Risk factors for bovine respiratory disease in dairy youngstock in The Netherlands: the perception of experts

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Abstract

This paper describes a study aimed at quantification of expert opinion on risk factors for clinical bovine respiratory disease (BRD) in dairy youngstock in The Netherlands. For this purpose, a panel of 21 experts working in the field of BRD was selected. Total expert consultation consisted of five different rounds and included four rounds that comprised questionnaires held by mail and a 1-day workshop (last round). During the expert consultation different elicitation methods were used, such as the Delphi procedure and Adapted Conjoint Analysis (ACA). The most important risk factor for, respectively, mild and severe pneumonia in dairy calves aged 0–3 months was perceived to be (poor) air circulation and purchase of cattle. The latter risk factor was also considered as having the highest impact on the incidence of severe outbreak cases in dairy youngstock aged 3–6 months, whereas a previous case of BRD was considered to be the most important risk factor for mild outbreak cases. Outbreaks (both mild and severe) in dairy youngstock aged 6–24 months were perceived to be influenced most by air circulation. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Bovine respiratory disease; Dairy youngstock; Risk factors; Delphi; Adaptive Conjoint Analysis

1. Introduction

Bovine respiratory disease (BRD) is important to the dairy industry, especially to the rearing of youngstock, because of the losses associated with both treatment and reduced performance of the affected animals. Insight into the risk factors for BRD can help farmers to improve their rearing system in attempt to decrease the risk and/or incidence of the disease on their farms. The risk factors for BRD in dairy youngstock were investigated both at farm and animal level in several epidemiological studies (Waltner-Toews et al., 1986; Curtis et al., 1988; Perez et al., 1990; Curtis et al., 1993; Sivula et al., 1996). The results of the majority of these studies might not be relevant to dairy youngstock elsewhere because of differences in rearing conditions of the youngstock under consideration. Moreover, the results of the studies reviewed varied widely.

To review and complement data that are available from literature, useful information can be obtained
by eliciting expert opinion and experiences (Cooke, 1991; Meyer and Booker, 1991). Expert judgement data have been widely used in management and technical science (Meyer and Booker, 1991). Several previous studies showed that elicitation of expert knowledge in the field of veterinary epidemiology and economics is of extra value (Horst et al., 1996; Stärk et al., 1997; Horst et al., 1998; Van Schaik et al., 1998).

This paper describes a study aimed at the quantification of expert information with regard to risk factors related to the incidence of clinical BRD in dairy youngstock in The Netherlands. The focus of this study was to identify and rank the most important risk factors for the disease.

2. Material and methods

2.1. Participants

At the beginning of 1998, 22 people who had been working in the field of BRD for several years and are often consulted as experts on the disease in dairy practice were approached to join the expert panel. Except for one person, all these experts responded positively. Two experts came from Belgium and the other 19 were Dutch. The experts’ background varied from practice to research, but many had had recent experiences in both these fields. At the time of the expert consultation, the experts had a occupation at the government (three persons), the Animal Health Service (five persons), the Institute for Animal Science and Health (three persons) or other institutes (two persons), or were veterinary practitioners (eight persons).

2.2. Design expert consultation

Total expert consultation consisted of five different rounds held over a total period of 8 months. Rounds one to four were done by mail, whereas the last round included a 1-day workshop. In each of the first four rounds the so-called Delphi procedure was used to reach a consensus among the experts (Cooke, 1991; Meyer and Booker, 1991). These rounds, therefore, could include several mailings. The Delphi rounds focused on qualitative aspects of BRD, especially the definition of clinical BRD, classes to be distinguished with respect to BRD type, severity of disease and age of youngstock, and the definitions of each of these classes. Furthermore, the experts were asked to define, select and rank the most important risk factors for the incidence of clinical BRD, assuming the disease (agents) to be present on the farm. Different types of BRD, disease and age classes were distinguished because the incidence and/or risk factors for the disease were expected to differ between the various classes considered. To select the most important risk factors the experts were asked to: (1) complement an extensive list of risk factors based on a literature search; (2) select a set of ten (at the most) most important risk factors from this list (including the ones added); and (3) rank these risk factors according to their impact on the incidence of BRD. They were asked to go through the last two steps for each of three different combinations of BRD type, age and disease class (‘BRD combinations’) separately.

During a 1-day workshop (round 5) the relative importance of the various risk factors for each of the BRD combinations considered was quantified using fully computer-supported questionnaires. These questionnaires were based on a method called Adaptive Conjoint Analysis (ACA) and designed using ACA software (Sawtooth Software, Evanston, IL).

2.3. Adaptive Conjoint Analysis

2.3.1. The ACA questionnaires

ACA is based on the principles of conjoint analysis, a questionnaire technique frequently used in marketing and consumer research in order to elicit the consumers’ preference for a product (Green and Srinivan, 1990). Products are thought of as possessing specific levels of defined characteristics or attributes. The consumer has a certain preference for each of the different attribute levels, and the product-specific combination of these attributes determines the consumer’s overall preference for the particular product (Steenkamp, 1987; Metenagro, 1994). ACA’s main distinguishing characteristic is its computerised administered format which is customised to each respondent (explaining the term ‘adaptive’ of ACA). Data are analysed as the interview progresses so that the respondent is asked in detail only about
those attributes he/she indicated to be most important. This approach minimises the number of questions and the time required to complete the interview, and therefore avoids fatigue bias (Metenagro, 1994). Using ACA, respondents can work with a large number of attributes and levels in relatively short a time: up to ten attributes with nine levels each (with the various attribute levels satisfying the requirement of independence) in the current system used.

In the context of the current study, a ‘product’ stands for a farm situation with attributes in this case representing risk factors that increase the risk and/or incidence of BRD on the farm. For example, a farm could be characterised by one of the levels of the risk factor ‘house type’, including ‘closed barn’, ‘open front stall’ or ‘porched stall’. In the ACA interview, the experts were asked to judge the various risk factors for their expected impact on the incidence of BRD on the farm. The ACA interview consisted of several sections, each with a specific purpose, which proceeded each other in a fixed order. First, the experts were asked to rank the levels (per risk factor) with regard to their impact on the on-farm incidence of BRD, and to rate the relative importance of each risk factor. After this first section, the most important risk factors together with their most salient levels were known and the initial estimates of the relative importance of the risk factor levels were calculated by the program. In the following section, i.e. the ‘paired-comparison’ section, the experts were asked to compare several pairs of farm concepts or ‘profiles’, and to rate the difference (in expected farm incidence of BRD) between each of the two profiles. The two profiles of a pair each consisted of two or three (identical) risk factors with differences in one or several risk factors levels. An example of a pair of profiles is given below:

<table>
<thead>
<tr>
<th>Profile 1</th>
<th>Profile 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor ventilation</td>
<td>Adequate ventilation</td>
</tr>
<tr>
<td>High density</td>
<td>Low density</td>
</tr>
<tr>
<td>Adequate bedding</td>
<td>Poor bedding</td>
</tr>
</tbody>
</table>

The ACA program selects each profile according to earlier answers given by the expert in order to maximise the information gain while still limiting the number of combinations of profiles to be evaluated. After each paired-comparison response, the additional scores provided by the expert are used to update the expert’s relative importance values for the various risk factors, and a new profile is chosen. In the final section, each expert was provided with a series of customised profiles or ‘calibrating concepts’, each consisting of several risk factor levels. These profiles were chosen to cover the entire range of their expected farm incidence of BRD based on the expert’s earlier answers. The profiles were presented one-at-the-time and the experts were asked to give an overall rate (scale 0–100) for the expected farm incidence of BRD. ACA uses the information gained in this section to calibrate the experts’ estimates for the risk factors, and to calculate the internal consistency of the answers given by the (individual) expert. The consistency is expressed by the correlation coefficient $R^2$ that varies between 0 (very inconsistent) and 1 (very consistent). It is estimated by comparing the expected responses to the customised profiles (based on answers given previously) and the expert’s actual response (Metenagro, 1994). After the interview is completed the experts’ correlation coefficients are directly available. Respondents having answered the interview inconsistently could be excluded from further analyses. According to Horst et al. (1998) results of inconsistent respondents should not be included in the analysis, regardless of the fact that they are outliers or not, to avoid a false sense of reliability.

Conjoint analysis is a so-called ‘de-compositional’ method. It starts with the respondent’s overall judgement of a profile, and breaks this total score down into the contributions of its attributes, also so-called ‘part-worth scores’, using ordinary least squares regression analysis. Thus, in this case the expert’s total score for a farm concept was broken down into its components belonging to the separate risk factors. These part-worth scores indicated the influence of each risk factor on the expert’s judgement for the particular farm profile. The scores given by the respondent are evaluated applying the following additive model:

$$\text{profile score} = \beta_0 + \beta_1 * x_1 + \cdots + \beta_n * x_n$$

In this formula, the profile score is the (overall)
score given by the respondent to a particular profile; \( \beta_0 \) is the intercept (a constant); the \( \beta_{1-n} \) are the estimated coefficients (part-worth scores) associated with the attributes (risk factors in this case); and the \( x_{1-n} \) represent the attribute levels (with value 0 = attribute base level and value 1 = attribute level). Interactions were not taken into account as the risk factors were assumed to be independent. Besides, when interaction occurs the additive model typically shows high robustness (Steenkamp, 1987). The relative importance of each risk factor is estimated as its regression coefficient divided by the total sum of coefficients (thus, all relative importances together add up to 100%).

At first sight, more ‘direct’ methods to quantify systematic components that underlie people’s evaluations of objects, such as direct questioning, may look less complicated. Such compositional methods ask respondents to assess values for attributes, and use these values to construct overall judgements for attribute profiles (Huber, 1974). However, many researchers have compared the predictive performance of Conjoint Analysis with self-explicated approaches and in most studies Conjoint Analysis outperforms the latter (Green et al., 1983; Huber et al., 1993). For a more detailed description of Conjoint Analysis the reader is referred to Green and Srinivasan (1990), and an exhaustive description of the backgrounds and estimation procedure of ACA can be found in Metenagro (1994) and Johnson (Johnson, 1987; Johnson, 1993).

2.3.2. The ACA sessions (workshop)

A different ACA questionnaire was drawn up for each BRD combination considered because the risk factors for BRD as well as the relative importance of their levels (might) differ between the different BRD types, disease severity classes and/or age classes. The risk factors together with their levels considered in each BRD combination as well as their definitions were based on the results of the Delphi rounds. The ACA questionnaires were pre-tested by 19 people who had a background in veterinary medicine and/or animal science and were currently working at the Department of Veterinary Medicine in The Netherlands or the Department of Economics and Farm Management in The Netherlands.

During the workshop each expert was provided with a personal computer to work on the self-explanatory ACA questionnaire individually and independently from the other experts. In this way interaction between the participants as well as between the participants and the workshop facilitators was minimised. Each expert was given two different ACA questionnaires held in two consecutive ACA sessions. The ACA questionnaires were distributed among the experts such that each BRD combination was evaluated by about the same number of experts. Half of the experts who evaluated a particular BRD combination did this during the first ACA session, and half of the experts did so during the second one. Each expert was provided a handout with the definitions of the risk factors (as defined during the Delphi rounds) for use during the ACA task at hand. Directly after each ACA session, the experts were asked to evaluate the particular ACA interview by completing a written questionnaire. This questionnaire consisted of five questions about, for example, the realism of the profiles and the clarity of the descriptions of the risk factors. The questions had to be answered by giving a score on a scale of 1–5, in which 1 meant bad and 5 very good. After the workshop, each expert was sent an overview of his/her own estimates of the relative importance of the risk factors for BRD, together with the average results of all experts. The experts were asked to check whether their estimates given during the ACA sessions reflected their true opinion.

2.3.3. Analyses

All questionnaires that had a consistency level of 0.6 or higher were included in the analyses. The relative importance estimates of the various risk factor levels were evaluated for each BRD combination, separately. First, the relative importance values of the various risk factor levels, provided at the individual level, were standardised so that they could be compared among the experts. This was done in such a way that, for each respondent, the sum of the importance values across all risk factor levels was equal to the number of risk factors times 100. Next, these values were converted to percentages, and the median relative importance value (percentage) of the
combined group of experts was calculated for each level.

The risk factors were ranked according to their relative importance. For each risk factor, the rank was based on the (median) relative importance value of the level of that risk factor that was considered most important, i.e. received the highest (median) importance value. As the relative importance values of some of the risk factors levels were not normally distributed, a non-parametric Spearman Rank Correlation test \((\alpha < 0.05)\) was used to investigate differences in the ranking of the risk factors within disease classes using a (higher) cut-off value of 0.8 as well as between two different disease classes of a particular combination of BRD type and age class. All data transformations and analyses were done using SPSS 8.0 (Norusis, 1993).

3. Results

3.1. Delphi rounds

3.1.1. Response

Four of the 21 experts responded to the first two Delphi rounds only, and not to the other ones. The majority of the other 17 experts responded to each Delphi round. In each of these rounds, the experts agreed on the subjects of the particular round after three to five mailings. On average, 15 experts (not always the same people) responded to the eight mailing rounds held in total.

3.1.2. Definition and classes

Clinical BRD in dairy youngstock between birth and 2 years of age was defined as ‘a clinical disease of the respiratory tract caused by a viral, bacterial or mycoplasmal infection (parasites were excluded) or a combination of these infections’. Youngstock were divided into three age classes with regard to BRD: (a) 0–3 months; (b) 3–6 months; and (c) 6–24 months. Two types of clinical BRD, being pneumonia and ‘outbreak cases’ of BRD, were distinguished and defined as follows:

Calf pneumonia: BRD cases seen one after the other, periodically or whole year round, mostly occurring in calves < 3 months of age. These cases can be caused by a variety of primary pathogens, but commonly are caused by bacteria, mainly Pasteurella spp., with a previous infection with respiratory viruses.

Outbreak cases: Cases seen during an outbreak of BRD, in which a certain number of animals in a group suddenly show clinical signs. Outbreaks of BRD mostly occur during the housing period, but also regularly during the grazing period. Mainly dairy youngstock aged ≥3 months is affected, but also regularly calves < 3 months. The cases of BRD seen during an outbreak are mostly caused by a primary viral infection, mainly Bovine Respiratory Syncytial Virus, with or without a secondary bacterial infection.

Three clinical BRD disease classes, i.e. mild, severe, and chronic BRD, were considered. These disease classes were defined by (clinical) signs that can be seen at the animal level without treating the animal and which are most characteristic of and distinguishing for the particular disease class as well as by the duration of these signs. The clinical signs of the BRD disease classes were divided into common signs which can be seen in each of the three disease classes and specific signs which can only be seen in the particular disease class. The definitions of the three disease classes are presented in Table 1.

3.1.3. Identification of risk factors

The experts considered six additional risk factors, not mentioned in the original list, also to be of relevance. To the experts’ opinion, some risk factors were very closely related and should be aggregated or combined to one risk factor. Therefore, for several risk factors, including the ones added, the particular risk factor was included as an additional level of a very closely related risk factor. The most important risk factors were selected for each of the three combinations of BRD type, disease severity and age class (BRD combinations), presented in Fig. 1. These combinations were chosen because they were thought to be the most relevant.

The risk factors identified as being highly important for the incidence of one or more of the three BRD combinations considered were:
Table 1
Common and specific signs present at the animal level without treatment in each of the three disease classes of BRD

<table>
<thead>
<tr>
<th>BRD combination</th>
<th>BRD type</th>
<th>Disease class</th>
<th>Age class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pneumonia</td>
<td>severe</td>
<td>0-3 months</td>
</tr>
<tr>
<td>2</td>
<td>outbreak cases</td>
<td>mild</td>
<td>3-6 months</td>
</tr>
<tr>
<td>3</td>
<td>outbreak cases</td>
<td>severe</td>
<td>6-24 months</td>
</tr>
</tbody>
</table>

Fig. 1. BRD combinations considered during Delphi rounds.

- Colostrum management during 1st day of life
- Season of birth
- Group size
- Density
- Housing system
- House type
- Bedding condition

The definitions of these risk factors together with their levels are given in Fig. 2.

Because the experts considered the most important risk factors to be identical for both the mild and severe disease class for each of the three combinations of BRD type and age class, the most important risk factors were actually identified for six different BRD combinations.

3.2. Workshop

One person only went through the ACA questionnaire given in the first session of the workshop. The other 19 experts each completed two ACA interviews, resulting in 39 completed ACA interviews in total. For each of the six BRD combinations, the relative importance values of the various risk factors were estimated by six to seven (different) experts. After the workshop all experts considered their estimates made during the ACA session to be in accordance with their opinion.

The average duration of the 20 ACA questionnaires held in the first session was 29 min (variation 13–44 min) whereas the duration of the 19
**Season of birth:**
- Winter: September 1st to February 28th
- Summer: March 1st to August 31st

**Colostrum management during the first day of life:**
- Adequate: newborn calves receive: 1) 1 to 2 litres of colostrum depending on weight at birth (possibly in 2 times) within 2 hours after birth, 2) a second dose of 1.5 litres of colostrum within 6 hours after birth, and 3) in total a minimum of 10-15% of weight at birth during the first day (24 hours) given in 3-4 doses.
- Poor: one or more of these 3 requirements are not met

**Housing system:**
- Separate space: not housed in one space (under one roof) with older youngstock and milking cows
- Milking cows: housed in one space with milking cows only
- Older youngstock: housed in one space with older youngstock and possibly milking cows

**Grazing during summer months:**
- Yes
- No

**Bedding condition:**
- Adequate: solid floor that allows adequate drainage of urine, and which is covered with absorbent material such as straw or wood shavings which is cleaned every time it gets (too) wet
- Poor: one or more of these criteria are not met

**Air circulation** (refers to barn in which youngstock is housed):
- Adequate: air quality is maintained at an adequate level by a continuous flow of fresh outside air with an adequate speed through the barn
- Poor: air refreshment does not meet one or more of these requirements and/or draught is present

**Density, i.e. total number of animals in the pen/group divided by the total surface of the pen:**
- High: number of animals per m² exceeds the standards on space requirements for animals in the particular age group as given in Quigley III et al. (1996)
- Low: number of animals per m² is less than or equal to the standards given in Quigley III et al. (1996)

**Group size, i.e. number of youngstock (in particular age class) present in a group/pen for cattle housed in groups:**
- Small: 2-6 animals per group
- Large: 7 or more animals per group
  (selected for youngstock < 6 months of age)

**Purchase new cattle/precautions:**
Possible risk factor because of introduction of ‘new’ pathogens or variants of pathogens already present on farm (selected for the age groups of 0-3 and 3-6 months)
- No purchase
- Purchase/precaution: (any) precaution measure is taken before mixing the newly purchased cattle with cattle of the same age already present on the farm
- Purchase/no precaution: no precaution measure (at all) is taken before mixing

**Introduction cattle/precautions:**
Introduction of cattle on the farm is distinguished to newly purchased youngstock and cattle that are returned from export (selected for youngstock aged between 6 to 24 months).
- No introduction
- Introduction/precaution: (any) precaution measure is taken before mixing with cattle of the same age already present on the farm
- Introduction/no precaution: no precaution measure (at all) is taken before mixing with cattle of the same age already present on the farm

**Cattle flow through pens:**
- All-in-all-out system: the composition of a group of cattle is constant during the complete growing period
- Continuous flow: individual animals go back to the previous group or on to the next group based on their weight

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Fig. 2. Definitions of risk factors and their levels.
ACA questionnaires held in the second session averaged 16 min (variation 9–28 min). Both the median correlation coefficient (for consistency) of the ACA interviews held in the first and in the second sessions separately, as well as the overall median correlation coefficient of all 39 completed ACA questionnaires was 0.86. Thirty-two questionnaires had an $R^2$ that was equal to or higher than the cut-off value of 0.6, and were included in the analyses.

### 3.2.2. Relative importance of risk factors

The (median) relative importance values (expressed as percentages) of the risk factors are presented in Table 2 for both mild and severe pneumonia in dairy calves aged 0–3 months (youngest age group), in Table 3 for both mild and severe outbreak cases in dairy youngstock aged 3–6 months (middle age group), and in Table 4 for mild and severe cases of outbreak cases in dairy youngstock aged 6–24 months (highest age group).

From Table 2 it can be seen that the two risk factors that were perceived to increase the incidence of pneumonia in dairy calves aged 0–3 months most (rank 1 and 2) were air circulation and housing system for mild cases, and purchase of cattle and colostrum management during the first day of life for severe cases, respectively. The most important risk factor (rank 1) for mild and severe outbreak cases in dairy youngstock aged 3–6 months was considered to be, respectively, a previous case of BRD and purchase of cattle. Additional risk factors perceived to be important for these two BRD combinations were cattle flow through pens, air circulation and housing system (mild cases only).

Two of the risk factors that were identified during the Delphi rounds to be important for pneumonia in the youngest age group (Table 2), being season of birth and colostrum management during the first day

### Table 2

Median relative importance values (expressed in percentage) and ranks of risk factors for both mild and severe pneumonia in dairy calves aged 0–3 months ($R^2=0.6$, $n=4$ for mild and $n=6$ for severe cases)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Mild cases</th>
<th></th>
<th>Severe cases</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Importance in % (min–max)</td>
<td>Rank</td>
<td>Importance in % (min–max)</td>
<td>Rank</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air circulation</td>
<td>14.1 (4.4–19.1)</td>
<td>1</td>
<td>11.8 (3.7–18.1)</td>
<td>3</td>
</tr>
<tr>
<td>Housing system</td>
<td>13.8 (8.5–17.2)</td>
<td>2</td>
<td>10.9 (2.6–16.8)</td>
<td>4</td>
</tr>
<tr>
<td>Density</td>
<td>10.8 (0.0–17.3)</td>
<td>3</td>
<td>8.2 (7.6–17.9)</td>
<td>6</td>
</tr>
<tr>
<td>Group size</td>
<td>10.2 (0.0–18.7)</td>
<td>4</td>
<td>7.0 (2.4–15.0)</td>
<td>7</td>
</tr>
<tr>
<td>Season of birth</td>
<td>9.5 (4.9–26.1)</td>
<td>5</td>
<td>9.8 (6.3–15.4)</td>
<td>5</td>
</tr>
<tr>
<td>Colostrum management during 1st day of life</td>
<td>8.8 (5.9–12.4)</td>
<td>6</td>
<td>14.1 (2.9–23.2)</td>
<td>2</td>
</tr>
<tr>
<td>Bedding condition</td>
<td>8.4 (1.7–12.2)</td>
<td>7</td>
<td>3.5 (0.0–9.8)</td>
<td>8</td>
</tr>
<tr>
<td>Purchase of cattle</td>
<td>8.2 (4.9–17.0)</td>
<td>8</td>
<td>15.7 (10.6–23.6)</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3
Median relative importance values (expressed in percentage) and ranks of risk factors for both mild and severe outbreak cases of BRD in dairy youngstock aged 3–6 months ($R^2 \geq 0.6, n=5$ for both mild and severe cases)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Mild cases</th>
<th></th>
<th>Severe cases</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Importance in %</td>
<td>Rank</td>
<td>Importance in %</td>
<td>Rank</td>
</tr>
<tr>
<td></td>
<td>(min–max)</td>
<td></td>
<td>(min–max)</td>
<td></td>
</tr>
<tr>
<td>Previous BRD</td>
<td>11.4 (4.7–13.0)</td>
<td>1</td>
<td>8.9 (3.7–15.4)</td>
<td>3</td>
</tr>
<tr>
<td>Cattle flow through pens</td>
<td>10.3 (8.1–13.2)</td>
<td>2</td>
<td>8.5 (0.0–11.9)</td>
<td>4</td>
</tr>
<tr>
<td>Housing system</td>
<td>10.3 (7.1–10.3)</td>
<td>3</td>
<td>7.2 (4.3–11.0)</td>
<td>7</td>
</tr>
<tr>
<td>Air circulation</td>
<td>8.8 (5.1–14.2)</td>
<td>4</td>
<td>9.4 (3.8–15.8)</td>
<td>2</td>
</tr>
<tr>
<td>Density</td>
<td>7.9 (6.2–8.9)</td>
<td>5</td>
<td>7.4 (5.1–15.7)</td>
<td>6</td>
</tr>
<tr>
<td>Purchase of cattle</td>
<td>7.3 (5.5–9.0)</td>
<td>6</td>
<td>12.3 (2.2–14.0)</td>
<td>1</td>
</tr>
<tr>
<td>Group size</td>
<td>6.1 (4.9–6.2)</td>
<td>7</td>
<td>7.7 (2.2–11.0)</td>
<td>5</td>
</tr>
<tr>
<td>House type</td>
<td>5.3 (2.0–9.8)</td>
<td>8</td>
<td>4.8 (0.0–5.9)</td>
<td>9</td>
</tr>
<tr>
<td>Grazing during summer</td>
<td>5.2 (3.2–8.3)</td>
<td>9</td>
<td>3.7 (0.0–8.0)</td>
<td>10</td>
</tr>
<tr>
<td>Bedding condition</td>
<td>4.9 (0.0–7.7)</td>
<td>10</td>
<td>6.2 (0.0–9.0)</td>
<td>8</td>
</tr>
</tbody>
</table>

of life, were not selected to be so for outbreak cases in the middle age group (Table 3). For the latter combination of BRD type and age class (both disease classes), four additional risk factors were identified during the Delphi rounds, two of which (previous BRD and cattle flow through pens) received high ranks during the workshop. To the experts’ opinion two risk factors, being air circulation and purchase of cattle (severe cases only), have a relatively high impact on the incidence of both pneumonia in the youngest age group and outbreak cases in the middle age group. Note that the relative importance values of these risk factors cannot be compared across the two combinations of BRD type and age group, because the number of attributes differ and the values sum to 100 within BRD combinations. Because the risk factors and levels selected were identical in both the mild and severe disease classes they can be compared within the two disease classes of a particular BRD type and age group.

The perceived most important risk factors for outbreaks in the highest age groups (Table 4) were almost identical to those selected for outbreaks in the middle age group (Table 3), but most of them were given different ranks.

Increasing the cut-off value for consistency of $R^2 \geq 0.8$ led to the exclusion of some questionnaires in most of the BRD combinations considered. However, it made no significant (Spearman’s rho; $\alpha > 0.05$) difference for the within disease class ranking of the risk factors. Differences between the two

Table 4
Median relative importance values (expressed in percentage) and ranks of risk factors for both mild and severe outbreak cases of BRD in dairy youngstock aged 6–24 months ($R^2 \geq 0.6, n=5$ for mild and $n=7$ for severe cases)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Mild cases</th>
<th></th>
<th>Severe cases</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Importance in %</td>
<td>Rank</td>
<td>Importance in %</td>
<td>Rank</td>
</tr>
<tr>
<td></td>
<td>(min–max)</td>
<td></td>
<td>(min–max)</td>
<td></td>
</tr>
<tr>
<td>Air circulation</td>
<td>11.8 (5.3–16.5)</td>
<td>1</td>
<td>12.5 (8.4–18.9)</td>
<td>1</td>
</tr>
<tr>
<td>Density</td>
<td>10.4 (5.5–10.9)</td>
<td>2</td>
<td>8.1 (3.5–13.8)</td>
<td>3</td>
</tr>
<tr>
<td>Introduction cattle</td>
<td>10.0 (7.4–14.8)</td>
<td>3</td>
<td>9.6 (0.0–14.6)</td>
<td>2</td>
</tr>
<tr>
<td>Housing system</td>
<td>9.1 (6.8–12.4)</td>
<td>4</td>
<td>7.0 (4.7–10.7)</td>
<td>5</td>
</tr>
<tr>
<td>Cattle flow through pens</td>
<td>7.7 (0.0–10.9)</td>
<td>5</td>
<td>7.8 (0.0–13.0)</td>
<td>4</td>
</tr>
<tr>
<td>House type</td>
<td>6.5 (0.0–10.0)</td>
<td>6</td>
<td>6.2 (4.4–12.4)</td>
<td>6</td>
</tr>
<tr>
<td>Previous BRD</td>
<td>6.7 (1.9–10.2)</td>
<td>7</td>
<td>6.2 (0.0–11.4)</td>
<td>7</td>
</tr>
<tr>
<td>Bedding condition</td>
<td>4.1 (2.8–7.9)</td>
<td>8</td>
<td>5.1 (1.9–11.4)</td>
<td>8</td>
</tr>
<tr>
<td>Grazing during summer</td>
<td>2.6 (0.0–2.6)</td>
<td>9</td>
<td>2.5 (0.0–2.5)</td>
<td>9</td>
</tr>
</tbody>
</table>
Table 5
Average (with minimum and maximum) credits given to the five evaluation questions for the ACA interviews, for both the 1st (n = 20) and 2nd session (n = 19) separately, and for all interviews

<table>
<thead>
<tr>
<th>Questions asked:</th>
<th>ACA interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st session</td>
</tr>
<tr>
<td>Unclear (1)–very clear (5) description of the risk factors</td>
<td>4.3 (2.0–5.0)</td>
</tr>
<tr>
<td>Unrealistic (1)–realistic (5) profiles</td>
<td>3.6 (2.0–5.0)</td>
</tr>
<tr>
<td>Low relation (1)–high relation (5) with Delphi rounds</td>
<td>4.2 (3.0–5.0)</td>
</tr>
<tr>
<td>Very short (1)–long (5) duration</td>
<td>2.8 (1.0–4.5)</td>
</tr>
<tr>
<td>Uninteresting (1)–interesting (5)</td>
<td>4.1 (3.0–5.0)</td>
</tr>
</tbody>
</table>

Disease classes were significant (Spearman’s rho; \(\alpha<0.05\)) for both pneumonia in the youngest age group (four observations for each of the two disease classes) and outbreaks in the middle age group (three observations for each of the two disease classes), but not for outbreaks in the highest age group (five and six observations for mild and severe cases, respectively). This also held when the (lower) cut-off value of 0.6 was used.

3.2.3. Evaluation of ACA interviews

The experts were very positive about the ACA interviews as can be seen from Table 5, which summarises the results of the evaluation of the ACA interviews. The ACA questionnaires in the first and second sessions received approximately the same credits for every question.

4. Discussion

4.1. Risk factors for BRD

Most respiratory diseases in dairy youngstock are infectious in nature but are multifactorial in causality, i.e. environmental and management factors are necessary to precipitate the disease. Among other things, aspects related to housing are considered very important for the risk of respiratory diseases in dairy youngstock and include, for example, climatic conditions such as ventilation, spatial conditions, and type of housing (Quigley III et al., 1996). However, only a few of the various risk factors related to housing circumstances that were studied in the epidemiological literature reviewed were found to be of significant importance (Waltner-Toews et al., 1986; Curtis et al., 1988; Perez et al., 1990; Curtis et al., 1993; Sivula et al., 1996). Curtis et al. (1988) reported that calves initially housed in hutches or individual stalls were at increased risk of respiratory diseases, conditional to season, compared to those initially housed in pens or loosely housed. Other studies observed no significant effects of risk factors related to housing (Waltner-Toews et al., 1986; Perez et al., 1990; Curtis et al., 1993; Sivula et al., 1996).

The majority of these studies, however, found several housing factors to increase the risk of diarrhoea, and the risk of respiratory disease being increased by a previous case of diarrhoea. Therefore, an indirect effect of these housing factors on the risk of respiratory diseases, mediated by a previous case of diarrhoea, may exist (Waltner-Toews et al., 1986; Perez et al., 1990; Curtis et al., 1993). In contrary to the findings from epidemiological literature, the majority of the risk factors identified by the experts in this study (Delphi rounds) to be important for the incidence of BRD in dairy youngstock were related to housing condition, but a previous case of diarrhoea was not selected. A previous case of BRD was identified to increase the risk of another case of this disease in youngstock aged 3–6 months, in accordance with the studies reviewed (Waltner-Toews et al., 1986; Curtis et al., 1988; Perez et al., 1990; Curtis et al., 1993). In addition, the experts considered season of birth and colostrum management during first day of life to be a risk factor for pneumonia in dairy calves younger than 3 months. The incidence of respiratory disease was also found to be affected by season of birth in most studies reviewed (Waltner-Toews et al., 1986; Curtis et al., 1988; Curtis et al., 1993), and factors related to colostrum management were also reported to be a risk factor for respiratory disease by Waltner-Toews et al. (1986), but not by some other studies (Curtis et
al., 1988; Perez et al., 1990; Curtis et al., 1993; Sivula et al., 1996).

In general, some of the factors perceived by the experts to highly increase the incidence of BRD in dairy calves were also reported to be a significant risk factor for the disease in (epidemiological) literature, but others were not. The differences might, at least partly, be explained by variation in rearing conditions of the calves under consideration, for example, caused by differences in geographical areas and production systems.

4.2. Methods used

Experiences gained in this study reveal that ACA is an easy-to-use technique that enables the quantification of expert opinion on the relative importance of risk factors related to an animal disease, supporting reports from earlier studies that dealt with a comparable task (Horst et al., 1996; Stärk et al., 1997; Van Schaik et al., 1998). The median correlation coefficient of the ACA questionnaires in this study was high both absolutely and relatively to previous studies (Stärk et al., 1997; Van Schaik et al., 1998). The experts’ answers being very consistent may be due to the fact the experts experienced the duration of the interviews not (too) long, the risk factors to be defined well and the profiles very realistic (Table 5). The high correlation coefficient might, at least partly, also have been caused by the very extensive Delphi rounds held prior to the ACA interviews. Besides the fact the Delphi procedure leaded to a clear definition of risk factors and other aspects of BRD, this method indirectly resulted in the experts being confronted with and reflecting upon their opinion on aspects related to BRD many times. This might have helped them to prepare a well-defined view on the subjects.

The cut-off value of the correlation coefficient of 0.6 was chosen arbitrarily, but results were very similar when a higher cut-off value was used. Van Schaik et al. (1998) used a cut-off value of 0.3 and reported no significant differences in results increasing this value to 0.5. So apparently, increasing the cut-off value has only a minor influence on the outcomes, at least not for small changes.

In general, the procedures and methods applied in this study together with the high consistency have led, although based on a small number of observations (per BRD combination), to an accurate elicitation of expert perception (identification and ranking) of the most important risk factors for BRD in dairy young stock in The Netherlands.

4.3. Final remarks

As the importance values of the risk factors are relative they need to be converted to absolute values in most instances for further use. Once the absolute risk of BRD for one particular set of risk factors (levels) is known, it is known for all combinations of risk factors, so a ‘reference’ value is needed.

In general, expert opinion on the importance of the risk factors might not reveal the true impact of these risk factors. However, it is very difficult, although not impossible, to obtain the unambiguous truth, i.e. the ‘gold standard’, concerning the impact of risk factors for animal diseases. Expert perception investigation can not replace traditional (epidemiological) field surveys and experimental research, but is considered to be undoubtedly useful as a complement to these studies. Until (these) better data are available, quantitative expert knowledge elicited using accurate methods, will be valuable information. Such information can be used, for example, as input for simulation models or to highlight fields of interest.

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References


