Effects of different intervention strategies on the incidence of papillomatous digital dermatitis in dairy cows

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The effects of four different intervention strategies on the incidence of severe lesions of digital dermatitis in an experimental dairy herd were compared with the effects of a control strategy consisting of walking the cows twice through a footbath containing 4 per cent formaldehyde on one day a week for 24 weeks. The four alternative strategies were the same treatment every other week; standing for 30 minutes in a footbath containing a 2 per cent multicompound solution on days 0, 7, 28 and 90 after having had their hooves cleaned indirectly with a medium pressure spray of water; walking twice through the multicompound solution on one day a week for 24 weeks; and, walking twice through a footbath containing 3 per cent sodium carbonate on one day a week for 24 weeks. The cows' hooves were inspected every three weeks by one trained claw trimmer who graded the lesions of digital dermatitis. None of the alternative strategies significantly reduced either the number or severity of the lesions in comparison with the control strategy. In the groups treated by the third and fourth strategies there were outbreaks of digital dermatitis in which more than 30 per cent of the cows suffered the most severe type of lesion, and there was a continuously high rate of new infections in the group treated by the fourth strategy.

DAIRY cows need healthy claws for a long active life (Webster 1995, Brand and others 1996). Poor hoof conditions are responsible for great economic losses (Enting and others 1997, Kossaibati and Esslemont 1997, Green and others 2002) and are considered to adversely affect cow welfare (Webster 1995, Logue 1996).

Hoof disorders can be divided into infectious disorders (papillomatous digital dermatitis [PDD], interdigital dermatitis/heel horn erosion [HHE] and interdigital pododermatitis) and metabolic or non-infectious disorders (laminitis, interdigital fibroma and trauma). Although PDD has been given several other names, it will be referred to here as digital dermatitis.

Digital dermatitis was first described in cattle in 1974 in Italy, and is characterised by inflammation of the skin, mostly in the region of the bulb of the heel and coronet of the hoof (Cheli and Mortellaro 1974, Blowey and Sharp 1988, van Amstel and others 1995, Read and Walker 1998b). The disease has spread all over the world, and has been reported as endemic in western and southern Europe and the USA (Brizzi 1993, van Amstel and others 1995, Clarkson and others 1996, Rodriguez-Lainz and others 1996, 1999, Read and Walker 1998a, Wells and others 1999, Murray and others 2002, Somers and others 2003). In Japan, Australia and New Zealand it is observed as an incidental lesion (Kimura and others 1993, McLennan and McKenzie 1996, Vermunt and Hill 2004), and in Norway it is considered as an increasing problem related to the change of housing system from tie-stalls to free stalls (Sogstad and others 2005).

A recent investigation by the Dutch Animal Health Service (DAHS) estimated that 91 per cent of herds and 21 per cent of cows were affected by the condition at the regular trimming of all dairy cows' hind hooves; in more than 10 per cent of the infected herds the infection resulted in serious problems defined as a 'continuous' prevalence of more than 40 per cent (Holzhauer and others 2006).

Almost all studies have concluded that the disease has a multifactorial aetiology and requires an integrated approach (Rodriguez-Lainz and others 1999, Somers and others 2005, Holzhauer and others 2006). The treatment of individual cows or the herd as a whole is labour-intensive and there is little scientific information about the effectiveness of herd therapy (Hoblet 2002). Topical applications of antibiotics and copper and/or zinc-containing preparations have been shown to be effective but labour-intensive and therefore difficult to apply in large herds or herds with a high prevalence of the disease (Britt and McClure 1988, Brizzi 1993, Shearer and others 1995, Berry and others 1996, 1999a, Hernandez and others 1999).

In several countries, including the Netherlands, footbaths containing antibiotics such as oxytetracyclin, lincomycin and erythromycin have been used to treat whole herds, but since 1998 they have been prohibited in the Netherlands because of the risk of the contamination of milk and the environment and the development of resistance against antibiotics; similarly only low concentrations of copper sulphate (0·5 per cent) and zinc sulphate (1 per cent) are permitted in footbaths in the Netherlands.

In the UK and the USA, there have been short-term studies of the effectiveness of antibiotics, formalin, zinc and copper sulphates and disinfectants such as glutaraldehyde and hydrogen peroxide or combinations of these compounds in footbaths (Grongnet and others 1981, Nowrouzian and Zareii 1998, Shearer and Elliot 1998, Berry and others 1999a, Shearer and Hernandez 2000, Berry and others 2002, Laven and Hunt 2002). In a recent study, Zemljic (2004) found that improper footbath management could even facilitate the spread of digital dermatitis. Blowey (2000) and Laven and Hunt (2002) have reported good results with formalin, Dutch farmers have also reported good results, and the DAHS recommends it as a standard herd strategy. Nevertheless formalin solutions remain a potential respiratory and conjunctival irritant and carcinogen (Collins and Lineker 2004, d'A Heck and Casanova 2004).

The objective of this study was therefore to compare the effects of several different intervention strategies over several months against a 4 per cent solution of formalin as the reference treatment. The formalin footbaths were prepared as advised by the DAHS and situated in well ventilated positions.

MATERIALS AND METHODS

The study was carried out between January 1 and June 30, 2005 and used the experimental herd of the Animal Sciences Group of Wageningen University. On January 1, the herd consisted of 140 lactating dairy cows; dry cows were excluded

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from the study. The lactating cows had been fed the same basic ration since December 1, 2004, composed of grass silage and maize silage, barley/pea, soya bean, and up to 8 kg of compound feeds, depending on the milk yield of the individual cow. More than 95 per cent of the cows were 100 per cent Holstein-Friesian. Sample size calculations based on a power of 80 per cent and a confidence of 95 per cent, indicated that experimental groups of 15 cows would be sufficient; the group size was calculated without correction for intra-cluster correlations.

The hind hooves of the cows were examined every third week (eight times in total) while they were held in a crush, and the stage and severity of any clinical signs of digital dermatitis were recorded (Fig 1). The cows were also inspected daily for signs of the disease, such as the permanent lifting of a leg, lameness or careful walking, resting on the tip of the claw and the typical smell. Any M2 (erosive painful dermatitis) lesions detected were treated topically with chlortetracycline spray (CTC-spray; Eurovet). When other claw horn diseases were diagnosed, they were also treated. In addition, any M2 lesions detected during the three-weekly examinations were treated topically, whether they caused clinical lameness or not.

All the diagnoses were made by one professional hoof-health manager and the results for each hoof were recorded by a student. An outbreak of the disease within the group was defined as more than 30 per cent of hind legs with M2 lesions at a three-weekly examination. To differentiate original lesions from an incomplete cure, the location of the lesion at each examination was recorded precisely. During the first two observations, the observers were carefully trained to use the scoring system, and the data from the first observation were excluded from the investigation. In the period from the second to the fifth observation no systematic interventions were applied. The lesions of digital dermatitis were scored on the basis of a visual inspection, using the system developed by Döpfer and others (1997). The location, clinical appearance, size and pain reaction were recorded: M0 Normal skin, no signs of the disease; M1 Small superficial dermatitis spot, 0·5 to 2 cm, not painful on palpation; M2 Erosive dermatitis, 2 to 4 cm, painful on palpation; M3 Healing stage of M2, with a scab, not painful on palpation; M4 Hyperkeratotic cutaneous lesion, not painful on palpation. If different stages of the disease were present, the classification category selected was that of the most prominent lesion. Because of its clinical effects, the most prominent M2 stage is chosen as the most important outcome variable (Mumba and others 1999).

Groups of cows and the interventions applied

The cows were allotted to five groups, one reference group and four experimental groups, on the basis of the results of the pre-intervention study. Deviations from a random selection were based on the presence of M2 lesions, parity and stage of lactation, and the fact that some of the cows were not accustomed to robotic milking.

The five groups were housed separately and milked during the study in such a way that there was no physical contact between the groups, or their manure. Removing and returning animals to an experimental group was arranged according to a protocol; cows that owing to illness or a dry period had been temporarily separated from one of the groups, were randomly replaced into one of the five groups, after a careful inspection of all four hooves and a standard treatment consisting of two sprayings with CTC-spray for three seconds with two minutes rest between, regardless of the presence or absence of lesions. This protocol was designed to prevent the reintroduction of new infections. The same protocol was used for the introduction of heifers. In addition, the hooves of cows that were introduced into group 3 were cleaned with a water cleaning apparatus (for reasons presented later).

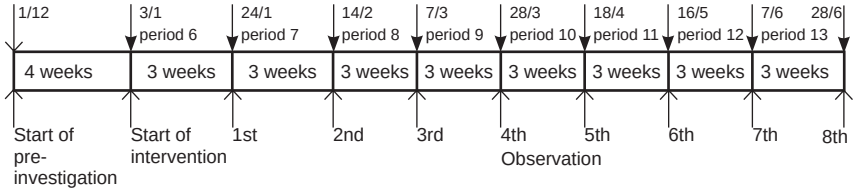


FIG 1: Timing of the eight observations made during the investigation

Reference treatment group (group 5)

This group consisted of 64 cows that were milked in an automatic milking system (visit frequency 2·8 times per day). On one day a week the cows were forced twice through a walk-through footbath containing a 4 per cent formalin solution, diluted from a 37 per cent formaldehyde solution (the standard Dutch advice). Directly after each passage the cows were locked at the feeder gate on a clean floor for at least 30 minutes. The footbath was not cleaned or refreshed between the two passages on the same day.

Group 1

This group consisted of 15 cows that were milked twice a day in a traditional milking parlour with a herringbone design. This group was treated like the reference herd, except that they were forced through the same type of walk-through footbath twice on one day, only every other week.

Group 2

This group consisted of 15 cows that were also milked twice a day in the traditional herringbone parlour. The slatted floors on which they were housed and their hindhooves (including the interdigital space) were cleaned indirectly (through the floor) with a medium pressure spray of water on days 7, 28 and 90. After each cleaning the cows were treated in a walk-in footbath, containing a 2 per cent multi-compound solution (Feetcare; ICI) in which they stood for 20 minutes, according to the recommendations of the manufacturer.

Group 3

This group consisted of 15 cows that were milked twice a day in the herringbone parlour. On one day a week the cows were forced twice through a walk-through footbath containing the 2 per cent multi-compound solution.

Group 4

This group consisted of 14 cows that were milked twice a day in the herringbone parlour. On one day a week, the cows were forced twice through a walk-through footbath containing 3 per cent sodium carbonate solution.

Dimensions and capacities of the footbaths

The footbaths used by groups 1, 3, 4 and 5 were 300 cm long by 80 cm wide and 15 cm high, and had a capacity of 288 l. The footbath used by group 2 was 400 cm long by 300 cm wide and 15 cm high, and had a capacity of 1800 l.

Cleaning and disinfection of the crush and hands of the claw trimmer

The crush was cleaned with high pressure water and/or a steam cleaner between the inspections of the different groups. In addition, the equipment and the hands and boots of the claw trimmer and investigators were cleaned systematically. After the examination and treatment of a cow with an M2 lesion, only the straw and manure were removed before another cow of the same group was allowed to enter the crush to be examined.

Typing the cows' infections with digital dermatitis

The types of infection were categorised on the basis of the repeated presence of M2 lesions in the same cow. Depending

TABLE 1: Numbers of cows in the groups, and their mean (sd) numbers of lactations and days in milk at the start of the study

Intervention group	Number of cows	Mean (sd) parity	Mean (sd) days in milk
1	14	1·4 (0·9)	149 (123)
2	16	1·8 (1·5)	220 (128)
3	14	1·7 (1·4)	166 (112)
4	15	1·5 (1·6)	172 (126)
5	62	2·2 (1·2)	162 (113)

on the transmission of the different M stages (M1 to M2, M1 to M3, and so on) the cows were categorised as type I, type II or type III according to the following scheme (Döpfer and others 2004): type I Cow remained negative during the whole period of intervention (usually less than 10 per cent of the cows); type II Cow experienced a 'normal' infection, that is, M0 to M1 to M2 to M3 to M4 to M0 (usually 30 to 60 per cent of the cows); type III Cow persisted in the infectious stage, M1 to M2 to (M3) to M4 to M1/M2 to M4, for a period of two to three weeks (usually 30 to 60 per cent of the cows). The type of infection was used as the dependent variable in the regression models.

Statistical analyses

The data were checked for missing values and typing errors. The descriptive statistics were based on individual hooves and the multivariable regression models were based on individual cows. Rank-sum tests were used to determine whether differences between the intervention groups were significant at $P \leq 0{\cdot}05$. The presence of cows with different types of infections was analysed with a logistic regression model, with an autoregressive correlation structure to correct for repeated measurements on a cow (SAS version 9.1). The five intervention periods, the type of intervention, and the cows' stage of lactation and parity were included as explanatory variables in the models. The observation periods were divided into the following intervals: the pre-intervention period (periods 3 to 5); the early intervention period (periods 6 to 8); the middle intervention period (periods 9 to 11), and the late intervention period (periods 12 to 13). The hypothesis was that the more effective the intervention, the smaller the number of type II and/or type III cows there would be in the intervention groups.

RESULTS

Descriptive results

A total of 2718 observations were made during the pre-intervention and intervention periods. During the intervention period 242, 232, 246, 236 and 994 observations were made in groups 1, 2, 3, 4 and 5, respectively, and the mean sizes of these groups were 14·3, 15·1, 14·5, 14·8 and 62·1 cows, respectively. The mean numbers of cows, their parity and stage of lactation in the different groups at the beginning of the study are shown in Table 1. There were no significant differences between the groups in terms of parity or stage of lactation.

The proportions of different M lesions observed in the whole dairy herd during each period of observation are shown in Fig 2. Fig 3 shows the cumulative proportions of the different lesions observed in each intervention group during the eight periods of observation. Fig 4 shows the development of the different lesions in each of the intervention groups during successive observation periods.

The proportion of M2 lesions in each observation period was about 10 per cent. Fig 2 shows that there was a temporary reduction in the proportion of M2 lesions at the beginning of the intervention (periods 6 to 9), followed by an increase during periods 10 to 13.

Fig 4 shows that during period six the reference treatment group (group 5) already had a smaller proportion of M2 lesions than groups 1 to 4 and the proportion decreased substantially to less than 1 per cent in period 9, followed by a slight increase. The proportion of M2 lesions increased in all the other groups, especially in groups 3 and 4, and there was an outbreak in group 3 during the end of May (period 12) and in group 4 from mid April until June (periods 9 to 13).

Logistic regression on type of digital dermatitis

Tables 2, 3 and 4 contain the results of the logistic regression of the type of digital dermatitis for the different groups of cows relative to the reference treatment group (group 5) and corrected for parity, stage of lactation and period of observation. Table 2 shows that there were significantly fewer type I cows in group 3 ($P=0{\cdot}04$) and that there was a trend towards fewer type I cows in group 1 ($P=0{\cdot}08$). There were also fewer type I cows in their first and second parity than in parity three or more. Table 3 shows that there were significantly more type II cows in group 3 than in the reference treatment group ($P=0{\cdot}02$), and there were fewer type II cows in the intervention periods than in the pre-intervention period. Table 4 shows that there were significantly more type III cows in groups 1 and 3 relative to the reference treatment group ($P<0{\cdot}05$). There was a strong correlation between the results of repeated observations on individual cows.

DISCUSSION

Because formalin can have adverse effects on the health of farmers (Collins and Lineker 2004, d'A Heck and Casanova 2004), copper sulphate and zinc sulphate are nowadays frequently applied either alone or in combination with formalin for the treatment of digital dermatitis. The reference treatment group, which underwent the standard herd treatment

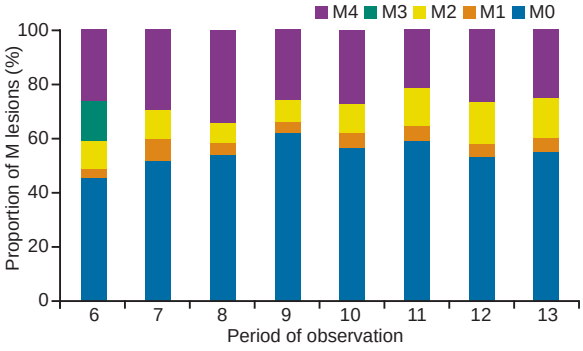


FIG 2: Proportions of the different types of lesions (M0 to M4) observed in the whole dairy herd during each period of observation

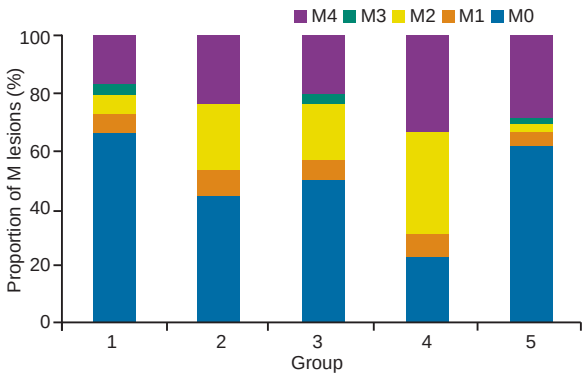
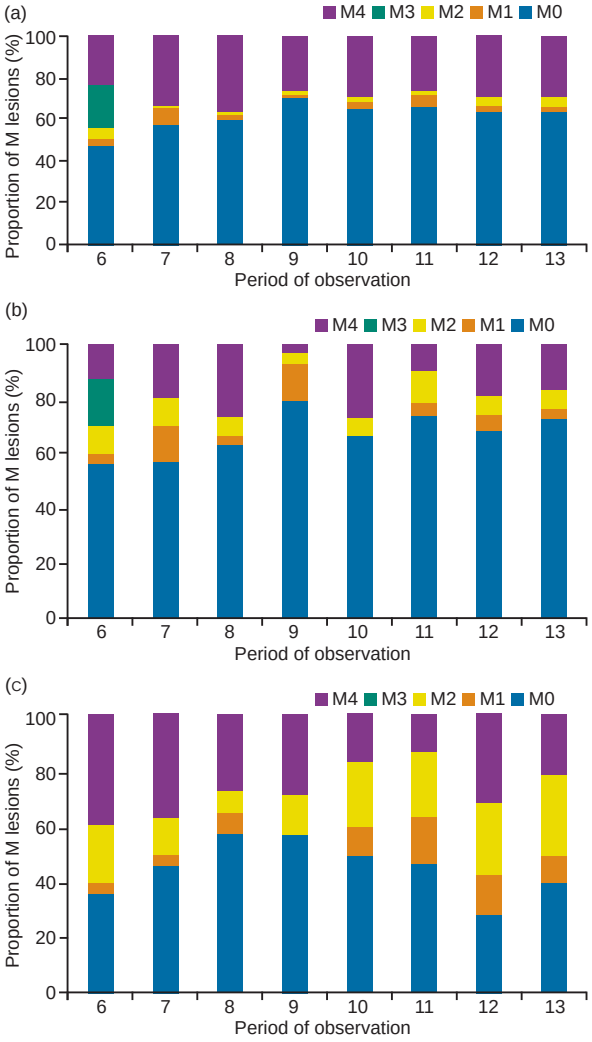


FIG 3: Cumulative proportions of the different types of lesions (M0 to M4) observed in each group during the whole investigation



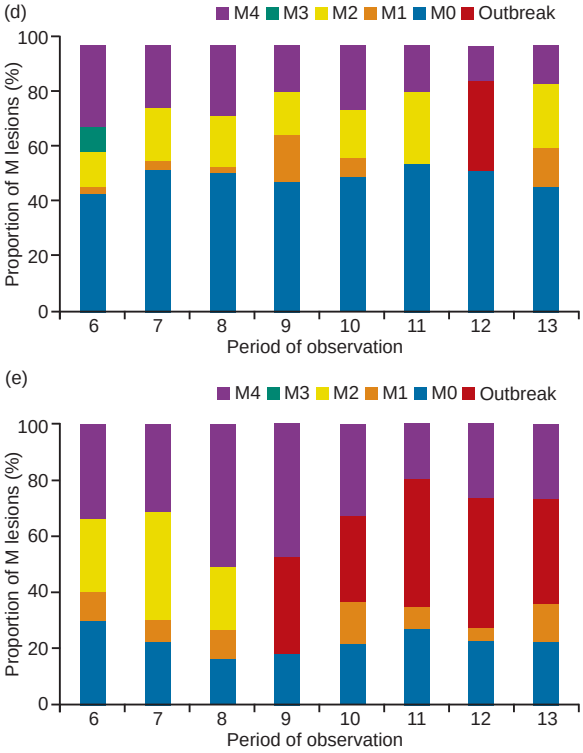


FIG 4: Proportions of the different types of lesions (M0 to M4) observed during the eight periods of observation in (a) reference group, group 5, (b) group 1, (c) group 2, (d) group 3, and (e) group 4

recommended in the Netherlands, was included for two reasons. First, because not treating cows with the disease may cause discomfort and pain and may significantly increase its rate of spread within the group, and secondly, to test the reference procedure against alternative strategies that might replace formalin footbaths as a control measure.

The study was carried out on an experimental farm whose staff were skilled in the precise execution of experiments. They managed five separate groups of cows, without allowing contacts between the animals or their manure, while the normal activities of calving, milking, serving and dry-cow management were continued. To minimise the influence of adding recently calved cows into one of the experimental groups, the cows were assigned randomly to the groups according to the protocol and after their legs had been treated with chlortetracycline spray. This protocol was designed to minimise the potential influence of switching cows between groups, but the additional treatments may have decreased the number of M2 lesions observed during the study.

The choice of the intervention strategies was determined by governmental restrictions, for example, antibiotics and products with heavy metals were forbidden, and the positive results obtained in other studies with formalin (Blowey 2000,

TABLE 2: Results of the logistic regression for cows with type I lesions

Variables	Categories	β	se	P	OR
Intercept		2·68	1·01	0·01	14·6
Group	5	Reference	–	–	–
	1	−1·72	0·98	0·08	0·18
	2	−0·16	0·77	0·84	0·85
	3	−3·50	1·66	0·04	0·03
	4	−1·08	0·94	0·25	0·34
Period of observation	Pre-intervention	Reference	–	–	–
	6-8	0·32	0·26	0·21	1·37
	9-11	0·35	0·26	0·19	1·42
	12-13	0·36	0·27	0·18	1·44
Parity	≥3	Reference	–	–	–
	1	−2·10	0·89	0·02	0·12
	2	−1·93	0·91	0·03	0·15
Stage of lactation (days in milk)	>180	Reference	–	–	–
	0-60	−0·39	0·25	0·12	0·68
	61-120	−0·07	0·19	0·72	0·94
	120-180	0·05	0·12	0·67	1·05

OR Odds ratio

TABLE 3: Results of the logistic regression for cows with type II lesions

Variables	Categories	β	se	P	OR
Intercept		−2·07	0·75	0·01	0·13
Group	5	Reference	–	–	–
	1	1·30	1·05	0·22	3·66
	2	0·46	0·80	0·57	1·58
	3	2·33	0·97	0·02	10·3
	4	1·38	0·89	0·12	3·96
Period of observation	Pre-intervention	Reference	–	–	–
	6-8	−0·70	0·30	0·02	0·50
	9-11	−0·78	0·32	0·01	0·46
	12-13	−0·87	0·34	0·01	0·42
Parity	≥3	Reference	–	–	–
	1	−0·10	0·76	0·90	0·91
	2	0·63	0·85	0·46	1·88
Stage of lactation (days in milk)	>180	Reference	–	–	–
	0-60	−0·12	0·37	0·74	0·88
	61-120	−0·27	0·33	0·41	0·76
	120-180	−0·03	0·18	0·88	0·97

OR Odds ratio

TABLE 4: Results of the logistic regression for cows with type III lesions

Variables	Categories	β	se	P	OR
Intercept		−3·48	0·74	<0·01	0·03
Group	5	Reference	–	–	–
	1	1·16	0·55	0·03	3·18
	2	0·88	0·87	0·31	2·41
	3	1·80	0·55	<0·01	6·06
	4	1·51	1·07	0·16	4·51
Period of observation	Pre-intervention	Reference	–	–	–
	6-8	0·15	0·31	0·62	1·17
	9-11	0·20	0·31	0·53	1·22
	12-13	0·22	0·31	0·48	1·25
Parity	≥3	Reference	–	–	–
	1	1·32	0·70	0·06	3·74
	2	0·99	0·54	0·07	2·70
Stage of lactation (days in milk)	>180	Reference	–	–	–
	0-60	0·29	0·29	0·31	1·34
	61-120	0·02	0·27	0·95	1·02
	120-180	−0·23	0·20	0·24	0·80

OR Odds ratio

Laven and Hunt 2002), with multi-compounds (Shearer and Hernandez 2000), with increased hygienic measures (J. Rietjens, personal communication), and with a walk-through footbath containing sodium carbonate solution (the personal experience of a number of farmers).

The groups differed slightly in parity and stage of lactation, but the multivariable models corrected for these factors, and the differences did not influence the results of the analyses.

The correlation between the repeated observations on individual cows was high, which resulted in few significant results. The finding that throughout the investigation there were fewer type I cows among the cows in their first and second parities than in cows in higher parities agrees with the results of other studies that have found that young cows are at higher risk of developing digital dermatitis (Frankena and others 1991, Smits and others 1992, Read and Walker 1998b, Rodriguez-Lainz and others 1999, Somers and others 2005, Holzhauer and others 2006).

Group 3, which walked through a footbath containing a 2 per cent multicompound, always had significantly more type II and type III cows than the reference group, but did not suffer any outbreaks. The few significant results may also have been due to the small size of the experimental groups and the small proportion (10 per cent) of M2 lesions. Groups 1, 2 and 4 tended to have more problems with the disease than the reference group. Thus, a weekly footbath with 4 per cent formalin seemed to be the most effective treatment. Either weekly or bi-weekly footbaths with formalin resulted in an initial decrease in the incidence of M2 lesions. There were significantly more type I cows in the reference treatment group than in group 3 and a similar but smaller difference in comparison with group 1. In the reference group and in group 2, in which additional hygienic measures were taken, the prevalence of the disease increased, but without serious outbreaks during the last period of observation (at the end of the housing period). This increase was similar to the results observed in other intervention studies (van Amstel and others 1995, Read and Walker 1998a, Shearer and Elliot 1998, Berry and others 1999b, Zemljic 2000) and supports the view that a multifactorial approach, combining systematic intervention and additional hygienic measures, may be necessary to reduce the incidence of M2 lesions.

Groups 2 and 3 were treated with a 2 per cent concentration of the multi-compound, to minimise the farmer's costs and the environmental pollution and in accordance with the recommendations for the use of the product (2 to 5 per cent concentration). In view of the positive results obtained in other studies with multicompounds (Shearer and Hernandez 2000, Blowey and Williams 2004) it may be advisable to repeat the study, increasing the frequency of foot bathing and/or the concentration of the product.

The positive effects of the formalin footbaths may be explained by a combination of a direct effect on the lesions of digital dermatitis, and presumably also by an indirect effect through a reduction in the incidence and severity of heel horn erosion. It has been shown that cows with serious heel horn erosions are at greater risk of developing digital dermatitis (Koniarova and others 1993, Blowey and others 1994, Walker and others 1995, Somers and others 2005, Holzhauer and others 2006).

The observed outbreaks in groups 3 and 4 are in line with the findings of Zemljic (2004), who observed that suboptimal hoof disinfection contributed to the spread of digital dermatitis. The spread of the disease may be stimulated by damp conditions in the cows' housing. Intervention strategies should therefore be combined with improvements in housing, regular claw trimming, a 'closed' herd strategy, and the prevention of periparturient immune suppression (Berry and others 1998, Laven 1999, Somers and others 2005, Holzhauer and others 2006).

The results of this study were obtained from one experimental farm and the treatments need to be investigated in other dairy herds. A follow-up study should provide practically applicable, well founded and affordable advice for the treatment and prevention of digital dermatitis; its application should decrease the pain suffered by dairy cows, reduce the economic losses and health risks for dairy farmers, and result in less environmental pollution.

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