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How does invert sugar syrup affect sealed worker brood and colony strength in Roger-Delon hives?

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Abstract: Honeybees are the most valuable pollinators for ecosystems. This study aimed to determine the effects of inverted sugar syrup on the sealed worker brood and colony strength in Roger-Delon hives. The study was conducted in 2024, involving 14 Roger-Delon hives. The experiment was conducted at an altitude of 860 meters in the area of the town of Tran, Pernik region. Bee colonies were assigned to two treatment groups: inverted sugar syrup supplementation (experimental group with 7 bee colonies) and supplementation with sugar solution (control group with 7 bee colonies), at a rate of 250 ml per colony twice a week. In the present experiment with Roger-Delon hives, the bee colonies supplemented with inverted sugar syrup had significantly higher average values of sealed worker brood and colony strength, than those in the control group ($p<0.001$), following spring and autumn feedings. These results confirm that inverted sugar syrup is more effective supplemental feed for improving brood production in honeybee colonies, probably due to its higher digestibility. Further studies are needed over longer periods of time, as they could provide a deeper insight into the long-term effects of inverted sugar syrup on bee colony growth and productivity in Roger-Delon hives.

Keywords: honeybees; inverted sugar syrup; sugar syrup; colony strength; sealed worker brood; Roger-Delon hive

INTRODUCTION

Honeybees (*Apis mellifera* L.), are one of the most valuable pollinators for ecosystems. However, they are experiencing several challenges and stressors including habitat destruction, pesticides and nutritional deficiencies (El-Seedi et al., 2022; Papa et al., 2022; Ahmed, 2023). Nutritional deficiencies in honeybees can lead to lowered immunity and diminished strength of a colony (Branchiccela et al., 2019). Sugar syrup, as a replenishing food reserve in bee colonies, can be used. The enzyme invertase, which breaks down sucrose in the syrup into glucose and fructose, is produced by honeybees. These processes exhaust the bees and, in this case, inverted sugar syrup is a very good opportunity (Ceksteryte and Racys, 2006). The health and productivity of the bee colonies can be ensured with inverted sugar syrup. Beekeepers use inverted sugar syrup in response to stimulate the growth of the colonies during the times of lack of nectar in nature (Papežíková et al., 2020; Pridal et al., 2023; Hu et al., 2024). This is achieved by hydrolyzing sucrose into glucose and fructose via an enzymatic or acid inversion (Gómez-Brizuela et al., 2017). This process results in a syrup, whose composition is similar to nectar from the flowers, making the syrup easier to digest for honeybees. The inverted sugar syrup serves as energy for worker bees to create royal jelly and take care of larvae, thus improving the quantity and quality of sealed brood (Kartik and Singh, 2024). In beekeeping, inverted sugar syrup serves as a prime resource to support the bee colonies (Frizzera et al., 2020). Jachimowicz (1976) suggested that the usage of inverted sugar syrup for bees should only be done after checking the hydroxymethylfurfural (HMF) content in it.

The design and management of hive types, particularly the Roger-Delon hives, can play a considerable role in how bee colonies are able to collect and use the inverted sugar syrup as a dietary supplement. This, in turn, significantly affects the colonies' strength and their brood development. The hive design determines the productivity and sustainability of a bee colony. Among all the hive systems, the Roger-Delon are not the most popular in Bulgaria, but they have unique structural features. The Roger-Delon hive is well known for its modular design (Heaf, 2009; Birloiu et al., 2015). It is possible that these design aspects affect the behaviors of the colonies, their thermoregulation abilities and their resource consumption, which in consequence, affect the strength of the colonies and the development of brood (Cook et al., 2021).

Sealed worker brood and strength of the bee colonies are two parameters considered for estimating the productivity and wellbeing of the bee colony. These are interconnected since the health of a colony is usually linked to the successful completion of brood development, and the existence of sealed brood suggests the hive is functioning properly (Chaand et al., 2017). A large number of reports indicate that feeding trials are one of the primary aspects of apiculture research. Nonetheless, there is a lack of literature concerning Roger-Delon hives.

This study aimed to determine the effects of inverted sugar syrup on the sealed worker brood and colony strength in Roger-Delon hives. Enhanced understanding of this problem would enable beekeepers to improve hive management practices with this hive type.

MATERIAL AND METHODS

Study design

The study was conducted about 4 months in 2024, involving 14 Roger-Delon hives. The experiment was conducted at an altitude of 860 meters in the area of the town of Tran, Pernik region. The area has the characteristic pasture for mountain areas. The honey plants are mainly meadow plants. The colonies were equilibrated in strength and quantity of food reserves before the start of the experiment. Bee colonies were assigned to two treatment groups: inverted sugar syrup supplementation (experimental group with 7 bee colonies) and supplementation with sugar solution (control group with 7 bee colonies).

Nutritional supplementation

The bee colonies in the experimental group were fed with inverted sugar solution prepared as follows: 7.5 kg of sugar dissolved in 2.5 litres of water. The resulting supersaturated solution was stirred and allowed to reach a temperature of 38°C. To the resulting solution, 1.8 kg of pure honey was added. While maintaining the temperature, the solution was stirred for 15 minutes at two three-hour intervals for about 7 days. The inverted sugar solution was given to the experimental colonies at a rate of 250 ml per colony, twice a week, from the beginning of the main spring inspection (at the beginning of April), until the first main pasture (spring feeding) in June. Autumn feeding is designed to stimulate queen egg-laying in order to optimise the number of physiologically young bees that successfully overwinter. It starts at the beginning of August and lasts until October.

The colonies in the control group are fed with a sugar solution (sugar:water = 1:1). The feeding of the colonies in this group was the same as that of the experimental group: 250 ml of sugar solution per colony, given twice a week.

Inverted sugar syrup and the sugar solution were provided to the treatment groups using hive-top feeders.

Determination of hydroxymethylfurfural (HMF) in inverted sugar syrup

The concentration of hydroxymethylfurfural in the inverted sugars syrup was established after White (Bogdanov et al., 1997). The analysis was conducted 1 day after the preparation of the product.

Data collection

Determining the sealed worker brood (Number of cells).

The assessment of sealed worker brood was conducted utilizing a measuring frame that had been

demarcated into 5 × 5 cm squares, with each square thus representing an area of 25 cm^2. Assuming that one square centimeter of comb contains approximately four worker cells, it can be deduced that each 5 × 5 cm square corresponds to a total of 100 cells (Delaplane et al., 2013). Sealed worker brood was measured during a period of 12 days.

Determining the strength of bee colonies (g)

The strength of the bee colonies was measured individually by shaking the bees off the frames into a polyethylene bag and weighing them on an electronic scale. The bees were then returned to the hive.

The strength of bee colonies was measured on two occasions: the first measurement was taken in the middle of April (spring), and the second measurement in the middle of October (autumn).

Statistical analysis

The results were processed with the SPSS 23.0 program for Windows. The data are presented as mean ± standard deviation for each period. Student's t-test was used to determine the significance of the differences. Level of statistical significance was defined as $p<0.001$.

RESULTS AND DISCUSSION

High levels of HMF indicate excessive heating or prolonged storage, which can affect the taste, color, and nutritional value of the syrup. The concentration of HMF in the inverted sugar syrup is between 7 – 11 mg/kg. This concentration is not toxic for the adult honeybees.

Sealed worker brood

The development of sealed worker brood is a critical indicator of colony health and productivity. It reflects the colony's capacity to produce new generations of worker bees. These bees are essential for foraging, hive maintenance and the overall survival of the colony. In this study, the development of sealed worker brood was compared between a control group fed with sugar solution and an experimental group fed with inverted sugar syrup over spring and autumn feeding of the bee colonies settled in Roger-Delon hives.

The sealed worker brood in the control and experimental groups showed consistent development and stable brood density in Roger-Delon hives. The sugar solution provided a sufficient energy source for the colony to maintain brood rearing. This result indicates that the sugar solution met the main needs of the colony, but did not optimise brood production. Supplementation with invert sugar syrup resulted in a significant increase in the average values of sealed worker brood area, compared to the control group ($p<0.001$) from 15.04 to 02.06 after spring feeding (Fig. 1). Furthermore, the experimental group showed a significant improvement in brood de-

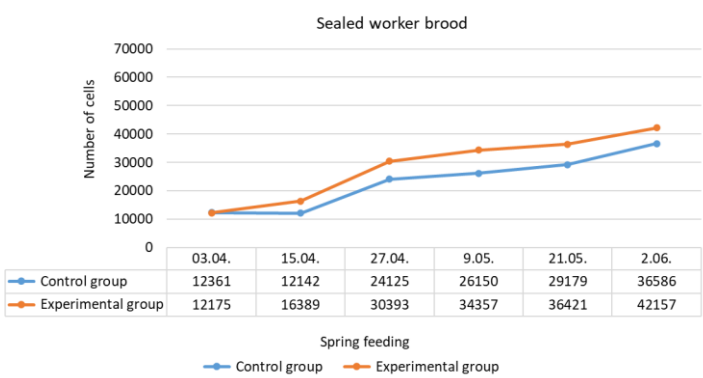

Figure 1. Sealed worker brood of the control and experimental in spring feeding

Legend: values are significant at p<0.001 from 15.04. to 2.06.

velopment. The inverted sugar syrup is more digestible and energy rich and probably stimulated the bees to produce more brood.

Brood development is very important for the bee colony health, directly influencing population growth and hive productivity. Figure 2 presents the sealed worker brood after the autumn feeding. On 17 August, the highest average values in the control and experimental groups were 54700 and 63289 Number of cells, respectively. After this date, the brood starts to decrease, which is a normal process at the end of the season.

Figure 2 shows the sealed worker brood after autumn feeding. Significant differences are found between the average sealed worker brood values from the experimental group ($p<0.001$), compared to the average values from the control for each date from 5 August to 4 October (Fig. 2). Data show that the highest average values were presented on 17 August. On this date, the control group has 54700 Number of cells and the experimental group has 63289 Number of cells (average value). After this date, the brood begins to decline, which is a normal process at the end of the season. This decline is typical as the bee colony prepares for winter, reducing brood production in response to declining temperatures and reduced food availability.

Hive design affects a lot of parameters, including temperature regulation and brood rearing efficiency. Roger-Delon hives feature a modular design with removable frames. Figure 3 shows a Roger-Delon frame fully covered with a sealed worker brood. A frame that is fully covered with sealed worker brood in a Roger-Delon hive is an indicator of a strong colony. This demonstrates effective queen performance and optimal hive conditions for brood development.

According to Ceksteryte and Racys (2006), the highest number of brood was found in colonies fed with Pchelit (inverted by yeast) sugar syrup for overwintering, compared to colonies

Figure 3. Frame fully covered with sealed worker brood in Roger-Delon hive

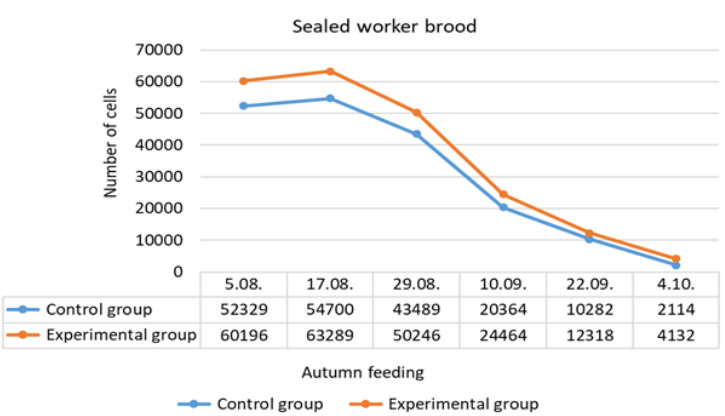

Figure 2. Sealed worker brood of the control and experimental in autumn feeding

Legend: values are significant at $p<0.001$ from 05.08. to 4.10.

fed with sugar syrup. Eşanu et al. (2018) also obtained higher values for brood after feeding on inverted sugar syrup, compared to the control group fed on sugar syrup. On the other hand, Pridal et al. (2023) found no statistically significant differences between the inverted and sucrose groups for all five growth parameters, including colony brood ($p>0.05$).

Strength of the bee colonies

A strong colony will have a high number of worker bees, which are essential for foraging, rearing the brood and maintaining the hive. The queen's egg-laying capacity directly influences population growth, making her health and productivity a key factor in colony strength.

Figure 4 presents the strength of the bee colonies measured in the middle of April and in the middle of October.

The findings demonstrate that inverted sugar syrup significantly enhances colony strength ($p<0.001$) in Roger-Delon hives, compared to the control group in the autumn measurement. The modular structure of the hive system under investigation may provide adequate access to supplemental feed, thus resulting in increased colony strength. Birloiu et al. (2015) state that the bee colonies reared in Roger-Delon hives have approximately 2.20 kg of bees in October. This value is higher compared to the values in the present study. The combination of the hive design with nutritional support could optimize colony health and productivity.

There is a relationship between the strength of the bee colonies and the sealed worker brood. A strong bee colony with a high proportion of worker bees is better able to care for the brood. On the other hand, more sealed brood makes the colony stronger, because it ensures a steady supply of new bee workers. This statement is confirmed by Al Ghamdi (2005). The author found a positive correlation between colony strength and percentage of eggs hatched and sealed brood in all three honeybee races. In another study, a significant positive correlation between colony strength and brood quantity ($r=0.442$) was found by Gabka (2014).

CONCLUSION

In the present experiment with Roger-Delon hives, the bee colonies supplemented with inverted sugar syrup had significantly higher average values of sealed worker brood and colony strength, than those in the control groups ($p<0.001$) following spring and autumn feedings. These results confirm that inverted sugar syrup is more effective supplemental feed for improving brood production in honeybee colonies, probably

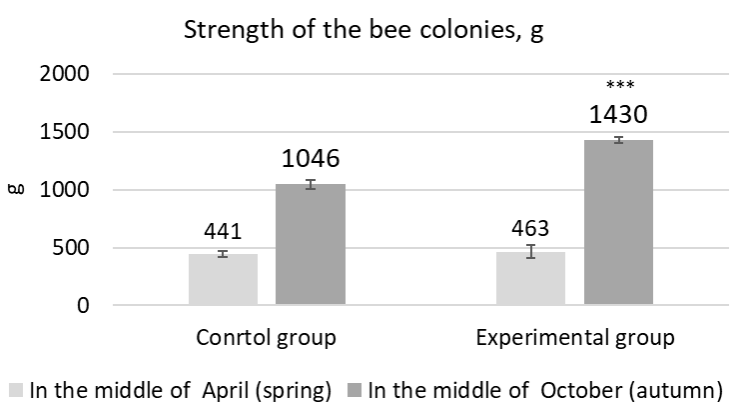

Figure 4. Strength of the bee colonies measured in the middle of April and in the middle of October

*Legend: *** value is significant at $p<0.001$*

due to its higher digestibility. Further studies are needed over longer periods of time, as they could provide a deeper insight into the long-term effects of inverted sugar syrup on bee colony growth and productivity in Roger-Delon hives.

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