Welfare Assessments Based on Lifetime Health and Production Data in Danish Dairy Cows

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The objective of this study was to describe how information about the whole lifetime of the cow can be used when defining nonhuman animal-based criteria of the welfare of animals on the farm. Often measured over a short period, disease occurrence provides information relevant for assessing the current welfare state of the herd. Arguably, however, if disease records are to be used as ethically relevant welfare indicators, it is also important to record disease occurrence over the individual animal’s entire life span. Thus, it matters ethically whether the burden of an outbreak of disease or other condition affecting animal welfare is carried by a few individuals or is distributed more evenly. To illustrate this principle, the study obtained data on disease treatment records and production from 392,287 cows from the Danish Cattle Database. The average cow had lived for 5 years and produced more than 22,000 L of milk. The medium number of treatments a cow had received for any disease was 2, but 10% of the cows had received more than 8 treatments for a disease. The study concluded that lifetime description provides a measure of disease occurrence that gives added value of ethical relevance to single-point prevalence or short-term incidence.

Traditionally, disease occurrence has often been calculated either as prevalence at a single point in time or incidence over a relatively short period. These frequency measures, moreover, have been widely used as nonhuman animal-
based welfare indicators. A few examples illustrate this point. As part of an overview of animal welfare in the U.S. dairy industry, incidences and prevalence of lameness, metabolic diseases, abomasal displacements, and other diseases have been presented by Garry (2004). The prevalence of lameness and other disease conditions has been used to describe welfare in different housing systems (Barberg, Endres, Salfer, & Reneau, 2007). It has also been suggested that the prevalence of leg disorders and mastitis should be included as welfare indicators in the development of an epidemiologically based on-farm welfare assessment system (Waiblinger, Knierim, & Winckler, 2001); in epidemiology, prevalence and incidence have been used routinely to identify risk factors for disease occurrence (Alban, 1995). Examples in literature describe longitudinal studies of chronic diseases conducted over a period of years. One such study showed in great detail the impact of Johne’s disease on milk production and clearly demonstrated the strength of having several repeated observations on the same animals (Smith et al., 2009).

Depending on the nature of the disease, presentation of the level of diseases as incidence (new cases over time) or as prevalence (cases present at a given point in time) has various advantages and disadvantages. Prevalence measures have the advantage in that they are generally rapidly obtained and relatively easy to establish. A defined maximum-acceptable limit (maximum prevalence of a certain disease) also affords authorities a relatively straightforward tool with which to control disease. In general, prevalence seems to be a relevant measure for chronic diseases in that the measure at one point in time gives a good indication of the animal’s state over longer stretches of time. However, diseases with short duration or high mortality will have a very small prevalence; therefore, incidence measures are much more relevant for such diseases (Toft, Agger, Houe, & Bruun, 2004). Incidences have the advantages in that they refer to a defined reference period and illustrate the burden of events in relation to the exact time period.

The point just made comparing prevalence and incidences can be generalized. Thus, from the perspective of animal welfare and ethics, the distribution of events between individuals over time is relevant to include in the measures. The underlying idea is that it matters ethically whether the burden of a disease is carried by a few individuals or is distributed more evenly. Hence, one may ask whether it makes sense to consider welfare at a time independent of what happens at other times (Broome, 2004).

This may be underpinned by the idea of fairness: We are, according to this idea, obliged to make sure to distribute as evenly as possible between individuals what matters in a complete life (Griffin, 1986). The important point here is not equality as such but that those worst off are above a minimum acceptable threshold and get as good a deal as possible (Rawls, 1971). Fair distribution is particularly important when it comes to avoiding negative welfare and other
forms of harm. In popular saying this is sometimes expressed by saying that you can measure the ethical quality of a society on how it treats those who are worst off. A similar thinking is often found in animal welfare (Tannenbaum, 1999).

This idea plays an important role in the field of research on animals in the laboratory, where it is widely accepted. From a legal point of view, animals who undergo harmful procedures may not—for ethical reasons—be reused for experimentation. Transferring that idea to animal production would mean that the focus should be on making sure, by means of focused treatment or by means of culling procedures, that as few animals as possible experience repeated painful diseases or other states of severely impaired welfare.

Clearly, that two herds, A and B, have the same incidence of a certain disease does not rule out the possibility that each animal contracts the disease at most once in Herd A, whereas several animals contract it several times in Herd B. It may well be that a welfare evaluation focusing on fairness would assess the welfare as acceptable in Herd A (no cow has a severe disease problem) but unacceptable in Herd B (several cows with repeated, and often severe, disease problems). Therefore, it can be relevant to include the sum of events experienced by the individual animal over the animal’s total lifetime. Including such a measure would give added value to the use of disease occurrence as a welfare indicator.

A measure of this kind can serve the purpose of finding the worst-off farms and thus be used by authorities to screen for herds with welfare problems over a certain threshold. Further, they can be used to document herds with good welfare.

Discussions of farm animal welfare are not just about how to optimize the situation of farm animals. Rather, the aim is often to make a fair compromise between concern for the animals and the goal of efficient production (Sandøe & Christiansen, 2008; Sandøe, Christiansen, & Appleby, 2003), the idea being that it is necessary to consider the welfare consequences for animals as well as potential benefits for humans. A certain loss of welfare for the cow—in the form of production-related disease—will sometimes, therefore, be viewed as justified if the farmer obtains significantly increased output in the form of milk, calves, and meat.

In many cases, however, welfare problems and low production seem to go hand in hand. Thus, taking a lifetime perspective may be a win-win situation from the point of view of both ethics and production. The animals with the lowest welfare may at the same time be the least productive animals in terms of daily milk yield (Thomsen, Østergaard, Sørensen, & Houe, 2007). Therefore, the lifetime measures can serve the purpose of supporting a culling policy that takes into account both production and animal welfare.

Thus, in addition to evaluating diseases at the individual level, production in future studies can be measured at the individual animal level. Again, such
an evaluation is best based on data covering the entire life span of the animal. Using this approach, a very high level of production at certain stages of life may not be positive if production at other times has been very low.

The objective of this study is to introduce an additional way of describing health and production variables using the sum of events relating to the individual animal over the course of the animal’s lifetime. The study uses data on disease treatments and production from Danish dairy cows to demonstrate the principles and potentials of an additional established approach to measure farm animal welfare.

MATERIALS AND METHODS

Extraction of Data From the Danish Cattle Database

In the spring of 2007, a subset of data on all cows leaving the herds by slaughter or death (including euthanasia) during 2005 and 2006 was extracted from the Danish Cattle Database. The data subset included the following variables for each cow:

1. Animal identification number and herd identification number;
2. Date of birth;
3. Cow born in the current herd (yes/no);
4. Dates of inseminations and recorded calvings, including information on calving difficulty and the condition of the calf;
5. Disease treatments;
6. Records at slaughter (slaughter weight, classification, and pathological lesions identified at meat inspection);
7. Information from yield control (date, cell count, and milk yield); and
8. Date of leaving the herd by slaughter, death, or euthanasia.

Only cows from herds participating in milk control (members of a milk control association) were included in the data set. However, approximately 90.2% of all cows and 87.8% of all Danish dairy herds participate in milk control. The assembled data set contained information on 392,287 cows.

Regrouping of Variables

From the detailed coding lists of clinical diseases recorded by practicing veterinarians and pathological lesions recorded by meat inspectors, the following major groups of disease and pathological lesion were established:
1. Reproductive disorders;
2. Udder disorders;
3. Metabolic disorders;
4. Locomotor disorders; and
5. Other disorders.

If a cow was treated for the same disease twice or more within a period of 8 days, the treatment was recorded as one disease.

Establishment of Lifetime Variables
The following variables were calculated from the original data:

1. Total life span: Date of slaughter or death/euthanasia minus birth date;
2. Total productive life span: Date of slaughter or death/euthanasia minus date of first calving;
3. Lifetime milk production calculated as energy-corrected milk (ECM), where KgECM (KgECM) was calculated from Kg milk (KgMlk), Kg fat (KgFat), and Kg protein (KgProt) using the following formula: KgECM = KgMlk*(38.3*1000*KgFat/KgMlk + 24.2*1000*KgProt/KgMlk + 783.2)/3140;
4. Total number of inseminations;
5. Total number of live calves delivered; and
6. Total number of disease treatments within each disease category

Data Control
Control of the extracted data was done by finding minimum and maximum values and by making frequency distributions. Hereafter, the data were evaluated for unplausible values.

RESULTS
Number of Observations
Observations on a total of 392,287 cows were included in the data set. However, for some variables the number was lower. Thus, data on inseminations did not include cows mated by the farmer’s own bull. The proportion of cows never inseminated (only mated by bull) in the data set was 12.4%.
TABLE 1
Descriptive Analysis of Lifetime Variables for Total Life Span, Milk Production, Total Number of Inseminations, Total Number of Live Calves Delivered, and Number of Treatments for Any Disease for All Danish Dairy Cows Leaving the Herd in 2005 or 2006

<table>
<thead>
<tr>
<th>Lifetime Variable</th>
<th>Min</th>
<th>P10</th>
<th>P25</th>
<th>P50</th>
<th>P75</th>
<th>Med</th>
<th>Q3</th>
<th>P90</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total life span(^a) (years)</td>
<td>1.32</td>
<td>2.85</td>
<td>3.63</td>
<td>4.67</td>
<td>6.02</td>
<td>7.43</td>
<td>18.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy-corrected milk(^b) (kg)</td>
<td>0</td>
<td>3,688</td>
<td>10,198</td>
<td>19,326</td>
<td>31,492</td>
<td>44,475</td>
<td>163,226</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum of inseminations (excluding cows mated by bull)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>12</td>
<td>67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum of live calves</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of treatments for any disease(^c)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>76</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) For the continuous variable total life span, the mean was 4.97 years with a standard deviation of 1.83 years.

\(^b\) For the continuous variable milk production, mean lifetime production was 22,336 kg with a standard deviation of 16,232 kg.

\(^c\) The mean value of number of total disease treatments was 3.28.

Lifetime Production Variables

Table 1 contains a descriptive analysis of lifetime variables for (a) total life span, (b) milk production, (c) total number of inseminations, (d) total number of delivered live calves, and (e) number of treatments for any disease. It can be seen that the average cow lived for 5 years, produced more than 22,000 L of milk, delivered a median of two live calves, and had been inseminated a median of six times. Among the more extreme values, it can be seen that 10% of the cows had delivered more than five live calves.

Lifetime Health Variables

The distribution of cows according to number of treatments of any disease is presented in the last row of Table 1 and in Figure 1. From Table 1, it can be seen that 10% of the cows had more than 8 treatments for any disease and that 1 cow had 76 treatments during her lifetime. On the other hand, Figure 1 shows that 25% of cows went through their whole life without a single disease treatment.

The frequency distribution of the five disease categories is shown in Table 2. Approximately 8% of cows had four or more treatments for udder disorders, whereas less than 1% of the cows had received four or more treatments for a disease in one of the other categories. Of the 392,287 cows, 86% were slaughtered and 14% died unassisted or were euthanized.
Findings in Data Control

No implausible values were found in the data control; hence, no observations were deleted due to the data control.

DISCUSSION

This study presents additional measures of health and production for dairy cows using the sum of events experienced by the individual animal over the animal’s total lifetime. The number of disease treatments presented in this article most likely represents an underestimate of the true occurrence of disease because disease data tend to be underreported (Bartlett, Agger, Houe, & Lawson, 2001). This problem, however, will arise whatever disease measure is used; in general, data quality should be continuously monitored when data from existing registers are used in welfare assessment.

The data presented in this study provide the opportunity to illustrate the principle that the balance between the productive output of the individual cow (milk and calves) and the health of the cow (measured by the number of disease treatments) can be presented in a way directly relevant to the issue of how many animals have suffered disproportionally and perhaps even unnecessarily. This information is an important addition to existing types of approaches to measuring animal health and welfare. Thus, when using the suggested lifetime-based incidence measure, there is benefit in making sure that the burden carried (and the production yielded) by individual animals is transparent.

The total number of recorded diseases per year/cow in Denmark was reported (annual incidence rate) as 1.34 in 2005 and 1.37 in 2006 (Buch, Boelling, & Pedersen, 2008). By adding the information that 10% of cows have had more
TABLE 2  
Frequency Distribution of 5 Disease Categories in Cows in a 
Danish Study on Lifetime Health and Production of Dairy Cows

<table>
<thead>
<tr>
<th>Disease Category</th>
<th>Number of Cases During Lifetime</th>
<th>% of Cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproductive disorders</td>
<td>0</td>
<td>73.4</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>0.3</td>
</tr>
<tr>
<td>Metabolic disorders</td>
<td>0</td>
<td>81.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>0.4</td>
</tr>
<tr>
<td>Udder disorders</td>
<td>0</td>
<td>53.2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>21.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>4.5</td>
</tr>
<tr>
<td>Locomotor disorders</td>
<td>0</td>
<td>85.1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>0.2</td>
</tr>
<tr>
<td>Other disorders</td>
<td>0</td>
<td>90.1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>&gt;4</td>
<td>0.1</td>
</tr>
</tbody>
</table>

than 8 treatments in their lives or that the cow with the highest number of disease treatments has received 76 treatments during her lifetime can add to the ethical discussion of what is fair to the animals. Looking at the positives, it is noteworthy that 25% of cows have lived their whole life without receiving any disease treatment at all.

It can be argued that we do not know the true welfare status of the individual animal until she has lived most of her lifetime; therefore, lifetime measures
are “late” measures of welfare. Thus, it is important to stress that traditional incidence measures are always important to provide more recent information of welfare state of all cows in the herd. Still, no matter what animal indicators are used, they will reflect poor welfare already experienced by some cows.

By adding the lifetime measures, the probability that an animal can experience above a certain number of treatments can be monitored continuously. Therefore, it is possible to identify herds in which animals have what looks like acceptable average welfare but where the distribution of welfare problems among the individuals in the herd is unacceptable because some animals are disproportionately affected by disease and hence are suffering from unacceptably low levels of welfare.

Although the lifetime health measures presented here will not help the animals who have already been culled, herds with health-related welfare problems can be identified for the benefit of animals currently in the herd. In addition, the method permits identification of individual animals whose welfare problems are building to an unacceptable level.

Furthermore, it will be possible to combine measures of welfare problems over time with information on production over time, thereby enabling a policy to be adopted involving the temporary or permanent removal of cows from production. This policy would be sensitive both to concerns about animal welfare and to the real need for efficient production.

Recently, the importance of an epidemiological approach for auditing the welfare of animals on the farm has been emphasized (Millman, Johnson, O’Connor, & Zanella, 2009). Hopefully, the principles outlined in this article will contribute to setting up valid and ethically relevant measures of animal welfare at the farm level. In future studies, the transparency of events experienced by the individual animals may be further elaborated on by adding individual incidence rate measures per year or by productive year.

ACKNOWLEDGMENTS

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