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COMPARISON OF TIME CONSUMPTION BETWEEN TRADITIONAL AND INNOVATIVE METHODS OF PRODUCING QUEEN CELL CUPS

Slobodan Dolasevic[1], Bogdan Cekic[1], Nenad Stojiljkovic[1], Nenad Micic[1], Milos Marinkovic[1], Maja Petričevic[1], Ratko Pavlovic[2]

[1] Institute for Animal Husbandry, Autoput Beograd-Zagreb 16, Zemun, 11080 Belgrade, Serbia
[2] Department of Biochemistry, Faculty of Chemistry, University of Belgrade, Studentski trg 12–16, 11000 Belgrade, Serbia
Correspnding author: Slobodan Dolasevic, dolasevicslobodan.izs@gmail.com

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Abstract: The production of high-quality honey bee queens is one of the most important beekeeping operations, considering the key role of the queen in the colony. On the other hand, queen rearing is a highly challenging process, so the simplification of certain production segments would represent a significant advantage. In this paper, we examined and compared the traditional method of producing wax queen cell cups using a wooden mold with an innovative method that involves the use of a silicone mold together with a specially designed cell bar. The comparison of efficiency between the tested methods was carried out through the measurement of time consumption for both methods. Our results indicate that the production of queen cell cups using the innovative method is 2.66 times faster compared to the traditional method. In addition, we examined the differences in queen cell cup height obtained by the traditional method, which showed high variability, ranging from 8.1 mm to 15.9 mm, unlike the innovative method in which queen cell cups were uniform and measured 11 mm. On professional apiaries, where there is a high demand for the production of honey bee queens, queen cells, and royal jelly, our innovative method can significantly facilitate production by accelerating the process of producing queen cell cups, while at the same time ensuring the uniformity of the produced cell cups. Also, using a specially designed cell bar allows all queen cells to be added or removed at once from the grafting frame and provides the possibility of simple individual separation of the queen cells.

Key words: queen cup, queen cell, wax, queen production

Introduction

The honey bee queen is crucial for colony survival and functioning due to her high egg-laying capacity and pheromonal regulation of social cohesion (Amiri et al., 2017). Beekeepers have developed techniques for rearing large numbers of young queens, which are used to replace old ones, as young queens enhance productivity and reduce swarming (Tarpy et al., 2000; Wu et al., 2018; Büchler et al., 2013; Akyol et al., 2008; Gatoria et al., 2004a). Most queen rearing methods require queen cell cups as holders for grafted larvae. Cup size affects queen quality parameters such as body weight, thorax size, and number of ovarioles (Wu et al., 2018), and may also influence grafting acceptance (Mattiello et al., 2022). In nature, queen cells are 8–10 mm in diameter, while plastic cups commonly measure about 9.4 mm (Büchler et al., 2013; Shi et al., 2011).

The grafting process and artificial queen rearing have been practiced since the 19th century (Doolittle, 1889). Early systems used wax cups, the basis of today's production (Büchler et al., 2013). In recent decades, synthetic materials such as plastic cups have been introduced (Laidlaw & Eckert, 1962; Warren et al., 1982; Abou-Shaara et al., 2024), along with devices such as Karl Jenter, Cupkit, and Nikot (Gatoria et al., 2004b; Wakijra et al., 2019). While useful, these systems face limitations in intensive production due to their small capacity (up to 150 cups), making large-scale use impractical (Sena et al., 2010; Dhaliwal et al., 2019). In contrast, queen isolation on standard frames provides several hundred to several thousand larvae for grafting into wax cups.

Wax is still commonly used in queen production for making cell cups, as it has shown good results in terms of larval acceptance (Lashari et al., 2022). Even with plastic cups, wax is required for attachment or rim coating to improve acceptance (Ruttner, 1983; Woodward, 2007; Büchler et al., 2013). However, preparing and attaching cups to cell bars is time-consuming and slows down production. Since commercial operations depend on efficiency, high productivity and time saving are essential, although most beekeeping is still carried out by small-scale or hobbyist beekeepers. Commercialization of queen rearing requires mass production of large numbers of high-quality queens (Hatjina et al., 2014; Büchler et al., 2013).

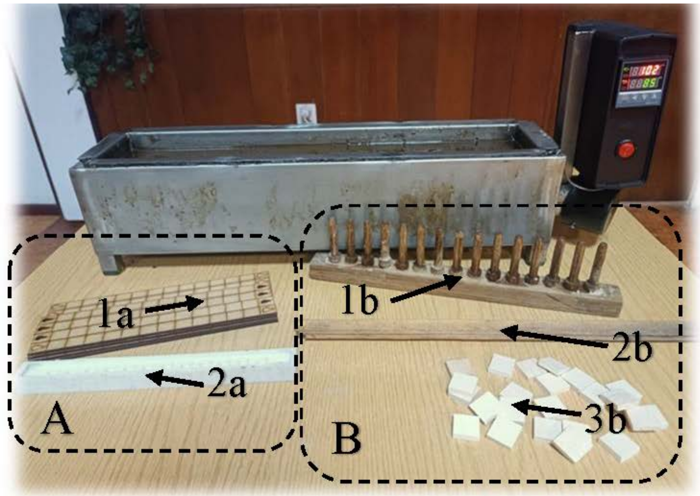
Many studies have examined the effects of queen morphology, nutrition, and rearing method on colony productivity (Skowronek et al., 2004; Akyol et al., 2008; Dolasevic et al., 2020). However, it should be kept in mind that the api-technique and the method of queen rearing are very important in intensive queen production, especially if it affects the speed and quality (improvement) of certain production segments. In this paper, we present an innovative method for producing queen cell cups and compare it with the traditional approach. High productivity and time saving are especially important in large and intensive production. It is important to point out that commercial beekeeping operations usually represent only a minor share of the overall beekeeping sector, as the majority of beekeeping operations are carried out by small-scale or hobbyist beekeepers.

Materials and Methods

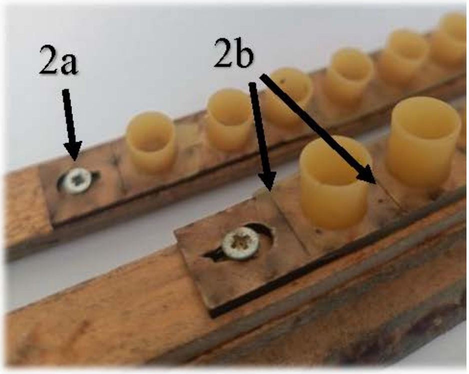
In this study, we examined the time consumption between the traditional and the innovative method of obtaining queen cell cups. During the experiment, we conducted comparative testing of the two technological processes, followed by analysis in order to determine the time differences and potential advantages.

The first technological process, the innovative method, involved the use of a new approach (Picture 1, A) consisting of a silicone mold (Picture 1, 2a) in combination with specially designed cell bars (Picture 1, 1a). The entire process included the simple pouring of melted wax (using a syringe) into the silicone mold. In our case, after pouring the wax into the silicone mold, a specialized cell bar was added to the top of the silicone mold, in the designated position. The placement of the specialized cell bar represents the final step, since all queen cell cups are simultaneously formed and attached to the specialized bar. At the ends of the specialized bar there are two conical openings (Picture 2, 2a) which allow direct attachment to the frame on cell bar. The attachment of the cell bar is ensured with two screws that provide a secure hold. The bar is cut with slots spaced at equal distances (containing segments) (Picture 2, 2b). The specialized bar contains a total of 12 segments designed for wax cell cups.

The second technological process, the traditional method, consisted of using a wooden mold, which is among the most commonly used methods for obtaining wax cups (Picture 1, B). The wooden mold (Picture 1, 1b) must be kept (soaked) in cold water before work begins, after which it is dipped into melted wax. The ideal dipping depth is 10–11 mm, with each subsequent dipping being shallower than the previous one. In our experiment, dipping was performed twice (in wax as well as in water) in three successive dips. The obtained wax cups were attached (glued with wax) with a syringe onto individual wooden holders (Picture 1, 3b), which were then attached to the cell bar (Picture 1, 2b).



Picture 1. Preparation for production of queen cup bases using different methods (A – Innovative method; B – Traditional method)



Picture 2. Principle of attaching the specialized bar to the frame bar in the innovative method

During the process of obtaining and attaching wax cups, we monitored the time consumption for each individual operation (T) in both tested methods.

Traditional method included:

Time required for obtaining (production) wax cups with a wooden mold (T1)
Time required for waxing (sticking) wooden holders to the cell bar (T2)
Time required for waxing (sticking) cups onto wooden holders (T3)

Innovative method included:

Time required for pouring melted wax in the silicone mold and adding the specialized bar (T4)
Time required for removing the specialized cell bar with cups from the silicone mold (T5)

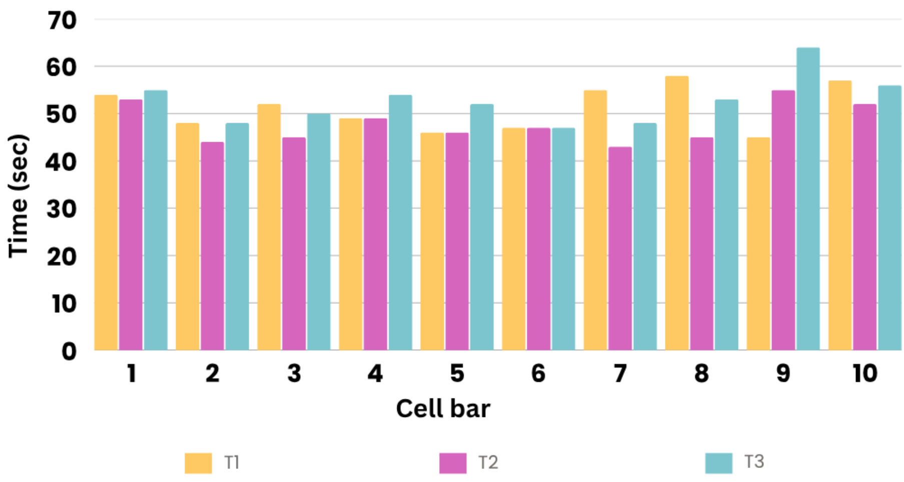
The mounting/attaching of the specialized cell bar with cups was not monitored because the specialized cell bar is mounted instantly — it simply slides onto two screws, allowing all queen cups to be positioned immediately. Time measurement for parameters T1–T5 was conducted after complete preparation (e.g., reaching the proper wax temperature, prior cooling of the wooden mold in water, etc.). In this way, preparatory activities were not taken into account; the efficiency of work was measured from the moment the process began. Time consumption for the listed parameters was calculated per cell bar containing 12 wax cups, expressed in seconds.

We also measured the height of queen cell cups obtained by both tested methods. The measurement of heights was carried out using a digital caliper from the outer side of the queen cup base. The total number of measured cups was 30.

The set temperature for obtaining cups with the wooden mold was 85 °C, while for obtaining cups with the silicone mold the temperature was 105 °C. Wax melting was performed in a special wax melter with digital temperature regulation, used for both methods. During wax heating, the temperature must not exceed 140 °C (Bogdanov, 2016). Sticking of wax cups and wooden holders was carried out with a 20 ml syringe (also at 105 °C). The wax used in the experiment was obtained by re-melting wax from honey cappings, characterized by high quality.

Results and Discussion

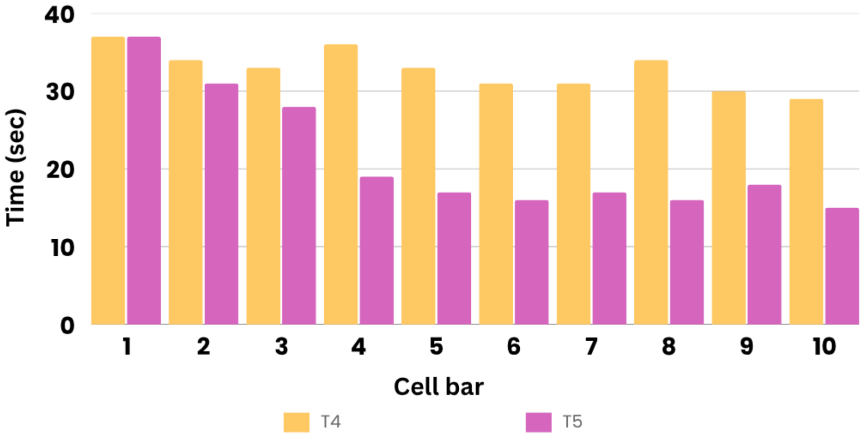
In Graph 1, the values of time consumption (T) using the traditional method are presented.



Graph 1. Time consumption expressed (sec) for the traditional method (T1 – time required for making 12 queen cell cups; T2 – time required for sticking wooden holders to the cell bar; T3 – time required for sticking cups onto wooden holders)

The values of time consumption (T1-T4 parameters) were carried out in 10 repetitions, with one cell bar containing 12 wax cell cups representing a single repetition (Σ = 240 wax cell cups). The average time consumption for making 12 cell cups using the traditional method was 51.1 seconds, the average time for sticking 12 wooden holders was 47.9 seconds, and the time required for sticking 12 cell cups to the wooden holders was 52.7 seconds. Accordingly, the total time consumption for the traditional method amounted to 151.7 seconds for the complete process per one cell bar.

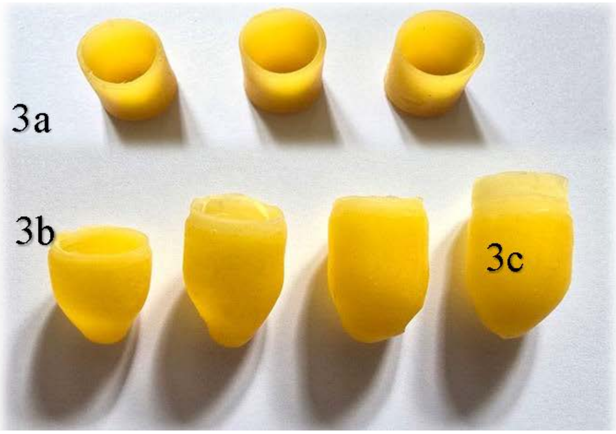
In Graph 2, the values of the time spent (T4 and T5) when using the innovative method are shown. Graph 2 presents the average values of ten independent measurements (i.e. cell bar), which represent the average time spent for 12 cell cups.



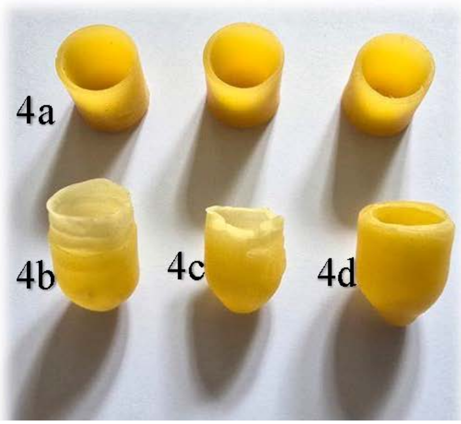
Graph 2. Time consumption expressed (sec) for the innovation method (T4 – time required for pouring melted wax in the silicone mold and adding the specialized bar; T5 – time required for removing the specialized cell bar with cups from the silicone mold)

The average time required for filling (pouring) the silicone mold (T4) was 32.8 seconds. The average time required for removing the cell bar with cups from the silicone mold (T5) was 21.4 seconds. The total time consumption with the innovative method was 56.9 seconds for the entire procedure per cell bar.

Furthermore, regarding the uniformity of queen cell cups, the innovative method produces bases that are completely uniform, which is achieved through the use of a silicone mold. Thus, the height of all queen cells obtained by the innovative method is consistent, measuring 11.0 mm (Picture 3, 3a). Contrary, the use of the traditional method primarily results in variation in the height of queen cell cups (Picture 3, 3b, 3c).



Picture 3. Differences in the size of cell cups (3a – innovative method, uniform cell cups; 3b, 3c – traditional method, 3b – smaller cell cup 3c – traditional method, larger queen cell cup).



Picture 4. Differences in the appearance of cell cups (4a – innovative method, uniform queen cells; 4b, 4c, 4d – traditional method, 4b – thin upper part of the queen cell; 4c – damaged edge; 4d – thick wall of the queen cell).

Moreover, with the traditional method, the appearance of queen cells largely depends on the individual producing them, since it is challenging to dip the wooden mold to the exact same depth in the wax melter each time, as the entire process is performed manually. As a result, various abnormalities occur in queen cells obtained by the traditional method, such as differences in wall thickness, damage caused during removal or handling, and other irregularities (Picture 4).

The following table (Table 1) presents the values of the height of the cell cups produced by the traditional method.

Table 1. Differences in the height (mm) of queen cells obtained using the traditional method

Queen cell	Height (mm)	Queen cell	Height (mm)	Queen cell	Height (mm)
1.	9	11.	12	21.	12
2.	13	12.	10	22.	13
3.	14	13.	14	23.	11
4.	11	14.	16	24.	16
5.	11	15.	9	25.	12
6.	14	16.	12	26.	11
7.	12	17.	14	27.	9
8.	13	18.	8	28.	10
9.	15	19.	12	29.	12
10.	9	20.	15	30.	13

The height of queen cell cups produced by the traditional method ranged between 8 mm and 16 mm, with a mean value of 12.0 ± 2.1 mm (SD = 2.17). The high coefficient of variation (17.5%) indicates significant inconsistency in cup height produced by the traditional method. Unequal queen cell height can be inappropriate, as bees are less likely to accept large or very small queen cell cups, resulting in lower acceptance rates. In addition, during the storage and handling of fragile cell bars (with queen cell cups), large cell cups are often damaged, leading to cracking and falling off the cell bar. This highlights that the traditional method should be standardized to improve the quality and efficiency of queen cell production.

By comparing all data of the tested methods, it can be concluded that the time savings with the innovative method is 2.66 times greater compared to the traditional method. This time saving indicates that the innovative method significantly increases productivity, which is very important in a large-scale beekeeping companies where it is often necessary to make tens of thousands of cell cups every year. Our innovative method directly results in greater efficiency in commercial beekeeping production of queen bees, queen cells or royal jelly.

In addition to the above, the presented innovative method has certain technical advantages (such as easier maintenance of the silicone mold compared to the wooden mold, uniformity of all obtained cell cups, and faster production of cell cups), as well as specific beekeeping (apitechnical) advantages (simplified handling during grafting since all queen cells are positioned on a specialized cell bar, one-step placement and removal all cell cups (queen cells) from the specialized cell bar, and the possibility of separating each individual queen cell by simply bending (cracking) the specialized bar). Silicone molds are inexpensive and highly durable, often lasting for many years if used properly. They do not require cleaning from wax residues, as wax does not adhere to silicone surfaces in the same way it does to wooden molds. These characteristics contribute to reduced maintenance time and long-term cost-effectiveness in queen cell production.

It should be mentioned that there are silicone molds (available today) that allow the making of individual wax cups, but individual production of queen cell cups is not a solution for intensive production since the process is very slow. In contrast, the specialized bar in our innovative method serves as a common holder for all queen cups, which eliminates the entire procedure of individual production of cups, their attachment to wooden holders, as well as attaching the wooden holders to the cell bar. In this way, the specialized bar enables one-step addition and removal of queen cell cups or ripe queen cells.

The bar contains slots spaced at equal distances, which allow that, with a simple slight bending, the segments of the specialized bar can be separated, enabling easy detachment of ripe (individual) queen cells. This structural advantage simplifies further manipulation during the rearing process.

When using the traditional method with a wooden mold, it is important to emphasize that multiple dips are necessary to ensure the required thickness of the cup walls (Gupta et al., 2014). Although the wooden mold we applied contained fifteen “fingers,” only twelve were used in our investigation in order to ensure comparability with the silicone molds.

Finally, the quality of the wax is an important factor influencing the success of obtaining queen cell cups. Wax originating from old comb may contain a significant amount of cocoons, feces, propolis, and pollen (Svečnjak et al., 2019), and therefore should be avoided for the production of wax queen cell cups.

Conclusion

The presented method of using a silicone mold and a specialized cell bar can greatly simplify work and increase the efficiency of queen cell cup production. The method of producing queen cell bases using the standard approach (with a wooden mold) requires considerable time and effort, with the final outcome being non-uniform queen cells obtained through a time-consuming process. For this reason, this type of wooden mold does not meet the requirements of intensive beekeeping operations.

The results presented here are part of a broader study that will also assess additional quality parameters. However, this study primarily focused on the efficiency of the production of queen cell cups themselves. Future research will include the integration of the specialized cell bar into the complete rearing system at the apiary, with the aim of examining its overall impact on production efficiency, the amount of wax needed, and the strength of adhesion between the queen cell cups produced by both examined methods. These parameters will contribute to a more comprehensive understanding of all the advantages of the presented innovative method.

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Conflict of interest
The authors declare no conflicts of interest.

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