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Поступила в редакцию 06.05.2026
Поступила после доработки 16.06.2026
Принята к публикации 27.06.2026

DOI:
IRSTI: 68.39.43

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ENVIRONMENTALLY SAFE APPROACHES TO THE CONTROL OF VARROATOSIS IN HONEY BEE COLONIES

Abstract: *Varroatosis caused by the ectoparasitic mite Varroa destructor remains one of the most important biological threats to managed honey bee colonies. The aim of this review was to summarize environmentally safe approaches to Varroa destructor control and to evaluate them according to acaricidal efficacy, ecological safety, colony productivity, practical applicability, and suitability for integrated pest management. Publications from 2021 to 2025 were analyzed, with priority given to peer-reviewed studies on chemical acaricides, organic acids, thermal treatment, biotechnical methods, acaricide resistance, and breeding for Varroa-tolerant honey bees. The reviewed evidence shows that amitraz-based chemical preparations can provide rapid mite reduction, but their sustainability is limited by residue risks and the development of acaricide resistance. Oxalic acid and thermal treatment showed the most balanced profile because they combine substantial mite reduction with low contamination risk and preservation of colony productivity. Biotechnical measures, including drone brood removal and brood interruption, are environmentally safe but are more effective as preventive or supportive components of a broader control program. The review concludes that sustainable varroatosis control should be based not on a single treatment but on integrated pest management that combines regular monitoring, threshold-based decision-making, ecologically safer treatments, resistance management, and selection of honey bee stocks with improved hygienic and grooming behavior.*

Key words: Apis mellifera; Varroa destructor; varroatosis; oxalic acid; thermal treatment; integrated pest management; acaricide resistance; hygienic behavior.

Introduction

Honey bees (Apis mellifera) play an essential role in agricultural production, ecosystem stability, and food security because of their contribution to pollination and the production of honey, wax, propolis, pollen, and other bee products. However, modern beekeeping is increasingly affected by biological and environmental stressors. Among them, varroatosis is considered one of the most destructive diseases of managed honey bee colonies.

Varroatosis is caused by the ectoparasitic mite Varroa destructor, which parasitizes both adult bees and brood. The mite weakens bees directly through feeding and indirectly through the transmission and amplification of viral pathogens. Recent virological studies confirm that Varroa destructor is not only a mechanical carrier but also an important biological component in the circulation of several honey bee-associated viruses, including deformed wing virus [1]. Colony susceptibility to Varroa pressure and viral infections is also influenced by bee genotype and by the expression of resistance-related traits [2].

The control of Varroa destructor is complicated by the mite's high reproductive potential, association with the brood cycle, regional variation in infestation dynamics, and the risk of resistance to acaricides. Modern detection and surveillance approaches, including molecular and environmental DNA methods, are being developed to improve early identification of infestations and support biosecurity in non-endemic or recently invaded regions [3,4]. Epidemiological studies also show that Varroa mites may occur together with other parasitic mites and honey bee pathogens, which strengthens the need for complex and regionally adapted control systems [5].

The problem is not only veterinary but also ecological and economic. Synthetic acaricides may provide rapid reduction of mite populations, but inappropriate or repeated use can result in toxic residues in hive products and the selection of resistant mite populations. Therefore, sustainable beekeeping requires control strategies that combine effectiveness with product safety, preservation of colony productivity, and reduction of chemical pressure on the apiary ecosystem.

The aim of this review is to summarize current approaches to varroatosis control and to evaluate them from the standpoint of sustainable beekeeping, with particular emphasis on ecological safety, productivity of honey bee colonies, and integration into a practical pest management system.

The scientific novelty of this review consists in the integrated assessment of varroatosis control methods according to several criteria at the same time: acaricidal efficacy, ecological safety of honey and wax, colony productivity, practical feasibility, and risk of acaricide resistance. Unlike descriptions that evaluate treatments mainly by mite mortality, the present review proposes a comparative decision framework for sustainable apiary management. The review also updates the discussion by including integrated pest management, mechanisms of acaricide resistance, and the prospects of selective breeding for Varroa-resistant honey bee stocks.

Materials and Methods

The manuscript is a narrative review with elements of structured literature selection. The literature search was focused on peer-reviewed publications indexed in international scientific databases and publisher platforms, including PubMed, Scopus, Web of Science, SpringerLink, ScienceDirect, MDPI, Oxford Academic, Taylor & Francis, and Google Scholar. The search covered publications from 2021 to 2025, earlier sources were used only when they were necessary for basic biological, taxonomic, or methodological context.

The main search terms and their combinations were: «Varroa destructor», «varroatosis», «Apis mellifera», «oxalic acid», «organic acids», «amitraz», «acaricide resistance», «thermal treatment», «drone brood removal», «brood interruption», «integrated pest management», «hygienic behavior», «Varroa sensitive hygiene», and «honey bee breeding».

The inclusion criteria were:

- relevance to Varroa destructor or varroatosis in Apis mellifera colonies;
- analysis of control, detection, resistance, productivity, or ecological safety;
- peer-reviewed article, review, or experimentally based study;
- sufficient methodological description to interpret the results; and
- availability of bibliographic data for verification. The exclusion criteria were: duplicate publications, non-peer-reviewed materials without scientific data, publications unrelated to honey bees, papers focused only on non-Varroa parasites, and studies without usable information on control or disease significance.

The review procedure included four stages: identification of potentially relevant publications, removal of duplicate or non-relevant records, screening of titles and abstracts, and full-text assessment of papers that met the topic and methodological criteria. For each selected publication, the following information was extracted: type of control method, active substance or physical/biotechnical intervention, reported mite reduction, colony productivity indicators, residue or ecological-safety data, practical limitations, and relevance to integrated pest management.

The analytical synthesis was carried out by grouping the selected publications into thematic blocks: chemical acaricides, organic acids, thermal treatment, biotechnical methods, integrated pest management, acaricide resistance, and breeding of Varroa-tolerant honey bees. The methods were compared using predefined criteria: acaricidal efficacy, safety of honey and wax, influence on colony productivity, labor and equipment requirements, risk of resistance development, and suitability for use at different infestation levels. This approach made it possible to formulate practical recommendations while avoiding unsupported statistical generalization across heterogeneous studies.

Because the available studies differ in treatment formulation, season, colony strength, brood status, infestation level, climate, and outcome measures, a formal meta-analysis was not performed. Quantitative values presented in this review, including mite reduction of 87,5%, 80,3%, 74,1%, and 52,8%, are treated as descriptive comparative indicators extracted from the analyzed literature and not as new experimental results obtained by the authors. When primary data on sample size, variance, or statistical significance were not available or not comparable across studies, this limitation was explicitly considered in the interpretation.

Biological and Epizootological Importance of Varroatosis

Varroatosis is one of the main causes of weakening, decreased productivity, and death of honey bee colonies. Varroa destructor parasitizes adult bees and brood, and its harmful effect is associated with direct feeding damage, disruption of normal development, immune suppression, and increased vulnerability to viral pathogens. The relationship between Varroa destructor and viruses is particularly important because mite infestation can transform latent viral infections into clinically significant colony-level disease problems [1].

From an epizootological perspective, the disease is difficult to control because the mite reproduces inside capped brood cells and its population growth is synchronized with colony development. The level of infestation is influenced by season, brood availability, re-invasion from neighboring colonies, drifting bees, and regional beekeeping practices. Genetic variation in Varroa populations and host fidelity of mite lineages may also affect the epidemiology of infestations and the regional performance of control methods [6,7].

The practical importance of varroatosis is strengthened by the fact that mite control failures usually have delayed but serious consequences: weakened winter bees, increased viral loads, reduced honey yield, and colony losses. Consequently, control programs should not be limited to emergency treatment after severe infestation. They should include monitoring, prevention, and timely combination of compatible methods.

Current Approaches to Varroatosis Control

Chemical acaricides

Synthetic acaricides remain widely used because they can rapidly decrease Varroa destructor populations in colonies with high infestation. Amitraz-based products are among the most common representatives of this group. In the descriptive comparative data analyzed in this review, the amitraz-based preparation Bipin showed the highest mite reduction, reaching 87.5%. Seasonal field evaluations also confirm that the effectiveness of chemical treatments may vary with treatment timing and colony conditions [8].

However, the ecological and long-term limitations of chemical acaricides must be considered. First, synthetic compounds may leave residues in honey, wax, and other hive products if they are misused or applied outside recommended periods. Second, repeated exposure to the same active ingredient increases the risk of resistance development. Recent review evidence on amitraz-based treatments shows that mite populations may differ in sensitivity and that resistance management is necessary for maintaining field efficacy [9]. Therefore, chemical acaricides should not be considered a universal solution; they are most appropriate as regulated, time-limited interventions within integrated pest management.

Organic acids: oxalic acid

Oxalic acid is one of the most important environmentally safer alternatives to synthetic acaricides. It is compatible with sustainable beekeeping because it has lower residue risks and can be used as part of treatment programs based on organic compounds. In the comparative data analyzed here, oxalic acid provided 80,3% mite reduction, which was slightly lower than the amitraz-based treatment but substantially more favorable from the standpoint of product safety. The highest average honey yield in the analyzed comparison was recorded in the oxalic acid group, reaching 23,2 kg per colony.

Recent studies support the practical value of oxalic acid formulations, but they also show that efficacy depends on dose, application method, season, brood status, and initial infestation. Oxalic acid and glycerin strips have been evaluated as a promising approach for Varroa destructor control, with attention to dose, administration method, colony development stage, residues, and honey quality [10]. A recent field study on oxalic acid vaporization showed that low doses may be insufficient under brood-present conditions, while higher doses suppress mites more effectively but can negatively affect larval development [11]. Thus, oxalic acid should be used according to evidence-based protocols rather than as an uncontrolled treatment.

Thermal treatment is a physical non-chemical method based on the lower tolerance of mites to elevated temperature compared with honey bees when exposure is carefully controlled. In the descriptive comparative data, exposure to 43 °C for 10 minutes resulted in a 74,1% reduction in mite infestation. Although this value was lower than that of amitraz and oxalic acid, the method has an important ecological advantage because it does not introduce chemical residues into honey or wax.

The practical value of thermal treatment is strengthened by its relationship with colony productivity in the analyzed comparison. Average honey yield reached 22,9 kg per colony, which was close to the oxalic acid group. At the same time, this method requires specialized equipment, accurate temperature regulation, and additional labor. Therefore, thermal treatment is most suitable for apiaries where product purity and avoidance of chemical pressure are priority goals.

Biotechnical methods aim to reduce mite reproduction without chemical exposure. Drone brood removal is based on the biological preference of Varroa destructor for drone brood and can reduce the reproductive reservoir of mites inside the colony. In the analyzed comparison, this method reduced mite infestation by 52,8%, which confirms its usefulness but also shows that its stand-alone efficacy is lower than chemical, organic acid, and thermal approaches.

The main limitation of drone brood removal is that it is usually insufficient as a stand-alone method under high infestation pressure. It may also temporarily affect colony development if used excessively. Brood interruption techniques, including queen caging and trapping combs followed by oxalic acid treatment, have been studied as integrated pest management components and can provide high acaricidal efficacy when applied at the correct time [12]. Therefore, biotechnical measures are best interpreted as preventive and supportive tools that reduce mite reproduction and improve the effectiveness of other environmentally safer treatments.

Table 1 – Descriptive comparison of selected varroatosis control approaches

Control approach	**Reported mite reduction**	**Productivity / safety indicator**	**Interpretation**
Amitraz-based chemical acaricide (Bipin)	87,5%	Rapid mite reduction, but possible residues in honey and wax if misused.	Effective for emergency or high-infestation intervention; should be regulated and rotated.
Oxalic acid	80,3%	Highest reported honey yield: 23,2 kg per colony; low residue concern when used correctly.	Best balance between efficacy, productivity, and environmental safety.
Thermal treatment	74,1%	Honey yield: 22,9 kg per colony; no chemical residues.	Residue-free physical method; requires equipment and strict temperature control.
Drone brood removal / biotechnical methods	52,8%	No contamination of hive products, but productivity may decrease if brood removal is excessive.	Useful as a preventive and supportive method within IPM.

The percentages in Table 1 are descriptive indicators from the analyzed literature. They are not presented as results of a new experiment or a statistical meta-analysis.

Figure 1 illustrates the relative level of mite reduction reported for the four compared control approaches. The graph is included to improve visual interpretation of the comparative data and should be read together with Table 1 and Table 2.

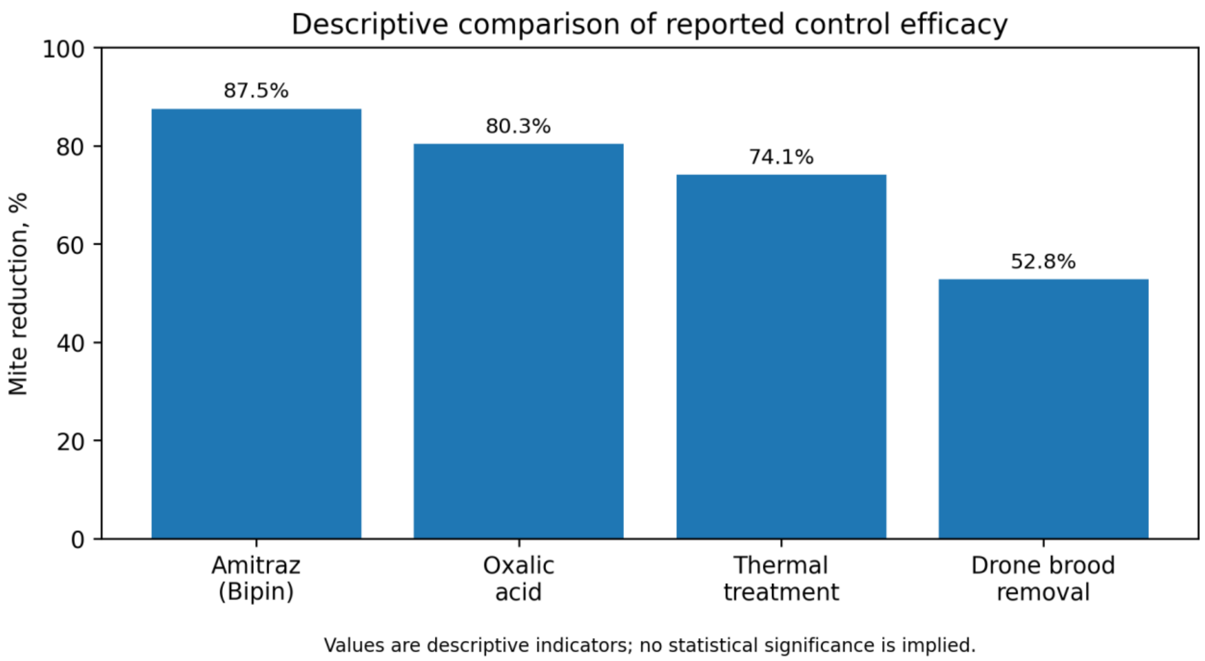

Figure 1- Descriptive comparison of mite reduction reported for selected varroatosis control methods

The figure is intended for visual comparison only; no statistical significance is implied because the original studies were heterogeneous and raw variance data were not uniformly available.

Table 2 – Advantages, limitations, and practical role of varroatosis control approaches in integrated pest management

Control approach	Main advantages	Main limitations	Practical role in IPM
Amitraz-based chemical acaricide	High and rapid acaricidal effect; useful when infestation is severe.	Residue risk, resistance selection, and possible treatment stress.	Reserve for justified cases; use according to regulations and resistance-management principles.
Oxalic acid	Soft acaricide; good efficacy; favorable residue profile; compatible with sustainable beekeeping.	Efficacy depends on brood status, dose, delivery method, and season.	Core treatment in low-residue control programs, especially when combined with monitoring.
Thermal treatment	No chemical contamination; maintains product purity; compatible with organic-oriented apiaries.	Equipment costs, labor demand, and risk of overheating if poorly controlled.	Physical non-chemical option for apiaries prioritizing residue-free production.
Biotechnical methods	Environmentally safe; reduce mite reproduction; no residues in hive products.	Lower stand-alone efficacy; labor-intensive; possible disturbance of colony development.	Preventive/supportive component combined with soft acaricides and regular monitoring.

Integrated Pest Management and Sustainable Beekeeping

Integrated pest management (IPM) is the most scientifically justified approach to sustainable varroatosis control. In honey bee colonies, IPM combines regular monitoring, prevention, threshold-based decision-making, compatible chemical and non-chemical treatments, and evaluation of treatment efficacy. The IPM approach is especially important because no single method is optimal under all climatic, seasonal, and epidemiological conditions [13].

The first component of IPM is monitoring. Treatment decisions should be based on infestation level, colony strength, brood status, season, and regional risk. Monitoring is also necessary after treatment to determine whether mite numbers were reduced sufficiently and whether re-invasion occurred. Molecular and environmental detection methods can complement traditional mite counts in surveillance programs and non-endemic regions [3,4].

The second component is the rational combination of methods. For example, brood interruption can increase the exposure of mites to oxalic acid by reducing protected reproductive mites inside capped cells. Experimental IPM protocols combining queen caging or trapping combs with oxalic acid have shown high acaricidal efficacy, although long-term effects on viral load and colony strength require further study [12].

The third component is resistance management. The long-term use of a single synthetic active ingredient creates selection pressure. For amitraz-based treatments, recent reviews show that reduced sensitivity and resistance risks must be considered when selecting treatment strategies [9]. Therefore, resistance management should include correct dosing, avoidance of unauthorized or repeated applications, rotation of treatment classes where appropriate, use of non-persistent organic acids, incorporation of physical and biotechnical measures, and periodic assessment of treatment outcomes. The fourth component is selection of honey bees with increased natural resistance. Breeding for low Varroa population growth, grooming behavior, hygienic behavior, and Varroa-sensitive hygiene can reduce the reproductive success of mites and decrease dependence on acaricides. Recent work shows that colonies selected for low Varroa population growth may express multiple resistance mechanisms, including behavioral, cellular, humoral, and antiviral components [14]. Studies of Varroa-sensitive hygiene also demonstrate that selected workers can detect and remove mite-infested brood, interrupting mite reproduction [15,16]. However, selective breeding should complement, not replace, monitoring and treatment.

Discussion

The reviewed evidence shows that the choice of varroatosis control method depends on which criterion is prioritized. If only immediate acaricidal efficacy is considered, amitraz-based treatment appears strongest in the descriptive comparison. However, when ecological safety, risk of residues, productivity, and resistance are included, the interpretation changes. As shown in Table 1, oxalic acid and thermal treatment provide a strong overall balance between mite suppression and preservation of colony and product safety.

The conclusion about the advantages of oxalic acid and thermal treatment is therefore based on a combined assessment of efficacy, productivity, ecological safety, and practical limitations rather than on mite mortality alone. Table 2 shows that each method has both strengths and restrictions: oxalic acid requires correct timing and dosing, thermal treatment requires equipment and strict temperature control, biotechnical measures are safer but weaker, and chemical acaricides are effective but carry residue and resistance risks.

This conclusion should not be interpreted as the absolute superiority of oxalic acid or thermal treatment in every apiary. At low to moderate infestation, monitoring, biotechnical measures, oxalic acid, and thermal treatment may be sufficient. At high infestation, a regulated chemical intervention may be justified, but it should be followed by evaluation of efficacy and measures that reduce future dependence on synthetic acaricides. In all cases, the health of the colony and safety of hive products should be considered alongside mite mortality.

Limitations of the Review

The main limitation of this review is the heterogeneity of the analyzed studies. Publications differ in colony size, bee genotype, climate, infestation level, season, brood status, treatment dose, formulation, and duration of observation. For this reason, the quantitative values presented in the manuscript are descriptive and should not be interpreted as statistically comparable experimental results. A formal meta-analysis would require access to primary datasets, sample sizes, standard deviations or confidence intervals, and harmonized outcome definitions. Additional local field trials are needed to validate the proposed IPM recommendations under specific regional conditions.

Conclusion

Varroatosis remains one of the central veterinary, ecological, and economic problems of modern beekeeping. Varroa destructor weakens honey bee colonies directly and indirectly by increasing the pressure of viral pathogens, reducing productivity, and contributing to colony losses. Effective control is therefore essential for the maintenance of honey bee health and sustainable apicultural production.

The comparative assessment demonstrates that treatment efficacy alone is not a sufficient criterion for selecting a control method. Environmental safety, residue risk, productivity, practicality, and resistance management should be evaluated together. Amitraz-based chemical acaricides can provide strong and rapid mite reduction, but their ecological and resistance-related limitations require careful regulation. Oxalic acid and thermal treatment offer the best overall balance of mite suppression, productivity preservation, and safety of hive products. Biotechnical methods are less powerful as stand-alone treatments but are valuable as preventive and supportive components.

The most sustainable strategy is integrated pest management based on monitoring, timely intervention, combination of compatible methods, resistance management, and selection of honey bee stocks with increased tolerance or resistance to Varroa destructor. Such an approach reduces chemical pressure, improves product safety, and supports the long-term stability of honey bee colonies.

For practical application, control measures should be selected according to infestation pressure rather than applied uniformly. Because intervention thresholds differ among regions and monitoring techniques, these recommendations should be interpreted as decision levels rather than fixed universal diagnostic values. At low infestation, below the local intervention threshold, priority should be given to regular monitoring, maintenance of strong colonies, drone brood removal or other biotechnical measures, and the use of bee stocks with hygienic or grooming behavior. At moderate infestation, oxalic acid, selected according to brood status, approved dosage, and application method, as well as thermal treatment where suitable equipment is available, may be combined with biotechnical measures to reduce mite numbers while maintaining product safety. At high infestation, especially when mite counts rapidly increase or threaten winter-bee development, an approved acaricide may be justified as a time-limited intervention within IPM, followed by post-treatment monitoring and rotation of active substances. In severe infestation or clinical weakening of colonies, urgent veterinary assessment and immediate approved treatment are required; after stabilization, the apiary should return to a preventive IPM program based on monitoring, method rotation, and selection of tolerant colonies.

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БАЛ АРАСЫ ОТБАСЫЛАРЫНДАҒЫ ВАРРОАТОЗДЫ БАҚЫЛАУДЫҢ ЭКОЛОГИЯЛЫҚ ҚАУІПСІЗ ТӘСІЛДЕРІ

Эктопаразиттік кене Varroa destructor қоздыратын варроатоз бал арасы отбасылары үшін аса маңызды биологиялық қауіптердің бірі болып қала береді. Бұл шолудың мақсаты Varroa destructor-ды бақылаудың экологиялық қауіпсіз тәсілдерін жинақтау және оларды акарицидтік тиімділігі, экологиялық қауіпсіздігі, ара отбасыларының өнімділігіне әсері, практикалық қолданылуы және зиянкестермен интеграцияланған күрес жүйесінде пайдалануға жарамдылығы бойынша бағалау болды. 2021–2025 жылдар аралығында жарияланған еңбектер талданды, бұл ретте химиялық акарицидтерге, органикалық қышқылдарға, термиялық өңдеуге, биотехникалық әдістерге, акарицидтерге төзімділікке және Varroa-ға төзімді бал араларын селекциялауға арналған рецензияланған зерттеулерге басымдық берілді. Қарастырылған деректер амитраз негізіндегі химиялық препараттардың кенелер санын жылдам азайта алатынын көрсетеді, алайда оларды тұрақты қолдану өнімдерде қалдық заттардың жиналу қаупімен және акарицидтерге төзімділіктің қалыптасуымен шектеледі. Қымыздық қышқылы мен термиялық өңдеу ең теңгерімді нәтижелер көрсетті, өйткені олар кенелер санын едәуір азайтуды өнімнің ластану қаупінің төмендігімен және ара отбасылары өнімділігінің сақталуымен ұштастырады. Биотехникалық шаралар, соның ішінде еркек ара төлін алып тастау және төл өсіру циклін үзу, экологиялық тұрғыдан қауіпсіз болып табылады, алайда олар кеңірек бақылау бағдарламасының профилактикалық немесе қосымша компоненттері ретінде тиімдірек. Шолуда варроатозды тұрақты бақылау бір ғана өңдеу әдісіне емес, тұрақты мониторингті, инвазияның шекті деңгейіне негізделген шешім қабылдауды, экологиялық қауіпсіздеу өңдеу тәсілдерін, төзімділікті басқаруды және гигиеналық әрі өзін-өзі тазалау мінез-құлқы жақсарған *бал арасы отбасыларын іріктеуді біріктіретін интеграцияланған күрес жүйесіне негізделуі тиіс деген қорытынды жасалды.*

Түйінді сөздер: *Apis mellifera; Varroa destructor; варроатоз; қымыздық қышқылы; термиялық өңдеу; зиянкестермен интеграцияланған күрес; акарицидтерге төзімділік; гигиеналық мінез-құлық.*

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ЭКОЛОГИЧЕСКИ БЕЗОПАСНЫЕ ПОДХОДЫ К КОНТРОЛЮ ВАРРОАТОЗА В ПЧЕЛИНЫХ СЕМЬЯХ

Варроатоз, вызываемый эктопаразитическим клещом Varroa destructor, остается одной из наиболее значимых биологических угроз для пчелиных семей. Целью настоящего обзора было обобщение экологически безопасных подходов к контролю Varroa destructor и их оценка по акарицидной эффективности, экологической безопасности, влиянию на продуктивность пчелиных семей, практической применимости и пригодности для использования в интегрированной системе борьбы с вредителями. Были проанализированы публикации за 2021–2025 гг., при этом приоритет отдавался рецензируемым исследованиям, посвященным химическим акарицидам, органическим кислотам, термической обработке, биотехническим методам, устойчивости к акарицидам и селекции медоносных пчел, устойчивых к Varroa. Проанализированные данные показывают, что химические препараты на основе амитраза способны обеспечивать быстрое снижение численности клещей, однако их устойчивое применение ограничивается риском накопления остаточных количеств в продуктах пчеловодства и развитием устойчивости к акарицидам. Щавелевая кислота и термическая обработка показали наиболее сбалансированные результаты, поскольку сочетают значительное снижение численности клещей с низким риском загрязнения продукции и сохранением продуктивности пчелиных семей. Биотехнические меры, включая удаление трутневого расплода и прерывание расплодного цикла, являются экологически безопасными, однако более эффективны как профилактические или вспомогательные компоненты комплексной программы контроля. В обзоре сделан вывод о том, что устойчивый контроль варроатоза должен основываться не на одном методе обработки, а на интегрированной системе борьбы, включающей регулярный мониторинг, принятие решений с учетом порогового уровня инвазии, применение экологически более безопасных методов обработки, управление рисками формирования устойчивости и отбор пчелиных семей с улучшенным гигиеническим поведением и поведением самоочищения.

Ключевые слова: *Apis mellifera; Varroa destructor; варроатоз; щавелевая кислота; термическая обработка; интегрированная система борьбы с вредителями; устойчивость к акарицидам; гигиеническое поведение.*

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Поступила в редакцию 14.05.2026
Поступила после доработки 10.06.2026
Принята к публикации 25.06.2026

DOI:
МРНТИ: 68.41.49

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ЭФФЕКТИВНОСТЬ УЛЬТРАЗВУКОВОГО МОНИТОРИНГА В ДИФФЕРЕНЦИАЛЬНОЙ ДИАГНОСТИКЕ ПАТОЛОГИЙ ЯИЧНИКОВ У КОРОВ

Аннотация: *Патологии яичников у коров являются одной из наиболее распространенных причин нарушения воспроизводительной функции в условиях промышленного молочного скотоводства и сопровождаются значительными репродуктивными и экономическими потерями. Целью настоящего исследования явилась оценка эффективности ультразвукового мониторинга в дифференциальной диагностике овариальных патологий у коров. Исследования проводились на базе ТОО «Опытное хозяйство масличных культур» Восточно-Казахстанской области в 2024–2025 гг. Объектом исследования служили коровы молочных пород (голштинская и черно-пестрая). Материал исследования включал 48 коров с клиническими признаками нарушения функции яичников и 12 клинически здоровых животных контрольной группы. Диагностику осуществляли методом трансректальной ультрасонографии с использованием линейного датчика частотой 7,5 МГц, динамического ультразвукового мониторинга с интервалом 7 суток, а также гормональной верификации на основе определения уровня прогестерона в сыворотке крови. Установлено, что диагностическая точность разового ультразвукового исследования составила 72,9%, тогда как применение динамического ультразвукового мониторинга позволило повысить данный показатель до 91,7%. Использование мониторинга способствовало сокращению сроков постановки точного диагноза с 18,6 ± 2,4 до 7,3 ± 1,1 суток и восстановлению половой цикличности у 79,2% коров. Полученные результаты свидетельствуют о высокой эффективности ультразвукового мониторинга как инструмента дифференциальной диагностики патологий яичников и оптимизации репродуктивного менеджмента в молочном скотоводстве.*

Ключевые слова: *коровы, патологии яичников, ультразвуковая диагностика, ультразвуковой мониторинг, прогестерон, репродуктивная функция, дифференциальная диагностика.*

Введение

Репродуктивная функция коров является одним из ключевых факторов, определяющих устойчивость и экономическую эффективность промышленного молочного скотоводства. Нарушения воспроизводства оказывают комплексное негативное влияние на производственные показатели хозяйств, выражаясь в снижении выхода телят, увеличении продолжительности сервис-периода, сокращении продуктивного долголетия животных и росте затрат на