AARHUS
UNIVERSITET
DCA - NATIONALT CENTER FOR FØDEVARER OG JORDBRUG

Til Fødevarestyrelsen

Vedr. bestillingen: ” Identifikation af risikofaktorer for nedsat dyrevelfærd samt cost-benefit af velfærdsforbedrende tiltag i danske malkekvægsbesætninger”.

DCA - Nationalt Center for Fødevarer og Jordbrug

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Fødevarestyrelsen har i bestilling dateret d. 8. januar 2016 bedt DCA – Nationalt Center for Fødevarer og Jordbrug – om levering af en redegørelse for ” Identifikation af risikofaktorer for nedsat dyrevelfærd samt cost-benefit af velfærdsforbedrende tiltag i danske malkekvægsbesætninger”.

Besvarelsen er udarbejdet af en bredere kreds af forskere fra Aarhus og Københavns Universitet med seniorrådgiver Anne Braad Kudahl, Institut for Husdyrvidenskab, Aarhus Universitet, som projektleder.

Besvarelsen er udarbejdet som led i ”Aftale mellem Aarhus Universitet og Fødevareministeriet om udførelse af forskningsbaseret myndighedsbetjening m.v. ved Aarhus Universitet, DCA – Nationalt Center for Fødevarer og Jordbrug, 2016-2019 (punkt BH214 i Aftalens Bilag 2 samt i Arbejdsprogram 2017 for Ydelsesaftale for Husdyrproduktion, 2017-2020)”.

Venlig hilsen

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Skema til afrapportering af ViD projekter

Videncenter for Dyrevelfærd
2017

1. Projekttitel:

Identification of risk factors and cost effective interventions for promoting animal welfare in Danish dairy herds.

In Danish: Identifikation af risikofaktorer for nedsat dyrevelfærd samt cost-benefit af velfærdsforbedrende tiltag i danske malkekvægsbesætninger

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3. Populærvidenskabeligt dansk resumé (max 250 ord)**:**

Projektets overordnede formål var at udpege de mest omkostningseffektive investeringer i forbedret velfærd for danske malkekvægsbesætninger ved at identificere de alvorligste velfærdsproblemer, klarlægge årsagerne bag dem, foreslå løsninger og beregne de økonomiske konsekvenser af dem.

I alt blev 60 malkekvægsbesætninger velfærdsevalueret og supplerende data (herunder klovbeskæringsdata, ydelsesniveau, udsætningsniveau, produktionstype, gulv- og sengebåseinformation og race-data) indsamlet. En række besætningsparametre var associeret med reducerede dyrevelfærdsparametre. Eksempelvis var der sammenhæng mellem lægge-sig-adfærd og sengebåsens kvalitet, ligesom halthed var forbundet med landmandens fokus på halthed samt sengebåsens kvalitet. Samlet set gav de fleste identificerede faktorer logisk eller biologisk mening.

Syv besætninger med alvorlige velfærdsproblemer blev besøgt. Som hos resten af de 60 besætninger var de alvorligste velfærdsproblemer dårlig hvilekomfort, skader, trykninger, halthed og manglende afgræsning. De vigtigste formodede årsager viste sig at være for små sengebåse med hårde, slidte måtter/madrasser samt forskellige problemer relateret til gulv, skrabere, spalter og gulvhygiejne. Løsningsmuligheder blev skitseret i et samarbejde mellem landmand, dyrlæge og en bygningskonsulent. De handlede bl.a. om udvidelse af båsene, et velfærdsareal, nye madrasser eller sand i båsene, og udbedring af gulv- og hygiejneproblemer. Praktiske muligheder for afgræsning blev også drøftet. Omkostningerne forbundet med velfærdsinvesteringerne blev beregnet af en bygningskonsulent og forventede produktionsstigninger simuleret med besætningernes egne data ved hjælp af SimHerd-modellen. Med en 10-årig afskrivningsperiode og 4 % renteniveau var alle investeringerne særdeles profitable, under forudsætning af, at ydelsen steg minimum 1.0 kg/ko/dag og haltheden blev reduceret med 10-20 %. Græsning var ikke profitabelt, da det er forbundet med store omkostninger og mulig nedsat ydelse.

4. Populærvidenskabeligt engelsk resumé (max 250 ord)**:**

The overall aim was to identify the most cost-effective investments in improving welfare for Danish dairy herds by identifying the most serious welfare problems and their causes, suggesting solutions and calculating their economic consequences.

Data including claw-trimming, milk yield and culling levels, production type, flooring and bedding information and other farm and management data were analysed from 60 farms. A number of these were associated with the welfare scores, e.g. time to lie down was associated with bedding quality, and lameness was associated with bedding quality and farmers' awareness of lameness. Overall, most of the identified associations were logical or made biological sense.

Seven herds with serious welfare problems were visited. The most serious welfare problems identified were poor comfort when resting, injuries, lameness and no grazing. The main reasons were cubicles that were too small, hard mats/mattresses and various problems related to the floor, scrapers, slats and floor hygiene. Solutions suggested by a housing advisor, vet and the farmer were extension of cubicles, placing soft mattresses or sand in cubicles, and improving floor-quality and hygiene. The feasibility of grazing was also discussed. By using the herd's own data in the SimHerd model, welfare improvements and their economic effects were simulated. With a 10-year payback period and a 4% interest rate, all investments were highly profitable as long as milk yield increased minimum 1.0 kg/cow/day and lameness was reduced by 10-20%. Grazing was found to be non-profitable, associated with high costs and milk yield losses.

5. Videnskabeligt dansk resumé af projektets formål, udførelse, væsentligste resultater og konklusion (max 500 ord)**:**

Projektets overordnede formål var at udpege de mest omkostningseffektive investeringer i forbedret velfærd for danske malkekvægsbesætninger ved at identificere de alvorligste velfærdsproblemer, klarlægge årsagerne bag dem, foreslå løsninger og beregne de samlede økonomiske konsekvenser af dem.

Welfare Quality ® velfærdsvurdering blev gennemført sammen med indsamling af supplerende data i 60 malkekvægsbesætninger. Velfærdsparametrene blev dernæst vurderet med generaliserede lineære modeller, hvor effekterne blev vurderet på besætningsniveau baseret på ko-niveaumålinger. Ni modeller blev sat op for at analysere, hvordan forskellige velfærdsmål blev påvirket af forskellige forklarende faktorer som fx gulvstandard og sengebåseindeks

Blandt de tre vurdere velfærdskriterier, som var de alvorligste velfærdsproblemer i alle besætninger, blev følgende sammenhænge identificeret:
Lægge-sig-adfærd = Landmandens fokus på halthed + Gulvstandard + Sengebåseindeks
Fravær af skader = Landmandens fokus på halthed + Sengebåseindeks + Ko-antal + Besætningsrace + Ydelsesniveau + Kobørstestandard + Observatør-gruppe
Udtryk for anden adfærd(græsningsadfærd) = Produktionstype + Liggeindeks + landmandens fokus på halthed + Observatør-gruppe

Samlet set blev det vurderet, at specielt opmærksomheden omkring halthed og sengebåseindekset havde en væsentlig indflydelse på dyrenes velfærd, men der var også en væsentlig indflydelse af observatøren på de fleste parametre. Der er dog korrigeret for denne effekt, og de nævnte parametre giver generelt logisk og biologisk mening.

Blandt besætningerne med de alvorligste problemer blev syv besætninger besøgt med henblik på vurdering af økonomi i velfærdsinvesteringer. De vigtigste velfærdsproblemer var også her: hvilekomfort, skader inklusiv halthed samt manglende græsningsmuligheder. De vigtigste årsager viste sig ved besætningsbesøget at bestå af for små sengebåse med hårde, slidte måtter/madrasser samt forskellige problemer relateret til gulv, skrabere, spalter og gulvhygiejne samt manglende afgræsning. Relevante løsninger blev skitseret sammen med landmanden, dyrlægen og en bygningskonsulent, som beregnede omkostningerne til velfærdsinvesteringerne. De blev omregnet til årlige omkostninger ved 10-årige lån med en rente på 4 %. Forventede effekter på produktionen blev baseret på et literatur-review, som resulterede i, at ydelsen kunne forventes at stige 0.5-1.5 kg EKM/ko/dag. Haltheden blev anslået at kunne reduceres med 10-20 % som følge af velfærdforbedringerne. Velfærdsforbedringerne blev simuleret med udgangspunkt i besætningernes egne data og økonomien fremskrevet med Simherd-modellen.

På baggrund af projektets resultater konkluderes det at:

- De vigtigste velfærdsproblemer i rangeret rækkefølge var: dårlig hvilekomfort, skader (inklusiv halthed), manglende græsningsmuligheder
- Den vigtigste risikofaktorer identificeret ud fra den statistiske analyse var landmandens fokus på halthed og sengebåseindekset.
- Relevante løsninger til fjernelse/reduktion af disse risikofaktorer er at udvide landmandens bevidsthed og viden om halthed og forbedre køernes hvilekomfort.
- De vigtigste risikofaktorer identificeret ved besætningsbesøg var: For små sengebåse med hårdt underlag, problemer relateret til gulv, skrabere, spalter og gulvhygiejne samt manglende afgræsning.
- Relevante løsninger inkluderede: Båseudvidelser, blødt hvileunderlag samt individuelle gulv- og hygiejneforbedringer.
- Alle investeringer i staldforbedringerne viste sig særdeles profitable, så længe ydelsen steg minimum 1.0 kg/ko/dag, og ofte også ved mindre ydelsesstigninger, hvis halthed blev reduceret med 20 %. Afgræsning var forbundet med store omkostninger og risiko for reduceret ydelse og derfor ikke profitabelt

6. Baggrund for projektet:

Over the last decades there has been increasingly critical focus on animal welfare in livestock farming including dairy herds. It has led to new legislation on the housing and management of cattle being phased in. The focus on animal welfare in dairy farming is expected to continue because new welfare problems develop over time (e.g. lameness due to permanent housing and larger cows not fitting into the dimensions of the stable and equipment). Therefore, there is an ongoing need for investment – both in terms of housing facilities and in time and labour when management routines must be changed – in order to obtain or maintain the desired level of animal welfare.

In order to provide advice on how to obtain the most effective interventions for welfare improvements, it is necessary to know the importance of risk factors and interactions between them, the feasibility of interventions changing management or housing to reduce these risk factors, and the expected costs and benefits of these interventions.

On-farm welfare assessment schemes have been developed to score selected welfare problems and establish information on the overall welfare at herd level. Such schemes include animal-based measures or resource-based measures or both. It is generally accepted that animal-based measures assess the current welfare status of the animals more directly, whereas resource-based measures may be seen as risk factors for welfare problems in the herd. The animal welfare status in a herd is dependent on the management and the interaction between management, the system and animal (origin/genetic). It is therefore likely that risk factors related to the animal origin, management and production system can be identified beyond resource-based animal welfare indicators.

As animal welfare levels vary considerably among farms, it is important to understand the inter-dependency between these external factors and single or compound measures of animal welfare, in order to implement further actions and make dairy farming more viable. It has been proven in previous studies in Europe that such farm-risk factors for selected welfare problems can be identified (KilBride, et al. 2010; Dippel, et al. 2009; Munsterhjelm, et al. 2015) and tackled in specific implementation studies to improve single measures (Ivemeyer, et al. 2009; March et al., 2010). This also leads to economic benefits for farmers in terms of lower medicine usage,

improved production, reduced replacement rates and less time-consuming management procedures (Ivemeyer, et al. 2012). To our knowledge, risk factors for aggregated welfare scores have not yet been published for dairy cows, except in project reports

The results of the project will inform future advice at both national and farm level in terms of recommendations on the most effective interventions for improving animal welfare.

Investments and changes in management practices to improve production and reproduction in dairy herds has shown a large between-herd variation in their effectiveness (Ettema et al., 2011), and that is also expected to be the case for animal welfare improvements. Over the last three decades, costs and benefits of numerous management changes in dairy herds have been evaluated in research projects using SimHerd - a research-based simulation model developed by the AU (Østergaard et al 2005). A commercialised version of SimHerd has become a widely used tool in cattle health advisory services (Kudahl et al., 2014). AU has used SimHerd in several research projects to evaluate management measures to improve reproduction and production (Anneberg et al. 2014), but not measures to improve animal welfare.

Cost-benefit calculations will focus on the main welfare problems in Danish dairy herds, highlight relevant interventions to improve welfare, and analyse the expected costs and benefits of the suggested interventions. Cost-benefit analyses will therefore show whether the improved welfare will result in improved production to such an extent that it can cover the investment costs. This would be of great help to farmers when deciding which welfare investments should be implemented immediately and which ones could wait – especially in situations like we currently face, with oscillating milk prices forcing farmers to prioritise only the most necessary investments.

7. Beskrivelse af projektets formål, hypoteser samt materialer og metoder:

The overall purpose was to provide advice on the most cost-effective interventions to improve dairy cattle welfare by identifying the most important welfare problems in Danish dairy herds, their risk factors, possible interventions to improve welfare, and the costs and benefits of these interventions. This was obtained by:

- identifying and ranking risk factors associated with overall and selected welfare problems
- identifying the most effective and relevant interventions to solve the identified welfare problems
- estimating the expected welfare and economic effects, costs and benefits related to the implementation of these welfare improvements, including changes in management and investment in housing and equipment.

The welfare indicators of the WQ protocol measured in 60 dairy herds in the Index project, together with the novel indicators of the project, were made available in September 2016. They were analysed in October, and the most common and most serious welfare problems were highlighted. The most effective interventions to address these welfare problems were identified and described during the risk-factor analysis between October 2016 and February 2017.

Twelve herds from the Index project were invited to participate as case herds. These herds had

scored below 20 in one or more WQ-criteria, or below 40 in more criteria indicating serious welfare problems. Seven farms were included, the rest were closed or declined the invitation. The seven farms were visited between October 2016 and November 2016. The herd veterinarian and a housing advisor from SEGES took part in all visits because modification of buildings or equipment was necessary at all farms. The local risk factors behind the welfare problems were identified, and realistic & relevant scenarios were described to diminish risk factors and improve welfare. Expected beneficial effects on the production of the described scenarios were estimated based on literature studies, and the economic effects of the identified production effects were calculated for the specific herd in question using the SimHerd model. The costs related to the welfare improvements were estimated, and when major investments (such as renovation or modification of buildings or equipment) were involved, a housing advisor made calculations of the expected costs. The total costs and benefits of the relevant solutions to welfare problems were evaluated in a range of real herds.

8. Oversigt over projektets samlede resultater (herunder hvordan resultaterne bidrager til at opfylde projektets formål)**:**

Identification of welfare problems

Based on average WQ-criterion scores, the three main problem areas identified in all farms were: *comfort when resting* (29.7±21.4 points), *expression of other behaviours* (15.7±28.8 points), and *absence of injuries* (39.3±18.3 points). Furthermore, we identified 14 farms with multiple areas of concern (WQ-criterion level), of which severe problems (<20points) were identified in: *comfort when resting* (14 farms), *expression of other behaviours* (9), *absence of diseases* (5), *absence of prolonged thirst* (3). Additionally, those farms had serious problems (<40 points) in *absence of prolonged hunger* (4 farms), *absence of diseases* (6), *positive emotional state* (2) and *absence of prolonged thirst* (1). Based on these individual results from farms with multiple problem areas, some were approached to take part in WP3 (case study).

Analysis of risk factors behind welfare problems

Potential risk factors for differences in individual farm scores were investigated for the 60 farms from the index project. Separate models were used to describe data relating to each of the eight welfare quality measure scores as follows: *time to lie down* (linear model at animal level), *colliding* (logistic regression at animal level), *lying outside cubicle* (logistic regression at herd level based on >3 %. vs <=3%.), *dirty lower legs, hind legs & udder* (all logistic regression at animal level), and *integument & lameness* (both ordinal logistic regression with three categories at animal level). For all analyses at animal level, farm was used as a random effect. Three additional linear regression models were also used to describe the three relevant criteria scores at herd level: comfort when resting, absence of injuries, expression of other behaviours (only included the 14 farms with access to pasture). For each model, a subset of the following possible risk factors were chosen based on biological plausibility and avoidance of direct confounding: *claw trimmings per year* (categorical: <3 vs. >=3), *trimmer* (categorical: professional only vs. farmer +/- professional), *ECM* (numeric; as reported by the farmer), *replacement rate* (numeric; as extracted from the database), *mean lactation number* (numeric; as extracted from the database), *production type* (categorical; organic vs. conventional), *herd size* (numeric), *main breed* (categorical; dairy vs. Jersey vs. cross), *lying assessment* (categorical; acceptable vs. unacceptable from index data), *floorage assessment* (categorical; acceptable vs. unacceptable from index data), *bedding assessment* (categorical; acceptable

vs. unacceptable from index data), *farmer lameness awareness* (categorical; absolute difference between the farmer and WQ assessment of *lameness prevalence* >5 percentage points vs. <= 5 percentage points), and *observer* (categorical; set of observers from group A vs. group B). For each outcome, the subset of chosen risk factors were selected using a forwards inclusion algorithm based on Akaike's Information Criterion (AIC; Akaike, 1973). All modelling was done using R (R Core Team 2016), with mixed models implemented using the lme4 package (Bates et al., 2015) and ordinal logistic regression models implemented using the ordinal package (Christensen, 2015).

Between 1 and 3 significant risk factors were identified for each measure outcome. Cows in farms with more frequent claw trimmings took longer to lie down (p=0.002), Jersey farms were associated with reduced time to lie down (p=0.024), and at farms with cows that took longer to lie down, the cows were more likely to collide with the equipment (p=0.010). Cows on farms with worse bedding were more likely to collide with the equipment (p=0.041) and more likely to be lame (p=0.004). Cows in larger herds were less likely to have dirty hind legs (p=0.013) and dirty udders (p=0.019). Farms with younger cows on average were more likely to have integument problems (p=0.007), and farmer lameness awareness was negatively associated with lameness in the cows (p=0.018). The observer effect was significantly associated (p-values between <0.001 and 0.044) with all measure outcomes, except dirty hind legs. For the criteria outcomes, no significant risk factors were identified for comfort when resting, but acceptable bedding was significantly positively associated with criterion scores for absence of injuries (p=0.003). Expression of other behaviours was positively associated with organic farms (p=0.005), and negatively associated with an acceptable lying score (p=0.045). There was a significant association between observer and absence of injuries (p=0.004).

Identified welfare problems on seven case herds

When ranking welfare problems at the seven case farms, the main welfare issue was *comfort when resting*, where all farms had a WQ scores below 20. The welfare problem ranked second was *expression of other behaviours* (5 of 7 farms were non-grazing systems), and *absence of injuries* (6 farms below WQ 40), *absence of hunger* (3 farms below WQ 40), *good human-animal relationship* (2 farms below 40) and *absence of thirst* (1 farm below 20) followed. The herds were visited before the main risk factor analysis was carried out, and therefore the reasons behind the welfare problems were identified locally as far as possible at the visit. In most cases, housing facilities were more than 20 years old, and provided cramped cubicles, only every second of which was occupied due to lack of space, creating an overstocking situation (Fig. 1). The majority of mats/mattresses were old, hard and often spoiled. Surfaces of loafing areas were often slippery or dirty. These conditions were assessed to be the main reasons for the reduced welfare in terms of injuries and comfort when resting. Additionally, cows had no access to pasture on five out of seven farms, resulting in low scores for expression of other behaviours. The welfare problems related to hunger (several cows with low body condition scores) were not clear, but seemed to have three different reasons: 1. Paratuberculosis, 2. Too little feed and 3. Wrong feed composition. Poor human-animal relationships on two farms were related to how roughly the cows were treated by the personnel. Thirst was related to insufficient access to water.

Fig. 1. Only every second cubicle is occupied when cubicles are too narrow

Costs

The costs of several different improvements were estimated individually for each farm. Table 1 lists the 2017 prices of relevant investments in buildings, estimated by the housing consultant. Costs for grazing were based on Lund et al. 2008. Enlarging the cubicles was relevant on all farms, and this implied that either the total number of cubicles had to be reduced, or other individual solutions should be found in order to maintain the number of cows (e.g. by enlarging the cow barn or utilising other buildings). Therefore, two or three different scenarios were normally put forward per farm – one with a reduced number of cows, and others with individual solutions to maintain or increase the herd size.

Table 1. Prices in 2017 of investments contributing to an improvement in comfort when resting, a reduction in injuries (including lameness) and to enable grazing

Subject of investment	Cost/investment
Increased width of cubicle incl. moving neck rail	1,755 Dkr/cubicle
Increased length of cubicle	2,400 Dkr/ cubicle
Enlargement of cow barn to compensate for fewer cubicles	20,035 Dkr/ cubicle
Mattresses replaced by sand incl. new slurry pump	2,990 Dkr/cubicle
New soft mattresses	1,200 Dkr/cubicle
Additional space around water troughs	7,500 Dkr/trough
Water trough	7,000 Dkr/trough
New slatted floor	535 Dkr/m2
Rubber layer on concrete flooring	500 Dkr/m2
Scraper-robot to clean slats	95,000 Dkr
Establishing feeding spaces without scraper-disturbance	1,018 Dkr/space
Establishing a separate welfare area for early-lactating cows	3,500 – 33,269 Dkr /area
Establishing pathways to pasture	225 Dkr/m2
Establishing pathways to pasture according to report	467,500 Dkr pr farm
Total costs of pasture 0.1 Ha /cow	352 - 845 Dkr/ cow / year

The costs for hunger were not estimated, as the contributing factors varied widely, were quite complicated, and called for more intense studies. In addition, they were more or less solved between the two visits. Costs for improving the human-animal relationship were set to zero, as this only involved a change in management.

Costs for all investments were recalculated into total annual costs and costs per cow using a payback period of 10 years and an interest rate of 4%. In two scenarios where investments involved the construction of new buildings, a payback period of 30 years was applied.

Benefits

Production effects of improved comfort when resting and fewer injuries (here interpreted mainly as injuries related to cubicles and the floor) were estimated based on findings in the literature. We assumed that by increasing cubicle size, more cows would have access to them since every cubicle would be available, not just every second cubicle. We also assumed that by changing old hard mats/mattresses for soft mattresses or sand we improved comfort when resting, increased lying time, reduced the number of injuries, and thereby reduced lameness. The effect of improved production related to reduced lameness was well documented and included in the SimHerd model used for calculating the benefits (Ettema et al., 2010, Andreasen & Forkman, 2012). We assumed a reduction in lameness of 10% or 20%. However, it is more difficult to find documentation for the production effect of increased comfort when resting and increased lying time. Older barns, hard-resting material, and over-stocking can lead to lying time reductions of 0.5-1.5 hours per day (Ito et al., 2014; Fregonezi et al., 2007; Krawzel et al., 2012; Rushen et al, 2007, Tucker et al., 2003, Tucker et al. 2009). Each one-hour reduction in lying time was associated with 1.7 kg ECM/day in a study by Grant et al. (2011). However, the association between lying time and milk yield is ambiguous – high-yielding dairy cows can have a shorter lying time than low yielding cows in the same herd because they spend more time eating (Bewley et al, 2010, De Vries et al., 2016, Fregonesi et al 2007, and Norring et al. 2012). However, when combining studies of overstocking effects on lying time with studies of overstocking effects on production, a reduction in milk yield of 0.57 kg ECM/day per 10% increase in stocking density can be expected **(**Bach et al., 2008, Grant et al., 2011, Fregonesi et al., 2007). Combining these effects, we assume that we can reduce overstocking by 10-30%, which would result in an increase in milk yield of 0.5 – 1.7 kg ECM/day. Finally, based on the variation within the literature, we considered it relevant to perform a sensitivity analysis and simulate three levels of milk yield improvement related to improved welfare (0.5, 1.0 and 1.5 kg ECM/cow/day) and two levels of lameness (10% and 20%). In total, six scenarios of benefits from improving welfare were simulated for every cost scenario, using price levels from February 2017.

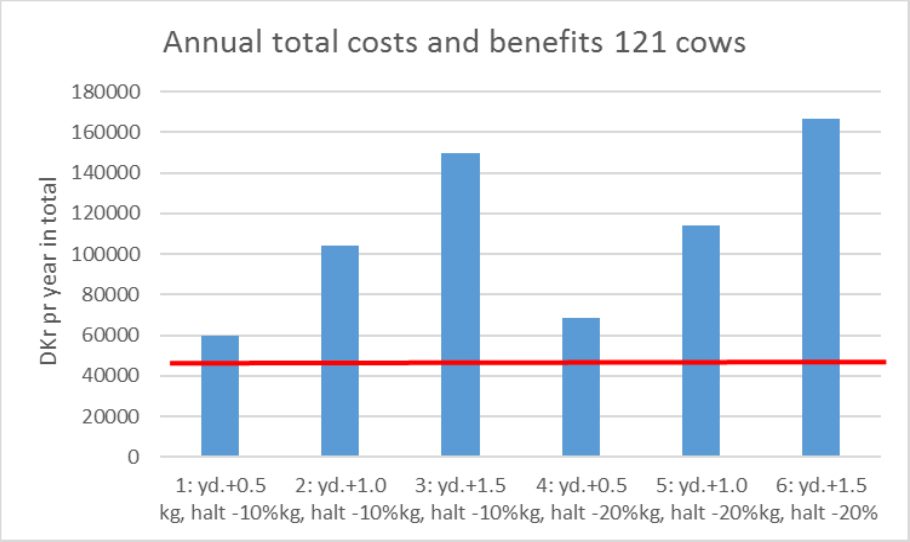
Production-related benefits from improving the cows' ability to *express other behavior* through grazing was estimated to be zero in the best case, with non-intense grazing of 300 FE per cow per year (Lund et al., 2008). More intense grazing of 875 FE per cow per year was estimated to reduce milk yield by 3%.

The benefit of *absence of hunger* was not estimated in this study, because the risk factors behind the problem differed between farms and could not be clearly defined.

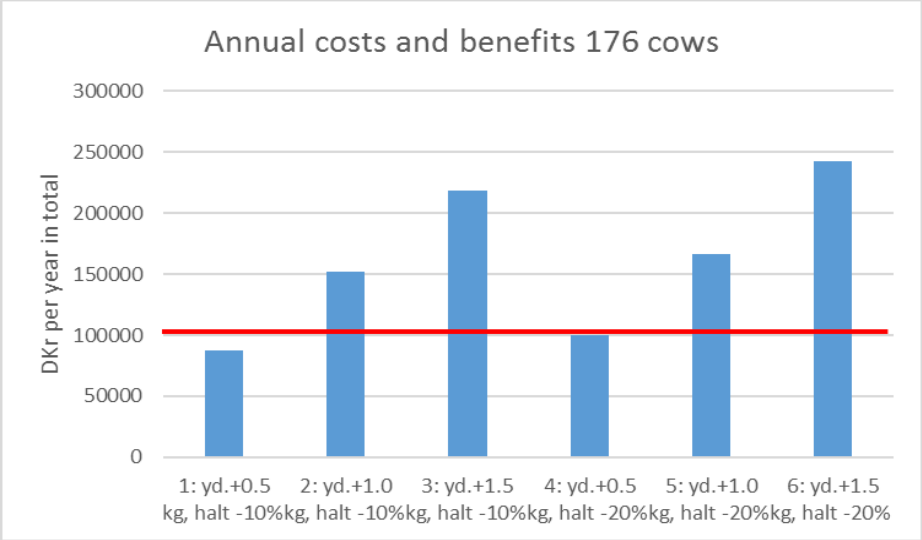
The benefits of a better human-animal relationship on production were also not estimated in this report because knowledge about the effects on production are poorly documented. However, a positive result would be expected. Calves that were stroked in the first weeks have an increased growth rate and shorter avoidance distance as cows (Lürzel et al., 2015). An increased growth rate will probably result in increased milk yield in the first lactation. Although not directly comparable, nervous cows are found to have a lower milk yield (Hedlund & Løvlie, 2015).

Costs versus benefits

Figure 2 shows examples of the scenarios simulated on one of the case farms where cubicles are enlarged, resulting in room for fewer cows (Fig 2a), and another where the cow barn is extended to compensate for the loss of cubicles (Fig 2b). The figure shows that the investment in Fig 2a is profitable (blue bars higher than the red line) in all cases, and an additional enlargement of the barn to compensate the reduced number of cubicles is profitable if milk yield increases by at least 1 kg per day.



2a



2b

Fig 2. Total annual costs (red line) and benefits (blue bars) on a case herd after improvements of comfort when resting (giving higher milk yields) and reduction of injuries (including lameness) by improving cubicle size, bedding material, creating a welfare area for early-lactating and injured cows and buying a scraper-robot to increase hygiene. In Fig 2a, herd size reflects a reduction in the number of cubicles due to increased width, and in Fig 2b, this reduction is compensated by enlarging the cowbarn.

By summing up all the scenarios in the seven case herds, the results (Fig 3) show that if milk yield increases by 1.5 kg/cow per day, all scenarios are profitable. If it increases by 1.0 kg, the majority of scenarios would be profitable. This was also the case if milk yield increased by only 0.5 kg and lameness was reduced by 20 %. Even the most pessimistic scenario with a milk yield increase of 0.5 kg/cow/day and a reduction in lameness of 10 % in some herds resulted in profitability.

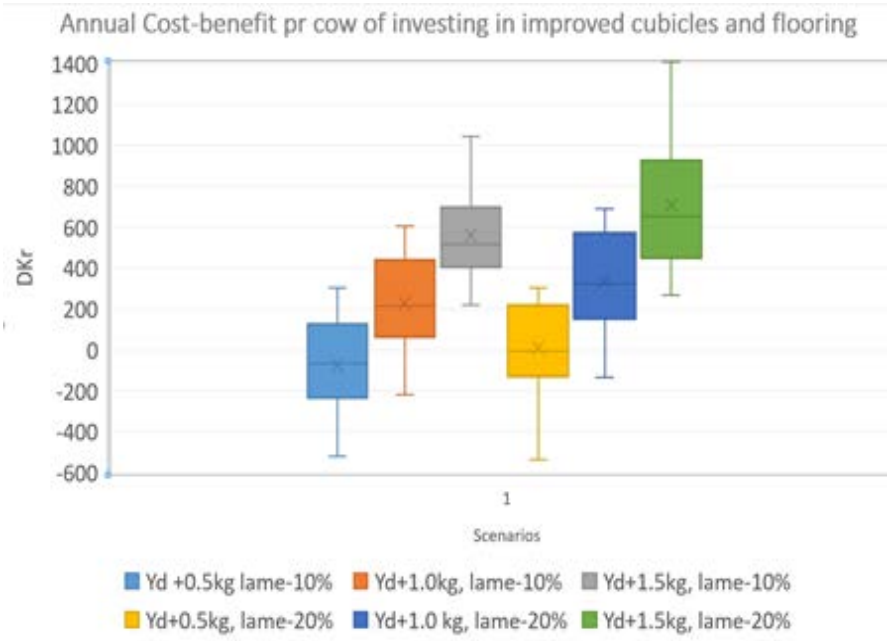


Fig 3. Profitability of six scenarios of welfare investments on seven farms to improve comfort when resting and reduce injuries including lameness. Profitability is calculated as annual increased gross margin per cow minus annual costs per cow of the investment.

Assessment of profitability of grazing was based on the report by Lund et al. (2008) suggesting that in the best case, non-intense grazing with 300 FE/year/cow, the milk yield was not affected, while intense grazing (875 FE/year/cow) resulted in a milk yield reduction of 3%. A reduction in profitability of between 352 to 845 Dkr/cow/year is thus expected.

9. Diskussion af projektets resultater:

The overall purpose of the project was to provide advice on the most cost-effective interventions for improving dairy cattle welfare by identifying the most important welfare problems in Danish dairy herds, their risk factors, possible interventions to improve welfare and the costs and benefits of these interventions.

The project points to three specific areas of reduced welfare in dairy cattle: *comfort when resting, expression of other behaviours,* and *absence of injuries*. These three areas of concern are affected by a number of risk factors. Although significant, the magnitude of the effect of many of the risk factors was quite small, most notably for herd size. The number of comparisons made is quite high so even the significant results should be treated with caution.

This being said, there are still a number of interesting and biologically relevant results. The two most promising risk factors are the effect of the bedding quality and farmer lameness awareness. Both of these are associated with the level of lameness, which is one of the main welfare outcomes known to affect the milk yield. Although we have only demonstrated an association, it is not unreasonable to assume a causal relationship in these two cases. An important factor in the implementation is the likely cost. Both increasing the quality of the bedding by using sand, or when that is not possible mattresses, as well as increasing farmer awareness are among the less costly actions, and do not necessitate rebuilding of the stables or preparing or acquiring additional outdoor areas.

Improvement of the second area of concern, *expression of other behaviours*, is likely to be more complex, since the main factor affecting this (and the way it is measured) is access to grazing. However, we showed that farms that scored highly on this seemed to score relatively badly on lying condition indoors, and that the farmers also showed a tendency for higher lameness awareness. Whether this implies that the famers' have implemented 'pasturing of cows' as a strategy for tackling lameness requires further investigation.

Our results also demonstrate the importance of including any potential observer bias within comparative analysis of different farms. There was a strong association between the identity of the observer and the results, with the most likely explanation being a difference in the way that the observers scored the animals. This effect is a recognised problem with these types of data.

The most severe welfare problems on the seven visited farms were: *comfort when resting*, *expression of other behaviours* and *absence of injuries*. Some of the risk factors behind these were quite obvious: cubicle size, bedding quality, floor quality and hygiene. However, other more indirect and less visible risk factors will probably also affect these welfare criteria, but this would require a more intense study of the farms' structure. If the identified risk factors are removed/reduced, there is a risk that unidentified risk factors will appear to be the next limiting factor for improved production.

Based on the cost-benefit analysis, the suggested welfare investments are likely to be very profitable in terms of improved *comfort when resting* and *reduced injuries and lameness*. However, the estimation of potential production effects includes some uncertainty. In particular, knowledge of production-effects of poor comfort when resting (e.g. lying time) was scarce and had to be assessed by combining studies with different results. This was addressed by simulating different levels of effects and by applying reasonably conservative estimates. These estimates were also chosen to avoid double-counting effects. The level of increased production results used in the simulations is therefore considered to be realistic (or perhaps even excessively small) as long as no other welfare problems are limiting factors for production increases.

Another factor contributing to uncertainty are prices. From sensitivity studies we know that the milk price is the most important parameter when assessing income in a dairy herd. Fluctuating milk prices, as is often seen following the quota-stop, can therefore be crucial to the profitability of the welfare investments.

Costs for all investments were based on a payback period of 10 years, except in two cases where new buildings were included. This long-term perspective means that farmers in deep financial

crises will probably be unable to obtain the necessary loans, and farmers close to retirement may not be interested in making these investments unless a handover to the next generation is planned.

The WQ criteria *expression of other behaviours* is mainly linked to pasture access. Grazing was estimated not to be profitable, because it only included costs and no production increases. However, the possibilities for grazing also depend on available fields around the farm, extra labour and the farmers' attitude. Another perhaps more feasible way to improve the cows *expression of other behaviours* could be access to nearby fields with simultaneous access to full feed ration on an external feeding table. Although grazing might not be cost-effective, it has a positive effect on animal welfare, and that alone could provide a good reason to consider it as an option, as with the two conventional farmers in the project who planned to start up grazing in 2017, mainly hoping for better claw health.

The less frequent welfare problems in the seven herds were down to individual factors, and the costs and benefits of improving them were impossible to estimate within the scope of this project.

10. Konklusion og perspektivering (herunder forslag til opfølgende projekter)**:**

Conclusions

- According to our data analysis, better bedding and increased farmer awareness of lameness are potentially promising measures against welfare problems. They are not costly, can reduce lameness and increase milk yield, which will facilitate the investments on the problem farms.
- Allowing more expression of other behaviour for cows in the majority of farms is a more complex challenge, which needs a further in-depth analysis of additional factors.
- Results of the risk-factor analysis agreed with findings on the seven visited herds where the main welfare problems were highlighted by the Welfare Quality® protocol to be: *comfort when resting, injuries* and *expression of other behaviours*.
- The most probable reasons for the welfare problems were: Too small cubicles with hard, old mats or mattresses and varying suboptimal flooring conditions (spoiled slats, slippery floor, and poor hygiene) combined with no grazing.
- Relevant interventions to solve the welfare problems consisted mainly of enlarging cubicles, changing bedding into soft mattresses or sand, establishing welfare areas for injured and early-lactating cows, solving the different floor-problems and letting cows on pasture.
- Cost-benefit analysis evaluated all the interventions that improved the comfort when resting and reduced injuries including lameness to be very profitable as long as a milk yield increased by a minimum of 1 kg/cow/day. For many interventions, it was also profitable with a milk yield increase of only 0.5 kg/cow/day, especially when lameness was improved more than 10%. Improving access to grazing was not found to be profitable.

Perspectives

The literature study uncovered a scarcity of studies on the effect of improved resting comfort, increased lying time and fewer lesions on production, and more studies are needed to document the effect more systematically. More knowledge in this area might be a motivating factor for farmers to improve animal welfare if they can be even more confident about the profitability, and it could be extremely interesting and relevant to carry out intervention studies where the effects of

improvements on production can be estimated directly.

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11. Redegørelse for hvordan projektet og projektets resultater har været eller forventes offentliggjort: The project was presented at the annual VID-meeting Nov. 2016 and an abstract has been submitted to the International Conference on the Assesment of animal welfare at farm level and group level (WAFL, Sept. 5-8. 2017, Wageningen). Furthermore, a presentation was held at the Welfare Quality Network Meeting in Helsinki, Dec. 2016.

The results will be presented in individual reports to farmers of the case herds and in farmers' magazines.

Two international publications will submitted preferably to Journal of Dairy Science/Preventive Veterinary Medicine:

- Risk factors for welfare problems in dairy herds
- Costs and benefits related to welfare improvements in dairy herds.