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Energetic feedings influence beeswax production by *Apis mellifera* L. honeybees

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ABSTRACT. The effect of different types of energy feeding (sugar syrup, inverted sugar and juice of sugar-cane) on beeswax production and its economic feasibility are evaluated. Twenty beehives of Africanized *Apis mellifera* were selected, and five were used for each type of feeding. The treatments were T1 (sugar-cane juice), T2 (sugar syrup) and T3 (inverted sugar). Feedings was provided by Boardman feeders and the amount was adjusted according to consumption. A layer of beeswax was manually set up into the honeybee nest and beeswax built area was measured weekly. Total reducing sugar, calorimetry, dry matter and ashes of all feedings were analyzed. Data were analyzed by analysis of variance with Tukey's test to determine differences among averages. The average consumption of inverted sugar was significantly lower than that of other treatments. The highest beeswax production average occurred in the sugar syrup treatment. The highest average of ashes, dry matter and reducing sugar occurred, respectively, in sugar-cane juice, inverted sugar and sugar syrup. Sugar syrup may be an alternative energy source for beeswax production, although sugar-cane juice may be more profitable.

Keywords: beekeeping, economic viability, feed, honeybee.

Alimentação energética influencia produção de cera por abelhas *Apis mellifera* L.

RESUMO. Os objetivos do presente trabalho foram avaliar a interferência de alimentos energéticos na produção de cera e sua viabilidade econômica. Foram selecionadas 20 colmeias de abelhas *Apis mellifera* africanizadas, cinco por tratamentos, sendo: T1: Garapa; T2: Xarope de açúcar e T3: Açúcar invertido. Os alimentos foram fornecidos por meio de alimentador tipo Boardman e a quantidade ajustada em função do consumo. A produção de cera foi analisada semanalmente. Foram analisados os açúcares redutores totais, a calorimétrica, a matéria seca e as cinzas. Para a análise dos dados foi utilizada a Análise de Variância seguida do teste de Tukey. O consumo médio de açúcar invertido foi significativamente menor em relação aos outros tratamentos. A maior produção média de cera ocorreu no T2. O maior valor de açúcar redutor e calorimetria foram encontrados no T2, em comparação com os demais tratamentos. Por outro lado, o T2 apresentou o menor valor de cinzas. Para matéria seca, o maior valor foi encontrado em T3. Com relação à análise econômica, esta tornou-se mais viável como uso da garapa de cana-de-açúcar. Pode-se concluir que o xarope de açúcar pode ser uma alternativa para induzir a produção de cera em abelhas *Apis mellifera* embora a garapa seja economicamente mais viável.

Palavras-chave: apicultura, viabilidade econômica, alimentação, abelhas.

Introduction

The beeswax-producing glands are composed of class I cells in the epidermal regions where columnar cells are covered by a cuticle without any modifications, found only in worker bees. The workers use 6-7 kg of honey to produce 1 kg of beeswax. The development of these glands depends on age and feeding (Brown, 2010).

Beekeeping may cause social and economic impacts while contributing towards the maintenance and preservation of the ecosystems. The chain of beekeeping not only promotes job opportunities but also increases family income. Consequently, their life quality improves and they are encouraged to continuing living in rural areas (Wolff et al., 2009).

Bees need food reserves to develop their brood. It is common for beekeepers to lose their swarms during the nectar and pollen offseason since the bees, weakened by hunger, migrate for better conditions (Marchini et al., 2006). However, in regions where the production period is short, beekeepers have to stimulate beeswax production before blossoming to prepare the cluster productive period (Pereira et al., 2006). Thus, during this period, the beekeepers have to provide artificial feeding which ensures the continued development of the colony, prepare it to collect nectar, pollinate crops and increase the queen's production, which consequently increases the number of workers.

The effect of different energy feedings (sugar syrup, inverted sugar and juice of sugar-cane) supplied artificially to produce *Apis mellifera* beeswax and to study its economic feasibility was evaluated.

Material and methods

The experiment was conducted at the Beekeeping Area, located in Lageado Experimental Farm, Faculty of Veterinary Medicine and Animal Sciences, at the Universidade Estadual Paulista (UNESP), Botucatu, São Paulo State, Brazil, at 22º04'90"S; 48º02'40"W; altitude 623 m; Cfa climate.

Twenty beehives of Africanized honeybees were selected and placed in Langstroth hives, externally oil-painted light green, kept in numbered 50-cm racks for easy identification. The selected colonies were standardized as to brood and food, with seven frames of open and closed brood, two frames of food and one frame with thin layer of beeswax provided by the Beekeeping Area of the Faculty of Veterinary Medicine and Animal Sciences, at the Universidade Estadual Paulista (UNESP), Botucatu, São Paulo State, Brazil.

A thin layer of beeswax was placed on the beeswax nest wire frames to induce beeswax production. A third of the frames was covered with a thin layer of beeswax which was used to guide the bees' construction. The 20 selected beehives were divided into four treatments with five beehives for each energetic feeding:

Treatment 1: control – no artificial feeding.

Treatment 2: sugar-cane juice – the juice used was obtained from sugar cane collected at Lageado Experimental Farm of the UNESP, Botucatu, São Paulo State, Brazil.

Treatment 3: sugar syrup – the syrup was prepared with boiled filtered water plus commercial crystallized sugar, at a ratio of 1:1 (by weight).

Treatment 4: inverted sugar - the inverted sugar was purchased from Cosan Sugar and Alcohol, São Paulo, Brazil.

Beehives were fed by Boardman feeder, twice a week, one liter per beehive for 60 days. They were previously numbered for better data control and appropriate swarm feeding management.

So that the beeswax production could be measured, the framework was placed in the center of the nest, and a 35 x 18 cm layer was used. The construction area was measured weekly. The methodology was adapted from Lomele et al. (2010). The design used in each treatment with lateral support wires was stretched, forming 2 x 2 cm squares, which were counted, on both sides of the honeycomb, resulting in the total building area, as follows:

Building Area (cm^2) = Number of squares x 4.

Beeswax production of each treatment was collected and weighed weekly.

The physico-chemical analyses were carried out in the Chemistry Laboratory at Lageado Experimental Farm, Faculty of Veterinary Medicine and Animal Sciences, at the Universidade Estadual Paulista (UNESP), Botucatu, São Paulo State, Brazil. Total sugar reduction was performed according to Welke et al. (2008); calorimetric and dry matter was assessed according to Sodré et al. (2011); ashes were measured according to Sodré et al. (2007).

Inverted sugar rates were obtained from the Atrium Food Group. The sugar syrup was prepared by water supplied by the Urban Water Distribution Company of São Paulo (SABESP); sugar was provided by the Center for Advanced Studies in Economics (ESALQ/USP) and tartaric acid was bought at Mega (Laboratory products) store in Botucatu. Sugar-cane juice rates were calculated on the price of sugar-cane. One ton of sugar-cane costs US$ 43.85 and yields 700 liters of juice.

Results were compared by ANOVA, followed by Tukey's test, to check differences among means. They were statistically different when $p < 0.05$ (Zar, 1999).

Results and discussion

Table 1 shows consumption data of different energy source feeding. A lower consumption of inverted sugar (399.6 ± 279.5 mL) was reported, which differed significantly from the treatments sugar-cane juice (634.5 ± 134.1 mL) and sugar syrup (586.5 ± 185.6 mL).

The average construction area of beeswax is shown in Table 1. Significant differences were observed in the beeswax construction area when sugar syrup was used (720.5 ± 371.2 cm^2), which differed significantly from that of sugar-cane juice (424.8 ± 289.5 cm^2), but not from control and inverted sugar treatments.

Table 1 displays data from average beeswax production, in grams. There was a significant difference in the average production of beeswax with the sugar syrup treatment (24.4 ± 12.8 g) when compared with that of the other groups (12.3 ± 9.79, 9.45 ± 7.6 g and 11.6 ± 8.7, respectively for control and inverted sugar syrup).

Data for physic-chemical analyses are shown in Table 2. Significant differences were observed in the analysis of sugar-cane juice ashes (0.27 ± 0.02%) which differed significantly from sugar syrup ashes (0.01 ± 0.00%), but not from inverted sugar ashes (0.11 ± 0.04%).

Table 1. Average feeding intake (mL), average beeswax construction area (cm^2) and average beeswax production (g) in the different treatments (control, sugar-cane juice, sugar syrup and inverted sugar) in *Apis mellifera*.

	Control	Sugar-cane juice	Sugar syrup	Inverted Sugar
Consumption (mL)	-	634.5 ± 134,1a	586.5 ± 185.6a	399.6 ± 279.5b
Construction Area (cm^2)	499.3 ± 277.6ab	424.8 ± 289.5a	720.5 ± 371.2b	520.8 ± 351.0ab
Production (g)	9.7 ± 12.3a	9.4 ± 7.6a	24.4 ± 12.8b	11.6 ± 8.7a

Different small letters in the row indicate statistical differences between averages ($p < 0.05$).

Table 2. Physico-chemical analysis of different energy feedings (sugar-cane juice, sugar syrup and inverted sugar).

	Ashes (%)	Calorimetric (kcal kg^{-1})	Dry matter (%)	Reducing sugars (%)
Sugar-cane juice	0.27±0.02a	3903.0	15.94±0,00a	21.15±1,6a
Sugar syrup	0.01±0.00b	4155.0	53.84±0.41b	41.52±2.8b
Inverted sugar	0.11±0.04ab	3895.0	75.66±0.75c	0.82±0.0c

Different small letters in the row indicate statistical difference between averages ($p < 0.05$).

The calorimetric analysis revealed that sugar syrup had the higher value (4,155.0 kcal kg^{-1}) when compared to that in other feedings (3,903.0 kcal kg^{-1} in the syrup and 3,895.0 kcal kg^{-1} in the inverted sugar).

In the case of dry matter, treatments differed significantly concerning inverted sugar (75.66 ± 0.75%), with the highest percentage, when compared with sugar syrup (53.84 ± 0.41%) and sugar-cane juice (15.94 ± 0.00%).

The analysis of total reducing sugars showed a higher rate for sugar syrup (41.52 ± 2.8%), which differed significantly from sugar-cane juice (21.15 ± 1.6%) and inverted sugar (0.82 ± 0.0%).

Table 3 shows data related to different feeding costs.

Table 3. Economic analysis of different energy feedings (Sugar-cane juice, sugar syrup and inverted sugar) for beeswax production.

Parameters	Sugar-cane juice	Sugar syrup	Inverted sugar
Total Consumption (mL)	0.6345	0.5865	0.399
Costs L (US$)	0.06	0.51	1.45
Production costs (US$)	0.04	0.30	0.46
Beeswax Production(g)	9.45	24.21	11.6
Production US$ g^{-1}	0.004	0.01	0.04

Lower consumption of inverted sugar may suggest that this energy feeding was less competitive when compared with that of other feedings, perhaps due to the higher viscosity of inverted sugar which was provided to the beehives in full concentration.

Since dry matter rates for sugar-cane juice and sugar syrup were higher than those for inverted sugar, higher moisture contents were indicated. In fact, inverted sugar showed higher dry matter contents and consequently lower moisture rates. This fact interferes in feeding viscosities, once the moisture is inversely proportional to viscosity (Cui et al., 2008; Mendes et al., 2009; Yanniotis et al., 2006). Therefore, the sugar syrup and the sugar-cane juice had a lower viscosity which may have favored their consumption. Literature data showed inverted sugar 1.07 Pa-s (Gratão et al., 2004) and cane-sugar juice 0.002 Pa-s (Yusof et al., 2000) viscosity.

In the case of beeswax production, the sugar syrup is the most suitable energy food to induce *Apis mellifera* beeswax production. There were no significant differences between sugar-cane juice and sugar syrup consumption. However, sugar syrup yielded higher production.

Physico-chemical analyses showed that sugar syrup had higher calorimetric rates and total reducing sugars when compared to those of other treatments. Since bees needed energy from nectar or artificial feedings to produce beeswax (Brown, 2010), high wax production was due to a higher concentration of sugars and, consequently, to greater energy rates.

The production costs of one gram of beeswax using sugar-cane juice as feeding amount to US$ 0.004. Moreover, it costs US$ 0.01 for sugar syrup (3.1 times as much as sugar-cane juice) and US$ 0.04 for inverted sugar (9.9 times as much as syrup) to produce the same amount. Data suggest that sugar-cane juice is the most viable feeding for beeswax production.

Despite its high costs, sugar syrup still yields the best beeswax production (Table 1). Thus, 1.62 L of sugar-cane juice would be necessary to produce the same amount of wax from sugar syrup (24.21 g), taking into consideration sugar-cane juice consumption and beeswax production in this treatment.

Bee artificial feeding is extremely important, but it should be performed with appropriate technical knowledge. The beekeeper should avoid large leftovers in the beehive, since they may ferment, affect swarm development and cause losses. Thus, for sugar-cane juice supply of 1.62 L, which has a high fermentation potential, the beekeeper should provide two or three feedings a day.

The above management may have other costs such as fuel for access to the apiary. Evaluating these points, even the sugar syrup, which is not the most viable, becomes an interesting alternative to beekeeping.

Castagnino et al. (2006) state that supplementation is a tool that beekeepers must use to increase production of bee products and thus obtain higher profits. Pereira et al. (2006) observed that dietary supplementation may be an important tool for beekeeping since it improves egg laying and the production of bee products.

Conclusion

The sugar-cane syrup may be an alternative source of energy to induce *Apis mellifera* beeswax production, although the juice of sugar-cane is more profitable.

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