Critical Discussion of Several Published Manuscripts Concerning Free-Stalls in Relation to Dairy Cattle Welfare

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This paper was inspired by the Presant Lecture given by Dan Weary, a prof. at UBC, in the fall of 2006. A self-professed cattle-fan fan, Michael chose to combine his enthusiasm for these animals with his interest in statistics, meticulously comparing the experimental approaches of Weary's group with the epidemiological approaches used by Dr. Nigel Cook and co-workers (Wisconsin).

1. Introduction

1.1 Scope

The dairy cow is an animal primarily selected to produce significant amounts of milk for human consumption. The intensification of these selection pressures and the changing economics of dairy farming have impacted many Canadian farmers. There are currently 15 000 Canadian dairy farms with slightly over 1 million animals; compared to 32 000 farms with 1.4 million animals 15 years ago (CDIC, 2007). The dairy industry has seen a concentration of animals on fewer farms with increased stocking densities. However, even with a decrease in total animals there has been a 10 million litre increase in production over the same time frame (CDIC, 2007). The United States of America (USA) have experienced similar trends with a decrease of 1 million animals to 9 million cows but an increase of 13 billion litres of milk (USDA, 2007). A small decrease in welfare could result in a significant amount of suffering given the immense production pressure and number of animals utilized in the dairy industry.

The increase in herd size has been offset by changes in management practices in an effort to minimize an increase in workload. The free-stall barn has gained popularity due to its ease of operation, flexibility and ability to cope with high stocking densities. However, there is a larger association with hoof injuries and diseases leading to lameness in free-stall barns compared to tie-stall or pasture managed cattle (Faye & Lescourret, 1989). As herds intensify and free-stall systems gain popularity, cattle will begin to show the signs of new welfare problems. The pain and discomfort caused by lameness is a serious problem for cattle existing in intensive dairy production (Whay et al., 1997). The welfare challenges surrounding lameness offer many avenues of exploration. The focus of this paper will be on the effects of free-stalls on the behaviour and prevalence of lameness in dairy cows.

1.2 Research Group Backgrounds

The primary focus of the manuscript review will be the publications from the Animal Welfare Program, Faculty of Land and Food Systems, University of British Columbia, Canada. The research team has been directed by Dr. Daniel Weary for the past 10 years. Dr. Weary is a professor of agroecology and Canadian Industry Research Chair in Animal Welfare. The Animal Welfare Program has focussed the majority of its research on dairy cattle because very little research is being conducted elsewhere in the world, UBC has extensive research facilities with the Dairy Education and Research Centre and dairy producers significantly support the program.

The Program has expanded its research into beef cattle, pigs, as well as laboratory, companion and wild animals. The past 10 years has seen 114 undergraduate and graduate students, postdoctoral fellows, research associates and visiting academics collaborate on research endeavours (UBC, 2007).

A comparison research group was selected from the Department of Medical Sciences, School of Veterinary Medicine, University of Wisconsin, USA. The primary researcher is Dr. Nigel Cook who administrates the Cow Comfort and Well-Being Program and is an assistant professor of clinical medicine in farm animal production. The primary research assesses the health and behaviour of dairy cows in relation to the environment in which they are kept. Ongoing areas of interest are the effect of stall design on a lame cow's behaviour, the effect of heat stress on stall use and lameness, the interrelationships of hoof lesions and the air quality in livestock buildings, the effect of pen movements on transition cow health and the risk factors of disease in transition cows (UW, 2007).

2. Discussion of Weary Manuscripts

2.1 Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows (Tucker et al., 2003).

Two experiments were conducted. The 12 cows in experiment one and 12 cows in experiment 2 were individually exposed to sand, sawdust or a geotextile mattress in the free-stall. There was a seven day adjustment phase, six day (nine day in experiment two) restriction phase (divided evenly amongst the three treatments) and followed by two days of free choice of treatment stalls. Time spend lying down in stall, time spent standing in stall and number of lying events were recorder from video tapes of the last 24 hours (48 hours in experiment two) of the adjustment phase, each of the restriction phase treatments and the free choice phase. The objectives were very well stated in this article: “Our objectives were to determine: 1) the preferences for stall surface, 2) how the different surfaces affect stall usage when animals are restricted to a single option for a few days and, 3) the relationship between these two measures.” No formal predictions or hypothesis was stated regarding the foreseen outcome of the objectives. I believe that the first two objectives can be met by the experimental design. However, the third objective is redundant. One would be choosing to measure these variables in the same experiment because they are believed to have a relationship. The relationship would be covered in the discussion regardless, making its appearance in the objectives superfluous. A hypothesis concerning the relationship would alleviate my objection to its inclusion.

The layout of the testing pens for the two experiments was excellent. There were three animals tested in individual pens at one time and the design was suitable to assess the free-stall surface preferences of the cows. However, I believe two confounding variables exist in the experiments. The first is prior exposure to free-stall surfaces. In Experiment One all cows were housed on sawdust bedding, while in experiment two all cows were housed on sand before the commencement of the trials. Previous exposure could cause bias, hence the strong preference for sawdust ($P<0.01$) in experiment one and the lack of preference ($P>0.2$) in experiment two. Restricting previous exposure to one treatment or equally distributing previous exposure between the three treatments would balance the bias and allow for comparisons between the experiments. The second confounding variable is that in experiment one all cows were open (not pregnant) and not lactating, while in experiment two all cows were pregnant. The differences cause difficulty in comparing the results of the two groups. Even within Experiment Two it is not stated if pregnant cows were balanced over the 279 day gestation period. I believe choosing open and pregnant and balancing on gestation would aid in minimizing the bias.

Friedman's rank test was used to determine preferences while t-tests were used to compare differences in behaviour. While Friedman's accounts for repeated measures I believe a general linear mixed model would more accurately accounted for the variance in the data for both preferences and behavioural differences. The random effects could have included focal cow, period in which testing occurred and parity (number of birthing events). I would include parity as an accumulation of experiences over time to different surfaces as opposed to age because age is biassed in dairy herds. If a cow is not producing offspring it is culled. An increase in statistical detail is needed to fully satisfy my concerns.

The manuscript concludes that cows prefer, lie more, lie more often and stand less in free-stalls that have soft surfaces. The previous study of Weary and Taszkun (2000) found that mattresses increase the incidence and severity of hock lesions. In an effort to decrease labour loads the increasing use of geotextile mattresses in free-stall barns is apparent. The implications for dairy cattle welfare is that ever increasing numbers of cattle are being exposed to mattresses when these free-stall surfaces may in fact be causing new welfare concerns by decreasing lying times. Cows spend a significant amount of time lying down and are quite motivated to lie. A fasted cow deprived of lying for three hours will forgo eating to lay (Metz, 1985). I feel with the slight modifications mentioned above the current methodology could be utilized for future welfare investigations.

2.2 Free-stall dimensions: effects on preference and stall usage (Tucker et al., 2004).

Preference testing and video recording was conducted with four different free-stall widths similar to experiment one of Tucker and colleagues (2003) for 15 Holstein cows, all in the last eight weeks of pregnancy. The second experiment built on the first but tested animals during commercial conditions with 27 lactating Holsteins. Over a total of nine weeks groups of nine animals were tested in a Latin square design reflecting the commercial range of three stall widths. Behaviour was recorded for last 24 hours of the first and third weeks. Commercial conditions were utilized in order to assess the impact on milk production (MP) and stall cleanliness. "The objective of the two experiments described in this paper was to assess the impact of free-stall size on dairy cattle behaviour, specifically stall usage and preference." The objective is clear, concise and testable with the current methodology. However, no formal hypothesis is stated regarding the predicted outcome of the treatments.

The experimental pens were suitable for testing purposes. It was important and good that it was stated the assignment of the first treatment for all animals was random because this greatly increase the power of the experiment. I feel there was a huge improvement over the first paper with all cows being in the last eight weeks of pregnancy for experiment one and in experiment two the animals were balanced on parity and days in milk (or stage of lactation). The crossover design of the second experiment would keep the variance lower and increase power by allowing each animal to partake in each treatment.

A general linear model was utilized to analyse the data. I believe this was a great improvement over the previous paper but a general linear mixed model could have accounted for random effects including, treatment period, focal animal (in experiment two in the group) and stall location in the barn. The accounting of these random effects could provide a refined estimate of the associations between the variables. Body weight and the presence of hoof or hock lesions would have been covariates that could have aided in the interpretation of the behavioural data. It was stated the all interaction terms were explored and found to be not significant.

The authors conclude that cows spent more time lying ($P<0.05$) and less time standing with two legs in wider stalls ($P<0.04$). There was no clear preference ($P>0.2$), no effect on MP ($P>0.3$) but the wider stalls were more likely to be soiled ($P=0.04$). The main welfare implication of this study is that no clear preference was shown for wider stalls even with an increase in lying behaviour. The authors postulate that since cattle are decedents of plain dwelling animals they may be strongly focussed on the evaluation of lying surfaces. It would be unlikely that plain animals would have to consider spatial constraints. Implications for dairy cattle welfare may be that welfare is compromised more by poor surface substrate compared to narrow stalls. The experimental design minimized confounders through the balancing of these variables. I believe the incorporation of other covariates, mentioned above, would allow for increase confidence when drawing causal associations from statistical association.

2.3 Bedding on geotextile mattresses: how much is needed to improve cow comfort (Tucker & Weary, 2004)?

The methodology used for data collection on fifteen pregnant and not lactating Holstein cows was similar to that used in experiment two of Tucker and colleagues (2003). One variation was that all free-stalls had geotextile mattresses with either zero, one or seven and a half kilograms of sawdust placed on its surface. The objective was not as clearly stated as in previous articles. The objectives can be articulated by summarizing the final introductory paragraph; to test the effect of geotextile mattresses with varying quantities of sawdust on the preference, lying, standing and head swinging behavioural elements. The authors did not hypothesis regarding the expected outcomes of these objectives.

A major confounding component of this experiment is previous exposure to the test surfaces. Previous to the experiment the animals were housed in a barn that had 75% of its free-stalls with deep bedding of either sand or sawdust and 25% of stalls where the mattresses with roughly one kilogram of sawdust covering the surface. There is no way to know how this might impact the results. The problem could have been resolved by ensuring either no previous exposure to the mattresses or that all animals are exposed equally. Parity was recorded on the cows; excellent. However, stage of pregnancy was not recorded which I believe should be taking into consideration when interpreting the results.

The authors utilized the PROC IML (interactive matrix programming) in SAS for data analysis. This is an improvement over past articles because IML allows for the inclusion of random effects in the model with an autoregressive correlation structure to account for repeated measures. One drawback of this modelling analysis is that the data's standardized residuals must be normally distributed thus requiring the log transformation of their data. The PROC GLIMMIX procedure in SAS alleviates this constraint and may be preferable. It was superb to see that the order of treatment was used as a random effect but parity and focal animal could also have been included to account for further sources of variance.

The discussion was introduced exceptionally. It explained thoroughly the framework by which the remaining text would follow. Cows preferred ($P<0.05$), lay more ($P=0.01$), stood less ($P=0.03$) and swung their heads less ($P<0.05$) when on the heavily bedded mattresses. Many producers have built new barns with geotextile mattresses to reduce labour and previous studies have found that other surfaces are preferred to mattresses. However, this study tries to address and improve the welfare of animals currently housed on the mattress. I feel the experimental methodology answered the objectives and is quite applicable for future welfare research.

2.4 Freestall maintenance: effects on lying behavior of dairy cattle (Drissler et al., 2005).

Three experiments were carried out using the same twenty-four lactating Holsteins in each. The animals were assigned into new groups at the commencement of each experiment.. The first experiment characterized the change in distribution of sand bedding over a 10 day period while video recording lying and standing behaviour. The cows were placed in two groups of 12 and housed in two pens with 12 free-stalls in each. The second experiment imposed four concave bedding depths, twice daily, for two days each onto four groups of six cows. Cows were recorded while lying time, number of lying bouts and bout duration was assessed. Experiment three was similar to experiment two except the four bedding depths were level and not concave. The introduction stated: "The objectives of the current study were, 1) to understand how the level of sand bedding in a free-stall changes after bedding is added, and 2) to measure how these changes in bedding affect lying behaviour of dairy cattle. No hypothesis was stated.

All cattle groups were balanced for parity and days in milk. The advantage is that these covariates are not confounding the results with the lesser disadvantage of having the animals assigned to the groups. The lack of group and treatment randomization caused a decrease in the power of the experiment in which the latter could have been avoided. The Latin square design for experiments two and three allowed for each animal to be its own control and minimizing the residual variation.

The descriptive statistics used to develop the sand distribution from the grid points was excellent. PROC IML was used to analyse experiments two and three; however, there was no mention of what random effects or repeated measures statements were included in the model. I believe including group and treatment period as random effects would be valuable in further explaining residual variation. The data for the later two experiments was analysed in groups with n=4. It may have been conducted in this manner because the treatments were assigned to the group but it seriously limits the data's interpretation to the individual cow level. A statistical association at the group or ecological level can not be accurately interpreted to the individual level (Robinson, 1950).

The authors conclude that sand depth in deep bedded free-stalls trended to decline over time ($P=0.16$) and dairy cattle respond to the decline by lying for less time ($P<0.03$) and lying less often ($P<0.01$). They feel this indicates a decrease in cow comfort in poorly bedded stalls. Previous studies have found that the deprivation of the opportunity to lie down acutely increases cortisol, decreases the response to ACTH challenges and decreases circulating growth hormone (Fisher et al., 2002). However, I still must caution the inferences of individual cow comfort when the statistical association is based on pen level behaviour. I believe this would be an acceptable approach for further research if 1) the inferences regarding comfort were with respect to pen or group comfort, or 2) the data were analysed at the individual level with n=24.

2.5 Effects of pasture on lameness in dairy cows (Hernandez-Mendo et al., 2007).

The experiment examined 72 Holsteins in 18 groups of four animals. Nine groups remained in the free-stalls while nine groups were allocated to the pasture diet and environment for four weeks. Gait analysis and lameness were assessed weekly by reviewing video recordings of the cows walking down a grooved concrete corridor. Lying behaviour was assessed with continuous monitoring using data loggers attached to the cows' rear leg. The objectives were clearly stated, "To test whether a relatively short period on pasture would improve the gait of lame cows, determine which elements of gait are most affected and the effects on lying behaviour." The only hypothesis was for the primary objective, "Time on pasture may reduce lameness of cows by providing access to more comfortable standing and lying surfaces."

I feel the design of this experiment was outstanding. All groups were balanced for gait score, days in milk, parity, milk production and body weight. To accomplish the balancing the groups were assigned but the treatment to the group was randomized. The weekly video analysis of lameness and gait score was conducted by one trained observer that was blind to all treatments and had a high intra-observer correlation. The lameness and gait score methodology had been validated by Flower and Weary (2006). My only suggestion might be to restrict the group members to the treatment animals only. For management reasons each of the 18 groups consisted of four animals in the project and eight animals not in the project. Since no data was collected on the other eight it would be impossible to assess the effect they may have had.

A general linear model was used to analyze the data. However, the statistical program utilized was not discussed. The data was once again analyses at the group level and I caution its use for reasons explained in the preceding article referring to the seriously possibility of individual misinterpretation. It was stated that group analysis was conducted since the treatments were randomly assigned to the group. Even though valid, the use of a general linear mixed model with group as a random effect would allow for the appropriate individual analysis. It would be wise to include focal cow and treatment period in the random effects as well.

During this project gait scores improved ($P<0.05$) with the reluctance to bear weight ($P<0.001$) showing the most dramatic improvement during the four weeks treatment of pasture. The low incidence of lameness for cattle on pasture compared to a free-stall system is well established (Leaver, 1988). The current experiment has shown that with as little as four weeks on pasture a lame cows can show rapid improvement. The shift from indoor stalls to outdoor pasture is a complex mixture of dietary and environmental variables. Further research is warranted to ascertain if the benefits would be maintained when the animals return indoors. I think it would also be worthy to explore if cows would work to gain pasture time. Lying time is universally considered to be an indicator of cow comfort (Leonard et al., 1996). However, in this study lying time decreased ($P<0.01$) but the number of lying bouts increased ($P<0.001$) indicating that cows may prefer to stand on comfortable surfaces. The authors pointed out that the current study may refocus cattle welfare research from assessing and measuring lying surfaces to whether or not the surface is appropriate for standing.

3. Discussion of Cook Manuscripts

3.1 Effect of free stall surface on daily activity patterns in dairy cows with relevance to lameness prevalence (Cook et al., 2004).

The prevalence of lameness was ascertained by a one time assessment of 3600 dairy cows in 12 herds. There were six herds with sand and six herds with mattresses as the surface in the free-stalls. Within each herd 10 cows in a high milk producing pen were selected for 24 hour video analysis of standing, lying, eating or drinking, with the location within pen and duration noted. The aim was clearly stated and suitable for the projects scope, "To determine differences in daily activity patterns for high yielding dairy cows housed in free-stall barns utilizing either sand or mattresses." They did not specifically make reference to lameness in the objectives but their introduction makes clear they believe differences in behaviour will be due to lameness caused by the different housing conditions.

The authors preformed an epidemiological cross-sectional study. Very specific inclusion and exclusion criteria were specified for herds and individual animals in the paper (very detailed description can be found on page 2913). Before data collection began analysis of stall dimensions, brisket board depth and neck rail height and were found not to significantly vary between herds ($P<0.001$). During the study the authors examined the behaviour of 73 not lame cows to enable them to clearly look at the effects of lameness on behaviour regardless of free-stall surface treatment. My only concern with the study design is that one can not infer causation from a cross-sectional study. It may be more effective to monitor 500 cows for six months because with a cohort or case-control study we may have the temporal component needed for causation.

The data was analysed with a general linear mixed model which included the random effect of farm and fixed effects of number of stall rows in pen, stocking density, curb height, milking frequency, parity, milk yield, days in milk and locomotion score. Significant detail was also provided surrounding the strategies involved in the model building process. I found it quite refreshing to have significant details surrounding the statistical approach.

There was a lameness prevalence rate of 24% for animals housed on mattresses and 11% for animals housed on sand ($P<0.001$) with cows on mattresses standing significantly more (P=0.02). I believe this has a substantial impact on welfare because it draws attention to the higher prevalence of lameness on mattresses. Further research is needed to test if the mattresses are causing lameness which can not be answered here due to the study constraints discussed above. I found it interesting that the authors graded the lameness from 1-4 rather than a yes/no. Any cow with a lameness score of four was removed from the project, but the reality is many high producing, very lame cows are kept in herds and research is needed to assess how their welfare could be improved. The study approach used in the article is very effective at detecting a welfare problem; however, other studies are necessary to determine causation.

3.2 Monitoring indices of cow comfort in free-stall-housed dairy herds (Cook et al., 2005).

The authors examined four commonly used indices of cow comfort at the individual and pen levels. The selection criterion was similar to Cook and colleagues (2004). Six herds with sand free-stalls and six herds with mattress free-stalls were selected and within each one pen of 85 cows was video recorded for 24 hours. 10 cows per herd were selected for individual indices calculations and the pen indices were calculated by the number of animals lying, standing, eating or drinking. The indices were calculated hourly to identify rhythmic patterns. A clearly defined objective was indicated as, "To determine how different indices of comfort vary throughout the day in herds with different stall types and determine if these indices are associated with lying or standing times at the individual or herd level." No hypothesis was specified.

The rigorous inclusion-exclusion criteria and confounding controls were described in the previous article. The time of milking varied among herds and to synchronize the observations regardless of actual time hour 0 was when cows began to leave for morning milking. A general linear mixed model was constructed with an autoregressive convergence structure to account for repeated measures and free-stall base as a random effect. I believe it would be a good idea to include herd and focal animal as random effects as well to decrease the residual variation. The authors used a Bonferroni correction on the P values because of the multiple testing of the same hypothesis. I feel this was a prudent choice because the correction decreases the likelihood of finding a significant association by chance alone. Each index had different optimal times for observation which varied according to free-stall surface. Consultants follow current recommendations and assess cow comfort with the indices at one hour after milking (Nelson, 1996). Identification of this variation demonstrates the need for future research to determine specific protocols to accurately assess dairy cattle welfare. The only behaviour associated with the indices was stall standing time at the pen level ($P=0.01$). The authors call for a change from an index that is based on lying times ($P>0.6$) to an index based on standing to reflect this finding. However, it is odd that they would call for such a change and then admit that the power of the experiment was extremely low and that an experiment with a minimum of 25 herds would provide adequate power. I am also quite cautious regarding the interpretation of cow comfort from pen level associations. These inferences cannot be accurately interpreted (Robinson, 1950). Another important finding with respect to dairy cattle welfare was the identification that the lameness prevalence rate of 29% for animals housed on mattresses and 8% for animals housed on sand (P<0.001) was more severe than the previous study.

4. Conclusions

The two research groups offer uniquely different approaches to identifying causes of welfare problems in dairy cattle. The research group from the University of Wisconsin perform very large epidemiological studies that have a great potential to identify risk factor that may compromise a cow's welfare. In contrast the group from the University of British Columbia have the ethological expertise and facilities to examine in detail and develop causal relationships of identified risk factors. I believe that both laboratories fulfil vital niches in the study of dairy cattle welfare and I would be honoured to collaborate with either group.

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