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NOTES AND COMMENTS

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Liquid and solid matrix formic acid treatment comparison against Varroa mites in honey bee colonies

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ABSTRACT

Beekeepers use organic acids to control the invasive parasitic mite *Varroa destructor* (Varroa mite) in honey bee colonies (*Apis mellifera*), as an alternative to synthetic acaricides, to which Varroa mites can develop resistance. Here, we tested the efficacy of two formic acid treatments for Varroa mite control: a solid matrix product (Formic Pro; $n = 10$ colonies) and a liquid product (Formivar 60; $n = 10$ colonies), relative to control colonies that were not treated with formic acid ($n = 10$). Both formic acid treatments killed >95% of the mites, however, the use of formic acid also resulted in 1.6 times more brood loss and 30% queen loss, relative to control colonies. Although the solid application was perceived as being more practical to use for treating against Varroa mites, both the solid and liquid application methods were equally effective and had similar negative side effects on honey bee colonies.

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The mite *Varroa destructor* Anderson & Trueman (2000) is an obligate parasite of honey bees *Apis mellifera*, L. It feeds on adult bees and pupae and vectors the deformed wing virus, which can lead to mortality of honey bee colonies (Genersch et al., 2010; Hasegawa et al., 2023). Therefore, managed honey bees require regular Varroa mite control. Organic acids such as oxalic acid and formic acid have become established treatment options in Central Europe (Brodschneider et al., 2023). Formic acid, unlike other treatment methods, penetrates through the porous surface of brood cell cappings and targets mites where they reproduce (Calis et al., 1998; Kubásek et al., 2022).

Though studies on formic acid show high efficacies in reducing mite infestation in honey bee colonies (Pietropaoli & Formato, 2019), beekeepers face the potential risk for skin and respiratory irritation when applying this treatment. Also, the use of formic acid requires careful consideration of dosage and application methods to prevent negative effects on honey bee survival and brood development (Ostermann & Currie, 2004). Since its efficacy can vary, e.g., based on the temperature, humidity and method of application, new application methods are being developed and marketed. We carried out a field trial to compare two formic acid medicines, registered for veterinary use in the Netherlands (REG NL 126198 and REG NL 118709, respectively), listed in an online database (Medicijnautoriteit CBG, 2023). We note that only registered Varroa treatment products are permitted to be used in the Netherlands.

The Bijen@wur research apiary (51°59′32.6"N; 5°39′47.3"E) was set up with 30 honey bee colonies: 10 colonies were treated with a solid matrix product (Formic Pro, NOD Apiary Products Ltd., Canada), 10 colonies received a 220 ml liquid application (Formivar 60, administered with a commercial "Liebig" dispenser, Andermatt Biovet GmbH, Switzerland), and 10 colonies were left untreated (negative control group). Throughout the study, all 30 colonies were fed sugar fondant since the colonies had little to no stored honey during the experiment.

The experiment ran from August 18th to October 18th, counting Varroa mites on bottom boards at two-day intervals. Treatments were applied on August 30th. The treatment duration was 36 days (Figure 1(A)). Two follow-up treatments were applied to kill remaining mites, by spraying the bees with a solution of 3.5% oxalic acid in water (October 4th and 10th). With queens caged three weeks prior, the follow up treatments were applied in absence of closed brood. Treatment efficacies were calculated as follows: (Number of mites killed by test compound/ (Number of mites killed by test compound + Number of mites killed by the follow-up treatments)) × 100. To check impact on brood development, the number of frames in colonies that contained closed brood cells were counted before and after treatment (August

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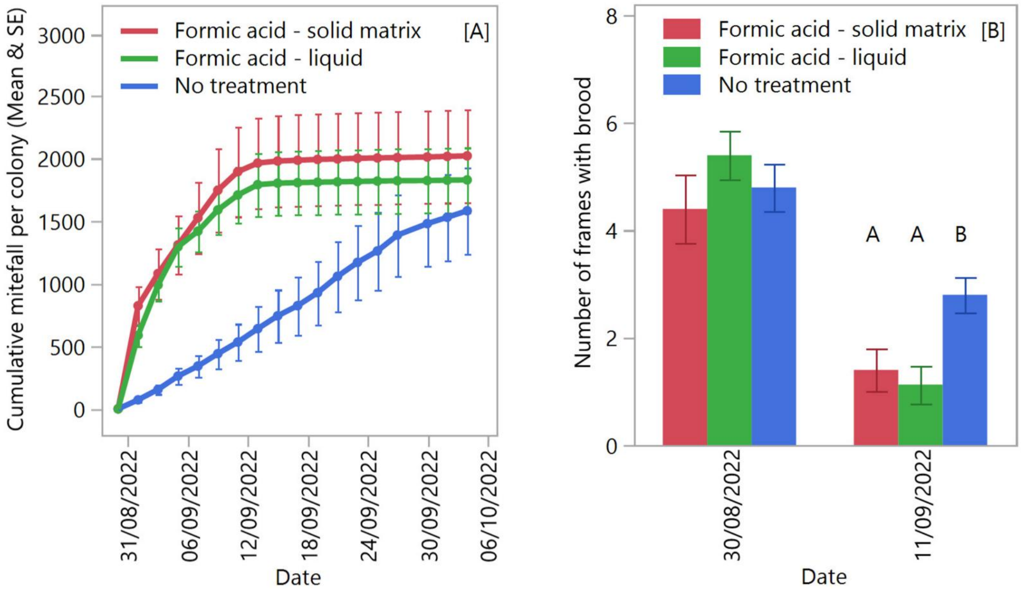

Figure 1. (A) Average cumulative mite counts of honey bee colonies. The formic acid treatments were applied August 30st–up to the follow treatments with oxalic acid (October 4th and 11th). (B) Number of brood frames in colonies, before and after treatment. Each treatment involved 10 replicate colonies.

30st and September 11th, resp.). Additionally, queen presence was verified by visual observation, before and after treatment (August 18th and September 11th). All collected data is accessible in an online repository (Hendriksma et al., 2023).

Between August 18th to October 18th 77,872 mites were counted, with mean 2596 mites per colony ($N = 30$). Before treatment (12 days; August 18th to 30st) the mite fall did not differ between treatment groups (Kruskal-Wallis Test; $Df = 2$, $ChiSquare = 0.07$, $p = 0.97$). The formic acid treated colonies groups showed an elevated mite-fall for 12 days (Figure 1(A)), i.e., the period that worker brood cells remain capped. The efficacy of killing Varroa mites was found to be 96.0% ± 1.0 SE for the solid formic acid matrix and 95.4% ± 2.0 SE for the liquid formic acid application method, with no significant difference between the two (one-way Anova: $F_{1,12} = 0.06$; $p = 0.81$). Multiple colonies were excluded because colony death or due to breeding drones.

Before the formic acid treatment, brood development did not differ significantly between treatment groups (one-way Anova: $F_{2,27} = 0.94$; $p = 0.40$; Figure 1(B)). Brood development in colonies did however declined significantly (one-way Anova: Figure 1(B); $F_{1,56} = 60.9$; $p < 0.001$). Relative to an average 2.00 frames brood loss in control colonies, the formic acid treated colonies lost 3.56 frames of brood (one-way Anova: $F_{2,25} = 6.17$; $p = 0.007$; Post hoc A A B; Figure 1(B)). Formic acid applications evoked notable stress in colonies, with five colonies exhibiting bearding outside the hive, and two colonies absconding. Queen loss in control colonies was 20% whereas in formic acid treatments the queen loss was approximately 50%, indicating a difference of 30% that may be attributed to the formic acid treatment, albeit as result not significant (Fisher's exact test, 2-tailed p-value = 0.13; $n = 29$ observations), excluding one colony for analyses because the queen was killed by accident.

In practice, the solid treatment method was found easier in use (i.e., quicker and safer) than the liquid method. However, both methods effectively killed Varroa mites (>95%). Despite the high efficacy, the results also highlighted several negative effects associated with formic acid use. In line with previous research our study revealed that formic acid treatment can result in increased worker bee and brood mortality (Ostermann & Currie, 2004), and induce queen supersedure. Therefore, to prevent adverse impacts on honey bee survival and queens, it is crucial to adhere to the appropriate dosage and follow the product label instructions (Van der Steen & Vejsnæs, 2021). Following instructions is essential to also prevent other negative impacts on colony health, beekeeper safety, and the quality of honey for consumers.

In adherence to guidelines, we treated one brood chamber with two Formic Pro strips. However, it is possible that higher concentrations than intended were reached, since the Dutch "simplex" hive type is 22% smaller in volume than the Langstroth hive for which the product was designed. The Liebig dispenser guideline regards colony size and hive type, and prescribed for our case to apply 2 × 150 ml Formivar 60: we however applied 1 × 220 ml. This dose evaporated with an average 22.7 ml per day in 12 days, being in the Liebig dispenser application target range of 20–25 ml per day.

The weather was 19.4 °C and 69.2% relative humidity, on average. Notwithstanding, the daytime temperatures often exceeded 25 °C, potentially escalating the formic acid evaporation. We further note extreme mite infections (Figure 1) with the colonies weakened by Varroa parasitosis (e.g., having Deformed Wing Virus). In all, our findings provide a worst-case representation of formic acid treatment practice and highlight associated negative consequences. While formic acid remains an effective treatment for Varroa in honey bee colonies, there is still room for treatment improvement regarding negative effects.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Anderson, D. L., & Trueman, J. W. (2000). *Varroa jacobsoni* (Acari: Varroidae) is more than one species. *Experimental and Applied Acarology*, *24*(3), 165–189. https://doi.org/10.1023/a:1006456720416

Brodschneider, R., Schlagbauer, J., Arakelyan, I., Ballis, A., Brus, J., Brusbardis, V., Cadahía, L., Charrière, J.-D., Chlebo, R., Coffey, M. F., Cornelissen, B., da Costa, C. A., Danneels, E., Danihlík, J., Dobrescu, C., Evans, G., Fedoriak, M., Forsythe, I., Gregorc, A., … Gray, A. (2023). Spatial clusters of *Varroa destructor* control strategies in Europe. *Journal of Pest Science*, *96*(2), 759–783. https://doi.org/10.1007/s10340-022-01523-2

Calis, J. N. M., Boot, W. J., Beetsma, J., van den Eijnde, J. H. P. M., de Ruijter, A., & van der Steen, J. J. M. (1998). Control of Varroa by combining trapping in honey bee worker brood with formic acid treatment of the capped brood outside the colony: Putting knowledge on brood cell invasion into practice. *Journal of Apicultural Research*, *37*(3), 205–215. https://doi.org/10.1080/00218839.1998.11100973

Genersch, E., von der Ohe, W., Kaatz, H., Schroeder, A., Otten, C., Büchler, R., Berg, S., Ritter, W., Mühlen, W., Gisder, S., Meixner, M., Liebig, G., & Rosenkranz, P. (2010). The German bee monitoring project: A long term study to understand periodically high winter losses of honey bee colonies. *Apidologie*, *41*(3), 332–352. https://doi.org/10.1051/apido/2010014

Hasegawa, N., Techer, M. A., Adjlane, N., Al-Hissnawi, M. S., Antúnez, K., Beaurepaire, A., Christmon, K., Delatte, H., Dukku, U. H., Eliash, N., El-Niweiri, M. A. A., Esnault, O., Evans, J. D., Haddad, N. J., Locke, B., Muñoz, I., Noël, G., Panziera, D., Roberts, J. M. K., … Mikheyev, A. S. (2023). Evolutionarily diverse origins of deformed wing viruses in western honey bees. *Proceedings of the National Academy of Sciences of the United States of America*, *120*(26), e2301258120. https://doi.org/10.1073/pnas.2301258120

Hendriksma, H. P., Cornelissen, B., & Panziera, D. (2023). Formic acid treatment comparison for Varroa in honey bee colonies. *Science Data Bank*, 2023[2023-11-21]. https://doi.org/10.57760/sciencedb.07760

Kubásek, J., Svobodová, K., Půta, F., & Bruce Krejčí, A. (2022). Honeybees control the gas permeability of brood and honey cappings. *iScience*, *25*(11), 105445. https://doi.org/10.1016/j.isci.2022.105445

Medicijnautoriteit CBG. (2023). Online database. https://www.diergeneesmiddeleninformatiebank.nl

Ostermann, D. J., & Currie, R. W. (2004). Effect of formic acid formulations on honey bee (Hymenoptera: Apidae) colonies and influence of colony and ambient conditions on formic acid concentration in the hive. *Journal of Economic Entomology*, *97*(5), 1500–1508. https://doi.org/10.1603/0022-0493-97.5.1500

Pietropaoli, M., & Formato, G. (2019). Acaricide efficacy and honey bee toxicity of three new formic acid-based products to control *Varroa destructor*. *Journal of Apicultural Research*, *58*(5), 824–830. https://doi.org/10.1080/00218839.2019.1656788

Van der Steen, J. J. M., & Vejsnæs, F. (2021). Varroa control: A brief overview of available methods. *Bee World*, *98*(2), 50–56. https://doi.org/10.1080/0005772X.2021.1896196