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Assessment of welfare indicators in dairy farms offering pasture at differing levels

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In terms of animal welfare, farming systems of dairy cows are perceived positively by consumers when compared to pigs or poultry. A main reason is that the majority of consumers associate dairy farming with pasture, which in turn they relate with benefits for animal health and welfare. However, holistic scientific assessments of the effects of pasturing on animal welfare are rare. Hence, it was the aim to study the animal welfare level in 61 German loose housing dairy farms by using the measures of the Welfare Quality® protocol for dairy cattle (WQP). Data were collected twice per farm at the end of the pasture season (July to October) and approximately 6 months later at the end of the barn season (December to April). Farms were classified based on the duration cows had access to pasture per day during the pasture season: group 1 (G1) > 10 h; group 2 (G2) 6 to 10 h; group 3 (G3) < 6 h and group 4 (G4) without pasture access. The average herd size was 129 Holstein-Friesian or Red-Holstein cows (range 58 to 527). In addition to WQP data, performance data were gathered from routine herd data recordings. The indicators were aggregated to criteria applying the scoring system of the WQP. G4 received lower scores at the first than at the second visit for the criterion absence of hunger, *while there were no differences between visits in the other groups (*$P = 0.58$ *– group × farm visit effect). All pasturing groups were scored better at the end of the pasture season than G4 for the criterion* comfort around resting *(*$P < 0.01$*). Compared with G1 for both farm visits and G2 for the end of the barn season, G4 reached inferior scores for the criterion* absence of injuries, *including indicators such as* hairless patches, lesions, *and* swellings *and* lameness. *At both assessments G2 was scored higher than the other groups for the criterion* absence of diseases *(*$P = 0.04$*). In conclusion, pasture access had positive effects only on selected welfare indicators, however, these effects were not maintained throughout the barn season.*

Keywords: dairy cows, pasture access, animal-based measures, animal health, welfare indicators

Implications

The positive perception of dairy farming by consumers and many other stakeholders is mainly due to their association of the system with access to pasture. This in turn, is related to benefits for animal health and welfare. Despite the positive effects pasture access during summer had on certain welfare indicators, results indicate that pasturing management has to be optimized in order to enhance its benefits. The fact, that benefits of pasture access were not maintained throughout the barn season also emphasizes that optimization of housing systems has to be continued to improve the welfare status of dairy cows.

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Introduction

In Germany, only 15% to 30% of the dairy cows have access to pasture during summer months, which is much lower compared to neighboring countries such as Austria (68%) or Switzerland (80%) (Weiß, 2014). Averaged over Europe, the proportion of dairy cows with pasture access declined from 52% in 2008 to 35% in 2012 (Reijs *et al.*, 2013). There are several reasons for the decrease of pasture access for dairy cows in Germany and many other European countries (Van den Pol-Van Dasselar, 2015). Driven by structural changes, dairy herd sizes continue to increase, which in turn, complicates the provision of adequate pasture areas near the milking parlor (Burow *et al.*, 2013b). In addition, the substitution of concentrates with grassland is not attractive for many farmers from an economic point of view; grassland productivity is often underestimated, practical experience lacking and advisory services not focusing on the opportunities of pasture feeding (Leisen, 2014). Indoor housing of dairy cows allows the control of environmental factors including an adjusted feed supply. However, it is often accompanied with an increased prevalence of several diseases (i.e. mastitis, lameness) and the inability of the animals to perform natural behavior (i.e. locomotion, lying down and standing up motions, resting comfort) and to synchronize it (Phillips *et al.*, 2013). In the current discussion about animal welfare in livestock farming, dairy cows are perceived positively when compared with other livestock species (Weinrich *et al.*, 2014). This can be explained mainly by the fact, that the majority of consumers associate dairy farming with access to pasture, which in turn is related to benefits for animal health and welfare (Weiß, 2014). In comparison to indoor-housed cows, animals with access to pasture proved to be superior in terms of hoof health, locomotion ability (Hernandez-Mendo *et al.*, 2007) and other animal-based health parameters such as prevalence of mastitis (Washburn *et al.*, 2002), mortality and integument alterations (Burow *et al.*, 2013a). However, comparative overall on-farm assessments of the effects of pasture access on animal welfare compiled in the barn as well as on the pasture are very limited. For example, De Graaf *et al.* (2017) applied the Welfare Quality® assessment protocol (WQP; Welfare Quality®, 2012) in ten dairy farms with pasturing at the beginning and end of the barn season. Findings indicated a carry-over of positive effects of access to pasture to the beginning of the barn season. The WQP has been developed as an overall on-farm assessment tool including mainly animal-based measures, beside some indicators related to management and farm resources. Hence, it was the aim of the study to assess the welfare level applying the measures of the WQP in zero-grazing dairy farms and farms providing pasture access at differing levels.

Material and methods

Farm selection

Data were collected on 61 conventional cubicle loose housing dairy farms located in Lower Saxony, Germany. Farms were selected with the help of the chamber of agriculture in Lower Saxony. Selection criteria were a minimum herd size of 60 Holstein-Friesian or Red-Holstein dairy cows, cubicle housing and participation at routine herd data recording. A total of 82 farms in Lower Saxony that fulfilled these requirements were contacted by the chamber of agriculture and asked for their willingness to participate in this study, which was part of the joint research project ‘Systemanalyse Milch’. Finally, 63 farms agreed to participate. After the first farm visit, two farms decided not to continue and data of these farms were not included in the further analysis. The remaining 61 farms were classified according to their pasture access per day: group 1 (G1) > 10 h, group 2 (G2) 6 to 10 h, group 3 (G3) < 6 h and group 4 (G4) without access to pasture. Pasture access in G1 to G3 was provided for at least 120 days per year. In 12 of the farms, cows had access to a concreted outdoor area. Cubicles were either straw-bedded (27 farms) or equipped with rubber mats (34 farms). The average number of cows per farm in the final set of farms was 141 (SD: 83, minimum: 55, maximum: 585). An equal distribution of herd sizes between the groups was intended during the selection process to reduce confounding effects of herd size. Mean energy-corrected milk (ECM) yield was 9 430 kg (SD: 892, minimum: 6 950, maximum: 11 460). Table 1 presents detailed characteristics of the farms.

Data collection

Farms were assessed twice between July 2014 and April 2015, using the 32 animal-, management- and resource-

Table 1 *Characteristics (herd size, energy-corrected milk yield (ECM), protein and fat percentage, cubicle design, animal-to-feeding place ratio and animal-to-cubicle ratio) of 61 dairy cattle farms with >10 h (G1,* n = 15 *farms), 6 to 10 h (G2,* n = 15 *farms), <6 h of pasture access/day (G3,* n = 15 *farms) or without pasture access (G4,* n = 16 *farms) (LS means ± standard error, minimum to maximum in brackets)*

	Group			
Items	G1	G2	G3	G4
Herd size	104 ± 14.47 (55 to 227)	111 ± 14.47 (63 to 243)	126 ± 14.47 (65 to 300)	181 ± 14.01$^{n.s.}$ (63 to 585)
ECM (kg)	9175^{a} ± 165 (7220 to 10 758)	9013^{a} ± 148 (6950 to 10 608)	9650^{b} ± 152 (7921 to 10 911)	9857 ^{b} ± 157 (7778 to 11 460)
Protein (%)	3.35 ± 0.03 (3.30 to 3.60)	3.32 ± 0.03 (3.21 to 3.49)	3.47 ± 0.03 (3.26 to 3.54)	3.33 ± 0.03$^{n.s.}$ (3.17 to 3.50)
Fat (%)	3.96 ± 0.05 (3.80 to 4.30)	4.01 ± 0.04 (3.86 to 4.44)	3.95 ± 0.04 (3.93 to 4.58)	3.96 ± 0.04$^{n.s.}$ (3.66 to 4.31)
Cubicle design (no. of farms)				
Deep-bedded*	4	6	6	11
Rubber mats	11	9	9	5
Animal-to-feeding place ratio	1.22 (0.89 to 1.80)	1.29 (0.89 to 1.71)	1.27 (0.82 to 2.40)	1.06$^{n.s.}$ (0.80 to 1.56)
Animal-to-cubicle ratio	1.05 (0.89 to 1.19)	1.14 (1.00 to 1.71)	1.05 (1.00 to 1.20)	1.04$^{n.s}$ (0.80 to 1.27).

[a,b]Values within a row with different superscripts differ significantly at $P < 0.05$ (Tukey–Kramer test).
[n.s.]Values within a row do not differ at $P < 0.05$ (Tukey–Kramer test).
*Distribution of cubicle flooring differs between groups $P < 0.05$ (Fisher's exact test).

based indicators as described in the WQP. The initial assessment was carried out from July to October 2014, when the cows in G1 to G3 had access to pasture. Approximately 6 months later (December 2014 to April 2015), the second assessment took place during the barn confinement season. The farm visits were randomized over the four pasture groups. One farm was assessed per day. All assessments were conducted by the first author. Before the study, an assessor, who previously had been trained by members of the WQP group, trained the first author for 5 days on dairy farms on the correct application of the WQP. Before the assessments for this study started, inter-observer reliability for any of the WQP measures between the trainer and the trained first author exceeded a κ coefficient of 0.80. Detailed definitions of all measures are given in Supplementary Table S1.

Timeline of Welfare Quality® assessments

Each assessment started within 1 h after morning milking. After the cows left the milking parlor feed was provided at the feed bunk. The order of measures was carried out as stated in the WQP. The first assessment was the test of *human avoidance distance*. Cows were selected for sampling when animals were indoors and locked in the feeding rack and by choosing every *n*th animal in the row. Details on the sampling size, which depended on the herd size, are provided in Supplementary Table S1. After the *human avoidance distance* test, cows were freed from the feeding rack in all farms and had access to pasture in groups G1 to G3. *Qualitative Behavioral Assessment (QBA)* was carried out 30 to 60 min later. QBA was then followed by the observations of social and lying behavior. For groups with pasture access, *QBA*, *social* and *lying behavior* was conducted in summer months on pasture, whenever weather conditions allowed, and indoors in winter. In total, 31 of the 45 farms with pasture access were assessed on the pasture on the first farm visit in summer (G1: 15 farms, G2: 9 farms, G3: 7 farms). Clinical scoring of animal-based indicators, which are described in detail below, was performed when the animals were in the barn or yard before the afternoon milking. Furthermore, the farmer was interviewed to collect data on farm resources and management routines. In addition to the WQP procedures, data on cubicle design, animal-to-feeding place ratio and animal-to-cubicle ratio were recorded.

Assessment of animal-based indicators

The animal-based measures consisted of clinical indicators and behavioral measures, which were assessed applying the *QBA*, a *human avoidance distance* test and observations of the social and lying behavior. Depending on the total herd size of the respective farm, the clinical scoring and *human avoidance distance* test were conducted on samples ranging between 34 and 82 cows (details in Supplementary Table S1). In total, 3 128 individual cows were scored for *lameness*, *diseases, skin lesions, cleanliness* and *human avoidance distance* during the first, and 3 226 during the second farm visit.

To measure the *human avoidance distance*, the observer approached the animal to be tested at the feed bunk from an initial distance of two meters. The observer started with an extended hand and approached the animal with a speed of one step per second. If the cow showed any sign of withdrawal, the *avoidance distance* was estimated between the hand and muzzle of the cow at the moment of the first sign of retraction. If the muzzle could not be touched, an *avoidance distance* of 10 to 200 cm was estimated in 10 cm intervals. For the *QBA*, the herd was divided into equally distributed segments (up to eight observation points) and was observed for a total of 20 min. The following adjectives were included in the *QBA* and assessed by a visual analogue scale: active, relaxed, fearful, agitated, calm, content, indifferent, frustrated, friendly, bored, playful, positively occupied, lively, inquisitive, irritable, uneasy, sociable, apathetic, happy and distressed. During a herd observation of 2 h, the *number of coughs* was recorded as well as *lying-down movements* and *social behaviors* assessed. For the lying-down behavior, the number of animals, which lay down, the number that were lying in their cubicles, but with their hindquarters on the edge of the cubicle, as well as the number of animals *lying outside of the lying area* were counted. In addition, the *time needed to lay down* and *collisions with the cubicle* were recorded. At least six lying-down movements were assessed per farm. The *social behavior* included the parameters fighting, chasing, displacing or head butting. For this assessment, the herd was divided into groups of maximum 25 animals. Assessment duration for each group was equal and summed up to 2 h. In large herds with more than 150 animals representative segments covering all areas of the barn were selected. This selection was necessary on one farm of G1, on three farms of G2 and G3 and on seven farms of G4.

The procedure of clinical scoring of the animals is provided by the WQP. For ease of assessment, only one side of the animal was examined. Measures included *skin alterations, cleanliness of legs, udders, upper legs* and *flanks* and indications of diseases like *nasal, ocular* or *vulva discharges*, *increased respiratory rate* and *diarrhea*. For *integument alterations*, the number of *hairless patches, lesions* and *swellings* was noted. These indicators were categorized as a binary variable (absent or present). A three-point scale was used for body condition score (0 = regular, 1 = very lean, 2 = very fat) and lameness (0 = not lame, 1 = slightly lame, 2 = severely lame).

Assessment of resource- and management-based indicators

Through a direct farmer interview, data on management routines (e.g. *dehorning practices* and the *use of analgetics* or *anesthetics*) were collected. Milk production data (i.e. yield, fat and protein percentage) were gathered from routine herd data recording. Other resource- and management-based indicators including the length (in cm), quantity, functionality (water flow) and cleanliness of water troughs were assessed during the farm visit by the assessor.

Statistical analysis
The data for the WQP were calculated for each farm using an excel sheet provided by INRA. The single indicators were aggregated to criteria applying the WQP scoring system. The following linear mixed effects model was used to analyze the criteria and indicators:

$$Y_{ijkl} = \mu + A_i + B_j + A_i \times B_j + A_i \times C_k + (C_k)A_i + D_l + e_{ijklm}$$

where Y_{ijkl} is the observed value of criteria/indicator, μ the overall average of sample, A_i the fixed effect of group i (G1, G2, G3, G4), B_j the fixed effect of farm visit *j* (1, 2), $A_i \times B_j$ the interaction between group *i* and farm visit *j*, $A_i \times C_k$ the interaction between group *i* and cubicle flooring *k* (deep-bedded, rubber mat), $(C_k)A_i$ the fixed effect of cubicle flooring *k* nested into group *i*, D_l the herd size as covariate and e_{ijklm} the residual error. Farm was included in the model as random effect. Except for the indicator *ocular discharge*, the interaction between group and cubicle flooring did not display an effect and was withdrawn from the final model. Data on milk production were analyzed with the same model including group as the only fixed effect. All statistical analyses were computed with SAS, version 9.3 (Statistical Analysis Systems, Cary, NC, USA) using the GLIMMIX procedure. Farm was defined as the statistical unit. Results were considered statistically significant at a probability of $\alpha < 0.05$. Differences between groups were assessed by applying the Tukey–Kramer test for unbalanced data. In order to approximate normal distribution, data of the criteria *absence of hunger* and *absence of injuries* were log-, of the indicators *very lean cows* and *seriously lame cows* were square-root- and of the criterion *comfort around resting* and the indicator *no integument alterations* were arcsin-transformed before analysis. For ease of interpretation, these transformed data are presented as back-transformed least square means in the tables and results section. As back-transformation of standard errors is not possible, they are not presented. For parameters that did not approximate normal distribution even after transformation (criteria: *absence of thirst*, *emotional state*, *absence of pain*, *social behavior*, indicators: *cows with ocular discharge*, *cows lying outside lying area*, *cows with diarrhea*, *duration of lying down movement*, *downer cows*, *collisions with cubicles*, *cows with severe alterations*, *cows with mastitis*, *dirty cows (leg, udder, flank)*, *cows avoidance distance* >100 cm), either Poisson or binomial distribution within the GLIMMIX procedure were applied to calculate *P*-values.

Groups were compared for cubicle flooring using the Fisher's exact test (FREQ procedure). For herd size, milk yield and composition the Tukey–Kramer post-hoc test (GLIMMIX procedure) was applied considering farm as random effect.

Results

Farm characteristics
As presented in Table 1, herd sizes in G4 averaged 181 cows while those in the pasture groups averaged 104 to 126 cows. The variation within groups was large. Groups with more than 6 h pasture access (G1, G2) showed lower ECM than the groups G3 and G4 ($P < 0.01$). Protein content was not different between groups and averaged 3.35% to 3.40%. For fat content group averages varied between 3.98% and 4.12%. The distribution of deep-bedded and rubber mat-equipped cubicles differed between groups ($P < 0.01$, $\chi 2$ test); whereas those in farms with pasture access were predominantly equipped with rubber mats and those in farms without pasture were mainly deep-bedded. The animal-to-feeding place ratio was above 1.20 for all farms with pasturing and averaged 1.06 for G4-farms. Variations between groups for the animal-to-cubicle ratio were lower (1.04 to 1.14). Except for two farms with automatic milking systems, all other farms had a milking parlor.

Welfare criteria
For the criterion *absence of hunger* G4 received lower scores at the first compared with the second farm visit in winter, while there were no differences between visits in the other groups ($P = 0.58$ – group × farm visit effect, Table 2). Scores were lower for cubicles with rubber mats (41.43 ± 3.11) than in deep-bedded ones (49.66 ± 3.28, $P = 0.04$). The criterion *absence of thirst* did not differ between groups ($P = 0.09$) or farm visits ($P = 0.72$). An effect of group ($P < 0.01$), farm visit ($P = 0.02$) and its interaction ($P < 0.01$) was found for the criterion *comfort around resting*. In summer, G1 received a higher score than all other groups. While G1 scores were higher in summer, it was vice versa for G4. At the end of the barn season, the level was similar among G1 and G4 concerning this criterion. As there is still no measure for *thermal comfort* identified in the WQP and all studied farms reached the maximum points for *ease of movement*, given that only loose housing farms were studied, both criteria are not presented in Table 2. Groups with more intensive pasturing (G1 for both farm visits and G2 after the barn season) showed better results than G4 for the criterion *absence of injuries* ($P < 0.01$). In cubicles with rubber mats (40.24 ± 1.98) lower scores regarding this criterion were found than in deep-bedded cubicles (49.72 ± 2.09, $P < 0.01$).

Absence of diseases showed differences between the groups ($P = 0.04$) but not between visits ($P = 0.45$) nor an interaction between group and farm visit ($P = 0.26$). G2 showed higher scores than the other three groups at both assessments. As another important criterion, *absence of pain* was rated better in G1 and G2 than in G4 ($P = 0.02$ – group effect). Neither of the tested effects affected the criteria *social behavior* ($P = 0.76$ – group effect). Of all tested effects, *emotional state* (aggregation of QBA) was only affected by cubicle design with higher scores for deep-bedded than for cubicles with rubber mats ($P = 0.05$). Group affected *human–animal relationship* ($P = 0.05$) with highest scores in G4.

Welfare indicators

Table 3 presents results at the level of WQP indicators. The proportion of very lean animals was higher during summer compared with winter months over all groups ($P = 0.02$ – farm visit effect). Dirty water troughs were only observed during summer, whereas G1 were the worst with 20% of farms having dirty water troughs. Animals of all groups needed more *time to lay down* in winter than in summer months ($P < 0.01$ – farm visit effect). Except for G1, animals were less clean in summer than in winter ($P < 0.01$ – group × farm visit effect). When further differentiating into body parts, *dirty legs* occurred more frequently in summer than in winter months in all groups (84.76 ± 2.45 *v.* 31.61 ± 2.45, $P < 0.01$ – farm visit effect), while there were no differences for *dirty udders* (10.39 ± 1.23 *v.* 7.87 ± 1.23, $P = 0.13$). G3 and G4 showed less *dirty legs* in the winter months than G1 and G2 ($P < 0.01$ – group × farm visit effect). The indicator *dirty flanks* showed a reduced prevalence in summer compared to winter months (34.39 ± 2.36 *v.* 47.75 ± 2.36, $P < 0.01$ – farm visit effect). For cubicles with rubber mats, there was a higher percentage of *animals with dirty flanks, udders and legs* than for deep-bedded cubicles (42.20 ± 1.65 *v.* 30.06 ± 1.55, $P < 0.01$).

Biased by the fact, that out of the 45 farms with pasture access in G1 to G3, 31 farms were assessed on the pasture during the summer assessment, the percentage of *lying outside of their designated lying area* increased steadily from 0% in G1 farms to more than 12% in G4. In winter, when all animals were assessed indoors, this percentage ranged from 2.2% in G2 to 5.3% in G4. The indicator *collisions with the housing equipment* is biased by the same effect. At a rate of 18.7% (G4) to 23.5% (G1) cows collided with cubicle when lying down at the winter assessment. In summer, this percentage was 37.3 in G4.

The prevalence of slightly lame animals was affected by a group effect ($P < 0.01$) and the interaction between group and farm visit ($P = 0.03$). In detail, an increase of slightly lame cows in G1 from summer to winter but no remarkable change in the other groups was observed. G1 and G2 indicated significantly less slightly lame cows than G4 after the pasture season. Seriously lame animals were most often found on G4- and least on G1-farms ($P = 0.01$ – group effect). In addition, the percentage was higher for cubicles with rubber mats than for deep-bedded cubicles (8.69 ± 0.60 *v.* 6.23 ± 0.69, $P < 0.04$). Animals with severe *integument alterations* were observed at higher prevalence in G3 and G4 ($P < 0.01$) compared to G1 and G2. Severe *integument alterations* occurred more often in summer than in winter in groups G3 and G4, while no difference between visits was found for the other two groups ($P < 0.01$ – group × farm visit effect). In cubicles with rubber mats prevalence of this indicator was higher than in deep-bedded cubicles (18.07 ± 1.13 *v.* 10.69 ± 1.30, $P < 0.01$). Animals with *hairless patches* were observed at lower prevalence in G1 compared to G3 and G4. The indicator *hairless patches* ($P = 0.39$) did not differ between farm visits, but more *hairless patches* were found when cubicles were equipped with rubber mats

Table 2 *Results of the Welfare Quality® assessments at the level of criteria during pasture (visit 1, summer 2014) and barn season (visit 2, winter 14/15) for dairy cattle farms with >10 h (G1,* n = *15 farms), 6 to 10 h (G2,* n = *15 farms), <6 h of pasture access/day (G3,* n = *15 farms) or without pasture access (G4,* n = *16 farms) (back-transformed LS means, minimum to maximum in brackets)*

	Group											
	G1		G2		G3		G4					
	Farm visit		Farm visit		Farm visit		Farm visit		*P*-value (*F*-value)[2]			
Criterion[1]	1	2	1	2	1	2	1	2	Group	Farm visit	Group × visit	Cubicle design (group)
Absence of hunger	43.31^{ab} (18 to 63)	50.04^{a} (28 to 79)	34.70^{b} (16 to 69)	48.36^{a} (30 to 100)	46.37^{ab} (20 to 100)	51.32^{a} (32 to 89)	44.57^{ab} (22 to 90)	45.68^{a} (31 to 82)	0.37 (1.06)	0.02 (6.15)	0.58 (0.66)	0.04 (2.65)
Absence of thirst	52.64^{ab} (3 to 100)	49.98^{a} (3 to 100)	61.61^{ab} (3 to 100)	65.77^{ab} (3 to 100)	66.83^{ab} (3 to 100)	71.43^{ab} (3 to 100)	71.46^{ab} (3 to 100)	76.53^{b} (3 to 100)	0.09 (2.23)	0.72 (0.13)	0.98 (0.07)	0.06 (2.35)
Comfort a. resting[3]	63.36^{a} (3 to 89)	26.98^{c} (8 to 45)	46.35^{b} (16 to 71)	35.22^{bc} (0 to 49)	39.17^{bc} (3 to 71)	33.97^{bc} (11 to 47)	11.42^{d} (0 to 37)	26.24^{b} (12 to 47)	< 0.01 (12.92)	0.02 (5.72)	< 0.01 (13.51)	0.58 (0.72)
Absence of injuries	58.99^{a} (35 to 83)	49.16^{b} (32 to 72)	44.45^{bc} (27 to 71)	49.18^{b} (33 to 66)	41.54^{c} (28 to 84)	45.31^{bc} (28 to 80)	32.54^{d} (16 to 51)	38.64^{cd} (27 to 62)	< 0.01 (12.14)	0.28 (1.20)	0.02 (3.32)	< 0.01 (6.18)
Absence of disease	34.87^{a} (22 to 45)	31.89^{a} (18 to 50)	36.10^{ab} (25 to 45)	42.01^{b} (27 to 65)	34.29^{a} (18 to 45)	36.25^{a} (20 to 57)	32.78^{a} (18 to 45)	32.67^{a} (18 to 45)	0.04 (2.89)	0.45 (0.57)	0.26 (1.37)	0.15 (1.75)
Absence of pain	64.52^{bc} (28 to 75)	69.05^{b} (28 to 75)	69.37^{ab} (28 to 75)	75.45^{a} (75 to 75)	59.45^{cd} (28 to 75)	62.83^{c} (28 to 75)	56.95^{d} (28 to 75)	58.18^{cd} (28 to 75)	0.02 (3.59)	0.26 (1.31)	0.98 (0.06)	0.13 (1.82)
Social behavior	93.95 (87 to 100)	95.28 (89 to 100)	97.61 (90 to 100)	92.47 (82 to 98)	94.18 (87 to 100)	94.20 (72 to 100)	91.86 (76 to 100)	92.67 (69 to 100)	0.76 (0.39)	0.68 (0.18)	0.55 (0.70)	0.85 (0.34)
Human–animal–relationship	53.68^{a} (20 to 74)	61.99^{ab} (40 to 87)	56.81^{ab} (44 to 87)	59.08^{ab} (41 to 87)	56.45^{ab} (36 to 82)	60.84^{ab} (26 to 86)	65.82^{ab} (49 to 93)	69.02^{b} (45 to 94)	0.05 (2.76)	0.07 (3.25)	0.84 (0.28)	0.96 (0.15)
Emotional state	79.51 (49 to 94)	78.00 (68 to 92)	79.43 (32 to 94)	77.16 (64 to 91)	78.14 (47 to 96)	75.18 (62 to 86)	76.10 (60 to 92)	73.67 (56 to 90)	0.51 (0.78)	0.21 (1.63)	0.99 (0.03)	0.05 (2.44)

[a,b,c,d]Values within a row with different superscripts differ significantly at $P < 0.05$ (Tukey–Kramer test).
[1]Criteria thermal comfort, ease of movement, expression of other behaviors were not shown.
[2]Degrees of freedom for each variable: 51.
[3]a. = around.

Table 3 *Selected results of Welfare Quality® assessments at indicator level during pasture (visit 1, summer 2014) and barn season (visit 2, winter 14/15) of dairy cattle farms with >10 h (G1,* n = *15 farms), 6 to 10 h (G2,* n = *15 farms), <6 h of pasture access/day (G3,* n = *15 farms) or without pasture access (G4,* n = *16 farms) (back-transformed LS means, minimum to maximum in brackets)*

	Group											
	G1 (*n* = 15)		G2 (*n* = 15)		G3 (*n* = 15)		G4 (*n* = 16)					
	Farm visit		Farm visit		Farm visit		Farm visit		*P*-values (*F*-values)[2]			
Indicator[1]	1	2	1	2	1	2	1	2	Group	Farm visit	Group × visit	Cubicle design (group)
Very lean cows (%)	12.37^{a} (6 to 36)	9.65^{a} (3 to 23)	17.43^{b} (5 to 40)	11.03^{a} (0 to 20)	12.86^{a} (0 to 34)	9.81^{a} (1 to 18)	12.98^{a} (1 to 31)	11.51^{a} (4 to 19)	0.38 (1.04)	0.02 (5.56)	0.49 (0.81)	0.07 (2.24)
Farms with dirty water points (%)	20.00	0.00	6.67	0.00	13.33	0.00	6.25	0.00	n.t.	n.t.	n.t.	n.t.
Ø water trough length / cow (cm)	4.29 (1 to 7)	4.39 (1 to 8)	6.04 (2 to 13)	6.19 (3 to 12)	6.87 (3 to 14)	6.51 (3 to 12)	6.59 (1 to 13)	6.58 (4 to 11)	n.t.	n.t.	n.t.	n.t.
Duration of lying down movem. (s)[3]	5.24^{a} (4 to 8)	8.79^{b} (8 to 12)	5.52^{a} (4 to 7)	8.06^{b} (6 to 12)	5.95^{ac} (4 to 8)	8.43^{b} (6 to 10)	7.49^{bc} (6 to 9)	9.38^{b} (7 to 12)	0.10 (2.10)	< 0.01 (29.44)	0.50 (0.79)	0.79 (0.43)
Dirty cows (leg, udder, flank) (%)	33.01^{a} (14 to 65)	34.00^{a} (19 to 62)	44.67^{b} (29 to 66)	31.37^{a} (9 to 65)	45.70^{b} (27 to 67)	23.85^{c} (8 to 58)	49.34^{b} (33 to 67)	27.09^{ac} (7 to 40)	0.30 (1.24)	< 0.01 (53.25)	< 0.01 (7.90)	< 0.01 (10.44)
Collisions with cubicles (%)	3.50 (0 to 33)	23.50 (0 to 43)	12.54 (0 to 50)	19.42 (0 to 43)	14.76 (0 to 56)	20.59 (0 to 86)	37.32 (0 to 67)	18.74 (0 to 36)	n.t.	n.t.	n.t.	n.t.
Cows lying outside lying area (%)	0.00^{a} (0 to 0)	3.92^{a} (0 to 13)	3.66^{a} (0 to 29)	2.21^{a} (0 to 13)	8.33^{bc} (0 to 29)	3.73^{a} (0 to 11)	12.14^{c} (2 to 27)	5.32^{b} (0 to 14)	< 0.01 (7.22)	0.75 (0.10)	< 0.01 (7.00)	0.14 (2.23)
Slightly lame cows (%)	13.16^{a} (2 to 19)	19.01^{b} (6 to 30)	18.25^{b} (4 to 27)	18.86^{b} (11 to 28)	20.06^{bc} (0 to 28)	18.88^{b} (8 to 22)	24.09^{c} (11 to 30)	21.54^{bc} (11 to 29)	< 0.01 (5.74)	0.50 (0.45)	0.03 (3.25)	0.95 (0.18)
Seriously lame cows (%)	4.30^{a} (0 to 13)	6.72^{ab} (0 to 21)	8.58^{bc} (0 to 18)	5.73^{ab} (2 to 17)	7.03^{ab} (0 to 13)	7.56^{ab} (0 to 22)	10.69^{c} (4 to 20)	9.08^{bc} (2 to 14)	0.01 (3.84)	0.72 (0.13)	0.16 (1.77)	0.04 (2.63)
Cows with hairless patches (%)	37.78^{a} (12 to 64)	43.47^{ab} (20 to 64)	49.11^{bc} (23 to 80)	46.50^{ab} (22 to 71)	55.48^{cd} (30 to 86)	52.46^{bc} (24 to 71)	64.95^{d} (19 to 80)	56.34^{cd} (21 to 86)	< 0.01 (9.22)	0.39 (0.74)	0.24 (1.42)	< 0.01 (9.35)
Cows with severe alterations (%)	8.21^{a} (0 to 26)	10.55^{ab} (2 to 34)	12.30^{b} (0 to 36)	10.10^{ab} (2 to 21)	20.15^{d} (6 to 46)	14.39^{c} (3 to 30)	23.63^{d} (4 to 77)	15.69^{c} (2 to 32)	< 0.01 (31.10)	< 0.01 (15.74)	< 0.01 (8.78)	< 0.01 (36.27)
Cows with nasal discharge (%)	23.99^{a} (3 to 44)	19.66^{c} (12 to 28)	15.63^{b} (7 to 33)	14.43^{b} (0 to 27)	23.03^{a} (13 to 46)	28.16^{d} (4 to 39)	22.35^{ac} (18 to 44)	26.58^{d} (3 to 37)	< 0.01 (8.06)	< 0.01 (20.72)	0.90 (0.19)	0.25 (1.38)
Cows with ocular discharge (%)	29.16^{a} (8 to 57)	7.79^{b} (0 to 19)	25.56^{a} (2 to 56)	5.55^{b} (0 to 20)	14.70^{c} (2 to 38)	6.55^{b} (0 to 19)	9.90^{bc} (3 to 34)	8.07^{b} (2 to 35)	< 0.01 (4.37)	< 0.01 (47.17)	< 0.01 (6.47)	0.19 (1.58)
Cows with diarrhea (%)	50.92^{a} (26 to 76)	17.40^{b} (3 to 28)	52.74^{a} (12 to 89)	18.72^{bc} (3 to 35)	53.40^{a} (35 to 78)	21.88^{c} (6 to 42)	53.25^{a} (19 to 80)	21.23^{c} (12 to 41)	0.41 (0.97)	< 0.01 (229.23)	0.54 (0.72)	0.39 (1.04)
Cows with mastitis (%)	6.75^{a} (0 to 20)	16.02^{b} (5 to 41)	7.70^{a} (0 to 22)	13.76^{bc} (3 to 44)	10.10^{ab} (0 to 25)	13.17^{b} (5 to 29)	15.90^{bc} (3 to 50)	12.32^{b} (2 to 57)	0.39 (1.01)	< 0.01 (7.55)	0.04 (2.96)	0.69 (0.56)
Downer cows (%)	3.32 (0 to 13)	2.41 (0 to 9)	4.36 (0 to 13)	3.97 (0 to 25)	3.84 (0 to 25)	2.28 (0 to 10)	5.98 (0 to 20)	2.15 (0 to 8)	n.t.	n.t.	n.t.	n.t.

Farms dehorning												
Without anesthetics (%)	20.00	13.33	13.33	0.00	46.67	33.33	31.25	25.00	n.t.	n.t.	n.t.	n.t.
Without analgetics (%)	53.33	6.67	80.00	0.00	60.00	13.33	50.00	18.75	n.t.	n.t.	n.t.	n.t.
Agonistic behaviors (per cow and hour)	0.09[a] (0 to 0.2)	0.06[a] (0 to 0.2)	0.02[a] (0 to 0.1)	0.07[a] (0 to 0.1)	0.07[a] (0 to 0.2)	0.05[a] (0 to 0.2)	0.09[a] (0 to 0.3)	0.07[a] (0 to 0.3)	0.96 (0.10)	0.91 (0.01)	0.91 (0.18)	0.99 (0.07)
Cows avoidance distance												
> 100 cm (%)	6.82 (0 to 50)	2.03 (0 to 13)	3.88 (0 to 12)	3.32 (0 to 11)	4.59 (0 to 15)	4.47 (0 to 35)	2.82 (0 to 14)	2.12 (0 to 10)	n.t.	n.t.	n.t.	n.t.
50 to 100 cm (%)	19.03[a] (6 to 42)	14.07[ab] (3 to 25)	17.87[ac] (0 to 30)	17.61[ac] (0 to 34)	18.54[a] (2 to 37)	14.10[ab] (0 to 28)	11.85[bc] (2 to 28)	10.00[b] (0 to 24)	0.03 (3.09)	0.07 (3.38)	0.69 (0.50)	0.79 (0.43)
< 50 cm, but not be touched (%)	44.56[ab] (17 to 69)	48.55[a] (20 to 62)	41.52[ab] (28 to 58)	39.78[ab] (26 to 56)	40.86[ab] (17 to 58)	40.43[ab] (24 to 59)	36.45[b] (8 to 57)	39.66[ab] (7 to 68)	0.11 (2.08)	0.57 (0.33)	0.75 (0.40)	0.06 (2.38)
Hampered respiration (%)	0.13 (0 to 1.6)	0.16 (0 to 2.0)	0.11 (0 to 1.5)	0.00 (0 to 0)	0.11 (0 to 1.8)	0.00 (0 to 0)	0.17 (0 to 2.1)	0.00 (0 to 0)	n.t.	n.t.	n.t.	n.t.
Frequency of coughing (count per 15 min)	0.07 (0 to 0.3)	0.10 (0 to 0.2)	0.08 (0 to 0.3)	0.10 (0 to 0.2)	0.09 (0 to 0.2)	0.12 (0 to 0.4)	0.10 (0 to 0.2)	0.07 (0 to 0.1)	0.10 (0.02)	0.85 (0.04)	0.98 (0.06)	0.10 (0.03)
Vulvar discharge (%)	1.07 (0 to 4.0)	2.78 (0 to 7.3)	0.34 (0 to 2.2)	0.97 (0 to 4.3)	1.65 (0 to 5.6)	1.79 (0 to 6.9)	0.63 (0 to 3.1)	3.02 (0 to 7.3)	n.t.	n.t.	n.t.	n.t.
Mortality (%)	1.87 (0 to 5)	0.94 (0 to 3)	1.30 (0 to 4)	0.91 (0 to 2)	1.61 (0 to 5)	1.48 (0 to 6)	3.03 (0 to 10)	1.23 (0 to 6)	0.12 (1.97)	< 0.01 (10.62)	0.20 (1.56)	0.48 (0.88)
Dystocia (%)	4.42 (0 to 10)	3.38 (0 to 8)	2.60 (0 to 10)	1.67 (0 to 6)	2.39 (0 to 10)	1.79 (0 to 4)	2.61 (0 to 15)	2.62 (0 to 10)	n.t.	n.t.	n.t.	n.t.

n.t. = not tested owing to lack of fulfillment of model assumptions.

[a,b,c,d]Values within a row with different superscripts differ significantly at $P < 0.05$ (Tukey–Kramer test).

[1]Cleanliness and functioning of water points, presence of tethering, access to outdoor loafing area, hampered respiration, vulvar discharge, tail docking and access to pasture are not presented in this table.

[2]Degrees of freedom for each variable = 51.

[3]movem. = movement.

than in deep-bedded ones (58.74 ± 2.44 *v.* 42.79 ± 2.57, $P < 0.01$).

Nasal discharge occurred more often in summer than in winter months ($P < 0.01$ – farm visit effect) and more often in G1, G3 and G4 than in G2 ($P < 0.01$ – group effect). The group ($P < 0.01$), farm visit ($P < 0.01$) as well as their interaction ($P < 0.01$) affected the indicator *ocular discharge*. In summer, the percentage of animals with *ocular discharge* decreased steadily from G1 (29.2%) to G4 (9.9%), while in winter the variation was lower ranging from 5.6% (G2) to 8.1% (G4), which differed only slightly from the summer value of this group. *Ocular discharge* was the only indicator for which an interaction of group and cubicle design was found ($P < 0.01$). In detail G1, G3 and G4 had a higher percentage of animals with *ocular discharge* in farms with deep-bedded than with rubber mat-equipped cubicles, while it was vice versa in G2.

Independent of the group ($P = 0.41$), more than half of the animals were found with *diarrhea* in summer and approximately one-fifth in winter ($P < 0.01$ – farm visit effect). Regarding G1 and G2, the *mastitis* rate was significantly lower in summer than in winter ($P = 0.04$ – group × farm visit effect). In summer, the prevalence was lower when more pasture access was provided. In all groups, anesthetics and analgetics were used more often at the second than at the first visit in summer.

The frequency of *agonistic behaviors* was very low in all four groups and was not affected by any of the effects included in the statistical model ($P > 0.05$). Similarly, only a small proportion of the animals had an *avoidance distance* of over 100 cm. Independent of farm visit ($P = 0.07$) or its interaction ($P = 0.69$), G1 and G3 showed a higher percentage of animals with an *avoidance distance* between 50 and 100 cm at the end of the pasture season when compared with G4 ($P = 0.03$ – group effect). Most of the animals (37% to 49% of the cows) showed an *avoidance distance* of under 50 cm, without being affected by any of the tested effects.

Values for *hampered respiration, frequency of coughing, vulvar discharge, mortality* and *dystocia* were low at both visits.

Discussion

In the WQP the duration of pasture access is used as a measure for the criterion *expression of other behaviors* and is rated high in the calculation of the overall farm welfare status. If farms provide access for more than 6 h per day, they are scored based on the number of days/year and hours/day on pasture, while farms with less than 6 h pasture access per day receive zero points. For the purpose of this study, it was consequently not plausible to include this measure, because pasture access depended on the study design. Consequently, results are presented at criteria and indicator level, without aggregating data to principle level or overall classification.

Holistic welfare assessments using the WQP of dairy cows comparing different housing systems are still rare. The protocol was used in studies of Gieseke *et al* (2018), De Graaf *et al.* (2017 and 2018), Andreasen *et al.* (2013), Heath *et al.* (2014) and De Vries *et al.* (2013) to assess the welfare status of dairy cows with different research objectives. Effects of pasture access are still widely unknown. For example, De Graaf *et al.* (2017) applied the protocol after the pasture season and at the end of the barn season, while assessing all measures in the barn. The authors found carry over effects of pasture access even after months of the barn season. In another study, Burow *et al.* (2013a) investigated the welfare of dairy cows with another multi-dimensional research method to compare pasture grazing and whole year indoor housing. Similar with the results of the present study, the welfare state of the cows was higher during summer grazing than during winter indoor housing. The authors related enhanced welfare with an increase in daily hours on pasture during the summer months. Considering the clear preference of high-yielding dairy cows for pasture (Motupalli *et al.*, 2014), it becomes obvious that efficient pasturing systems is among others one feasible way to improve welfare of dairy cows.

Limitations of the study

The objective of this study was to assess the effect of pasture access on welfare indicators in conventional dairy farms using WQP as a holistic on-farm assessment tool. Though the protocol has been used for several years, its implementation in dairy research is still very limited. Previous studies revealed critiques on the assessment of the measures as such and aggregation procedures. For example, De Graaf *et al.* (2017) recommended using two observers at the same time to avoid any influence of observer bias. In the present study, all assessments were conducted by the same person to at least reduce inter-observer bias. Following Tuyttens *et al.* (2014), *QBA*, representing a substantial measure of the WQP, is at high risk for involuntary subjective assessment of animal's behavior. In the present study, this might have been impacted by the fact that *QBA* was assessed on pasture for most of the G1, G2 and G3 farms at the first visit. As another weakness of the protocol the time-consuming assessment procedures with 6 to 8 h per farm is often criticized (Andreasen *et al.*, 2013).

Regarding the aggregation procedures, De Vries *et al.* (2013) and Heath *et al.* (2014) criticized that the calculated WQP scores are very sensitive to certain measures, especially the water supply of the animals. On the one hand, water intake of a cow is related with the number and size of drinkers in herds, which is assessed in the WQP, but it is on the other, also influenced by various other factors that are not recorded. In agreement, De Graaf *et al.* (2018) found a relatively large impact of the measurements regarding water supply and questioned the prescribed resource-based measures. They suggested direct measures of thirst using animal-based indicators. This may, however, require time- and cost-intensive blood analyses.

In contrast, other measures, particularly regarding cow health, were not sensitive enough (De Vries *et al.*, 2013;

Heath *et al*., 2014). Exemplarily, De Vries *et al*. (2013) argued that due to compensating mechanisms during the WQP aggregation process the indicator *lameness* lacked enough weight to affect scores of the criterion *absence of injuries*. Likewise, the aggregation process of the criterion *absence of disease* is not absolutely coherent as the measure of *mastitis* is converted into an ordinal score. As a result, farms with 27% of the cows having a somatic cell count >400 000 cells/ml receive the same score than farms with only 5% of the cows exceeding this threshold.

The benefits of WQP measures are that they generally have good repeatability on repeated farm assessments after weeks and months as shown by Forkman and Keeling (2009). The main advantage of the WQP, the large proportion of animal-based welfare measures, was attributed by De Vries *et al*. (2013) and Tuyttens *et al*. (2014). Animal-based measures are preferred over resource-based measures because they are believed to be more directly linked to the true welfare status of animals.

With the aim of the present study to assess the effect of pasturing at differing levels in mind, it must be considered that for most of the farms that provided access to pasture several measures were measured outdoors at the first visit, even though animals were outside only part of the day. This especially holds true for the measures *lying outside of their designated lying area*, *collisions with the housing equipment* and the *duration of lying down movements*. For future studies it should be considered to weight assessments in- and outdoors based on the duration animals have access to pasture. Either some indicators may solely be assessed on pasture and others in the barn or all indicators are partly assessed in the barn and partly on pasture. Nevertheless, both further complicate WQP assessments and may outweigh benefits of this strategy.

In the present study, farms were classified by their daily duration of pasture access and compared to zero-grazing farms. In all classes the variation in herd size as well as milk yield was high and the sampled farms can be assumed to be representative of conventional loose housing dairy farms in Central Europe. However, a major limitation of this study is that pasture access was confounded with other factors that influence welfare but which are not assessed within WQP. One of these factors is the milk yield, which was around 500 kg ECM lower in the two groups with most intensive pasture access compared with the other two groups. Our results did not show any relationship between milk yield and animal welfare, comparable to the results of Coignard *et al.* (2013) who did not find associations between milk yield and WQP results in commercial French dairy herds. However, other studies pointed out that there are direct effects of milk yield on the prevalence of several diseases in dairy cows (Fleischer *et al*., 2001) or indirect effects like metabolic disorders resulting in the necessary use of more concentrates in the fodder to generate a high milk yield (Knaus, 2009).

As none of the farmers practiced seasonal calving, an equal distribution of lactation stages at the time of welfare assessment can be assumed. To minimize other confounding effects farmers were instructed that any specific interference, for example, claw trimming or re-grouping, should be avoided and farms were not assessed when the veterinarian did any animal treatments the day before the assessment. Another limitation, which has to be taken into account, is that animals on farms with pasture access were partly assessed on pasture during the summer visit where some measures such as *lying outside of their designated lying area* or *collisions with the housing equipment* needs a more differentiated approach. Despite the different environments (barn and pasture), the measurement of the associated indicators followed the procedure as described in the WQP in order to ensure comparability with other studies. The time the cows needed to lay down was measured in the same way, regardless of whether the cows were in- or outdoor. Results for the indicator *collisions with the cubicles* are biased when the assessments were done on pasture and are therefore only valid for assessments at the end of the barn season. Nevertheless, it has to be acknowledged that there is no risk of *collisions with cubicles* when cows are on pasture. Likewise, the indicator *lying outside the designated lying area* is only valid for the second farm visit.

All assessments were performed as objectively as possible, though changing weather and environmental conditions must be considered as additional influencing factor when comparing to WQP assessments that were solely conducted indoors. This especially holds true for indicators such as *QBA* and *social behavior*. On pasture, the cows had more space to realize their individual *human avoidance distance*; hence there could be less negative social contacts and more natural behavior due to soft and non-slip underground and environmental stimuli. Perhaps the assessments of *emotional state* and *social behavior*, which did not show significant differences in this study, might have shown different results if all farms of G2 and G3 had been assessed on the pasture. Nevertheless, effects of pasture in this study cannot only be derived from group comparisons, but also from comparisons between the assessments at the end of the pasture and barn season within the groups.

Criterion absence of hunger

Suboptimal environmental conditions during summer months with heat stress conditions in barns of G4 on the one hand, and pastures that do not meet the requirements of high-yielding cows in the pasture groups on the other, may explain why *body condition* was worse in all groups in the present study in summer compared with winter. The larger differences of the *body condition* between summer and winter in groups with access to pasture (G1, G2 and G3), however, reflects the importance of an optimized pasture management. Results are in wide agreement with Burow *et al*. (2013a) who found a worse *body condition* in pasturing cows during summer, compared with winter months when assessing 41 Danish dairy farms with cubicle housing and access to pasture for at least 120 days per year for at least 5 h daily. Washburn *et al*. (2002) and Hernandez-Mendo *et al*.

(2007) also reported that pasturing is associated with problems for high yielding cows, especially in terms of *body condition*.

Problems with *body condition* can be mainly explained by suboptimal pasture management or by the use of the high yielding and at the same time high-quality feed requiring Holstein-Friesian breed, which is not optimally adapted to pasture feeding (Thomet *et al*., 2014). Consequently, pasturing systems for these animals require optimal feed supplementations, while high pasture quality has to be maintained.

Criterion comfort around resting

For this criterion, it has to be considered that the assessment of the lying conditions, generally took place on pasture in G1, and on most farms of G2 and G3. On the 14 farms in G2 and G3, where the farmers decided to leave the cows in the barn for the day of the WQP assessment due to the weather conditions, results might have been different if the animals would have been assessed on pasture like the other farms of these two groups as well. Lying conditions are supposed to be more appropriate on the pasture than in cubicles, where lying and resting is impeded (Krohn and Munksgaard, 1993). In winter, when all cows were housed indoors, groups did not differ. Thus, it can be assumed that better scores for *comfort around resting* for the groups with pasture access in summer were mainly attributed to the availability of pasture, next to other factors such as the flooring, cleanliness of floors and cubicles or cubicle design.

The lower percentage of *dirty flanks* in farms with deep-bedded cubicles than with rubber mat-equipped cubicles in this study is supported by results of Kanswohl and Sanftleben (2006), where additional litter of chopped straw on the rubber mats was provided and barns were equipped with mechanical cow brushes.

Criterion absence of injuries

This study as well as previous studies of Hernandez-Mendo *et al*. (2007) indicated that pasture access in summer has a positive effect on *lameness* and can help the cows to recover hoof and leg injuries from the barn season. The high prevalence of claw diseases, recently found by Armbrecht *et al*. (2018) in selected farms of the present study, highlights the importance of claw health as a welfare problem. In the cited study, a positive effect of pasture was found for claw diseases that are related to moist environments, though a greater effect might be attributed to free-stall design and claw trimming routine. This effect was probably reflected in the present study by the lower prevalence of slightly and severely lame animals of the pasture groups during the summer assessment. The finding that this was not substantiated throughout the barn season again points to the fact that cubicle design and management routines may be more important for animal welfare than just the access to pasture, because the positive effects of pasture could not be maintained until the end of the barn season (De Graaf *et al*., 2017). The positive effect of pasture on *lameness* may be mainly related to the prevention of strained joints and of excessive growth of poor claw horn because of the soft ground (Algers *et al*., 2009).

However, despite group differences in less severe *integument alterations* for groups with more than 6 h pasture access, there was also an interaction effect of group and farm visit. Only G1 showed less severe *integument alterations* in summer compared with winter, while it was vice versa and at a higher prevalence level in G3 and G4. Comparable to this study, decreasing prevalence of *integument alterations*, hair loss, lesions and swellings with increasing intensity of pasture were demonstrated by Burow *et al*. (2013b). Cows with 3 to 9 h on pasture showed a 2.2 times and cows with 9 to 21 h showed a 4.8 times lower probability of *integument alterations*, than cows without access to pasture. The soft underground and the extra space availability are main explanations for the reduced prevalence of injuries. In cubicles, there is a higher risk of injuries compared to the pasture, because of collisions with the barn interior or abrasions of tarsal joints on rubber mats (Wechsler *et al*., 2000). This is highlighted by the fact that for almost 40% of the lying down movements, cows in the zero-grazing group collided with the barn interior during the summer assessment. In this context, the fact that there is no risk of colliding with cubicles when cows are pasturing has to be acknowledged as an important benefit of pasturing. With regard to the cubicle design, findings are in line with those of Dippel *et al*. (2009), who attributed a better lying comfort and a lower risk for *lameness* and/or claw lesions to deep-bedded in comparison to mats/mattresses.

Criterion absence of disease

With regard to the indicator *diarrhea,* it remains questionable whether loose watery manure, which may be caused by diets without appropriate crude fiber contents or by excessive protein contents of the grass on pasture, should be classified – as done in the WQP – at the same level with *diarrhea* caused by bacterial or viral infection. The prevalence of *diarrhea* was twice as high in summer than in winter in all four groups. Burow *et al*. (2013a) also showed worse feces consistency during summer months. The critical threshold for the indicator *diarrhea*, as stated in the WQP (>6.5% of the herd), was exceeded by all farms in this study. This emphasizes that all assessed farms should aim to minimize its occurrence.

In agreement with the present study, White *et al*. (2002) found that lactating cows without access to pasture showed a higher prevalence of *mastitis*. Moreover, Washburn *et al*. (2002) verified that cows without pasture access had 1.8 times as many clinical cases of *mastitis* and were eight times more frequently culled because of *mastitis*, compared to cows with access to pasture.

Criterion absence of pain

In all groups, obviously more farms used anesthetics and analgetics for *dehorning* at the second visit, which mainly resulted from a decree from the Lower Saxony Ministry of Food, Agriculture and Consumer Protection. Following this decree, farmers have to use anesthetics and analgetics for *dehorning* since June 2015. Even though this might have biased results to some degree, regulations were implemented at a comparable rate in all groups.

Criterion emotional state
The criterion is composed of the aggregated scores of the *QBA*, which can be referred to as a reliable method for the assessment of an animal's behavior (Forkman and Keeling, 2009); even though Tuyttens *et al.* (2014) indicated that the observer bias influenced results of the *QBA*. Overall, differences between groups or seasons were not detected in this study. Nevertheless, there is still no other validated method to assess multiple behavioral signals and behavioral expression of animals, which could substitute *QBA* in the protocol.

Criterion thermal comfort
There is still no indicator for the criterion *thermal comfort* as an assessment of the housing conditions in the WQP. However, heat stress conditions during summer months may impair welfare on pasture and in barns alike. First reports already indicate heat stress effects in dairy cows in the studied region (Lambertz *et al.*, 2014). The provision of shade, for example, is an important factor of an optimized pasture management due to reduced heat stress (Kendall *et al.*, 2006) and protection against solar radiation (Tucker *et al.*, 2008). Therefore, the provision of shade on pasture and cooling systems in barns is warranted to be assessed in future studies on the effects of pasture access on welfare.

Conclusions

For a number of important animal-based indicators, such as *slightly* and *seriously lame cows*, *hairless patches* and *severe alterations*, cows with access to pasture were scored superior to animals housed indoor year-round. The level of pasturing, however, did not show a consistent effect for these indicators. Neither of the pasture groups showed a difference to zero-grazing farms at the end of the barn season, in which cows of all groups were kept under comparable indoor housing conditions.

Only extended pasturing of at least 10 h/day can be associated with benefits for the criteria *comfort around resting* and *absence of injuries*. As the majority of the animals even in farms with pasturing spent most of the time indoors, herd management and housing conditions (e.g. cubicle design) are most important to increase animal welfare. Negative aspects of pasture access in terms of the criterion *human–animal relationship* highlights the importance of improving animal handling to further exploit potential welfare benefits of pasturing.

Findings are limited by the potential effect of confounding factors such as an unequal distribution of cubicle flooring in the four groups, different milk yields, and the fact that assessments in farms with pasturing were done in- as well as outdoors. In future studies evaluating the effects of pasture on welfare, other important pasture management factors, such as the provision of shade and/or cooling systems and distance and condition of walkways to pasture areas, need to be assessed in addition to the measures defined in the WQP.

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Declaration of interest

The authors declare that they have no competing interests.

Ethics Statement

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. No ethical approval was required as non-invasive procedures were carried out in this study.

Software and data repository resources

None of the data were deposited in an official repository.

Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1751731119000570

References

Algers B, Bertoni G, Broom D, Hartung J, Lidfors L, Metz J, Munksgaard L, Pina TN, Oltenacu P, Rehage J and Rushen J 2009. Scientific report on the effects of farming systems on dairy cow welfare and disease. Report of the Panel on Animal Health and Welfare. Annex to the EFSA Journal 1143, 114–284.

Andreasen SN, Wemelsfelder F, Sandoe P and Forkman B 2013. The correlation of qualitative behavior assessments with Welfare Quality® protocol outcomes in on-farm welfare assessment of dairy cattle. Applied Animal Behaviour Science 143, 9–17.

Armbrecht L, Lambertz C, Albers D and Gauly M 2018. Does access to pasture affect claw condition and health in dairy cows? Veterinary Record 182, 79.

Burow E, Rousing T, Thomsen PT, Otten D and Sørensen JT 2013a. Effect of grazing on the cow welfare of dairy herds evaluated by a multidimensional welfare index. Animal 7, 834–842.

Burow E, Thomsen PT, Rousing T and Sørensen JT 2013b. Daily grazing time as a risk factor for alterations at the hock joint integument in dairy cows. Animal 7, 160–166.

Coignard M, Guatteo R, Veissier I, Lehébel A, Hoogveld C, Mounier L and Bareille N 2013. Does milk yield reflect the level of welfare in dairy herds? The Veterinary Journal 199, 184–187.

De Graaf S, Ampe B, Buijs S, Andreasen SN, De Boyer des R, van Eerdenburg FJCM, Haskell MJ, Kirchner MK, Mounier L, Radeski M, Winckler C, Bijttebier J, Lauwers L, Verbeke W and Tuyttens FAM 2018. Sensitivity of the integrated Welfare Quality® scores to changing values of individual dairy cattle welfare measures. Animal Welfare 27, 157–166.

De Graaf S, Ampe B and Tuyttens FAM 2017. Assessing dairy cow welfare at the beginning and end of the indoor period using the Welfare Quality® protocol. Animal Welfare 26, 213–221.

De Vries M, Bokkers EAM, van Schaik G, Boltreau R, Engel B, Dijkstra T and de Boer IJM 2013. Evaluating results of the Welfare Quality multi-criteria evaluation model for classification of dairy cattle welfare at the herd level. Journal of Dairy Science 96, 1–10.

Dippel S, Doleza M, Brenninkmeyer C, Brinkmann J, March S, Knierim U and Winckler C 2009. Risk factors for lameness in cubicle housed Austrian Simmental dairy cows. Preventive Veterinary Medicine 90, 102–112.

Fleischer P, Metzner M, Beyerbach M, Hoedemaker M and Klee W 2001. The relationship between milk yield and the incidence of some diseases in dairy cows. Journal of Dairy Science 84, 2025–2035.

Forkman B and Keeling LJ 2009. Assessment of animal welfare measures for dairy cattle, beef bulls and veal calves. Welfare Quality® Reports 11, 297.

Gieseke D, Lambertz C and Gauly M 2018. Relationship between herd size and animal welfare in dairy cattle. Journal of Dairy Science 101, 1–15.

Heath CAE, Browne WJ, Mullan S and Main DCJ 2014. Navigating the iceberg: reducing the number of parameters within the Welfare Quality® Assessment protocol for dairy cows. Animal 8, 1978–1986.

Hernandez-Mendo O, von Keyserlingk MAG, Veira DM and Weary DM 2007. Effects of pasture on lameness in dairy cows. Journal of Dairy Science 90, 1209–1214.

Kanswohl N and Sanftleben P 2006. Analyse und Bewertung von Hoch- und Tiefboxen für Milchrinder aus arbeitswirtschaftlicher, ethologischer, hygienischer und ökonomischer Sicht. Research Paper of Research Institute of Agriculture and Fisheries of Mecklenburg Vorpommern, Germany. Retrieved on 1 September 2017 from http://www.landwirtschaft-mv.de/Fachinformationen/Tierproduktion/Milcherzeugung/ ?id=339&processor=processor.sa.lfaforenbeitrag.

Kendall PE, Nielsen PP, Webster JR, Verkerk GA, Littlejohn RP and Matthews RW 2006. The effects of providing shade to lactating dairy cows in a temperate climate. Livestock Science 103, 148–157.

Knaus W 2009. Dairy cows trapped between performance demands and adaptability. Journal of the Science of Food and Agriculture 89, 1107–1114.

Krohn CC and Munksgaard L 1993. Behaviour of dairy cows kept in extensive (loose housing/pasture) or intensive (tie stall) environments. Applied Animal Behavior Science 37, 1–16.

Lambertz C, Sanker C and Gauly M 2014. Climatic effects on milk production traits and somatic cell score in lactating Holstein-Frisian cows in different housing systems. Journal of Dairy Science 97, 319–329.

Leisen E 2014. Weidebasierte Milchviehhaltung in Deutschland. In Proceedings of the International Conference on Grasland- and Pasture-based Milk Production, 21–22 August 2014, Zollikofen, Switzerland, pp. 98–101.

Motupalli PR, Sinclair LA, Charlton GL, Bleach EC and Rutter SM 2014. Preference and behavior of lactating dairy cows given free access to pasture at two herbage masses and two distances. Journal of Animal Science 92, 5175–5184.

Phillips CJC, Beerda B, Knierim U, Waiblinger S, Lidfors L, Krohn CC, Canali E, Valk H, Veissier I and Hopster H 2013. A review of the impact of housing on dairy cow behaviour, health and welfare. In Livestock housing: modern management to ensure optimal health and welfare of farm animals (eds. A. Aland and T. Banhazi), pp. 37–54. Wageningen Academic Publishers, Wageningen, The Netherlands.

Reijs J, Daatselaar C, Helming J, Jager J and Beldman A 2013. Grazing dairy cows in north-west Europe. LEI Report 2013-001. LEI Wageningen UR, The Hague, The Netherlands.

Thomet P, Ineichen S and Jörg H 2014. Züchten von Kühen für eine effiziente graslandbasierte Milchproduktion. In Proceedings of the International Conference on Grasland- and Pasture-Based Milk Production, 21–22 August 2014, Zollikofen, Switzerland, pp. 61–70.

Tucker CBA, Rogers AR and Schütz KE 2008. Effect of solar radiation on dairy cattle behaviour, use of shade and body temperature in a pasture-based system. Applied Animal Behaviour Science 109, 141–154.

Tuyttens FAM, de Graaf S, Heerkens JLT, Jacobs L, Nalon E, Ott S, Stadig L, van Laer E and Ampe B 2014. Observer bias in animal behaviour research: can we believe what we score, if we score what we believe? Animal Behaviour 90, 273–280.

Van den Pol-van Dasselaar A, de Vliegher A, Hennessy D, Isselstein J and Peyraud J-L 2015. The future of grazing. In Proceedings of the 3rd Meeting of the EGF Working Group 'Grazing'. Wageningen UR (University and Research Centre) Livestock Research, Livestock Research Report 906, Wageningen, The Netherlands.

Washburn SP, White SL, Green JT Jr and Benson GA 2002. Reproduction, mastitis, and body condition of seasonally calved Holstein and Jersey cows in confinement or pasture systems. Journal of Dairy Science 85, 105–111.

Wechsler B, Schaub J, Friedli K and Hauser R 2000. Behaviour and leg injuries in dairy cows kept in cubicle systems with straw bedding or soft lying mats. Applied Animal Behaviour Science 69, 189–197.

Weiß D 2014. Imagewirkung von weidenden Kühen. In Proceedings of the International Conference on Grasland- and Pasture-Based Milk Production, 21–22 August 2014, Zollikofen, Switzerland, pp. 43–48.

Weinrich R, Kühl S, Zühlsdorf A and Spiller A 2014. Consumer attitudes in Germany towards different dairy housing systems and their implications for the marketing of pasture raised milk. International Food and Agribusiness Management Review 17, 205–222.

Welfare Quality 2012. Welfare Quality® assessment protocol for cattle applied to dairy cows. Welfare Quality® Consortium, Lelystad, The Netherlands.

White SL, Benson GA, Washburn SP and Green JTJ 2002. Milk production and economic measures in confinement or pasture systems using seasonally calved Holstein and Jersey cows. Journal of Dairy Science 85, 62–104.