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Relationship between quality of facilities, animal-based welfare indicators and measures of reproductive and productive performances on dairy farms in the northwest of Spain

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ABSTRACT

The aim of the present study was to evaluate the effect of facility comfort level on animal-based welfare indicators as well as on productive and reproductive parameters of 187 dairy farms in the northwest of Spain. Fifty-eight facility-based parameters, which included both housing facilities and management parameters, were evaluated in each farm and used to classify the 187 farms in 5 groups (from 1: top farms to 5: worst farms). Animal-based welfare indicators and reproductive and productive parameters were compared among farm groups. Lameness score significantly differed ($p < .005$) in top farms (67% of cows having normal gait) versus groups 4 (55%) and 5 (53%). The proportion of cows with dirty lower legs and udder was lower ($p < .05$) in top farms (80% and 31%, respectively) than in groups 4 (92% and 51%) and 5 (95% and 56%). Other animal-based indicators were not different among farm groups. Heat detection rate was higher ($p < .001$) in top farms (56.5%) versus groups 4 (51%) and 5 (47%), and milk production/cow/day was also significantly higher ($p < .001$) in top farms (34.4 L) versus groups 3 (31.2 L), 4 (30.5 L) and 5 (27.4 L). Other reproductive or productive parameters were not different among farm groups. Facility-based measures were compared only between the top and worst farms. In top farms, most facility-based parameters met the welfare-related objectives, whereas in the worst farms only a few facility-based parameters met the welfare objectives.

HIGHLIGHTS

- Fifty-eight facility-based parameters, including housing measures and some management practices, were evaluated and scored in 187 dairy farms.
- Top-performing farms (i.e. with the best scores) had lower incidence of lameness and of cows with dirty legs and udder than poor-performing farms.
- Top-performing farms had higher rates of heat detection and higher milk production/cow/day than poor-performing farms.

Introduction

Animal welfare has become a topic of great interest to EU citizens, and legislation concerning animal welfare in modern livestock production is frequently revised. The livestock industries are not only sensitive to the welfare of farm animals, in part because poor welfare conditions are often associated with reduced productive performance of animals, but also because they need to project a welfare-friendly image of their products to be competitive (Hemsworth and Coleman 2011).

In Europe, public opinion perceives that, compared with laying hens or pigs, dairy cows are reared in fairly good welfare conditions (European Commission 2005). Because the public opinion may be influential in determining legislative decisions on animal welfare standards, this may be the reason for the lack of specific regulations concerning animal welfare in dairy farms. Among all factors influencing animal welfare, perhaps the most evident is the quality and comfort ability of facilities, which may widely differ among the dairy farms in a region or a country.

Inadequate animal welfare conditions are known to cause chronic stress and numerous health issues in dairy farms (Abeni and Bertoni 2009), but objective and systematic assessment of animal welfare aspects, including comfort ability of facilities, is not routinely

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done by veterinarians and therefore, insufficient or poor cow comfort may be overlooked.

Assessment of animal welfare conditions provides an opportunity to address ethical issues and also to improve the productive performance of dairy farms (Abeni and Bertoni 2009), as cow discomfort is known to hinder full development of the productive potential. Various different studies have demonstrated that some facility-related aspects, as well as management practices, may influence animal health, longevity and reproductive and productive performance (Cook and Reinemann 2007; Erina et al. 2008). Bach et al. (2008) found that milk production differed considerably among herds of similar genetic background and fed with the same ration. In the cited study, non-dietary factors (i.e. management practices) accounted for 56% of the variation in milk production not attributable to diet.

The dairy industry in developed countries is characterised by high production costs and a final product of low price, and farmers therefore operate with narrow profit margins. In this context, despite that a positive relationship between cow comfort and productivity has long been known, farmers are often reluctant to renovate existing facilities or to build new ones with larger stall dimensions (Grant and Miner 2015), unless they are convinced that the cost is financially worthwhile. As milk production is affected by many different variables, estimating the impact that improved facilities may have on farm productivity is a difficult task, and it may be the reason not to undertake reforms or improvements since the benefit that can be reported is not known.

In the present study, the level of cow comfort provided by facilities and some management practices was objectively assessed and quantified in a representative number of dairy farms located in the province of Lugo, which is the most important dairy province of Spain. Then, animal-based indicators of welfare and productive and reproductive performance were compared among farms with different degrees of cow comfort. Feeding practices and genetic background were uncontrolled factors, but they were similar for all the farms in the region. The global aim of the study was to determine if herd health and production differed among farms with better or worse facilities and/or management, and the magnitude of the difference. More concretely, the specific objectives of the study were:

1. To assess and score 58 facility-based parameters, which included both housing measurements and evaluation of some management practices, in 187 dairy farms located in the province of Lugo.
2. To determine if the quality of facilities was related with: (i) animal-based measures of welfare (body condition score, lameness score, hock lesions and hygiene), (ii) reproductive performance (postpartum intervals, fertility, heat detection rate and cull rate), and (iii) productive parameters (somatic cell count, milk production and percentages of fat and protein in milk).

Materials and methods

Farms

The study involved 187 dairy farms in the province of Lugo (Galicia, northwest of Spain). A substantial proportion (19%) of the 844,000 dairy cows registered in Spain in 2015 was from farms in the province of Lugo.

Farms were recruited through the veterinary surgeons responsible for reproductive control on dairy farms in the region. Only free stall farms were included in the study, as tie stall farms usually have old facilities and are becoming increasingly less frequent in the study area. In most farms (160) cows were all year round indoors without access to pasture.

All farms had Holstein cows; no other breeds were present in any farm. The average number of lactating cows per farm was 55 (range: 10–240), and a total of 9228 lactating cows were evaluated. Average parity per farm was 2.5 ± 0.5 (range: 1.7-4.9).

All farms milked twice a day and all had conventional milking parlour. Feeding management was not evaluated in each farm, but all farms in the region tended to use the same type of raw materials to formulate rations, and all used mixer trucks. In general, rations were based on corn and grass silages supplemented with concentrates, which were adjusted depending on production.

Farms were visited once, by the same evaluator, for collection of the data specified below.

Data collection

Reproductive parameters

Reproductive data from the previous 12 months were obtained from the reproduction records kept by the veterinary surgeons attending each farm. The following parameters were considered: interval between calving and first artificial insemination (AI), conception rate at the first AI, interval between calving and conception, heat detection rate, average fertility and cull rate.

Productive parameters

The following milk production data were obtained from the Galician Dairy Control Programme records provided by veterinary surgeons: somatic cell count (SCC; mean value for the previous 12 months), milk production per cow and day (L/Cow/day) and percentages of fat and protein (mean values for the previous 12 months).

Facility-based measures

The facility-based measures considered are specified in Table 1. Facility-based parameters that complied with the welfare objective were scored 0 points, whereas those that did not comply with the welfare goals were scored 1 point. Distance measurements were done using a laser metre or, for small distances, a roll metric tape. Data collection in the different farm areas was done following always the same order.

Animal-based measures

Eighty to one hundred per cent of cows on each farm were evaluated for the parameters specified in Table 2. Animal-based measures were collected around the time of the first milking. At the start of the evaluation, all cows were restrained in headlocks. Each cow was first scored for body condition (BCS), hock injuries and hygiene, and then released and scored for lameness from an average distance of 3 metres. Each of these measurements was recorded once for each herd and all scores were done by the same evaluator.

Body condition score (BCS) was based on a scale of 1 to 5 with 0.25 point intervals (Ferguson et al. 1994). For each cow, BCS and days in milk (DIM) data were compared against the objectives proposed by PennState Extension (2017). The proportions of cows with normal, low or high BCS according to the objectives for DIM were determined for each farm.

Hygiene score was based on a scale of 1 to 4, as proposed by Cook (2002), where 1 represents the highest and 4 the lowest level of cleanliness. Cows were scored separately for leg, udder and flank hygiene. The proportion of cows with dirty legs, udder or flanks (i.e. scored 3 or 4 for any of the 3 measures) was calculated separately for each farm.

Hock injuries were recorded as present or absent, and different degrees of injury were not considered. Tarsal joints of each cow within the herd were evaluated. The percentage of cows with lesions (scratch, swelling, abrasion or trauma) in one or the two limbs was used for the analysis.

Lameness was scored as described by Sprecher et al. (1997) on a scale of 1 to 5, where healthy cows were awarded a score of 1 and severely lame cows were awarded a score of 5.

Statistical analysis

Regarding facility-based measures, farms were scored for each parameter specified in Table 1 and were awarded a score of 0 for compliance with the objective and a score of 1 for non-compliance with the objective. The sum of all scores awarded to each farm corresponded to the number of parameters that did not comply with the objective; and therefore, low scores represent high quality facilities. The total score awarded to farms was used to calculate quintiles and thus divide the farms into five groups (Table 3). Farms were divided in quintiles to try to satisfy two conditions: (1) to have a sufficient number of farms per group, and (2) that farms in group 1 (considered the top-performing farms) and those in group 5 (considered the poorest-performing farms) were as far each other as possible, so that differences could be detected. Animal-based measures and productive and reproductive parameters of farms in group 1 were compared with those of the other groups by means of ANOVA and Dunnet's t test. A Fisher's exact test was used to compare facility-based measures between the top-performing group and poorest-performing group of farms. ANOVA was also used to compare animal-based measures and productive and reproductive parameters between farms with or without outdoor run.

Results

For facility-based measures, the lowest score obtained was 6 out of 58 points and the highest score, 39 out of 58 points. The ranges of scores awarded to the five groups of farms, as well as the mean farm size, parity and percentage of farms with outside access per group, are shown in Table 3.

Comparison of animal-based measures and of measures of productivity and reproductive performance between the top-performing farms and the other groups of farms revealed significant differences in the following items: lameness score, leg and udder hygiene, heat detection rate and daily milk production per cow (Table 4). The proportion of cows with normal gait (scored 1) was higher in the top-performing group than in the other groups (67% relative to 55–54% in groups 4 and 5), as was the proportion of

Table 1. Objectives to be met (zero score) for the different facility-based parameters evaluated.

Area	Parameter	Score 0	Score 1	References
Resting	Stocking density	≤100	>100	Fregonesi, Tucker, et al. (2007)
	Quarantine pen	Yes	No	Laurence (2014)
	Calving pen	Yes	No	Vasseur et al. (2010)
	Dry bedding	Yes	No	Fregonesi, Veira, et al. (2007)
	Level bed surface	Yes	No	Drissler et al. (2005)
	Bedding maintenance	≥2	<2	Drissler et al. (2005)
	Bedding materials	Sand/straw/mattress	Rubber/concrete	Tucker and Weary (2001)
	Calcium carbonate	Yes	No	Fregonesi, Veira, et al. (2007)
	Stall width	117–127 cm.	<117/>127 cm.	Cook and Nordlund (2005); Hulsen (2007); Córdoba et al. (2012)
	Brisket broad distance from curb	178–183 cm.	<178/>183 cm.	Cook and Nordlund (2005); Anderson (2007); Hulsen (2007)
	Brisket broad height	<15 cm.	15 cm.	Cook and Nordlund (2005); Hulsen (2007); Córdoba et al. (2012)
	Total stall length	>270 cm.	≤270 cm.	Anderson (2007); Hulsen (2007); Córdoba et al. (2012)
	Neck rail distance from curb	178–183 cm.	<178/>183 cm.	Cook and Nordlund (2005); Anderson (2007); Córdoba et al. (2012)
	Neck rail height	117–127 cm.	<117/>127 cm.	Cook and Nordlund (2005); Anderson (2007); Hulsen (2007); Córdoba et al. (2012)
	Curb height	15–20 cm.	<15/>20 cm.	Anderson (2007); Córdoba et al. (2012)
Circulation	Width crossovers	≥250 cm. without water troughs ≥420 cm. with water troughs	<250 cm. without water troughs <420 cm. with water troughs	Pereira et al. (2003)
	Width fed alley	≥420 cm	<420 cm.	Pereira et al. (2003)
	Width free stall alley	≥300 cm.	<300 cm.	Pereira et al. (2003)
	Striped surface	Yes	No	Juaristi et al. (2004); Telezhenko et al. (2007)
	Rubber floor	Yes	No	Telezhenko and Bergsten (2005); Telezhenko et al. (2007); Fjeldaas et al. (2011)
	Blind alleys	No	Yes	Juaristi et al. (2004); Mülling et al. (2006)
	Slippery floor	No	Yes	Juaristi et al. (2004); Telezhenko et al. (2007)
	Slatted floor	No	Yes	Telezhenko and Bergsten (2005); Fjeldaas et al. (2011)
	Slurry pit under barn	No	Yes	
	Accumulation of manure in the alley	No	Yes	Mülling et al. (2006)
Cows	Presence of ectoparasites	No	Yes	Hulsen (2007)
	Presence of flies	No	Yes	Juaristi et al. (2004); Hulsen (2007)
	Presence of cows with horns	≤1	>1	Fraser et al. (2013)
	Presence of cows with tail	Yes	No	Fraser et al. (2013)
	flight zone	≤75 cm.	>75 cm.	Juaristi et al. (2004)
	Stress for a scarce commodity	No	Yes	Hulsen (2007)
	Cow crowding	No	Yes	Hulsen (2007)
	Preventive claw trimming	≥1/year	No	Lagger (2007); Cook et al. (2016)
	Footbaths	Yes	No	Lagger (2007); Cook et al. (2016)
	Welfare objects	Yes	No	Hulsen (2007)
Feeding	Feeding table smooth and clean	Yes	No	Juaristi et al. (2004)
	Cleaning feeding table	≥1 /day	<1 /day	Juaristi et al. (2004)
	Continuous feed availability	Yes	No	Juaristi et al. (2004)
	Feeding table with shadow	Yes	No	Juaristi et al. (2004)
	Feeding table covered	Yes	No	Juaristi et al. (2004)
	Height from feeding table to cow foot	10–15 cm.	<10/>15 cm.	Anderson (2007); Hulsen (2007); Trillo et al. (2017)
	Water analysis	Yes	No	Juaristi et al. (2004)
	Cleaning water troughs	≥1 /day	<1 /day	Juaristi et al. (2004)
	Water troughs design	Flip	Flip and fixed/Only fixed	Juaristi et al. (2004)
	Cm. of water troughs /cow	≥8 cm./cow	<8 cm./cow	Trillo et al. (2017)
	Water troughs at the exit of the milking parlour	Yes	No	Juaristi et al. (2004)
	Width of headlocks	≥60 cm.	<60 cm.	Trillo et al. (2017)
Ventilation	Orientation	East-West	Other	Juaristi et al. (2004)
	Air movement on the face of the cow	Yes, slight	No/Yes, excessive	Juaristi et al. (2004)
	Condensation	No	Yes	Juaristi et al. (2004)
	Ceiling insulation	Yes	No	Juaristi et al. (2004)

(*continued*)

Table 1. Continued.

Area	Parameter	Score 0	1	References
	Sidewall height	≤4 m.	>4 m.	Juaristi et al. (2004)
	Lateral opening	Yes	No	Juaristi et al. (2004)
	Cow curtain	Yes	No	Juaristi et al. (2004)
	Height to ridge	≥6 m.	<6 m.	Juaristi et al. (2004)
	Forced ventilation systems	Yes	No	D'Emilio et al. (2017)
	Humidity	No	Yes	Juaristi et al. (2004)
	Spiderwebs (sign of poor ventilation)	No	Yes	

Table 2. Scores for animal-based welfare indicators.

Variable	Levels	Description	References
Body condition score	1	Severe under conditioning	Ferguson et al. (1994)
	2	Frame obvious	
	3	Frame and covering well balanced	
	4	Frame not as visible and covering	
	5	Severe over conditioning	
Lameness score	1	Stands and walks normally with a level back. Makes long confident strides.	Sprecher et al. (1997)
	2	Stands with flat back, but arches when walks. Gait is slightly abnormal.	
	3	Stands and walks with an arched back and short strides with one or more legs. Slight sinking of dewclaws in limb opposite to the affected limb may be evident.	
	4	Arched back standing and walking. Favouring one or more limbs but can still bear some weight on them. Sinking of the dewclaws is evident in the limb opposite to the affected limb.	
	5	Pronounced arching of back. Reluctant to move, with almost complete weight transfer off the affected limb.	
Hygiene score lower leg/ udder/upper leg and flank	1	Clean, little or no evidence of manure	Cook (2002)
	2	Clean, only slight manure splashing	
	3	Dirty, distinct demarcated plaques of manure	
	4	Filthy, confluent plaques of manure	
Hock lesions	No	Absent	
	Yes	Hair loss, ulceration or swelling	

Table 3. Distribution (N, %), mean size (number of lactating cows), parity and proportion of farms with outside access, within the farm groups constructed in function of facility-based scores.

Farm groups (facility-based score)	N	%	Farm size (mean ± sd)	Parity (mean ± sd)	Farms with outside access N (%)*
Top-performing farms (<21)	61	32.6	60.9 ± 36.4	2.5 ± 0.3	5 (8.2)
Group 2 (21–22)	17	9.1	60.8 ± 41.0	2.5 ± 0.4	2 (11.8)
Group 3 (23–25)	43	23.0	66.7 ± 46.9	2.5 ± 0.5	4 (9.3)
Group 4 (26–29)	38	20.3	44.8 ± 22.5	2.5 ± 0.6	6 (15.8)
Poorest-performing farms (>29)	28	15.0	35.6 ± 12.7	2.7 ± 0.5	10 (35.7)
TOTAL	187	100	55.1 ± 36.3	2.5 ± 0.5	27 (14.4)

(%)*: percentage relative to the number of farms per group.

cows with dirty udders (31% relative to 49–56% in groups 3-5). The rate of heat detection was also higher in the top-performing group (56.5% relative to 51–47% in groups 4–5). Finally, the daily milk production per cow was higher in the top-performing group (34 relative to 31–27 L in groups 3–5).

When animal-based measures, as well as productivity and reproductive performance, were compared between farms with outdoor run ($n = 27$) and only-indoor farms ($n = 160$), significant differences were found in some parameters: the proportion of cows scored 2 for lameness was higher ($p < .05$) in farms with outdoor run (31.7 ± 17.4% vs. 26 ± 12.8%); percentages of cows with normal gait or with higher lameness scores did not differ.

Also proportions of cows with dirty legs and udder (94% and 57%, respectively) were higher ($p < .05$) in farms with outdoor run than in indoor farms (84% and 40%, respectively). However, somatic cell count in milk (191.2 ± 45.5 vs. 242.3 ± 91.6 × 103 cells/mL) and culling rate (19.5 ± 10.3 vs. 24.4 ± 10.9%) were lower in farms with outside access than in indoor farms.

Regarding facility-based measures, the main differences between the top-performing (group 1) and poorest-performing (group 5) farms (Table 5) were associated with the type and maintenance of bedding, type of floor, dimensions and cleaning of alleys, care of cows, accessibility to water and food, and the farm environment. However, stall dimensions were not different in these two groups of farms, being inadequate in both.

Table 4. Animal-based welfare indicators, reproductive and productive measures (means ± sd) in the five groups of farms.

	Top-performing farms	Group 2	Group 3	Group 4	Poorest-performing farms	p Value
Body condition (%)						
Suitable	57.2 ± 13.0	60.9 ± 15.7	53.0 ± 13.8	53.6 ± 19.2	52.4 ± 12.9	.224
Low	34.6 ± 14.4	31.3 ± 17.1	40.6 ± 15.7	38.1 ± 19.0	40.1 ± 16.4	.173
High	8.2 ± 6.3	7.8 ± 12.1	6.4 ± 7.1	8.3 ± 9.2	7.4 ± 8.4	.835
Lameness score (%)						
1	66.6 ± 16.2	68.3 ± 13.4	64.8 ± 17.6	55.2 ± 15.8**	53.9 ± 19.5**	.001
2	23.3 ± 12.2	23.7 ± 12.0	24.9 ± 14.4	32.6 ± 13.0**	32.6 ± 14.4*	.002
3	6.4 ± 5.3	6.9 ± 5.2	7.1 ± 6.5	7.7 ± 6.6	9.6 ± 9.1	.314
4	3.0 ± 4.5	1.1 ± 1.5	2.6 ± 3.1	3.4 ± 4.4	3.5 ± 5.7	.330
5	0.7 ± 1.6	0.1 ± 0.2	0.8 ± 1.4	1.0 ± 2.7	0.3 ± 1.0	.338
Dirty cows (%)						
Lower leg	79.8 ± 25.6	83.7 ± 18.8	87.2 ± 18.6	91.9 ± 8.6*	95.4 ± 6.6*	.033
Udder	30.8 ± 23.9	35.1 ± 27.4	48.9 ± 28.3**	51.3 ± 28.3**	56.0 ± 20.3**	.001
Upper leg and flank	38.1 ± 30.2	28.2 ± 22.9	42.2 ± 25.9	39.6 ± 26.3	42.8 ± 26.3	.554
Hock lesions (%)	22.2 ± 21.7	21.2 ± 18.9	17.3 ± 24.1	23.1 ± 23.0	28.7 ± 25.8	.368
Reproductive measures						
Interval calving to first AI (d)	76.8 ± 11.3	84.3 ± 11.3*	81.4 ± 10.5	77.0 ± 10.3	82.5 ± 10.0	.018
Fertility in the first AI (%)	32.7 ± 8.7	33.9 ± 11.6	33.1 ± 10.9	32.7 ± 12.3	30.7 ± 11.9	.892
Interval calving to conception (d)	145.3 ± 23.5	149.4 ± 24.4	151.6 ± 22.5	150.0 ± 32.0	157.3 ± 38.5	.465
% **Heat detection**	56.5 ± 7.0	52.7 ± 8.9	53.1 ± 9.0	51.4 ± 9.2*	46.7 ± 8.5**	.000
Mean fertility (%)	32.7 ± 6.4	34.3 ± 8.4	34.7 ± 9.2	35.0 ± 9.7	35.6 ± 9.9	.575
Culling rate (%)	24.7 ± 9.6	21.4 ± 16.2	23.9 ± 9.3	25.3 ± 10.8	20.3 ± 11.7	.337
Productivity						
L/cow/day	34.4 ± 3.8	33.7 ± 5.6	31.2 ± 5.1**	30.5 ± 4.0**	27.4 ± 2.3**	.000
L/cow/day normalised 4% fat/3.3% protein	35.3 ± 4.3	34.9 ± 5.7	32.8 ± 5.6	31.1 ± 4.3**	28.1 ± 3.6**	.000
Somatic cells ($\times 10^3$ cells/mL)	217.1 ± 62.5	264.7 ± 119.3	225.2 ± 81.1	264.2 ± 110.9	244.9 ± 90.7	.114
% Fat	3.8 ± 0.8	3.8 ± 0.6	3.9 ± 0.5	3.7 ± 0.3	3.6 ± 0.9	.556
% Protein	3.3 ± 0.1	3.3 ± 0.1	3.3 ± 0.1	3.3 ± 0.1	3.3 ± 0.2	.997

*$p < .05$ and **$p < .01$: for comparison with top-performing farms.

Discussion

The results of this study indicated a difference of 33 points, out of a possible 58, between the top-performing farm (scored 6 points) and the poorest-performing farm (scored 39 points). However, the distance between the two groups, top-performing (score: 6–20) and poorest-performing farms (score: 30–39) was shorter, which made it difficult to identify differences between the middle groups. This was the reason why facility-based parameters were only compared between the top-performing and the poorest-performing farms.

Hygiene

The proportions of cows with hygiene score >2 for legs, udder and flanks in all groups of farms included in the present study (Table 4) were higher than reported by Cook and Reinemann (2007) both for the 25% top-performing farms (47%, 11%, and 8% for legs, udder and flanks, respectively) and for the average-performing farms (59%, 19%, and 15%, for legs, udder and flanks, respectively). Although hygiene scores were far from optimal in any of the groups of farms in the present study, there were significant differences between top-performing farms and those in groups 3, 4 and 5. This was probably related to the better quality of bedding materials and bedding maintenance, and with the better cleaning practices used on top-performing farms.

Clean resting areas and clean alleys contribute to cow cleanliness (Cook and Reinemann 2007) and lower incidence of hoof disease because humidity and dirtiness cause soft hoofs that are more likely to become damaged and infected (Mülling et al. 2006; Lagger 2007). A high incidence of lameness will in turn contribute to poor bedding and cow hygiene, as lame cows tend to lie down more time than healthy ones (Ito et al. 2010).

Poor cow hygiene is known to be associated with a high incidence of mammary infections as manure and bedding materials are the main sources of *E. coli* and environmental *Streptococcus* (*S. uberis, S. dysgalactiae, Enterococcus spp*; Cook and Reinemann 2007). However, there were no differences in somatic cell counts between the groups of farms included in the present study, probably because there were high percentages of dirty cows in all farm groups. In farms with outdoor run, there were more cows with dirty legs and udder, however, somatic cell counts were lower than in indoor farms. Although there is not an obvious explanation for this, dirtiness of cows with outside access might be due to soil and mud more than to manure, that is considered the main contaminating source.

Table 5. Proportions (expressed as percentages) of the top-performing and poorest-performing farms that met the objectives established for the facility-based measures evaluated.

Area	Parameter	Top-performing farms (n = 61) %	Poorest-performing farms (n = 28) %	p Value
Resting	Stocking density	72.1	57.1	.124
	Quarantine pen	23.0	10.7	.141
	Calving pen	**77.0**	46.4	.005
	Dry bedding	**90.2**	42.9	.000
	Level bed surface	**88.5**	57.1	.001
	Bedding maintenance	**95.1**	53.6	.000
	Bedding materials	**67.2**	28.6	.001
	Calcium carbonate	**70.5**	35.7	.002
	Stall width	**50.8**	14.3	.001
	Brisket broad distance from curb	29.5	21.4	.299
	Brisket broad height	26.2	46.4	.051
	Total stall length	9.8	7.1	.512
	Neck rail distance from curb	8.2	14.3	.297
	Neck rail height	37.7	28.6	.276
	Curb height	24.6	10.7	.107
Alley	Width crossovers	9.8	25.0	.063
	Width fed alley	**62.3**	7.1	.000
	Width free stall alley	**70.5**	17.9	.000
	Striped surface	**91.8**	21.4	.000
	Rubber floor	8.2	0.0	.143
	Blind alleys	**60.7**	25.0	.002
	Slipping floor	**95.1**	28.6	.000
	Slatted floor	**95.1**	25.0	.000
	Slurry pit under barn	**100.0**	53.6	.000
	Manure accumulation in the alley	**98.4**	67.9	.000
Cows	Presence of ectoparasites	78.7	64.3	.120
	Presence of flies	95.1	89.3	.278
	Presence of cows with horns	**44.3**	21.4	.031
	Presence of cows with tail	**93.4**	78.6	.048
	Flight zone	95.1	82.1	.061
	Stress for a scarce commodity	**95.1**	57.1	.000
	Cow crowding	**91.8**	71.4	.016
	Preventive claw trimming	**73.8**	46.4	.012
	Footbaths	**93.4**	57.1	.000
	Welfare objects	52.5	**78.6**	.016
Feeding	**Feeding table smooth and clean**	**45.9**	3.6	.000
	Cleaning feeding table	100.0	96.4	.315
	Continuous feed availability	100.0	96.4	.315
	Feeding table with shadow	**73.8**	50.0	.026
	Feeding table covered	100.0	92.9	.097
	Height from feeding table to cow foot	**50.8**	28.6	.040
	Water analysis	93.4	92.9	.618
	Cleaning water troughs	**50.8**	7.1	.000
	Water troughs design	**78.7**	14.3	.000
	Cm. of water troughs /cow	73.8	57.1	.094
	Water troughs at the exit of the parlour	**75.6**	32.1	.003
	Width headlocks	**82.0**	60.7	.031
Ventilation	Orientation	31.1	35.7	.423
	Air movement on the face of the cow	91.8	75.0	.038
	Condensation	**98.4**	50.0	.000
	Ceiling insulation	**21.3**	0.0	.005
	Sidewall height	**91.8**	46.4	.000
	Lateral opening	**95.1**	39.3	.000
	Cow curtain	**41.0**	0.0	.000
	Height to ridge	**98.4**	71.4	.000
	Forced ventilation systems	**31.1**	7.1	.010
	Humidity	**100.0**	67.9	.000
	Spider webs	**96.7**	35.7	.000

Parameters and numbers shown in bold type indicate significant differences between the two farm groups.

Lameness scoring

According to Juaristi et al. (2004), dairy farmers should aim for lameness scores to be distributed as follows: >75% of cows with normal gait, <15% with slight lameness, <9% of cows moderately lame, <0.5% of cows scored lame and <0.5% severely lame. None of the five groups of farms considered in this study complied with this objective (Table 4), indicating that lameness may be somewhat neglected by farmers in the region. Nonetheless, the proportion of cows scoring 1, 2 and 3 differed significantly between the top-performing group and groups 4 and 5. Such

differences may be related to the use of suitable material for bedding and floors, rigorous cleaning practices, adequate dimensions of alleys and preventive measures against hoof disease, all which were observed on most top-performing farms (Table 5).

For optimal hoof health, cows should be lying down for around 12 h daily to minimise hoof stress and the incidence of lameness (Mülling et al. 2006; Erina et al. 2008). Adequate stall dimensions (Mülling et al. 2006; Espejo and Endres 2007) and comfortable, clean and dry bedding (Mülling et al. 2006; Fregonesi, Veira, et al. 2007) are essential factors in this regard. Ninety percent of the farms included in this study showed some deficiencies in relation to stall dimensions, although the beds were cleaner and bedding materials of higher quality in the top-performing group of farms than in group 5. Moreover, although the difference was not significant, 25% of the top-performing farms and 40% of the farms in group 5 provided less than 1 stall per cow. Higher than 100% stocking density is known to be associated to reduced resting time and increased idle standing in alleys (Fregonesi, Tucker, et al. 2007; Hill et al. 2009; Krawczel et al. 2010), which will favour lameness. Lame cows and heifers are the most affected by high stocking density as they are not competitive.

Another important aspect related to hoof disease is the type of floor and the cleanliness and dimensions of alleys (Mülling et al. 2006). In free stall farms, cows walk long distances (up to 1 Km a day) to gain access to feeding tables, water troughs and the milking parlour (Fjeldaas et al. 2011). The type of floor, as well as the state of conservation and hygiene will determine the comfort provided, the abrasive capacity, level of humidity and degree of contamination. Seventy-four percent of the farms included in the present study had textured (striped or grooved) concrete floors, and only a few of the top-performing farms had rubber floors, which have been reported to be best for hoof health (Telezhenko et al. 2007), although it has also been suggested (Kremer et al. 2007) that the scarce abrasive effect of rubber may favour some claw diseases if claws are not cut frequently. Concrete floors tend to be more slippery (Mülling et al. 2006) unless textured, in which case they provide a rough, abrasive surface. However, the abrasive capacity of concrete floors should not be so high as to cause excessive wear of hoofs nor as low as to favour abnormal growth of claws and slipping (Mülling et al. 2006). Slatted floors tend to be less abrasive and slippier than compact floors (Telezhenko and Bergsten 2005).

The slats can also become misaligned and difficult for cows to walk on.

Adequate cleaning of alleys is essential for hoof hygiene and to prevent cows slipping. Alley dimensions should be such that two cows walking in the opposite direction should not have to touch each other. Narrow or blind alleys, when existing dominant cows, may favour stressful situations and sudden avoidance movements causing hoof injuries (Mülling et al. 2006).

Most of the top-performing farms in the present study applied measures to prevent hoof diseases. These included regular claw trimming and installation of footbaths, which may partly account for group 1 having lower (i.e. better) lameness scores (Lagger 2007) than groups 4 and 5, in which such preventive measures were less frequently applied.

Farms with outdoor run were more frequent in groups 4 and 5 than in the other farm groups (Table 3). Having an external area for cows to walk around helps to maintain hoof health, as walking on meadows or yards would prevent excessive wear or growth of claws caused by concrete floors, and the prolonged exposure of hoofs to humidity and manure typical of indoor farms. However, in the present study, in some of the farms with outdoor access, cows were allowed to go outside for short periods of time daily or only in good weather, or sometimes yards were not properly drained. So, these handicaps added to poor facilities and/or poor management would account for outdoor run-farms not having better lameness scores than indoor farms.

Lameness is known to decrease dry matter intake and body condition (Bach et al. 2007) and to reduce reproductive performance and milk production (Huxley 2013), leading to important economic losses. According to Liang et al. (2017), the mean cost associated with each lame cow on a dairy farm is around 160 € for primiparous and 300 € for multiparous cows, including production and fertility losses and treatment costs.

Reproduction and milk production

The heat detection rate and milk production were significantly higher in the top-performing group of farms than in groups 4 and 5. This finding may be associated with the higher incidence of lameness in groups 4 and 5. Lame cows feel pain and may move less than healthy cows, thus affecting dry matter intake and reducing the chance that heat symptoms will be detected. Lameness may therefore have a significant

impact on heat detection and milk production (Cha et al. 2010).

The difference in milk production between the top-performing and the poorest-performing farms was 7 L/cow present on farm/day. Differences in milk production may reflect differences in genetic and in feeding management. It is likely that larger farms with modern facilities and good management practices had also animals of higher genetic merit, but this could be highly variable among farms within groups, so in this study we cannot speculate about the influence of genetic on milk production. Although rations offered by the different farms were not evaluated, they probably did not differ too much since practically all farms recruited worked with a nutritionist. However, the feeding environment provided by top-performing farms was better than that in farms of group 5. Clean and dry feeding tables, continuous feed availability, and adequate space of manger and water trough per cow will favour optimal dry matter intake (Grant et al. 2010). Feeding tables that are unsuitable or of difficult access may lead to insufficient or imbalanced intake of food and water by cows, being the lame cows and heifers the most harmed as they cannot be competitive. Although not evaluated in this study, it is very likely that management practices known to increase dry matter intake and milk production, such as feeding for feed refusals or feed push up (Bach et al. 2008), were more frequent in the top-performing group of farms than in the poorest-performing group.

Other facility-related factors such as the level of comfort of stalls may also affect milk production, as cows may rest for shorter periods in uncomfortable stalls (Espejo and Endres 2007; Fregonesi, Veira, et al. 2007). During rest periods, blood flow to the mammary gland increases by 21.6%, which enhances milk production (Erina et al. 2008). As already mentioned, stocking density >100% is associated to shortened resting times and reduced milk production (Hill et al. 2009).

Inadequate ventilation systems may be ineffective in counteracting heat stress in summer, another factor known to affect milk production (Bernabucci et al. 2014; De Rensis et al. 2015). Heat stress is known to reduce the feeding, resting and rumination behaviours of cows, and thus, feeding intake and milk production (Tapki and Sahin 2006). Facilities designed to allow good ventilation and avoid humidity and condensation were present in most of the top-performing farms, but they were less frequent in the poorest-performing farms.

Conclusions

The present study showed that comfort and quality of facilities differed significantly among the dairy farms recruited for the study, but some defects were common to all farm groups. Most farms, either in the top-performing or in the other groups, had stalls with insufficient dimensions, and an important proportion of farms (25–40%) provided less than one stall per cow. Proportions of lame cows were high in all groups of farms, varying between 33% and 46%. Inadequate facilities and poor facility maintenance were associated with significantly higher incidence of lameness and with significantly poorer hygiene in legs and udder, with lower heat detection rate and lower milk production. The observed differences in productivity among farm groups, although not entirely due to facility-related aspects, should serve as incentive for farmers to undertake reforms and/or changes in management practices so that cow comfort could be significantly improved. On the other hand, lameness and cow hygiene measures can be used as rapid indicators of unsuitable facilities.

Ethical statement

The present study was carried out in accordance with European Union legislation (2010/63/EU) as transposed in Spanish law (RD53/2013).

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Abeni F, Bertoni G. 2009. Main causes of poor welfare in intensively reared dairy cows. Ital J Anim Sci. 8 (sup1): 45–66.

Anderson N. 2007. Free stall dimensions. INFO Sheet. Ontario: Ministry of Agriculture, Food and Rural Affairs; p. 15.

Bach A, Dinares M, Devant M, Carre X. 2007. Associations between lameness and production, feeding and milking

attendance of Holstein cows milked with an automatic milking system. J Dairy Res. 74(1):40–46.

Bach A, Valls N, Solans A, Torrent T. 2008. Associations between non-dietary factors and dairy herd performance. J Dairy Sci. 91(8):3259–3267.

Bernabucci U, Biffani S, Buggiotti L, Vitali A, Lacetera N, Nardone A. 2014. The effects of heat stress in Italian Holstein dairy cattle. J Dairy Sci. 97(1):471–486.

Cha E, Hertl JA, Bar D, Gröhn YT. 2010. The cost of different types of lameness in dairy cows calculated by dynamic programming. Prev Vet Med. 97(1):1–8.

Cook NB. 2002. The influence of barn design on dairy cow hygiene, lameness and udder health. Proceedings of the 35th Annual Convention of American Association Bovine Practitioners, September 26-28; Madison (WI): Frontier Printers Inc; p. 97–103.

Cook NB, Nordlund KV. 2005. An update on dairy cow free-stall design. Bov Pract. 39:29–36.

Cook NB, Reinemann DJ. 2007. A tool box for assessing cow, udder and teat hygiene. Proceedings of the 46th Annual Meeting of the National Mastitis Council, 21-24 January. San Antonio (TX): National Mastitis Council; [accessed 2017 May 26]. http://www.uwex.edu/uwmril/pdf/MilkMachine/Cleaning/07%20NMC%20Hygiene%20Toolbox%5B1%5D.pdf

Cook NB, Hess JP, Foy MR, Bennett TB, Brotzman RL. 2016. Management characteristics, lameness, and body injuries of dairy cattle housed in high-performance dairy herds in Wisconsin. J Dairy Sci. 99(7):5879–5891.

Córdoba JD, Castillo MP, Ormeño N, Acosta G, Tadich N. 2012. Descripción de los cubículos utilizados en granjas lecheras en el sur de Chile y su relación con el confort de las vacas. Arch Med Vet. 44(1):75–80.

D'Emilio A, Porto SM, Cascone G, Bella M, Gulino M. 2017. Mitigating heat stress of dairy cows bred in a free-stall barn by sprinkler systems coupled with forced ventilation. J Agric Eng. 48(4):190–195.

De Rensis F, Garcia-Ispierto I, López-Gatius F. 2015. Seasonal heat stress: clinical implications and hormone treatments for the fertility of dairy cows. Theriogenology. 84(5):659–666.

Drissler M, Gaworski M, Tucker CB, Weary DM. 2005. Free-stall maintenance: effects on lying behavior of dairy cattle. J Dairy Sci. 88(7):2381–2387.

Erina S, Stanciu G, Cziszter LT, Acatincăi S, Tripon I, Baul S, Gavojdian D. 2008. Study on the resting behavior in Romanian Black and White primiparous cows. Sci Pap Anim Sci Biotechnol. 41:398–402.

Espejo LA, Endres MI. 2007. Herd-level risk factors for lameness in high-producing Holstein cows housed in freestall barns. J Dairy Sci. 90(1):306–314.

European Commission. 2005. Attitudes of consumers towards the welfare of farmed animals. Special Eurobarometer. Brussels: European Commission 229; p. 14–17.

Ferguson JD, Galligan DT, Thomsen N. 1994. Principal descriptors of body condition score in Holstein cows. J Dairy Sci. 77(9):2695–2703.

Fjeldaas T, Sogstad ÅM, Østerås O. 2011. Locomotion and claw disorders in Norwegian dairy cows housed in free-stalls with slatted concrete, solid concrete or solid rubber flooring in the alleys. J Dairy Sci. 94(3):1243–1255.

Fraser D, Duncan IJ, Edwards SA, Grandin T, Gregory NG, Guyonnet V, Hemsworth PH, Huertas SM, Huzzey JM, Mellor DJ, Mench JA, et al. 2013. General principles for the welfare of animals in production systems: the underlying science and its application. Vet J. 198(1):19–27.

Fregonesi JA, Tucker CB, Weary DM. 2007. Overstocking reduces lying time in dairy cows. J Dairy Sci. 90(7):3349–3354.

Fregonesi JA, Veira DM, Von Keyserlingk MAG, Weary DM. 2007. Effects of bedding quality on lying behavior of dairy cows. J Dairy Sci. 90(12):5468–5472.

Grant RJ, Tylutki T, Krawczel P. 2010. Modeling the influence of management on dry matter intake in dairy cattle. J Dairy Sci. 84(E-suppl.1):468.

Grant R, Miner WH. 2015. Economic benefits of improved cow comfort. St. Charles (MO): Novus International.

Hemsworth PH, Coleman GJ. 2011. Farm animal welfare: assessment, issues and implications. In: Paul H. Hemsworth and Grahame J. Coleman (Eds.), Human-livestock interactions: The stockperson and the productivity and welfare of intensively farmed animals. 2nd ed. Oxford shire, UK: CAB International; p. 21–46.

Hill CT, Krawczel PD, Dann HM, Ballard CS, Hovey RC, Falls WA, Grant RJ. 2009. Effect of stocking density on the short-term behavioural responses of dairy cows. Appl Anim Behav Sci. 117(3–4):144–149.

Hulsen J. 2007. Cow signals (el lenguaje de las vacas). 1st ed. Madrid, Spain: Ediciones Técnicas Reunidas SL; p 96.

Huxley JN. 2013. Impact of lameness and claw lesions in cows on health and production. Livest Sci. 156(1–3):64–70.

Ito K, Von Keyserlingk MAG, LeBlanc SJ, Weary DM. 2010. Lying behavior as an indicator of lameness in dairy cows. J Dairy Sci. 93(8):3553–3560.

Juaristi JL, Bach A, Rodríguez P. 2004. Cuadernos de campo: cow comfort. Zaragoza, España: Laboratorios Merial; p. 221.

Krawczel PD, Klaiber LB, Butzler RE, Klaiber LM, Mooney CS, Dann HM, Grant RJ. 2010. Short-term overcrowding affects the lying and social behaviour of lactating Holstein dairy cows. J Dairy Sci. 93(E-suppl.1):789.

Kremer PV, Nueske S, Scholz AM, Foerster M. 2007. Comparison of claw health and milk yield in dairy cows on elastic or concrete flooring. J Dairy Sci. 90(10):4603–4611.

Lagger J. 2007. Estrategias de bienestar animal para prevenir lesiones podales en vacas lecheras. Veterinaria Argentina. 24:588–602.

Laurence M. 2014. 13 Biosecurity and beef cattle health, husbandry and welfare. In: David Cottle and Lewis Kahn (Eds.), Beef Cattle Production and Trade. Collingwood, Australia: CSIRO Publishing; p. 251–289.

Liang D, Arnold LM, Stowe CJ, Harmon RJ, Bewley JM. 2017. Estimating US dairy clinical disease costs with a stochastic simulation model. J Dairy Sci. 100(2):1472–1486.

Mülling CK, Green L, Barker Z, Scaife J, Amory J, Speijers M. 2006. Risk factors associated with foot lameness in dairy cattle and a suggested approach for lameness reduction. Proceedings of the 24th World Buiatric Congress, 15-19 October. World Association for Buiatrics: Nice, France; p. 531–543.

PennState Extension. 2017. Body Condition Scoring as a Tool for Dairy Herd Management: dairy. [accessed 2017 May 25]. http://extension.psu.edu/animals/dairy/nutrition/nutrition-and-feeding/body-condition-scoring/body-condition-scoring-as-a-tool-for-dairy-herd-management.

Pereira JM, Barrasa M, González JJ. 2003. Parametrización dimensional de alojamientos de ganado vacuno lechero. Proceedings of the VII Congreso Internacional de Ingeniería de Proyectos, October 8-10, 2003, Pamplona, Spain: Universidad Pública de Navarra; p. 1431–1440.

Sprecher DJ, Hostetler DE, Kaneene JB. 1997. A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. Theriogenology. 47(6):1179–1187.

Tapki I, Sahin A. 2006. Comparison of the thermoregulatory behaviours of low and high producing dairy cows in a hot environment. Appl Anim Behav Sci. 99:1–11.

Telezhenko E, Bergsten C. 2005. Influence of floor type on the locomotion of dairy cows. Appl Anim Behav Sci. 93(3–4):183–197.

Telezhenko E, Lidfors L, Bergsten C. 2007. Dairy cow preferences for soft or hard flooring when standing or walking. J Dairy Sci. 90(8):3716–3724.

Trillo Y, Quintela LA, Barrio M, Becerra JJ, Vigo M, Peña AI, Herradón PG. 2017. Description of measurable parameters related to animal welfare in free-stall and tie-stall farms in Northwestern Spain. Arch Zootec. 66(254): 203–213.

Tucker CB, Weary DM. 2001. Stall design: enhancing cow comfort. Adv Dairy Technol. 13:155–168.

Vasseur E, Borderas F, Cue RI, Lefebvre D, Pellerin D, Rushen J, Wade KM, de Passillé AM. 2010. A survey of dairy calf management practices in Canada that affect animal welfare. J Dairy Sci. 93(3):1307–1316.