Research in Veterinary Science 166 (2024) 105094

Contents lists available at ScienceDirect

Research in Veterinary Science

journal homepage: www.elsevier.com/locate/rvsc

Prevalence and risk factors for hair loss in outdoor-wintered beef cattle under cold weather conditions

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ARTICLE INFO

Keywords:
Hair loss
Outdoor cattle
Lice
Prevalence
Risk factor
Management

ABSTRACT

Keeping cattle outdoors year-around is considered an attractive alternative to indoor winter-housing, due to lower investment costs and better welfare. However, hair loss, attributed to lice, may impair cattle's thermal balance during harsh winters. During the winters of 2019–2021, outdoor cattle in Sweden were studied for the prevalence and development of hair loss, while surveys were conducted among the farmers on their perceptions and attitudes around hair loss. Of the 463 groups of cattle from 75 farms enrolled in a welfare control program issued by the Swedish Board of Agriculture, 25.7% ($n = 119$) had at least one animal with hair loss. When we followed up a subset of animals ($n = 3673$) which did not receive prophylactic delousing, 15.7% developed hair loss. Hair loss occurrence increased between visits within each winter in these animals, suggesting a contagious etiology. Logistic regression analyses, using the information collected in the control program and the hair loss outcome, showed that preventive delousing before November was effective, alongside keeping animals clean and the group size small. Meanwhile, being older (>2 years) and having access to bedding materials was shown to increase the risk at an animal-level. Some groups ($n = 34$) had no hair loss despite receiving no prophylactic delousing. Based on the survey conducted among the farmers ($n = 15$), groups with lower hair loss prevalence belonged to farmers who were more observant of hair loss and gave prompt treatment. This study provides knowledge useful to limit delousing interventions without compromising animal welfare.

1. Introduction

Keeping cattle outdoors year-around is an attractive alternative for farmers due to the low investment cost and the fact that free-range cattle is often an appealing rearing system for many meat consumers. Furthermore, keeping the animals outside may have a more positive impact on animal health and welfare compared to confined settings. In Nordic countries, the climate can be a challenge though, as extreme cold and harsh wind can negatively affect an animal's thermal balance (Webster, 1970). Hair is an important parameter in the thermal retention capacity of an animal. Tregear (Tregear, 1965) saw that wind (at a speed of 3.6 m/s) penetrated deep into fur with <1000 hairs per cm2, while the wind effect was insignificant at a higher hair density. Cold stress can lead to increased mortality and morbidity, as well as reduced weight gain in calves (Roland et al., 2016). Thus, if the hair thins out and bald spots appear, the welfare of the animal may be negatively affected, along with the production value of the animal.

Considering this challenge, in Sweden it is mandatory to have outdoor cattle (i.e., cattle kept outdoor year-around without access to a shelter) enrolled in a welfare control program. The current control program (Jordbruksverket, 2019), approved by the Swedish Board of Agriculture since 2010, is largely based on a previous study which reported a variation in the proportion and level of hair loss in outdoor cattle between herds and assessed biting lice as the cause (Sandgren, 2007). One of the basic requirements in the program is to have a documented preventive treatment against lice infestation. Also, farms in

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https://doi.org/10.1016/j.rvsc.2023.105094
Received 8 May 2023; Received in revised form 9 November 2023; Accepted 15 November 2023
Available online 20 November 2023
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the control program must have at least one inspection by a veterinarian every winter season, where parameters important in the absence of a shelter are inspected. The assessed parameters include factors like wind protection, feeding condition, and routines for delousing, as well as the physical condition and cleanliness of animals, and their hair loss status.

The number of farms and cattle in the control program has been increasing in the last decade, from 25 farms with 4006 animals in 2010 to 63 farms with 8672 cows in 2021, reflecting the growing interest and investment in this form of beef production in Sweden. Alongside the growth of the industry, there is increasing concern over the continuous use of delousing drugs, such as ivermectin, deltamethrin, and flumethrin, used as preventive treatment against lice infestation. Routine treatment with these drugs increases the risk of selecting resistant ectoparasites (McNair, 2015), threatening the efficacy of the drugs and subsequently negatively impacting animal welfare in the long run. Furthermore, these substances can have long-term negative effects on terrestrial and aquatic organisms in the environment (Mesa et al., 2017).

There are more causes of hair loss beyond lice infestation, like parasitic fungi and mites, making careful diagnostics important. Yet, the clinical findings and positive effect of delousing treatment observed in the control program indicate lice as the major etiological cause of hair loss in outdoor cattle in Sweden. The usual occurrence of large populations of these lice makes them one of the most critical ectoparasites causing economical losses. General performance, including growth and weight gain in beef and dairy calves, as well as milk production, are lower in infested animals, and winter mortality of cattle can also increase if proper care is absent. These parasites are also responsible for the reduced value of hides due to the self-induced skin damage they cause. In a Swedish study, it was reported that 30% of the hides received negative scoring because of the presence of “light spots”, areas of the skin previously affected by lice that tend to take in less stain than the surrounding areas, therefore appearing to be discoloured (Christensson et al., 1994).

Acknowledging the knowledge gap and the need for better assessment and prevention approaches for this important health issue for outdoor cattle, we conducted a cross-sectional study to examine the epidemiology of hair loss in outdoor cattle in Sweden during the winters of 2019–2021.

The three main objectives were:

i) To describe the prevalence of hair loss in outdoor cattle,
ii) To examine the development of hair loss in animals when no prophylactic ectoparasite treatment (delousing) is applied, and
iii) To investigate the factors associated with hair loss.

To complement the findings, surveys were conducted among the farmers to examine their perceptions and attitude towards the issue of hair loss, while a subset of samples were collected for the identification and characterization of the lice species.

2. Materials and methods

2.1. Study design

In the initial assessment of the outdoor cattle population, three different levels – farm, group, animal- were identified (Fig. 1). Group-level data was primarily used for the assessment of hair loss prevalence and for examining associated factors. This was because i) it was observed that the same farmer could have more than one group of animals, and ii) each group was characterized by (or shared) the same geographical location, resources and environmental conditions. To examine the prevalence and development of hair loss in the absence of prophylactic delousing, we conducted a study at the animal-level, in which a subset of the studied population was selected to not receive prophylactic delousing. These animals received one or two additional visits after the control program visit. Finally, to study perceptions and attitudes towards the issue of hair loss in their cattle, surveys were devised and given to all the farmers to complete in 2019–2020. An additional survey was done among the farmers who participated in the animal-level study in 2020 to gain more insight into the relation between the farmers' reactions and hair loss in their cattle. The details of how each study was conducted at different levels are described in the following sections. Each year indicates the winter from the previous year, i.e., 2019 refers to the winter that started in 2018.

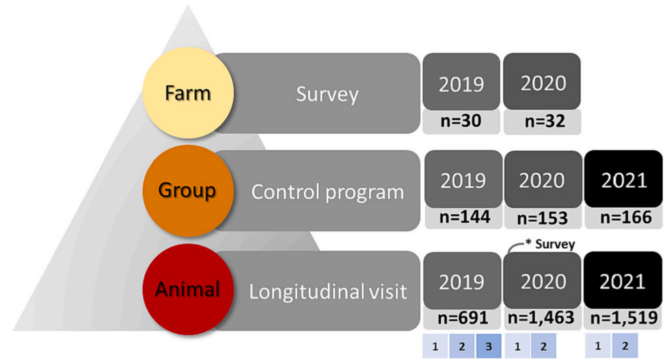

Fig. 1. The structure of the study (2019–2021). A farm-level study was conducted through surveys with the farmers registered in the control program in 2019 and 2020. Both group- and animal-level studies were carried out over all three winters through the control program and longitudinal visits, respectively. For the animal-level study, 1 to 3 visits were conducted each year, with the first visit being part of the control program. The number of visits for each year is represented in the blue-scaled boxes. An additional survey was carried out with the farmers who participated in the animal-level study in 2020. The number of participating farmers, groups, and animals used in the study for each year are also indicated. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2.2. Survey on the perceptions and attitudes around the issue of hair loss among the farmers: farm-level study (2019–2020)

The first-year survey was designed to assess the general awareness and perception of farmers registered in the control program on the issue of hair loss in their cattle. The questions in the survey included the specific month and magnitude of hair loss observed during the previous winter, the measures taken afterwards, and their thoughts on the cause of the hair loss and effective preventive measures. Based on the results, a follow-up survey was devised for the second year with a focus on preventive measures. In this survey, all the preventive measures mentioned by the farmers in the first survey were included, for which farmers were asked to give a rank from 1 (low) to 4 (high) on whether (1) they thought the measure was effective, (2) they were using the measure, (3) they were willing to implement the measure in the future. Additionally, to get more detailed insight of when and how farmers handled the hair loss issue, and how it impacts the hair loss outcome, additional questions were asked to the farmers who participated in the animal-level study in 2020.

2.3. Study of hair loss prevalence and associated factors: group-level study (2019–2021)

Following the standardized protocol for the control program (Gård and Djurhälsan, 2019), all the groups registered as outdoor cattle at the Swedish Board of Agriculture in 2019–2021 were inspected for hair loss in the winter of each year. During these visits, group-level data, such as size and breed of the group, and information on delousing treatment (date, drug) was collected, along with the inspection of parameters included in the control program. The parameters, and how the assessment and categorization was done are described in detail (supplementary data 1). Briefly, the physical condition and cleanliness of the cows, the cleanliness and dryness of lying areas, and the condition of the ground around the feeding place and windbreak were assessed as part of the control program. For the study, additional parameters (i.e., presence of feeding hedge, use of ground feeding, whether the group stayed in the same area all season, and if there had been any new animal in the group) were included in the assessment.

The status of hair loss in each animal in the group was assessed by veterinarians during the control program visits. In this assessment, only the side of the animal which was exposed to the examiner at the time was assessed. It was recorded as positive when the total aggregated size of hair loss area was larger than the size of a palm (approximately 100 cm^2).

2.4. Follow-up of individual animals for recording the development of hair loss in the absence of prophylactic delousing: animal-level study (2019–2021)

Each winter, a subset of the study population, either a whole group or a part of a group, were exempted from the mandatory delousing requirement in the control program in order to study the development of hair loss at the animal-level. The selection of these groups was done on a voluntary basis each year, and an agreement was made with the farmers not to give a group-level prophylactic delousing treatment unless there were signs of lice infestation like itching and hair loss, in which case individual treatment was given. These animals received one (2020–2021) or two (2019) additional visits, until March or April of each year, beyond the control program visit. Specifically, each animal was inspected from both sides and behind. They were recorded as being positive for hair loss when the total (aggregated) hair loss area was bigger than the size of a coin (approximately 10 cm^2). To further assess the hair loss level that is comparable to the control program result, hair loss areas bigger than the size of a palm (approximately 100 cm^2) were also recorded. Along with the status of hair loss, each animal's sex, breed, and birth date was recorded. The study was approved by the ethical board (Swedish board of Agriculture: Dnr 5.8.18–14,496/2020).

2.5. Laboratory diagnostics

In the first year of the study (2019), a subset of hair and skin samples from animals which showed hair loss during one of the visits was collected and sent to the Section of parasitological diagnostics at the National Veterinary Institute (SVA) for parasitological investigation. Up to 10 samples were collected per herd. In detail, hair from areas with hair loss was collected and packed separately in a plastic bag or a test tube to detect lice. A scalpel was used to scrape skin and hair for mite detection, and these samples were also put into a test tube for transport. At SVA, hair was examined under a stereomicroscope to detect the presence of lice, which were then identified at the species level using morphological keys (Price and Graham, 1997). Skin scrapings were transferred to conical centrifuge tubes and submerged entirely in 10% NaOH. The tubes were incubated overnight at 37 °C and inverted twice, before being centrifuged for 3 min at 214*g*. The supernatant fluid was carefully aspirated and decanted, and the sediment was suspended in a few drops of glycerol before being microscopically examined to detect mites.

2.6. Data analysis

After initial collection in the field on paper, the data was recorded in Excel, and then cleaned and managed in R, in which all the plotting and analyses were performed. Logistic regression was used to examine the association between the collected animal- and group- level factors, and the status of hair loss. For the group-level analysis, any factors that were shown to be significant in the univariate analysis ($p < 0.2$) were included in a multivariate model. Using the lme4 package(Bates et al., 2015), the possibility of clustering of hair loss by farm was assessed, and a mixed-effect regression model was built using a backward stepwise selection until only factors with $p \leq 0.1$ remained in the model. The year of sample collection (2019, 2020, 2021) was added as a fixed effect to the model to account for potential differences between years, such as climate, the characteristics of groups, and veterinarians involved. For animal-level risk factor analysis, the base model was built to examine the impact of adding both group and farm as random effects, and then factors were added to the model using a forward stepwise elimination procedure to find the best minimal adequate model.

3. Results

3.1. Description of the outdoor cattle population in the control program by group

A total of 463 groups were registered in the control program during the study period. For each year, the number of registered groups was 144, 153, and 166 groups for the year 2019, 2020, and 2021, respectively. The groups were owned by 75 farmers, whose presence in the program changed over the years: 44 of them had groups for all three years, while 10 farmers were present for 2 consecutive years, and 21 farmers for only one year.

The median size of the groups was 30 animals, but the sizes ranged quite significantly, from 2 to 698 animals in a group (Fig. 2). Among the 399 groups with breed information, the most common breed was cross ($n = 215$), followed by Highland cattle ($n = 91$), Angus ($n = 55$) and Hereford ($n = 32$). Other breeds observed in the study population included Charolais (n = 2), Swedish Holstein (n = 2), and Simmental ($n = 1$).

During the control program visit, 15 groups (3.2%) had at least one cow that had a poor body score (Table 1). One hundred and seventy-eight groups (38.4%) and 42 groups (9.1%) had animals assessed as ‘somewhat dirty’ and ‘dirty’, respectively, while the majority (60.7%) of the groups only contained animals assessed as ‘clean’. The lying areas for the animals were assessed for dryness and cleanliness, for which 61 groups (13.2%) were assessed as having a wet lying area and 72 groups (15.6%) were assessed as having an unclean lying area. A total of 111 groups (25.1%) had bedding in their lying area; this was mostly straw (98.2%), with only two using sawdust. Regarding feeding management, 30 groups (6.5%) were assessed as having a wet and soft feeding area, and 337 groups (72.8%) used a feeding hedge, while 133 groups (28.7%) fed on the ground. From the groups with available information for 2019–2020 ($n = 209$), the majority (64.6%) were reported as having stayed in the same area all season. From the groups in 2020–2021, about 30% ($n = 89$) had new animals introduced into the group during the respective year. Regarding the windbreak, which is a parameter for assessing how well cattle are protected from the wind, especially in low temperatures, 63.3% of the groups ($n = 293$) were assessed as having a good windbreak, while 3 groups had no windbreak at all. The presence of hilly grounds inside the fence was the most commonly observed form of windbreak ($n = 265$), followed by dense forest inside the fence ($n = 199$), sparse forest inside the fence ($n = 183$), and dense forest outside the fence ($n = 112$). Sixty-one groups (13.2%) were reported as having an artificial windbreak.

Most of the control program visits were carried out in January ($n = 232$) and February ($n = 226$) of each year, while five groups in 2021 were visited in December 2020. At the time of each control visit, 72.6% ($n = 336$) of the groups were given delousing treatment. The majority (87.4%) of the groups without treatment were part of the animal-level study. November and December were the most common months in which the farmers treated their animals with delousing drugs, and ivermectin (64.3%) was the most commonly used drug for delousing, followed by deltamethrin (30.4%) and flumethrin (3.6%) (Table 1).

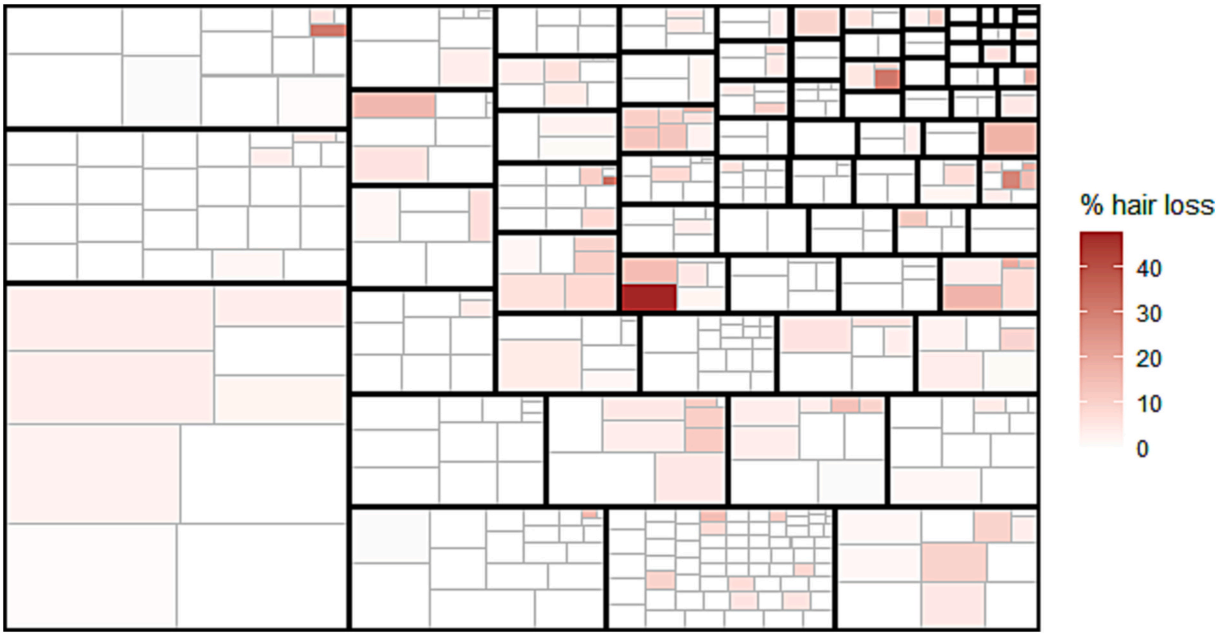

Fig. 2. Percentage of hair loss observed in each group at the control program visit. Groups are marked with gray lines while thick black lines mark each farm, with the area representing the number of cows included in each unit and the color scheme showing the variation of percentage hair loss.

3.2. Prevalence of hair loss assessed in the control program during the winters of 2019–2021

At the time of the control program visit, 25.7% (n = 119) of all the groups included in the control program (n = 463) had at least one cow that showed hair loss on its body. Among the groups with hair loss, a wide range of prevalence was observed, as the percentage of animals with hair loss in each group varied from 0.6% to 47.9%, with an average of 8.2% (Fig. 2). When aggregated by farm, the prevalence ranged from 0% to 19.2%, with an average of 2.3%. A total of 31 farms (41.3%) had no hair loss observed, with 11 of these in the control program for all three years, while 5 were in the program for two years. When aggregated by year, a decreasing trend was observed for the proportion of groups with hair loss, from 31.3% in 2019 to 26.6% in 2020 and 19.9% in 2021. When stratified by performance of prophylactic delousing, 23.2% of the groups with the treatment (n = 336) had at least one animal with hair loss, while 32.3% of the groups without the treatment (n = 127) had animals with hair loss. The difference was significant ($p < 0.05$).

3.3. Group-level factors associated with hair loss

A group was counted as being positive for hair loss if there was at least one cow with hair loss in the group. The size of group was significantly associated with hair loss ($p < 0.01$) in the univariate logistic regression analysis (Table 2). The most distinct difference was observed for the smallest groups (2–14 animals) as there was a significantly lower likelihood of having hair loss in these groups compared to larger groups (OR = 0.40 [0.22, 0.68], $p < 0.001$). Breed was also significantly associated with the hair loss outcomes for a group ($p < 0.01$), particularly groups with Anguses, as this breed had a higher likelihood of hair loss (OR = 2.29 [1.02, 5.10]). Additionally, having dirty animals in the group (OR = 2.65 [1.39, 5.07], p < 0.01) and feeding on the ground (OR = 1.86 [1.20, 2.90], p < 0.001) significantly increased the likelihood of hair loss. Notably, delousing treatment significantly decreased the risk of hair loss in a group (OR = 0.63 [0.40, 0.99], $p < 0.05$); the earlier this delousing was performed for each year, the lower the likelihood of hair loss (Fig. 3). When the delousing was done before November (OR = 0.30 [0.11, 0.78], $p < 0.01$) and the delousing drug used was ivermectin (OR = 0.53 [0.35, 0.82], p < 0.01), the likelihood of hair loss was further reduced. A mixed-effect logistic regression was built with all variables with $p < 0.2$ and, as significant clustering of hair loss was observed by farm (Intraclass-Correlation Coefficient (ICC) = 0.34), farm was added as a random effect. In the final model, the size of the group (p < 0.01) was still significantly associated with hair loss outcome, with small groups (<14 animals) having lower odds (Table 2). Also, having at least one dirty cow in the group significantly increased the odds for hair loss (OR = 4.35 [1.74, 10.89], p < 0.01), while delousing treatment significantly lowered the likelihood of hair loss in a group (OR = 0.43 [0.20, 0.90], $p < 0.05$).

3.4. Prevalence and development of hair loss in animals without prophylactic delousing

A total of 3673 animals were included in the groups in which no prophylactic delousing was performed for the study. These animals were visited one (n = 236), two (n = 2899) or three (n = 538) times, including the control program visit, to be assessed for hair loss. Overall, 576 animals (15.7%) showed at least one patch of hair loss that was bigger than the size of coin. For all three years combined, 249 animals showed hair loss (6.78%) in the first visit, while the proportion increased to 12.02% (413/3437) in the second visit and 18.22% (98/538) in the third visit. Among the animals that did not show any hair loss at the first visit (n = 3424), 3213 animals were followed up for a second visit, with 277 of these animals (8.62%) now showing hair loss. Among the 471 animals that did not show any hair loss during either the first or the second visit and which were followed up on for in the third, 10.51% (n = 50) developed hair loss. When aggregated by year, a decreasing trend of hair loss was observed over the years as observed in the group-level data, from 23.87% in 2019 (n = 691) to 14.42% in 2020 (n = 1463) and 13.17% in 2021 (n = 1519).

These animals belonged to 82 groups from 18 farms, and the status of hair loss was clustered by group and farm (data not shown). There were 2 farms and 34 groups that did not have any animals with hair loss throughout the study period. The prevalence for those with positive hair loss animals varied from 0.57% to 87.5% (median = 20.9%) and 1.33% to 59.9% (median = 12.6%) by group and farm, respectively. For each group with hair loss, an increasing trend of prevalence was observed between visits within each year, suggesting the spread of hair loss within

Table 1
Description of the groups in the study.

Demography	No. of groups (%)	Environment	No. of groups (%)
Group size		Windbreak**	
2–14 animals	119 (25.7%)	Good	293 (63.3%)
15–30 animals	113 (24.4%)	Moderate	167 (36.1%)
31–68 animals	116 (25.1%)	Bad	3 (0.6%)
69–698 animals	115 (24.8%)	Dense forest inside the fence	
		Yes	199 (43.0%)
Breed		No	264 (57.0%)
Angus	55 (11.9%)	Hilly grounds inside the fence	
Charolais	2 (0.4%)	Yes	265 (57.2%)
Cross	215 (46.4%)	No	198 (42.8%)
Dexter	1 (0.2%)	Artificial windbreak inside the fence	
Hereford	32 (6.9%)	Yes	61 (13.2%)
Highland	91 (19.7%)	No	402 (86.8%)
Simmental	1 (0.2%)	Sparse forest inside the fence	
Swedish Holstein	2 (0.4%)	Yes	183 (39.5%)
Unknown	64 (13.8%)	No	280 (60.5%)
		Dense forest outside the fence	
		Yes	112 (75.8%)
		No	351 (24.2%)

Management	No. of groups (%)	Delousing	No. of groups (%)
Cow		Treatment	
Body condition*		Yes	336 (72.6%)
Failed (1–3)	15 (3.2%)	No	127 (27.4%)
Passed	448 (96.8%)		
Cleanliness**		Delousing month	
Somewhat dirty (1–28)	178 (38.4%)	September	2 (0.6%)
Dirty (1–12)	42 (9.1%)	October	52 (15.6%)
Clean	281 (60.7%)	November	125 (37.5%)
Lying area		December	111 (33.3%)
Dryness		January	38 (11.5%)
Dry	401 (86.8%)	February	5 (1.5%)
Moist	61 (13.2%)		
Wet	0 (0%)	Delousing drug	
Cleanliness		Flumetrin	12 (3.6%)
Clean	390 (84.4%)	Deltametrin	102 (30.4%)
Somewhat dirty	72 (15.6%)	Ivermectin	216 (64.3%)
Dirty	0 (0%)	Ivermectin or Deltametrin	3 (0.9%)
Bedding		Unknown	3 (0.9%)
Yes	111 (25.1%)		
No	331 (74.9%)		
Feeding			
Condition of the area			
Dry	432 (93.5%)		
Wet & soft	30 (6.5%)		
Feeding hedge			
Yes	337 (72.8%)		
No	126 (27.2%)		
Ground feeding			
Yes	133 (28.7%)		
No	330 (71.3%)		
Same area all season***			
Yes	135 (64.6%)		
No	74 (35.4%)		
New animal in the group****			
Yes	89 (29.1%)		
No	217 (70.9%)		

The percentages are based on the number of groups for which information was available for each variable. *A group was categorized as 'Failed' if there was at least one animal in the group that failed the body score assessment: the numbers in the parenthesis indicate the number of animals with a failed body score. ** A group was categorized as 'Somewhat dirty' or 'Dirty' if there was at least one animal that was assessed as such; the numbers in the parenthesis indicate the number of animals with this assessment. The groups without either assessment were categorized as 'Clean'; 38 groups had both 'Somewhat dirty' and 'Dirty' animals *** This variable was only collected in 2019 and 2020. **** This variable was only collected in 2020 and 2021.

Table 2
Univariate and multivariate analyses of factors associated with hair loss at the group-level.

Characteristic	Univariate analysis			Multivariate analysis*		
	OR	95% CI	p	OR	95% CI	p
Group size			<0.001			<0.01
Size 1 (2–14 animals)	ref.	-		ref.	-	
Size 2 (15–30 animals)	2.92	1.53–5.58		3.67	1.62–8.32	
Size 3 (31–68 animals)	1.73	0.88–3.40		1.26	0.53–3.02	
Size 4 (69–698 animals)	3.08	1.62–5.85		2.87	1.16–7.10	
Breed**			<0.01			
Angus	2.29	1.02–5.10				
Cross	1.77	0.92–3.41				
Hereford	0.74	0.24–2.27				
Highland	0.73	0.32–1.65				
Body score						
Not passed	2.63	0.93–7.40	0.075			
Cleanliness of animals						
Somewhat dirty	1.41	0.92–2.15	0.115			
Dirty	2.65	1.39–5.07	<0.01	4.35	1.74–10.89	<0.01
Feeding						
Condition of the area – Wet & soft	1.74	0.80–3.77	0.173			
Ground feeding	1.86	1.20–2.90	<0.001			
Delousing						
Yes	0.63	0.40–0.99	<0.05	0.43	0.20–0.90	<0.05
Year						<0.01
2019				ref.	-	
2020				0.62	0.33–1.15	
2021				0.29	0.15–0.58	

* Mixed-effect logistic regression with farm added as random effect and the year of sample collection added as a fixed effect.
** ORs was calculated for each breed with other breeds (Charolais, Dexter, Simmental, Swedish Holstein, Unknown) as the reference.

the group over time (Fig. 4).

When only animals with hair loss patches covering a total area bigger than a palm (approximately 100 cm^2) were counted as being positive for hair loss, as in the control program inspection, the overall hair loss prevalence was 9.10% ($n = 334$), which also increased between the visits, from 3.06% in the first visit to 6.83% in the second visit and 14.88% in the third visit.

3.5. Animal-level factors associated with hair loss

Sex was known for 3660 of the animals, among which 3122 (85.3%) were female and 538 (14.7%) were male. In this subset of the study population, the most common breed was cross ($n = 1579$), followed by Angus ($n = 1050$), Hereford ($n = 532$), and Highland cattle ($n = 465$). The age of animals ranged from <1 year to 19 years at the time of inspection, with an age of 1–2 years being the most common ($n = 1408$). In the univariate analysis with animal-level factors without the inclusion of group or farm as random effects, a significant association between sex and hair loss status was observed, with males having a lower likelihood of developing hair loss (OR = 0.71, $p < 0.05$). Age was also significantly

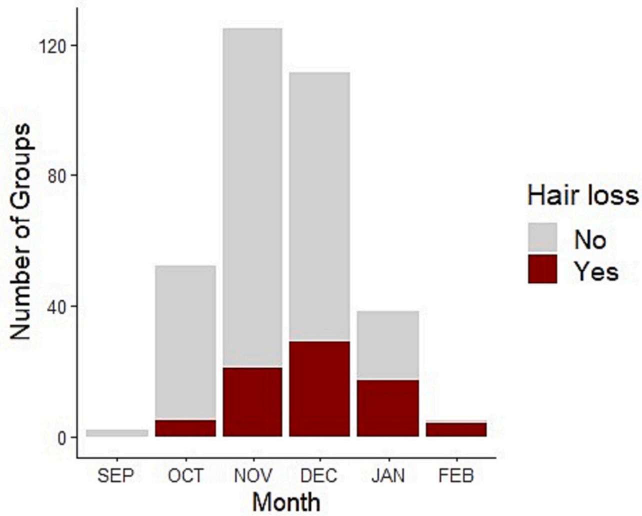

Fig. 3. Number of groups by month which received delousing treatment and the hair loss outcome.

associated with hair loss in an animal, and when categorized into two age groups, ≤2 years and > 2 years, animals older than 2 years had a significantly higher likelihood of having hair loss (OR = 2.91 [2.35, 3.63], $p < 0.001$). Breed was also significantly associated with hair loss outcome (p < 0.001), with the Hereford breed having significantly lower odds of developing hair loss compared to other breeds (OR = 0.61 [0.45, 0.81], p < 0.001).

We further explored the animal-level data by merging it with the group-level management data (Table 1), matching by farm, group and year. Observing the significant clustering of the hair loss outcome by group (ICC = 0.56) and farm (ICC = 0.38), a multi-level mixed effect logistic regression model was built with at least one instance of hair loss as the binary outcome for each animal ($n = 3180$). In the final model, in which year was also added as a fixed effect to take into account the differences between years, being >2 years old (OR = 10.50 [3.93–28.08], p < 0.001) and having bedding (OR = 4.02 [2.19, 7.38], p < 0.001) were significantly associated with a higher likelihood of hair loss in an animal (Table 3). Also, in the final model, compared to other breeds, Anguses had significantly higher odds (OR = 7.85 [1.32, 46.76, $p < 0.05$) of developing hair loss.

3.6. Diagnostics performed on the subset of samples

Hair and skin scraping samples were collected from 40 animals in 12 herds and were sent to SVA. Lice or their eggs were identified in 50% of the herds and in 35% of the sampled animals. The following species were identified: *Bovicola bovis* ($n = 1$), *Linognathus vituli* (n = 1) and *Haematopinus eurysternus* (n = 3). The most common findings ($n = 9$) were eggs that could not be identified at the species level. *Chorioptes* spp. mites were found in one sample. Since none of the sampled animals had shown clinical signs linked with fungal infection, mycological analysis was not performed.

3.7. The perceptions and attitudes of the farmers on the issue of hair loss and the actions taken as preventive measures at the farm level

There were 55 farms registered in the 2019 control program and 30

Table 3
Multivariate mixed-effects logistic regression analyses of hair loss at the animal-level: farm and group added as random effects and year of sample collection added as a fixed effect.

Characteristic	OR	95% CI	p
Animal-level			
Age			
≤2 years	ref.	-	-
>2 years	10.50	3.93–28.08	<0.001
Breed			
Angus	7.85	1.32–46.76	0.024
Cross	2.87	0.55–14.88	0.210
Hereford	0.68	0.05–10.07	0.777
Highland	2.60	0.32–20.85	0.368
Other	ref.		
Group-level			
Bedding			
Yes	4.02	2.19–7.38	<0.001
No	ref	-	-

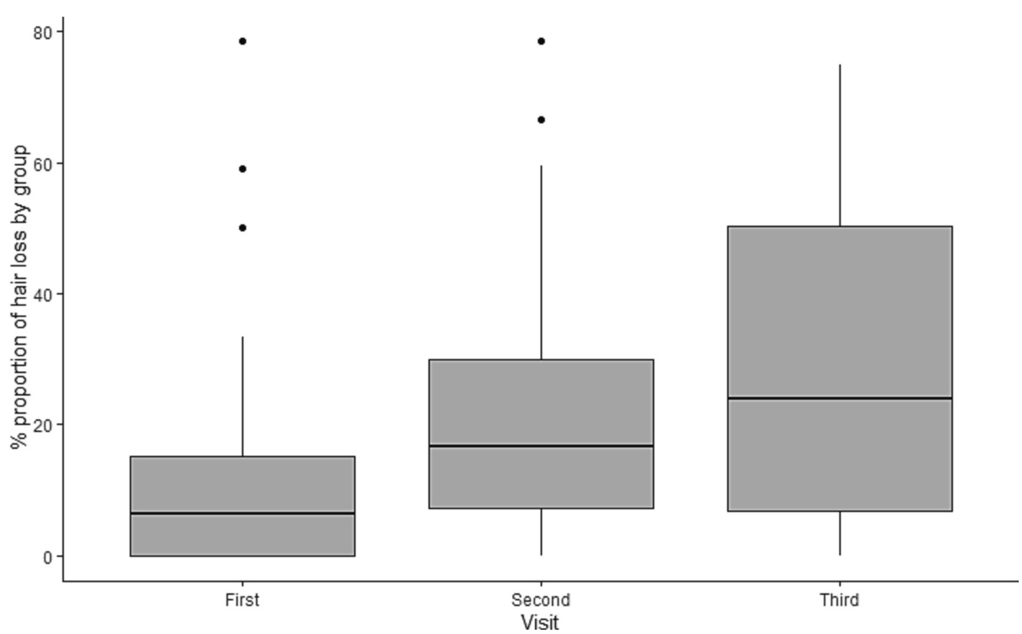

Fig. 4. An increasing trend of percentage hair loss was observed by group between visits among the animals which did not have prophylactic delousing treatment.

(54.5%) answered the first survey in the study. Seventeen farmers (56.7%) answered that they had noticed hair loss among their cattle in the winter of 2018–2019 despite prophylactic delousing treatment. According to the responses, most hair loss cases were seen in January or February, and they were of a size between a coin (approximately 10 cm^2) and a palm (approximately 100 cm^2). The majority (75%) of the farmers speculated that lice infestation was the cause of the hair loss, while other presumptive causes included chorioptic mange (caused by *Chorioptes* spp.), fungal infections, abrasions from feeding hedges and alopecia areata.

Thirty-two farmers (58.2%) answered the second survey in 2020, of which 15 participated in the animal-level study. The preventive measures ($n = 18$) raised in the first-year survey and focused on in detail in the second survey are listed in Supplementary Fig. 1 with the respective average scores given by the farmers for each action. Regarding perception of measures' effectiveness (defined as P in Supplementary Fig. 1), delousing new animals and isolating new animals in addition to delousing were considered the most effective measures, followed by delousing all animals and keeping the animals clean. Ringworm vaccination and separating pregnant animals were considered to be the least effective. When asked the actual measures taken (defined as D in Supplementary Fig. 1), keeping the animals clean had the highest average score, followed by access to cow brushes or trees. The lowest scoring measure being taken was clipping of the affected area, followed by instant removal of animals with hair loss, ringworm vaccination, and making notes of animals with hair loss and isolating them right away or slaughtering them before the next season. When asked to evaluate the willingness to implement each measure (defined as W in Supplementary Fig. 1), some of the actions scored low despite having being perceived as effective by the farmers; these included clipping hair around the affected area and avoiding clustering of the animals. On the other hand, measures like setting up cow brushes, feeding on the ground, making notes of hair loss animals, keeping the animals that are pregnant or to be slaughtered separately, and keeping cows clean were scored high on the willingness than they were considered effective.

3.8. The handling of animals with hair loss on the farms which participated in the animal-level study

A separate set of questions was asked to the farmers who participated in the animal-level study in 2020 ($n = 15$), and the responses are shown in Fig. 5. Based on the answers from 13 farmers, hair loss covering at least the size of a coin was the most common symptom for starting a delousing treatment (Fig. 5A), and 1–7 days after seeing the first animal with symptoms was the most common timeline for starting a treatment (Fig. 5B). When asked about how the treatment was given, the majority of farmers ($n = 7$) answered that they could easily approach the animal affected and give an individual treatment (Fig. 5D). When we classified these farms into farms with low (< 5%) and high (>5%) hair loss prevalence based on the percentage of hair loss observed in the animal-level study, a tendency was observed that the farms with low prevalence were more proactive in their handling of hair loss. In particular, only these farms recognized itching as a symptom for starting a treatment (Fig. 5A), and they did not wait until >3 animals showed symptoms before starting a treatment (Fig. 5C); all of them answered that they could give an individual treatment without gathering the animals together (Fig. 5D).

4. Discussion

4.1. The prevalence of hair loss in the outdoor cattle and the etiology

Hair loss was common in this study, both at a group-level (25.7%) and an animal-level (15.7%), and the prevalence increased over time in

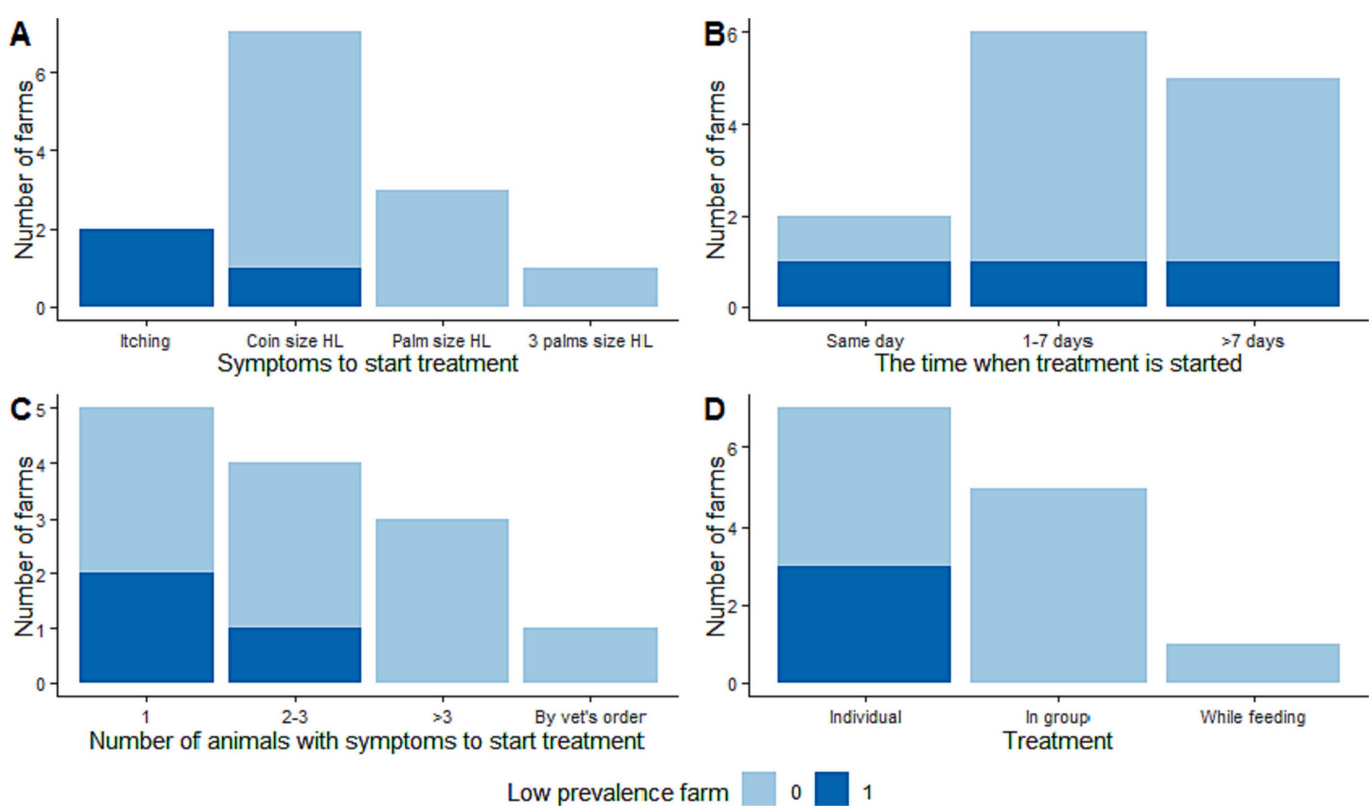

Fig. 5. The responses from farmers who participated in the animal-level study in 2020 ($n = 15$). A. the symptoms they recognize to start a treatment, B. the timeline of starting a treatment after observing an animal with symptom, C. the number of animals with symptom before starting a treatment, and D. how the treatment was given to an animal. Low prevalence farms are those with <5% hair loss observed in the animal-level study.

animals in absence of prophylactic delousing each year, indicating a contagious etiology. Although only a limited number of animals were sampled ($n = 40$) for the diagnosis, our findings through different approaches including diagnostics in the lab and risk factor analyses indicate lice as the main cause of hair loss (35%). Early delousing treatment significantly lowered the odds of getting hair loss in the group. Previous experience (e.g., clinical findings, predilection sites, season) by veterinarians in the control program and the farmers also indicated lice to be the main cause of hair loss and confirmed delousing treatment as an effective preventive measure. This is in line with findings from bordering countries, like Norway, where surveys on lice indicated that lice are a significant and underestimated problem in untreated herds (Nafstad and Grønstøl, 2001). Moreover, cattle in Sweden are free from psoroptic or sarcoptic mange, and chorioptc mange usually only affects certain parts of the body (feet, legs and tail), which was not the case in this study. These facts contribute to the evidence that lice was the most common cause of hair loss in this study. Regarding the species of lice, the species observed in this study were *B. bovis*, *L. vituli* and *H. eurysternus*. Very little old data is available in Sweden regarding the occurrence of lice in cattle, and the data that is available reports the same lice species, in addition to another species, *Solenopotes (S.) capillatus.* Persson et al. (Persson and J.B.B.A, 1981) examined cattle showing clinical signs and found lice in 40% of the samples, among which *B. bovis* was the most common. In another study from 1994 (Christensson et al., 1994), animals were chosen randomly in March and April, and lice were found in nearly all the farms (92%). At the animal level, around 29% of the animals were found positive. *B. bovis* was the most common species in the study (58%), followed by L. *vituli* (25%). These two species were also present together, i.e., as a coinfection (16%), while *H. eurysternus* was found alone and only on one dairy cattle. The study also reported a higher frequency of lice on beef cattle (45%) than on dairy cattle (17%).

4.2. Factors that may increase the risk of hair loss

At a group-level, an association between smaller group size and lower hair loss was observed. Lice are mainly spread through direct contact between animals (Loomis, 1986) and the risk of spread and infection will therefore increase with increased group size. Also, when the group is larger, it becomes harder to identify animals with hair loss and take timely action. Indeed, when the same risk factor analysis using multivariate logistic regression was performed by stratifying the groups by prophylactic delousing status, the only significant factor that was associated with higher odds of hair loss was the group size (>68 animals) for the groups that did not have any prophylactic delousing (data not shown). Another factor identified to be associated with hair loss at the group-level was having at least one dirty cow in the group. Having a dirty cow may be linked to poor management of the herd in general. However, this should be interpreted with caution as the association found in this study was not with the magnitude, i.e., the number of dirty animals in the group. Moreover, animals with dirt on them can get bald patches, which is not easy to differentiate from other reasons for hair loss, like lice. To our knowledge, an association between hair loss and cleanliness has not been reported previously.

In the animal-level analysis, older cows (>2 years) had a higher likelihood of hair loss compared to young ones. Previous studies, however, have reported calves and youngstock to be more susceptible to lice infestation (Chalmers and Charleston, 1980; Christensson et al., 1994; Geden et al., 1990; Nafstad, 1998). We speculate that the difference could be due to different categorizations of ages between studies and the fact that there were only a few calves included in this study, as there were only 23 animals (0.6%) in total that were <1 year old. Another factor identified to be significantly associated with hair loss at the animal-level was access to bedding materials. The animals with lice are the main source of infection and the survival time of lice in this environment is short (Matthysse, 1986; Wall and Shearer, 2008), making this finding rather debatable. One reason for higher hair loss in animals with access to bedding material may be due to the animals lying closer to each other if the bedding is spread over a limited area. Thus, the size of the bedding area is of importance, as well as the dryness and cleanliness of the bedding, warranting further detailed investigation on the risks of bedding on hair loss. Another significant factor associated with hair loss at the animal-level was breed. In particular, Anguses had higher odds of hair loss than other breeds, both in the group- and animal-level analysis. There is no previous literature that reports breed differences in association with hair loss, but we speculate that different fur types and colors may influence the outcome of hair loss in the control program. For instance, it may be easier to spot hair loss on cows with short, dark hair compared to long, light hair. Also, we know from experience that there are different attitudes and traditions among farmers with different breeds that might affect how they manage their animals in general, which may affect the hair loss outcome.

4.3. Farmers' perceptions and attitudes, and hair loss outcome

Farmers perceived delousing, especially delousing new animals in the herd, to be the most effective preventive measure for hair loss. Delousing all the animals in the group was confirmed as an effective preventive method in this study, especially when it was done before November. This could be a consequence of coats being thinner before the winter coat has grown out, which will facilitate the pour-on preparation reaching the skin. It may also be due to a lower prevalence of lice at the time, especially eggs, which are naturally resistant to delousing. Keeping the animals clean was also perceived as being effective, and most of the farmers in the survey felt they were doing well on this measure. This was supported by the control program results, as only 9.1% of the groups had animals assessed as dirty. Notably, some measures, like clipping the affected area and avoiding clustering of animals, were scored low on the willingness to implement even though they were considered effective, while measures like setting up cow brushes and feeding on the ground were scored high on willingness while considered less effective. These gaps between perception and willingness on different effective measures may be due to practical reasons, depending on the feasibility of implementation.

Throughout the study period, there were 2 farms and 34 groups that did not have any animals with hair loss, even though no delousing had been performed on them. It was observed that farmers with access to treatment facilities for individual animals without delay and the ability to spot early symptoms, like itching, were more successful in preventing and limiting the spread of hair loss in the group.

There was a decreasing trend in the proportion of hair loss, both at the group- and animal-level, over the years. The difference was most clear and significant in the groups with delousing treatment (data not shown), which we speculate is because more groups in later years deloused animals earlier; the proportion of groups which received delousing before November increased from 9.72% in 2019 to 11.76% in 2020 and 13.25% in 2021. The same trend was also observed in the groups without delousing treatment. There may have been other factors that contributed to the trend, like changes in climate and lice population, but we believe that our communication with the farmers on the issue of hair loss and possible preventive measures through surveys and dialogues with vets in this study may have also contributed to the trend.

5. Conclusions

For outdoor cattle in Sweden, for which hair loss is an important health and animal welfare issue, lice is the primary reason for hair loss. Delousing all animals in a group before November was shown to be an effective preventive measure, along with keeping animals clean and ensuring a smaller group size. However, we also identified a number of groups which managed to have no hair loss even without receiving delousing treatment. The owners of the groups with a lower prevalence of hair loss were generally more proactive in identifying hair loss and giving individual treatment with little delay. This is important knowledge for reducing the use of antiparasitic drugs without compromising animal welfare. Furthermore, previous studies from Norway have suggested that it is possible to eradicate lice in cattle (Nafstad and Grønstøl, 2001). To explore the possibility of lowering the use of antiparasitic drugs and, ultimately, to eradicate lice in Swedish outdoor cattle, further studies are warranted, such as a case-control study to examine general management, e.g., bedding, and preventive measures against lice infestation taken in the successful groups with no delousing treatment.

Funding sources

This work was supported by the Swedish Board of Agriculture [grant numbers Dnr: 5.2.18-0444222/2018 and Dnr: 5.2.18-05165/2019].

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We are grateful to the veterinarians at Farm & Animal Health who worked in the control program for outdoor cattle and assisted the data collection. We would like to also acknowledge the farmers who took the extra time to participate in the survey and accommodated additional visits, as well as the staff at the section for diagnostic parasitology at SVA for the handling and examination of the samples.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rvsc.2023.105094.

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