



Efficacy of Queen Isolation and organic Acid Treatment as control strategy against *Varroa destructor*

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Abstract

The global beekeeping industry faces ongoing losses due to *Varroa destructor*. In Korea, large-scale overwintering colony losses from 2022 to 2024 were linked to Varroa infestations. Despite various control methods, climate change and resistance to conventional treatments have hindered effective management. Integrated pest management (IPM) strategies combining multiple approaches are increasingly emphasized. This study evaluated the efficacy and side effects of queen isolation combined with formic acid treatment for Varroa control. Results showed that queen isolation effectively exposed mites on worker bees, and 98.7% of those mites were eliminated by formic acid. However, this method caused a 60% reduction in worker bee population higher than in other groups and negatively impacted queen survival. These findings underscore the need for further research to develop safer and more effective Varroa control strategies that ensure colony stability.

Keywords: *Varroa destructor*, *Apis mellifera*, Queen isolation, Formic acid, IPM

Materials & Methods

Queen isolation

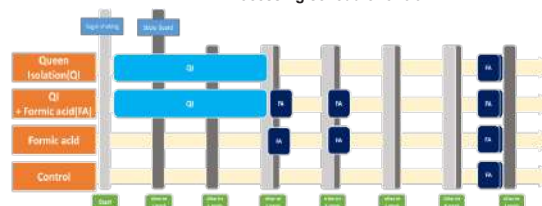
- Rectangular isolation cage (7.5 × 5.7 × 1.8 cm) made of a wooden frame covered with a 1.5 mm² metal
- fully covered comb frame was considered to contain approximately 2,300 bees
- brood cell estimation, the area occupied by sealed brood was measured and converted into the number of brood cells based on a standard calculation of 100 brood cells per 5 × 5 cm section



Varroa detection methods



Processing schedule for trt



Results

Colony Strength by Group

Worker Bee Population &

Table 1. Linear regression analysis of standardized worker bee population (%) trends across experimental groups over the entire experimental period. * Indicates a significant difference. ** Indicates a significant difference

Experimental group	Slope	R-squared	p-Value
Queen isolation	-0.8117	0.3734	0.0078
Queen isolation + acaricide	-1.5851	0.4760	0.0008*
Acaricide	-0.0402	0.0003	0.9304
Control	-0.2219	0.0200	0.4916

Comparison of Brood Cell Numbers

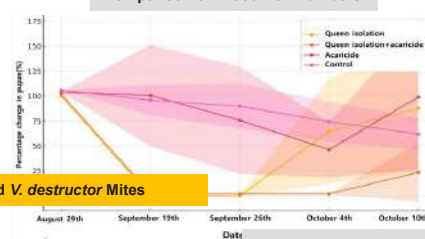


Figure 1. Pupa percentage (%) among treatment group. Each line represents the mean pupae percentage for a specific group, with shaded areas indicating the standard deviation.

Comparison of Detected *V. destructor* Mites

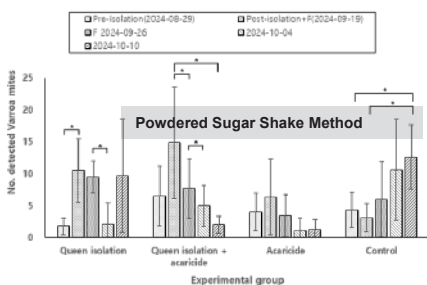


Figure 2. Comparison of detected Varroa mites using the sugar shake method after experimental treatments (queen isolation and formic acid application) across experimental groups. The data represent the mean and standard deviation of Varroa mites detected in each group. F=Formic acid, * indicates significant difference at P<0.05.

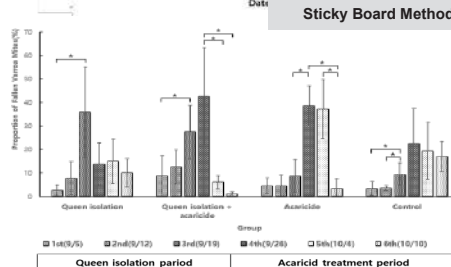


Figure 3. Comparison of fallen Varroa mite proportions during the queen isolation period and after acaricide treatments at weekly intervals. Error bars indicate standard deviation. Significant differences between groups are marked with an asterisk (*), P<0.05.

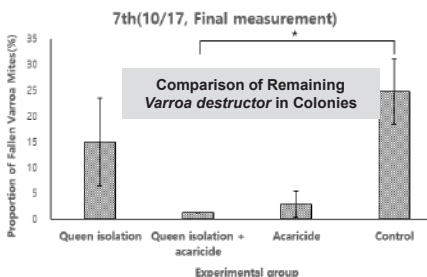


Figure 4. Proportion of Varroa mites detected after the final intensive acaricide treatment. Error bars indicate standard deviation. Significant differences between groups are marked with an asterisk.

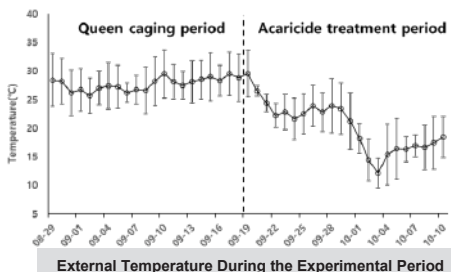


Figure 5. Average external temperature during the queen caging and acaricide treatment periods. Error bars represent the standard deviation.

Discussion

1. A 20-day queen confinement effectively removes brood, causing Varroa mites to move onto worker bee bodies.
 2. Combined treatment of queen confinement and formic acid shows high efficacy in Varroa mite control, but side effects occur, such as worker bee reduction and queen loss.
 - Additional treatment adjustment experiments are needed to reduce these side effects.
 3. When formic acid is applied after queen confinement, a single treatment removes most Varroa mites.
 - Applying formic acid only once reduces side effects caused by formic acid treatment.
- Further experiments are required to establish the optimal integrated Varroa mite control strategy that enhances control effectiveness while minimizing side effects.



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The global beekeeping industry has sustained continuous damage due to Varroa mites. In Korea, large-scale disappearance and mortality of overwintered honeybee colonies were reported between 2022 and 2024, with Varroa mites identified as one of the primary causes. Although various methods have been employed to control this pest, a lack of appropriate control manuals in the face of climate change and the emergence of Varroa mites resistant to conventional treatments have made effective control difficult. In light of the limitations of single-method approaches, integrated pest management (IPM) strategies that combine multiple methods are gaining attention. In this study, we evaluated the efficacy and adverse effects of queen isolation and formic acid application, together as a means of Varroa mite (*Varroa destructor*) control. The results showed that queen isolation effectively exposed Varroa mites on worker bees, and 98.7% of those mites were eliminated by formic acid treatment. However, this combined treatment reduced the worker bee population by an average of 60%—significantly higher than in other treatment groups—and also negatively affected queen survival. These findings highlight the need for further research aimed at securing colony stability while pursuing safer and more effective strategies for Varroa mite control, both in single-method and integrated approaches.