ТҮЙІН

Зерттеу Қазақстан Республикасының әртүрлі аймақтарындағы сүтті ірі қара малын өсіретін шаруашылықтарда жүргізілді. Зерттеу нәтижелері бойынша 2019 жылы симментал тұқымды сиырлардың өсіретін үш шаруашылық бойынша орта есеппен 21,9%, алатау (2 шаруашылық) – 11,1%, голштин (6 шаруашылық) – 28,6% табыннан шығарылғаны анықталды. Шаруа қожалықтары бойынша сауын маусымының 305 күніндегі сиырлардың орташа сүт өнімділігі: симментал тұқымы бойынша – 5361 кг, алатау тұқымы – 5800 кг, голштин тұқымы – 8103 кг. 2020 жылы симментал тұқымды сиырлардың өсіретін үш шаруашылық бойынша орташа табыннан шығарылғаны 24,6%, алатау (2 шаруашылық) – 18,0%, голштин (6 шаруашылық) – 25,8% құрады. Шаруашылықтар бойынша сиырлардың 305 сауын маусымы күніндегі орташа сүт өнімділігі: симментал тұқымы бойынша 5695 кг, алатау бойынша 6253 кг, голштин бойынша 8298 кг сүт сауылды. 2020 жылы симментал тұқымды сиырлар арасында табыннан шығарылуының негізгі себептері - гинекологиялық аурулар (32,4%) және желін аурулары (24,7%) болып табылды. Голштин сиырларында – өнімділік (26,0%) және тұяқ аурулары (22,4%). Жүргізілген зерттеулер жылына 3%-бен шектелген импорттық сүтті ірі қара малдың табиғи шығыны (өлу) нормаларын сақтау міндетті түрде сиыр өнімділігінің күрт төмендеуіне, соның салдарынан ауру және өнімділігі төмен сиырларды ұстауға негізсіз шығындарға әкелетінін дәлелденді, сайып келгенде, шаруашылық жүргізуші субъектілердің тиімсіздігіне. Отандық селекциясының сиырларын табыннан шығару кем дегенде 25%, ал шет елден әкелінген сиырларды 30-35% құрауы керектігі дәлелденді.

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REMOTE FORMS OF MONITORING THE VITAL ACTIVITY OF THE BEE COLONY AND THEIR APPLICATION IN BEEKEEPING PRACTICE

ANNOTATION

Beekeeping has long been facing increasing problems related to stress factors that threaten the lives and productivity of bees in apiaries. Since the late 20th century, global climate change, destruction of natural habitats, environmental pollution, and pesticide use have led to deteriorating living conditions for bees and increased mortality rates. As a result, a new direction called Precision Beekeeping (PB) has emerged in agriculture, utilizing digital technologies to protect bees, support beekeepers, and optimize production in apiaries.

This article discusses the latest advancements in the field of precision beekeeping, including the use of Internet of Things (IoT) systems and various types of sensors for monitoring bee activity in the Republic of Kazakhstan. It describes data collection and analysis, and evaluates the effectiveness of precision beekeeping in the face of modern challenges. The article also considers the sustainability and scalability of the proposed solutions, as well as their economic implications.

This article provides an overview and explores the potential of emerging precision beekeeping technologies in the Republic of Kazakhstan. It can serve as a valuable resource for beekeepers,

researchers, and industrial enterprises interested in employing innovative approaches to protect and support beekeeping in the country.

Key words: *precision beekeeping, honey bee, remote monitoring, bee colony, hive, vitality*

Introduction. In the early 2000s, the phenomenon of Colony Collapse Disorder (CCD) emerged, which is associated with the sudden disappearance of honey bee populations [1]. There are several factors that can contribute to bee mortality, such as pesticides, Varroa mites (a destructive mite species), genetic strains, habitat degradation, Asian hornets, and viruses. However, it is still challenging to establish a causal relationship and predict future consequences. In order to reduce bee colony mortality, beekeepers need to improve the diagnosis of honey bee health and pay more attention to prevention [2].

Interest in continuous monitoring of bee colonies arose in the early 20th century. In 1914, Gates published data on hive temperature collected manually every hour over several days in 1907 [3]. In 1926, Dunham measured hive temperature using thermocouples [4]. The development of sensors and electronic data collection systems has improved measurement processes. Various monitoring methods have been employed, ranging from simple data observation in hives to systems capable of analyzing this data [5].

"Precision beekeeping" is a branch of precision agriculture that was first mentioned in the article by Zacepins et al. (2012) and described as a "hive management strategy based on monitoring individual bee colonies to minimize resource consumption and increase bee productivity" [6]. Its aim is to address the challenges of beekeeping, particularly high mortality rates, by utilizing collected data on bees at two main biological levels: the apiary and the colony. The apiary level consists of multiple hives, each containing one bee colony. The colonies are located in the same geographical area. The colony level focuses on an individual hive and encompasses the organization of bee life and behavior.

In programming, the term "connected hive" is used to refer to a hive capable of collecting data about bees and transmitting or storing data as part of the "Precision Beekeeping" setup in the apiary. A "smart hive" is a connected hive with data analysis capabilities, for example, a hive capable of diagnosing colony health issues.

The main goal of Precision Beekeeping is to enable beekeepers to use automated tools to reduce their workload while simultaneously increasing hive productivity. It also aims to protect bees and enhance their long-term survival. The technological aspect of Precision Beekeeping lies in providing beekeepers with time-saving solutions, as wireless installations allow them to receive real-time hive data directly on their mobile phones.

The system operates as follows: electronic scales and a sensor unit (including temperature, humidity, and sound sensors) record sensor readings at specific time intervals. The recorded data is transmitted to a central hub where it is processed by a microprocessor, compiled, and sent to a database. In turn, the information from the database can be accessed through a mobile phone application (Figure 1).

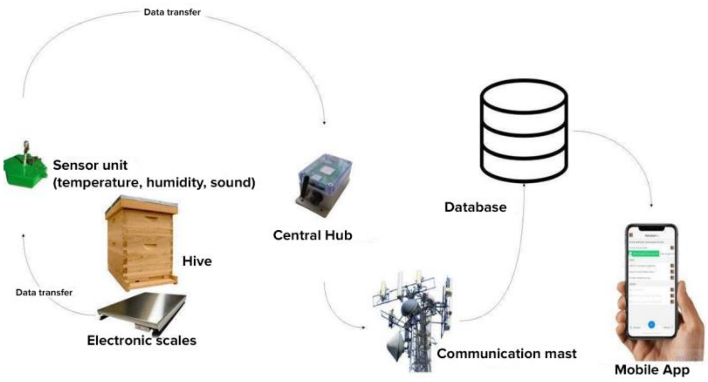

Figure 1 – "The Internet of Things" (IoT) describes physical objects or groups of objects with sensors capable of processing data using software and other technologies, which can connect and exchange data with other devices and systems through the Internet or other communication networks.

In articles related to Precision Beekeeping and IoT, a connected hive consists of a standard hive with sensors connected to a microprocessor, which is powered by a battery or connected to a network to send the collected data to a remote server. The design of the connected hive should meet the needs of beekeepers, be technically feasible and accessible, and not hinder the activities of the bees.

Each connected hive has a common structure, consisting of a microcontroller that controls the sensor. At regular intervals, the microcontroller collects and centralizes the data before transmitting it to the remote server. There are different families of microcontrollers, with Arduino and Raspberry Pi being the main ones. Each type of microcontroller has its strengths and weaknesses. For example, Arduino-based boards consume very little power and are more specialized compared to Raspberry Pi models, which consume more power but also run a full Linux-based operating system, providing more capabilities.

Larger embedded computing devices are used for systems that require real-time results and the execution of complex tasks.

The sensors are the organs of the connected hive. They are either directly connected to the microcontroller or transmit the collected data through wireless protocols. The following are various types of sensors.

Once the data has been collected using the sensors, it can be transmitted to a remote server. The information is either formatted and displayed for beekeepers in an application that groups data by hives, or the data can be analyzed by researchers.

Precision Beekeeping is not just a bee monitoring methodology; it involves the use of various innovative technologies to optimize honey production and preserve bee populations. In one study, the authors demonstrate how the use of precision beekeeping technologies, including wireless monitoring devices and automated feeding systems, can significantly increase hive productivity and maintain bee health[7].

Precision beekeeping technologies are applied not only in commercial beekeeping but also in scientific research, such as studying the impact of climate change on bee populations. In one study, wireless monitoring devices were used in different climatic conditions to study the influence of temperature on bee activity and hive productivity[8].

One of the key advantages of precision beekeeping is the ability to obtain real-time data. This allows beekeepers to quickly respond to changes in the apiary and take appropriate measures. In another study, the use of a monitoring system helped detect bee health problems at an early stage, leading to a reduction in bee mortality and improved honey quality[9].

Precision beekeeping can also play an important role in biodiversity conservation. In one study, the authors demonstrate how the use of wireless monitoring devices allows determining the optimal timing for honey harvesting, which contributes to the preservation of vegetation integrity and improves conditions for other insect species[10].

Material and research methods. In 2022, as part of a scientific and technical program aimed at developing technologies for efficient management of the breeding process in beekeeping, remote monitoring systems for honeybee colony vitality were installed in base farms. These systems are based on the use of modern electronic scales and sensor modules, including temperature, humidity, and sound sensors. This equipment was acquired in Ukraine, where it has mainly been used as an experimental tool for monitoring bee activity and preparing bees for wintering [11].

The operation principle of the systems is as follows: electronic scales and sensor modules record measurements at specific intervals. A central hub is used to coordinate the sensors in the apiary, ensuring the collection of high-quality information and its transmission for processing to a cloud storage. The main function of the central hub is to collect and transmit data obtained from the sensors to a database for subsequent processing (Figure 2a).

The information collected from hives equipped with sensors is transmitted through the LORA wireless network every 30 minutes. Subsequently, the gathered information is sent to the central server once every 30 minutes via Wi-Fi or GSM channel.

Thus, remote monitoring systems for honeybee colony vitality, based on the use of electronic scales and sensor modules, represent an effective tool for monitoring the condition of bees and help reduce the risks of diseases and mortality.

Influence of Hive Weight on Honeybee Colony Activity. Hive weight is one of the most important indicators of honeybee colony activity. During the honey collection period, the hive weight reflects the weight of gathered pollen and nectar, as well as the number of bees inside the hive. In the winter period, the number of bees decreases, and the available resources also become limited, which can affect the bees' health and their honey storage level. To assess honey reserves, which serve as the primary food for bees during winter, a wireless weight sensor can be used. For instance, Figure 2b shows a wireless weight sensor with the ability to transmit data via Bluetooth.

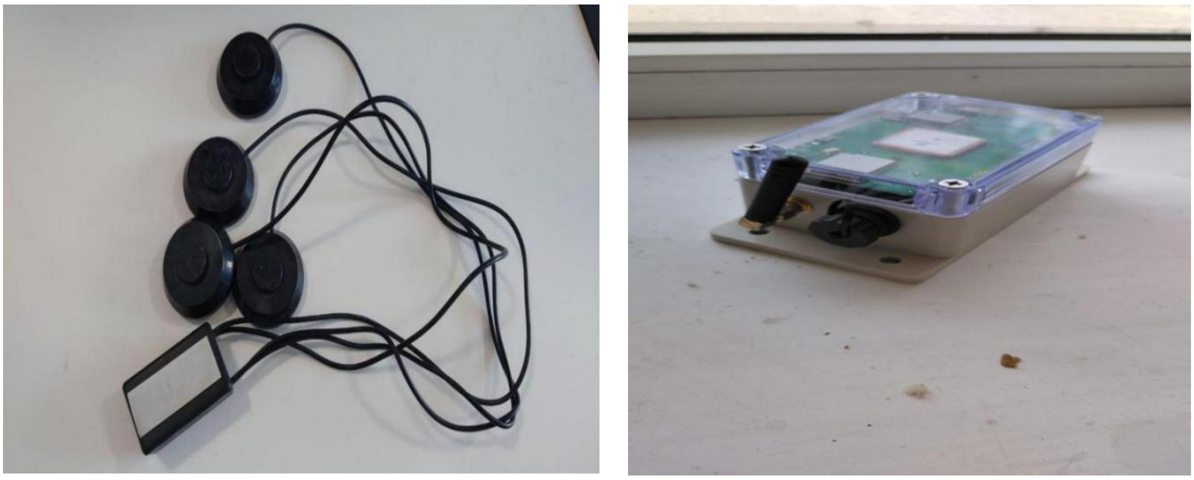

Figure 2 a, b – The central hub and electronic scales

The sensor module, which includes temperature, humidity, and sound sensors, represents a valuable tool for monitoring the health of the honeybee colony [12]. Temperature regulation inside the hive is a key indicator of the honeybee family's well-being. During the summer, bees ventilate the hive to ensure proper air exchange. An increase in internal temperature may indicate the presence of swarming processes [13] (Figure 3).

Figure 3 – Snsor block

The honeybee colony is capable of regulating the temperature inside its hive. The internal hive temperature serves as an indicator of colony health. Failure to regulate temperature puts the colony at risk, particularly during winter when bees form a cluster to maintain a life temperature ranging from 32°C to 37°C [7]. In summer, bees typically ventilate the hive to ensure proper air exchange. An increase in internal temperature may be associated with swarming [8]. The sounds produced by honeybees reflect the state of the colony as a whole and can be detected by sensors. For example, acoustic signals may be related to swarm preparation, queen identification, and pest infestation. Knowing that bees produce sounds in the range of 0 to several thousand hertz, the frequency range of the sound sensor should encompass this range for further data analysis.

The humidity sensor measures the moisture level inside the hive and indicates the adaptability of bees to environmental fluctuations. Bees generate moisture through processes such as water collection, moist nectar, and even respiration. While it is important to maintain brood above a certain humidity level, it is crucial to prevent excessive moisture condensation on the inner hive walls or even on the combs themselves. A strong colony copes much better with humidity fluctuations than a weaker colony [14].

Results and their discussion. The honeybee vitality monitoring system has been successfully adapted and implemented in various environments, including the foothills of Fabrichnyi village (Almaty region), the urban area on the roof of Kazakh Research Institute of Livestock and Fodder Production (further KazRILFP) LLP in Almaty city, the industrial area of East Kazakhstan region (Ust-Kamenogorsk city), the steppe zone in the fields of Akmola region, and the mountainous terrain in Lepsi village (Almaty region). Examples of system installations in the East Kazakhstan, Akmola, and Almaty regions are shown in Figure 4.

Figure 4 – Examples of installations in East Kazakhstan, Akmola, and Almaty regions:
1. IE Mayer
2. RodinaLLP
3. Lepsinsk OnimiLLP
4. Fabrichnyi
5. KazRILFP LLP

Measurement of bee weight was performed using a sensor, and the total weight of the hive, including brood, bees, and food, was determined based on this data. Noise measurement was based on the sound intensity inside the hive, while temperature and humidity were measured only inside the hive.

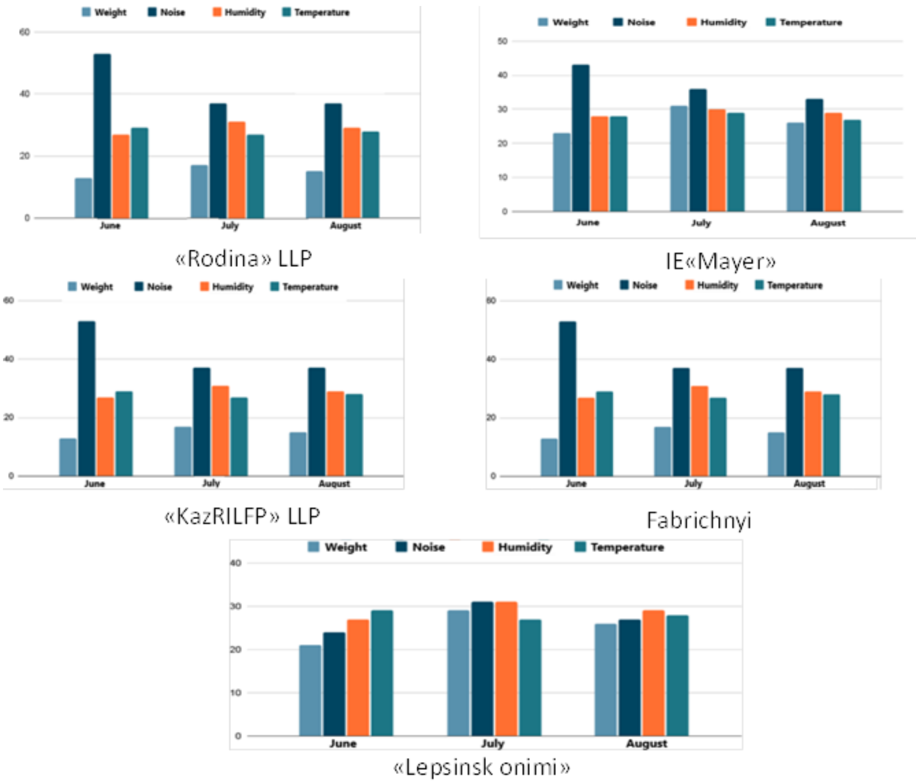

Figure 5 – Data on the vital activity of bees (weight, noise, humidity, temperature) 1.Rodina LLP, 2. IE Mayer, 3. KazRILFP LLP, 4.Fabrichnyi, 5. Lepsinsk onimi LLP

Observations of bee vitality revealed certain patterns during the period from June to August. For example, a decrease in hive temperature corresponds to an increase in relative humidity. On average, noise intensity inside the hives was higher in the industrial locations of Almaty and Ust-Kamenogorsk. In all locations, there was a consistent pattern of the hive's minimum weight in June, weight increase in July, and slight weight decrease in August. Data obtained from the sensors for these four indicators are presented in diagrams related to beekeeping operations (Figure 5).

Furthermore, after discussions with local beekeepers, it was discovered that they conducted fewer hive inspections after implementing the monitoring system. On average, there was a reduction in the number of interventions in the activities of bee colonies. Data from the electronic scales proved to be particularly valuable for beekeepers as they could assess the health status and ongoing processes within the bee colonies based on that information.

Following the use of the monitoring system, beekeepers expressed the need for a simplified system due to the high cost of some existing systems, which hindered their widespread adoption. Most systems require a subscription fee and cost more than 150,000 tenge per unit[15]. Data on bee vitality, such as temperature, humidity, and hive noise levels, are of interest to beekeepers. However, they relied more on the data from the electronic scales. Based on this information and their own experience, beekeepers could assess the state of their colonies and take appropriate measures. There were also difficulties with accessing mobile networks in all locations except Almaty. Therefore, a monitoring system model capable of functioning independently of network connectivity would be preferable in the territory of the Republic of Kazakhstan. Additionally, beekeepers expressed the assumption that it would be economically feasible to use such equipment for mass pollination (over 100 hectares) of oilseed crops and fruit orchards.

The high noise levels observed in June are likely associated with the bees' intense activity during pollen collection and their increased efficiency in gathering nectar and producing honey [16].

For studies on the bee vitality period, it is necessary to record data throughout the year since bees have vastly different lifestyles between summer and winter periods, and their behavior also varies at the beginning and end of the main nectar flow.

*Problems.*One of the main challenges in collecting data for statistical modeling (analytics) in beekeeping is the bias and quality of data collection on-site. Typically, the duration of collected data ranges from a few minutes to a few weeks. Furthermore, each bee colony is unique, so analyzing only a few hives and only a portion of the bee's life cycle is insufficient to understand all the intricacies of the apiary. Bias is more prevalent in analytical models trained on data from a single hive [17]. For studies aimed at studying bee life, it is necessary to record data throughout the year because bees lead vastly different lifestyles between summer and winter periods, and their behavior also differs at the beginning and end of the main nectar flow [18].

Conclusion. Precision beekeeping remains a relevant research topic, and over the years, numerous publications have emerged from various scientific fields, ranging from computer science to agriculture [19]. However, tracking research in this field remains a challenging task as systems, services, and data are initially developed for scientific purposes but transition into the commercial realm. In other words, some working groups exhibit high productivity for a short period and then disappear from the scientific community, often due to transitioning to commercial activities and ceasing publication of their discoveries.

Due to the needs of beekeepers, there is a need for the development of more accessible commercial solutions. However, currently available solutions on the market remain uncertain in terms of cost and economic viability for widespread use in precision beekeeping. Commercial implementation for industrial pollination of gardens and agricultural crops could be a catalyst for the mass adoption of precision beekeeping, but only with a large number of interested participants seeking to increase their productivity [20]. It is necessary to justify to farmers and beekeepers the potential benefits of using precision beekeeping in terms of efficiency and economic feasibility. It is difficult to envision the profitability of beekeepers' investments in the use of precision beekeeping without scaling. The described application cases in the Republic of Kazakhstan are not profitable due to the low production volume.

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РЕЗЮМЕ

Пчеловодство уже давно сталкивается с возрастающими проблемами, связанными с факторами стресса, угрожающие жизни и производительности пчел на пасеках. С конца 20-го века начались глобальные изменения климата, уничтожение естественных мест обитаний, загрязнение окружающей среды и использование пестицидов, что привело к ухудшению условий жизни пчел и увеличению их смертности. В связи с этим, в сельском хозяйстве появилось новое направление, называемое точным пчеловодством (ТП), где используются цифровые технологии для защиты пчел, поддержки пчеловодов и оптимизации производства на пасеках.

В данной статье рассматриваются последние достижения в области точного пчеловодства, включая использование системы Интернета вещей (IoT) и различных типов датчиков для мониторинга жизнедеятельности пчел в Республике Казахстан. Описывается сбор и анализ данных, а также оценивается эффективность точного пчеловодства в условиях современных вызовов. В статье также рассматривается устойчивость и масштабируемость предлагаемых решений, а также их экономические затраты.

Эта статья представляет обзор и потенциал использования развивающихся технологий точного пчеловодства в Республике Казахстан. Она может стать полезным ресурсом для пчеловодов, исследователей и промышленных предприятий, которые заинтересованы в использовании инновационных подходов для защиты и поддержки пчеловодства в стране.

ТҮЙІН

Ара шаруашылығы ұзақ уақыт бойы омартадағы аралардың өмірі мен өнімділігіне қауіп төндіретін стресс факторларына байланысты өсіп келе жатқан мәселелерге тап болды. 20 ғасырдың аяғынан бастап жаһандық климаттың өзгеруі, табиғи мекендеу орындарының жойылуы, қоршаған ортаның ластануы және пестицидтерді қолдану басталды, бұл аралардың

өмір сүру жағдайының нашарлауына және олардың өлімінің артуына әкелді. Осыған байланысты ауыл шаруашылығында араларды қорғау, омарташыларды қолдау және омарта өндірісін оңтайландыру үшін цифрлық технологияларды қолданатын ара шаруашылығы (ТП) деп аталатын жаңа бағыт пайда болды.

Бұл мақалада Қазақстан Республикасындағы аралар тіршілігінің мониторингі үшін заттар интернеті (IoT) жүйесін және датчиктердің әртүрлі түрлерін пайдалануды қоса алғанда, ара шаруашылығы саласындағы соңғы жетістіктер қарастырылады. Деректерді жинау және талдау сипатталған, сонымен қатар қазіргі заманғы сын-қатерлер жағдайында ара шаруашылығының тиімділігі бағаланады. Мақалада ұсынылған шешімдердің тұрақтылығы мен ауқымдылығы, сондай-ақ олардың экономикалық шығындары қарастырылады.

Бұл мақала Қазақстан Республикасында ара шаруашылығының дамып келе жатқан технологияларына шолу мен пайдалану әлеуетін ұсынады. Бұл елдегі ара шаруашылығын қорғау және қолдау үшін инновациялық тәсілдерді қолдануға мүдделі омарташылар, зерттеушілер және өнеркәсіптік кәсіпорындар үшін пайдалы ресурс бола алады.

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ПРОГРАММНОЕ ОБЕСПЕЧЕНИЕ В МОРФОМЕТРИИ ДЛЯ ОПРЕДЕЛЕНИЯ ПОРОДНОЙ ПРИНАДЛЕЖНОСТИ МЕДОНОСНЫХ ПЧЁЛ
SOFTWARE IN MORPHOMETRY FOR DETERMINING THE BREED AFFILIATION OF HONEY BEES

ANNOTATION

In modern beekeeping, an important role is played by the use of technologies that help to manage the processes of selection and breeding work on bee families as efficiently and accurately as possible. One of these tools was morphometric analysis, a method used to study the shape, structure and size of various parts of the body of bees.

Morphometric analysis provides valuable information about many aspects of bee life. It allows beekeepers to assess the health status of bees, their reproductive capabilities, as well as to detect possible pathologies or deviations. Thus, morphometric analysis is a key element in ensuring the productivity and health of bee colonies.

Modern technologies greatly simplify and accelerate the process of morphometric analysis. There are many software solutions on the market designed specifically for morphometric analysis in beekeeping. They offer a variety of functionality, including automated measurements, data visualization, statistical processing, and more.

The article combines an overview on the issue of software for conducting morphometry of honey bees and recommendations on the choice and use of this software. The software for classical and geometric morphometry was systematized and analyzed according to their functional capabilities.