Exploring Surfactant-Based Treatments for Varroa Mite Infestations in Western Honey Bee Colonies

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Abstract

- Honey bee populations are vital for global food security and agricultural productivity, yet they face significant threats from colony collapse disorder and parasitic infestations, particularly by Varroa mites. In this study, we explore the potential of surfactant-based treatments as an alternative to conventional miticides, which are increasingly compromised by resistance. Using a series of dose–response bioassays, we evaluated the toxicity of several surfactants including insecticidal soap, AE-13, BC-12, CE-13, SE-11, and L-7500 on both Apis mellifera (Western honey bees) and Varroa destructor mites. Mortality rates were analyzed via log-probit regression, yielding LD50 values and confidence intervals, which were compared with those obtained using the standard miticide amitraz. Our results indicate that while most surfactants exhibited a dose- dependent increase in mortality, insecticidal soap demonstrated a promising profile by effectively reducing mite populations with minimal bee toxicity. Further analysis suggested that specific surfactant structures may play a role in their differential effects, highlighting insecticidal soap as a promising candidate for further research. These findings underscore the potential of surfactants as safer and more sustainable alternatives for Varroa mite control in apiculture. Future work will focus on optimizing field application methods to translate these laboratory results into practical beekeeping practices.

Background & Significance

Honey bees (Apis mellifera) are essential pollinators, supporting the growth of over 130 types of crops—including apples, cucumbers, and nuts—and contributing over $15 billion annually to the U.S. food industry. Globally, animal pollinators add up to $577 billion in crop value.[4, 5, 6]

A major threat to bee colonies is the Varroa mite, a parasitic pest that weakens bees. Traditional chemical treatments like amitraz have become less effective over time due to growing resistance.[15] This project explores alternative treatments: surfactants such as Safer Soap, AE-13, BC-12, CE-13, SE-11, and L-7500. These compounds may work by disrupting the mites' protective waxy coating, leading to dehydration and death—while remaining safe for the bees themselves.

MARK MOFFETT/MINDEN PICTURES

Hypothesis & Research Objectives

Hypothesis:

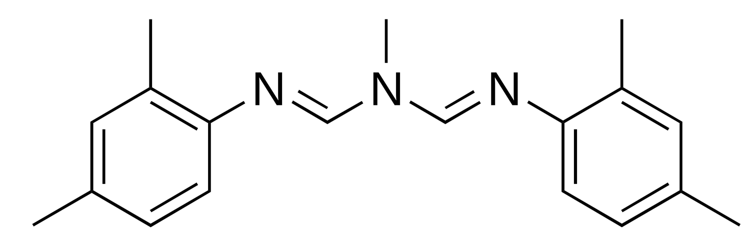
Surfactants—specifically insecticidal soaps—can effectively kill Varroa destructor mites by disrupting their waxy cuticle, while maintaining low toxicity to Apis mellifera (honey bees), due to differences in their physiological susceptibility.

Research Objectives:

- Evaluate the miticidal efficacy of various surfactants, including Safer Soap, AE-13, BC-12, CE-13, SE-11, and L-7500.
- Compare the toxicity of each surfactant to honey bees and mites using dose–response bioassays.
- Determine LD_{50} values for both species to assess treatment selectivity.
- Explore structure–activity relationships and the role of Hydrophilic-Lipophilic Balance (HLB) in toxicity profiles.

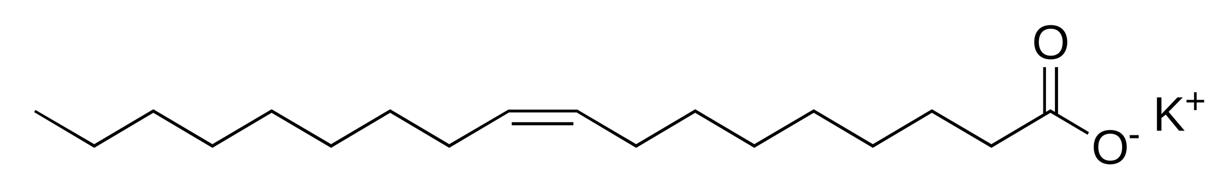
Properties of Surfactants

Surfactant	Type	HLB	Composition	Function	OMRI-Listed
AE-13	Nonionic	13.0	Polyethylene Glycol	Wetting agent, emulsifier	Yes
BC-12	Nonionic	12.0	Polyethylene Glycol Monobutyl	Wetting agent, emulsifier	Yes
CE-13	Nonionic	13.0	Castor Oil	Wetting agent, emulsifier	Yes
SE-11	Nonionic	12.0	Methyl Ester	Wetting agent, emulsifier	Yes
L-7500	Nonionic	N/A	Organo-Silicone	Industrial surfactant, defoamer, wetting agent	No
Safer Soap	Soap (Fatty Acid Salt)	~15.0	Potassium salts of fatty acids	Insecticidal soap, surfactant	Yes
Amitraz	Formamidine Insecticide	N/A	Formamidine compound	Acaricide	No



Structure of Amitraz

Amitraz is a synthetic formamidine insecticide and acaricide traditionally used to control Varroa destructor mites in honey bee colonies. It functions by binding to octopamine receptors in the mites' nervous systems, leading to paralysis and death. Despite its initial efficacy, widespread use has led to emerging resistance in mite populations, reducing its effectiveness and necessitating alternative treatments.

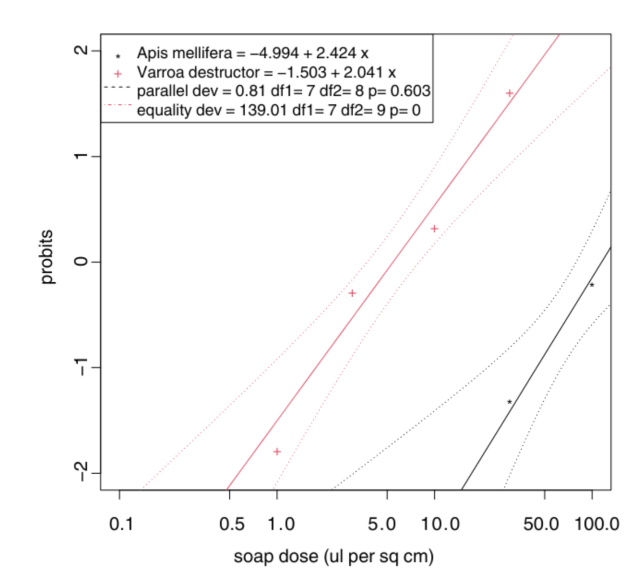


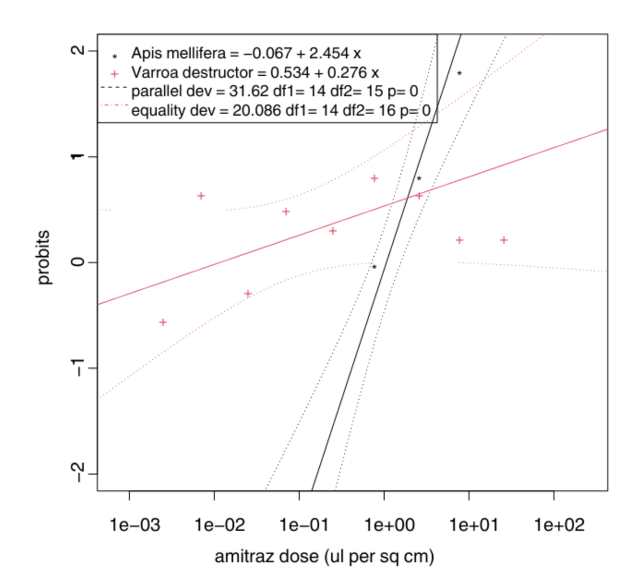
Structure Fatty Acid Potassium Salt (Soap)

This structure represents potassium salts of fatty acids, the active ingredients in insecticidal soaps like Safer Soap. These surfactants disrupt the lipid-rich waxy coating of mites' exoskeletons, leading to dehydration and death. Unlike conventional neurotoxic miticides, this mode of action is physical, making it less likely to trigger resistance. Insecticidal soap demonstrated the highest selectivity in this study, effectively killing Varroa mites while remaining relatively non-toxic to honey bees, making it a promising candidate for sustainable mite control.

LD50 Readings of Surfactants

Treatment Series	LD 50 (µL/cm²) (Bee)	95% CI (Bee)	LD 50 (µL/cm²) (Mite)	95% CI (Mite)
Amitraz	1.07	0.710 - 1.57	0.0116	N/A
Insecticidal Soap	105	79.1- 260	5.45	3.73 - 7.96
AE-13	460	228 - 2500	168	56.9 - 24000
BC-12	133	97.1 - 202	175	N/A
CE-13	334	NA	124	N/A
L-7500	171	123 - 263	71.7	N/A
SE-11	84.5	N/A	35.3	3.18 - 8820





Experimental Design

Honey bees and Varroa mites were collected from high-infestation colonies. Amitraz and six surfactants, including Safer Soap, were serially diluted in acetone or water and applied to jars or vials. Bees were placed in treated jars with sugar-water feeders for 24 hours. Mites were exposed in treated vials with bee larvae for 6 hours. Mortality was recorded, and dose–response data were used to calculate LD_{50} values and assess the selectivity and toxicity of each compound.

scint. (µg)	µg / cm2	Uline (µg)		Stock (µg / ml)	ml added scint	ml added Uline
10000	258	14612		10,000	1	1.46
3000	77.5	4384		10,000	0.3	0.438
1000	25.8	1461		1,000	1	1.46
300	7.75	438		1,000	0.3	0.438
100	2.58	146		100	1	1.46
30	0.775	43.8		100	0.3	0.438
10	0.258	14.6		10	1	1.46
3	0.0775	4.4		10	0.3	0.438

Stock dilution (ug / ml)	Previous (ml)	Acetone (ml)	Taken (ml)	Total Remaining (ml)
10000		5	1	4
1000	1	9	1	9
100	1	9	1	9
10	1	9	1	9
1	**1**	9		10
mg needed	**50**			
acetone needed	**5**			

Key Findings

- Insecticidal soaps like Safer Soap were highly effective against Varroa mites while remaining much safer for honey bees, with mites showing 19 times greater sensitivity — indicating strong selectivity.
- AE-13 had the best safety profile for bees (LD_{50} = 460 µL/cm²) and the highest selectivity ratio, making it a strong candidate for future development despite only moderate mite toxicity.
- Surfactants with lower HLB values (like BC-12 and SE-11) were more toxic to bees, suggesting membrane disruption plays a key role in toxicity.
- Amitraz resistance was observed in mites, shown by shallow dose–response curves, reinforcing the urgent need for new treatment options.
- Field trials are essential: Lab results are promising, but real-world testing will be crucial to assess delivery methods, environmental stability, and long-term safety in active hives.

Future Research

- Field validation is needed to assess treatment effectiveness in real-world hive conditions.
- Key factors include hive size, brood presence, environmental conditions, and bee behavior.
- Future studies should test application methods (spray vs. vapor), dosing frequency, and long-term colony health.
- Modifying surfactants like AE-13 may enhance mite toxicity while keeping bees safe.
- Understanding resistance development and compound breakdown in hives is crucial for sustainable use.

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