Use of Essential Oils for the Control of *Varroa jacobsoni*

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ABSTRACT

Essential oils and essential oil components offer an attractive alternative to synthetic acaricides for the control of *Varroa jacobsoni.* They are generally inexpensive and most pose few health risks. Terpenes (mainly monoterpenes) are the main components of essential oils, comprising about 90% of the total. More than 150 essential oils and components of essential oils have been evaluated in laboratory screening tests. Very few of them, however, have proven successful when tested in field trials. Thymol and thymol blended with essential oils or essential oil components offer a promising exception. Mite mortality obtained with these formulations typically exceeds 90% and often approaches 100%. In addition, residues in honey are low, even after long-term treatments. The exact conditions under which these formulation will yield reliable and effective control, however, have only been determined for certain European regions. Based on the available studies, relying solely on a single treatment with an essential oil or essential oil component is generally not sufficient to maintain mite populations below the economic injury level. Therefore, efforts are necessary to optimise the use of these substances and to incorporate them, along with other measures for limiting mite populations, into an integrated pest management strategy for control of *Varroa jacobsoni*.

INTRODUCTION

Colonies in temperate regions must be treated once or twice a year against *Varroa jacobsoni* to maintain their populations below economic injury levels. During the last 10 years, the pyrethroids have been the primary source of insecticides used to control *V. jacobsoni*. Recently, mites in parts of Europe and North America have developed resistance to pyrethroids. The widespread use of synthetic lipophilic acaricides has lead to the accumulation of residues in beeswax, propolis and to a much lesser degree, in honey.

The development of acaricide resistance in *V. jacobsoni* populations and the spectre of the contamination of hive products provide considerable incentive to develop new treatment strategies that minimise the potential for acaricide resistance and the accumulation of residues. Since *V. jacobsoni* was introduced to Europe, intensive efforts have been made to develop alternative chemical control measures based on formic, lactic and oxalic acids combined with biotechnical measures.

It is well known that many essential oils and their components exhibit acaricidal activity. Before *V. jacobsoni* was a world wide pest, different components of essential oils were tested for their activity against *Acarapis woodi*. Methyl salicylate and menthol proved to be toxic to the tracheal mite. In the last 15 years, research has shown that several essential oils and individual compounds of essential oils also have a high acaricidal activity against *Varroa jacobsoni*.

THE POTENTIAL OF ESSENTIAL OILS AS VARROACIDES

In extensive screening tests, many oils show significant acaricidal activity. Some oils are repellent to *V. jacobsoni*, others are attractive, and some cause mite mortality. However, of more than 150 essential oils and components of oils tested, only very few have proven effective when applied in hives in field trials. This is most probably due to the fact, that the screenings tests used were incapable of predicting the acaricidal effect under field conditions. Difficulty in obtaining standardised essential oils also affects treatment predictability. Only a combination of wintergreen oil and thermal treatment, an aerosol treatment of a thyme-sage oil mixture, and the passive evaporation of thymol, oregano oil and marjoram oil in combination with diluted formic acid have been used successfully for mite control. For different reasons, however, none of these treatments have been widely adopted by beekeepers, with the exception of thymol. Indeed, thymol and thymol blends are widely used to control *V. jacobsoni* in Europe and in most cases their varroacidal efficacy is greater than 90 % (Tab. 1 and 2). Different thymol containing products are available on the market.

Because of insufficient predicting capacity of the screening tests used until now, we devised an assay, in which the dose-response relationship of an airborne acaricide and the corresponding mite and bee mortalities can be assayed under laboratory conditions.

Picture: Screening test for essential oils

Table 1 - Treatment of *V. jacobsoni* with pure thymol

Authors	year	thymol formulation	dosage	place of application	days of treat-ment	time of treatment	numb er of colo-nies	number of su-pers	number of apia-ries	type of hive	mean efficacy of treatme nt %	mean treat-ment mitefall
Marchetti et al. [69]	1984	powder in bag	4 x 15g	between combs	16	Oct./Nov.	10	1	1	Dadant	66.0	3229
Lodesani et al. [62]	1990	powder	3 x 4.5/6g	dusted over com	21	Oct./Nov.	38	1	2	Dadant	81.0	190
Frilli et al. [33]	1991	powder	4 x 1g	on comb bars	8	Nov.	7	1	1	Dadant	95.0	
Chiesa [17]	1991	powder	5 x 0.5g/comb	on comb bars	8	Oct./Nov.	21	1	3	Dadant	96.8	1917
Liebig [60]	1995	on compound	2 x 15g	on comb bars		Aug./Nov.		1		Zander		
		on compound	2 x 30g	on comb bars		Aug./Nov.		2		Zander		
Higes et al. [40]	1996	powder	5 x 1g beeway	on comb bars	19	Feb.	4	1	1	Autocol.	97.8	977
Higes and Llorente [39]	1997	powder	4 x 8g	petri on combs	28	Apr./May	4		1	Langstr.	97.6	1119
Flores et al. [31]	1997	powder	2 x 10 g	petri on combs							97.0	
		on compound	2 x 10g	on comb bars							95.0	
Bollhalder [10]	1998	on compound	2 x 15g	on comb bars	49	Aug./Oct.	22	1	4	CH	85.0-97.0	

Table 2 - Treatment of V. jacobsoni with blends of thymol, eucalyptol, camphor and menthol (N.C. = non commercial)

Authors	year	product	number of com-pounds	place of appli-catio n	days of treat-ment	time of treatment	number of colonies	number of supers	number of apiaries	type of hive	mean efficacy of treatment %	mean treatment mitefall
Contessi and Donati [22]	1985	Biovarroin	2 x 1	top	35	Nov./Dec.	2	1	1	Dadant	92.6	316
Tonelli [88]	1989	Api Life VAR	2 x 1	top		Nov./Dec.					93.8	
Rickli et al. [80]	1991	Api Life VAR	2 x 1	top	38	Aug./Sep.	20	1	1	CH	96.4	986
		Api Life VAR	2 x 1	top	79	Aug./Oct.	20	1	1	CH	99.0	2453
Mutinelli et al. [unpbl.	1991	Api Life VAR	2 x 1	below	40		13	1	1	Dadant	89.0	593
van der Steen [91]	1992	Api Life VAR	2 x1	top	42	Sep./Oct.	5		1		74.0	
		N.C.+ camphor	2 x 1	top	42	Sep./Oct.	5		1		92.0	
		N.C. - camphor	2 x 1	top	42	Sep./Oct.	5		1		88.0	
Moosbeckhofer [76]	1993	Api Life VAR	2 x 1		29	Sep./Oct.	23	2	3	Zander	98.6	1400
Mutinelli et al. [77]	1993	Api Life VAR	2 x 1	top	49	Aug./Oct.	27	1	4	Dadant	68.7	4925
Liebig [59]	1993	Api Life VAR	2 x 1	top		Sep./Dec.	14	1	4	Zander	97.4	1276
		Api Life VAR	2 x 1	top		Sep./Dec.	26	2	4	Zander	63.9	1276
Schulz [84]	1993	Api Life VAR	2 x 1	top		Aug./Dec.	3	2	1	Zander	74.7	
		Api Life VAR	2 x 2	top		Aug./Dec.	4	2	1	Zander	94.9	
		Api Life VAR	2 x 3	top		Aug./Dec.	2	2	1	Zander	99.5	
		Thymix	2 x 1 or 2	top		Sep./Dec.	77	1 or 2	7	Zander	94.8	3492
Imdorf et al. [50]	1994	Api Life VAR	2 x 1	top	56	Aug./Oct.	83	1	8	CH	97.7	602
Imdorf et al. [46]	1995	Api Life VAR	2 x 1	top	42-56	Aug./Oct.	19	1	1	Dadant	91.7	1078
Calderone and Spivak	1995	N.C.	2 x 2	top	19	Nov.	8	2	2	Langstr	96.7	
Gregorc and Jelenc [35]	1996	Api Life VAR	2 x 1	top	30	Aug./Sep..	14	2	1	Alberti.	66.4	
Loglio et al. [65]	1997	Api Life VAR	3 x ½	top	21	Jul./Aug.	32	1	1	Dadant	72.6	
Calderone [14]	1999	N.C.	2 x 1	top	32	Oct./Nov.	6	2	1	Langstr oth	67.0	

Using this technique, a high mite toxicity, combined with good bee tolerance, were demonstrated, besides thymol, for the following components of essential oils: camphene, camphor, p-cymene, eugenol, isopinocamphon (ysop oil), menthol and α-thujone. Identifying compounds with acceptable acaricidal activity but with low toxicity to honey bees is essential for providing candidate compounds for field trials. After finding suitable substances under laboratory conditions we will measure the air concentration under field conditions to test their efficacy in a bee colony. This procedure can serve as a powerful screening technique because it guides subsequent field research into the most productive avenues. The development of effective delivery systems for essential oils remains one of the greatest obstacles to their implementation as mainstream control measures. Highly volatile substances like camphor are difficult to use, but formulations retarding the evaporation rate, e.g. special gels, might overcome this difficulty. Products with mixtures of different components with different modes of action, might also provide effective solutions. For example, substances that disrupt the mite's host finding behaviour may be effective in conjunction with substances that kill mites.

RESIDUES

Residues pose another challenge to the use of essential oils. Most essential oils are mixtures of more than 50 components. Depending on the individual partition coefficients of the constituents, residues in honey and wax are to be expected. Residues in honey can lead to adverse effects on taste, while residues in wax can render it unsuitable for some applications. Quantitative residue analyses are required for product registration. The complex nature of many essential oils, combined with the fact that many essential oil components are naturally occurring in honey, makes such residue analysis difficult. Thus, the successful development of products employing essential oils can be extremely difficult unless the particular essential oil has been granted an exemption from tolerance (no maximum residue limit). In the EU, thymol, menthol and camphor have this status. The use of individual components of essential oils makes residue analysis much easier and limits the potential for producing off-flavour honey. Long-term studies have demonstrated that when used properly, residues of thymol in honey remain at low and safe levels (Tab.3).

CONCLUSIONS

Based on the available studies, relying solely on one treatment per bee season with essential oils or essential oil components can not be recommended as an effective and reliable method to maintain mite populations below the economic injury level. The challenge for future research is to optimise the use of essential oils and essential oil components and to incorporate the resulting products along with other measures for limiting mite populations such as cutting out of drone brood, trapping combs, formation of nucleus colonies or the use of organic acids into an integrated pest management strategy for the control of *V. jacobsoni*. Adapting these strategies to local climatic conditions, to diverse apicultural management practices and to beekeeping operations of varying sizes pose additional and significant challenges. Finally, resistance to essential oils may eventually develop, as it has with synthetic pesticides. Consideration must be given to the development of resistance management plans to maximise the useful life span of effective acaricides and delivery systems once they are developed.

The results, reported in the present manuscript, are presented in detail in the review cited below.

Table 3 - Thymol residues in honey after different treatments

Type of thymol treatment	average mg/ kg	Min-Max mg/kg
Thymol frame a whole year use in Switzerland, 1997 (n = 22)	0.33	≤ 0.02-0.83
Thymol frame a whole year use in Switzerland, 1998 (n=34)	0.40	0.11-1.06
Thymol frame use outside the honey flow period in Switzerland 1998 (n=10)	0.17	≤ 0.02-0.32
Thymol frame a whole year use in Germany, Wallner 1997 (n = 19)	0.63	0.07-2.0
Api Life VAR 8 weeks treatment in autumn, 1 to 5 use (n=28)	0.16	≤ 0.02-0.48
Lime honey (Guyot et al. 1998)	0.08	0.02-0.16
Thymol concentration affecting honey taste	1.1-1.3	
Maximum residue limit for Switzerland	0.8	

LITERATURE

A complete literature list on this topic you will find in the following review:

Imdorf A., Bogdanov S., Ibáñez Ochoa R., Calderone N. W. (1999) Use of Essential Oils for the Control of *Varroa jacobsoni* in Honey Bee Colonies. Apidologie (30) 209-228