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A VERTICAL COMPARTMENTED HIVE DESIGNFORREDUCINGPOST-HARVEST COLONY LOSSES IN THREE AFROTROPICAL STINGLESS BEE SPECIES (APIDAE: MELIPONINAE)

***[1]Nkoba Kiatoko, [1]Suresh Kumar Raina and [2]Frank Langevelde**

[1]African Reference Laboratory for Bee Health, International Centre of Insect Physiology and Ecology (icipe), PO Box 30772-00100, Nairobi, Kenya
[2]Resource Ecology Group, Wageningen University, P.O. Box 47, 6700 AA Wageningen, The Netherlands

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ABSTRACT

Domestication of Meliponinae in log hive or simple box has often been used in Africa. However, colonyloss in these two hive types due to pest infestation after honey harvesting still occurs. We hypothesized that the two hive types were the probable causes for the infestations.We designed and assessed the hive acceptance andpostharvest colony losses of three Afrotropical Meliponinae namely *Plebeina hildebrandti, Meliponula bocandei* and two *M. ferruginea* morpho-speciesin a vertical compartmented hive (called the *icipe*-4M), as an alternative. We observed that *P. hildebrandti* had the lowest acceptance rate compared to the other species. However, all the bee species occupied the different hive compartments (brood and honey chamber) of the hive. Postharvest loss was lower in *M. bocandei* and the reddish brown *M. ferruginea*morpho-species. Average honey yieldand honey composition were also evaluatedper species. Annually, *M. bocandei* produced more honey followed by *M. ferruginea* morpho-speciesand*P. hildebrandti*. Honey composition also varied among the species.We recommend that rural communities switch to using the *icipe*-4M hive to domesticate these stingless bee species, to decrease the losses of brood to pests, and increase the yields of harvested honey in domestication.

INTRODUCTION

Stingless bees are a group of bees that belong to the Apidae family and are closely related to honey bees, carpenter bees, bumblebees, and orchid bees (Meyer, 2005). In Africa, over 20 species of stingless bees belonging to six genera are known that arespecies-specific to the continent (Eardly, 2004). Stingless bees are of economic importance as key contributors in ecosystem support services vital to the survival of several forest plant species as well as crop through pollination (Richards, 1993; Roubik, 1995; Heard, 1999; Slaa *et al*., 2006).Nonetheless, African stingless bee species are in danger, and are declining in their natural habitatbecause of honey gatherers spoiling the colony broods by abandoning it after honeyharvesting. In Africa, stingless bee honey is used for traditional rituals, traditional medicine, and for sustenance (Raina *et al*., 2006).

****Corresponding author: Nkoba Kiatoko,***
African Reference Laboratory for Bee Health, International Centre of Insect Physiology and Ecology (icipe), PO Box 30772-00100, Nairobi, Kenya

Harvesting of stingless bee honey from wild colonies consists ofabandoning the broods with bees in the open cavity which utterly results indestruction and thus leads to the death of the colony. To rescue stingless bee colonies, initiatives to hive the brood before scrapping off the nest to harvest honey have beenstartedfor conservation ofthe stingless bees. This will supply of honey to the beekeeper. Meliponiculture is reported to improve the livelihoods of rural communities through honey production (Cortopassi-Laurino *et al*., 2006). In Africa, stingless bees are maintainedin traditional log hive (Plate 1) and simple box hives with a single cavity simulating a cavity in a tree trunk. In thesehives, stingless bees construct the brood combs and store food in the same cavity. A log hive or simple box hives has the disadvantage that when harvesting honey the entire nest is disturbed due to scrapping. Moreover, honey from disturbed pots drizzles into the nest on the brood and bees, and creates uncomfortable living conditions for the bees. Invariably, these conditions attracts predators such as ants, honey bees, small hive beetles and parasitic phorid flies, and threaten the survival of the colony (Sommeijer, 1999; Core *et al*., 2012).

Plate 1. A colony of *M. ferruginea*(the black morpho-species) (up) and *M. bocandei* (down) hived in a log hive at a homestead surrounding the Kakamega forest

Consequently, efforts to conserve the stingless bee biodiversity in the wild using these hives, and to utilize their pollination services on wild and cultivated plants in African rural landscapes are still decreasing (Raina *et al*., 2006). One solution to this problem is introducing of appropriate hive designs that facilitate proper management of the meliponines for economic development of the rural people, especially through honey production (Cortopassi-Laurino *et al*., 2006). *Plebeina hildebrandti* (Friese, 1900), *Meliponula bocandei* (Spinola, 1853), and *M. ferruginea* (Lepeletier, 1841) (where *M. ferruginea* is separated into two morpho-species[*M. ferruginea* (reddish-brown), *M. ferruginea* (black)]) (all Meliponinae) are Afro-tropical Meliponini bees, well-known in many Afrotropical countries (Raina *et al.,* 2006). These species are either reared in log hive or a simple box hive with a single cavity. To contribute to the conservation of the Afrotropical stingless bee biodiversity through rearing, and for reduced nest damage andcleaner harvesting of the honey, we designed and tested a simple vertical compartmented hive in Kakamega forest for rearing three meliponine beespecies. The hive is compartmented into two chambers to separately accommodate the brood and the stored food. Because the honey chamber is separated from the brood chamber and can be manipulated in any manner, there is no disturbance of the brood during honey harvesting. Here, we test this alternative hive, which, after honey harvesting, the beekeepers can clean its honey chamber or replace it with a new chamber without the bees rejecting it, thus avoiding the risk of hive invasion by predators.

We assessed the acceptance of this hive design by the different stingless bee species that differ in their body size and selection of nesting site. We also measured annual honey production and determined the physicochemical composition of the honeyamong the three bee species. Improved management of stingless bees holds promise for conservation of their biodiversity withincreased economic benefits (Cortopassi-Laurino *et al*., 2006; Souza *et al*., 2006) which was the goal of this study.

MATERIAL AND METHODS

Study insect

The Afrotropical Meliponinae *P. hildebrandti*, *M. bocandei*, and two morpho-species of *M. ferruginea* [*M. ferruginea* (reddish-brown), *M. ferruginea* (black)] (all Apidae: Meliponinae) were studied. These Meliponinae are reported to differ in their selection of nesting site in the African wild (Kajobe, 2007) as well as body size (Eardley,2004). A study carried out on the selection of nesting site by these bees in the Kakamega forest reported that *M. bocandei* species has a large body size (7.0 mm) and organizes its brood in clusters, while the *M. ferruginea*morpho-species are smaller than *M. bocandei* but larger in body size (5.1–5.9 mm) than *P. hildebrandti* (3.3–5.2 mm). *Meliponula ferruginea* [*M. ferruginea* (reddish-brown), *M. ferruginea* (black)] and *P. hildebrandti*organize their brood in horizontal combs. The *M. bocandei* and *M. ferruginea* (black) nest in tree cavities of live tree trunks and branches at an average height of 31.1 ± 1.79 meters and 21.9 ± 1.05 meters respectively from the ground surface. *Plebeina hildebrandti* is an underground cavity nester and its nests are found in termite mounds located at an average depth of 1.1±0.4 meters from the ground surface. *Meliponula ferruginea* (reddish-brown) morpho-species nests either in cavities in trees (trunk, branch), underground or in walls of human residential houses at a height/depth of 15.0 ± 2.09 meters, 0.5 ± 0.05 meters and 1.4 ± 0.08 meters respectively from the ground surface. The volume occupied by the brood in cavities is large in *M. bocandei*, equally small in the *M. ferruginea* morpho-species and smaller in *P. hildebrandti*.

Description of the vertical compartmented hive for housing stingless bees colonies

The experimental hive designed for housing of the studied Meliponinae bees is a simple vertical compartmented hive, called *icipe*-4M. The hive has two chambers that are different in size, superimposed vertically, and easy to disconnect from each other. The brood chamber measures 20cm x 18cm x 18cm and the food storage chamber measures 20cm x 18cm x 35cm (Plate 2). The smallest chamber receives the brood and the bees harvested from a wild nest, while the largest chamber stores the food (honey, pollen) in pots once the colony accepts to establish in the hive (Plate 3a,b). During honey harvesting, the store chamber can be removed from the brood chamber to facilitate harvesting of honey without disturbance and pouring dripping honey on the brood when scrapping of the store pots. The risk of hive invasion by predators after harvesting is reduced because the farmers can completely clean the harvested honey chamber with a soft cloth or either connect a new honey chamber to the brood chamber without the bees rejecting it. A suitable feeder (Plate 3a) that consists of an external reservoir with an open tube on its extremity built into the honey chamber is used for feeding the bee colony during

droughts to prevent absconding due to poor resource availability.

The batumen and food storage pots were removed with caution to avoid compressing the layers of brood and involucrums.

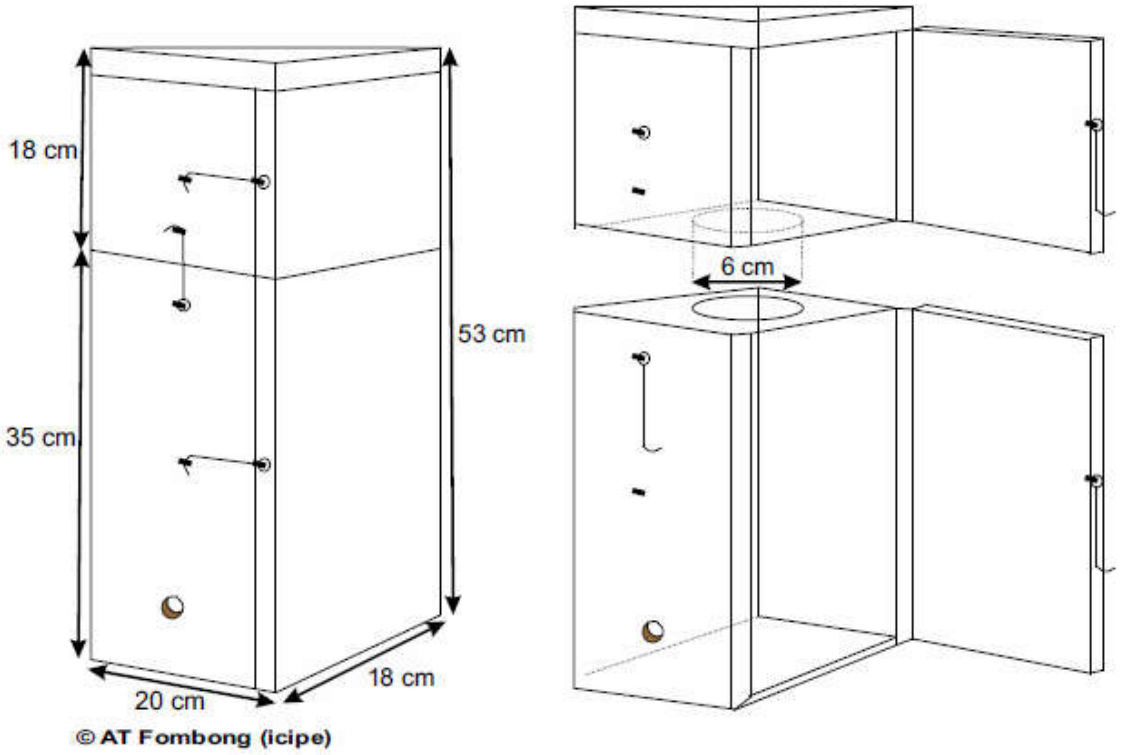


Plate 2. The vertical compartmented hive (*icipe*-4M) design for rearing of Meliponinae

Plate 3. a) The brood chamber (open chamber) to receive the brood and bees harvested from a wild nest; b) Food storage chamber (open chamber) forstoring food

Harvesting of nests and transfer of the brood and bees into the hive for the experiment occurred in the wild. Nest harvesting was carried out during the morning hours (06:00 hr) before the worker bees embarked on the foraging flights. Removal of the brood along with the bees in a nest was carried out by opening the nest cavity in a tree, wall, or underground, in such a way that three quarters of the batumen enveloping the nest could be seen and removed without causing damage to the brood.

After complete removal of the food storage pots, the brood and bees wrapped by the layers of involucrums were introduced into the brood chamber of the hive. The funnel of the nest entrance built by the bees in the wild was smeared around the entrance hole of the hive to attract the bees to fly into the hive during opening of the cavity and removal of the food storage pots. Each nested hive was coded for easy identification of the colony in the records. To protect the nested hives from rain

and exposure to sun, all hives were placed in a shed constructed in a farmland surrounding the Kakamega forest at Isecheno forest block in Ivihiga village, Kakamega East district, western Kenya. Data were collected on acceptance and post honey harvest colony loss of the designed hive by each Meliponinae species, annual honey production, and honey composition in the designed hive for each species foraging at the same forest site.

Assessment of hive acceptance

One year after we introduced the colonies in the hives, we recorded the acceptance of the designed hive by each of the studied bee species, by establishing whether the colony had absconded or not. An accepted hive was scored as one (1) and none accepted hive was scored as zero (0). A nested hive was considered as accepted by a bee colony if the established bee colony remained for one year and stored food in pots in the food store chamber. A hive in which the nested colony had absconded or had remained in it for one year but did not build up and store food in the food chamber was considered as a rejected hive. We conducted the experiment for three years, continuing with the colonies that did not abscond their hives. Hives in which bees had absconded were replaced by a new colony the next year.

Assessment of hive postharvest colony loss

Absconding of colony in the bee species after harvesting of honey in the designed hive was recorded whether the colony nest was infested or not. A colony damaged by pests invasion in hive was scored as one (1) and the no damaged was scored as zero (0). We repeated the experiment for two years continuing with the colonies not been damaged by pests and parasites after honey harvesting. Colonies in which were damaged were replaced by a new colony the next year.

Assessment of honey production

Honey was collected from hives where the colonies had established for a year from the 32 hives that were occupied by the three species. Harvesting of honey stored in the food store chamber of the designed hiveswas done after scrapping the honey pots. The extracted honey pots were squeezed and the flowing honey sieved to remove all solid particles. A one litre measuring cup with precise graduation of 5 ml was used to quantify the harvested honey.

Assessment of honey composition

The honey composition was determined using six variables, namely water, proline, diastase, free acidity, hydroxy methylfurfural (HMF) and total sugars (AOAC, 1984; Souza *et al*., 2006; Suntiparapop *et al*., 2012). Honey was collected from 30 colonies of *M. ferruginea* (reddish brown), 18 colonies of *P. hildebrandti*, 12 colonies of *M. bocandei* and 27 colonies of *M. ferruginea* (black). Moisture content of the honey samples was measured using a hand-held Abbe refract meter specially adapted for honey samples. The moisture content was expressed in percentage (g moisture per 100g fresh weight) (Bogdanov *et al*., 1997).

Proline concentration was determined using the 3000 series spectrophotometer at 510nm according to Ough (1969). Proline and ninhydrin formed a colored complex. After adding 2-propanol, the extinction of the sample solution and a reference solution at a wavelength maximum was determined. The proline content was determined from the ratio and expressed as a proportion of the mass of honey in mg/kg. The diastase activity was quantified by the spectrophotometric method according to Schade *et al*. (1961) and modified by Hardon (1972). The method is based on measuring the necessary time for the diastase which is naturally present in honey, to hydrolyze a known quantity of starch added to the diluted sample of honey. The results are expressed in Schade units per gram of honey. The free acidity was measured by titration to pH 8.3 according to Bogdanov *et al*. (1997). Each honey sample was dissolved in water, the pH measured and the solution titrated with 0.1M sodium. The result was expressed in mill equivalents of acid per 100g of honey. The honey content on hydroxymethylfurfural (HMF) was determined spectrophotometrically (White, 1979; Bogdanov *et al*., 1997). The method is based on the determination of UV absorbance of HMF at 284 nm. The difference between the absorbances of a clear aqueous honey solution and the same solution after addition of bisulphate was determined to avoid interference of other components at this wavelength. The HMF content was calculated after subtraction of the background absorbance at 336nm. The result was expressed in milligrams per kilogram. The total sugars in each honey samples was measured using a hand refract meter and was expressed in ºBrix according to Souza *et al*. (2006).

Statistical analysis

To test the differences in hive acceptance between the different stingless bee species, we used the Generalized Estimating Equations (GEE) with a binomial distribution and a logit link function. This way, we measured the occurrence of absconding or not in the same hives during three years. GEE was followed by the sequential Sidak posthoc test to distinguish the differences between the species or the years. Generalized Linear Model assuming binomial distribution and logit link was used to model the postharvest probability colony loss after harvesting honey from the icipe-4M designed hive. A Tukey test using glht was applied for mean separation. To test the differences in honey production between the different stingless bee species, we used a Linear Mixed Model (LMM) with year as a random factor. The LMM was followed by a Sidak post-hoc test to determine the significant differences between the species. We log-transformed the honey production values to meet the requirements of the LMM to have normally distributed residuals. The LMM was applied with a diagonal covariance structure.

We used Principal Component Analysis (PCA) to explore the differences in honey composition between the different bee species. To test these differences in each of the elements of the honey between the different species, we used Analysis of variance (ANOVA). We transformed the dependent variables if needed to meet the requirements of normally distributed residuals and homogeneity of the variances. The ANOVA was followed by a Tukey posthoc test to determine the significant differences between the species.

RESULTS

Hive acceptance

The probability of the *icipe*-4M hive design being accepted by each of the different bee species is indicated in Figure 1. There was no difference in hive acceptance between the years (GEE: Wald Chi square = 3.098, df = 2, p = 0.212), whereas there was a difference between the bee species (Wald Chi square = 17.349, df = 3, p = 0.001). The probability that bees accepted the new hive design was significantly lower for *P. hildebrandti* compared to *M. bocandei* and the *M. ferruginea* morpho-species. No difference in hive acceptance was observed between *M. bocandei* and *M. ferruginea*morpho-species (Figure 1). All the species perfectly occupied the different hive compartments (brood and honey chamber) of the icipe-4M hive design. The brood chamber is below the honey chamber for *P. hildebranti* and *M. bocandei* species and upper in the *M. ferruginea* morpho-species.

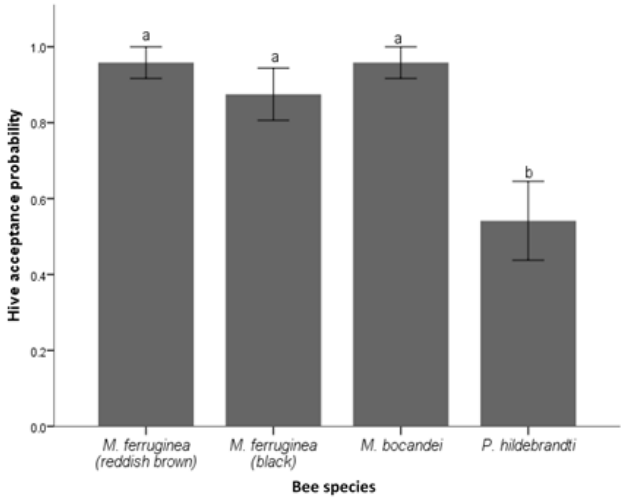


Figure 1. Probability of hive acceptance (± S.E.) for the different meliponinae bee species. Error bars with different letters indicate probabilities that are statistically different at α = 0.05

Loss of the bee colonies post-harvest

The probability at which colonies across the three bee species were lost after post-harvest of the honey stored by the colonies in the *icipe*-4M hive design is indicated in Figure 2. There was a significant different (χ_3^2=14.95, p = 0.002) between the bee species in post-harvest colony lost probability after harvesting honey in the designed hive. The probability of losing a colony was significantly lower for *M. bocandei* and the *M. ferruginea* reddish brown morpho-speciescompared totwo other bee species. No difference in post-harvest colony lost was observed between *M. bocandei* and the *M. ferruginea* reddish brown morpho-species. About 50% of *P. hildebrandti* nested colonies were being lost after post-harvest of the honey stored in hive.

Honey production

The average amount of honey stored in the hive by the different species after one year of domestication is indicated in Figure 3. There was a significant variation in honey production between the bee species (LMM: F3, 42.6=431.49, p<0.001).

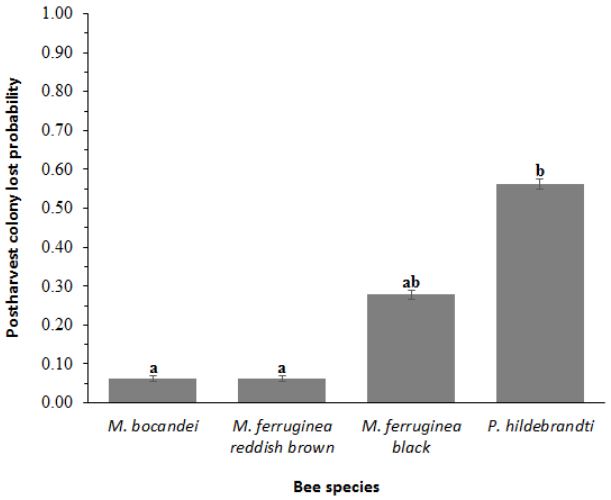


Figure 2. Probability of post-harvest colony loss (± S.E.) for the different meliponinae bee species. Error bars with different letters indicate probabilities that are statistically different at α = 0.05

Meliponula bocandei species produced more honey than the other species, and *P. hildebrandti* produced the least amount of honey. No significant difference in the average amount of honey harvested was observed between the *M. ferruginea* (black) and *M. ferruginea* (reddish brown) morpho-species (Figure 3).

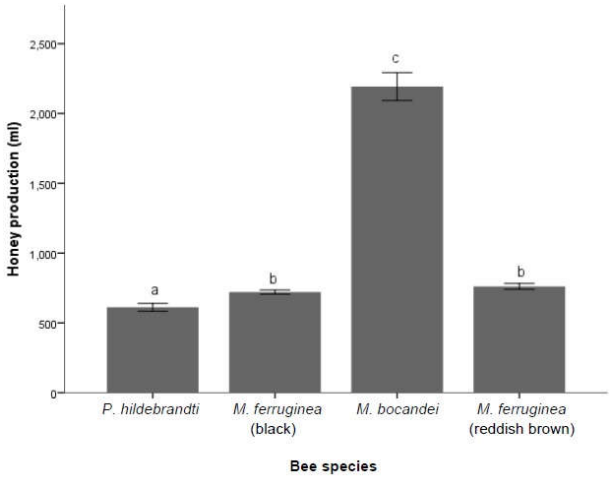


Figure 3. Mean honey yield (± S.E.) of different meliponinae bee species. Error bars with different letters indicate honey yield that is statistically different at α = 0.01

Honey composition

The differences in honey composition on seven components namely, water, pH, proline, diastase, free acidity, hydroxymethylfurfural (HMF) and total sugar between the Meliponinae bee species is reported in Figures 4 and 5. Proline, free acidity and HMF were positively correlated and explained at 94% by the first ordination axis. The honey samples of *M. bocandei* were located at the right-hand side of the first axis and differed from those of the three other meliponinae species especially in higher level of proline and free acidity. Diastase, total sugar concentration and pH were correlated and explained 5.3% of the variation along the second axis. The honey composition of *M. ferruginea* (reddish brown), *M. ferruginea* (black) and *P. hildebrandti* were

ordered along the second axis. The honey of *M. ferruginea* (reddish brown) had apparently the highest values of diastase and lowest values of pH and total sugar. The honey of *M. ferruginea* (black) had the opposite values and the honey of *P. hildebrandti* was intermediate.

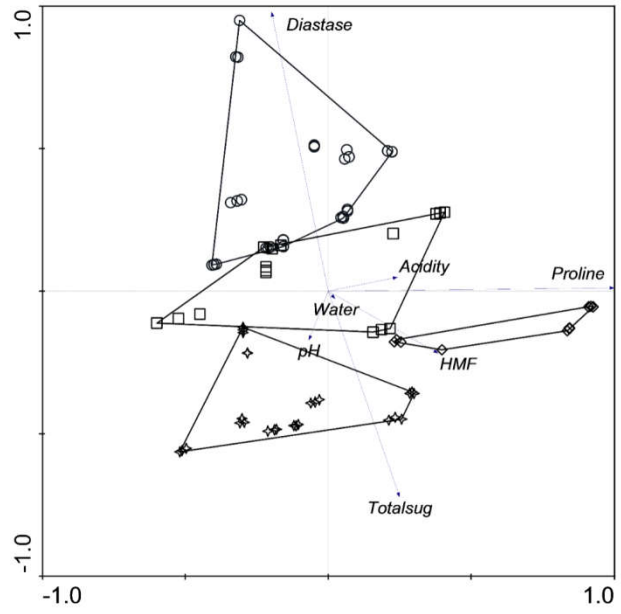
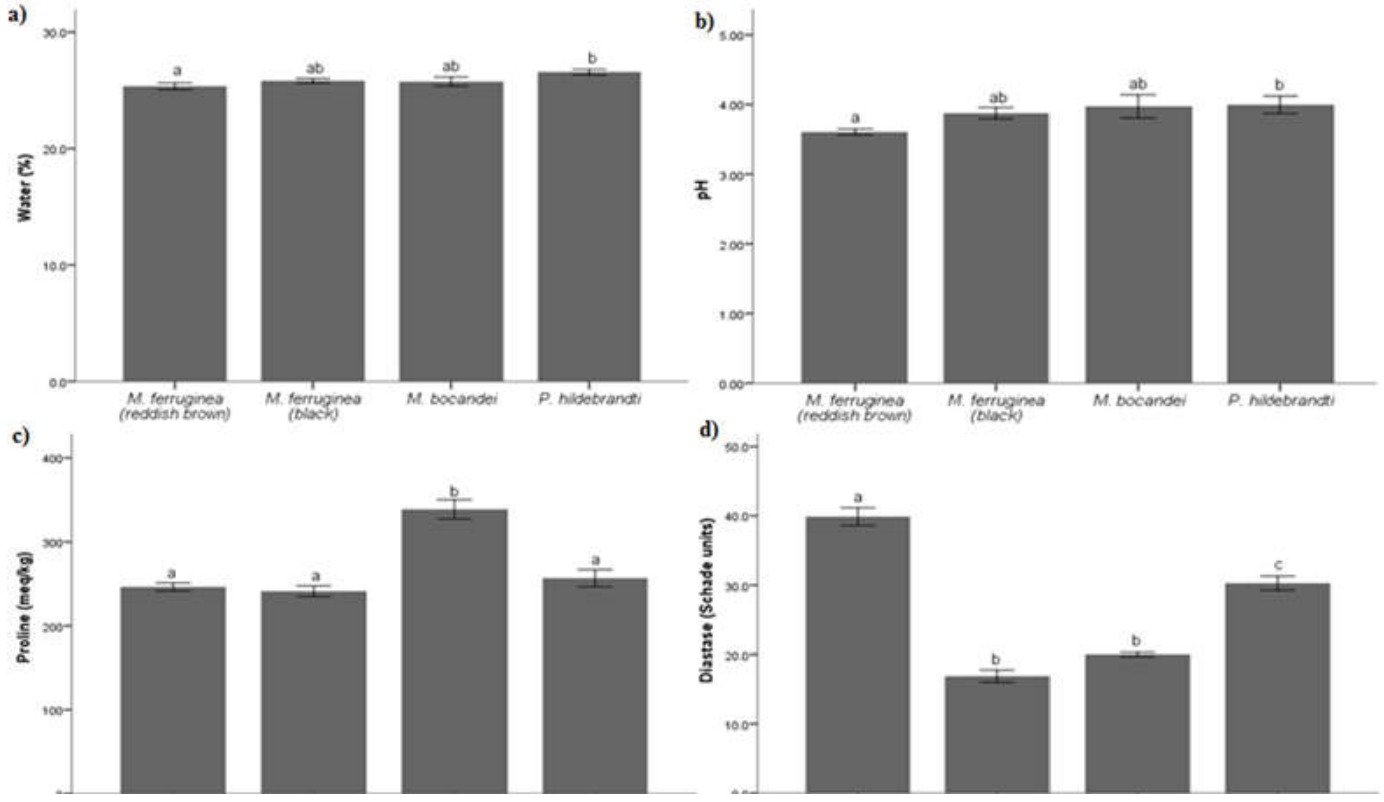


Figure 4. Ordination plot of the honey composition of the stingless bee (morho-) species. The elements are indicated with arrows: water concentration (in %), pH, proline (in meq/Kg), diastase (in Schade units), acidity (in meq/kg), HMF (in mg/kg) and concentration total sugars (in %). The samples of the different bee (morpho-) species are indicated with the different symbols: *M. ferruginea* (reddish brown) with circles, *M. ferruginea* (black) with stars, *M. bocandei* with diamonds and *P. hildebrandti* with squares

The percentage of water in the honey differed significantly between the Meliponinae species (Anova: $F_{3,83}=5.54$, $p=0.020$, Fig. 5a): The water content was highest in honey of *P. hildebrandti* , whereas the percentage of water in honey of *M. ferruginea* (reddish brown) was lowest and intermediate in the honey of *M. bocandei* and *M. ferruginea* (black). The pH of the honey also varied significantly between the meliponinae species ($F_{3,83}=4.43$, $p=0.007$, Fig. 5b). The pH was highest in honey of *P. hildebrandti*, whereas was lowest in *M. ferruginea* (reddish brown) and intermediate in *M. bocandei* and *M. ferruginea* (black). The concentration on proline (ln-transformed) in the honey also differed significantly between the species ($F_{3,83}=20.11$, $p<0.001$, Fig. 5c). Honey produced by *M. bocandei* species had the highest concentration on proline as compared to the other meliponinae species. The concentration of diastase was significantly different within the meliponinae species ($F_{3,83}=101.28$, $p<0.001$, Fig. 5d); and decreased from one species to another.

The *Meliponula ferruginea*(reddish brown) had the highest concentration of diastase in the honey followed by *P. hildebranti* species. The honey of *Meliponula bocandei* and *M. ferruginea* (black) species had the lowest concentration of diastase. A significant difference in free acidity value (ln transformed) was observed between the meliponinae species ($F_{3,83}=4.49$, $p=0.006$ Fig. 5e). The highest value of free acidity was recorded in honey of *P. hildebrandti*and *M. bocandei*; followed by *M. ferruginea* (reddish brown), whereas *M. ferruginea* (black) had the lowest value. HMF also significantly differed between the meliponinae species ($F_{3,83}=30.34$, $p<0.001$, Fig. 5f). The *Meliponula ferruginea* (reddish brown) and *M. ferruginea* (black) morphospecies had the lowest concentration of HMF (ln-transformed), whereas *M. bocandei*had the highest concentration.



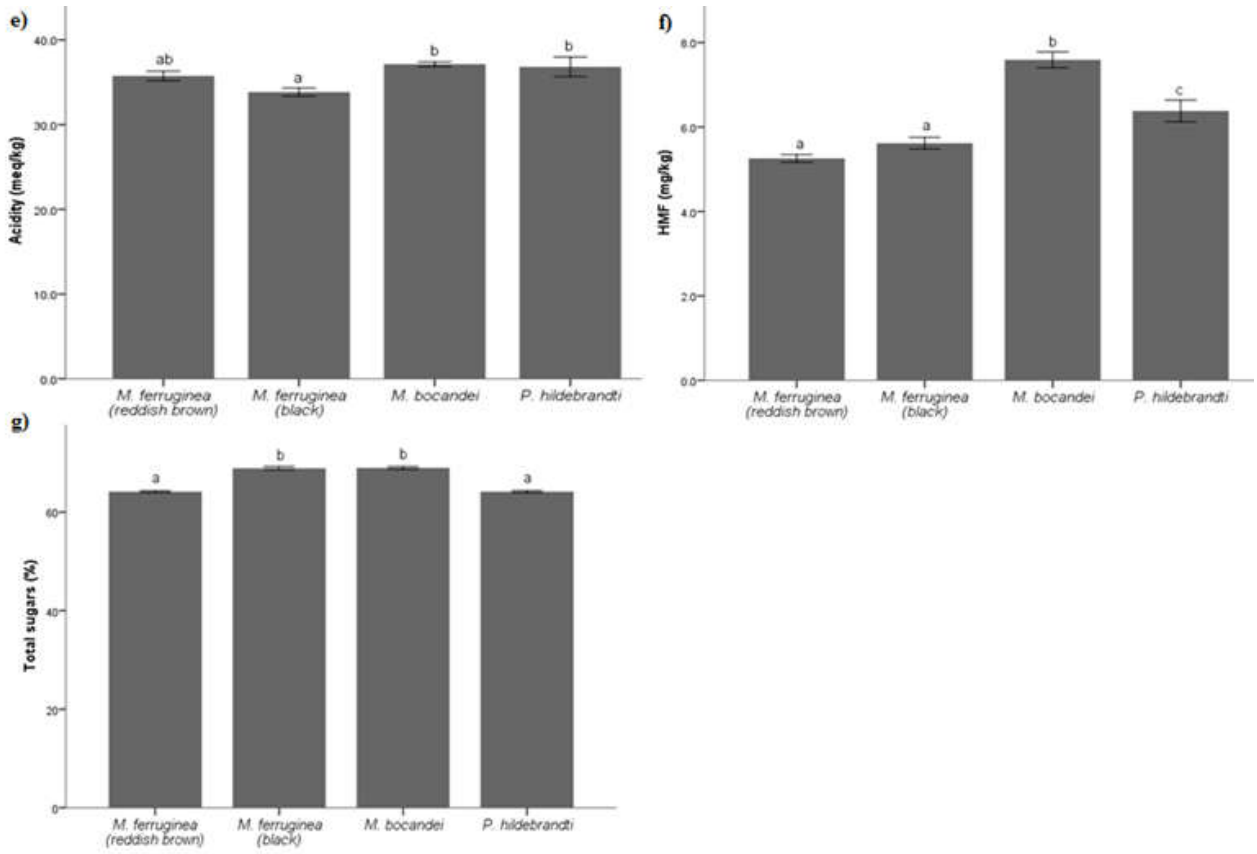


Figure 5. Differences in mean (± S.E.) percentage water (a), pH (b), Proline (c), Diastase (d), Acidity (e), HMF (Hydroxymethylfurfural) (f) and total sugars (g) between the different (morpho-) species of stingless bees. Error bars with different letters indicate honey compoundthat is statistically differentbetween the stingless bee species

A significant difference in the total sugars was observed between the honey of the meliponinae species ($F_{3,83}=96.89$, $p<0.001$, Fig. 5g). The honey from *Meliponula ferruginea* (reddish brown) and *P. hildebrandti* had the lowest concentration on sugar, whereas honey of *M.bocandei* and *M. ferruginea* (black) had the highest sugar concentration values.

DISCUSSION

The two species (*Plebeina hildebrandti*, *Meliponula bocandei*) as well as the two morpho-species of *M. ferruginea* [*M. ferruginea* (reddish-brown), *M. ferruginea*(black)], accepted to nest in the vertical compartmented wooden hive design *icipe*-4M, and showed no difference in accepting the designed hive. However, the probability that *P. hildebrandti* species accepted the wooden hive design was significantly lower compared to *M. bocandei* species and the two morpho-species of *M. ferruginea*. According to Cortopassi-Laurino *et al*. (2006), stingless bee species that nest in subterranean hollows are difficult to maintain in wooden hives compared to those thatconstruct their nests in tree cavities. Thus, it can be suggested that this is the reason for the low acceptance to nest in the designed hive observed in *P. hildebrandti*because it nest underground in termite nests. Each of the Meliponinae species utilized the different hive compartments (brood and honey chamber) of the *icipe*-4M hive design adequately (Plate 4). The brood chamber is below the honey chamber for *P.*

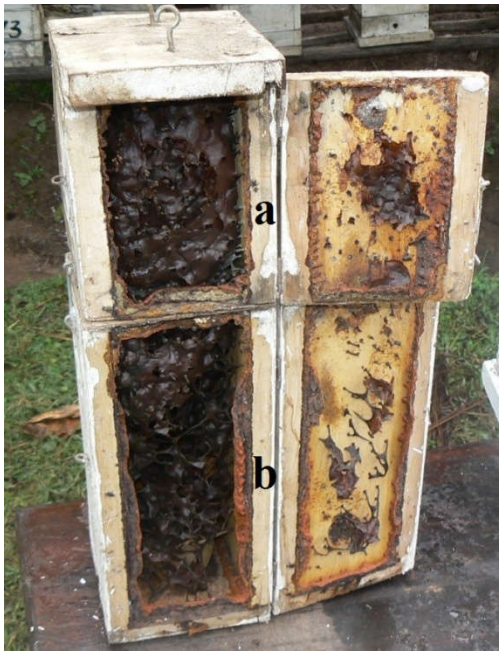


Plate 4. Occupancy of the different compartments of the *icipe*-4M hive design by *Meliponula ferruginea* (reddish brown). a = brood and b= Food pots (honey and pollen)

In the wild, stingless bees nests are found in simple cavities that offer them ease of use inarranging their brood and food

stores in such a way that the brood occupies the central part of the nest cavity and is surrounded by food stores. Such arrangement of the nest in artificial cavities is possible in a non-compartmented hive design rather than in the compartmented hive design (Cortopassi-Laurino *et al*., 2006). Based on this observation,we designed the hive so that the bees could utilize the cavities for food storage round the main nest cavity that it uses to establish the brood. Average annual honey production in meliponiculture varie between the stingless bee (morpho-) species and was related to body size. *Meliponula bocandei*which is the biggest bee species, produced a higher amount of honey compared to *P. hildebrandti* and the *M. ferruginea* morpho-species. *Meliponula ferruginea*morpho-species which is larger than *P. hildebrandti*, produced more honey. No difference in average honey production was observed between the two morpho-species of *M. ferruginea*as their body sizes is similar. We can compare the annual amount of honey of the study stingless bee species to that of Neotropical stingless bee species (Cortopassi-Laurino *et al*., 2006).

Average annual production of honey in meliponiculture in Brazil among seven species from the genus *Melipona*varied from one to three litres, and from one litre to about four litres among three species of the genus *Scaptorigona* (Cortopassi-Laurino *et al.,* 2006). In our study, the species reared showed good potential for honey production comparable to some species promoted in Brazil for honey production through meliponiculture. *Meliponula ferruginea* (reddish brown) produced an average quantity of honey of 1.05 ± 0.07 litres, which is similar to *Melipona asilvai* and *Trigona angustula* (1.0 litres) in Brazil. *Meliponula ferruginea* (black) produced an average quantity of honey of 1.37 ± 0.08 litres, comparable to *Scaptotrigona postica* (1.5 litres) in Brazil. *Meliponula bocandei* produced an average quantity of honey of 3.13 ± 0.21 litres, similar to *Melipona rufiventris* (3.0 litres) and *Melipona scutellaris* (3.0 litres), but higher than *Melipona quadrifasciata* (2.0 litres), *Melipona fasciculata*(2.4 litres) and *Melipona subnitida* (2.5 litres) in Brazil. Honey production in *P. hildebrandti* species was lowest (0.7 ± 0.31litre) than the average annual production of honey among seven species from the genera *Melipona* and genus *Scaptotrigona* in Brazilian meliponiculture.

A large variation in honey composition was observed in this study among the different species of stingless bees. The average honey composition from the studied species varied from 25.35 to 26.57% for water content, 3.61 to 4.00 for pH, 241.19 to 338.79 meq/kg for proline, 16.88 to 39.88 Schades for diastase activity, 33.85 to 37.14 meq/kg for free acidity, 5.26 to 7.59 mg/kg for HMF and 64.17 to 69 °Brix for total sugar. Variation in the average physicochemical composition of honey from groups of stingless bee species was also reported for some species found in Brazil, Venezuela, Costa Rica, Trinidad and Tobago and Suriname. According to Souza *et al*. (2006), the physicochemical composition of the honey samples from Neotropical bees ranges from 19.9 to 41.9% for water content, 3.15 to 4.66 for pH, 0.9-23.0DN for the diastase activity, 5.9 to 109.0 meq/kg for free acidity, 0.4 to 78.4 mg/kg for HMF and 58.0 to 75 °Brix for the total sugar. Duarte *et al*. (2012) also observed a variation in proline values of honey (20.16 to 94.26 mg/100g) for four stingless bee species in the state of Alagoas in Brazil. Though, compared to the average physicochemical composition of the honey of the Neotropical bee species, the composition of the honey of *P. hildebrandti*, *M. bocandei* and the *M. ferruginea*morpho-species were at intermediate values reported by Souza et al. (2006) and Duarte et al. (2012). However, the proline value in honey of the species *P. hildebrandti* and the morpho-species *M. ferruginea* (reddishbrown) was higher than what was reported by Duarte et al. (2012) in Brazil.

Conclusion

We propose that the vertical compartmented *icipe*-4M hive be used as alternative to the log hives, as the tested stingless bee species accepted this hive design and produced honey had the composition that is comparable with honey of Neotropical stingless bees. The *icipe*-4M hive design can be used in Africa to solve the colony losses and reduced honey yields that stingless beekeepers face from using simple hollow log hives. The icipe-4M hive design has the advantage of improving and rationalizing the management of the domesticated stingless bees colonies mentioned in this study, as it provides better housing for the bees, increases the amounts of honey harvested, andfacilitates ease of colony multiplication, whichwill provide new opportunities for rural people. The *icipe*-4M hive does not have many loose parts (a parts from the two parts that are superposed vertically) and is easy to assemble for any farmer. The food storage chamber can be opened for inspection causing minimal trouble to the colony, or can be removed for harvesting honey without disturbing the brood nest and the involucres. The brood chamber is adequate and can house a large brood nest and with adequate food storage area. Farmers canincrease their colonies byadding a second empty brood chamber on top of the main brood chamber for colony to build up its brood.

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