which are acceptable by Indonesian national standard and international standard has been regulated by Codex Alimentarius (Erwan et al. 2020). However, the studied about the chemical composition of honey from the bee *A. cerana* which are produced from the sugar palm sap, coconut sap and their honey potency production from both sap sugar palm and coconut have not been studied. Therefore, the objectives of this study were to evaluate the honey quality based on the chemical composition from the bee *A. cerana*, honey potency produced by the coconut and sugar palm saps.

MATERIALS AND METHODS

Study area

This research has been conducted in the North Duman Village (8º32'10"S 116º09'32"E), Lingsar Sub-district, West Lombok (West Nusa Tenggara Province, Indonesia). In this research, we used thirty of *A. cerana* colonies were divided into six treatments and each five colonies per treatment as the replication. The saps were used in our study were obtained from coconut (*Cocos nucifera* L.) and sugar palm (*Arenga pinnata*). The treatments in our study were sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

The technique was used to given sugar palm and coconut saps and sugar palm pollen was according to previously method has been reported by Erwan et al. (2022, 2021b) briefly as follows: fresh coconut and sugar palm saps were given to the bee *A. cerana* by using a plastic plate and split bamboo were completed by 4 to 5 twigs for foragers perch. The plastic plate and split bamboo were placed one meter of the box hives, while the sugar palm pollen was hung besides and above of the box hives. The distance of 600 meters to place colony to avoid the foragers to collect pollen and sap from the other treatments.

Proceduress

Honey quality

Honey from the *A. cerana* was harvested after beekeeping for three months by using a coconut and sugar palm saps. Honey from the five hives in one treatment group was composited into one honey sample and then used to analysis of their chemical composition. Honey quality from the *A. cerana* were evaluated based on the chemical composition consists of moisture, reducing sugar, sucrose, diastase enzyme activity, hydroxymethylfurfural (HMF), and acidity. The moisture content was analyzed by using a proximate analysis based on the method from Association of Official Agricultural Chemists (AOAC) (AOAC 2005). Reducing sugar was analyzed by using a Layne-Enyon method and sucrose content was analyzed by a Luff Schoorl method were described by AOAC (2005). Diastase enzyme activity, hydroxymethylfurfural (HMF), and free acidity were analyzed based on the harmonised methods of the international honey commission (Machado et al. 2022).

Honey production from sugar palm and coconut saps

Sugar palm and coconut saps each ten liters were used to measuring the honey production from the bee *A. cerana* for three months of beekeeping. The sugar palm and coconut saps were placed in the plastic plate in front of the box hives at the distance of one meter. In addition, the honey production without using of sugar palm and coconut saps were measured for one year of the beekeeping which is used to calculate the contribution of sugar palm and coconut saps in honey production.

Production of saps from coconut and sugar palm

The production of sap from coconut was measured for a year, while the sugar palm sap based on the previously studied was used to calculate the production per hectare area and was also obtained from the deep interview with the farmers. The production of coconut and sugar palm saps per hectare which was calculated from the sap production per hectare multiplied by the tress number in one hectare area. After three months of beekeeping, honey from both treatments sugar palm and coconut saps were harvested to measure the honey production from the use of ten litters sap and then honey production was measured by cylinder glass

Data analysis

The data of honey quality, production potency of honey from sugar palm and coconut saps, honey production, and production of saps were analyzed by using a descriptive analysis (Steel et al. 1997).

RESULTS AND DISCUSSION

Moisture content of honey

Honey is composed by water as the second largest of honey constituent and its ranging from 15 to 21 g/100 g, depending on the plant types as the nectar source which is affected by the botanical origin. Furthermore, honey moisture is also affected by honey maturity level, processing postharvest, and storage condition (Da Silva et al. 2016). The honey moisture is affecting the physical properties such as crystallization, viscosity, flavor, color, taste, solubility, specific gravity, and conservation (Da Silva et al. 2016; Escuredo et al. 2013). In addition, honey moisture is also affected by the temperature and humidity or depending on the season (rain and dry seasons) and honey moisture can increase during the postharvest processing such as storage condition because honey is hygroscopic that can absorbs the moisture in the air (Da Silva et al. 2016; Karabagias et al. 2014).

The recent study showed that the honey moisture from the bee *A. cerana* which was produced by sugar palm and coconut saps and their combination was ranging from 20.76 to 21.80% (Table 1). This honey moisture content is accepted by Indonesian national standard (SNI) where the moisture for beekeeping honey including the bee *A. cerana* and *A. mellifera* is not exceed 22% (National Standardization Agency of Indonesia 2018) and higher compared to international standard which is regulated by Codex Alimentarius is not exceed 20% (Thrasyvoulou et al. 2018). The variation of honey moisture of the bee *A. cerana* in our study may be caused by the different moisture content of both saps from sugar palm and coconut, however in our study has not measured. The higher moisture content is requiring the long time to ripening of honey and process decreasing of honey moisture have been started by the bees when they are taken a nectar from plant flowers or saps as the raw material to produce honey. Furthermore, small portion of moisture content has been evaporated in the honey sack before transferred to the other bee which is working in the hive. This transfer is rapid depending on the temperature, colony strength, and nectar availability (Da Silva et al. 2016).

Table 1. The moisture, reducing sugar, and sucrose contents of honey from the bee *A. cerana*

Treatments	Moisture (%)	Reducing sugar (%)	Sucrose (%)
SP0	21.60	65.24	2.86
CP0	20.76	68.37	1.96
SCP0	21.40	64.55	2.51
SP1	21.80	62.78	3.42
CP1	21.58	65.37	1.72
SCP1	20.98	67.33	1.44

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Honey production process is started from the foragers collecting a nectar from the plant flowers or extrafloral nectar and then stored in honey stomach. After that, the foragers will be transferring a nectar has been collected to the other bees whom working to processing a nectar into honey in their mouth, then put in honey stomach and then is transferred to other bees for several times until honey is ripening. A considerable of water amount will be evaporated in this process and this continues with the help of wing fans that can regulate the air humidity for about 15 to 20 minutes (Balasubramanyam 2021; Zhang et al. 2021). The honey moisture content in our study was differed to reported by Wang et al. (2021) that honey moisture from the bee *A. cerana* which is collected from 42 different honeycombs from China is ranging from 17.03 to 18.44%, 18.65% for *A. cerana cerana* from Hainan province, China (Wu et al. 2020), and 16.99% for *A. cerana* from Borneo (Malaysian honey) (Moniruzzaman et al. 2013). Furthermore, Erwan et al. (2020) was also reported that the honey moisture was produced by the *A. mellifera* bee by using a sugar palm and coconut saps is ranging from 19.34 to 20.94%. The different honey moisture content has been reported are affected by the different geographical origins which is impact on the different plant types can be growth each region, different environmental condition (temperature and humidity), and also different bee species which is impact on the different ability to evaporate water in the honey.

Reducing sugar and sucrose contents of honey

Sugars in honey are composed by monosaccharides for about 75%, disaccharides are 10 to 15%, and other sugars in small amounts. Honey sugars are responsible as the energy source, hygroscopic, viscosity, and granulation. Several sugars in honey have been reported such as glucose, fructose, sucrose, trehalose, rhamnose, isomaltose, nigerobiose, maltotriose, maltotetraose, melezitose, melibiose, maltulose, nigerose, raffinose, palatinose, erlose and others (Da Silva et al. 2016).

The recent study showed that the honey s reducing sugar from the bee *A. cerana* were beekeeping by using a sugar palm and coconut saps and their combination as the nectar source to produce honey is ranging from 62.78 to 68.37 % (Table 1). This honey reducing sugar is acceptable by the SNI for treatments SP0, CP0, CP1, and SCP1, but not acceptable for treatments SCP0, SP1 (Table 1), where the minimum reducing sugar is 65% (National Standardization Agency of Indonesia 2018). This sugar is produced by the mechanism of invertase enzyme activity that change the sap sucrose into simple sugars. It is known that this enzyme is responsible for the conversion of sucrose into glucose and fructose. These sugars are included in reducing sugar group and as the main component present in honey. In honey maturity process, the sucrose is break down by the invertase enzyme into simple sugars simultaneously and water will be evaporated so that it will be increasing the reducing sugar content. In addition, enzymes secreted by the worker bees are also can break down the carbohydrate into simple sugars. Furthermore, other enzyme present in honey is diastase enzyme that role to break down starch into simple sugars (Da Silva et al. 2016). The honey reducing sugar in our study (Table 1) was differed to reported by Erwan et al. (2020) that honey reducing sugar from the bee *A. mellifera* which was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 60.15 to 73.69%. The different reducing sugar may be affected by the different bee species which is impact on the different their ability to evaporate water present in honey especially when they are convert the complex sugars into simple sugars and different season when done the study which are related to temperature and humidity environmental.

The honey sucrose content from the bee *A. cerana* in our study is ranging from 1.44 to 3.42% (Table 1) and acceptable by SNI is not exceed 5% for the beekeeping honey including *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also accepted by the International standard has been regulated by Codex Alimentarius is not exceed 5% for blossom and honeydew honeys (Thrasyvoulou et al. 2018). Naturally, sucrose present in honey in our study is originated from sugar palm and coconut saps. The low of honey sucrose content in our study is caused the honey which is harvested in mature condition that characterized by honey cells have been covered by the wax. Furthermore, the invertase enzyme which is produced by the worker bees is actively break down of sucrose from saps into simple sugars. There are two types of invertase enzymes which are produced by the worker bees, namely glucoinvertase which is converts sucrose into glucose and fructoinvertase which is converts sucrose into fructose. These enzymes are mostly derived from the bee's secretion and only a small portion from the nectar, while the honeydew from the insect's secretion is mostly contain invertase enzyme (Da Silva et al. 2016). The honey sucrose content in our study (Table 1) was differed to reported by Erwan et al. (2020) that honey sucrose content from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 4.21 to 4.40%%.

The honey sucrose content is a very important parameter to evaluate the maturity of honey to identifying manipulation, where the high levels may be indicated adulterations by adding the several sweeteners such cane sugar or refined beet sugar. In addition, also indicating the early of harvest, where sucrose is not completed transformed into fructose and glucose, the bees feeding artificial in prolonged time by using a sucrose syrup (Da Silva et al. 2016; Puscas et al. 2013; Escuredo et al. 2013; Tornuk et al. 2013). Honey is sugar solution that is supersaturated and unstable so it's easy to crystallize. The honey crystallization is affected by concentration of glucose, fructose, and water. Fructose is the dominant sugar present in honey from *A. mellifera* was produced by several plants as the nectar source which is used by workers to produce honey such as eucalyptus, acacia, bramble, lime, chestnut, sunflower, and from honeydew, except in rape honey was produced by *Brassica napus*. Rape honey is higher in glucose and lower in fructose which is impact on the rapidly crystallization (Escuredo et al. 2014). The sugars content present in honey is dependent on the geographical origins which is impact on the different plant types can growth in each region and impact on the different sugars content from the nectar which is produced by the nectary gland of plant flowers (Agus et al. 2021; Agussalim et al. 2019; Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013). Furthermore, sugars content in honey is influenced by climate (season, temperature, and humidity), processing (heating process), and storage time (Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013).

Diastase enzyme activity and hydroxymethylfurfural of honey

The recent study showed that the diastase enzyme activity from the bee *A. cerana* honey was produced by the sugar palm and coconut saps was ranging from 5.17 to 9.04 DN (Table 2). This enzyme activity is acceptable by SNI with the minimum of 3 DN for the beekeeping honey including the bee *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also acceptable by international standard has been regulated by Codex Alimentarius with the minimum 3 DN (Thrasyvoulou et al. 2018). One of the honey characteristics is contain enzymes which is originate from the bees, pollen, and nectar from plant flowers, but the mostly enzymes are added by the bees when they are convert nectar into honey (Da Silva et al. 2016; Thrasyvoulou et al. 2018). The honey diastase enzyme activity in our study (Table 2) was differed to reported by Erwan et al. (2020) that the diastase enzyme activity of honey from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 16.48 to 17.12 Schade unit.

Diastases is divided into α- and β-amylases which are the natural enzymes present in honey. The α-amylase is separate the starch chain randomly in the central to produce dextrin, while the β-amylase to separate the maltose in the end chain. Diastase enzyme content in honey is influenced by nectar source (floral and extrafloral nectars) to produce honey and honey geographical origins which are impact on the different chemical composition of the nectar can be produced by the plants which is impact on the honey chemical composition especially diastase enzyme activity. In addition, the bee species is also influencing the activity diastase because it's related to the distance and the flowers plant numbers can be visited by the foragers when they are collecting nectar and pollen were using to produce honey and bee bread (Da Silva et al. 2016).

Generally, diastase enzyme is role to break down the complex sugars into simple sugars. This enzyme is role to digest of starch into maltose (disaccharide) and maltotriose (trisaccharide) which are sensitive to heat or thermolabile. Thus, this condition can be used to evaluate of overheating and preservation degree of honey (Da Silva et al. 2016). Furthermore, the diastase activity is also used to evaluate honey age which is related to storage time and the temperature because the diastase activity may be reducing when heating above 60ºC and longtime storage (Da Silva et al. 2016; Yücel and Sultanoğlu 2013). The honey diastase activity from the bee *A. cerana* in our study (Table 2) was differed to reported by Wu et al. (2020) for multifloral honey produced by the *A. cerana cerana* from Hainan province (China) was 6.70 Göthe. Furthermore, also was differed to reported by Wang et al. (2021) that the diastase activity of *A. cerana* honey from Qinling Mountains (China) is ranging from 22.05 to 35.67 Göthe. The different diastase activity of honey from *A. cerana* were reported by previously researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Furthermore, the HMF of *A. cerana* honey was produced by the sugar palm and coconut saps in our study was ranging from 2.24 to 5.81 mg/kg (Table 2). This HMF indicate that honey from our study in fresh condition and acceptable by SNI for the beekeeping honey including from *A. cerana* and *A. mellifera* is not exceed 40 mg/kg (National Standardization Agency of Indonesia 2018) and also acceptable by the international standard has been regulated by Codex Alimentarius is not exceed 40 mg/kg for blossom and honeydew honeys (Thrasyvoulou et al. 2018). The fresh honey after harvested is generally contain the low of HMF is ranging from 0 to 4.12 mg/kg honey. Hydroxymethylfurfural is resulted from the degradation of honey monosaccharide especially fructose and glucose under acid condition and accelerated by the heating. This reaction is producing levulinic and formic acids (Da Silva et al. 2016).

Table 2. The diastase enzyme activity, hydroxymethylfurfural, and acidity of honey from the bee *A. cerana*

Treatments	Diastase enzyme activity (DN)	Hydroxymethylfurfural (mg/kg)	Acidity (ml NaOH/kg)
SP0	7.57	5.78	36.33
CP0	5.17	5.04	26.00
SCP0	9.04	4.75	28.60
SP1	6.86	4.77	29.68
CP1	8.51	5.81	28.26
SCP1	6.85	2.24	30.61

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Hydroxymethyfurfural is formed after honey removed from the comb or when the wax covers was opened and the advanced processing like heating process. The increasing of the HMF content is occur in honey with the high acidity and accelerated by the heating process. However, the HMF content also influenced by several factors such as sugars content, organic acids presence, pH, moisture content, water activity, and the plant types as the nectar source (floral source). In addition, HMF is also can be formed at the low temperatures, acidic condition, and sugars dehydration reactions. Therefore, the higher of HMF content is impact on the honey color is darker (Da Silva et al. 2016; Tornuk et al. 2013). The HMF of honey from the *A. cerana* in our study (Table 2) was differed to previously reported by Wu et al. (2020) for multifloral honey of *A. cerana cerana* from China is 3.80 mg/kg and 1.69 mg/kg for *A. cerana* honey from Qinling Mountains, China is 1.69 mg/kg. The different HMF content of honey from *A. cerana* were reported by previously researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Acidity of honey

Free acidity is one of an important parameter to evaluate the honey deterioration which is characterized by the organic acids presence in equilibrium with internal esters, lactone and several inorganic ions such as sulfates, chlorides, and phosphates (Da Silva et al. 2016). The recent study showed that the honey acidity from *A. cerana* was produced by the sugar palm and coconut saps was ranging from 26.00 to 36.33 ml NaOH/kg (Table 2). The acidity of *A. cerana* honey in our study is acceptable by SNI is not exceed 50 ml NaOH/kg for the beekeeping honey including *A. cerana* and *A. mellifera*. Furthermore, is also acceptable of the international standard has been regulated by the Codex Alimentarius is not exceed 50 meq/kg for blossom and honeydew honeys (Thrasyvoulou et al. 2018).

The sour taste of honey originated from the several of organic and inorganic acids, where the dominant of organic acid present in honey is gluconic acid. This organic acid is produced by the enzyme activity of glucose-oxidase which is added by the bees when they are convert a nectar into honey, so can protecting a nectar until honey maturity. This protecting mechanism is occurred by the inhibit of microorganisms activity present in honey (Da Silva et al. 2016). This inhibit mechanism includes the combination several factors such as low moisture and presence hydrogen peroxide which is produced by the enzyme glucose-oxidase can inhibit the metabolism activity in the microbe cell through the destruction of cell wall resulting in change in cytoplasmic membrane permeability (Nainu et al. 2021; Pasias et al. 2018).

The acidity total content in honey is small quantity, but the present in honey is very important because can influencing the honey stability on the microorganisms, taste or flavor, and aroma of honey. The high acidity is indicating the fermentation process had been occurred when some reducing sugar is break down into acetic acid. Honey acidity content is related to the yeast number where them is break down some reducing sugar into ethanol and if it's reaction with the oxygen is formed the acetic acid which is increasing the honey acidity. The values higher of acidity may be indicating the fermentation process of sugars into organic acids. The honey acidity is affected by several factors such as different content of organic acids, different geographical origin and the seasonal when honey harvested (Da Silva et al. 2016; Tornuk et al. 2013). The honey acidity from the bee *A. cerana* in our study (Table 2) was differed to previously studied by Wu et al. (2020) for *A. cerana cerana* honey is 0.80 mol/kg and Guerzou et al. (2021) is ranging 11 to 47 meq/kg for Algerian honey. Furthermore, is differed to reported by Erwan et al. (2020) that honey acidity from the bee *A. mellifera* were produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 22.00 to 43.00 ml NaOH/kg. The different acidity has been reported previously with our studied is affected by the different plant types as the nectar source to produce honey, honey pH, geographical origin, and organic acids compound, however in our study has not measured the organic acid compound and honey pH.

Honey production potency from the sugar palm and coconut saps

Coconut and sugar palm plants have a good prospect to be developed because almost part of the plants can be utilized which can contributing for communities' income. Generally, the main production from the coconut (*Cocos nucifera* L.) was harvested is coconut fruit to advanced process into coconut oil and copra. Theses commodities have a high price, but if just to producing coconut oil and copra are high risk for the farmers because they are just preparing in the raw material. Therefore, the utilizing of the sap can be produced by the coconut and sugar palm were also potency feed for the bees was used as the nectar source to produce honey. Sugar palm and coconut saps are the feed potential which is studied by Erwan et al. (2021b) that the coconut and sugar palm saps can increasing the number of honey cell and bee bread cell of the bee *A. cerana*. Furthermore, is also reported that sugar palm and coconut are improving the productivity of the bee *A. cerana* such as increase the brood cells number, colony weight, and the honey production (Erwan et al. 2022). In addition, the saps from coconut and sugar palm are usually used by the farmers to produce sugar by using a traditional process.

The coconut plants can produce of 12 stalks in a year and in one of stalk can produce sap of 90 liters, thus, in one coconut plant can produce of 1,080 liters of sap. Furthermore, if the farmers have one hectare of the land which are planted by 100 coconut plants (distance 10 m × 10 m), so can be produced for about 108,000 liters of coconut sap. To produce 1 kg of honey is required coconut sap for about 7 liters and in a year is required 84 liters to produce 12 kg of honey. Thus, honey potency in a year from 100 hectares of the land can be calculated as follows: 10,800,000 liters of sap divided by 84 liters of sap and multiplied by 12 kg of honey and obtained 1,542,857,14 kg/year (1,542.857 tons/year) or equivalent with 128.571 tons/month in 100 hectares of the land. Based on the sap production showing that the coconut plants have a big potency to produce honey. This potency was also supported by the harvest area of coconut in West Lombok (Nusa Tenggara Province, Indonesia) was 10,629.36 hectares (Department of Agricultural and Plantations 2021).

Sugar palm plant can be tapped to collect sap for about 5 to 6 months in one stalk, but generally can be tapping not exceed of 4 months. Wahyuni et al. (2021) reported that the production of sugar palm sap per plant is ranging from 8 to 22 liters/plant or 300 to 400 liters/season (3 to 4 months) or 800 to 1,500 liters/plant/year (average is 1,150 liters/plant/year). Furthermore, if in one hectare of plantation we have 100 sugar palm plants with the distance for planted is 10 m × 10 m, so can be obtained of sap for 115,000 liters.

Based on the field investigation showed that to produce 1 kg of honey from the sugar palm sap is required for about 10 liters and in a year is required for about 120 liters to produce 12 kg of honey. Thus, the honey potency from the sugar palm sap in a year from the 100 hectares of the sugar palm field is 11,500,000 liters which was divided by 120 liters and multiplied by 12 kg, so is obtained 1,150,000 kg of honey per year (1,150 tons of honey) or equivalent with 95.833 tons/month in 100 hectares area. This potency indicate that the sugar palm sap has a big potency to produce honey which is supported by the report data from the Department of Agricultural and Plantations (2021) that the sap production, sap productivity, and harvest area for sugar palm plants in West Lombok (West Nusa Tenggara Province, Indonesia) are 57.46 tones, 304.80 quintals/hectare, and 188.52, respectively, in the year of 2021. It can be concluded that Honey is produced by the bee *A. cerana* from sugar palm and coconut saps as the feed have the quality which is acceptable by Indonesian national standard and international standard has been regulated by the Codex Alimentarius. Honey potency production from the coconut sap in 100 hectares area can produce honey of 1,542.857 tons/year or equivalent with 128.571 tons/month, while in sugar palm can produce honey of 1,150 tons/year or equivalent with 95.833 tons/month.

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Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

Abstract. One of the big problems when keeping of honeybees is the limited of sustainable feed, especially in the rain season. The objectives of this study were to evaluate the honey quality from the bee *A. cerana* based on the chemical composition, honey potency produced by the coconut and sugar palm saps. This study using thirty colonies of the bee *A. cerana* were divided into six treatments consists of sugar palm sap without sugar palm pollen; coconut sap without sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% without sugar palm pollen; sugar palm sap was added by sugar palm pollen; coconut sap was added by sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen. The chemical composition of honey from the *A. cerana* were moisture (20.76 to 21.80%), reducing sugar (62.78 to 68.37%), sucrose (1.44 to 3.42%), diastase enzyme activity (5.17 to 9.04 DN), hydroxymethylfurfural (2.24 to 5.81 mg/kg), and acidity (26.00 to 36.35 ml NaOH/kg). Honey potency produced by the coconut and sugar palm saps in 100 hectares area produces honey was 1,542.857 tons/year and 1,150 tons/year, respectively. It can be concluded that honey quality is produced by sugar palm and coconut saps, and potential as the bee feed.

Keywords: *Arenga pinnata*, beekeeping, *Cocos nucifera* L., extrafloral nectar, multifloral nectar

Running title: Honey quality of *Apis cerana* produced by sugar palm and coconut saps

INTRODUCTION

Honeybee of *A. cerana* is one of the bees from the *Apis* genus which is include the local bee which is spread in some regions in Indonesia are Kalimantan, Sumatera, Java, Bali, Lombok, Sumbawa, Sulawesi, Papua, and Seram (Radloff et al. 2011; Hepburn and Radloff 2011). In Indonesia, beekeeping of the bee *A. cerana* has been practiced by the beekeepers using a traditional hives (for example using a coconut log hive) and semi modern hive (box hive without nest frame) to produce honey. Furthermore, several regions have been practices the beekeeping of the bee *A. cerana* has been reported by Schouten et al. (2019) are Riau, North Sumatera, Lampung, Banten, Java, Yogyakarta region, Bali, and Lombok. However, the beekeeping of *A. cerana* is mostly using traditional hives although using a box hives because is not completed by the honey frame like a beekeeping of *A. mellifera*. The bee *A. cerana* can produce honey, bee bread, royal jelly, and propolis, however their production is lower compared to the bee *A. mellifera*.

One of the problems faced by the beekeepers in Indonesia is the limited of feed sustainability as the raw material to produce honey, bee bread, and royal jelly. The limitation feed is the very serious problem have been faced by the beekeepers because they have not area which is used to planted several plants which are used the feed source to produce the honeybees products. Honeybees feeds is divided into two types namely nectar and pollen, where nectar is obtained by the foragers from the plant flowers (nectar floral) and nectar extrafloral which is obtained by the foragers from stalk and leaf of plants (Agussalim et al. 2018, 2017). Pollen is obtained by the foragers from plant flowers which is collected by using all body part and then deposited in the corbicula (Agussalim et al. 2018, 2017; Erwan et al. 2021a). When collecting nectar and pollen from the plant flowers, the foragers is role as the pollinator agent by transporting pollen from the anther to pistil so that the pollination process occurs. This process is continuously done by the foragers until their honey stomach is full by a nectar and their corbicula has been deposited by the pollen. This pollination which is impacts on the increasing the plants productivity (Pohorecka et al., 2014; Supeno et al., 2021).

One of the strategies to produce the sustainability honey from the bee *A. cerana* by using a sap from the plants such as sugar palm and coconut. Several studies have been conducted by using a sugar palm and coconut saps as the *A. cerana* feed. Erwan et al. (2021b) reported that the feed combination of coconut sap and sugar palm pollen as the *A. cerana* feed can enhancing the production of honey cells and bee bread cells. However, the use each of sap from coconut and sugar palm can increasing the honey and bee bread cells compared to control group without sap as the feed (multifloral nectar). Furthermore, Erwan et al. (2022) was also reported that the use of sugar palm and coconut saps which each added by sugar palm pollen can improving the bee *A. cerana* productivity such as increase the honey production, brood cells number, and

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It can be concluded that the quality of *A. cerana* honey which are produced by the sugar palm and coconut saps are acceptable by the Indonesia national standard and international standard. The sugar palm and coconut saps have a big potential as the bee feed especially for the bee *A. cerana*.

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colony weight. In addition, in other study showed that the use of extrafloral nectar namely sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera* L.) saps as the *A. mellifera* bee feed which is resulting the honey chemical composition (reducing sugar, sucrose, acidity, moisture, and diastase enzyme activity) which are acceptable by Indonesian national standard and international standard has been regulated by Codex Alimentarius (Erwan et al. 2020). However, the studied about the chemical composition of honey from the bee *A. cerana* which are produced from the sugar palm sap, coconut sap and their honey potency production from both sap sugar palm and coconut have not been studied. Therefore, the objectives of this study were to evaluate the honey quality based on the chemical composition from the bee *A. cerana*, honey potency produced by the coconut and sugar palm saps.

MATERIALS AND METHODS

Study area

This research has been conducted in the North Duman Village (8º32'10"S 116º09'32"E), Lingsar Sub-district, West Lombok (West Nusa Tenggara Province, Indonesia). In this research, we used thirty of *A. cerana* colonies were divided into six treatments and each five colonies per treatment as the replication. The saps were used in our study were obtained from coconut (*Cocos nucifera* L.) and sugar palm (*Arenga pinnata*). The treatments in our study were sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

The technique was used to given sugar palm and coconut saps and sugar palm pollen was according to previously method has been reported by Erwan et al. (2022, 2021b) briefly as follows: fresh coconut and sugar palm saps were given to the bee *A. cerana* by using a plastic plate and split bamboo were completed by 4 to 5 twigs for foragers perch. The plastic plate and split bamboo were placed one meter of the box hives, while the sugar palm pollen was hung besides and above of the box hives. The distance of 600 meters to place colony to avoid the foragers to collect pollen and sap from the other treatments.

Proceduress

Honey quality

Honey from the *A. cerana* was harvested after beekeeping for three months by using a coconut and sugar palm saps. Honey from the five hives in one treatment group was composited into one honey sample and then used to analysis of their chemical composition. Honey quality from the *A. cerana* were evaluated based on the chemical composition consists of moisture, reducing sugar, sucrose, diastase enzyme activity, hydroxymethylfurfural (HMF), and acidity. The moisture content was analyzed by using a proximate analysis based on the method from Association of Official Agricultural Chemists (AOAC) (AOAC 2005). Reducing sugar was analyzed by using a Layne-Enyon method and sucrose content was analyzed by a Luff Schoorl method were described by AOAC (2005). Diastase enzyme activity, hydroxymethylfurfural (HMF), and free acidity were analyzed based on the harmonised methods of the international honey commission (Machado et al. 2022).

Honey production from sugar palm and coconut saps

Sugar palm and coconut saps each ten liters were used to measuring the honey production from the bee *A. cerana* for three months of beekeeping. The sugar palm and coconut saps were placed in the plastic plate in front of the box hives at the distance of one meter. In addition, the honey production without using of sugar palm and coconut saps were measured for one year of the beekeeping which is used to calculate the contribution of sugar palm and coconut saps in honey production.

Production of saps from coconut and sugar palm

The production of sap from coconut was measured for a year, while the sugar palm sap based on the previously studied was used to calculate the production per hectare area and was also obtained from the deep interview with the farmers. The production of coconut and sugar palm saps per hectare which was calculated from the sap production per hectare multiplied by the tress number in one hectare area. After three months of beekeeping, honey from both treatments sugar palm and coconut saps were harvested to measure the honey production from the use of ten litters sap and then honey production was measured by cylinder glass

Data analysis

The data of honey quality, production potency of honey from sugar palm and coconut saps, honey production, and production of saps were analyzed by using a descriptive analysis (Steel et al. 1997).

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RESULTS AND DISCUSSION

Moisture content of honey

Honey is composed by water as the second largest of honey constituent and its ranging from 15 to 21 g/100 g, depending on the plant types as the nectar source which is affected by the botanical origin. Furthermore, honey moisture is also affected by honey maturity level, processing postharvest, and storage condition (Da Silva et al. 2016). The honey moisture is affecting the physical properties such as crystallization, viscosity, flavor, color, taste, solubility, specific gravity, and conservation (Da Silva et al. 2016; Escuredo et al. 2013). In addition, honey moisture is also affected by the temperature and humidity or depending on the season (rain and dry seasons) and honey moisture can increase during the postharvest processing such as storage condition because honey is hygroscopic that can absorbs the moisture in the air (Da Silva et al. 2016; Karabagias et al. 2014).

The recent study showed that the honey moisture from the bee *A. cerana* which was produced by sugar palm and coconut saps and their combination was ranging from 20.76 to 21.80% (Table 1). This honey moisture content is accepted by Indonesian national standard (SNI) where the moisture for beekeeping honey including the bee *A. cerana* and *A. mellifera* is not exceed 22% (National Standardization Agency of Indonesia 2018) and higher compared to international standard which is regulated by Codex Alimentarius is not exceed 20% (Thrasyvoulou et al. 2018). The variation of honey moisture of the bee *A. cerana* in our study may be caused by the different moisture content of both saps from sugar palm and coconut, however in our study has not measured. The higher moisture content is requiring the long time to ripening of honey and process decreasing of honey moisture have been started by the bees when they are taken a nectar from plant flowers or saps as the raw material to produce honey. Furthermore, small portion of moisture content has been evaporated in the honey sack before transferred to the other bee which is working in the hive. This transfer is rapid depending on the temperature, colony strength, and nectar availability (Da Silva et al. 2016).

Table 1. The moisture, reducing sugar, and sucrose contents of honey from the bee *A. cerana*

Treatments	Moisture (%)	Reducing sugar (%)	Sucrose (%)
SP0	21.60	65.24	2.86
CP0	20.76	68.37	1.96
SCP0	21.40	64.55	2.51
SP1	21.80	62.78	3.42
CP1	21.58	65.37	1.72
SCP1	20.98	67.33	1.44

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Honey production process is started from the foragers collecting a nectar from the plant flowers or extrafloral nectar and then stored in honey stomach. After that, the foragers will be transferring a nectar has been collected to the other bees whom working to processing a nectar into honey in their mouth, then put in honey stomach and then is transferred to other bees for several times until honey is ripening. A considerable of water amount will be evaporated in this process and this continues with the help of wing fans that can regulate the air humidity for about 15 to 20 minutes (Balasubramanyam 2021; Zhang et al. 2021). The honey moisture content in our study was differed to reported by Wang et al. (2021) that honey moisture from the bee *A. cerana* which is collected from 42 different honeycombs from China is ranging from 17.03 to 18.44%, 18.65% for *A. cerana cerana* from Hainan province, China (Wu et al. 2020), and 16.99% for *A. cerana* from Borneo (Malaysian honey) (Moniruzzaman et al. 2013). Furthermore, Erwan et al. (2020) was also reported that the honey moisture was produced by the *A. mellifera* bee by using a sugar palm and coconut saps is ranging from 19.34 to 20.94%. The different honey moisture content has been reported are affected by the different geographical origins which is impact on the different plant types can be growth each region, different environmental condition (temperature and humidity), and also different bee species which is impact on the different ability to evaporate water in the honey.

Reducing sugar and sucrose contents of honey

Sugars in honey are composed by monosaccharides for about 75%, disaccharides are 10 to 15%, and other sugars in small amounts. Honey sugars are responsible as the energy source, hygroscopic, viscosity, and granulation. Several sugars in honey have been reported such as glucose, fructose, sucrose, trehalose, rhamnose, isomaltose, nigerobiose, maltotriose, maltotetraose, melezitose, melibiose, maltulose, nigerose, raffinose, palatinose, erlose and others (Da Silva et al. 2016).

The recent study showed that the honey s reducing sugar from the bee *A. cerana* were beekeeping by using a sugar palm and coconut saps and their combination as the nectar source to produce honey is ranging from 62.78 to 68.37 % (Table 1). This honey reducing sugar is acceptable by the SNI for treatments SP0, CP0, CP1, and SCP1, but not acceptable for treatments SCP0, SP1 (Table 1), where the minimum reducing sugar is 65% (National Standardization Agency of Indonesia 2018). This sugar is produced by the mechanism of invertase enzyme activity that change the sap sucrose into simple sugars. It is known that this enzyme is responsible for the conversion of sucrose into glucose and fructose. These

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sugars are included in reducing sugar group and as the main component present in honey. In honey maturity process, the sucrose is break down by the invertase enzyme into simple sugars simultaneously and water will be evaporated so that it will be increasing the reducing sugar content. In addition, enzymes secreted by the worker bees are also can break down the carbohydrate into simple sugars. Furthermore, other enzyme present in honey is diastase enzyme that role to break down starch into simple sugars (Da Silva et al. 2016). The honey reducing sugar in our study (Table 1) was differed to reported by Erwan et al. (2020) that honey reducing sugar from the bee *A. mellifera* which was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 60.15 to 73.69%. The different reducing sugar may be affected by the different bee species which is impact on the different their ability to evaporate water present in honey especially when they are convert the complex sugars into simple sugars and different season when done the study which are related to temperature and humidity environmental.

The honey sucrose content from the bee *A. cerana* in our study is ranging from 1.44 to 3.42% (Table 1) and acceptable by SNI is not exceed 5% for the beekeeping honey including *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also accepted by the International standard has been regulated by Codex Alimentarius is not exceed 5% for blossom and honeydew honeys (Thrasyvoulou et al. 2018). Naturally, sucrose present in honey in our study is originated from sugar palm and coconut saps. The low of honey sucrose content in our study is caused the honey which is harvested in mature condition that characterized by honey cells have been covered by the wax. Furthermore, the invertase enzyme which is produced by the worker bees is actively break down of sucrose from saps into simple sugars. There are two types of invertase enzymes which are produced by the worker bees, namely glucoinvertase which is converts sucrose into glucose and fructoinvertase which is converts sucrose into fructose. These enzymes are mostly derived from the bee's secretion and only a small portion from the nectar, while the honeydew from the insect's secretion is mostly contain invertase enzyme (Da Silva et al. 2016). The honey sucrose content in our study (Table 1) was differed to reported by Erwan et al. (2020) that honey sucrose content from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 4.21 to 4.40%%.

The honey sucrose content is a very important parameter to evaluate the maturity of honey to identifying manipulation, where the high levels may be indicated adulterations by adding the several sweeteners such cane sugar or refined beet sugar. In addition, also indicating the early of harvest, where sucrose is not completed transformed into fructose and glucose, the bees feeding artificial in prolonged time by using a sucrose syrup (Da Silva et al. 2016; Puscas et al. 2013; Escuredo et al. 2013; Tornuk et al. 2013). Honey is sugar solution that is supersaturated and unstable so it's easy to crystallize. The honey crystallization is affected by concentration of glucose, fructose, and water. Fructose is the dominant sugar present in honey from *A. mellifera* was produced by several plants as the nectar source which is used by workers to produce honey such as eucalyptus, acacia, bramble, lime, chestnut, sunflower, and from honeydew, except in rape honey was produced by *Brassica napus*. Rape honey is higher in glucose and lower in fructose which is impact on the rapidly crystallization (Escuredo et al. 2014). The sugars content present in honey is dependent on the geographical origins which is impact on the different plant types can growth in each region and impact on the different sugars content from the nectar which is produced by the nectary gland of plant flowers (Agus et al. 2021; Agussalim et al. 2019; Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013). Furthermore, sugars content in honey is influenced by climate (season, temperature, and humidity), processing (heating process), and storage time (Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013).

Diastase enzyme activity and hydroxymethylfurfural of honey

The recent study showed that the diastase enzyme activity from the bee *A. cerana* honey was produced by the sugar palm and coconut saps was ranging from 5.17 to 9.04 DN (Table 2). This enzyme activity is acceptable by SNI with the minimum of 3 DN for the beekeeping honey including the bee *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also acceptable by international standard has been regulated by Codex Alimentarius with the minimum 3 DN (Thrasyvoulou et al. 2018). One of the honey characteristics is contain enzymes which is originate from the bees, pollen, and nectar from plant flowers, but the mostly enzymes are added by the bees when they are convert nectar into honey (Da Silva et al. 2016; Thrasyvoulou et al. 2018). The honey diastase enzyme activity in our study (Table 2) was differed to reported by Erwan et al. (2020) that the diastase enzyme activity of honey from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 16.48 to 17.12 Schade unit.

Diastases is divided into α- and β-amylases which are the natural enzymes present in honey. The α-amylase is separate the starch chain randomly in the central to produce dextrin, while the β-amylase to separate the maltose in the end chain. Diastase enzyme content in honey is influenced by nectar source (floral and extrafloral nectars) to produce honey and honey geographical origins which are impact on the different chemical composition of the nectar can be produced by the plants which is impact on the honey chemical composition especially diastase enzyme activity. In addition, the bee species is also influencing the activity diastase because it's related to the distance and the flowers plant numbers can be visited by the foragers when they are collecting nectar and pollen were using to produce honey and bee bread (Da Silva et al. 2016).

Generally, diastase enzyme is role to break down the complex sugars into simple sugars. This enzyme is role to digest of starch into maltose (disaccharide) and maltotriose (trisaccharide) which are sensitive to heat or thermolabile. Thus, this condition can be used to evaluate of overheating and preservation degree of honey (Da Silva et al. 2016). Furthermore, the diastase activity is also used to evaluate honey age which is related to storage time and the temperature because the

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diastase activity may be reducing when heating above 60ºC and longtime storage (Da Silva et al. 2016; Yücel and Sultanoğlu 2013). The honey diastase activity from the bee *A. cerana* in our study (Table 2) was differed to reported by Wu et al. (2020) for multifloral honey produced by the *A. cerana cerana* from Hainan province (China) was 6.70 Göthe. Furthermore, also was differed to reported by Wang et al. (2021) that the diastase activity of *A. cerana* honey from Qinling Mountains (China) is ranging from 22.05 to 35.67 Göthe. The different diastase activity of honey from *A. cerana* were reported by previously researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Furthermore, the HMF of *A. cerana* honey was produced by the sugar palm and coconut saps in our study was ranging from 2.24 to 5.81 mg/kg (Table 2). This HMF indicate that honey from our study in fresh condition and acceptable by SNI for the beekeeping honey including from *A. cerana* and *A. mellifera* is not exceed 40 mg/kg (National Standardization Agency of Indonesia 2018) and also acceptable by the international standard has been regulated by Codex Alimentarius is not exceed 40 mg/kg for blossom and honeydew honeys (Thrasyvoulou et al. 2018). The fresh honey after harvested is generally contain the low of HMF is ranging from 0 to 4.12 mg/kg honey. Hydroxymethylfurfural is resulted from the degradation of honey monosaccharide especially fructose and glucose under acid condition and accelerated by the heating. This reaction is producing levulinic and formic acids (Da Silva et al. 2016).

Table 2. The diastase enzyme activity, hydroxymethylfurfural, and acidity of honey from the bee *A. cerana*

Treatments	Diastase enzyme activity (DN)	Hydroxymethylfurfural (mg/kg)	Acidity (ml NaOH/kg)
SP0	7.57	5.78	36.33
CP0	5.17	5.04	26.00
SCP0	9.04	4.75	28.60
SP1	6.86	4.77	29.68
CP1	8.51	5.81	28.26
SCP1	6.85	2.24	30.61

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Hydroxymethyfurfural is formed after honey removed from the comb or when the wax covers was opened and the advanced processing like heating process. The increasing of the HMF content is occur sin honey with the high acidity and accelerated by the heating process. However, the HMF content also sinfluenced by several factors such as sugars content, organic acids presence, pH, moisture content, water activity, and the plant types as the nectar source (floral source). In addition, HMF is also can be formed at the low temperatures, acidic condition, and sugars dehydration reactions. Therefore, the higher of HMF content is impact on the honey color is darker (Da Silva et al. 2016; Tornuk et al. 2013). The HMF of honey from the *A. cerana* in our study (Table 2) was differed to previously reported by Wu et al. (2020) for multifloral honey of *A. cerana cerana* from China is 3.80 mg/kg and 1.69 mg/kg for *A. cerana* honey from Qinling Mountains, China is 1.69 mg/kg. The different HMF content of honey from *A. cerana* were reported by previously researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Acidity of honey

Free acidity is one of an important parameter to evaluate the honey deterioration which is characterized by the organic acids presence in equilibrium with internal esters, lactone and several inorganic ions such as sulfates, chlorides, and phosphates (Da Silva et al. 2016). The recent study showed that the honey acidity from *A. cerana* was produced by the sugar palm and coconut saps was ranging from 26.00 to 36.33 ml NaOH/kg (Table 2). The acidity of *A. cerana* honey in our study is acceptable by SNI is not exceed 50 ml NaOH/kg for the beekeeping honey including *A. cerana* and *A. mellifera*. Furthermore, is also acceptable of the international standard has been regulated by the Codex Alimentarius is not exceed 50 meq/kg for blossom and honeydew honeys (Thrasyvoulou et al. 2018).

The sour taste of honey originated from the several of organic and inorganic acids, where the dominant of organic acid present in honey is gluconic acid. This organic acid is produced by the enzyme activity of glucose-oxidase which is added by the bees when they are convert a nectar into honey, so can protecting a nectar until honey maturity. This protecting mechanism is occurreds by the inhibit of microorganisms activity present in honey (Da Silva et al. 2016). This inhibit mechanism includes the combination several factors such as low moisture and presence hydrogen peroxide which is produced by the enzyme glucose-oxidase can inhibit the metabolism activity in the microbe cell through the destruction of cell wall resulting in change in cytoplasmic membrane permeability (Nainu et al. 2021; Pasias et al. 2018).

The acidity total content in honey is small quantity, but the present in honey is very important because can influencing the honey stability on the microorganisms, taste or flavor, and aroma of honey. The high acidity is indicating the fermentation process had been occurred when some reducing sugar is break down into acetic acid. Honey acidity content is related to the yeast number where them is break down some reducing sugar into ethanol and if it’s reaction with the oxygen is formed the acetic acid which is increasing the honey acidity. The values higher of acidity may be indicating the

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fermentation process of sugars into organic acids. The honey acidity is affected by several factors such as different content of organic acids, different geographical origin and the seasonal when honey harvested (Da Silva et al. 2016; Tornuk et al. 2013). The honey acidity from the bee *A. cerana* in our study (Table 2) was differed to previously studied by Wu et al. (2020) for *A. cerana cerana* honey is 0.80 mol/kg and Guerzou et al. (2021) is ranging 11 to 47 meq/kg for Algerian honey. Furthermore, is differed to reported by Erwan et al. (2020) that honey acidity from the bee *A. mellifera* were produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 22.00 to 43.00 ml NaOH/kg. The different acidity has been reported previously with our studied is affected by the different plant types as the nectar source to produce honey, honey pH, geographical origin, and organic acids compound, however in our study has not measured the organic acid compound and honey pH.

Honey production potency from the sugar palm and coconut saps

Coconut and sugar palm plants have a good prospect to be developed because almost part of the plants can be utilized which can contributing for communities' income. Generally, the main production from the coconut (*Cocos nucifera* L.) was harvested is coconut fruit to advanced process into coconut oil and copra. Theses commodities have a high price, but if just to producing coconut oil and copra are high risk for the farmers because they are just preparing in the raw material. Therefore, the utilizing of the sap can be produced by the coconut and sugar palm were also potency feed for the bees was used as the nectar source to produce honey. Sugar palm and coconut saps are the feed potential which is studied by Erwan et al. (2021b) that the coconut and sugar palm saps can increasing the number of honey cell and bee bread cell of the bee *A. cerana*. Furthermore, is also reported that sugar palm and coconut are improving the productivity of the bee *A. cerana* such as increase the brood cells number, colony weight, and the honey production (Erwan et al. 2022). In addition, the saps from coconut and sugar palm are usually used by the farmers to produce sugar by using a traditional process.

The coconut plants can produce of 12 stalks in a year and in one of stalk can produce sap of 90 liters, thus, in one coconut plant can produce of 1,080 liters of sap. Furthermore, if the farmers have one hectare of the land which are planted by 100 coconut plants (distance 10 m × 10 m), so can be produced for about 108,000 liters of coconut sap. To produce 1 kg of honey is required coconut sap for about 7 liters and in a year is required 84 liters to produce 12 kg of honey. Thus, honey potency in a year from 100 hectares of the land can be calculated as follows: 10,800,000 liters of sap divided by 84 liters of sap and multiplied by 12 kg of honey and obtained 1,542,857,14 kg/year (1,542.857 tons/year) or equivalent with 128.571 tons/month in 100 hectares of the land. Based on the sap production showing that the coconut plants have a big potency to produce honey. This potency was also supported by the harvest area of coconut in West Lombok (Nusa Tenggara Province, Indonesia) was 10,629.36 hectares (Department of Agricultural and Plantations 2021).

Sugar palm plant can be tapped to collect sap for about 5 to 6 months in one stalk, but generally can be tapping not exceed of 4 months. Wahyuni et al. (2021) reported that the production of sugar palm sap per plant is ranging from 8 to 22 liters/plant or 300 to 400 liters/season (3 to 4 months) or 800 to 1,500 liters/plant/year (average is 1,150 liters/plant/year). Furthermore, if in one hectare of plantation we have 100 sugar palm plants with the distance for planted is 10 m × 10 m, so can be obtained of sap for 115,000 liters.

Based on the field investigation showed that to produce 1 kg of honey from the sugar palm sap is required for about 10 liters and in a year is required for about 120 liters to produce 12 kg of honey. Thus, the honey potency from the sugar palm sap in a year from the 100 hectares of the sugar palm field is 11,500,000 liters which was divided by 120 liters and multiplied by 12 kg, so is obtained 1,150,000 kg of honey per year (1,150 tons of honey) or equivalent with 95.833 tons/month in 100 hectares area. This potency indicate that the sugar palm sap has a big potency to produce honey which is supported by the report data from the Department of Agricultural and Plantations (2021) that the sap production, sap productivity, and harvest area for sugar palm plants in West Lombok (West Nusa Tenggara Province, Indonesia) are 57.46 tones, 304.80 quintals/hectare, and 188.52, respectively, in the year of 2021. It can be concluded that Honey is produced by the bee *A. cerana* from sugar palm and coconut saps as the feed have the quality which is acceptable by Indonesian national standard and international standard has been regulated by the Codex Alimentarius. Honey potency production from the coconut sap in 100 hectares area can produce honey of 1,542.857 tons/year or equivalent with 128.571 tons/month, while in sugar palm can produce honey of 1,150 tons/year or equivalent with 95.833 tons/month.

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[biodiv] Editor Decision

3 pesan

Smujo Editors <smujo.id@gmail.com> 1 November 2022 pukul 10.35
Kepada: Erwan <apiserwan@gmail.com>, Agussalim <agussalim@mail.ugm.ac.id>

Erwan, Agussalim:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Honey quality from the bee Apis cerana, honey potency produced by coconut and sugar palm saps".

Our decision is: Revisions Required

Reviewer A:

This study aimed to evaluate the honey quality based on the chemical composition from the bee A. cerana and the honey potency produced by the coconut and sugar palm saps. The paper is clear objectives. The topic is an important subject. However, I have the following comments for revision consideration that I put in the text.

Recommendation: Revisions Required

Biodiversitas Journal of Biological Diversity

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erwan apis <apiserwan@gmail.com> 1 November 2022 pukul 13.26
Kepada: Smujo Editors <smujo.id@gmail.com>

Dear Editor in Chief Biodiversitas

Thanks very much for the information and we will revise according to reviewer comments
[Kutipan teks disembunyikan]
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Best Regards,

Dr. Ir. Erwan, M.Si.
Faculty of Animal Science, University of Mataram, Indonesia

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erwan apis <apiserwan@gmail.com>
Kepada: Smujo Editors <smujo.id@gmail.com>

2 November 2022 pukul 22.38

Dear Editor in Chief Biodiversitas

We have been revising our paper according to reviewer comments and the revision is made for red color (File is attached). In addition, we also have been submitted to the Biodiversitas System. Please find the attached file.

[Kutipan teks disembunyikan]

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Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

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Abstract. One of the big problems when keeping of honeybees is the limited of sustainable feed, especially in the rain season. The objectives of this study were to evaluate the honey quality from the bee *A. cerana* based on the chemical composition, honey potency produced by the coconut and sugar palm saps. This study using thirty colonies of the bee *A. cerana* were divided into six treatments consists of sugar palm sap without sugar palm pollen; coconut sap without sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% without sugar palm pollen; sugar palm sap was added by sugar palm pollen; coconut sap was added by sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen. The chemical composition of honey from the *A. cerana* were moisture (20.76 to 21.80%), reducing sugar (62.78 to 68.37%), sucrose (1.44 to 3.42%), diastase enzyme activity (5.17 to 9.04 DN), hydroxymethylfurfural (2.24 to 5.81 mg/kg), and acidity (26.00 to 36.35 ml NaOH/kg). Honey potency produced by the coconut and sugar palm saps in 100 hectares area produces honey was 1,542.857 tons/year and 1,150 tons/year, respectively. It can be concluded that the quality of *A. cerana* honey which are produced by the sugar palm and coconut saps are acceptable by the Indonesia national standard and international standard. The sugar palm and coconut saps have a big potential as the bee feed especially for the bee *A. cerana*.

Key words: *Arenga pinnata*, beekeeping, *Cocos nucifera* L., extrafloral nectar, multifloral nectar

Running title: Honey quality of *Apis cerana* produced by sugar palm and coconut saps

INTRODUCTION

Honeybee of *A. cerana* is one of the bees from the *Apis* genus which is include the local bee which is spread in some regions in Indonesia are Kalimantan, Sumatera, Java, Bali, Lombok, Sumbawa, Sulawesi, Papua, and Seram (Radloff et al. 2011; Hepburn and Radloff 2011). In Indonesia, beekeeping of the bee *A. cerana* has been practiced by the beekeepers using traditional hives (for example using a coconut log hive) and semi modern hive (box hive without nest frame) to produce honey. Furthermore, several regions have been practicing the beekeeping of the bee *A. cerana* has been reported by Schouten et al. (2019) are Riau, North Sumatera, Lampung, Banten, Java, Yogyakarta region, Bali, and Lombok. However, the beekeeping of *A. cerana* is mostly using traditional hives or use box hives, but is not completed by the honey frame like a beekeeping of *A. mellifera*. The bee *A. cerana* can produce honey, bee bread, royal jelly, and propolis, however their production is lower compared to the bee *A. mellifera*.

One of the problems faced by the beekeepers in Indonesia is the limited feed sustainability as the raw material to produce honey, bee bread, and royal jelly. The limitation feed is the very serious problem have been faced by the beekeepers because they have no area which is used to plant several plants which are used as the feed source to produce the honeybees products. Honeybees feeds is divided into two types namely nectar and pollen, where nectar is obtained by the foragers from the plant flowers (nectar floral) and nectar extrafloral which is obtained by the foragers from stalk and leaf of plants (Agussalim et al. 2018, 2017). Pollen is obtained by the foragers from plant flowers which is collected by using all body parts and then deposited in the corbicula (Agussalim et al. 2018, 2017; Erwan et al. 2021a). When collecting nectar and pollen from the plant flowers, the foragers role as the pollinator agent by transporting pollen from the anther to pistil so that the pollination process occurs. This process is continuously done by the foragers until their honey stomach is full of nectar and their corbicula has been deposited by the pollen. This pollination impacts on the increasing the plants productivity (Pohorecka et al., 2014; Supeno et al., 2021).

One of the strategies to produce the sustainability honey from the bee *A. cerana* by using a sap from the plants such as sugar palm and coconut. Several studies have been conducted by using a sugar palm and coconut saps as the *A. cerana* feed. Erwan et al. (2021b) reported that the feed combination of coconut sap and sugar palm pollen as the *A. cerana* feed can enhance the production of honey cells and bee bread cells. However, the use of sap from coconut and sugar palm can increasing the honey and bee bread cells compared to control group without sap as the feed (multifloral nectar). Furthermore, Erwan et al. (2022) was also reported that the use of sugar palm and coconut saps which are each added by sugar palm pollen can improving the bee *A. cerana* productivity such as increase the honey production, brood cells number, and colony weight. In addition, in other study showed that the use of extrafloral nectar namely sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera* L.) saps as the *A. mellifera* bee feed which is resulting the honey chemical composition (reducing sugar, sucrose, acidity, moisture, and diastase enzyme activity) which are acceptable by Indonesian national standard and international standard has been regulated by Codex Alimentarius (Erwan et al. 2020). However, the studies about the chemical composition of honey from the bee *A. cerana* which are produced from the sugar palm sap, coconut sap and their honey potency production from both sap sugar palm and coconut have not been studied. Therefore, the objectives of this study were to evaluate the honey quality based on the chemical composition from the bee *A. cerana*, honey potency produced by the coconut and sugar palm saps.

MATERIALS AND METHODS

Study area

This research has been conducted in the North Duman Village (8º32’10”S 116º09’32”E), Lingsar Sub-district, West Lombok (West Nusa Tenggara Province, Indonesia). In this research, we used thirty of *A. cerana* colonies were divided into six treatments and each five colonies per treatment as the replication. The saps were used in our study were obtained from the stalk of coconut (*Cocos nucifera* L.) and sugar palm (*Arenga pinnata*) and the pollen source from the sugar palm were shown in Figure 1. The stalks of coconut and sugar palm were cut and then put in the plastic bottle which was used to storage the sap which was secreted by their stalks. The treatments in our study were sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Figure 1. Coconut sap (left), sugar palm sap (center), and sugar palm pollen (right)

The technique was used to given sugar palm and coconut saps and sugar palm pollen (shown in Figure 2) was according to previously method has been reported by Erwan et al. (2022, 2021b) briefly as follows: fresh coconut and sugar palm saps were given to the bee *A. cerana* by using a plastic plate and split bamboo were completed by 4 to 5 twigs for foragers perch. The plastic plate and split bamboo were placed one meter of the box hives, while the sugar palm pollen was hung besides and above of the box hives. The distance of 600 meters to place colony to avoid the foragers to collect pollen and sap from the other treatments.

Figure 2. Technique to given the sugar palm and coconut saps (left) and sugar palm pollen (right) (Erwan et al. 2022, 2021b)

Procedures

Honey quality

Honey from the *A. cerana* (shown in Figure 2) was harvested after beekeeping for three months by using a coconut and sugar palm saps. Honey from the five hives in one treatment group was composited into one honey sample and then used to analysis of their chemical composition. Honey quality from the *A. cerana* were evaluated based on the chemical composition consists of moisture, reducing sugar, sucrose, diastase enzyme activity, hydroxymethylfurfural (HMF), and acidity. The moisture content was analyzed by using a proximate analysis based on the method from Association of Official Agricultural Chemists (AOAC) (AOAC 2005). Reducing sugar was analyzed by using a Layne-Enyon method and sucrose content was analyzed by a Luff Schoorl method were described by AOAC (2005). Diastase enzyme activity, hydroxymethylfurfural (HMF), and free acidity were analyzed based on the harmonised methods of the international honey commission (Machado et al. 2022).

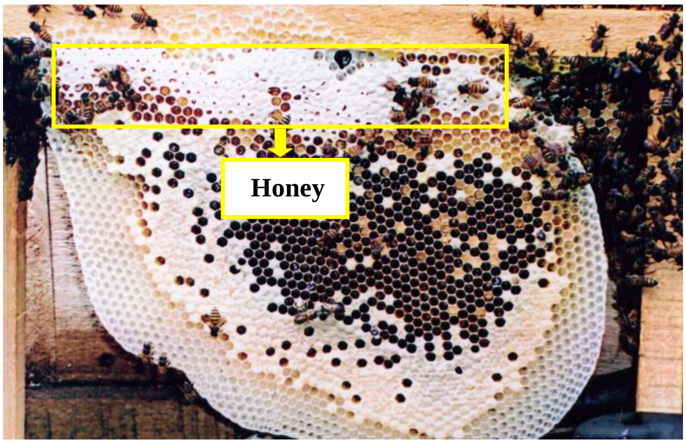

Figure 2. Honey from *A. cerana* was produced from the sugar palm and coconut saps

Honey production from sugar palm and coconut saps

Sugar palm and coconut saps each ten liters were used to measuring the honey production from the bee *A. cerana* for three months of beekeeping. The sugar palm and coconut saps were placed in the plastic plate in front of the box hives at the distance of one meter. In addition, the honey production without using of sugar palm and coconut saps were measured for one year of the beekeeping which is used to calculate the contribution of sugar palm and coconut saps in honey production. Honey from *A. cerana* was harvested with cut the honey cells (Figure 2) and squezed to separate wax and honey. Afterward, honey was measured their production by using a digital scale and stored in the regrigerator.

Production of saps from coconut and sugar palm

The production of sap from coconut was measured for a year, while the sugar palm sap based on the previously studied was used to calculate the production per hectare area and was also obtained from the deep interview with the farmers. The production of coconut and sugar palm saps per hectare which was calculated from the sap production per tree multiplied by the trees number in one hectare area. After three months of beekeeping, honey from both treatments sugar palm and coconut saps were harvested to measure the honey production from the use of ten litters sap and then honey production was measured by cylinder glass

Data analysis

The data of honey quality, production potency of honey from sugar palm and coconut saps, honey production, and production of saps were analyzed by using a descriptive analysis (Steel et al. 1997).

RESULTS AND DISCUSSION

Moisture content of honey

Honey is composed by water as the second largest of honey constituents and its ranging from 15 to 21 g/100 g, depending on the plant types as the nectar source which is affected by the botanical origin. Furthermore, honey moisture is also affected by honey maturity level, processing postharvest, and storage condition (Da Silva et al. 2016). The honey moisture is affecting the physical properties such as crystallization, viscosity, flavor, color, taste, solubility, specific gravity, and conservation (Da Silva et al. 2016; Escuredo et al. 2013). In addition, honey moisture is also affected by the temperature and humidity or depending on the season (rain and dry seasons) and honey moisture can increase during the postharvest processing such as storage condition because honey is hygroscopic that can absorbs the moisture in the air (Da Silva et al. 2016; Karabagias et al. 2014).

The recent study showed that the honey moisture from the bee *A. cerana* which was produced by sugar palm and coconut saps and their combination was ranging from 20.76 to 21.80% (Table 1). This honey moisture content is accepted by Indonesian national standard (SNI) where the moisture for beekeeping honey including the bee *A. cerana* and *A. mellifera* is not exceed 22% (National Standardization Agency of Indonesia 2018) and higher compared to international standard which is regulated by Codex Alimentarius is not exceed 20% (Thrasyvoulou et al. 2018). The variation of honey moisture of the bee *A. cerana* in our study may be caused by the different moisture content of both saps from sugar palm and coconut, however in our study has not been measured. The higher moisture content is requiring the long time to ripening of honey and process of decreasing honey moisture has been started by the bees when they are taking nectar from plant flowers or saps as the raw material to produce honey. Furthermore, a small portion of moisture content has been evaporated in the honey sack before transferred to the other bee which is working in the hive. This transfer is rapid depending on the temperature, colony strength, and nectar availability (Da Silva et al. 2016).

Table 1. The moisture, reducing sugar, and sucrose contents of honey from the bee *A. cerana*

Treatments	Moisture (%)	Reducing sugar (%)	Sucrose (%)
SP0	21.60	65.24	2.86
CP0	20.76	68.37	1.96
SCP0	21.40	64.55	2.51
SP1	21.80	62.78	3.42
CP1	21.58	65.37	1.72
SCP1	20.98	67.33	1.44

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Honey production process is started from the foragers collecting a nectar from the plant flowers or extrafloral nectar and then stored in the honey stomach. After that, the foragers will be transferring a nectar that has been collected to the other bees who are working to process a nectar into honey in their mouth, then put in honey stomach and then is transferred to other bees for several times until honey is ripening. A considerable amount of water will be evaporated in this process and this continues with the help of wing fans that can regulate the air humidity for about 15 to 20 minutes (Balasubramanyam 2021; Zhang et al. 2021). The honey moisture content in our study was differed to reported by Wang et al. (2021) that honey moisture from the bee *A. cerana* which is collected from 42 different honeycombs from China is ranging from 17.03 to 18.44%, 18.65% for *A. cerana cerana* from Hainan province, China (Wu et al. 2020), and 16.99% for *A. cerana* from Borneo (Malaysian honey) (Moniruzzaman et al. 2013). Furthermore, Erwan et al. (2020) was also reported that the honey moisture produced by the *A. mellifera* bee by using sugar palm and coconut saps is ranging from 19.34 to 20.94%. The different honey moisture content has been reported are affected by the different geographical origins which is impact on the different plant types can be growth each region, different environmental condition (temperature and humidity), and also different bee species which is impact on the different ability to evaporate water in the honey.

Reducing sugar and sucrose contents of honey

Sugars in honey are composed by monosaccharides for about 75%, disaccharides are 10 to 15%, and other sugars in small amounts. Honey sugars are responsible as the energy source, hygroscopic, viscosity, and granulation. Several sugars in honey have been reported such as glucose, fructose, sucrose, trehalose, rhamnose, isomaltose, nigerobiose, maltotriose, maltotetraose, melezitose, melibiose, maltulose, nigerose, raffinose, palatinose, erlose and others (Da Silva et al. 2016).

The recent study showed that the honey reducing sugar from the bee *A. cerana* were beekeeping by using a sugar palm and coconut saps and their combination as the nectar source to produce honey is ranging from 62.78 to 68.37 % (Table 1). This honey reducing sugar is acceptable by the SNI for treatments SP0, CP0, CP1, and SCP1, but not acceptable for treatments SCP0, SP1 (Table 1), where the minimum reducing sugar is 65% (National Standardization Agency of Indonesia 2018). This sugar is produced by the mechanism of invertase enzyme activity that change the sap sucrose into simple sugars. It is known that this enzyme is responsible for the conversion of sucrose into glucose and fructose. These sugars are included in reducing sugar group and as the main component present in honey. In honey maturity process, the sucrose is break down by the invertase enzyme into simple sugars simultaneously and water will be evaporated so that it will be increasing the reducing sugar content. In addition, enzymes secreted by the worker bees are also can break down the carbohydrate into simple sugars. Furthermore, other enzyme present in honey is diastase enzyme that role to break down starch into simple sugars (Da Silva et al. 2016). The honey reducing sugar in our study (Table 1) was differed to reported by Erwan et al. (2020) that honey reducing sugar from the bee *A. mellifera* which was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 60.15 to 73.69%. The different reducing sugar may be affected by the different bee species which is impact on the different their ability to evaporate water present in honey especially when they are convert the complex sugars into simple sugars and different season when done the study which are related to temperature and humidity environmental.

The honey sucrose content from the bee *A. cerana* in our study is ranging from 1.44 to 3.42% (Table 1) and acceptable by SNI is not exceed 5% for the beekeeping honey including *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also accepted by the International standard has been regulated by Codex Alimentarius is not exceed 5% for blossom and honeydew honeys (Thrasyvoulou et al. 2018). Naturally, sucrose present in honey in our study originated from sugar palm and coconut saps. The low honey sucrose content in our study is caused by the honey which is harvested in mature condition that is characterized by honey cells that have been covered by wax. Furthermore, the invertase enzyme which is produced by the worker bees actively break down sucrose from saps into simple sugars. There are two types of invertase enzymes which are produced by the worker bees, namely glucoinvertase which converts sucrose into glucose and fructoinvertase which converts sucrose into fructose. These enzymes are mostly derived from the bee's secretion and only a small portion from the nectar, while the honeydew from the insect's secretion mostly contains invertase enzymes (Da Silva et al. 2016). The honey sucrose content in our study (Table 1) was differed to reported by Erwan et al. (2020) that honey sucrose content from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 4.21 to 4.40%%.

The honey sucrose content is a very important parameter to evaluate the maturity of honey to identify manipulation, where the high levels may be indicate adulterations by adding the several sweeteners such cane sugar or refined beet sugar. In addition, also indicating the early of harvest, where sucrose is not completed transformed into fructose and glucose, the bees feeding artificial in prolonged time by using a sucrose syrup (Da Silva et al. 2016; Puscas et al. 2013; Escuredo et al. 2013; Tornuk et al. 2013). Honey is sugar solution that is supersaturated and unstable so it's easy to crystallize. The honey crystallization is affected by concentration of glucose, fructose, and water. Fructose is the dominant sugar present in honey from *A. mellifera* was produced by several plants as the nectar source which is used by workers to produce honey such as eucalyptus, acacia, bramble, lime, chestnut, sunflower, and from honeydew, except in rape honey was produced by *Brassica napus*. Rape honey is higher in glucose and lower in fructose which is impact on the rapidly crystallization (Escuredo et al. 2014). The sugars content present in honey is dependent on the geographical origins which is impact on the different plant types can growth in each region and impact on the different sugars content from the nectar which is produced by the nectary gland of plant flowers (Agus et al. 2021; Agussalim et al. 2019; Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013). Furthermore, sugars content in honey is influenced by climate (season, temperature, and humidity), processing (heating process), and storage time (Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013).

Diastase enzyme activity and hydroxymethylfurfural of honey

The recent study showed that the diastase enzyme activity from the bee *A. cerana* honey was produced by the sugar palm and coconut saps was ranging from 5.17 to 9.04 DN (Table 2). This enzyme activity is acceptable by SNI with the minimum of 3 DN for the beekeeping honey including the bee *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also acceptable by international standard has been regulated by Codex Alimentarius with the minimum 3 DN (Thrasyvoulou et al. 2018). One of the honey characteristics is contain enzymes which is originate from the bees, pollen, and nectar from plant flowers, but the mostly enzymes are added by the bees when they are convert nectar into honey (Da Silva et al. 2016; Thrasyvoulou et al. 2018). The honey diastase enzyme activity in our study (Table 2) was differed to reported by Erwan et al. (2020) that the diastase enzyme activity of honey from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 16.48 to 17.12 Schade unit.

Diastases are divided into α- and β-amylases which are the natural enzymes present in honey. The α-amylase separates the starch chain randomly in the central to produce dextrin, while the β-amylase separates the maltose in the end chain. Diastase enzyme content in honey is influenced by nectar source (floral and extrafloral nectars) to produce honey and honey geographical origins which are impact on the different chemical composition of the nectar can be produced by the plants which is impact on the honey chemical composition especially diastase enzyme activity. In addition, the bee species is also influencing the activity diastase because it's related to the distance and the flowers plant numbers can be visited by the foragers when they are collecting nectar and pollen were used to produce honey and bee bread (Da Silva et al. 2016).

Generally, diastase enzyme is role to break down complex sugars into simple sugars. This enzyme is role to digesting starch into maltose (disaccharide) and maltotriose (trisaccharide) which are sensitive to heat or thermolabile. Thus, this condition can be used to evaluate the overheating and preservation degree of honey (Da Silva et al. 2016). Furthermore, the diastase activity is also used to evaluate honey age which is related to storage time and the temperature because the diastase activity may be reducing when heating above 60ºC and longtime storage (Da Silva et al. 2016; Yücel and Sultanoğlu 2013). The honey diastase activity from the bee *A. cerana* in our study (Table 2) was differed to reported by Wu et al. (2020) for multifloral honey produced by the *A. cerana cerana* from Hainan province (China) was 6.70 Göthe. Furthermore, it was also differed to reported by Wang et al. (2021) that the diastase activity of *A. cerana* honey from Qinling Mountains (China) is ranging from 22.05 to 35.67 Göthe. The different diastase activity of honey from *A. cerana* were reported by previously researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Furthermore, the HMF of *A. cerana* honey was produced by the sugar palm and coconut saps in our study was ranging from 2.24 to 5.81 mg/kg (Table 2). This HMF indicate that honey from our study in fresh condition and acceptable by SNI for the beekeeping honey including from *A. cerana* and *A. mellifera* is not exceed 40 mg/kg (National Standardization Agency of Indonesia 2018) and also acceptable by the international standard has been regulated by Codex Alimentarius is not to exceed 40 mg/kg for blossom and honeydew honeys (Thrasyvoulou et al. 2018). The fresh honey after harvested is generally contains the low of HMF is ranging from 0 to 4.12 mg/kg honey. Hydroxymethylfurfural is the result of the degradation of honey monosaccharide, especially fructose and glucose, under acid conditions and accelerated by heating. This reaction is producing levulinic and formic acids (Da Silva et al. 2016).

Table 2. The diastase enzyme activity, hydroxymethylfurfural, and acidity of honey from the bee *A. cerana*

Treatments	Diastase enzyme activity (DN)	Hydroxymethylfurfural (mg/kg)	Acidity (ml NaOH/kg)
SP0	7.57	5.78	36.33
CP0	5.17	5.04	26.00
SCP0	9.04	4.75	28.60
SP1	6.86	4.77	29.68
CP1	8.51	5.81	28.26
SCP1	6.85	2.24	30.61

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Hydroxymethyfurfural is formed after honey removed from the comb or when the wax cover was opened and the advanced processing like heating process. The increasing of the HMF content occurs in honey with the high acidity and accelerated by the heating process. However, the HMF content is also influenced by several factors such as sugars content, organic acids presence, pH, moisture content, water activity, and the plant types as the nectar source (floral source). In addition, HMF can also be formed at low temperatures, acidic condition, and sugars dehydration reactions. Therefore, the higher of HMF content's impact on the honey color is darker (Da Silva et al. 2016; Tornuk et al. 2013). The HMF of honey from the *A. cerana* in our study (Table 2) was differed to previously reported by Wu et al. (2020) for multifloral honey of *A. cerana cerana* from China is 3.80 mg/kg and 1.69 mg/kg for *A. cerana* honey from Qinling Mountains, China is 1.69 mg/kg. The different HMF content of honey from *A. cerana* were reported by previously researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Acidity of honey

Free acidity is one of an important parameter to evaluate the honey deterioration which is characterized by the organic acids presence in equilibrium with internal esters, lactone and several inorganic ions such as sulfates, chlorides, and phosphates (Da Silva et al. 2016). The recent study showed that the honey acidity from *A. cerana* was produced by the sugar palm and coconut saps was ranging from 26.00 to 36.33 ml NaOH/kg (Table 2). The acidity of *A. cerana* honey in our study is acceptable by SNI is not to exceed 50 ml NaOH/kg for the beekeeping honey including *A. cerana* and *A. mellifera*. Furthermore, it is also acceptable by the international standard has been regulated by the Codex Alimentarius is not to exceed 50 meq/kg for blossom and honeydew honeys (Thrasyvoulou et al. 2018).

The sour taste of honey originated from the several organic and inorganic acids, where the dominant organic acid present in honey is gluconic acid. This organic acid is produced by the enzyme activity of glucose-oxidase which is added by the bees when they convert a nectar into honey, so it can protect a nectar until honey maturity. This protecting mechanism is caused by the inhibition of microorganisms activity in honey (Da Silva et al. 2016). This inhibit mechanism includes the combination several factors such as low moisture and presence hydrogen peroxide which is produced by the enzyme glucose-oxidase can inhibit the metabolism activity in the microbe cell through the destruction of cell wall resulting in change in cytoplasmic membrane permeability (Nainu et al. 2021; Pasias et al. 2018).

The acidity total content in honey is small quantity, but the present in honey is very important because can influencing the honey stability on the microorganisms, taste or flavor, and aroma of honey. The high acidity is indicating the fermentation process had been occurred when some reducing sugar is break down into acetic acid. Honey acidity content is related to the yeast number where them is break down some reducing sugar into ethanol and if it's reaction with the oxygen is formed the acetic acid which is increasing the honey acidity. The values higher of acidity may be indicating the fermentation process of sugars into organic acids. The honey acidity is affected by several factors such as different content of organic acids, different geographical origin and the seasonal when honey harvested (Da Silva et al. 2016; Tornuk et al. 2013). The honey acidity from the bee *A. cerana* in our study (Table 2) was differed to previously studied by Wu et al. (2020) for *A. cerana cerana* honey is 0.80 mol/kg and Guerzou et al. (2021) is ranging 11 to 47 meq/kg for Algerian honey. Furthermore, is differed to reported by Erwan et al. (2020) that honey acidity from the bee *A. mellifera* were produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 22.00 to 43.00 ml NaOH/kg. The different acidity has been reported previously with our studied is affected by the different plant types as the nectar source to produce honey, honey pH, geographical origin, and organic acids compound, however in our study has not measured the organic acid compound and honey pH.

Honey production potency from the sugar palm and coconut saps

Coconut and sugar palm plants have a good prospect to be developed because almost part of the plants can be utilized which can contribute to communities' income. Generally, the main production from the coconut (*Cocos nucifera* L.) was harvested as coconut fruit to advance the process into coconut oil and copra. These commodities have a high price, but producing coconut oil and copra are high risk for the farmers because they are just preparing raw material. Therefore, the utilizing of the sap can be produced by the coconut and sugar palm were also potency feed for the bees was used as the nectar source to produce honey. Sugar palm and coconut saps are the feed potential which is studied by Erwan et al. (2021b) that the coconut and sugar palm saps can increase the number of honey cell and bee bread cells of the bee *A. cerana*. Furthermore, it is also reported that sugar palm and coconut are improving the productivity of the bee *A. cerana* such as increasing the brood cells number, colony weight, and the honey production (Erwan et al. 2022). In addition, the saps from coconut and sugar palm are usually used by the farmers to produce sugar by using a traditional process.

The coconut plants can produce 12 stalks in a year and in one stalk can produce sap of 90 liters, thus, in one coconut plant can produce 1,080 liters of sap. Furthermore, if the farmers have one hectare of the land which are planted by 100 coconut plants (distance 10 m × 10 m), so can be produced for about 108,000 liters of coconut sap. To produce 1 kg of honey requires coconut sap for about 7 liters and in a year 84 liters is required to produce 12 kg of honey. Thus, honey potency in a year from 100 hectares of the land can be calculated as follows: 10,800,000 liters of sap divided by 84 liters of sap and multiplied by 12 kg of honey and obtained 1,542,857,14 kg/year (1,542.857 tons/year) or equivalent with 128.571 tons/month in 100 hectares of the land. Based on the sap production showing that the coconut plants have a big potency to produce honey. This potency was also supported by the harvest area of coconut in West Lombok (Nusa Tenggara Province, Indonesia) was 10,629.36 hectares (Department of Agricultural and Plantations 2021).

Sugar palm plants can be tapped to collect sap for about 5 to 6 months in one stalk, but generally can be tapped not to exceed 4 months. Wahyuni et al. (2021) reported that the production of sugar palm sap per plant is ranging from 8 to 22 liters/plant or 300 to 400 liters/season (3 to 4 months) or 800 to 1,500 liters/plant/year (average is 1,150 liters/plant/year). Furthermore, if in one hectare of plantation we have 100 sugar palm plants with the distance for planted is 10 m × 10 m, so can be obtained of sap for 115,000 liters.

The field investigation showed that to produce 1 kg of honey from the sugar palm sap is required for about 10 liters and in a year it is required for about 120 liters to produce 12 kg of honey. Thus, the honey potency from the sugar palm sap in a year from the 100 hectares of the sugar palm field is 11,500,000 liters which was divided by 120 liters and multiplied by 12 kg, so is obtained 1,150,000 kg of honey per year (1,150 tons of honey) or equivalent with 95.833 tons/month in 100 hectares area. This potency indicate that the sugar palm sap has a big potency to produce honey which is supported by the report data from the Department of Agricultural and Plantations (2021) that the sap production, sap productivity, and harvest area for sugar palm plants in West Lombok (West Nusa Tenggara Province, Indonesia) are 57.46 tones, 304.80 quintals/hectare, and 188.52, respectively, in the year of 2021. It can be concluded that honey is produced by the bee *A. cerana* from sugar palm and coconut saps as the feed have the quality which are acceptable by Indonesian national standard and international standard has been regulated by the Codex Alimentarius. Honey potency production from the coconut sap in 100 hectares area can produce honey of 1,542.857 tons/year or equivalent with 128.571 tons/month, while in sugar palm can produce honey of 1,150 tons/year or equivalent with 95.833 tons/month.

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Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

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Abstract. One of the big problems when keeping ~~of~~ honeybees is the limited of sustainable feed, especially in the rainy season. The objectives of this study were to evaluate the honey quality from the bee *A. cerana* based on the chemical composition~~,~~ and honey potency produced by the coconut and sugar palm saps. This study using thirty colonies of the bee *A. cerana* was~~ere~~ divided into six treatments consistings~~s~~ of sugar palm sap without sugar palm pollen; coconut sap without sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% without sugar palm pollen; sugar palm sap was added by sugar palm pollen; coconut sap was added by sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen. The chemical composition of honey from the *A. cerana* were moisture (20.76 to 21.80%), reducing sugar (62.78 to 68.37%), sucrose (1.44 to 3.42%), diastase enzyme activity (5.17 to 9.04 DN), hydroxymethylfurfural (2.24 to 5.81 mg/kg), and acidity (26.00 to 36.35 ml NaOH/kg). Honey potency produced by the coconut and sugar palm saps in 100 hectares area produces honey was 1,542.857 tons/year and 1,150 tons/year, respectively. It can be concluded that the quality of *A. cerana* honey, ~~which are~~ produced by the sugar palm and coconut saps, is~~are~~ acceptable by the Indonesian national ~~standard~~ and international standards. The sugar palm and coconut saps have ~~a~~ big potential as ~~the~~ bee feed, especially for the bee *A. cerana*.

Key words: *Arenga pinnata*, beekeeping, *Cocos nucifera* L., extrafloral nectar, multifloral nectar

Running title: Honey quality of *Apis cerana* produced by sugar palm and coconut saps

INTRODUCTION

The h~~H~~oneybee of *A. cerana* is one of the bees from the *Apis* genus, which ~~is~~ includes the local bee which is spread in some regions in Indonesia, including ~~are~~ Kalimantan, Sumatera, Java, Bali, Lombok, Sumbawa, Sulawesi, Papua, and Seram (Radloff et al. 2011; Hepburn and Radloff 2011). In Indonesia, beekeeping of the bee *A. cerana* has been practiced by ~~the~~ beekeepers using traditional hives (for example using a coconut log hive) and semi~~-~~modern hives (box hives without nest frames) to produce honey. Furthermore, several regions have been practicing the beekeeping of the bee *A. cerana* has been reported by Schouten et al. (2019) are Riau, North Sumatera, Lampung, Banten, Java, Yogyakarta region, Bali, and Lombok. However, the beekeeping of *A. cerana* is mostly using traditional hives or use box hives~~,~~ but is not completed by the honey frame like the~~a~~ beekeeping of *A. mellifera*. The bee *A. cerana* can produce honey, bee bread, royal jelly, and propolis. H~~, h~~owever their production is lower compared to the bee *A. mellifera*.

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One of the problems faced by the beekeepers in Indonesia is the limited of feed sustainability as the raw material to produce honey, bee bread, and royal jelly. The limitation feed is a~~the~~ very serious problem that has~~ve~~ been faced by ~~the~~ beekeepers because they have no area ~~which is~~ used to plant several plants which are used as the feed source to produce the honeybees' products. Honeybee~~s~~ feeds are~~is~~ divided into two types, namely nectar and pollen, where nectar is obtained by the foragers from the plant flowers (nectar floral) and nectar extrafloral, which is obtained by the foragers from stalk and leaf of plants (Agussalim et al. 2018, 2017). Pollen is obtained by the foragers from plant flowers which is collected by using all body parts and then deposited in the corbicula (Agussalim et al. 2018, 2017; Erwan et al. 2021a). When collecting nectar and pollen from the plant flowers, the foragers role as the pollinator agent by transporting pollen from the anther to pistil so that the pollination process occurs. This process is continuously done by the foragers until their honey stomach is full of nectar and their corbicula has been deposited by the pollen. This pollination impacts on the increasing the plants productivity (Pohorecka et al.~~,~~ 2014; Supeno et al.~~,~~ 2021).

One of the strategies to produce ~~the~~ sustainable~~ility~~ honey from the bee *A. cerana* is by using ~~a~~ sap from the plants such as sugar palm and coconut. Several studies have been conducted by using ~~a~~ sugar palm and coconut saps as the *A. cerana* feed. Erwan et al. (2021b) reported that the feed combination of coconut sap and sugar palm pollen as the *A. cerana* feed could~~an~~ enhance the production of honey cells and bee bread cells. However, the use of sap from coconut and sugar palm can increase~~ing~~ the honey and bee bread cells compared to the control group without sap as the feed (multi-floral nectar).

Furthermore, Erwan et al. (2022) ~~was~~ also reported ~~that the~~ usinge ~~of~~ sugar palm and coconut saps which are each added with~~by~~ sugar palm pollen can improv~~e~~eing the bee *A. cerana* productivity, such as increas~~inge~~ ~~the~~ honey production, brood cell~~s~~ number, and colony weight. In addition, ~~in~~ another study showed that the use of extrafloral nectar, namely sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera* L.) saps as the *A. mellifera* bee feed, which is resulting the honey chemical composition (reducing sugar, sucrose, acidity, moisture, and diastase enzyme activity) which are acceptable by Indonesian national standard and the international standard has been regulated by Codex Alimentarius (Erwan et al. 2020). However, ~~the~~ studies about the chemical composition of honey from the bee *A. cerana* ~~which are~~ produced from the sugar palm sap, coconut sap, and their honey potency production from both sap sugar palm and coconut have yet to be ~~not been~~ studied. Therefore, the objectives of this study were to evaluate the honey quality based on the chemical composition o~~from~~ the bee *A. cerana* and, the honey potency produced by the coconut and sugar palm saps.

MATERIALS AND METHODS

Study area

This research has been conducted in the North Duman Village (8°32'10"S; 116°09'32"E), Lingsar Sub-district, West Lombok (West Nusa Tenggara Province, Indonesia). In this research, we used thirty ~~of~~ *A. cerana* colonies ~~were~~ divided into six treatments and every~~ach~~ five colonies per treatment as the replication. The saps ~~were~~ used in our study were obtained from the stalk of coconut (*Cocos nucifera* L.) and sugar palm (*Arenga pinnata*) and the pollen source from the sugar palm ~~were shown in~~ (Fig.~~ure~~ 1). The stalks of coconut and sugar palm were cut and then put in a~~the~~ plastic bottle, which was used to stor~~ag~~e the sap ~~which was~~ secreted by their stalks. The treatments in our study were sugar palm sap without added ~~by~~ sugar palm pollen (SP0); coconut sap without added ~~by~~ sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added ~~by~~ sugar palm pollen (SP1); coconut sap was added ~~by~~ sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added ~~by~~ sugar palm pollen (SCP1).

Figure 1. Coconut sap (left), sugar palm sap (center), and sugar palm pollen (right)

The technique ~~was~~ used to give~~n~~ sugar palm and coconut saps and sugar palm pollen (~~shown in~~ Fig.~~ure~~ 2) was according to the previous~~ly~~ method has been reported by Erwan et al. (2022, 2021b) briefly as follows: fresh coconut and sugar palm saps were given to the bee *A. cerana* by using a plastic plate and split bamboo was~~ere~~ completed by 4 to 5 twigs for foragers perch. The plastic plate and split bamboo was~~ere~~ placed one meter from~~of~~ the box hives, while the sugar palm pollen was hung beside~~s~~ and above ~~of~~ the box hives. The distance of 600 meters to place the colony to avoid the foragers ~~to~~ collecting pollen and sap from the other treatments.

Figure 2. Technique to given the sugar palm and coconut saps (left) and sugar palm pollen (right) (Erwan et al. 2022, 2021b)

Procedures

Honey quality

Honey from the *A. cerana* (~~shown in~~ Fig.~~ure~~ 2) was harvested after beekeeping for three months ~~by~~ using ~~a~~ coconut and sugar palm saps. Honey from the five hives in one treatment group was composited into one honey sample and then used to analysis of their chemical composition. Honey quality from the *A. cerana* was~~ere~~ evaluated based on the chemical composition consisisting~~ts~~ of moisture, reducing sugar, sucrose, diastase enzyme activity, hydroxymethylfurfural (HMF), and acidity. The moisture content was analyzed by using a proximate analysis based on the method from the Association of Official Agricultural Chemists (AOAC) (AOAC 2005). Reducing sugar was analyzed ~~by~~ using a Layne-Enyon method, and sucrose content was analyzed by a Luff Schoorl method, ~~were~~ described by AOAC (2005). Diastase enzyme activity, hydroxymethylfurfural (HMF), and free acidity were analyzed based on the harmoniz~~s~~ed methods of the international honey commission (Machado et al. 2022).

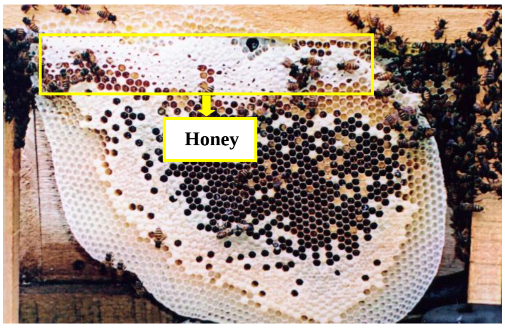

Figure 2. Honey from *A. cerana* was produced from the sugar palm and coconut saps

Honey production from sugar palm and coconut saps

Sugar palm and coconut saps every~~ach~~ ten liters were used to measure~~ing~~ the honey production from the bee *A. cerana* for three months of beekeeping. The sugar palm and coconut saps were placed o~~i~~n the plastic plate in front of the box hives at a~~the~~ distance of one meter. In addition, the honey production without using ~~of~~ sugar palm and coconut saps ~~were~~ was measured for one year of the beekeeping, which ~~is used to~~ calculates the contribution of sugar palm and coconut saps in honey production. Honey from *A. cerana* was harvested with cut the honey cells (Figure 2) and squeezed to separate wax and honey. Afterward, honey was measured ~~their~~ production by using a digital scale and stored in the ref~~g~~rigerator.

Production of saps from coconut and sugar palm

The production of sap from coconut was measured for a year, while the sugar palm sap based on the previously studied was used to calculate the production per hectare area and was also obtained from the deep interview with the farmers. The production of coconut and sugar palm saps per hectare ~~which~~ was calculated from the sap production per tree multiplied by the ~~trees~~ number of trees in a one hectare area. After three months of beekeeping, honey from both treatments, sugar palm and coconut saps were harvested to measure the honey production from the use of ten litters sap, and then honey production was measured by cylinder glass

Data analysis

The data on~~f~~ honey quality, production potency of honey from sugar palm and coconut saps, honey production, and production of saps were analyzed by using ~~a~~ descriptive analysis (Steel et al. 1997).

RESULTS AND DISCUSSION

Moisture content of honey

Honey is composed of~~by~~ water as the second largest of honey constituents, ~~and its~~ ranging from 15 to 21 g/100 g, depending on the plant species~~types~~ as the nectar source, which is affected by the botanical origin. Furthermore, honey moisture is also affected by honey maturity level, processing postharvest, and storage conditions (Da Silva et al. 2016).

The honey moisture is affectsing the physical properties such as crystallization, viscosity, flavor, color, taste, solubility, specific gravity, and conservation (Da Silva et al. 2016; Escuredo et al. 2013). In addition, honey moisture is also affected by the temperature and humidity or depending on the season (rainy and dry seasons)., and Hhoney moisture can increase during the postharvest processing, such as storage conditions, because honey is hygroscopic that can absorbs the moisture in the air (Da Silva et al. 2016; Karabagias et al. 2014).

A The recent study showed that the honey moisture from the bee *A. cerana*, which was produced by sugar palm and coconut saps, and their combination was ranging from 20.76 to 21.80% (Table 1). This honey moisture content is accepted by the Indonesian national standard (SNI), where the moisture for beekeeping honey, including the bee *A. cerana* and *A. mellifera*, does is not exceed 22% (National Standardization Agency of Indonesia 2018) and is higher compared to the international standard which is regulated by Codex Alimentarius regulated is not exceed 20% (Thrasyvoulou et al. 2018). The variation of honey moisture of the bee *A. cerana* in our study may be caused by the different moisture content of both saps from sugar palm and coconut, however in our study has not been measured. The higher moisture content is requiresing the a long time to for ripening of honey, and process of decreasing honey moisture has been started by the bees start the process of -decreasing honey moisture when they are takingtake nectar from plant flowers or saps as the raw material to produce honey. Furthermore, a small portion of moisture content has been evaporated in the honey sack before being transferred to the other bee, which is working in the hive. This transfer is rapid depending on the temperature, colony strength, and nectar availability (Da Silva et al. 2016).

Table 1. The moisture, reducing sugar, and sucrose contents of honey from the bee *A. cerana*

Treatments	Moisture (%)	Reducing sugar (%)	Sucrose (%)
SP0	21.60	65.24	2.86
CP0	20.76	68.37	1.96
SCP0	21.40	64.55	2.51
SP1	21.80	62.78	3.42
CP1	21.58	65.37	1.72
SCP1	20.98	67.33	1.44

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

The Hhoney production process is started withfrom the foragers collecting a nectar from the plant flowers or extrafloral nectar and then stored in the honey stomach. After that, the foragers will be transferring athe nectar that has been collected to the other bees who are working to process athe nectar into honey in their mouth, then put it in the honey stomach and then is transferred it to other bees for several times until honey is ripening. A considerable amount of water will be evaporated in this process, whichand this continues with the help of wing fans that can regulate the air humidity for about 15 to 20 minutes (Balasubramanyam 2021; Zhang et al. 2021). The honey moisture content in our study was differed fromto reported by Wang et al. (2021) that honey moisture from the bee *A. cerana*, which is collected from 42 different honeycombs from China rangesis ranging from 17.03 to 18.44%, 18.65% for *A. cerana cerana* from Hainan province, China (Wu et al. 2020), and 16.99% for *A. cerana* from Borneo (Malaysian honey) (Moniruzzaman et al. 2013). Furthermore, Erwan et al. (2020) was also reported that the honey moisture produced by the *A. mellifera* bee by using sugar palm and coconut saps is rangesing from 19.34 to 20.94%. The different honey moisture content has been reported to beare affected by the different geographical origins, which is impacts on the different plant types that can be grownth in each region, different environmental conditions (temperature and humidity), and also different bee species, which is impact on the different ability to evaporate water in the honey.

Reducing sugar and sucrose contents of honey

Sugars in honey are composed ofby monosaccharides for about 75%, disaccharides are 10 to 15%, and other sugars in small amounts. Honey sugars are responsible as the energy source, hygroscopic, viscosity, and granulation. Several sugars in honey have been reported such as glucose, fructose, sucrose, trehalose, rhamnose, isomaltose, nigerobiose, maltotriose, maltotetraose, melezitose, melibiose, maltulose, nigerose, raffinose, palatinose, erlose and others (Da Silva et al. 2016).

A The recent study showed that the honey- reducing sugar from the bee *A. cerana* wasere beekeeping by using a sugar palm and coconut saps, and their combination as the nectar source to produce honey is rangesing from 62.78 to 68.37 % (Table 1). This honey- reducing sugar is acceptable by the SNI for treatments SP0, CP0, CP1, and SCP1, but not acceptable for treatments SCP0, and SP1 (Table 1), where the minimum reducing sugar is 65% (National Standardization Agency of Indonesia 2018). This sugar is produced by the mechanism of invertase enzyme activity that changes the sap sucrose into simple sugars. It is known that this enzyme is responsible for the convertingsion of sucrose into glucose and fructose. These sugars are included in the reducing sugar group and as the main component present in honey. In the honey maturity process, the sucrose is break down by the invertase enzyme into simple sugars simultaneously, and water will be evaporated tso that it will be increaseing the reduceding sugar content. In addition, enzymes secreted by the worker bees are also can also break down the carbohydrate into simple sugars. Furthermore, another enzyme present in honey is the diastase enzyme that role to breaks down starch into simple sugars (Da Silva et al. 2016). The honey-reducing sugar in our study (Table 1) was differed from what wasto reported by Erwan et al. (2020), that honey reducing sugar from the bee *A. mellifera* which was produced by extrafloral nectar (sugar palm and coconut saps) is rangesing from 60.15 to 73.69%. The different reducing sugar may be affected by the different bee species, which is impacts on the different their ability to evaporate water present in honey, especially when they are convert the complex sugars into simple sugars and different seasons when done the study which areis related to temperature and humidity environmental.

The honey sucrose content from the bee *A. cerana* in our study is rangesing from 1.44 to 3.42% (Table 1) and acceptable by SNI is not exceed 5% for the beekeeping honey including *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also accepted by the International standard has been regulated by Codex Alimentarius is not exceed 5% for blossom and honeydew honeys (Thrasyvoulou et al. 2018). Naturally, sucrose present in honey in our study originated from sugar palm and coconut saps. The low honey sucrose content in our study is caused by the honey which is harvested in mature condition that is characterized by honey cells that have been covered by wax. Furthermore, the invertase enzyme which is produced by the worker bees actively breaks down sucrose from saps into simple sugars. There are two types of invertase enzymes thatwhich are produced by the worker bees, namely glucoinvertase, which converts sucrose into glucose and fructoinvertase, which converts sucrose into fructose. These enzymes are mostly derived from the bee's secretion and only a small portion from the nectar, while the honeydew from the insect's secretion mostly contains invertase enzymes (Da Silva et al. 2016). The honey sucrose content in our study (Table 1) was differed from to reported by Erwan et al. (2020), that honey sucrose content from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 4.21 to 4.40%%.

The honey sucrose content is a very important parameter to evaluate the maturity of honey to identify manipulation, where the high levels may be indicate adulterations by adding the several sweeteners such as cane sugar or refined beet sugar. In addition, also indicating the early of harvest, where sucrose is not completelyd transformed into fructose and glucose, the bees feeding artificially for ain prolonged time by using a sucrose syrup (Da Silva et al. 2016; Puscas et al. 2013; Escuredo et al. 2013; Tornuk et al. 2013). Honey is a sugar solution that is supersaturated and unstable, so it's easy to crystallize. The honey crystallization is affected by the concentration of glucose, fructose, and water. Fructose is the dominant sugar present in honey from *A. mellifera* was produced by several plants as the nectar source that workers usewhich is used by workers to produce honey such as eucalyptus, acacia, bramble, lime, chestnut, sunflower, and from honeydew, except in rape honey was produced by *Brassica napus*. Rape honey is higher in glucose and lowers in fructose which is impacts on theits rapidly crystallization (Escuredo et al. 2014). The sugars content present in honey is dependent on the geographical origins which is impacts on the different plant types that can growth in each region and impact on the different sugars content from the nectar, which is produced by the nectary gland of plant flowers (Agus et al. 2021; Agussalim et al. 2019; Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013). Furthermore, the sugars content in honey is influenced by climate (season, temperature, and humidity), processing (heating process), and storage time (Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013).

Diastase enzyme activity and hydroxymethylfurfural (HMF) of honey

TheA recent study showed that the diastase enzyme activity from the bee *A. cerana* honey was produced by the sugar palm and coconut saps was rangeding from 5.17 to 9.04 DN (Table 2). This enzyme activity is acceptable by SNI with the a minimum of 3 DN for the beekeeping honey, including the bee *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018), and also acceptable by the international standard has been regulated by Codex Alimentarius with the minimum 3 DN (Thrasyvoulou et al. 2018). One of the honey characteristics is that it contains enzymes which is originatinge from the bees, pollen, and nectar from plant flowers, but the mostly enzymes are added by the bees when they are convert nectar into honey (Da Silva et al. 2016; Thrasyvoulou et al. 2018). The honey diastase enzyme activity in our study (Table 2) was differed from what wasto reported by Erwan et al. (2020), that the diastase enzyme activity of honey from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 16.48 to 17.12 Schade unit.

Diastases are divided into α- and β-amylases, which are the natural enzymes present in honey. The α-amylase separates the starch chain randomly in the centerral to produce dextrin, while the β-amylase separates the maltose in the end chain. The nectar source Diastase enzyme content in honey is influenceds diatase enzyme content in honey by nectar source (floral and extrafloral nectars) to produce honey and honey geographical origins, which are impacts on the different chemical composition of the nectar can be produced by the plants which is impacts on the honey chemical composition, especially diastase enzyme activity. In addition, the bee species are is also influencing the activity diastase because it's related to the distance, and the flowers plant numbers that can be visited by the foragers when they are collecting nectar and pollen were used to produce honey and bee bread (Da Silva et al. 2016).

Generally, the diastase enzyme has theis role of to breaking down complex sugars into simple sugars. In addition, tThis enzyme is role to digesting starch into maltose (disaccharide) and maltotriose (trisaccharide), which are sensitive to heat or thermolabile. Thus, this condition can be used to evaluate the overheating and preservation degree of honey (Da Silva et al. 2016). Furthermore, the diastase activity is also used to evaluate honey age, which is related to storage time and the temperature because the diastase activity may be reducing when heating above 60°C and longtime storage (Da Silva et al. 2016; Yücel and Sultanoğlu 2013). The honey diastase activity from the bee *A. cerana* in our study (Table 2) was differed to reported byfrom Wu et al. (2020) for multifloral honey produced by the *A. cerana cerana* from the Hainan province

(China) was 6.70 Göthe. Furthermore, it ~~was~~ also differed from ~~to reported by~~ Wang et al. (2021) that the diastase activity of *A. cerana* honey from Qinling Mountains (China) is ranging from 22.05 to 35.67 Göthe. The different diastase activities~~y~~ of honey from *A. cerana* were reported by previous~~ly~~ researchers are influenced by the different plant types as the nectar source to produce honey, different sugar~~s~~ content, and different geographical origin.

Furthermore, the HMF of *A. cerana* honey ~~was~~ produced by the sugar palm and coconut saps in our study ~~was~~ ranged~~ing~~ from 2.24 to 5.81 mg/kg (Table 2). This HMF indicates that honey from our study in fresh condition and acceptable by SNI for ~~the~~ beekeeping honey, including from *A. cerana* and *A. mellifera*, ~~is~~ not exceed 40 mg/kg (National Standardization Agency of Indonesia 2018) and also acceptable by the international standard ~~has been~~ regulated by Codex Alimentarius is not to exceed 40 mg/kg for blossom and honeydew honey~~s~~ (Thrasyvoulou et al. 2018). After harvesting, ~~The~~ fresh honey ~~after harvested is~~ generally contains a~~the~~ low ~~of~~ HMF is ranging from 0 to 4.12 mg/kg honey. Hydroxymethylfurfural is the result of the degradation of honey monosaccharides, especially fructose and glucose, under acid conditions and accelerated by heating. This reaction ~~is~~ produces~~ing~~ levulinic and formic acids (Da Silva et al. 2016).

Table 2. The diastase enzyme activity, hydroxymethylfurfural, and acidity of honey from the bee *A. cerana*

Treatments	Diastase enzyme activity (DN)	Hydroxymethylfurfural (mg/kg)	Acidity (ml NaOH/kg)
SP0	7.57	5.78	36.33
CP0	5.17	5.04	26.00
SCP0	9.04	4.75	28.60
SP1	6.86	4.77	29.68
CP1	8.51	5.81	28.26
SCP1	6.85	2.24	30.61
SNI	>3	<40	<50
Codex Alimentarus	>3	<40	<50

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Hydroxymethylfurfural is formed after the honey is removed from the comb or when the wax cover i~~wa~~s opened and the advanced processing like heating process. The increase~~ing~~ of the HMF content occurs in honey with the ~~high~~ acidity and is accelerated by the heating process. However, the HMF content is also influenced by ~~several factors such as~~ sugar~~s~~ content, organic acids presence, pH, moisture content, water activity, and the plant types as the nectar source (floral source). In addition, HMF can also be formed at low temperatures, acidic conditions, and sugar~~s~~ dehydration reactions. Therefore, the higher ~~of~~ HMF content's impact on the honey color is darker (Da Silva et al. 2016; Tornuk et al. 2013). The HMF of honey from the *A. cerana* in our study (Table 2) was differed to previously reported by Wu et al. (2020) for multifloral honey of *A. cerana cerana* from China is 3.80 mg/kg and 1.69 mg/kg for *A. cerana* honey from Qinling Mountains, China is 1.69 mg/kg. The different HMF content of honey from *A. cerana* ~~were~~ reported by previous~~ly~~ researchers are influenced by the different plant types as the nectar source to produce honey, different sugar~~s~~ content, and different geographical origin.

Acidity of honey

Free acidity is one of the ~~an~~ important parameters to evaluate ~~the~~ honey deterioration which is characterized by the presence of the organic acids presence in equilibrium with internal esters, lactone, and several inorganic ions such as sulfates, chlorides, and phosphates (Da Silva et al. 2016). This~~The recent~~ study showed that the honey acidity from *A. cerana* ~~was~~ produced by the sugar palm and coconut saps ~~was~~ ranged~~ing~~ from 26.00 to 36.33 ml NaOH/kg (Table 2). The acidity of *A. cerana* honey in our study is acceptable by SNI ~~is~~ not to exceed 50 ml NaOH/kg for the beekeeping honey, including *A. cerana* and *A. mellifera*. Furthermore, it is also acceptable by the international standard has been regulated by the Codex Alimentarius is not to exceed 50 meq/kg for blossom and honeydew honey~~s~~ (Thrasyvoulou et al. 2018).

The sour taste of honey originated from ~~the~~ several organic and inorganic acids, where the dominant organic acid present in honey is gluconic acid. This organic acid is produced by the enzyme activity of glucose-oxidase, which is added by the bees when they convert ~~a~~ nectar into honey, so that it can protect the~~a~~ nectar until honey maturity. This protection~~ing~~ mechanism is caused by ~~the~~ inhibiti~~o~~ng of microorganisms' activity in honey (Da Silva et al. 2016). This inhibit mechanism includes the combination of several factors, such as low moisture and the presence of hydrogen peroxide, which is produced by the enzyme glucose-oxidase can inhibit the metabolism activity in the microbe cell through the destruction of the cell wall resulting in a change in cytoplasmic membrane permeability (Nainu et al. 2021; Pasias et al. 2018).

The total acidity ~~total~~ content in honey is a small quantity. Still, ~~, but~~ the presence~~t~~ in honey is very important because it can influence~~ing~~ the honey stability on the microorganisms, taste or flavor, and aroma of honey. The high acidity ~~is~~ indicates~~ing~~ the fermentation process ~~had been~~ occurs~~ed~~ when some reducing sugar is broken~~eak~~ down into acetic acid. Honey acidity content is related to the yeast number where they~~m~~ ~~is~~ break down some reducing sugar into ethanol, and if the~~it's~~ reaction with the oxygen is formed, the acetic acid which is increasing the honey acidity. Therefore, the higher

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acidity values ~~higher of acidity~~ may ~~be~~ indicate~~ing~~ the sugars fermentation process ~~of sugars~~ into organic acids. ~~The~~ ~~h~~Honey acidity is affected by several factors, such as different content of organic acids, different geographical origins, and the season~~al~~ when honey is harvested (Da Silva et al. 2016; Tornuk et al. 2013). The honey acidity from the bee *A. cerana* in our study (Table 2) ~~was~~ differed ~~to~~ from previously studied by Wu et al. (2020) for *A. cerana cerana* honey is 0.80 mol/kg, and Guerzou et al. (2021) ~~is~~ ranging from 11 to 47 meq/kg for Algerian honey. Furthermore, it is differed from ~~to reported by~~ Erwan et al. (2020) that honey acidity from the bee *A. mellifera* was~~ere~~ produced by extrafloral nectar (sugar palm and coconut saps) ~~is~~ ranging from 22.00 to 43.00 ml NaOH/kg. The different acidity ~~has been~~ reported previously with our study~~ied~~ is affected by the different plant types as the nectar source to produce honey, honey pH, geographical origin, and organic acids compound;~~,~~ however ~~in~~ our study has not measured the organic acid compound and honey pH.

Honey production potency from the sugar palm and coconut saps

Coconut and sugar palm plants have a good prospect to be developed because almost part of the plants can be utilized ~~which can~~ contributing~~e~~ to communities' income. Generally, the main product~~ion~~ from the coconut (*Cocos nucifera* L.) was harvested as coconut fruit to advance the process into coconut oil and copra. These commodities have a high price, but producing coconut oil and copra are high risk for the farmers because they are just preparing raw materials. Therefore, the utilizing of the sap can be produced by the coconut and sugar palm were also potency feed for the bees was used as the nectar source to produce honey. Sugar palm and coconut saps are the feed potential ~~which is~~ studied by Erwan et al. (2021b) that the coconut and sugar palm saps can increase the number of honey cells and bee bread cells of the bee *A. cerana*. Furthermore, it is also reported that sugar palm and coconut are improving the productivity of the bee *A. cerana*, such as increasing the brood cells number, colony weight, and ~~the~~ honey production (Erwan et al. 2022). In addition, the saps from coconut and sugar palms are usually used by ~~the~~ farmers to produce sugar ~~by~~ using a traditional process.

The coconut plants can produce 12 stalks in a year, and ~~in~~ one stalk can produce sap of 90 liters.~~,~~ T~~t~~hus, ~~in~~ one coconut plant can produce 1,080 liters of sap. Furthermore, if the farmers have one hectare of ~~the~~ land ~~which are~~ planted by 100 coconut plants (distance 10 m × 10 m), so they can ~~be~~ produce~~d~~ ~~for~~ about 108,000 liters of coconut sap. To produce 1 kg of honey requires coconut sap for about 7 liters, and in a year 84 liters are~~is~~ required to produce 12 kg of honey. Thus, honey potency in a year from 100 hectares of ~~the~~ land can be calculated as follows: 10,800,000 liters of sap divided by 84 liters of sap and multiplied by 12 kg of honey and obtained 1,542,857,14 kg/year (1,542.857 tons/year) or equivalent with 128.571 tons/month in 100 hectares of the land. Based on the sap production showing that the coconut plants have a big potency to produce honey. This potency was also supported by the harvest area of coconut in West Lombok (Nusa Tenggara Province, Indonesia) was 10,629.36 hectares (Department of Agricultural and Plantations 2021).

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Sugar palm plants can be tapped to collect sap for about 5 to 6 months in one stalk, but generally can be tapped not to exceed 4 months. Wahyuni et al. (2021) reported that the production of sugar palm sap per plant ~~is~~ ranges~~ing~~ from 8 to 22 liters/plant or 300 to 400 liters/season (3 to 4 months) or 800 to 1,500 liters/plant/year (average is 1,150 liters/plant/year). Furthermore, if in one hectare of the plantation, we have 100 sugar palm plants, ~~with~~ the distance for planting~~ed~~ is 10 m × 10 m, so can be obtained of sap for 115,000 liters.

The field investigation showed that ~~to~~ producing~~e~~ 1 kg of honey from the sugar palm sap ~~is~~ required ~~for~~ about 10 liters, and in a year, it is required ~~for~~ about 120 liters to produce 12 kg of honey. Thus, the honey potency from the sugar palm sap in a year from the 100 hectares of the sugar palm field is 11,500,000 liters which was divided by 120 liters and multiplied by 12 kg, so is obtained 1,150,000 kg of honey per year (1,150 tons of honey) or equivalent with 95.833 tons/month in 100 hectares area. This potency indicates that the sugar palm sap has a big potency to produce honey which is supported by the report data from the Department of Agricultural and Plantations (2021) that the sap production, sap productivity, and harvest area for sugar palm plants in West Lombok (West Nusa Tenggara Province, Indonesia) are 57.46 tones, 304.80 quintals/hectare, and 188.52, respectively, in the year of 2021. Therefore, ~~I~~it can be concluded that honey is produced by the bee *A. cerana* from sugar palm and coconut saps as the feed have a~~the~~ quality ~~which~~ that is~~are~~ acceptable by Indonesian national standard, and the international standard has been regulated by the Codex Alimentarius. Honey potency production from the coconut sap in 100 hectares area can produce honey of 1,542.857 tons/year or equivalent with 128.571 tons/month, while ~~in~~ sugar palm can produce honey of 1,150 tons/year or equivalent with 95.833 tons/month.

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Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

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Abstract. One of the big problems when keeping honeybees is the limited of sustainable feed, especially in the rainy season. The objectives of this study were to evaluate the honey quality from the bee *A. cerana* based on the chemical composition, and honey potency produced by the coconut and sugar palm saps. This study using thirty colonies of the bee *A. cerana* was divided into six treatments consistings of sugar palm sap without sugar palm pollen; coconut sap without sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% without sugar palm pollen; sugar palm sap was added by sugar palm pollen; coconut sap was added by sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen. The chemical composition of honey from the *A. cerana* were moisture (20.76 to 21.80%), reducing sugar (62.78 to 68.37%), sucrose (1.44 to 3.42%), diastase enzyme activity (5.17 to 9.04 DN), hydroxymethylfurfural (2.24 to 5.81 mg/kg), and acidity (26.00 to 36.35 ml NaOH/kg). Honey potency produced by the coconut and sugar palm saps in 100 hectares area produces honey was 1,542.857 tons/year and 1,150 tons/year, respectively. It can be concluded that the quality of *A. cerana* honey, produced by the sugar palm and coconut saps, is acceptable by the Indonesian national and international standards. The sugar palm and coconut saps have a big potential as the bee feed especially for the bee *A. cerana*.

Key words: *Arenga pinnata*, beekeeping, *Cocos nucifera* L., extrafloral nectar, multifloral nectar

Running title: Honey quality of *Apis cerana* produced by sugar palm and coconut saps

INTRODUCTION

The honeybee of *A. cerana* is one of the bees from the *Apis* genus which includes the local bee which is spread in some regions in Indonesia, including Kalimantan, Sumatera, Java, Bali, Lombok, Sumbawa, Sulawesi, Papua, and Seram (Radloff et al. 2011; Hepburn and Radloff 2011). In Indonesia, beekeeping of the bee *A. cerana* has been practiced by beekeepers using traditional hives (for example using a coconut log hive) and semi-modern hives (box hives without nest frames) to produce honey. Furthermore, several regions have been practicing the beekeeping of the bee *A. cerana* has been reported by Schouten et al. (2019) are Riau, North Sumatera, Lampung, Banten, Java, Yogyakarta region, Bali, and Lombok. However, the beekeeping of *A. cerana* is mostly using traditional hives or use box hives but is not completed by the honey frame like the beekeeping of *A. mellifera*. The bee *A. cerana* can produce honey, bee bread, royal jelly, and propolis. However their production is lower compared to the bee *A. mellifera* (Agussalim and Agus 2022).

One of the problems faced by the beekeepers in Indonesia is the limited of feed sustainability as the raw material to produce honey, bee bread, and royal jelly. The limitation feed is a very serious problem that has been faced by beekeepers because they have no area used to plant several plants which are used as the feed source to produce the honeybees' products. Honeybee feeds are divided into two types, namely nectar and pollen, where nectar is obtained by the foragers from the plant flowers (nectar floral) and nectar extrafloral, which is obtained by the foragers from stalk and leaf of plants (Agussalim et al. 2018, 2017). Pollen is obtained by the foragers from plant flowers which is collected by using all body parts and then deposited in the corbicula (Agussalim et al. 2018, 2017; Erwan et al. 2021a). When collecting nectar and pollen from the plant flowers, the foragers role as the pollinator agent by transporting pollen from the anther to pistil so that the pollination process occurs. This process is continuously done by the foragers until their honey stomach is full of nectar and their corbicula has been deposited by the pollen. This pollination impacts on the increasing the plants productivity (Pohorecka et al. 2014; Supeno et al. 2021).

One of the strategies to produce sustainable honey from the bee *A. cerana* is by using sap from the plants such as sugar palm and coconut. Several studies have been conducted by using sugar palm and coconut saps as the *A. cerana* feed. Erwan et al. (2021b) reported that the feed combination of coconut sap and sugar palm pollen as the *A. cerana* feed could enhance the production of honey cells and bee bread cells. However, the use of sap from coconut and sugar palm can increase the honey and bee bread cells compared to the control group without sap as the feed (mult-ifloral nectar). Furthermore, Erwan et al. (2022) also reported using sugar palm and coconut saps which are each added with sugar palm pollen can improve the bee *A. cerana* productivity, such as increasing honey production, brood cell number, and colony weight. In addition, another study showed that the use of extrafloral nectar namely sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera* L.) saps as the *A. mellifera* bee feed which is resulting the honey chemical composition (reducing sugar, sucrose, acidity, moisture, and diastase enzyme activity) which are acceptable by Indonesian national standard and the international standard has been regulated by Codex Alimentarius (Erwan et al. 2020). However, studies about the chemical composition of honey from the bee *A. cerana* produced from the sugar palm sap, coconut sap, and their honey potency production from both sap sugar palm and coconut have yet to be studied. Therefore, the objectives of this study were to evaluate the honey quality based on the chemical composition of the bee *A. cerana*, honey potency produced by the coconut and sugar palm saps.

MATERIALS AND METHODS

Study area

This research has been conducted in the North Duman Village (8º32'10"S 116º09'32"E), Lingsar Sub-district, West Lombok (West Nusa Tenggara Province, Indonesia). In this research, we used thirty *A. cerana* colonies were divided into six treatments and every five colonies per treatment as the replication. The saps used in our study were obtained from the stalk of coconut (*Cocos nucifera* L.) and sugar palm (*Arenga pinnata*) and the pollen source from the sugar palm (Figure 1). The stalks of coconut and sugar palm were cut and then put in a plastic bottle which was used to store the sap secreted by their stalks. The treatments in our study were sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added sugar palm pollen (SCP1).

Figure 1. Coconut sap (left), sugar palm sap (center), and sugar palm pollen (right)

The technique was used to give sugar palm and coconut saps and sugar palm pollen (Figure 2) was according to the previous method has been reported by Erwan et al. (2022, 2021b) briefly as follows: fresh coconut and sugar palm saps were given to the bee *A. cerana* by ussing a plastic plate and split bamboo was completed by 4 to 5 twigs for foragers perch. The plastic plate and split bamboo was placed one meter from the box hives, while the sugar palm pollen was hung besides and above of the box hives. The distance of 600 meters to place the colony to avoid the foragers collecting pollen and sap from the other treatments.

Figure 2. Technique to given the sugar palm and coconut saps (left) and sugar palm pollen (right) (Erwan et al. 2022, 2021b)

Procedures

Honey quality

Honey from the *A. cerana* (Figure 3) was harvested after beekeeping for three months using coconut and sugar palm saps. Honey from the five hives in one treatment group was composited into one honey sample and then used to analysis of their chemical composition. Honey quality from the *A. cerana* was evaluated based on the chemical composition consisting of moisture, reducing sugar, sucrose, diastase enzyme activity, hydroxymethylfurfural (HMF), and acidity. The moisture content was analyzed by using a proximate analysis based on the method from the Association of Official Agricultural Chemists (AOAC) (AOAC 2005). Reducing sugar was analyzed using a Layne-Enyon method and sucrose content was analyzed by a Luff Schoorl method, described by AOAC (2005). Diastase enzyme activity, hydroxymethylfurfural (HMF), and free acidity were analyzed based on the harmonized methods of the international honey commission (Machado et al. 2022).

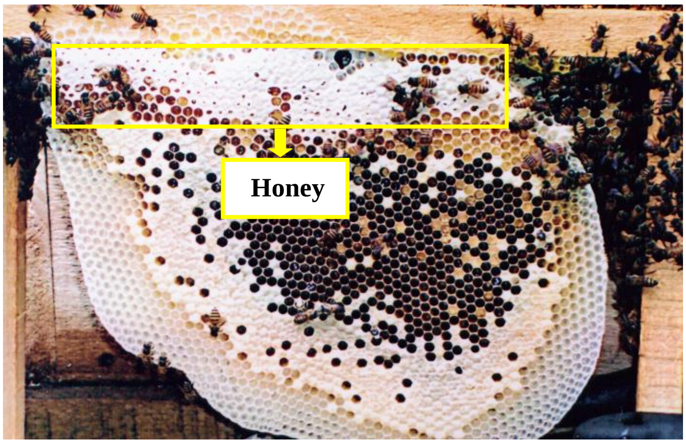

Figure 3. Honey from *A. cerana* was produced from the sugar palm and coconut saps

Honey production from sugar palm and coconut saps

Sugar palm and coconut saps every ten liters were used to measure the honey production from the bee *A. cerana* for three months of beekeeping. The sugar palm and coconut saps were placed on the plastic plate in front of the box hives at a distance of one meter. In addition, the honey production without using sugar palm and coconut saps was measured for one year of the beekeeping, which calculates the contribution of sugar palm and coconut saps in honey production. Honey from *A. cerana* was harvested with cut the honey cells (Figure 3) and squeezed to separate wax and honey. Afterward, honey was measured production by using a digital scale and stored in the refrigerator.

Production of saps from coconut and sugar palm

The production of sap from coconut was measured for a year and also based on dept interview with farmers, while the sugar palm sap based on the previously studied was used to calculate the production per hectare area and was also obtained from the deep interview with the farmers. The production of coconut and sugar palm saps per hectare was calculated from the sap production per tree multiplied by the number of trees in a one hectare area. After three months of beekeeping, honey from both treatments sugar palm and coconut saps were harvested to measure the honey production from the use of ten litters sap, and then honey production was measured by cylinder glass

Data analysis

The data on honey quality, production potency of honey from sugar palm and coconut saps, honey production, and production of saps were analyzed by using descriptive analysis (Steel et al. 1997).

RESULTS AND DISCUSSION

Moisture content of honey

Honey is composed of water as the second largest of honey constituents, ranging from 15 to 21 g/100 g, depending on the plant species as the nectar source which is affected by the botanical origin. Furthermore, honey moisture is also affected by honey maturity level, processing postharvest, and storage conditions (Da Silva et al. 2016). The honey moisture affects the physical properties such as crystallization, viscosity, flavor, color, taste, solubility, specific gravity, and conservation (Da Silva et al. 2016; Escuredo et al. 2013). In addition, honey moisture is also affected by the temperature and humidity depending on the season (rainy and dry seasons). Honey moisture can increase during postharvest processing such as storage conditions, because honey is hygroscopic that can absorb the moisture in the air (Da Silva et al. 2016; Karabagias et al. 2014).

A recent study showed that the honey moisture from the bee *A. cerana*, produced by sugar palm and coconut saps and their combination was ranging from 20.76 to 21.80% (Table 1). This honey moisture content is accepted by the Indonesian national standard (SNI), where the moisture for beekeeping honey, including the bee *A. cerana* and *A. mellifera*, does not exceed 22% (National Standardization Agency of Indonesia 2018) and is higher compared to the international standard which Codex Alimentarius regulated is not exceed 20% (Thrasyvoulou et al. 2018). The variation of honey moisture of the bee *A. cerana* in our study may be caused by the different moisture content of both saps from sugar palm and coconut, however our study has not been measured. The higher moisture content requires a long time for ripening of honey, and the bees start the process of decreasing honey moisture when they take nectar from plant flowers or saps as the raw material to produce honey. Furthermore, a small portion of moisture content has been evaporated in the honey sack before being transferred to the other bee which is working in the hive. This transfer is rapid depending on the temperature, colony strength, and nectar availability (Da Silva et al. 2016).

Table 1. The moisture, reducing sugar, and sucrose contents of honey from the bee *A. cerana*

Treatments	Moisture (%)	Reducing sugar (%)	Sucrose (%)
SP0	21.60	65.24	2.86
CP0	20.76	68.37	1.96
SCP0	21.40	64.55	2.51
SP1	21.80	62.78	3.42
CP1	21.58	65.37	1.72
SCP1	20.98	67.33	1.44

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

The honey production process is started with the foragers collecting nectar from the plant flowers or extrafloral nectar and then stored in the honey stomach. After that, the foragers will transfer the nectar that has been collected to the other bees who are working to process the nectar into honey in their mouth, then put it in the honey stomach and then transfer it to other bees several times until honey is ripening. A considerable amount of water will be evaporated in this process, which continues with the help of wing fans that can regulate the air humidity for about 15 to 20 minutes (Balasubramanyam 2021; Zhang et al. 2021). The honey moisture content in our study differed from Wang et al. (2021) that honey moisture from the bee *A. cerana* which is collected from 42 different honeycombs from China ranges from 17.03 to 18.44%, 18.65% for *A. cerana cerana* from Hainan province, China (Wu et al. 2020), and 16.99% for *A. cerana* from Borneo (Malaysian honey) (Moniruzzaman et al. 2013). Furthermore, Erwan et al. (2020) also reported that the honey moisture produced by the *A. mellifera* bee by using sugar palm and coconut saps ranges from 19.34 to 20.94%. The different honey moisture content has been reported to be affected by the different geographical origins, impacts the different plant types that can be grown in each region, different environmental conditions (temperature and humidity), and also different bee species, which impact the different ability to evaporate water in the honey.

Reducing sugar and sucrose contents of honey

Sugars in honey are composed of monosaccharides for about 75%, disaccharides are 10 to 15%, and other sugars in small amounts. Honey sugars are responsible as the energy source, hygroscopic, viscosity, and granulation. Several sugars in honey have been reported such as glucose, fructose, sucrose, trehalose, rhamnose, isomaltose, nigerobiose, maltotriose, maltotetraose, melezitose, melibiose, maltulose, nigerose, raffinose, palatinose, erlose and others (Da Silva et al. 2016).

A recent study showed that the honey reducing sugar from the bee *A. cerana* was beekeeping by using sugar palm and coconut saps, and their combination as the nectar source to produce honey ranges from 62.78 to 68.37 % (Table 1). This honey reducing sugar is acceptable by the SNI for treatments SP0, CP0, CP1, and SCP1 but not acceptable for treatments SCP0, and SP1 (Table 1), where the minimum reducing sugar is 65% (National Standardization Agency of Indonesia 2018). This sugar is produced by the mechanism of invertase enzyme activity that change the sap sucrose into simple sugars. It is known that this enzyme is responsible for converting of sucrose into glucose and fructose. These sugars are included in the reducing sugar group and the main component in honey. In the honey maturity process, the sucrose is break down by the invertase enzyme into simple sugars simultaneously, and water will be evaporated to increase the reduced sugar content. In addition, enzymes secreted by the worker bees can also break down the carbohydrate into simple sugars. Furthermore, another enzyme in honey is the diastase enzyme that breaks down starch into simple sugars (Da Silva et al. 2016). The honey reducing sugar in our study (Table 1) differed from what was reported by Erwan et al. (2020), that honey reducing sugar from the bee *A. mellifera* which was produced by extrafloral nectar (sugar palm and coconut saps) ranges from 60.15 to 73.69%. The different reducing sugar may be affected by the different bee species, which impacts their ability to evaporate water in honey, especially when they convert the complex sugars into simple sugars and different seasons when the study is related to temperature and humidity environmental.

The honey sucrose content from the bee *A. cerana* in our study ranges from 1.44 to 3.42% (Table 1) and acceptable by SNI is not exceed 5% for the beekeeping honey including *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also accepted by the International standard has been regulated by Codex Alimentarius is not exceed 5% for blossom and honeydew honey (Thrasyvoulou et al. 2018). Naturally, sucrose present in honey in our study originated from sugar palm and coconut saps. The low honey sucrose content in our study is caused by the honey harvested in mature condition characterized by honey cells that have been covered by wax. Furthermore, the invertase enzyme which is produced by the worker bees actively breaks down sucrose from saps into simple sugars. There are two types of invertase enzymes that are produced by the worker bees, namely glucoinvertase which converts sucrose into glucose and fructoinvertase, which converts sucrose into fructose. These enzymes are mostly derived from the bee's secretion and only a small portion from the nectar, while the honeydew from the insect's secretion mostly contains invertase enzymes (Da Silva et al. 2016). The honey sucrose content in our study (Table 1) differed from Erwan et al. (2020), that honey sucrose content from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 4.21 to 4.40%%.

The honey sucrose content is a very important parameter to evaluate the maturity of honey to identify manipulation, where the high levels may indicate adulterations by adding several sweeteners such as cane sugar or refined beet sugar. In addition, indicating the early harvest, where sucrose is not completely transformed into fructose and glucose, the bees feed artificially for a prolonged time using a sucrose syrup (Da Silva et al. 2016; Puscas et al. 2013; Escuredo et al. 2013; Tornuk et al. 2013). Honey is a sugar solution that is supersaturated and unstable so it's easy to crystallize. The honey crystallization is affected by the concentration of glucose, fructose, and water. Fructose is the dominant sugar present in honey from *A. mellifera* was produced by several plants as the nectar source that workers use to produce honey such as eucalyptus, acacia, bramble, lime, chestnut, sunflower, and from honeydew, except in rape honey was produced by *Brassica napus*. Rape honey is higher in glucose and lower in fructose which impacts its rapid crystallization (Escuredo et al. 2014). The sugars content present in honey is dependent on the geographical origins which impacts on the different plant types that can grow in each region and impacts the different sugars content from the nectar, which is produced by the nectary gland of plant flowers (Agus et al. 2021; Agussalim et al. 2019; Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013). Furthermore, the sugar content in honey is influenced by climate (season, temperature, and humidity), processing (heating process), and storage time (Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013).

Diastase enzyme activity and hydroxymethylfurfural (HMF) of honey

A recent study showed that the diastase enzyme activity from the bee *A. cerana* honey produced by the sugar palm and coconut saps ranges from 5.17 to 9.04 DN (Table 2). This enzyme activity is acceptable by SNI with a minimum of 3 DN for beekeeping honey including the bee *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018), and also acceptable by the international standard has been regulated by Codex Alimentarius with the minimum 3 DN (Thrasyvoulou et al. 2018). One of the honey characteristics is that it contains enzymes originating from the bees, pollen, and nectar from plant flowers, but mostly enzymes are added by the bees when they are convert nectar into honey (Da Silva et al. 2016; Thrasyvoulou et al. 2018). The honey diastase enzyme activity in our study (Table 2) differed from what was reported by Erwan et al. (2020) that the diastase enzyme activity of honey from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 16.48 to 17.12 Schade unit.

Diastases are divided into α- and β-amylases, the natural enzymes present in honey. The α-amylase separates the starch chain randomly in the center to produce dextrin, while the β-amylase separates the maltose in the end chain. The nectar source influences diastase enzyme content in honey (floral and extrafloral nectars) to produce honey and honey geographical origins, which impacts the different chemical composition of the nectar can be produced by the plants which is impact on the honey chemical composition especially diastase enzyme activity. In addition, the bee species are also influencing the activity diastase because it's related to the distance, and the flowers plant numbers that can be visited by the foragers when they are collecting nectar and pollen used to produce honey and bee bread (Da Silva et al. 2016).

Generally, the diastase enzyme has the role of breaking down complex sugars into simple sugars. In addition, this enzyme is role to digesting starch into maltose (disaccharide) and maltotriose (trisaccharide) which are sensitive to heat or thermolabile. Thus, this condition can be used to evaluate the overheating and preservation degree of honey (Da Silva et al. 2016). Furthermore, diastase activity is also used to evaluate honey age related to storage time and temperature because the diastase activity may be reducing when heating above 60°C and longtime storage (Da Silva et al. 2016; Yücel and Sultanoğlu 2013). The honey diastase activity from the bee *A. cerana* in our study (Table 2) was differed from Wu et al. (2020) for multifloral honey produced by the *A. cerana cerana* from the Hainan province (China) was 6.70 Göthe. Furthermore, it also differed from Wang et al. (2021) that the diastase activity of *A. cerana* honey from Qinling Mountains (China) is ranging from 22.05 to 35.67 Göthe. The different diastase activities of honey from *A. cerana* were reported by previous researchers are influenced by the different plant types as the nectar source to produce honey, different sugar content, and different geographical origin.

Furthermore, the HMF of *A. cerana* honey produced by the sugar palm and coconut saps in our study ranges from 2.24 to 5.81 mg/kg (Table 2). This HMF indicates that honey from our study in fresh condition and acceptable by SNI for beekeeping honey, including from *A. cerana* and *A. mellifera*, not exceed 40 mg/kg (National Standardization Agency of Indonesia 2018) and also acceptable by the international standard regulated by Codex Alimentarius is not to exceed 40 mg/kg for blossom and honeydew honey (Thrasyvoulou et al. 2018). After harvesting, fresh honey generally contains a low HMF ranges from 0 to 4.12 mg/kg honey. Hydroxymethylfurfural is the result of the degradation of honey monosaccharides, especially fructose and glucose, under acid conditions and accelerated by heating. This reaction produce levulinic and formic acids (Da Silva et al. 2016).

Table 2. The diastase enzyme activity, hydroxymethylfurfural, and acidity of honey from the bee *A. cerana*

Treatments	Diastase enzyme activity (DN)	Hydroxymethylfurfural (mg/kg)	Acidity (ml NaOH/kg)
SP0	7.57	5.78	36.33
CP0	5.17	5.04	26.00
SCP0	9.04	4.75	28.60
SP1	6.86	4.77	29.68
CP1	8.51	5.81	28.26
SCP1	6.85	2.24	30.61

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Hydroxymethyfurfural is formed after the honey is removed from the comb or when the wax cover is opened and the advanced processing like heating process. The increase of the HMF content occurs in honey with the acidity and is accelerated by the heating process. However, the HMF content is also influenced by sugars content, organic acids presence, pH, moisture content, water activity, and the plant types as the nectar source (floral source). In addition, HMF can also be formed at low temperatures, acidic conditions, and sugar dehydration reactions. Therefore, the higher HMF content's impact on the honey color is darker (Da Silva et al. 2016; Tornuk et al. 2013). The HMF of honey from the *A. cerana* in our study (Table 2) was differed to previously reported by Wu et al. (2020) for multifloral honey of *A. cerana cerana* from China is 3.80 mg/kg and 1.69 mg/kg for *A. cerana* honey from Qinling Mountains, China is 1.69 mg/kg. The different HMF content of honey from *A. cerana* reported by previous researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Acidity of honey

Free acidity is one of the important parameters to evaluate honey deterioration which is characterized by the presence of the organic acids in equilibrium with internal esters, lactone and several inorganic ions such as sulfates, chlorides, and phosphates (Da Silva et al. 2016). This study showed that the honey acidity from *A. cerana* produced by the sugar palm and coconut saps ranges from 26.00 to 36.33 ml NaOH/kg (Table 2). The acidity of *A. cerana* honey in our study is acceptable by SNI not to exceed 50 ml NaOH/kg for the beekeeping honey including *A. cerana* and *A. mellifera*. Furthermore, it is also acceptable by the international standard has been regulated by the Codex Alimentarius is not to exceed 50 meq/kg for blossom and honeydew honeys (Thrasyvoulou et al. 2018).

The sour taste of honey originated from several organic and inorganic acids, where the dominant organic acid present in honey is gluconic acid. This organic acid is produced by the enzyme activity of glucose-oxidase which is added by the bees when they convert nectar into honey, so that it can protect the nectar until honey maturity. This protection mechanism is caused by inhibiting of microorganisms activity in honey (Da Silva et al. 2016). This inhibit mechanism includes the combination of several factors, such as low moisture and the presence of hydrogen peroxide which is produced by the enzyme glucose-oxidase can inhibit the metabolism activity in the microbe cell through the destruction of the cell wall resulting in a change in cytoplasmic membrane permeability (Nainu et al. 2021; Pasias et al. 2018).

The total acidity content in honey is a small quantity. Still, the presence in honey is very important because it can influence the honey stability on the microorganisms, taste or flavor, and aroma of honey. The high acidity indicates the fermentation process occurs when some reducing sugar is break down into acetic acid. Honey acidity content is related to the yeast number where they break down some reducing sugar into ethanol, and if the reaction with the oxygen is formed, the acetic acid which is increasing the honey acidity. Therefore, the higher acidity values may indicate the sugars fermentation process into organic acids. Honey acidity is affected by several factors such as different content of organic acids, different geographical origins, and the season when honey is harvested (Da Silva et al. 2016; Tornuk et al. 2013). The honey acidity from the bee *A. cerana* in our study (Table 2) differed from previous studied by Wu et al. (2020) for *A. cerana cerana* honey is 0.80 mol/kg and Guerzou et al. (2021) ranges from 11 to 47 meq/kg for Algerian honey. Furthermore, it is differed from Erwan et al. (2020) that honey acidity from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) ranges from 22.00 to 43.00 ml NaOH/kg. The different acidity reported previously with our study is affected by the different plant types as the nectar source to produce honey, honey pH, geographical origin, and organic acids compound; however our study has not measured the organic acid compound and honey pH.

Honey production potency from the sugar palm and coconut saps

Coconut and sugar palm plants have a good prospect to be developed because almost part of the plants can be utilized contributing to communities' income. Generally, the main product from the coconut (*Cocos nucifera* L.) was harvested as coconut fruit to advance the process into coconut oil and copra. These commodities have a high price, but producing coconut oil and copra are high risk for the farmers because they are just preparing raw materials. Therefore, the utilizing of the sap can be produced by the coconut and sugar palm were also potency feed for the bees was used as the nectar source to produce honey. Sugar palm and coconut saps are the feed potential studied by Erwan et al. (2021b) that the coconut and sugar palm saps can increase the number of honey and bee bread cells of the bee *A. cerana*. Furthermore, it is also reported that sugar palm and coconut are improving the productivity of the bee *A. cerana* such as increasing the brood cells number, colony weight, and honey production (Erwan et al. 2022). In addition, the saps from coconut and sugar palm are usually used by farmers to produce sugar using a traditional process.

The coconut plants can produce 12 stalks in a year, and one stalk can produce sap of 90 liters. Thus, one coconut plant can produce 1,080 liters of sap. Furthermore, if the farmers have one hectare of land planted by 100 coconut plants (distance 10 m × 10 m), so they can produce about 108,000 liters of coconut sap. To produce 1 kg of honey requires coconut sap for about 7 liters and in a year 84 liters are required to produce 12 kg of honey. Thus, honey potency in a year from 100 hectares of land can be calculated as follows: 10,800,000 liters of sap divided by 84 liters of sap and multiplied by 12 kg of honey and obtained 1,542,857,14 kg/year (1,542.857 tons/year) or equivalent with 128.571 tons/month in 100 hectares of the land. Based on the sap production showing that the coconut plants have a big potency to produce honey. This potency was also supported by the harvest area of coconut in West Lombok (Nusa Tenggara Province, Indonesia) was 10,629.36 hectares (Department of Agricultural and Plantations 2021).

Sugar palm plants can be tapped to collect sap for about 5 to 6 months in one stalk, but generally can be tapped not to exceed 4 months. Wahyuni et al. (2021) reported that the production of sugar palm sap per plant ranges from 8 to 22 liters/plant or 300 to 400 liters/season (3 to 4 months) or 800 to 1,500 liters/plant/year (average is 1,150 liters/plant/year). Furthermore, if in one hectare of the plantation we have 100 sugar palm plants, the distance for planting is 10 m × 10 m, so can be obtained of sap for 115,000 liters.

The field investigation showed that producing 1 kg of honey from the sugar palm sap required about 10 liters and in a year, it is required about 120 liters to produce 12 kg of honey. Thus, the honey potency from the sugar palm sap in a year from the 100 hectares of the sugar palm field is 11,500,000 liters which was divided by 120 liters and multiplied by 12 kg, so is obtained 1,150,000 kg of honey per year (1,150 tons of honey) or equivalent with 95.833 tons/month in 100 hectares area. This potency indicate that the sugar palm sap has a big potency to produce honey which is supported by the report data from the Department of Agricultural and Plantations (2021) that the sap production, sap productivity, and harvest area for sugar palm plants in West Lombok (West Nusa Tenggara Province, Indonesia) are 57.46 tones, 304.80 quintals/hectare, and 188.52, respectively, in the year of 2021. Therefore, it can be concluded that honey is produced by the bee *A. cerana* from sugar palm and coconut saps as the feed have at quality that is acceptable by Indonesian national standard, and the international standard has been regulated by the Codex Alimentarius. Honey potency production from the coconut sap in 100 hectares area can produce honey of 1,542.857 tons/year or equivalent with 128.571 tons/month, while sugar palm can produce honey of 1,150 tons/year or equivalent with 95.833 tons/month.

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Gmail **erwan apis <apiserwan@gmail.com>**

[biodiv] Editor Decision

2 pesan

Smujo Editors <smujo.id@gmail.com> 2 Oktober 2022 pukul 13.21
Kepada: Erwan <apiserwan@gmail.com>, Agussalim <agussalim@mail.ugm.ac.id>

Erwan, Agussalim:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Honey quality from the bee Apis cerana, honey potency produced by coconut and sugar palm saps".

Our decision is: Revisions Required

Biodiversitas Journal of Biological Diversity

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erwan apis <apiserwan@gmail.com> 2 Oktober 2022 pukul 13.33
Kepada: Smujo Editors <smujo.id@gmail.com>

Dear Editor in Chief Biodiversitas

Thanks very much for the information, but we inform you that in the attached file we can not found the comments for our paper because the attached file is the same with the revision file that has been uploaded in the Biodiversitas System. Can you help me explain or send the comments again for our paper ?

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Best Regards,

Dr. Ir. Erwan, M.Si.
Faculty of Animal Science, University of Mataram, Indonesia

Gmail **erwan apis <apiserwan@gmail.com>**

[biodiv] Editor Decision

3 pesan

Ayu Astuti <smujo.id@gmail.com> 12 November 2022 pukul 07.14
Kepada: ERWAN <apiserwan@gmail.com>, AGUSSALIM <agussalim@mail.ugm.ac.id>

ERWAN, AGUSSALIM:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Honey quality from the bee Apis cerana, honey potency produced by coconut and sugar palm saps".

Our decision is to: Accept Submission

Biodiversitas Journal of Biological Diversity

erwan apis <apiserwan@gmail.com> 12 November 2022 pukul 19.44
Kepada: Ayu Astuti <smujo.id@gmail.com>

Dear Editor in Chief Biodiversitas

Thanks very much for the information
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Dr. Ir. Erwan, M.Si.
Faculty of Animal Science, University of Mataram, Indonesia

erwan apis <apiserwan@gmail.com> 12 November 2022 pukul 19.57
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Dear Editor in Chief Biodiversitas

We have been check the copyedited in the system and we found some mistake for example in Universitas Mataram should be University of Mataram, the references not have DOI, so DOI we have been deleted and the references are Agussalim, Agus A. 2022. Production of honey, pot-pollen and propolis production from Indonesian stingless bee *Tetragonula laeviceps* and the physicochemical properties of honey: A review. Livest Res Rural Dev 34 (8): 66. Agussalim, Agus A, Nurliyani, Umami N. 2019. The sugar content profile of honey produced by the Indonesian Stingless bee, *Tetragonula laeviceps*, from different regions. Livest Res Rural Dev 31 (6): 91.

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Faculty of Animal Science, University of Mataram, Indonesia

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Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

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Abstract. *Erwan, Agussalim. 2022. Honey quality from the bee* Apis cerana, *honey potency produced by coconut and sugar palm saps. Biodiversitas 23: 5854-5861.* One of the big problems when keeping honeybees is the limited sustainable feed, especially in the rainy season. The objectives of this study were to evaluate the honey quality from the bee *Apis cerana* based on the chemical composition and honey potency produced by the coconut and sugar palm saps. This study using thirty colonies of the bee *A. cerana* was divided into six treatments consisting of sugar palm sap without sugar palm pollen, coconut sap without sugar palm pollen, coconut sap of 50% + sugar palm sap of 50% without sugar palm pollen, sugar palm sap was added by sugar palm pollen; coconut sap was added by sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen. The chemical composition of honey from the *A. cerana* was moisture (20.76 to 21.80%), reducing sugar (62.78 to 68.37%), sucrose (1.44 to 3.42%), diastase enzyme activity (5.17 to 9.04 DN), hydroxymethylfurfural (2.24 to 5.81 mg/kg), and acidity (26.00 to 36.33 mL NaOH/kg). Honey potency produced by the coconut and sugar palm saps in 100 hectares area produces honey was 1542.857 tons/year and 1150 tons/year, respectively. It can be concluded that the quality of *A. cerana* honey, produced by the sugar palm and coconut saps, is acceptable by the Indonesian national and international standards. The sugar palm and coconut saps have big potential as bee feed, especially for the bee *A. cerana*.

Keywords: *Apis cerana*, coconut, honey, sugar palm pollen

INTRODUCTION

The honeybee of *Apis cerana* is one of the bees from the *Apis* genus, which includes the local bee which is spread in some regions in Indonesia, including Kalimantan, Sumatera, Java, Bali, Lombok, Sumbawa, Sulawesi, Papua, and Seram (Hepburn and Radloff 2011; Radloff et al. 2011). In Indonesia, beekeeping of the bee *A. cerana* has been practiced by beekeepers using traditional hives (for example, using a coconut log hive) and semi-modern hives (box hives without nest frames) to produce honey. Furthermore, several regions have been practicing the beekeeping of the bee *A. cerana*, has been reported by Schouten et al. (2019) are Riau, North Sumatera, Lampung, Banten, Java, Yogyakarta region, Bali, and Lombok. However, the beekeeping of *A. cerana* is mostly using traditional hives or use box hives but is not completed by the honey frame like the beekeeping of *A. mellifera*. The bee *A. cerana* can produce honey, bee bread, royal jelly, and propolis. However, their production is lower compared to the bee *A. mellifera* (Schouten et al. 2019; Agussalim and Agus 2022).

One of the problems faced by the beekeepers in Indonesia is the limited of feed sustainability as the raw material to produce honey, bee bread, and royal jelly. The limitation of feed is a very serious problem that has been faced by beekeepers because they have no area used to plant several plants which are used as the feed source to produce the honeybees' products. Honeybee feeds are divided into two types, namely nectar and pollen, where nectar is obtained by the foragers from the plant flowers (nectar floral) and nectar extrafloral, which is obtained by the foragers from stalk and leaf of plants (Agussalim et al. 2018, 2017). Pollen is obtained by the foragers from plant flowers which are collected by using all body parts and then deposited in the corbicula (Agussalim et al. 2017, 2018; Erwan et al. 2021a). When collecting nectar and pollen from the plant flowers, the forager's role as the pollinator agent by transporting pollen from the anther to the pistil so that the pollination process occurs, this process is continuously done by the foragers until their honey stomach is full of nectar and their corbicula has been deposited by the pollen. This pollination impacts the increase of the plant's productivity (Pohorecka et al. 2014; Supeno et al. 2021).

One of the strategies to produce sustainable honey from the bee *A. cerana* is by using sap from the plants such as sugar palm and coconut. Several studies have been conducted by using sugar palm and coconut saps as the *A. cerana* feed. Erwan et al. (2021b) reported that the feed combination of coconut sap and sugar palm pollen as the *A. cerana* feed could enhance the production of honey cells and bee bread cells. However, using sap from coconut and sugar palms can increase the honey and bee bread cells compared to the control group without sap as the feed (multi-floral nectar). Furthermore, Erwan et al. (2022) also reported using sugar palm and coconut saps which are each added with sugar palm pollen, can improve the bee *A.*

cerana productivity, such as increasing honey production, brood cell number, and colony weight. In addition, another study showed that the use of extrafloral nectar namely sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera*) saps as the *A. mellifera* bee feed which is resulting the honey chemical composition (reducing sugar, sucrose, acidity, moisture, and diastase enzyme activity) which are acceptable by Indonesian national standard and the international standard has been regulated by Codex Alimentarius (Erwan et al. 2020). However, studies about the chemical composition of honey from the bee *A. cerana* produced from the sugar palm sap, coconut sap, and their honey potency production from both sap sugar palm and coconut have yet to be studied. Therefore, the objectives of this study were to evaluate the honey quality based on the chemical composition of the bee *A. cerana* honey potency produced by the coconut and sugar palm saps.

MATERIALS AND METHODS

Study area

This research has been conducted in the North Duman Village (8°32'10" S 116°09'32" E), Lingsar Sub-district, West Lombok, West Nusa Tenggara Province, Indonesia. In this research, we used thirty *A. cerana* colonies divided into six treatments and every five colonies per treatment as the replication. The saps used in our study were obtained from the stalk of coconut (*Cocos nucifera*) and sugar palm (*Arenga pinnata*) and the pollen source from the sugar palm (Figure 1). The stalks of coconut and sugar palm were cut and then put in a plastic bottle which was used to store the sap secreted by their stalks. The treatments in our study were sugar palm sap without added by sugar palm pollen (SP0), coconut sap without added sugar palm pollen (CP0), coconut sap of 50% + sugar palm sap of 50% without added sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added sugar palm pollen (SCP1).

The technique used to give sugar palm and coconut saps and sugar palm pollen (Figure 2) was according to the previous method has been reported by Erwan et al. (2021b, 2022) briefly as follows: fresh coconut and sugar palm saps were given to the bee *A. cerana* by using a plastic plate and split bamboo was completed by 4 to 5 twigs for foragers perch. The plastic plate and split bamboo was placed one meter from the box hives, while the sugar palm pollen was hung beside and above the box hives. The distance of 600 meters to place the colony to avoid the foragers collecting pollen and sap from the other treatments.

Figure 1. Coconut sap (*left*), sugar palm sap (*center*), and sugar palm pollen (*right*)

Figure 2. Technique to given the sugar palm and coconut saps (*left*) and sugar palm pollen (*right*) (Erwan et al. 2021b, 2022)

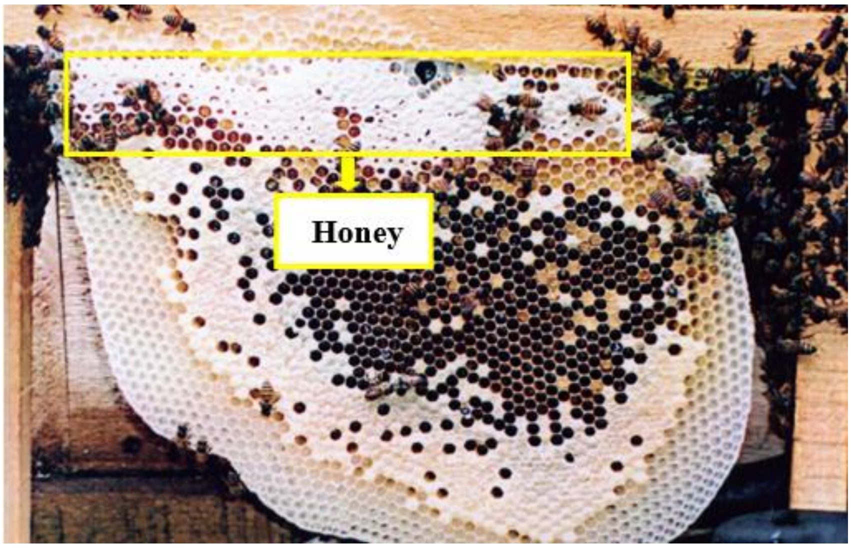

Figure 3. Honey from *Apis cerana* was produced from the sugar palm and coconut saps

Procedures

Honey quality

Honey from the *A. cerana* (Figure 3) was harvested after beekeeping for three months using coconut and sugar palm saps. Honey from the five hives in one treatment group was composited into one honey sample and then used to analysis of their chemical composition. Honey quality from the *A. cerana* was evaluated based on the chemical composition consisting of moisture, reducing sugar, sucrose, diastase enzyme activity, hydroxymethylfurfural (HMF), and acidity. The moisture content was analyzed by using a proximate analysis based on the method from the Association of Official Agricultural Chemists (AOAC) (AOAC 2005). Reducing sugar was analyzed using a Layne-Enyon method and sucrose content was analyzed by a Luff Schoorl method, described by AOAC (2005). Diastase enzyme activity, HMF, and free acidity were analyzed based on the harmonized methods of the international honey commission (Machado et al. 2022).

Honey production from sugar palm and coconut saps

Sugar palm and coconut saps every ten liters were used to measure the honey production from the bee *A. cerana* for three months of beekeeping. The sugar palm and coconut saps were placed on the plastic plate in front of the box hives at a distance of one meter. In addition, the honey production without using sugar palm and coconut saps was measured for one year of beekeeping, which calculates the contribution of sugar palm and coconut saps in honey production. Honey from *A. cerana* was harvested with cut the honey cells (Figure 3) and squeezed to separate wax and honey. Afterward, honey was measured production by using a digital scale and stored in the refrigerator.

Production of saps from coconut and sugar palm

The production of sap from coconut was measured for a year and also based on dept interviews with farmers, while the sugar palm sap based on the previously studied was used to calculate the production per hectare area and was also obtained from the deep interview with the farmers. The production of coconut and sugar palm saps per hectare was calculated from the sap production per tree multiplied by the number of trees in a one-hectare area. After three months of beekeeping, honey from both treatments, sugar palm and coconut saps, were harvested to measure the honey production from the use of ten litters sap, and then honey production was measured by cylinder glass

Data analysis

The data on honey quality, production potency of honey from sugar palm and coconut saps, honey production, and production of saps were analyzed by using descriptive analysis (Steel et al. 1997).

RESULTS AND DISCUSSION

Moisture content of honey

Honey is composed of water as the second largest of honey constituents, ranging from 15 to 21g/100 g, depending on the plant species as the nectar source, which is affected by the botanical origin. Furthermore, honey moisture is also affected by honey maturity level, processing postharvest, and storage conditions (Da Silva et al. 2016). The honey moisture affects the physical properties such as crystallization, viscosity, flavor, color, taste, solubility, specific gravity, and conservation (Escuredo et al. 2013; Da Silva et al. 2016). In addition, honey moisture is also affected by the temperature and humidity depending on the season (rainy and dry seasons). Honey moisture can increase during postharvest processing, such as storage conditions because honey is hygroscopic that can absorb the moisture in the air (Karabagias et al. 2014; Da Silva et al. 2016).

Table 1. The moisture, reducing sugar, and sucrose contents of honey from the bee *Apis cerana*

Treatments	Moisture (%)	Reducing sugar (%)	Sucrose (%)
SP0	21.60	65.24	2.86
CP0	20.76	68.37	1.96
SCP0	21.40	64.55	2.51
SP1	21.80	62.78	3.42
CP1	21.58	65.37	1.72
SCP1	20.98	67.33	1.44

Notes: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1)

A recent study showed that the honey moisture from the bee *A. cerana*, produced by sugar palm and coconut saps and their combination ranged from 20.76 to 21.80% (Table 1). This honey moisture content is accepted by the Indonesian national standard (SNI), where the moisture for beekeeping honey, including the bee *A. cerana* and *A. mellifera*, does not exceed 22% (National Standardization Agency of Indonesia 2018) and is higher compared to the international standard which Codex Alimentarius regulated is not exceeded 20% (Thrasyvoulou et al. 2018). The variation of honey moisture of the bee *A. cerana* in our study may be caused by the different moisture content of both saps from sugar palm and coconut, however, our study has not been measured. The higher moisture content requires a long time for the ripening of honey, and the bees start the process of decreasing honey moisture when they take nectar from plant flowers or saps as the raw material to produce honey. Furthermore, a small portion of moisture content has been evaporated in the honey sack before being transferred to the other bee, which is working in the hive. This transfer is rapid depending on the temperature, colony strength, and nectar availability (Da Silva et al. 2016).

The honey production process is started with the foragers collecting nectar from the plant flowers or extrafloral nectar and then stored in the honey stomach. After that, the foragers will transfer the nectar that has been collected to the other bees who are working to process the nectar into honey in their mouth, then put it in the honey stomach and then transfer it to other bees several times until honey is ripening. A considerable amount of water will be evaporated in this process, which continues with the help of wing fans that can regulate the air humidity for about 15 to 20 minutes (Balasubramanyam 2021; Zhang et al. 2021). The honey moisture content in our study differed from Wang et al. (2021), that honey moisture from the bee *A. cerana*, which is collected from 42 different honeycombs from China, ranges from 17.03 to 18.44%, 18.65% for *A. cerana cerana* from Hainan province, China (Wu et al. 2020), and 16.99% for *A. cerana* from Borneo (Malaysian honey) (Moniruzzaman et al. 2013). Furthermore, Erwan et al. (2020) also reported that the honey moisture produced by the *A. mellifera* bee by using sugar palm and coconut saps ranges from 19.34 to 20.94%. The different honey moisture content has been reported to be affected by the different geographical origins, impacts the different plant types that can be grown in each region, different environmental conditions (temperature and humidity), and also different bee species, which impact the different ability to evaporate water in the honey.

Reducing sugar and sucrose contents of honey

Sugars in honey are composed of monosaccharides for about 75%, disaccharides are 10 to 15%, and other sugars in small amounts. Honey sugars are responsible as the energy source, hygroscopic, viscosity, and granulation. Several sugars in honey have been reported such as glucose, fructose, sucrose, trehalose, rhamnose, isomaltose, nigerobiose, maltotriose, maltotetraose, melezitose, melibiose, maltulose, nigerose, raffinose, palatinose, erlose and others (Da Silva et al. 2016).

A recent study showed that the honey-reducing sugar from the bee *A. cerana* was beekeeping by using sugar palm and coconut saps, and their combination as the nectar source to produce honey ranges from 62.78 to 68.37% (Table 1). This honey-reducing sugar is acceptable by the SNI for treatments SP0, CP0, CP1, and SCP1 but not acceptable for treatments SCP0, and SP1 (Table 1), where the minimum reducing sugar is 65% (National Standardization Agency of Indonesia 2018). This sugar is produced by the mechanism of invertase enzyme activity that changes the sap sucrose into simple sugars. It is known that this enzyme is responsible for converting sucrose into glucose and fructose. These sugars are included in the reducing sugar group and the main component in honey. In the honey maturity process, the sucrose is broken down by the invertase enzyme into simple sugars simultaneously, and water will be evaporated to increase the reduced sugar content. In addition, enzymes secreted by the worker bees can also break down the carbohydrate into simple sugars. Furthermore, another enzyme in honey is the diastase enzyme that breaks down starch into simple sugars (Da Silva et al. 2016). The honey-reducing sugar in our study (Table 1) differed from what was reported by Erwan et al. (2020), that honey-reducing sugar from the bee *A. mellifera* which was produced by extrafloral nectar (sugar palm and coconut saps) ranges from 60.15 to 73.69%. The different reducing sugar may be affected by the different bee species, which impacts their ability to evaporate water in honey, especially when they convert the complex sugars into simple sugars and different seasons when the study is related to temperature and humidity environmental.

The honey sucrose content from the bee *A. cerana* in our study ranges from 1.44 to 3.42% (Table 1) and acceptable by SNI is not exceed 5% for the beekeeping honey including *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also accepted by the international standard has been regulated by Codex Alimentarius is not exceed 5% for blossom and honeydew honey (Thrasyvoulou et al. 2018). Naturally, sucrose present in honey in our study originated from sugar palm and coconut saps. The low honey sucrose content in our study is caused by the honey harvested in a mature condition characterized by honey cells that have been covered by wax. Furthermore, the invertase enzyme which is produced by the worker bees actively breaks down sucrose from saps into simple sugars. There are two types of invertase enzymes that are produced by the worker bees, namely glucoinvertase, which converts sucrose into glucose and fructoinvertase, which converts sucrose into fructose. These enzymes are mostly derived from the bee's secretion and only a small portion from the nectar, while the honeydew from the insect's secretion mostly contains invertase enzymes (Da Silva et al. 2016). The honey sucrose content in our study (Table 1) differed from Erwan et al. (2020), that honey sucrose content from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) ranging from 4.21 to 4.40%.

The honey sucrose content is a very important parameter to evaluate the maturity of honey to identify manipulation, where the high levels may indicate adulterations by adding several sweeteners such as cane sugar or refined beet sugar. In addition, indicating the early harvest, where sucrose is not completely transformed into fructose and glucose, the bees feed artificially for a prolonged time using a sucrose syrup (Escuredo et al. 2013; Puscas et al. 2013; Tornuk et al. 2013; Da Silva et al. 2016). Honey is a sugar solution that is supersaturated and unstable, so it's easy to crystallize. The honey crystallization is affected by the concentration of glucose, fructose, and water. Fructose is the dominant sugar present in honey from *A. mellifera* was produced by several plants as the nectar source that workers use to produce honey, such as eucalyptus, acacia, bramble, lime, chestnut, sunflower, and from honeydew, except in rape honey was produced by *Brassica napus*. Rape honey is higher in glucose and lowers in fructose which impacts its rapid crystallization (Escuredo et al. 2014). The sugars content present in honey is dependent on the geographical origins, which impacts the different plant types that can grow in each region and impacts the different sugars content from the nectar, which is produced by the nectary gland of plant flowers (Tornuk et al. 2013; Escuredo et al. 2014; Da Silva et al. 2016; Agussalim et al. 2019; Agus et al. 2021). Furthermore, the sugar content in honey is influenced by climate (season, temperature, and humidity), processing (heating process), and storage time (Tornuk et al. 2013; Escuredo et al. 2014; Da Silva et al. 2016).

Diastase enzyme activity and hydroxymethylfurfural (HMF) of honey

A recent study showed that the diastase enzyme activity from the bee *A. cerana* honey produced by the sugar palm and coconut saps ranges from 5.17 to 9.04 DN (Table 2). This enzyme activity is acceptable by SNI with a minimum of 3 DN for beekeeping honey, including the bee *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018), and also acceptable by the international standard has been regulated by Codex Alimentarius with the minimum 3 DN (Thrasyvoulou et al. 2018). One of the honey characteristics is that it contains enzymes originating from the bees, pollen, and nectar from plant flowers, but mostly enzymes are added by the bees when they convert nectar into honey (Da Silva et al. 2016; Thrasyvoulou et al. 2018). The honey diastase enzyme activity in our study (Table 2) differed from what was reported by Erwan et al. (2020) that the diastase enzyme activity of honey from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 16.48 to 17.12 Schade unit.

Diastases are divided into α- and β-amylases, the natural enzymes present in honey. The α-amylase separates the starch chain randomly in the center to produce dextrin, while the β-amylase separates the maltose in the end chain. The nectar source influences diastase enzyme content in honey (floral and extrafloral nectars) to produce honey and honey geographical origins, which impacts the different chemical compositions of the nectar that can be produced by the plants, which impacts the honey chemical composition, especially diastase enzyme activity. In addition, the bee species are also influencing the activity diastase because it's related to the distance and the flowers plant numbers that can be visited by the foragers when they are collecting nectar and pollen used to produce honey and bee bread (Da Silva et al. 2016).

Generally, the diastase enzyme has the role of breaking down complex sugars into simple sugars. In addition, this enzyme is a role in digesting starch into maltose (disaccharide) and maltotriose (trisaccharide), which are sensitive to heat or thermolabile. Thus, this condition can be used to evaluate the overheating and preservation degree of honey (Da Silva et al. 2016). Furthermore, diastase activity is also used to evaluate honey age-related to storage time and temperature because the diastase activity may be reduced when heating above 60ºC and longtime storage (Yücel and Sultanoğlu 2013; Da Silva et al. 2016). The honey diastase activity from the bee *A. cerana* in our study (Table 2) differed from Wu et al. (2020) for multifloral honey produced by the *A. cerana* cerana from the Hainan province (China) was 6.70 Göthe. Furthermore, it also differed from Wang et al. (2021) that the diastase activity of *A. cerana* honey from Qinling Mountains (China) ranged from 22.05 to 35.67 Göthe. The different diastase activities of honey from *A. cerana* were reported by previous researchers and are influenced by the different plant types as the nectar source to produce honey, different sugar content, and different geographical origin.

Furthermore, the HMF of *A. cerana* honey produced by the sugar palm and coconut saps in our study ranges from

2.24 to 5.81 mg/kg (Table 2). This HMF indicates that honey from our study in fresh condition and acceptable by SNI for beekeeping honey, including from *A. cerana* and *A. mellifera*, does not exceed 40 mg/kg (National Standardization Agency of Indonesia 2018) and is also acceptable by the international standard regulated by Codex Alimentarius is not to exceed 40 mg/kg for blossom and honeydew honey (Thrasyvoulou et al. 2018). After harvesting, fresh honey generally contains a low HMF ranging from 0 to 4.12 mg/kg honey. Hydroxymethylfurfural is the result of the degradation of honey monosaccharides, especially fructose and glucose, under acid conditions and accelerated by heating. This reaction produces levulinic and formic acids (Da Silva et al. 2016).

Hydroxymethylfurfural is formed after the honey is removed from the comb or when the wax cover is opened and the advanced processing like heating process. The increase of the HMF content occurs in honey with acidity and is accelerated by the heating process. However, the HMF content is also influenced by sugar content, organic acids presence, pH, moisture content, water activity, and the plant types as the nectar source (floral source). In addition, HMF can also be formed at low temperatures, acidic conditions, and sugar dehydration reactions. Therefore, the higher HMF content's impact on the honey color is darker (Tornuk et al. 2013; Da Silva et al. 2016). The HMF of honey from the *A. cerana* in our study (Table 2) was differed to previously reported by Wu et al. (2020) for multifloral honey of *A. cerana cerana* from China is 3.80 mg/kg and 1.69 mg/kg for *A. cerana* honey from Qinling Mountains, China is 1.69 mg/kg. The different HMF content of honey from *A. cerana* reported by previous researchers are influenced by the different plant types as the nectar source to produce honey, different sugar content, and different geographical origin.

Acidity of honey

Free acidity is one of the important parameters to evaluate honey deterioration which is characterized by the presence of the organic acids in equilibrium with internal esters, lactone, and several inorganic ions such as sulfates, chlorides, and phosphates (Da Silva et al. 2016). This study showed that the honey acidity from *A. cerana* produced by the sugar palm and coconut saps ranges from 26.00 to 36.33 mL NaOH/kg (Table 2). The acidity of *A. cerana* honey in our study is acceptable by SNI not to exceed 50 mL NaOH/kg for the beekeeping honey, including *A. cerana* and *A. mellifera*. Furthermore, it is also acceptable by the international standard has been regulated by the Codex Alimentarius is not to exceed 50 meq/kg for blossom and honeydew honey (Thrasyvoulou et al. 2018).

The sour taste of honey originated from several organic and inorganic acids, where the dominant organic acid present in honey is gluconic acid. This organic acid is produced by the enzyme activity of glucose-oxidase, which is added by the bees when they convert nectar into honey so that it can protect the nectar until honey maturity. This protection mechanism is caused by inhibiting of microorganisms' activity in honey (Da Silva et al. 2016). This inhibit mechanism includes the combination of several factors, such as low moisture and the presence of hydrogen peroxide, which is produced by the enzyme glucose-oxidase can inhibit the metabolism activity in the microbe cell through the destruction of the cell wall resulting in a change in cytoplasmic membrane permeability (Pasias et al. 2018; Nainu et al. 2021).

The total acidity content in honey is a small quantity. Still, the presence of honey is very important because it can influence the honey stability on the microorganisms, taste or flavor, and aroma of honey. The high acidity indicates the fermentation process occurs when some reducing sugar is broken down into acetic acid. Honey acidity content is related to the yeast number where they break down some reducing sugar into ethanol, and if the reaction with the oxygen is formed, the acetic acid which is increasing the honey acidity. Therefore, the higher acidity values may indicate the sugars fermentation process into organic acids. Honey acidity is affected by several factors, such as different content of organic acids, different geographical origins, and the season when honey is harvested (Tornuk et al. 2013; Da Silva et al. 2016). The honey acidity from the bee *A. cerana* in our study (Table 2) differed from previous studied by Wu et al. (2020) for *A. cerana cerana* honey is 0.80 mol/kg, and Guerzou et al. (2021) ranges from 11 to 47 meq/kg for Algerian honey. Furthermore, it differed from Erwan et al. (2020) that honey acidity from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) ranging from 22.00 to 43.00 mL NaOH/kg. The different acidity reported previously with our study is affected by the different plant types as the nectar source to produce honey, honey pH, geographical origin, and organic acids compound; however, our study has not measured the organic acid compound and honey pH.

Table 2. The diastase enzyme activity, hydroxymethylfurfural, and acidity of honey from the bee *Apis cerana*

Treatments	Diastase enzyme activity (DN)	Hydroxymethylfurfural (mg/kg)	Acidity (mL NaOH/kg)
SP0	7.57	5.78	36.33
CP0	5.17	5.04	26.00
SCP0	9.04	4.75	28.60
SP1	6.86	4.77	29.68
CP1	8.51	5.81	28.26
SCP1	6.85	2.24	30.61

Notes: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1)

Honey production potency from the sugar palm and coconut saps

Coconut and sugar palm plants have a good prospect to be developed because almost part of the plants can be utilized, contributing to communities' income. Generally, the main product from the coconut (*Cocos nucifera*) was harvested as coconut fruit to advance the process into coconut oil and copra. These commodities have a high price but producing coconut oil and copra are high risk for the farmers because they are just preparing raw materials. Therefore, the utilizing of the sap can be produced by the coconut and sugar palm was also potency feed for the bees was used as the nectar source to produce honey. Sugar palm and coconut saps are the feed potential studied by Erwan et al. (2021b) that the coconut and sugar palm saps can increase the number of honey and bee bread cells of the bee *A. cerana*. Furthermore, it is also reported that sugar palm and coconut are improving the productivity of the bee *A. cerana*, such as increasing the number of brood cells number, colony weight, and honey production (Erwan et al. 2022). In addition, the saps from coconut and sugar palms are usually used by farmers to produce sugar using a traditional process.

The coconut plants can produce 12 stalks in a year, and one stalk can produce sap of 90 liters. Thus, one coconut plant can produce 1080 liters of sap. Furthermore, if the farmers have one hectare of land planted by 100 coconut plants (distance 10×10 m), so they can produce about 108,000 liters of coconut sap. To produce 1 kg of honey requires coconut sap for about 7 liters and in a year, 84 liters are required to produce 12 kg of honey. Thus, honey potency in a year from 100 hectares of land can be calculated as follows: 10,800,000 liters of sap divided by 84 liters of sap and multiplied by 12 kg of honey and obtained 1,542,857,14 kg/year (1542.857 tons/year) or equivalent with 128.571 tons/month in 100 hectares of the land. Based on the sap production showing that the coconut plants have a big potency to produce honey. This potency was also supported by the harvest area of coconut in West Lombok (Nusa Tenggara Province, Indonesia) was 10,629.36 hectares (Department of Agricultural and Plantations 2021).

Sugar palm plants can be tapped to collect sap for about 5 to 6 months in one stalk but generally can be tapped not to exceed 4 months. Wahyuni et al. (2021) reported that the production of sugar palm sap per plant ranges from 8 to 22 liters/plant or 300 to 400 liters/season (3 to 4 months) or 800 to 1500 liters/plant/year (average is 1150 liters/plant/year). Furthermore, if in one hectare of the plantation we have 100 sugar palm plants, the distance for planting is 10×10 m, so can be obtained of sap for 115,000 liters.

The field investigation showed that producing 1 kg of honey from the sugar palm sap required about 10 liters and, in a year, it required about 120 liters to produce 12 kg of honey. Thus, the honey potency from the sugar palm sap in a year from the 100 hectares of the sugar palm field is 11,500,000 liters which was divided by 120 liters and multiplied by 12 kg, so obtained 1,150,000 kg of honey per year (1150 tons of honey) or equivalent with 95.833 tons/month in 100 hectares area. This potency indicates that the sugar palm sap has a big potency to produce honey which is supported by the report data from the Department of Agricultural and Plantations (2021) that the sap production, sap productivity, and harvest area for sugar palm plants in West Lombok (West Nusa Tenggara Province, Indonesia) are 57.46 tones, 304.80 quintals/hectare, and 188.52, respectively, in the year of 2021. Therefore, it can be concluded that honey is produced by the bee *A. cerana* from sugar palm and coconut saps as the feed have at a quality that is acceptable by Indonesian national standards, and the international standard has been regulated by the Codex Alimentarius. Honey potency production from the coconut sap in 100 hectares area can produce honey of 1542.857 tons/year or equivalent with 128.571 tons/month, while sugar palm can produce honey of 1150 tons/year or equivalent with 95.833 tons/month.

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Honey quality from the bee *Apis cerana*, honey potency produced by coconut and sugar palm saps

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Abstract. *Erwan, Agussalim. 2022. Honey quality from the bee* Apis cerana*, honey potency produced by coconut and sugar palm saps. Biodiversitas 23: xxxx.* One of the big problems when keeping honeybees is the limited of sustainable feed, especially in the rainy season. The objectives of this study were to evaluate the honey quality from the bee *A. cerana* based on the chemical composition, and honey potency produced by the coconut and sugar palm saps. This study using thirty colonies of the bee *A. cerana* was divided into six treatments consisting of sugar palm sap without sugar palm pollen; coconut sap without sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% without sugar palm pollen; sugar palm sap was added by sugar palm pollen; coconut sap was added by sugar palm pollen; coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen. The chemical composition of honey from the *A. cerana* were moisture (20.76 to 21.80%), reducing sugar (62.78 to 68.37%), sucrose (1.44 to 3.42%), diastase enzyme activity (5.17 to 9.04 DN), hydroxymethylfurfural (2.24 to 5.81 mg/kg), and acidity (26.00 to 36.33 ml NaOH/kg). Honey potency produced by the coconut and sugar palm saps in 100 hectares area produces honey was 1,542.857 tons/year and 1,150 tons/year, respectively. It can be concluded that the quality of *A. cerana* honey, produced by the sugar palm and coconut saps, is acceptable by the Indonesian national and international standards. The sugar palm and coconut saps have a big potential as the bee feed especially for the bee *A. cerana*.

Keywords: *Arenga pinnata*, beekeeping, *Cocos nucifera* L., extrafloral nectar, multifloral nectar

INTRODUCTION

The honeybee of *A. cerana* is one of the bees from the *Apis* genus which includes the local bee which is spread in some regions in Indonesia, including Kalimantan, Sumatera, Java, Bali, Lombok, Sumbawa, Sulawesi, Papua, and Seram (Radloff et al. 2011; Hepburn and Radloff 2011). In Indonesia, beekeeping of the bee *A. cerana* has been practiced by beekeepers using traditional hives (for example using a coconut log hive) and semi-modern hives (box hives without nest frames) to produce honey. Furthermore, several regions have been practicing the beekeeping of the bee *A. cerana* has been reported by Schouten et al. (2019) are Riau, North Sumatera, Lampung, Banten, Java, Yogyakarta region, Bali, and Lombok. However, the beekeeping of *A. cerana* is mostly using traditional hives or use box hives but is not completed by the honey frame like the beekeeping of *A. mellifera*. The bee *A. cerana* can produce honey, bee bread, royal jelly, and propolis. However, their production is lower compared to the bee *A. mellifera* (Agussalim and Agus 2022; Schouten et al. 2019).

One of the problems faced by the beekeepers in Indonesia is the limited of feed sustainability as the raw material to produce honey, bee bread, and royal jelly. The limitation feed is a very serious problem that has been faced by beekeepers because they have no area used to plant several plants which are used as the feed source to produce the honeybees' products. Honeybee feeds are divided into two types, namely nectar and pollen, where nectar is obtained by the foragers from the plant flowers (nectar floral) and nectar extrafloral, which is obtained by the foragers from stalk and leaf of plants (Agussalim et al. 2018, 2017). Pollen is obtained by the foragers from plant flowers which is collected by using all body parts and then deposited in the corbicula (Agussalim et al. 2018, 2017; Erwan et al. 2021a). When collecting nectar and pollen from the plant flowers, the foragers role as the pollinator agent by transporting pollen from the anther to pistil so that the pollination process occurs. This process is continuously done by the foragers until their honey stomach is full of nectar and their corbicula has been deposited by the pollen. This pollination impacts on the increasing the plants productivity (Pohorecka et al. 2014; Supeno et al. 2021).

One of the strategies to produce sustainable honey from the bee *A. cerana* is by using sap from the plants such as sugar palm and coconut. Several studies have been conducted by using sugar palm and coconut saps as the *A. cerana* feed. Erwan et al. (2021b) reported that the feed combination of coconut sap and sugar palm pollen as the *A. cerana* feed could enhance the production of honey cells and bee bread cells. However, the use of sap from coconut and sugar palm can increase the honey and bee bread cells compared to the control group without sap as the feed (multi-floral nectar). Furthermore, Erwan et al. (2022) also reported using sugar palm and coconut saps which are each added with sugar palm pollen can improve the bee *A. cerana* productivity, such as increasing honey production, brood cell number, and colony weight. In addition, another study showed that the use of extrafloral nectar namely sugar palm (*Arenga pinnata*) and coconut (*Cocos nucifera* L.) saps as the *A. mellifera* bee feed which is resulting the honey chemical composition (reducing sugar, sucrose, acidity, moisture, and diastase enzyme activity) which are acceptable by Indonesian national standard and the international standard has been regulated by Codex Alimentarius (Erwan et al. 2020). However, studies about the chemical composition of honey from the bee *A. cerana* produced from the sugar palm sap, coconut sap, and their honey potency production from both sap sugar palm and coconut have yet to be studied. Therefore, the objectives of this study were to evaluate the honey quality based on the chemical composition of the bee *A. cerana*, honey potency produced by the coconut and sugar palm saps.

MATERIALS AND METHODS

Study area

This research has been conducted in the North Duman Village (8º32’10” S 116º09’32” E), Lingsar Sub-district, West Lombok (West Nusa Tenggara Province, Indonesia). In this research, we used thirty *A. cerana* colonies were divided into six treatments and every five colonies per treatment as the replication. The saps used in our study were obtained from the stalk of coconut (*Cocos nucifera* L.) and sugar palm (*Arenga pinnata*) and the pollen source from the sugar palm (Figure 1). The stalks of coconut and sugar palm were cut and then put in a plastic bottle which was used to store the sap secreted by their stalks. The treatments in our study were sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added sugar palm pollen (SCP1).

The technique was used to give sugar palm and coconut saps and sugar palm pollen (Figure 2) was according to the previous method has been reported by Erwan et al. (2022, 2021b) briefly as follows: fresh coconut and sugar palm saps were given to the bee *A. cerana* by using a plastic plate and split bamboo was completed by 4 to 5 twigs for foragers perch. The plastic plate and split bamboo was placed one meter from the box hives, while the sugar palm pollen was hung besides and above of the box hives. The distance of 600 meters to place the colony to avoid the foragers collecting pollen and sap from the other treatments.

Figure 1. Coconut sap (left), sugar palm sap (center), and sugar palm pollen (right)

Figure 2. Technique to given the sugar palm and coconut saps (left) and sugar palm pollen (right) (Erwan et al. 2022, 2021b)

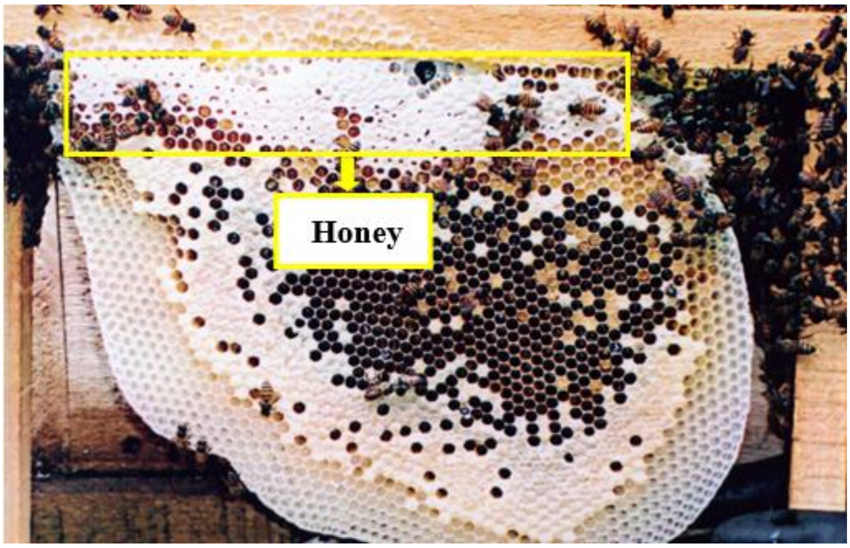

Figure 3. Honey from *A. cerana* was produced from the sugar palm and coconut saps

Procedures

Honey quality

Honey from the *A. cerana* (Figure 3) was harvested after beekeeping for three months using coconut and sugar palm saps. Honey from the five hives in one treatment group was composited into one honey sample and then used to analysis of their chemical composition. Honey quality from the *A. cerana* was evaluated based on the chemical composition consisting of moisture, reducing sugar, sucrose, diastase enzyme activity, hydroxymethylfurfural (HMF), and acidity. The moisture content was analyzed by using a proximate analysis based on the method from the Association of Official Agricultural Chemists (AOAC) (AOAC 2005). Reducing sugar was analyzed using a Layne-Enyon method and sucrose content was analyzed by a Luff Schoorl method, described by AOAC (2005). Diastase enzyme activity, HMF, and free acidity were analyzed based on the harmonized methods of the international honey commission (Machado et al. 2022).

Honey production from sugar palm and coconut saps

Sugar palm and coconut saps every ten liters were used to measure the honey production from the bee *A. cerana* for three months of beekeeping. The sugar palm and coconut saps were placed on the plastic plate in front of the box hives at a distance of one meter. In addition, the honey production without using sugar palm and coconut saps was measured for one year of the beekeeping, which calculates the contribution of sugar palm and coconut saps in honey production. Honey from *A. cerana* was harvested with cut the honey cells (Figure 3) and squeezed to separate wax and honey. Afterward, honey was measured production by using a digital scale and stored in the refrigerator.

Production of saps from coconut and sugar palm

The production of sap from coconut was measured for a year and also based on dept interview with farmers, while the sugar palm sap based on the previously studied was used to calculate the production per hectare area and was also obtained from the deep interview with the farmers. The production of coconut and sugar palm saps per hectare was calculated from the sap production per tree multiplied by the number of trees in a one hectare area. After three months of beekeeping, honey from both treatments sugar palm and coconut saps were harvested to measure the honey production from the use of ten litters sap, and then honey production was measured by cylinder glass

Data analysis

The data on honey quality, production potency of honey from sugar palm and coconut saps, honey production, and production of saps were analyzed by using descriptive analysis (Steel et al. 1997).

RESULTS AND DISCUSSION

Moisture content of honey

Honey is composed of water as the second largest of honey constituents, ranging from 15 to 21 g/100 g, depending on the plant species as the nectar source which is affected by the botanical origin. Furthermore, honey moisture is also affected by honey maturity level, processing postharvest, and storage conditions (Da Silva et al. 2016). The honey moisture affects the physical properties such as crystallization, viscosity, flavor, color, taste, solubility, specific gravity, and conservation (Da Silva et al. 2016; Escuredo et al. 2013). In addition, honey moisture is also affected by the temperature and humidity depending on the season (rainy and dry seasons). Honey moisture can increase during postharvest processing such as storage conditions, because honey is hygroscopic that can absorb the moisture in the air (Da Silva et al. 2016; Karabagias et al. 2014).

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Table 1. The moisture, reducing sugar, and sucrose contents of honey from the bee *A. cerana*

Treatments	Moisture (%)	Reducing sugar (%)	Sucrose (%)
SP0	21.60	65.24	2.86
CP0	20.76	68.37	1.96
SCP0	21.40	64.55	2.51
SP1	21.80	62.78	3.42
CP1	21.58	65.37	1.72
SCP1	20.98	67.33	1.44

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

A recent study showed that the honey moisture from the bee *A. cerana*, produced by sugar palm and coconut saps and their combination was ranging from 20.76 to 21.80% (Table 1). This honey moisture content is accepted by the Indonesian national standard (SNI), where the moisture for beekeeping honey, including the bee *A. cerana* and *A. mellifera*, does not exceed 22% (National Standardization Agency of Indonesia 2018) and is higher compared to the international standard which Codex Alimentarius regulated is not exceed 20% (Thrasyvoulou et al. 2018). The variation of honey moisture of the bee *A. cerana* in our study may be caused by the different moisture content of both saps from sugar palm and coconut, however our study has not been measured. The higher moisture content requires a long time for ripening of honey, and the bees start the process of decreasing honey moisture when they take nectar from plant flowers or saps as the raw material to produce honey. Furthermore, a small portion of moisture content has been evaporated in the honey sack before being transferred to the other bee which is working in the hive. This transfer is rapid depending on the temperature, colony strength, and nectar availability (Da Silva et al. 2016).

The honey production process is started with the foragers collecting nectar from the plant flowers or extrafloral nectar and then stored in the honey stomach. After that, the foragers will transfer the nectar that has been collected to the other bees who are working to process the nectar into honey in their mouth, then put it in the honey stomach and then transfer it to other bees several times until honey is ripening. A considerable amount of water will be evaporated in this process, which continues with the help of wing fans that can regulate the air humidity for about 15 to 20 minutes (Balasubramanyam 2021; Zhang et al. 2021). The honey moisture content in our study differed from Wang et al. (2021) that honey moisture from the bee *A. cerana* which is collected from 42 different honeycombs from China ranges from 17.03 to 18.44%, 18.65% for *A. cerana cerana* from Hainan province, China (Wu et al. 2020), and 16.99% for *A. cerana* from Borneo (Malaysian honey) (Moniruzzaman et al. 2013). Furthermore, Erwan et al. (2020) also reported that the honey moisture produced by the *A. mellifera* bee by using sugar palm and coconut saps ranges from 19.34 to 20.94%. The different honey moisture content has been reported to be affected by the different geographical origins, impacts the different plant types that can be grown in each region, different environmental conditions (temperature and humidity), and also different bee species, which impact the different ability to evaporate water in the honey.

Reducing sugar and sucrose contents of honey

Sugars in honey are composed of monosaccharides for about 75%, disaccharides are 10 to 15%, and other sugars in small amounts. Honey sugars are responsible as the energy source, hygroscopic, viscosity, and granulation. Several sugars in honey have been reported such as glucose, fructose, sucrose, trehalose, rhamnose, isomaltose, nigerobiose, maltotriose, maltotetraose, melezitose, melibiose, maltulose, nigerose, raffinose, palatinose, erlose and others (Da Silva et al. 2016).

A recent study showed that the honey reducing sugar from the bee *A. cerana* was beekeeping by using sugar palm and coconut saps, and their combination as the nectar source to produce honey ranges from 62.78 to 68.37% (Table 1). This honey reducing sugar is acceptable by the SNI for treatments SP0, CP0, CP1, and SCP1 but not acceptable for treatments SCP0, and SP1 (Table 1), where the minimum reducing sugar is 65% (National Standardization Agency of Indonesia 2018). This sugar is produced by the mechanism of invertase enzyme activity that change the sap sucrose into simple sugars. It is known that this enzyme is responsible for converting of sucrose into glucose and fructose. These sugars are included in the reducing sugar group and the main component in honey. In the honey maturity process, the sucrose is break down by the invertase enzyme into simple sugars simultaneously, and water will be evaporated to increase the reduced sugar content. In addition, enzymes secreted by the worker bees can also break down the carbohydrate into simple sugars. Furthermore, another enzyme in honey is the diastase enzyme that breaks down starch into simple sugars (Da Silva et al. 2016). The honey reducing sugar in our study (Table 1) differed from what was reported by Erwan et al. (2020), that honey reducing sugar from the bee *A. mellifera* which was produced by extrafloral nectar (sugar palm and coconut saps) ranges from 60.15 to 73.69%. The different reducing sugar may be affected by the different bee species, which impacts their ability to evaporate water in honey, especially when they convert the complex sugars into simple sugars and different seasons when the study is related to temperature and humidity environmental.

The honey sucrose content from the bee *A. cerana* in our study ranges from 1.44 to 3.42% (Table 1) and acceptable by SNI is not exceed 5% for the beekeeping honey including *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018) and also accepted by the International standard has been regulated by Codex Alimentarius is not exceed 5% for blossom and honeydew honey (Thrasyvoulou et al. 2018). Naturally, sucrose present in honey in our study originated from sugar palm and coconut saps. The low honey sucrose content in our study is caused by the honey harvested in mature condition characterized by honey cells that have been covered by wax. Furthermore, the invertase enzyme which is produced by the worker bees actively breaks down sucrose from saps into simple sugars. There are two types of invertase enzymes that are produced by the worker bees, namely glucoinvertase which converts sucrose into glucose and fructoinvertase, which converts sucrose into fructose. These enzymes are mostly derived from the bee's secretion and only a small portion from the nectar, while the honeydew from the insect's secretion mostly contains invertase enzymes (Da Silva et al. 2016). The honey sucrose content in our study (Table 1) differed from Erwan et al. (2020), that honey sucrose content from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 4.21 to 4.40%%.

The honey sucrose content is a very important parameter to evaluate the maturity of honey to identify manipulation, where the high levels may indicate adulterations by adding several sweeteners such as cane sugar or refined beet sugar. In addition, indicating the early harvest, where sucrose is not completely transformed into fructose and glucose, the bees feed artificially for a prolonged time using a sucrose syrup (Da Silva et al. 2016; Puscas et al. 2013; Escuredo et al. 2013; Tornuk et al. 2013). Honey is a sugar solution that is supersaturated and unstable so it's easy to crystallize. The honey crystallization is affected by the concentration of glucose, fructose, and water. Fructose is the dominant sugar present in honey from *A. mellifera* was produced by several plants as the nectar source that workers use to produce honey such as eucalyptus, acacia, bramble, lime, chestnut, sunflower, and from honeydew, except in rape honey was produced by *Brassica napus*. Rape honey is higher in glucose and lower in fructose which impacts its rapid crystallization (Escuredo et al. 2014). The sugars content present in honey is dependent on the geographical origins which impacts on the different plant types that can grow in each region and impacts the different sugars content from the nectar, which is produced by the nectary gland of plant flowers (Agus et al. 2021; Agussalim et al. 2019; Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013). Furthermore, the sugar content in honey is influenced by climate (season, temperature, and humidity), processing (heating process), and storage time (Da Silva et al. 2016; Escuredo et al. 2014; Tornuk et al. 2013).

Diastase enzyme activity and hydroxymethylfurfural (HMF) of honey

A recent study showed that the diastase enzyme activity from the bee *A. cerana* honey produced by the sugar palm and coconut saps ranges from 5.17 to 9.04 DN (Table 2). This enzyme activity is acceptable by SNI with a minimum of 3 DN for beekeeping honey including the bee *A. cerana* and *A. mellifera* (National Standardization Agency of Indonesia 2018), and also acceptable by the international standard has been regulated by Codex Alimentarius with the minimum 3 DN (Thrasyvoulou et al. 2018). One of the honey characteristics is that it contains enzymes originating from the bees, pollen, and nectar from plant flowers, but mostly enzymes are added by the bees when they are convert nectar into honey (Da Silva et al. 2016; Thrasyvoulou et al. 2018). The honey diastase enzyme activity in our study (Table 2) differed from what was reported by Erwan et al. (2020) that the diastase enzyme activity of honey from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) is ranging from 16.48 to 17.12 Schade unit.

Diastases are divided into α- and β-amylases, the natural enzymes present in honey. The α-amylase separates the starch chain randomly in the center to produce dextrin, while the β-amylase separates the maltose in the end chain. The nectar source influences diastase enzyme content in honey (floral and extrafloral nectars) to produce honey and honey geographical origins, which impacts the different chemical composition of the nectar can be produced by the plants which is impact on the honey chemical composition especially diastase enzyme activity. In addition, the bee species are also influencing the activity diastase because it's related to the distance, and the flowers plant numbers that can be visited by the foragers when they are collecting nectar and pollen used to produce honey and bee bread (Da Silva et al. 2016).

Generally, the diastase enzyme has the role of breaking down complex sugars into simple sugars. In addition, this enzyme is role to digesting starch into maltose (disaccharide) and maltotriose (trisaccharide) which are sensitive to heat or thermolabile. Thus, this condition can be used to evaluate the overheating and preservation degree of honey (Da Silva et al. 2016). Furthermore, diastase activity is also used to evaluate honey age related to storage time and temperature because the diastase activity may be reducing when heating above 60ºC and longtime storage (Da Silva et al. 2016; Yücel and Sultanoğlu 2013). The honey diastase activity from the bee *A. cerana* in our study (Table 2) was differed from Wu et al. (2020) for multifloral honey produced by the *A. cerana cerana* from the Hainan province (China) was 6.70 Göthe. Furthermore, it also differed from Wang et al. (2021) that the diastase activity of *A. cerana* honey from Qinling Mountains (China) is ranging from 22.05 to 35.67 Göthe. The different diastase activities of honey from *A. cerana* were reported by previous researchers are influenced by the different plant types as the nectar source to produce honey, different sugar content, and different geographical origin.

Furthermore, the HMF of *A. cerana* honey produced by the sugar palm and coconut saps in our study ranges from

2.24 to 5.81 mg/kg (Table 2). This HMF indicates that honey from our study in fresh condition and acceptable by SNI for beekeeping honey, including from *A. cerana* and *A. mellifera*, not exceed 40 mg/kg (National Standardization Agency of Indonesia 2018) and also acceptable by the international standard regulated by Codex Alimentarius is not to exceed 40 mg/kg for blossom and honeydew honey (Thrasyvoulou et al. 2018). After harvesting, fresh honey generally contains a low HMF ranges from 0 to 4.12 mg/kg honey. Hydroxymethylfurfural is the result of the degradation of honey monosaccharides, especially fructose and glucose, under acid conditions and accelerated by heating. This reaction produce levulinic and formic acids (Da Silva et al. 2016).

Hydroxymethylfurfural is formed after the honey is removed from the comb or when the wax cover is opened and the advanced processing like heating process. The increase of the HMF content occurs in honey with the acidity and is accelerated by the heating process. However, the HMF content is also influenced by sugars content, organic acids presence, pH, moisture content, water activity, and the plant types as the nectar source (floral source). In addition, HMF can also be formed at low temperatures, acidic conditions, and sugar dehydration reactions. Therefore, the higher HMF content's impact on the honey color is darker (Da Silva et al. 2016; Tornuk et al. 2013). The HMF of honey from the *A. cerana* in our study (Table 2) was differed to previously reported by Wu et al. (2020) for multifloral honey of *A. cerana cerana* from China is 3.80 mg/kg and 1.69 mg/kg for *A. cerana* honey from Qinling Mountains, China is 1.69 mg/kg. The different HMF content of honey from *A. cerana* reported by previous researchers are influenced by the different plant types as the nectar source to produce honey, different sugars content, and different geographical origin.

Acidity of honey

Free acidity is one of the important parameters to evaluate honey deterioration which is characterized by the presence of the organic acids in equilibrium with internal esters, lactone and several inorganic ions such as sulfates, chlorides, and phosphates (Da Silva et al. 2016). This study showed that the honey acidity from *A. cerana* produced by the sugar palm and coconut saps ranges from 26.00 to 36.33 ml NaOH/kg (Table 2). The acidity of *A. cerana* honey in our study is acceptable by SNI not to exceed 50 ml NaOH/kg for the beekeeping honey including *A. cerana* and *A. mellifera*. Furthermore, it is also acceptable by the international standard has been regulated by the Codex Alimentarius is not to exceed 50 meq/kg for blossom and honeydew honeys (Thrasyvoulou et al. 2018).

The sour taste of honey originated from several organic and inorganic acids, where the dominant organic acid present in honey is gluconic acid. This organic acid is produced by the enzyme activity of glucose-oxidase which is added by the bees when they convert nectar into honey, so that it can protect the nectar until honey maturity. This protection mechanism is caused by inhibiting of microorganisms activity in honey (Da Silva et al. 2016). This inhibit mechanism includes the combination of several factors, such as low moisture and the presence of hydrogen peroxide which is produced by the enzyme glucose-oxidase can inhibit the metabolism activity in the microbe cell through the destruction of the cell wall resulting in a change in cytoplasmic membrane permeability (Nainu et al. 2021; Pasias et al. 2018).

The total acidity content in honey is a small quantity. Still, the presence in honey is very important because it can influence the honey stability on the microorganisms, taste or flavor, and aroma of honey. The high acidity indicates the fermentation process occurs when some reducing sugar is break down into acetic acid. Honey acidity content is related to the yeast number where they break down some reducing sugar into ethanol, and if the reaction with the oxygen is formed, the acetic acid which is increasing the honey acidity. Therefore, the higher acidity values may indicate the sugars fermentation process into organic acids. Honey acidity is affected by several factors such as different content of organic acids, different geographical origins, and the season when honey is harvested (Da Silva et al. 2016; Tornuk et al. 2013). The honey acidity from the bee *A. cerana* in our study (Table 2) differed from previous studied by Wu et al. (2020) for *A. cerana cerana* honey is 0.80 mol/kg and Guerzou et al. (2021) ranges from 11 to 47 meq/kg for Algerian honey. Furthermore, it is differed from Erwan et al. (2020) that honey acidity from the bee *A. mellifera* was produced by extrafloral nectar (sugar palm and coconut saps) ranges from 22.00 to 43.00 ml NaOH/kg. The different acidity reported previously with our study is affected by the different plant types as the nectar source to produce honey, honey pH, geographical origin, and organic acids compound; however, our study has not measured the organic acid compound and honey pH.

Table 2. The diastase enzyme activity, hydroxymethylfurfural, and acidity of honey from the bee *A. cerana*

Treatments	Diastase enzyme activity (DN)	Hydroxymethylfurfural (mg/kg)	Acidity (ml NaOH/kg)
SP0	7.57	5.78	36.33
CP0	5.17	5.04	26.00
SCP0	9.04	4.75	28.60
SP1	6.86	4.77	29.68
CP1	8.51	5.81	28.26
SCP1	6.85	2.24	30.61

Abbreviations: sugar palm sap without added by sugar palm pollen (SP0); coconut sap without added by sugar palm pollen (CP0); coconut sap of 50% + sugar palm sap of 50% without added by sugar palm pollen (SCP0); sugar palm sap was added by sugar palm pollen (SP1); coconut sap was added by sugar palm pollen (CP1); coconut sap of 50% + sugar palm sap of 50% was added by sugar palm pollen (SCP1).

Honey production potency from the sugar palm and coconut saps

Coconut and sugar palm plants have a good prospect to be developed because almost part of the plants can be utilized contributing to communities' income. Generally, the main product from the coconut (*Cocos nucifera* L.) was harvested as coconut fruit to advance the process into coconut oil and copra. These commodities have a high price, but producing coconut oil and copra are high risk for the farmers because they are just preparing raw materials. Therefore, the utilizing of the sap can be produced by the coconut and sugar palm was also potency feed for the bees was used as the nectar source to produce honey. Sugar palm and coconut saps are the feed potential studied by Erwan et al. (2021b) that the coconut and sugar palm saps can increase the number of honey and bee bread cells of the bee *A. cerana*. Furthermore, it is also reported that sugar palm and coconut are improving the productivity of the bee *A. cerana* such as increasing the brood cells number, colony weight, and honey production (Erwan et al. 2022). In addition, the saps from coconut and sugar palm are usually used by farmers to produce sugar using a traditional process.

The coconut plants can produce 12 stalks in a year, and one stalk can produce sap of 90 liters. Thus, one coconut plant can produce 1,080 liters of sap. Furthermore, if the farmers have one hectare of land planted by 100 coconut plants (distance 10 m × 10 m), so they can produce about 108,000 liters of coconut sap. To produce 1 kg of honey requires coconut sap for about 7 liters and in a year 84 liters are required to produce 12 kg of honey. Thus, honey potency in a year from 100 hectares of land can be calculated as follows: 10,800,000 liters of sap divided by 84 liters of sap and multiplied by 12 kg of honey and obtained 1,542,857,14 kg/year (1,542.857 tons/year) or equivalent with 128.571 tons/month in 100 hectares of the land. Based on the sap production showing that the coconut plants have a big potency to produce honey. This potency was also supported by the harvest area of coconut in West Lombok (Nusa Tenggara Province, Indonesia) was 10,629.36 hectares (Department of Agricultural and Plantations 2021).

Sugar palm plants can be tapped to collect sap for about 5 to 6 months in one stalk, but generally can be tapped not to exceed 4 months. Wahyuni et al. (2021) reported that the production of sugar palm sap per plant ranges from 8 to 22 liters/plant or 300 to 400 liters/season (3 to 4 months) or 800 to 1,500 liters/plant/year (average is 1,150 liters/plant/year). Furthermore, if in one hectare of the plantation we have 100 sugar palm plants, the distance for planting is 10 m × 10 m, so can be obtained of sap for 115,000 liters.

The field investigation showed that producing 1 kg of honey from the sugar palm sap required about 10 liters and in a year, it is required about 120 liters to produce 12 kg of honey. Thus, the honey potency from the sugar palm sap in a year from the 100 hectares of the sugar palm field is 11,500,000 liters which was divided by 120 liters and multiplied by 12 kg, so is obtained 1,150,000 kg of honey per year (1,150 tons of honey) or equivalent with 95.833 tons/month in 100 hectares area. This potency indicate that the sugar palm sap has a big potency to produce honey which is supported by the report data from the Department of Agricultural and Plantations (2021) that the sap production, sap productivity, and harvest area for sugar palm plants in West Lombok (West Nusa Tenggara Province, Indonesia) are 57.46 tones, 304.80 quintals/hectare, and 188.52, respectively, in the year of 2021. Therefore, it can be concluded that honey is produced by the bee *A. cerana* from sugar palm and coconut saps as the feed have at quality that is acceptable by Indonesian national standard, and the international standard has been regulated by the Codex Alimentarius. Honey potency production from the coconut sap in 100 hectares area can produce honey of 1,542.857 tons/year or equivalent with 128.571 tons/month, while sugar palm can produce honey of 1,150 tons/year or equivalent with 95.833 tons/month.

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Thanks very much for the good information
[Kutipan teks disembunyikan]
--
Best Regards,

Dr. Ir. Erwan, M.Si.
Faculty of Animal Science, University of Mataram, Indonesia

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[biodiv] New notification from Biodiversitas Journal of Biological Diversity

2 pesan

DEWI NUR PRATIWI <support@mail.smujo.id> 17 November 2022 pukul 14.10
Balas Ke: Ahmad Dwi Setyawan <editors@smujo.id>
Kepada: Erwan <apiserwan@gmail.com>

You have a new notification from Biodiversitas Journal of Biological Diversity:

There is new activity in the discussion titled "BILLING" regarding the submission "Honey quality from the bee Apis cerana, honey potency produced by coconut and sugar palm saps".

Link: https://smujo.id/biodiv/authorDashboard/submission/12166

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

erwan apis <apiserwan@gmail.com> 17 November 2022 pukul 17.35
Kepada: Ahmad Dwi Setyawan <editors@smujo.id>

Dear Editor in Chief Biodiversitas
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