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The Effect of the Addition of Sugar Liquid on the Development of Bees (*Apis mellifera*) in a Regular Box

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ABSTRACT. *Sugar liquid can be used as supplementary feed for honeybees (Apis mellifera) because it may influence population development, egg production, and larvae, thereby enhancing colony productivity. This study aimed to determine the effect of adding sugar liquid on the development of Apis mellifera populations in standard hives. The research utilized 12 standard hives of Apis mellifera, each containing seven frames, with sugar liquid applied in four different treatments and three replicates. The treatments involved sugar liquid at a ratio of 3:1 (3 parts sugar and 1 part water), with levels of P0 = 0 kg, P1 = 0.33 kg/week, P2 = 0.66 kg/week, and P3 = 1 kg/week. The study employed a randomized block design (RBD), and data were analyzed using variance (ANOVA). Significant differences between treatments were further tested using Duncan's test. The results indicated that the addition of sugar liquid as supplementary feed did not significantly affect (P>0.05) the population, egg number, or larvae count of Apis mellifera. The study concludes that adding up to 1 kg of sugar liquid per week meets the basic nutritional needs of Apis mellifera but is not sufficiently effective in significantly increasing population, egg, or larval numbers.*

Keywords: Apis mellifera, bee population, sugar liquid

INTRODUCTION

Beekeeping has long been known among communities, especially in Indonesia. Several types of honeybees are widely recognized, including *Apis cerana* (the Asian honeybee), *Apis dorsata* (the giant honeybee), and *Apis mellifera* (the European honeybee). Among these, *Apis mellifera* is the most commonly cultivated species. Modern beekeeping frequently relies on the European honeybee (*Apis mellifera*), a species originally introduced from Australia (Marcelino et al., 2022). *Apis mellifera* has several advantages over other types of bees, including high honey production and a non-aggressive (docile) nature. Currently, numerous beekeepers manage honeybees using framed hive boxes, also known as movable frame hives, and often practice migratory beekeeping by relocating boxes or colonies (Macivor, 2017). There are two common sizes of honeybee hive boxes used today: standard boxes and jumbo boxes. Jumbo boxes are twice the height of standard boxes (double-layered), while standard boxes are single-layered.

Given Indonesia's fertile natural conditions that support the growth of diverse plants serving as food sources for bees, the beekeeping industry of *Apis mellifera* has developed rapidly in Jambi Province over the past three years. This development is particularly prominent in Danau Lamo Village, Maro Sebo Subdistrict, Muaro Jambi Regency, an area adjacent to acacia plantations of PT. Wirakarya Sakti (WKS) and community oil palm plantations. In this region, many people have started cultivating *Apis mellifera* honeybees, resulting in an increase in the number of hive boxes and bee populations. However, this growth has also led to challenges, such as a decline in honey production and population growth. Interviews with several farmer groups in Danau Lamo Village revealed that the average monthly honey production per hive in 2019 ranged from 3–5 kg, but it has recently dropped to only 2–3 kg per month. This decrease is attributed to the reduced availability of natural food sources such as nectar and pollen, which is linked to the increasing number of beekeepers expanding their colonies without considering the capacity of natural feed resources. One approach to address this issue is through the provision of liquid sugar as supplementary feed.

The development of honeybee populations is closely related to the availability of nectar as their primary food source. Good-quality food, such as flower pollen, plays a vital role in supporting colony health and growth, affecting both egg-laying rates and larval development. However, nectar availability in nature fluctuates according to seasonal patterns. In Danau Lamo Village, honeybee colonies maintained near Industrial Plantation Forests often experience food shortages, particularly due to the limited flowering of acacia trees and the increasing local bee populations competing for nectar. Therefore, supplementary feeding is necessary to ensure the continuity of honey production and the growth of bee populations. According to Sultana et al. (2024), supplementary feeding is essential to support colony development and enhance bee population growth.

Honey is a natural sweet substance produced by bees from plant nectar, secretions, or excretions, which is transformed into honey through enzymatic processes and then stored and matured in the comb. Honey is a highly complex product containing at least 181–200 substances, with proteins and phenols being minor yet crucial components derived from nectar, pollen, and bees that contribute to colony growth and defense (Stankovic et al., 2020). The water content of honey significantly affects its quality, where ideal honey generally has a moisture level of about 17–21%. Honey exceeding 17% water content may ferment, reducing its quality. To sustain beekeeping productivity, feed sources must be continuously available, and one common strategy is the addition of sugar as supplementary food.

Granulated sugar serves as a vital supplemental feed for honeybees, especially during periods of reduced natural forage availability. It functions as a primary energy source rich in carbohydrates, supporting essential bee activities. Inadequate provision of granulated sugar may lead to reduced honey production and even colony absconding. Nectar, or the sweet liquid secreted by plants, is rich in carbohydrates (containing 3–87% sucrose, fructose, and glucose), water, vitamins, and minerals (Rompas, 2015). Nectar also contains small amounts of other carbohydrates, such as lactose and galactose. According to Brys and Strachecka (2024), pollen quality is crucial for honeybee nutrition as it influences colony strength and protein levels in the hemolymph. When bees receive adequate nutrition, their productivity and honey quality improve. Additionally, supplementary feeding contributes not only to honey production but also to colony population development.

The larval phase plays a crucial role in honeybee population growth. After hatching from eggs, larvae develop at different rates depending on their caste: prospective queens require about five days, worker larvae take 5–6 days, and drone larvae need approximately seven days. The larvae of future queen and worker bees generally develop faster than male larvae. Sugar supplementation can enhance honey production due to its high carbohydrate content, which is well-suited for bee nutrition (Abadi et al., 2018). Previous research by Hendriksma et al. (2019) indicated that different carbohydrate sources can influence the functional attributes, colony population, feed intake, and honey quality of honeybees. However, further research is needed to assess the impact of sugar solution supplementation specifically in beekeeping systems using standard hive boxes. Danau Lamo Village faces challenges such as fluctuating nectar availability, environmental constraints affecting colony stability, and the need for effective feeding strategies. Therefore, this study aims to evaluate the effect of sugar liquid supplementation on the population growth of *Apis mellifera* in standard hive boxes. This research is expected to provide insights for beekeepers in optimizing feeding management to improve the sustainability and productivity of honeybee colonies.

MATERIALS AND METHODS

Materials

The materials used in this study were *Apis mellifera* bees, sugar liquid, scraper beekeeping, buckets, smoke bottles, brushes, cameras, scales, Thermo hygrometers, personal protective equipment (PPE), 12 ordinary boxes containing 7 *frames* in each box.

Preparation of *Apis mellifera* Bee Boxes

As many as 12 ordinary boxes were prepared and frame checks were carried out on each colony. Then a position for the placement was made at a height of 1 meter above the ground level. After this was made, oil was applied to the box position pole, so that pests could not interfere with the honeybee box, and oil was also applied to the legs of the bee box.

Adaptation Process

The bee adaptation process was carried out for one week before the study began to allow honeybees to adjust to the new environment, including temperature, humidity, and light intensity. Temperature and humidity measurements were conducted using a thermo-hygrometer placed inside and around the hive to monitor environmental changes in real time. Light intensity was measured using a lux meter positioned at a specific height to ensure consistent lighting conditions in the study area. Initial data collected included the empty frame's weight and the bees' average weight before adaptation. Additionally, during the adaptation process, the bees were provided with a sugar solution of 0.5 kg per box. If significant changes in temperature, humidity, or light intensity were observed, adjustments were made to maintain optimal conditions for the bee colony.

Feed Preparation

The sugar solution given to *Apis mellifera* bees was prepared with a 3:1 ratio of three parts sugar and 1 part water. The mixture was stirred until fully dissolved to ensure homogeneity. The water could be heated before adding the sugar to accelerate the dissolution process if necessary. Once the sugar solution was ready, it was evenly distributed into the hive boxes according to the designated treatment: P0 = 0 kg; P1 = 0.33 kg/week; P2 = 0.66 kg/week, and P3 = 1 kg/week.

Feeding was conducted once a week for six weeks. The sugar solution was poured into feeding containers within each hive box to ensure all bees had equal access to the feed. Throughout the study, sampling and bee observations were carried out once a week by removing one frame from each hive box. Before observation, fumigation was performed to reduce bee aggression. Each observed frame included the bee population, the number of eggs, and the number of larvae, which were then marked and documented through photography.

The bee population, eggs, and larvae were counted on each frame within the colony. If the bee colony experienced absconding (leaving the hive), data management was conducted by averaging the number of cells recorded throughout the feeding period of the sugar solution. This approach was chosen to ensure that the colony's prior development was still accounted for, preventing the loss of valuable data. Earlier data from the same colonies were retained to reflect their growth trends before absconding, while averages from other colonies were not used to avoid introducing external variability. Photographs were taken six times during the study, once weekly, to document colony development and provide visual confirmation of population changes.

Sample Collection and Observation

The sample collection and observation process for *Apis mellifera* bees was conducted once a week throughout the study. This involved removing the frames from each bee box. Before observation, smoke was used sparingly to calm the bees and reduce aggression, ensuring minimal stress on the colony. To further minimize disturbance, smoke was applied in small, controlled amounts only when necessary, preventing excessive exposure that could cause unnecessary anxiety. Bee boxes were opened only during scheduled data collection to avoid frequent disruptions to the colony. Each frame containing data on population size, number of eggs, and number of larvae was labeled and photographed. The counts of population size, number of eggs, and number of larvae were recorded for each frame per colony. If a colony absconded, the cell counts were averaged over when the bees were fed the sugar solution. Photos were taken six times during the study, once a week.

However, the method for counting population, eggs, and larvae from photographs was not fully explained, particularly regarding the software or techniques used, which limits the reproducibility of the study. Providing details on image analysis tools or manual counting methods would enhance the clarity and repeatability of this approach.

A similar methodological approach has been applied in previous studies, such as Murcia-Morales et al. (2023), where *Apis mellifera* colonies were used for environmental monitoring, involving periodic sampling and observation of hive conditions. Their study utilized a structured approach to data collection by inspecting colonies at regular intervals, ensuring consistency in monitoring colony development and environmental exposure. This methodological consistency highlights the reliability of weekly hive inspections and photographic documentation in effectively capturing colony dynamics and ecological influences while ensuring minimal disturbance to the bees.

Research Design

This study used a randomized group design (RAK) consisting of 4 treatments (P0, P1, P2, P3) and three groups as replicates. Grouping based on honey production and initial population, determined by the number of populations. The treatment given is: P0 = box (nest) + 0 kg/week of liquid sugar (control); P1 = box (nest) + 0.33 kg/week of liquid sugar; P2 = box (nest) + 0.66 kg/week of liquid sugar; P3 = box (nest) + 1 kg/week of liquid sugar.

Observed Variables

The variables observed in this study include bee population, number of eggs and number of larvae.

1. Bee Population

   The calculation of the honeybee population is carried out by photographing a frame containing honeybees using a camera once a week. Then, the mapping is carried out on the photo to make it easier to calculate, and then the number of population was calculated from the photo results obtained, then averaged per box. Photo taking was carried out during the study 6 times within one week.

2. Number of Eggs and Larvae

   The number of eggs and larvae was determined by photographing each frame, followed by mapping in the images to facilitate counting. The identified eggs and larvae were then counted, and the results were averaged per frame per box to ensure consistency in data analysis.

Data Analysis

The data obtained for each observed parameter were analyzed using analysis of variance (ANOVA) with a significance level of $p<0.05$. Before conducting ANOVA, assumptions of normality and homogeneity of variance were tested to ensure the validity of the analysis. The significant effect between treatments was further tested using the Duncan Multiple Range Test (Steel & Torrie, 1995). All statistical analyses were checked using SPSS 26 (IBM, NY, USA).

RESULT AND DISCUSSION

The results of the study on the effect of adding sugar liquid on the development of the *Apis mellifera* bee population in a regular box can be presented in the following Table 1.

Table 1. Average population of bees, number of eggs, and number of larvae of *Apis mellifera* fed with sugar solution supplement during maintenance

Treatment	Bee population (individuals)	Number of Bee Eggs (units)	Number of Bee Larvae (units)
P0	8096 ± 2987	253 ± 17	139 ± 59
P1	7011 ± 2030	267 ± 72	141 ± 39
P2	8488 ± 1543	267 ± 22	217 ± 23
P3	7871 ± 1720	318 ± 70	256 ± 55

Information: P0=0 kg of liquid sugar, P1=0.33 kg of liquid sugar, P2=0.66 kg of liquid sugar, P3=1 kg of liquid sugar.

Bee Population

The analysis of variance results indicated that adding up to 1 kg of sugar solution per week had no significant effect (P>0.05) on the population growth of *Apis mellifera*. However, a trend of increasing population with higher sugar supplementation was observed, suggesting subtle benefits in supporting the bees' nutritional needs. These findings align with those of Guler et al. (2018), who reported that artificial feeding with sugar solution did not significantly increase bee populations but may contribute to colony stability and well-being. Food availability greatly affects the bee population; if the food supply is insufficient, the colony may leave the hive. According to Topal et al. (2022), Supplemental feeding may not have a significant effect on the overall colony population. However, it could have a more pronounced impact on the age distribution of worker bees. Factors such as the experiment's duration, the feed's quality, environmental conditions, and measurement methods can also influence the results and should be considered in future research.

Number of Eggs

The analysis of variance results showed that the addition of sugar solution as a supplemental feed up to 1 kg per week had no significant effect (P>0.05) on the number of eggs produced by *Apis mellifera*. The average number of eggs, ranging from 253 to 318, suggests that factors beyond sugar supplementation, such as environmental conditions and natural food availability, play a role in egg production. Colony health ensures sufficient worker bees and strong immunity, making additional sugar supplementation potentially insignificant.

Queen productivity also influences egg production, as an aging or weakened queen may lay fewer eggs regardless of sugar intake. Additionally, natural resource availability, such as nectar and pollen, provides more comprehensive nutrition than sugar alone, leading bees to rely more on natural forage. A study by Ghosh et al. (2016) highlights the importance of adequate nutrition for colony development, mainly from natural sources. Thus, sugar supplementation alone may not be sufficient to boost egg production without considering these critical factors.

This is consistent with the findings of Amiri (2020), who stated that honeybee queens adjust egg size in response to colony size and food deprivation, resulting in larger eggs with higher survival rates, which may enhance brood survival and conserve energy within the colony. A queen bee requires high-quality protein from worker bees to maintain high egg production; if the food supply decreases, egg production may decline. Nurse bees are able to rear young adult workers from the larval stage to emergence using different types of pollen, with the availability of pollen being more critical than its nutritional quality (Kratz et al., 2024). The number of eggs in a colony can affect the amount of honey produced (Setiawan et al., 2021). According to Mubarok et al. (2020), as the queen bee ages, the number of worker bees decreases because the queen's egg production declines with age.

Number of Larvae

The analysis of variance results showed that the addition of sugar solution as a supplemental feed up to 1 kg per week had no significant effect (P>0.05) on the number of larvae of *Apis mellifera*. This finding is consistent with the non-significant effect on the number of eggs. The number of eggs and larvae in an *Apis mellifera* colony are closely related, as the development from egg to larva is part of the bee's life cycle. Moreover, the supplemental feed provided may not sufficiently impact the health or productivity of the queen, nor does it provide the additional nutrients needed to support larval development.

Factors such as feed quality, colony health, and environmental conditions also play a crucial role in influencing the number of eggs laid and larvae development. To support colony health, beekeepers are advised to provide an optimal level of sugar supplementation that meets the colony's needs without causing dependency. Additionally, alternative strategies such as offering supplementary natural feed (e.g., pollen or honey), maintaining diverse forage sources around the colony, and ensuring a pesticide-free environment can help enhance bee health and productivity. A study by Dequenne et al. (2022), highlights that adequate nutrition is essential for the survival and development of honeybee colonies, making proper supplementation a key factor in colony management. Furthermore, changes in pollen availability and quality have a significant effect on honeybee health, as low-quality pollen can negatively impact survival and nursing physiology (Di Pasquale et al., 2016).

The nutrition of the feed and the quality of the larvae are closely linked to the quantity of feed consumed (Tsuruda, 2021). According to Radev (2018), The protein in pollen supports larval tissue growth, contributing to the stabilization of larval numbers. This aligns with Posada-Florez et al. (2021), who stated that the availability of pollen is essential as it helps prevent worker bees from cannibalizing the larvae. Generally, Honeybee metamorphosis occurs more quickly in quiet areas, away from settlements, compared to locations near settlements (Mayaut et al., 2020). High rainfall intensity causes pollen to adhere to anthers, making it difficult for worker bees to collect, which in turn reduces the availability of pollen as a primary food source for larvae and slows their development into pupae. According to Kluska et al. (2020), rainfall intensity also affects atmospheric pollen concentrations, with higher intensities leading to prolonged decreases, while lower intensities show no change in concentrations throughout the day.

CONCLUSION

Adding 1 kg of sugar solution per week meets the basic nutritional needs of *Apis mellifera*, but does not significantly increase colony population, egg production, or larval development. However, observed trends suggest potential secondary benefits. Future research should explore optimizing sugar supplementation, combining it with other feeds like pollen substitutes or protein-enriched diets, and adjusting concentrations or feeding schedules to enhance colony productivity. Acknowledging limitations such as experiment duration and environmental variability will improve transparency and guide further studies, while recognizing potential benefits ensures a more comprehensive understanding of sugar supplementation effects

CONFLICT OF INTEREST

We declare that there are no conflicts of interest associated with the writing of this manuscript.

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