Pilot study findings of the vibration cleaning process of honeycombs

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Abstract. The paper outlines the technique and shows the findings of a multifactorial study. It is connected with the working process of a vibrating unit designed for the non-destructive removal of organic components, mainly beebread, from honeycombs. The honeycombs should be cleaned from the beebread prior to their reheating (in case of their rejection), or for reuse as nest-based honeycomb frames. The aim of the experiment described in the paper is to establish the influence of the main operating parameters of vibration cleaning of honeycombs such as the frequency and amplitude of vibration on the productivity of the workflow. The study was performed on a specially manufactured laboratory unit consisting of a shaking table, controls, measuring devices and sensors. The specific feature of the conducted study is the uneven intensity of beebread extraction from honeycomb cells during the working cycle, which should be considered during the experiment.

1. Introduction
The absence of foreign impurities is essential for the use of honeycombs as wax raw materials [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]. Frequently rejected honeycombs are heavily polluted with bee waste products: beebread, bee glue, fragments of cocoons remaining from the brood, etc [12, 13, 14, 15,]. The main share among organic pollutants is taken by beebread [16, 17, 18, 19, 20, 21, 22]. Its content in honeycombs can be hundreds of percent of their net weight. During the reheating of such honeycombs, the melted wax remains on the surface of the beebread particles and is absorbed into it. The amount of bound wax remains in the waste grows, and the quality of the melted wax reduces [23, 24, 25, 26]. We have suggested various techniques and motorized means of cleaning wax raw materials before reheating [27, 28, 29]. One of such solutions is non-destructive vibration cleaning with the use of a vibration unit developed by us [30].

The aim of the study is to identify the influence of the main operating parameters of vibration cleaning of honeycombs such as the frequency and amplitude of vibration on the productivity of the workflow. For achievement of the aim it is required to solve the following research tasks: 1) identify the rational value of the amplitude and frequency of the vibration effect exerted on the wax base of the honeycomb; 2) to identify the rational value of the vibration exposure time, at which the wax base maintains its integrity (does not collapse); 3) to identify the possible percentage yield of extracted organic pollutants at rational values of the amplitude, frequency and time of vibration exposure.
2. Materials and methods
The laboratory unit for vibration cleaning of honeycombs from pollution consists of a shaking table, controls, measuring devices and sensors (figure 1).

![Figure 1](image)

**Figure 1.** A laboratory unit for vibration cleaning of honeycombs from pollution: a – shaking table diagram; b – general view of the unit during testing.

Conventional symbols: 1 – immovable frame; 2 – moving frame; 3 – honeycomb holder; 4 – roller ways; 5 – spring pad; 6 – electric vibration exciter; 7 – discharge neck; 8 – a set of storage tanks; 9 – oscillograph; 10 – laboratory transformer; 11 – supply unit; 12 – measuring devices for the removal of electrical parameters (M-838).

The frame with honeycombs is fixed in the honeycomb holders 3 (Fig. 1), and the unit is activated. The amplitude and frequency of vibration were controlled by changing the supply voltage using laboratory transformer 10 and mounting various eccentrics on the shaft of the vibration exciter 6. The frequency and amplitude of the oscillations were measured using an oscillograph 9 (Fig. 1).

In order to perform the study, the dried honeycombs were used, rejected by beekeepers during the formation of a bee nest for the winter. The honeycomb frames taken from apiaries of various districts of the Ryazan region were set up on shelves located in heated rooms and kept in such conditions for 1.5-2 months. As a result, the humidity of contamination in the honeycombs reduced to 6-11%. In the existence of “fresh honeycombs”, they were dried convectively to the required value of importance. The humidity of the contamination was detected according to the standard technique for determining the humidity of beebread (TU 10 RF 505-92).

The preliminary tests allowed us to identify factors that considerably affect the process under study. For example: the frequency of vibrations; the amplitude; the duration of the vibration effect on the honeycomb. As an optimization criterion, pp percentage of extracted pollutants is taken \( P \), %; cleaning process performance \( Q \), kg/h. As a result of preliminary studies, it has also been found that the time after which the wax base is destroyed depends on the frequency and amplitude of vibration. At frequencies of 60-90 Hz, destruction is rapid, while a sufficient amount of untreated beebread remains in the honeycombs. At a frequency of 30 Hz, the wax base preserves its integrity for a long time, and a potentially possible amount of beebread is extracted before destruction. In connection with the abovementioned, it is not practicable to perform a two-factor regression analysis of the percentage of extracted contaminants depending on the vibration mode according to the experimental obtained data.

The study was performed at three different values of the vibration amplitude: 0.5; 1.25 and 2 mm. In the process of vibration cleaning of honeycombs, the time of vibration exposure to the honeycomb

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frame was calculated; then, by weighing the extracted pollutants on laboratory scales VLKT-500M, the number of extracted pollutants was defined; the percentage of extraction and the productivity of the cleaning process were identified.

The findings of preliminary experiments have demonstrated that the productivity of bee bread granules extraction is not the same throughout the entire cycle of vibration cleaning. Thus, in order to measure performance at different time intervals, the cleaning cycle was split into control intervals of the same duration. It was 20 seconds. During an interval, the bee bread granules extracted from the honeycombs, passing through the discharge neck, accumulated in a separate container (fig. 1, pos. 8). After each interval, the capacity was changed. Therefore, the amount of parchment extracted during one control time interval was calculated. The dimension was stopped when the bee bread ceased to come out of the discharge neck, or when the honeycombs were destroyed. Hence, for each experiment (for each honeycomb frame), the number of intervals is a variable value. The remaining bee bread in the honeycomb was extracted manually. The amount of bee bread in each control container and the amount of bee bread extracted manually from the honeycombs were weighed on a scale.

Percentage of extracted pollutants \( P_i \) (%) in each control tank; it means that the \( i \)-th time interval was calculated by the formula:

\[
P_i = \frac{m_i}{m_p + \sum_{i=1}^{n} m_i} \times 100,
\]

where \( m_i \) – mass of extracted pollutants in \( i \)-th tank, g;
\( \sum_{i=1}^{n} m_i \) – the total mass of the extracted bee bread for the entire cycle, g;
\( m_p \) – mass of pollutants extracted manually, g;
\( n \) – number of intervals per 1 cycle (frame, test).

Percentage of granules \( P \) (%), extracted in one working cycle, characterizes the cleaning quality of a separate honeycomb and is resolved by the expression:

\[
P = \frac{\sum_{i=1}^{n} m_i}{m_p + \sum_{i=1}^{n} m_i} \times 100
\]

Since the bee bread content in the honeycombs varies widely – from 50 to 800 g [1, 2, 15], the mass yield of the extracted pollutants, both total and within the control time intervals, will also be different for varying honeycombs. Thus, when determining the performance of the vibration cleaning process, it is reasonable to choose not a weight indicator as a unit of measurement of productivity, but a percentage per unit of time. Therefore, the vibration cleaning performance at each cycle interval \( Q_i \) (\% per second) will equal to:

\[
Q_i = \frac{P}{\tau},
\]

where \( \tau \) – duration of an interval (\( \tau = 20 \) sec).

The tests were performed with a 5-fold repetition (for 5 cells with varying degrees of contamination with bee bread) at different values of the frequency and amplitude of vibration.

3. Results and discussion
During the experiment, the vibration effect was prolonged until the honeycomb was destroyed, while the time of preserving the integrity of the wax base was fixed. Figure 2 represents a histogram describing the percentage yield of the bee bread from the honeycombs at various time intervals \( i \) of the vibration action process at a frequency of 30 Hz and the value of the oscillation amplitude of the frame with the honeycombs equal to 2 mm.
Figure 2. Beebread output at a frequency of 30 Hz and an amplitude of 2 mm.

This histogram demonstrates that the most intensive removal of beebread granules from the honeycombs occurred during the first 20 seconds of vibration exposure. The following cleaning of the honeycombs occurs with a gradual slowing down of the rate of leaving the cells of the honeycomb cells, and within 3.5 ... 4 minutes the main mass of pollutants is extracted – 80-87% of the total beebread content in the honeycombs.

Then the total pollution output (accumulated percentage) was estimated in each control time interval. According to the obtained data, regression models are constructed determining the dependence of the total percentage of pollution yield on the time of vibration exposure at a frequency of 30 Hz and amplitudes of 2, 1.25 and 0.5 mm:

\[
P_2(t) = -10.144 + 17.723 \cdot \ln(t) \\
P_{1.25}(t) = -17.424 + 18.906 \cdot \ln(t) \\
P_{0.5}(t) = -19.0 + 18.447 \cdot \ln(t)
\]

if the corresponding values of the determination coefficient are 0.998; 0.995 and 0.994. The obtained analytical relationships are shown graphically in Figure 3.
Figure 3. Dependence of the overall (total) percentage $P$ (%) of removed pollutants on the duration $t$ (sec) of vibration exposure at a frequency of 30 Hz and various amplitude values.

4. Conclusions
It follows from the analysis of the obtained dependences that at small values of the amplitude of the vibration effect (0.5 mm), the total percentage of extracted pollutants stabilizes at the level of 80% 4 minutes after the beginning of the cleaning process. If the amplitude increases to 2 mm, the indicator rises to 85-87%. The vibration cleaning of honeycombs is appropriate to be done at a vibration frequency of 30 Hz.

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