

Efficacy of deltamethrin (Butox® 7.5 pour on) against nymphs and adults of ticks (*Ixodes ricinus*, *Rhipicephalus sanguineus*) in treated hair of cattle and sheep

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Abstract Ticks are known to be able to transmit a broad spectrum of agents of diseases in cattle or sheep. Therefore, measurements are needed to keep ticks away from the body of any ruminant belonging to the agricultural life stock. The present study dealt with investigations to measure the efficacy of the insecticide deltamethrin (Butox® 7.5 pour on) against specimens of two important species (*Ixodes ricinus* and *Rhipicephalus sanguineus*). Four sheep and four young cattle were treated *lege arte* along the vertebral column with 10 ml Butox® (deltamethrin) per sheep or 30 ml Butox® per cattle. Day 7, 14, 21, and 28 after the treatment, hair was shaved off from the head, ears, the back, belly, and the feet being collected in separate, suitable

plastic bags, and transported to the institute, where these hair were brought into close contact with either adult and/or nymph stages of *I. ricinus* and *R. sanguineus*. As results, strong, acaricidal effects were seen, which varied according to the parasite species, the origin of the hair (e.g., head, leg, etc.) and according to the period after the treatment. In sheep, the acaricidal effect was noted for the whole period of 28 days along the whole body with respect to adults and nymphs of *I. ricinus*, while the acaricidal effects of deltamethrin were reduced for *R. sanguineus* stages beginning at day 21 after treatment. In cattle, the full acaricidal effect was seen for 21 days in *I. ricinus* stages and for 14 days in *R. sanguineus*, while the acaricidal efficacy became reduced after these periods of full action—beginning at the hair taken from the legs. Only *R. sanguineus* adults did not show any reaction on day 28 after treatment. Besides these acaricidal effects, repellent effects were also noted. Full repellency for both species was seen during the first 14 days in sheep and cattle against *Ixodes* and *Rhipicephalus*, while the repellency was later reduced, especially in contact with hair from the legs. As conclusion, deltamethrin, besides its very good effects against biting insects, brings acaricidal as well as repellent effects against ticks, thus protecting the sheep and cattle from transmission of agents of diseases.

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Introduction

Ticks are distributed worldwide (Sonenshine 1991-1992), and it was shown in thousands of publications that they are vectors of important diseases in animals and humans. Since most of the ticks suck blood at many hosts—although they have some prevalences—they may be of zoonotic importance. Thus, for example, *Ixodes ricinus* ticks may transmit

Borrelia burgdorferi from mice or rabbits to humans or *Hyalomma marginatum* may transmit the Crim-Congo fever virus from cattle to humans (Aspöck and Dobler 2008; Mehlhorn and Mehlhorn 2009). Cattle and sheep are the most important sources to cover the human need of food proteins. Therefore, it is obligatory to protect them from the enormous loss of blood due to infestations with blood-sucking ticks, the number of which may reach up to 10,000 per animal. However, even a low amount of attached ticks may introduce hyperkeratosis, strong itching, anemia, loss of weight, and disturbances during the development of the animals. Furthermore—and even more important—is a protection from the transmission of agents of diseases, which may occur in wild or game animals (without producing their severe symptoms due to a long coevolution) and which might be taken up by a tick larva or nymph and then transmitted as nymph or adult stage to farmed cattle or sheep that have not yet been immunized during their rather young career as species on earth. Examples of such a vectorship are found in Europe (babesiosis, virosis), in the African tropics (theileriosis, virosis; Mehlhorn and Schein 1984), or in the Americas (babesiosis, borreliosis; Eckert et al. 2008; Mehlhorn et al. 1993; Lane and Crosskey 1993). Protection of cattle and sheep was and is done by “dipping” cattle and sheep into water containing chemical acaricides and/or by application of chemical insecticides/acaricides along the vertebral column of the animals (Turberg and Hansen 2008). Applications of plant extracts are still rare (Mehlhorn et al. 2010), but have several advantages compared to the chemical products, since there are already resistances against some of the chemical products and there are often obligatory waiting times before the meat and/or milk might be again used as human food. Therefore, it is needed to check from time to time whether some of the chemical products are still efficient against attacking ticks. The present study deals with the anti-tick efficacy of the product Butox[®] 7.5 pour on, which was shown to be highly efficient against insects, e.g., against the vector of the bluetongue virus (Mehlhorn et al. 2007, 2008a, b, 2009; Semmler et al. 2009; Schmahl et al. 2009a, b).

Materials and methods

Sheep

Four sheep of about 40 kg bodyweight were treated *lege arte* by application (pour on) with 10 ml of the product Butox[®] 7.5 directly onto the skin along the backside of the animals. Butox[®] 7.5 contains 7.5 g deltamethrin per liter of the ready-to-use solution (reg. trademark of Intervet B.V. Netherlands).

At days 7, 14, 21, and 28 after the treatment, hair was shaved off from the head/ears, the back, the belly, and the feet, collected in separate, suitable plastic bags and transported to the institute, where the hair were brought into close contact with either four adult or two nymph stages of *I. ricinus* specimens, or with two *Rhipicephalus sanguineus* specimens. The test specimens were incubated with treated hair in Eppendorf snap vials of 2 ml in volume, which were closed by a cap perforated by needle piercings for a sufficient aeration. As untreated controls, the same procedure was done with hair from two sheep without Butox[®] treatment using two adult or two nymph stages of *I. ricinus* or one adult *R. sanguineus* at the same control days as in the treated group.

Cattle

One group of four young cattle of about 400 kg body weight were treated *lege arte* by application (pour on) of 30 ml of the product Butox[®] 7.5 along the backside of the animals. As untreated control, two young cattle were used. The hair probes from the back and the legs of either treated or untreated animals were taken in the same way as described above, and the test conditions were also identical.

Test criteria

When incubated with hair in the Eppendorf snap vials, the tick specimens were carefully taken out from the hair within the individual vials and monitored at regular intervals (5–10 min) using a dissection microscope (Olympus SZH 10) to record reactions and the time of death after the start of the incubation with treated or untreated hair. When still alive, the specimens were immediately incubated again with the hair probe. The observations were listed in protocols. Ticks were clearly defined as dead, when they showed no reaction when being gently squeezed with a forceps, or after touching them with a wooden tooth picker.

Results

Untreated controls

When incubated in untreated hair of sheep or cattle, all adult *Ixodes* and all but one of the nymphs survived for a minimum period of 7 days. In only one case, one nymph of *Ixodes* died within 5 days in a sample of hair taken from the belly of a sheep. Considering the adults of *R. sanguineus*, all specimens were still alive 7 days after the incubation in untreated hair from either sheep or cattle.

Acaricidal efficacy of Butox[®] 7.5 pour on after treatment of sheep

Effects on adult females of *I. ricinus*

Treated hair from the head and the ears The results of the monitoring are summarized in Tables 1, 2 and 3. At day 7 after the treatment, all ticks died within a 3 h 05 min–6 h 20 min period (Table 3). At day 14 after treatment, all ticks died within a 6 h 30 min–12 h 30 min interval (Tables 2 and 3). At day 21 after treatment, all ticks were found dead within a 6 h 30 min–9 h 20 min period (Tables 1 and 2). At day 28 after the treatment, all ticks died within 8 h 40 min–21 h 30 min (Table 1). Thus, the time until death was constantly prolonged.

Treated hair from the back After 7 day of application, all adult *Ixodes* females died within a 2 h 50 min–6 h 50 min period (Table 2). At day 14 after treatment, the death of ticks occurred within 7 h 35 min–11 h 40 min (Tables 1 and 2). At day 21 after treatment, all ticks died within a 6 h 20 min–13 h 30 min period (Tables 1 and 2). At day 28, all ticks were dead within a 10–20 h period (Tables 1 and 2).

Treated hair from the belly After 7 days of treatment, all ticks were found dead within a 2 h 15 min–5 h 40 min period (Tables 2 and 3). At day 14 after treatment, the periods until death of ticks ranged from 7 h 40 min–11 h 40 min (Tables 1 and 2), and at day 21, all specimens died within 17 h 10 min–12 h 50 min period (Tables 2 and 3). At day 28, all ticks were dead within 11–20 h (Table 1).

Treated hair from the feet When incubation of adult *Ixodes* females was done with hair from the feet, all ticks died within 1 h 40 min–5 h 40 min (Table 2). At day 14 after the treatment, all ticks died within 6 h 50 min–11 h 20 min (Table 3). At day 14 after the application of Butox[®], all ticks died within 6 h 50 min–11 h 20 min (Table 3), and at

day 21, all ticks were found dead within 8–25 h (Table 2). At day 28, all ticks were dead within 9 h–19 h 30 min (Tables 1 and 3).

Effects on nymph stages of *I. ricinus*

Treated hair from the head and the ears After 7 days of treatment with Butox[®] 7.5 (when incubated with hair from the head/the ears), all nymphs died within a 8 h 30 min–11 h 20 min period (Tables 4 and 5), and at day 21, death of the nymphs occurred within 9 h 50 min–12 h 40 min (Tables 4 and 5). At day 28, all nymphs died within 10 h 50 min–18 h (Tables 7 and 8).

Treated hair from the back At day 7 (when incubated in treated hair from the back), all nymphs died within 5 h 50 min–8 h (Tables 4 and 5). At day 14, all nymphs died within 6 h 30 min–12 h (Tables 4 and 5), and at day 28, all nymphs were dead within 11 h–18 h 20 min (Table 4).

Treated hair from the belly After 7 days of application of Butox[®] 7.5 (when incubated within treated hair), all nymphs were dead within 6 h 50 min–10 h 20 min (Table 5). At day 14, all nymphs were dead within 10 h 50 min to 18 h (Tables 4 and 5). At day 21, the death of all incubated nymphs occurred within 11 h 50 min–15 h 30 min (Tables 4 and 5). At day 28, all nymphs were dead within 16 h 40 min–22 h 10 min (Table 5).

Treated hair from the feet At day 7 after the treatment of the sheep (when incubated with the treated hair), all nymphs died within 5 h 50 min–8 h 30 min (Tables 4 and 5). At day 14, all nymphs were dead within 9–14 h (Tables 4 and 5). At day 21, all nymphs died within 9 h 50 min–14 h (Tables 4 and 5). At day 28, the death of all incubated nymphs occurred within 9 h 20 min–17 h 30 min (Table 5).

Table 1 Efficacy of Butox[®] 7.5 pour on after treatment of sheep against ticks (*Ixodes ricinus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Sheep no.1, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Ear/head	Dead between 4 and 6 h	Dead between 7 h 30 min and 9 h 10 min	Dead between 6 h 30 min and 8 h 50 min	Dead between 8 h 40 min and 21 h 30 min
Sheep no.1, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Back	Dead between 4 h 40 min and 6 h	Dead between 7 h 35 min and 8 h 30 min	Dead between 6 h 20 min and 7 h 50 min	Dead between 10 h and 13 h 20 min
Sheep no.1, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Belly	Dead between 3 h 50 min and 5 h 10 min	Dead between 7 h 40 min and 9 h	Dead between 8 h 20 min and 9 h 20 min	Dead between 11 and 15 h
Sheep no.1, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Foot	Dead between 4 h 15 min and 5 h 45 min	Dead between 7 h 45 min and 10 h	Dead between 8 h 30 min and 9 h 40 min	Dead between 9 h and 13 h 20 min

Treatment: 1×10 ml Butox[®] 7.5 pour on

n Number of ticks/probe, *d* days after treatment

Table 2 Efficacy of Butox[®] 7.5 pour on after treatment of sheep against ticks (*Ixodes ricinus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Sheep no. 2, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Ear/head	Dead between 3 h 5 min and 6 h 10 min	Dead between 8 h and 10 h 10 min	Dead between 8 h 50 min and 11 h	Dead between 10 h 20 min and 15 h 10 min
Sheep no. 2, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Back	Dead between 3 h 10 min and 6 h 50 min	Dead between 8 h 30 min and 11 h	Dead between 9 h and 10 h 20 min	Dead between 14 and 19 h
Sheep no. 2, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Belly	Dead between 2 h 15 min and 4 h 25 min	Dead between 9 h 30 and 11 h	Dead between 6 h and 10 h 20 min	Dead between 11 and 16 h
Sheep no. 2, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Foot	Dead between 1 h 40 min and 5 h 40 min	Dead between 9 h and 10 h 40 min	Dead between 8 h and 25 h	Dead between 12 h 20 min
Sheep no. 3, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Ear/head	Dead between 4 h 10 min and 5 h 50 min	Dead between 6 h 50 min and 12 h 30 min	Dead between 9 h 20 min and 12 h 10 min	Dead between 11 h 50 min and 13 h 40 min
Sheep no. 3, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Back	Dead between 2 h 50 min and 6 h 10 min	Dead between 9 h and 11 h 40 min	Dead between 10 h 20 min and 13 h 30 min	Dead between 16 and 20 h
Sheep no. 3, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Belly	Dead between 3 h 50 min and 4 h 40 min	Dead between 7 h 50 min and 10 h 40 min	Dead between 9 h 30 min and 12 h 50 min	Dead between 15 and 20 h
Sheep no. 3, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Foot	Dead between 2 h 30 min and 5 h	Dead between 8 h 20 min and 11 h 10 min	Dead between 8 h 40 min and 13 h 10 min	Dead between 17 and 19 h

Treatment: 1×10 ml Butox[®] 7.5 pour on

n Number of ticks/probe; *d* days after treatment

Effects on adult males and females of *R. sanguineus*

Treated hair from the head and the ears At day 7 after the treatment of the sheep (when incubated with the treated hair from the head/the ears), all *Rhipicephalus* specimens died within 1 h 40 min–4 h 50 min (Tables 6 and 7). At day 14, all specimens died within 5 h 40 min–8 h 30 min (Tables 6 and 7). At day 21, one *Rhipicephalus* only died at day 4 after incubation with treated hair, while all others survived for a minimum period of 12 days (Tables 6 and 7). At day 28, all *Rhipicephalus* females survived for a minimum period of 5 days (Tables 6 and 7).

Treated hair from the back At day 7 after the treatment, all *Rhipicephalus* specimens were dead within 2 h 40 min–5 h 10 min (Table 7). At day 14, all specimens died within 6 h 20 min–10 h 20 min (Tables 6 and 7). At day 21, only a few ticks died within 22 h up to 6 days (Table 6), whereas most of them survived for a minimum period of 12 days (Tables 6

and 7). At day 28, all specimens of *Rhipicephalus* survived for a minimum period of 5 days.

Treated hair from the belly At day 7 after the treatment, all specimens died within 6 h 20 min–10 h 20 min (Tables 6 and 7). At day 21, when incubated with hair of sheep no. 1 (Table 6), the two *Rhipicephalus* tested died within 4–5 days. When incubated with hair of sheep no. 2, one of the ticks tested died at day 3 after the start of the incubation (Table 6). At day 28, all *Rhipicephalus* specimens survived for a minimum period of 5 days (Tables 6 and 7).

Treated hair from the feet At day 7 after the treatment, all specimens died within 3 h 20 min–5 h 30 min (Tables 6 and 7). At day 14, specimens tested died within 5 h 40 min–9 h 20 min (Tables 6 and 7). At days 21 and 28, all *Rhipicephalus* specimens survived for a minimum of 5–12 or 5 days, respectively (Tables 6 and 7).

Table 3 Efficacy of Butox[®] 7.5 pour on after treatment of sheep against ticks (*Ixodes ricinus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Sheep no. 4, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Ear/head	Dead between 3 h 50 min and 6 h 20 min	Dead between 6 h 40 min and 9 h 30 min	Dead between 7 h 20 min and 9 h	Dead between 10 h 20 min and 17 h
Sheep no. 4, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Back	Dead between 15 h 10 min and 6 h 20 min	Dead between 7 h 50 min and 9 h 10 min	Dead between 5 h 40 min and 8 h 10 min	Dead between 12 h 30 min and 19 h 40 min
Sheep no. 4, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Belly	Dead between 4 h and 5 h 40 min	Dead between 8 h min and 10 h 40 min	Dead between 7 h 10 min and 10 h 50 min	Dead between 12 h 10 min and 16 h 50 min
Sheep no. 4, treated	<i>I. ricinus</i> , ♀, adult; 4 n	Foot	Dead between 5 h and 6 h 40 min	Dead between 6 h 50 min and 11 h 20 min	Dead between 8 h 20 min and 9 h 20 min	Dead between 10 h and 19 h 30 min

Treatment: 1×10 ml Butox[®] 7.5 pour on

n Number of ticks/probe; *d* days after treatment

Table 4 Efficacy of Butox[®] 7.5 pour on after treatment of sheep against ticks (*Ixodes ricinus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Sheep no. 1, treated	<i>I. ricinus</i> , ♀, nymphs; 2 n	Ear/head	Dead between 8 h and 11 h 20 min	Dead between 9 h and 11 h 20 min	Dead between 10 h and 12 h 30 min	Dead between 11 and 14 h
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Back	Dead between 6 h 20 min and 8 h	Dead between 9 h 20 min and 11 h 20 min	Dead between 8 h and 10 h 10 min	Dead between 13 h and 18 h 20 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Belly	Dead between 7 h 20 min and 8 h 30 min	Dead between 11 h 25 min and 18 h	Dead between 13 h 10 min and 14 h 20 min	Dead between 18 h and 19 h 10 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Leg	Dead between 6 h and 7 h 40 min	Dead between 10 h and 11 h 30 min	Dead between 9 h 50 min and 12 h	Dead between 14 h and 17 h 30 min
Sheep no. 2, treated	<i>I. ricinus</i> , ♀, nymphs; 2 n	Ear/head	Dead between 7 h 40 min and 8 h 30 min	Dead between 8 h 30 min and 10 h 20 min	Dead between 10 h 50 min and 11 h 40 min	Dead between 12 h 10 min and 18 h
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Back	Dead between 5 h 50 min and 6 h 20 min	Dead between 6 h 50 min and 7 h 30 min	Dead between 8 h 10 min and 11 h 40 min	Dead between 11 and 15 h
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Belly	Dead between 8 h and 8 h 50 min	Dead between 10 h 50 min and 12 h	Dead between 11 h 50 min and 12 h 40 min	Dead between 17 h and 20 h 40 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Leg	Dead between 7 h 10 min and 8 h 30 min	Dead between 9 h and 11 h 40 min	Dead between 10 h 10 min and 12 h 50 min	Dead between 9 h 20 min and 15 h

Treatment: 1 × 10 ml Butox[®] 7.5 pour on

n Number of ticks/probe; *d* days after treatment

Acaricidal efficacy of Butox[®] 7.5 pour on after the treatment of cattle

The results are summarized in Tables 8, 9 and 10.

Effects on adult females of *I. ricinus*

Treated hair from the back When cattle were treated with Butox[®] 7.5 and hair probes of their backs—taken at day 7—were mixed with adult females of *I. ricinus*, all ticks died within 2 h 40 min–6 h 30 min (Table 8). At day 14, death in all *I. ricinus* specimens occurred within 3 h

40 min–7 h 50 min (Table 8). At day 21, eight specimens out of 16 died within 5 h 40 min–23 h (Table 8), whereas the other eight specimens survived for a minimum period of 5 days (Table 8). At day 28, only one *I. ricinus* was killed within 18 h after the start of the incubation, while all others survived for a minimum period of 5 days (Table 8).

Treated hair from the legs At day 7, all specimens of *I. ricinus* died within 4 h 50 min–6 h 20 min (Table 8). At day 14, all specimens were found dead within 5 h 10 min–11 h (Table 8). At day 21, only two *I. ricinus* were found dead within 17–23 h (Table 8), whereas six were alive for a

Table 5 Efficacy of Butox[®] 7.5 pour on after treatment of sheep against ticks (*Ixodes ricinus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Sheep no. 3, treated	<i>I. ricinus</i> , ♀, nymphs; 2 n	Ear/head	Dead between 6 h 40 min and 8 h 30 min	Dead between 9 h 20 min and 10 h 40 min	Dead between 9 h 50 min and 12 h 10 min	Dead between 12 h 10 min and 15 h 40 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Back	Dead between 7 h and 7 h 50 min	Dead between 9 h 50 min and 12 h	Dead between 7 h 30 min and 11 h 20 min	Dead between 11 h 10 min and 16 h 30 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Belly	Dead between 6 h 50 min and 9 h	Dead between 9 h 50 min and 12 h 30 min	Dead between 11 h 20 min and 13 h 20 min	Dead between 14 h 20 min and 17 h 10 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Leg	Dead between 6 h 30 min and 7 h 50 min	Dead between 9 h 50 min and 12 h 30 min	Dead between 11 h 20 min and 13 h 20 min	Dead between 14 h 20 min and 17 h
Sheep no. 4, treated	<i>I. ricinus</i> , ♀, nymphs; 2 n	Ear/head	Dead between 6 h 50 min and 9 h	Dead between 8 h 30 min and 10 h 50 min	Dead between 10 h 10 min and 12 h 30 min	Dead between 10 h 50 min and 17 h 20 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Back	Dead between 4 h 50 min and 7 h	Dead between 6 h 30 min and 7 h 50 min	Dead between 8 h 50 min and 10 h 50 min	Dead between 12 h and 13 h 50 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Belly	Dead between 9 h and 10 h 20 min	Dead between 10 h 50 min and 13 h 10 min	Dead between 13 h 10 min and 15 h	Dead between 16 h 40 min and 20 h 50 min
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Leg	Dead between 5 h 50 min and 7 h	Dead between 9 h 20 min and 14 h	Dead between 10 h 50 min and 14 h	Dead between 11 h and 13 h 50 min

Treatment: 1 × 10 ml Butox[®] 7.5 pour on

n Number of ticks/probe; *d* days after treatment

Table 6 Efficacy of Butox[®] 7.5 pour on after treatment of sheep against ticks (*Rhipicephalus sanguineus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Sheep no.1, treated	<i>R. sanguineus</i> adult; 2 n	Head/ears	Dead between 2 h 40 min and 3 h 50 min	Dead between 7 h 30 min and 8 h 30 min	2/2 alive 12 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Back	Dead between 3 h and 4 h 20 min	Dead between 8 h and 9 h 40 min	Dead between 22 h and 6 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Belly	Dead between 9 h 50 min and 10 h 20 min	Dead between 4 and 5 days	2/2 alive 5 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Leg	Dead between 3 h 20 min and 6 h 40 min	Dead between 7 h 10 min and 9 h 20 min	2/2 alive 5 days	2/2 alive 5 days
Sheep no.2, treated	<i>R. sanguineus</i> adult; 2 n	Head/ears	Dead between 1 h 40 min and 2 h 30 min	Dead between 6 h 50 min and 8 h 10 min	2/2 alive 12 h	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Back	Dead between 3 h and 4 h 20 min	Dead between 9 h 50 min and 10 h 20 min	2/2 alive 5 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Belly	Dead between 2 h 30 min and 3 h 50 min	Dead between 8 h 20 min and 10 h 30 min	1/2 dead 3 days, 1/2 alive 12 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Leg	Dead between 4 h 10 min and 6 h 20 min	Dead between 7 h 20 min and 9 h 20 min	2/2 alive 12 days	2/2 alive 5 days

Treatment: 1×10 ml Butox[®] 7.5 pour on

n Number of ticks/probe; *d* days after treatment

minimum period of 5 days (Table 8). At day 28, all specimens survived for a minimum period of 5 days (Table 8).

Effects on nymph stages of *I. ricinus*

Treated hair from the back At day 7, all specimens of *I. ricinus* died within 5 h 10 min–7 h 20 min (Table 9). At day 14, all specimens died within 4 h 50 min–8 h (Table 9). At day 21, two ticks out of eight died within 8–10 h (Table 9). At day 28, only the two nymphs incubated with hair from cattle no. 1 died within 26 h–32 h, whereas, in all other cases, the nymphs survived for a minimum period of 5 days (Table 9).

Treated hair from the legs At day 7, all nymphs of *I. ricinus* when incubated in hair from the legs of treated

cattle were dead within 5 h 10 min–7 h 50 min (Table 9). At day 14, all specimens were found dead within 6 h 30 min–8 h 50 min (Table 9). At day 21, two specimens only died within 11–21 h (Table 9), whereas the others survived for a minimum period of 5 days. At day 28, all nymphs were found to survive for a minimum period of 5 days (Table 9).

Effects on adult males and females of *R. sanguineus*

Treated hair from the back At day 7, all specimens of *R. sanguineus* died within 4 h 20 min–6 h when incubated with hair from the back of treated cattle (Table 10). At day 14, all specimens died within 4 h 10 min–70 h (Table 11). At day 21, three specimens (total: eight) died within 8 h 10 min–28 h (Table 11), whereas the others were alive to a minimum period of 5 days. At day 28, all survived for 5 days (Table 11).

Table 7 Efficacy of Butox[®] 7.5 pour on after treatment of sheep against ticks (*Rhipicephalus sanguineus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Sheep no.3, treated	<i>R. sanguineus</i> adult; 2 n	Head/ears	Dead between 3 h and 4 h 50 min	Dead between 6 h 40 min and 7 h 20 min	1 dead 4 days, 1 alive 12 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Back	Dead between 2 h 40 min and 5 h 10 min	Dead between 7 h 10 min and 8 h 50 min	2/2 alive 12 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Belly	Dead between 2 h 50 min and 3 h 50 min	Dead between 7 h 20 min and 9 h 30 min	2/2 alive 12 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Leg	Dead between 4 h 10 min and 5 h 30 min	Dead between 6 h 40 min and 7 h 40 min	2/2 alive 12 days	2/2 alive 5 days
Sheep no.4, treated	<i>R. sanguineus</i> adult; 2 n	Head/ears	Dead between 2 h 50 min and 4 h	Dead between 5 h 40 min and 7 h	2/2 alive 12 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Back	Dead between 3 h 30 min and 4 h 50 min	Dead between 6 h 20 min and 8 h 20 min	1/2 dead 3 days, 1/2 alive 12 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Belly	Dead between 4 h and 5 h 20 min	Dead between 6 h 50 min and 10 h	2/2 alive 12 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Leg	Dead between 3 h 40 min and 4 h 50 min	Dead between 5 h 40 min and 7 h 30 min	2/2 alive 12 days	2/2 alive 5 days

Treatment: 1×10 ml Butox[®] 7.5 pour on

n Number of ticks/probe; *d* days after treatment

Table 8 Efficacy of Butox[®] 7.5 pour on after treatment of cattle against ticks (*Ixodes ricinus*)

Cattle number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Cattle no. 1, treated	<i>I. ricinus</i> , ♀, adults; 4 n	Back	Dead between 5 h 10 min and 6 h 30 min	Dead between 3 h 40 min and 6 h 40 min	Dead between 5 h 40 min and 8 h 20 min	1/4 dead 18 h, 3/4 alive 5 days
	<i>I. ricinus</i> , ♀, adults; 4 n	Leg	Dead between 5 h 20 min and 6 h	Dead between 8 h 10 min and 10 h 30 min	4/4 alive 5 days	4/4 alive 5 days
Cattle no. 2, treated	<i>I. ricinus</i> , ♀, adults; 4 n	Back	Dead between 5 h 20 min and 6 h 30 min	Dead between 4 h 10 min and 5 h 20 min	1/4 dead 19 h, 3/4 alive 5 days	4/4 alive 5 days
	<i>I. ricinus</i> , ♀, adults; 4 n	Leg	Dead between 4 h 50 min and 5 h 30 min	Dead between 6 h 50 min and 11 h	1/4 dead 17 h, 3/4 alive 5 days	4/4 alive 5 days
Cattle no. 3, treated	<i>I. ricinus</i> , ♀, adults; 4 n	Back	Dead between 4 h 30 min and 6 h 20 min	Dead between 4 h 50 min and 7 h 50 min	Dead between 10 h 10 min and 13 h 20 min	4/4 alive 5 days
	<i>I. ricinus</i> , ♀, adults; 4 n	Leg	Dead between 5 h 20 min and 6 h 20 min	Dead between 5 h 10 min and 7 h 20 min	4/4 alive 5 days	4/4 alive 5 days
Cattle no. 4, treated	<i>I. ricinus</i> , ♀, adults; 4 n	Back	Dead between 2 h 40 min and 3 h	Dead between 4 h and 6 h 10 min	2/4 dead 18–23 h, 2/4 alive 5 days	4/4 alive 5 days
	<i>I. ricinus</i> , ♀, adults; 4 n	Leg	Dead between 5 h 30 min and 6 h 20 min	Dead between 7 h 30 min and 9 h 50 min	1/4 dead 23 h, 3/4 alive 5 days	4/4 alive 5 days

Treatment: 1×30 ml Butox[®] 7.5 pour on

n Number of ticks/probe; *d* days after treatment

Treated hair from the legs At day 7, all specimens died within 4 h 40 min–6 h 20 min (Table 11). At day 14, four specimens (*n*=8) died within 6 h 30 min–61 h, and four were alive for a minimum of 5 days (Table 11). At day 21, and also at day 28, all *R. sanguineus* survived for a minimum of 5 days (Table 10).

Repellent effects

In treated hair from either sheep or cattle, effects against the adult females of *I. ricinus* and *R. sanguineus* were observed

at days 7 and 14 after the treatment with the exception of the hair from the legs of cattle at day 14. Nymphs of *I. ricinus*, however, were not repelled by Butox[®] as there was no repellent effect in untreated hair.

Discussion

Since ticks are important vectors of diseases in ruminants (Table 11; Mehlhorn 2008; Eckert et al. 2008), insecticides and acaricides are periodically used to protect the different specimens of ruminant from the attachment and blood

Table 9 Efficacy of Butox[®] 7.5 pour on after treatment of cattle against ticks (*Ixodes ricinus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Cattle no. 1, treated	<i>I. ricinus</i> , ♀, nymphs; 2 n	Back	Dead between 6 h and 7 h 20 min	Dead between 5 h and 5 h 40 min	Dead between 8 h and 9 h 20 min	Dead between 26 and 32 h
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Leg	Dead between 5 h 10 min and 5 h 50 min	Dead between 9 h 30 min and 11 h 20 min	1/2 dead 21 h, 1/2 alive 5 days	2/2 alive 5 days
Cattle no. 2, treated	<i>I. ricinus</i> , ♀, nymphs; 2 n	Back	Dead between 6 h 40 min and 7 h 10 min	Dead between 4 h 50 min and 5 h 30 min	2/2 alive 5 days	2/2 alive 5 days
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Leg	Dead between 6 h 30 min and 7 h	Dead between 6 h 30 min and 8 h 20 min	2/2 alive 5 days	2/2 alive 5 days
Cattle no. 3, treated	<i>I. ricinus</i> , ♀, nymphs; 2 n	Back	Dead between 5 h 10 min and 6 h 50 min	Dead between 6 h 10 min and 7 h 50 min	2/2 alive 5 days	2/2 alive 5 days
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Leg	Dead between 6 h and 7 h 10 min	Dead between 7 h 30 min and 8 h 20 min	1/2 dead 11 h, 1/2 live 5 days	2/2 alive 5 days
Cattle no. 4, treated	<i>I. ricinus</i> , ♀, nymphs; 2 n	Back	Dead between 5 h 30 min and 6 h 40 min	Dead between 6 h 20 min and 8 h	1/2 dead 10 h, 1/2 alive 5 days	2/2 alive 5 days
	<i>I. ricinus</i> , ♀, nymphs; 2 n	Leg	Dead between 6 h 50 min and 7 h 50 min	Dead between 7 h 10 min and 8 h 50 min	2/2 alive 5 days	2/2 alive 5 days

Treatment: 1×30 ml Butox[®] 7.5 pour on

n Number of ticks/probe; *d* days after treatment

Table 10 Efficacy of Butox[®] 7.5 pour on after treatment of cattle against ticks (*Rhipicephalus sanguineus*)

Sheep number	Tick species	Origin of probe	7 days	14 days	21 days	28 days
Cattle no. 1, treated	<i>R. sanguineus</i> adult; 2 n	Back	Dead between 5 h and 5 h 30 min	Dead between 4 h 10 min and 5 h 30 min	Dead between 8 h 10 min and 0 h 10 min	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Leg	Dead between 4 h 40 min and 5 h 40 min	2/2 alive 5 days	2/2 alive 5 days	2/2 alive 5 days
Cattle no. 2, treated	<i>R. sanguineus</i> adult; 2 n	Back	Dead between 4 h 30 min and 5 h	Dead between 59 and 70 h	2/2 alive 5 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Leg	Dead between 5 h 10 min and 5 h 50 min	2/2 alive 5 days	2/2 alive 5 days	2/2 alive 5 days
Cattle no. 3, treated	<i>R. sanguineus</i> adult; 2 n	Back	Dead between 4 h 50 min and 5 h 20 min	Dead between 6 h 30 min and 8 h 40 min	1/2 dead: 28 h, 1/2 alive 5 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Leg	Dead between 5 h and 6 h 20 min	Dead between 7 h 20 min and 10 h 10 min	2/2 alive 5 days	2/2 alive 5 days
Cattle no. 4, treated	<i>R. sanguineus</i> adult; 2 n	Back	Dead between 4 h 20 min and 6 h	Dead between 18 and 31 h	2/2 alive 5 days	2/2 alive 5 days
	<i>R. sanguineus</i> adult; 2 n	Leg	Dead between 5 h 20 min and 6 h 50 min	Dead between 54 and 61 h	2/2 alive 5 days	2/2 alive 5 days

Treatment: 1×30 ml Butox[®] 7.5 pour on

n Number of ticks/probe; d days after treatment

sucking of various tick species. While many typical insecticides, such as flumethrin, lambda-cyhalothrin, permethrin, fenvalerate, deltamethrin, cyfluthrin, and some others, had been successfully tested on their activity against a broad spectrum of insects, their activity against ticks was only occasionally a topic of investigations (literature c.f. Liebisch and Liebisch 2008; Liebisch et al. 2008a, b; Mehlhorn et al. 2008a, b, 2010; Schmahl et al. 2008a, b, 2009a, b). When comparing the acaricidal effects of all the

above-cited insecticides to their insecticidal power, it can be stated that the effects against insects, in general, last longer. Differences are also found in the susceptibility of different species of insects and ticks. None of the different insecticides has an identical long-reaching efficacy on all treated species—neither in insects nor in Acari (ticks, mites). This is also the case in deltamethrin treatments. While *I. ricinus* adults and nymphs died from at least being exposed to hair taken even at 4 weeks after application (at

Table 11 Agents of diseases transmitted by ticks to cattle (C), goats (G) and sheep (S)

Agent/type	Disease	Vector tick	Ruminant host	Endemic region
Spring–summer meningoencephalitis (V)	Encephalitis	<i>Ixodes</i> species	C, G, S	Europe, Russia, Siberia
Louping-ill virus (V)	Louping-ill disease	<i>Ixodes ricinus</i>	S, G	Scotland, Ireland, UK
Crim-Congo fever virus (V)	Crim-Congo fever	<i>Hyalomma</i> species	C, S	Africa, Near East, the Balcan states
Nairobi virus (V)	Nairobi sheep disease	<i>Rhipicephalus</i> species	S, G	East Africa
<i>Anaplasma marginale</i> (B)	Malign bovine anaplasmosis	<i>Rhipicephalus</i> , <i>Dermacentor</i> species	C	Tropics, subtropics, Europe
<i>Anaplasma centrale</i> (B)	Benign bovine anaplasmosis	<i>Rhipicephalus</i> species	C	South Africa
<i>Anaplasma ovis</i> (B)	Anaplasmosis	<i>Rhipicephalus</i> , <i>Dermacentor</i> species	S, G	Near East, Africa, Mediterranean
<i>Anaplasma phagocytophilum</i> (formerly <i>Ehrlichia</i>) (B)	Granulotic anaplasmosis	<i>Ixodes</i> species	C, S	Europe, USA
<i>Ehrlichia</i> (syn. <i>Cowdria</i>) <i>ruminantium</i> (B)	Heartwater	<i>Amblyomma</i> species	C, S, G	Tropical Africa, Caribbean
<i>Rickettsia africae</i> (B)	African tick bite fever (mainly in humans)	<i>Amblyomma</i> species	C	South Africa, Tropical Africa
<i>Coxiella burnetii</i> (B)	Q-fever	<i>Dermacentor</i> , <i>Amblyomma</i> species	C, S, G	Worldwide
<i>Borrelia</i> species (B)	Borreliosis	<i>Ixodes</i> species	C, S, G	Europe, USA
<i>Dermatophilus congolense</i> (B)	Dermatophilosis	<i>Amblyomma</i> species	C, S, G	Tropics; rare: Europe
<i>Babesia bigemina</i> (P)	Babesiosis, Texas fever	<i>Rhipicephalus</i> species	C	Tropics, Africa, South, Central America, South Europe
<i>Babesia bovis</i> (P)	Babesiosis	<i>Rhipicephalus</i> species	C	Tropics, Africa, South, Central America, South Europe
Other <i>Babesia</i> species (P)	Babesiosis	<i>Hyalomma</i> , <i>Haemaphysalis</i> , <i>Rhipicephalus</i> species	C, S, G	Worldwide
<i>Babesia divergens</i> (P)	Meadow Red	<i>Ixodes</i> species	C	Europe
Different <i>Theileria</i> species (P)	Theileriosis, u.a. East Coast fever	<i>Hyalomma</i> , <i>Rhipicephalus</i> , <i>Haemaphysalis</i> species	C, S, G	Europe, Africa, Asia
<i>Dipetalonema</i> , <i>Acanthocheilonema</i> species (H)	Skin filariosis	<i>Rhipicephalus</i> species	C	Europe, Africa

B Bacterium; V virus; P protozoans; H helminths

all places from backside to feet) of sheep, members of the species *R. sanguineus* may survive, if ticks come into contact with treated hair beginning 3 weeks after treatment. Considering the situation in cattle, it is more complicated. While protection on the back is rather good for 3 weeks, the effects are less good, if the hair of the feet come into contact with the ticks. This makes it advisable to distribute the product not only on the back of the animal but also on the legs. The efficacy against *Rhipicephalus* in cattle is also somewhat lower than in sheep. Comparing the efficacy of deltamethrin to the other acaricidal/insecticidal compounds above (while neglecting other, much more toxic ones) deltamethrin is in the range of the group. Since with respect to protection from important insect vectors such as *Culicoides* species (vector of bluetongue disease), it was recommended to use Butox[®] (deltamethrin) at intervals of 3 weeks (Mehlhorn et al. 2007, 2010), this product offers, under these conditions, a very good protection as well against ticks as insects.

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