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Original article

Study of the depletion of tylosin residues in honey extracted from treated honeybee (*Apis mellifera*) colonies and the effect of the shook swarm procedure*,**

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Abstract – Bee colonies were dosed with tylosin tartrate 1.1 g per hive (single dose in sucrose solution) and samples of honey were then collected at intervals over a 20-week period. The samples were analysed for tylosin A and desmycosin (tylosin B) using LC-MS/MS. The mean concentration of tylosin A in the honey (pooled results) 3 days after dosing was 17 μg/g, declining to 0.9 μg/g after 140 days. The mean concentration of desmycosin was 2.3 μg/g, 3 days after dosing declining to 1.1 μg/g after 140 days. The shook swarm procedure was investigated and resulted in a tylosin A concentration in brood honey of 10 μg/g, 3 days after dosing declining to 0.02 μg/g, 140 days after dosing. A corresponding decrease in the mean concentrations of desmycosin in brood honey, 1.1 μg/g, 3 days after dosing to 0.03 μg/g, 140 days after dosing also was observed. Tylosin A depletes to desmycosin in honey and can still be detected 238 days after dosing. Thus a more accurate residue definition is the sum of tylosin A and desmycosin.

Tylosin / desmycosin / honey / veterinary drug / residues / apiculture

1. INTRODUCTION

Tylosin along with other macrolides comprise a group of antibacterial compounds that have a wide range of applications in the field of veterinary medicine, including use as therapeutic agents and as growth-promoting antibiotics. In therapeutic applications tylosin is used to control certain Gram-positive bacteria, mycoplasma and Gram-negative bacteria (EMEA, 1997). Tylosin, along with lincomycin, erythromycin and monensin, has been identified as an effective treatment in oxytetracycline (OTC) resistant strains of American Foulbrood (AFB) (Kochansky et al., 2001). In October 2005 Tylan Soluble (tylosin tartrate) was approved in the USA to control AFB (FDA, NADA 013-076, 2005).

Current EU legislation does not permit the use of tylosin or any other antibiotics in bees for the treatment of either European or American Foulbrood. Residues of tylosin at concentrations up to 0.006 μg/g have been detected in retail samples of honey analysed in the 2004 UK Non-Statutory Surveillance scheme (VRC Annual Report, 2004). The Canadian Food Inspection Agency (CFIA) has reported the presence of tylosin residues in honey, in the range of 0.0012–0.1156 μg/g (CFIA, 2003–2004 survey). The CFIA currently has a working residue limit (WRL) of 0.06 μg/g to account for 'extra label' usage (CFIA, 2005). Recently published methods for the analysis of tylosin in honey have been established with limits of quantification as low as 0.0025 μg/g for a biosensor screening approach (Caldow et al., 2005) and 0.0005 μg/g for a LC-MS/MS (liquid chromatography coupled

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to mass spectrometry) confirmation procedure (Wang, 2004). A method for the determination of tylosin based on the measurement of zones of inhibition of the microbial activity has also been reported (Feldlaufer et al., 2004).

The main purpose of this study was to investigate the depletion of tylosin A in a hive system and to ascertain if there is a relationship between tylosin A and desmycosin concentrations detected in the collected honey. Kochansky previously identified desmycosin as a degradation product of tylosin in honey (Kochansky, 2004). Therefore it is important to include the determination of both tylosin A and desmycosin when monitoring for the (mis)use of this drug in honey.

Additionally the shook swarm procedure was investigated as a possible method to reduce residue concentrations after treatment (dosing). Thompson et al. reported the use of the shook swarm technique to successfully reduce concentrations of OTC in honey collected from dosed bee colonies. Therefore one of the aims of the project was to determine the persistence of tylosin and desmycosin with and without the application of the shook swarm procedure.

2. METHODS AND MATERIALS

2.1. Bee colonies and treatments

The dosing study was carried out in June 2005–February 2006. Eight standardised free flying colonies of UK honeybees (*Apis mellifera* L.), housed in double Smith brood boxes with 11 British standard frames (33.6 cm by 20.4 cm giving 685.4 cm^2 per side of brood frame) per brood box and at least one super box, with 18–20 frames of bees in each colony, were used in this study. The colonies were maintained and owned by the Central Science Laboratory (CSL), National Bee Unit. At the start of the trial these colonies showed no clinical signs of European or American foulbrood, sacbrood or baldbrood and had only a low incidence of chalkbrood. Six colonies were treated with tylosin and were located at an experimental apiary approximately 10 km from two undosed control colonies that were established in parallel at the CSL site. This was to reduce the risk of cross-contamination by drifting.

The six treated colonies were dosed with a solution of 1.1 g of tylosin tartrate in 200–250 mL aqueous sucrose solution (50–60% w/v) by pouring into the marked top empty brood frame. The treatment comb was placed in the top brood box, two frames in (usually on the edge of the brood nest with the treated side of the frame out). The two control colonies were fed with untreated sucrose using the same method of application. Seven days after dosing and honey sampling, two of the treated colonies were randomly selected and shook swarmed. The shook swarm treatment involved the transfer of the adult bees onto clean foundation with the brood and original frames being removed and destroyed. During winter i.e. after October sampling, the colonies were fed with 50% w/v sucrose using a rapid tray feeder

2.2. Sampling

Table I outlines the sampling time points.

In June 2005, two to four days before treatment (D-2 to D-4) samples of up to 100 g of nectar/honey were taken from each colony to establish a baseline residue concentration for the colonies, i.e. to confirm antibiotic residues were not present. Samples of brood honey were collected at eight different time points during the bee keeping season. Samples of super honey were not available for all colonies on D3, D58, D84 and D238. Post-wintering samples were collected in February 2006, at D238.

Each sampling day, four comb samples (approximately 8 cm by 10 cm) were taken from each hive, two from the brood chamber and two from the super. The four samples were taken from different frames in the hive. For each colony these samples were bulked as super sources and brood chamber sources, except at D28 when each of the individual samples were extracted separately to enable an assessment of the distribution of tylosin within each colony. The honey/nectar samples were extracted by filtering the sample through cloth into a clean container. All samples were stored at –20 °C prior to analysis.

At the end of the trial bees from all treated colonies were shaken onto new foundation and the brood combs and super combs incinerated.

2.3. Apparatus and reagents

Tylosin tartrate (cell culture tested) was purchased from Sigma Aldrich (Dorset, UK) containing desmycosin 4% by weight. OASIS HLB SPE cartridges (6 mL/200 mg) were purchased from Waters (Manchester, UK). All other reagents were of analytical grade and obtained from either BDH

Table I. Honey sampling plan from the 8 experimental hives.

Time point from dosing (days)	Dosed hives without shook swarm procedure	Dosed hives with shook swarm procedure	control hives
−4 to −2 (baseline sample)	✓	✓	✓
3	✓	✓	✓
7	✓	✓	✓
14	✓	✗	✓
21	✓	✗	✓
28	✓	✗	✓
56	✓	✓	✓
84	✓	✗*	✓
140	✓	✓	✓
238 (over winter)	✓	✓	✓

✓ = sampling,
✗ = no sampling,
*= insufficient honey available.

(Poole, UK) or Fisher Scientific (Loughborough, UK). Phosphate buffer (pH 7) was prepared by dissolving 13.6 g dipotassium hydrogen orthophosphate and 4.0 g potassium dihydrogen orthophosphate in 1 litre of water.

2.3.1. Preparation of standard solutions

A stock standard of tylosin A (1 mg/mL) was prepared in methanol with a shelf life of one month. Desmycosin was prepared immediately before use from Tylosin A. A small volume (approximately 200 μL) of formic acid (98%) in water (9.7 mL) with a pH <4 was added to 100 μL of tylosin stock standard. The solution was then transferred to a 50 mL falcon tube and placed in a water bath at 50 °C overnight to hydrolyze tylosin A to desmycosin.

2.4. Extraction of control samples and samples containing residues at low concentration

Phosphate buffer (10 mL) was added to the sample (2 g) and placed in a water bath (45 °C) for 10 min. The sample was vortex mixed to dissolve the honey and allowed to cool to room temperature (20 °C).

The extract (10 mL) was cleaned up using an OASIS HLB SPE cartridge; conditioned with methanol (5 mL) and extraction buffer (5 mL). The extract was loaded onto the cartridge, which then was washed with 40% methanol in water (5 mL). Tylosin A and desmycosin were eluted with acetonitrile (5 mL). The eluate was evaporated to dryness at 40–50 °C under a stream of nitrogen and reconstituted in 50% methanol in water (1 mL). Matrix extracted calibration standards (prepared by spiking honey with tylosin A and desmycosin and then taken through the extraction procedure) were prepared over the range 0.001–0.3 μg/g for tylosin A and 0.01–0.25 μg/g for desmycosin. Method validation data is shown in Table II. Batch recovery samples spiked with Tylosin A and desmycosin, gave recoveries in the range 75% to 101% and 69% to 131%, respectively.

2.5. Dilution of samples containing residues at high concentration

Honey samples (1.25 g) were dissolved with H_2O (25 mL). An aliquot (0.1 mL) was mixed with 50% methanol in water (0.9 mL). Matrix matched calibration standards (honey solution spiked with tylosin A and desmycosin after dilution) were prepared in the range, 0.2–200 μg/g for tylosin A and 0.2–20 μg/g for desmycosin. The results from several validation batches gave satisfactory results; these data are shown in Table II.

2.6. Quantification

The LC-MS/MS system comprised a Quattro Ultima Platinum Triple Quadrupole (Micromass, Manchester, UK) coupled to an Alliance 2695 Separations Module (Waters) controlled by Mass Lynx version 4.0. An isocratic separation was performed

Table II. Method validation information for tylosin A and desmycosin analysed during this study.

Spike concentration (μg/g)	Extraction method	No. of replicates	Tylosin A Measured concentration (μg/g)	Tylosin A RSD	Desmycosin Measured concentration (μg/g)	Desmycosin RSD
20	Dilution	7	18.5	6	NA	NA
10	Dilution	7	10.2	4.8	NA	NA
5	Dilution	7	4.7	2.7	6.1	1.9
1	Dilution	7	1	3.7	1.2	3.3
0.5	Dilution	7	0.4	4.3	0.5	3.6
0.2	SPE	7	0.18	2	0.18	3.5
0.05	SPE	7	0.046	1.4	0.046	5.1
0.004	SPE	21	0.004	6.8	NA	NA

SPE = Solid Phase Extraction,
RSD = Relative Standard Deviation,
NA= method not validated at this concentration.

Table III. Results from 4 non shook swarmed colonies; tylosin A residue concentrations obtained from the 34-week tylosin tartrate dosing study (n = number of honey samples analysed from all hives per time point).

Time point (days from dosing)	Mean of pooled results for brood and super honey μg /g ± SD	Brood honey mean residue μg/g (n) ± SD	Super honey mean residue μg/g (n) ± SD
D-4 - D-2 (Baseline)	< 0.006	< 0.004 (4)	< 0.002 (2)
D3	17 ± 15	8.0 (4) ± 3.7	29 (3) ± 17
D7	12 ± 6.2	11 (4) ± 7.3	13 (4) ± 5.8
D14	9.9 ± 6.6	10 (4) ± 9.3	9.5 (4) ± 4.0
D21	7.4 ± 6.1	8.4 (4) ± 8.2	6.3 (4) ± 4.3
D28	6.1 ± 4.7	4.8 (8) ± 4.3	7.4 (8) ± 5.1
D56	3.3 ± 2.3	3.4 (4) ± 3.0	3.2 (3) ± 1.7
D84	1.7 ± 1.6	1.7 (4) ± 1.5	1.9 (3) ± 2.2
D140	0.92 ± 0.84	0.65 (4) ± 0.65	1.2 (4) ± 1.6
D238 (over winter)	0.93 ± 0.77	0.45 (4) ± 0.26	1.4 (3)± 0.93

on a Waters Sunfire C18 (100 mm × 2.1 mm, particle size 3.5 μm) with a C18 guard column installed. The mobile phase was 10 mM ammonium acetate in water, 0.5% formic acid in water/methanol, 40/10/50 v/v/v with a flow rate of 0.2 mL/min and an injection volume of 10 μL. The LC-MS/MS was operated in electrospray in the positive ion mode and the transitions monitored were for Tylosin A, 916.5 > 156, 916.5 > 174 and 916.5 > 772.4; for desmycosin 772.4 > 132, 772.4 > 156 and 772.4 > 174. The limit of quantification for tylosin A was 0.001 μg/g and for desmycosin was 0.01 μg/g.

3. RESULTS

The results obtained for tylosin A and desmycosin for the brood and super honey are shown in Tables III and IV respectively. The results obtained for tylosin A D0 control samples were all <0.001 μg/g. Subsequent results for tylosin A in control samples were all <0.01 μg/g. The control samples were not screened for desmycosin. The highest mean concentration of tylosin A found in super honey was 29 μg/g, at D3 and for brood honey 11 μg/g, at D7. The mean concentrations for tylosin A detected in both brood and super honey were similar until D84. The mean concentration for tylosin A in super honey at D84 was 1.9 μg/g and 1.4 μg/g at D238, whilst the mean concentration for tylosin A in brood honey was 1.7 μg/g at D84 and 0.4 μg/g at D238. The highest mean concentration for desmycosin found in super honey

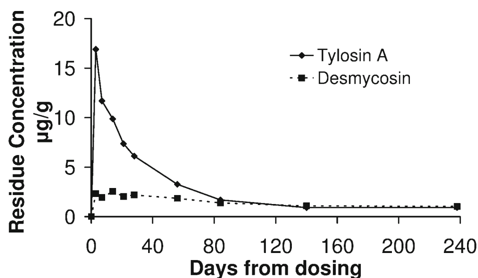

Figure 1. Results from 4 non shook swarmed colonies; depletion of tylosin A and occurrence of desmycosin in honey (pooled brood and super results) 0 to 238 days; after dosing with tylosin tartrate.

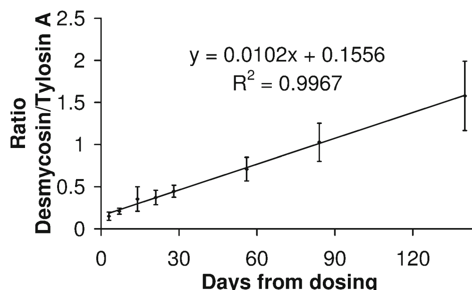

Figure 2. Molar concentration ratio of desmycosin to tylosin A (pooled brood and super results), after dosing with tylosin tartrate, error bars = S.D.

was 3.7 µg/g, at D3 and for brood honey 2.5 µg/g, at D14. Desmycosin concentrations were 1.4 µg/g in super honey and 0.6 µg/g in brood honey, at D238.

The results from brood honey and super honey collected from the dosed hives were averaged and summarized in Figure 1 (honey is harvested and bulked from several colonies prior to bottling for human consumption). The highest mean (results for the brood and super honey pooled together) concentration, 17 µg/g, of tylosin A was detected in samples collected at D3, at D7 was 12 µg/g decreasing to 1.7 µg/g at D84 and 0.9 µg/g at D140 with no further reduction at D238. The mean (results for the brood and super honey pooled together) concentrations of desmycosin remained relatively constant over the period from D3 to D238.

The desmycosin to tylosin A ratio using molar concentrations is summarised in Figure 2. These results show that the ratio of desmycosin to tylosin A increases at a constant rate over the first 140 days of the dosing study with the molar concentration of desmycosin becoming equal to tylosin A at 84 days.

The effects of the shook swarm procedure on the concentration of tylosin detected within a colony's honey stores are summarized in Table V. Prior to the shook swarm procedure the initial concentrations of tylosin A and desmycosin were similar in all dosed colonies. After the procedure the mean concentrations of tylosin A and desmycosin at D56 were approximately 10 times lower than colonies that did not undergo the procedure. The over-winter samples from the non shook swarm and shook swarm colonies taken at D238 contained detectable residues of tylosin A (0.65 µg/g and 0.13 µg/g respectively) and desmycosin (1.1 µg/g and 0.20 µg/g respectively).

The variation of concentrations of tylosin A and desmycosin in samples taken from different points within the hive are presented in Table VI. Analysis of the individual samples confirms that there is variability within the hives and across hives.

4. DISCUSSION

The degradation of tylosin A to desmycosin in mild acidic conditions (< pH 4) is thought to be relevant to honey, which has a pH, range of 3.4–6.1 (Kochansky, 2004). The rapid depletion of tylosin A in the 28 day period after dosing can be attributed to dilution into the honey and distribution around the colony as well as degradation to desmycosin. The desmycosin concentration during this period remains constant as displayed in Figure 1 whilst it is clearly evident that the tylosin A concentration is declining. The fact that the concentration of desmycosin remains constant indicates that there is some conversion of tylosin A to desmycosin. Figure 2 shows an increasing molar concentration of desmycosin in the honey relative to tylosin A and equality of concentrations of both compounds at D84. As the dilution factor is constant for both compounds the equalisation of concentrations must be due to the conversion

Table IV. Results from 4 non shook swarmed colonies; desmycosin residue concentrations obtained from the 34-week tylosin tartrate dosing study (n = number of honey samples analysed from all hives per time point).

Time point (days from dosing)	Mean of pooled results for brood and super honey µg /g ± SD	Brood honey mean residue µg/g (n) ± SD	Super honey mean residue µg/g (n) ± SD
D-4 - D-2 (Baseline)	Not Measured	Not Measured	Not Measured
D3	2.3 ± 2.1	1.0 (4) ± 0.35	3.7 (3) ± 2.5
D7	1.9 ± 0.93	1.6 (4) ± 0.91	2.3 (4) ± 1.6
D14	2.6 ± 1.1	2.5 (4) ± 1.6	2.7 (4) ± 0.40
D21	2.0 ± 1.3	2.2 (4) ± 1.6	1.9 (4) ± 1.1
D28	2.6 ± 1.5	1.8 (8) ± 1.4	2.6 (8) ± 1.5
D56	1.9 ± 1.9	2.1 (4) ± 1.6	1.6 (3) ± 0.79
D84	1.4 ± 1.2	1.6 (4) ± 1.2	1.2 (3) ± 1.4
D140	1.1 ± 1.0	1.1 (4) ± 1.1	1.2 (4) ± 0.84
D238 (over winter)	1.0 ± 0.77	0.62 (4) ± 0.47	1.4 (3) ± 0.94

Table V. Concentrations of tylosin A and desmycosin in brood honey from 6 dosed colonies (4 shook swarmed and 2 non shook swarmed colonies). Individual values are given in brackets.

	Average concentration (µg/g)						
	Day 3	Day 7	Shook swarm Procedure At D7	Day 56	Day 84	Day 140	Day 238 (Over Winter)
Tylosin A	**8.0** (9.9, 4.2, 12, 5.6)	**11** (14, 6.7, 19, 2.8)	No	**3.4** (1.7, 1.5, 7.8, 2.4)	**1.7** (0.87, 0.51, 3.8, 1.5)	**0.65** (0.34, 0.18, 1.6, 0.45)	**0.45** (0.48, 0.26, 0.80, 0.25)
Desmycosin	**1.0** (1.0, 0.47, 1.2, 1.2)	**1.6** (2.2, 1.1, 2.6, 0.67)	No	**2.1** (1.1, 0.85, 4.4, 2.0)	**1.6** (1.0, 0.49, 3.2, 1.7)	**1.1** (0.63, 0.20, 2.6, 0.75)	**0.62** (0.44, 0.44, 1.3, 0.29)
Tylosin A	**10** (13, 7.3)	**9.7** (8.1, 11)	Yes	**0.28** (0.073, 0.48)	No Samples Collected	**0.017** (0.027, 0.007)	**0.13** (0.023, 0.25)
Desmycosin	**1.1** (1.3, 0.90)	**1.6** (1.3, 1.9)	Yes	**0.31** (0.073, 0.55)	No Samples Collected	**0.032** (0.051, 0.013)	**0.20** (0.040, 0.36)

of tylosin A to desmycosin in a biological system. This is comparable to the half-lives of tylosin A in sugar syrup (75 days) and in honey at 34 °C (130 days) based on the measurement of the depletion of tylosin A in a static system (Kochansky et al., 1999; Kochansky, 2004).

The residue concentrations of tylosin A and desmycosin in over winter samples of brood honey showed a further decline but at a lower rate compared to the honey flow period. This could be explained by the absence of honey flow and dilution effect of the remaining drug residues. A possible explanation for the different rates of degradation for residues in super and brood honey could be the drop in temperature during the winter period, which encourages the bees to self regulate their temperature by clustering together within the brood box and leaving the other areas of the hive which will become cooler.

The shook swarm treatment was shown to significantly reduce the residue concentrations

Table VI. Variation in tylosin A concentrations within the dosed colonies, from week 4 samples.

	Concentration (μg/g)				
	Brood Honey		Super Honey		
	Top	Bottom	Inner	Outer	Colony average ± SD
1st Dosed Colony	5.2	0.6	5.5	5.3	4.2 ± 2.4
2nd Dosed Colony	3.0	0.7	2.8	2.4	2.2 ± 1.1
3rd Dosed Colony	10.9	11.7	13.6	15.9	13.0 ± 2.2
4th Dosed Colony	4.4	2.1	4.2	9.9	5.1 ± 3.3
Average of Dosed Colonies ± SD	5.9 ± 3.5	3.8 ± 5.5	6.5 ± 5.0	8.4 ± 5.9	

of tylosin A and desmycosin in the honey samples, with residue concentrations 30 times lower for tylosin A and desmycosin in the end of season honey samples (140 days after dosing). Also residues of tylosin A and desmycosin were still detected in the over winter honey samples from both shook swarm and non shook swarm treated colonies.

It has been reported that the use of sequential treatments (3 × 200 mg) of Tylan Soluble™, one-week apart followed by a Tylan withdrawal period of 3 weeks resulted in concentrations of tylosin A at 160 μg/g (Feldlaufer et al., 2004). Subsequently the Food and Drug Adminstration has recommended a withdrawal period of at least 4 weeks to further reduce the concentration of tylosin A. However, this study (using a single dose of 1000 mg per hive) has demonstrated that tylosin A can still be detected in honey from treated colonies 238 days after treatment. Recent work on OTC (oxytetracycline) has suggested that sugar powder applications may prolong the residence time of the residue rather than reducing it as it is possible that the bees do not treat the sugar powder as a food source (Thompson et al., 2006).

From the results of this study it is concluded that tylosin A degrades to desmycosin within a colony's honey store and thus a more accurate residue definition of tylosin should be the sum of tylosin A and desmycosin concentrations. The investigation into the shook swarm technique proved successful in reducing the residue concentrations of both tylosin A and desmycosin. However residues of both compounds were readily detected in the over winter samples. This demonstrates that (mis)use of tylosin can be detected up to 34 weeks after application even if the shook swarm technique is used in an attempt to 'clean' the colony.

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Étude de la déplétion des résidus de tylosine dans le miel extrait de colonies d'abeilles domestiques (*Apis mellifera*) et influence de la méthode de l'essaim artificiel.

tylosine / desmycosine / antibiotique / résidu / miel / technique apicole

Zusammenfassung – Untersuchung zur Verringerung von Tylosin-Rückständen in Honig aus behandelten Bienenvölkern (*Apis mellifera*) und der Einfluss der Kunstschwarmmethode. Tylosin wurde kürzlich in den USA für die Bekämpfung der Amerikanischen Faulbrut in Bienenvölkern zugelassen und stellt somit ein alternatives Antibiotikum zu Oxytetracyclin dar. Allerdings sind nach EU-Bestimmungen Tylosinrückstände in Honig nicht erlaubt und Honige aus den USA mit Tylosinrückständen wären auf dem EU-Markt nicht verkehrsfähig. Daher wurde hier die Beziehung

zwischen Tylosin A und dem Abbauprodukt Desmykosin untersucht. Damit sollte eine Markersubstanz etabliert werden, um den Abbau von Tylosin im Bienenvolk zu erfassen und die Verwendung dieses Wirkstoffes in der Imkerei nachzuweisen.
Bienenvölkern wurde eine Dosis von 1,1 g Tylosintartrat pro Volk in Form einer einmaligen Zuckerlösung gegeben. Die Proben wurden vor der Futtergabe und danach über 20 Wochen in regelmäßigen Abständen und schließlich nach der Überwinterung gezogen. Die Proben wurden über HPLC-MS auf Tylosin A und Desmycosin analysiert.
Die Konzentration an Tylosin A im Honig nahm im Zeitraum der Probennahmen kontinuierlich ab: Von 17 μg/g 3 Tage nach Applikation über 3,3 μg/kg 56 Tage danach bis auf 0,9 μg/kg 140 Tage danach. Die Konzentration von Desmycosin nahm lediglich von 2,3 μg/kg 3 Tage nach Applikation auf 1,1 μg/kg 140 Tage danach ab (Abb. 1, Tab. III und IV). Es gibt einen raschen Abbau an Tylosin A während der ersten 28 Tage nach Applikation gefolgt von einer geringeren Abbaurate danach. Trotz der Abnahme an Tylosin bleibt die Konzentration an Desmycosin weitgehend konstant, vermutlich wegen einer kontinuierlichen Umwandlung von Tylosin A zu Desmycosin. Die Konzentrationen von Desmycosin und Tylosin A gleichen sich 84 Tage nach der Applikation an (Abb. 2).
Die Kunstschwarmbildung auf neues Wabenwerk 7 Tage nach der Applikation reduzierte die Rückstandskonzentrationen von Tylosin A und Desmycosin um den Faktor 30 zum Ende der Probennahme (140 Tage nach Applikation). Tab. V zeigt vergleichend die Abnahme der Rückstandskonzentrationen für behandelte Bienenvölker mit und ohne Kunstschwarmbildung. Nach Applikation von Tylosin können Rückstände auch 238 Tage danach noch nachgewiesen werden selbst wenn zwischenzeitlich die Kunstschwarmmethode angewendet wird. Tylosin A ist eine geeignete Markersubstanz um den Gebrauch bzw. Missbrauch von Tylosin nachzuweisen. Eine exakte Bestimmung von Tylosinrückständen sollte allerdings über die Summe von Tylosin A und Desmycosin erfolgen.

Tylosin / Desmycosin / Honig / Rückstände / Tierarzneimittel / Imkerei

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