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Biopolymer carriers of natural miticides with application in organic beekeeping

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Introduction

The development of sustainable and environmentally friendly pest management strategies is critically important in modern organic apiculture. Varroa destructor, a parasitic mite, remains one of the most serious threats to honeybee health and colony sustainability worldwide. While synthetic miticides initially demonstrated high efficacy, widespread resistance among Varroa populations has significantly reduced their long-term effectiveness. This situation highlights the pressing necessity for sustainable, environmentally safe alternative methods of control that are consistent with organic principles.
Among natural acaricides, formic acid is well-established and highly effective due to its ability to penetrate capped brood cells and target mites both on the surface and inside brood chambers. However, traditional application methods—such as vaporizers or pads—often face limitations, including uncontrolled volatilization, uneven distribution, and potential negative effects on bees if not carefully dosed. These issues limit optimal use.
The use of formic acid in gel form offers a promising solution. Gel formulations allow controlled, sustained release of the active compound, increasing mite mortality while reducing volatilization and stress on bees. Furthermore, gels can be easily applied, take various shapes, and distribute evenly in the hive, ensuring uniform treatment. Encapsulating formic acid in biopolymer-based gels, especially those derived from natural sources, enhances these benefits by ensuring biodegradability, biocompatibility, and environmental safety. A key advantage is that after evaporation, only minimal biodegradable waste remains—eliminating environmental pollution. Additionally, the formulation contains only natural components, making it fully compatible with organic beekeeping practices.

Results

Conclusions

This research demonstrates that biopolymer-based gels encapsulating formic acid offer a promising solution for controlling Varroa destructor in organic beekeeping. The innovative gel formulations facilitate controlled and sustained release of the active compound, significantly improving efficacy while minimizing stress on bee colonies. The use of this biodegradable carrier ensures that the treatment is environmentally friendly, leaving minimal residual fully biodegradable waste and aligning with organic principles.

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Honey bees Apis mellifera are vital to pollination and food production, making them a biologically significant species with profound economic, agricultural, and ecological importance. However, in recent years, the number of bee colonies has sharply declined due to habitat destruction, pesticide exposure, and various parasitic diseases. Among these threats, Varroa destructor stands out as the primary parasite responsible for significant global bee colony losses, making its management one of the most challenging aspects of organic beekeeping. Organic beekeeping is required to comply with Regulation (EU) 2018/848 and to use only specific organic miticides, including formic acid and oxalic acid, as well as menthol and thymol, in cases of infestation with Varroa destructor. The use of formic acid presents challenges primarily related to its application within hives. To address these issues and mitigate associated risks, we explored the integration of liquid miticides into a gel matrix. In this study, we successfully developed a self-supporting composite matrix made from biodegradable polymers that is loaded with organic miticides. The polymer concentration is varied from 1% to 20% by weight. The newly developed self-standing gels have their own shape, allowing for experimentation and evaluation of their effectiveness as a function of their geometric characteristics. The functional properties of these innovative carriers were rigorously evaluated, focusing on stability, rheological behaviour, and release profiles. This comprehensive assessment aimed to elucidate how these factors affect the controlled release and overall effectiveness of the miticides. Preliminary field trials were conducted at a bio-apiary in Bulgaria under real environmental conditions to evaluate the carriers' effectiveness, their impact on bee health, and overall performance within a natural setting. Our findings offer valuable insights into the carriers' resilience against diverse weather conditions and their capacity to safeguard bees from pests without compromising their health, thereby promoting sustainability and safety within apiculture practices.