Early detection of metabolic disorders in dairy cows by using sensor data

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This presentation

- Backgrounds
  - Smart Dairy Farming project
  - Transition period / metabolic disorders
- Material and methods
  - Literature study
  - Data collection
  - Model formulation
- Results and discussion
- Conclusions
Smart Dairy Farming project

- **Mission:**
  To help dairy farmers with information and technology to improve health and longevity of the cows

- **Goal:**
  - longevity: +2 lactations
  - production: +20,000 kg milk

- Development and testing at eight practical dairy farms

www.smartdairyfarming.nl (only in Dutch)
Smart Dairy Farming: organisation

- Research topics:
  - Animal health
  - Fertility
  - Feeding
- Work packages:
  - Chain transparency
  - Model development
  - Sensors
  - Learning networks
Smart Dairy Farming: partners

Group of six practical farmers
Transition period / metabolic disorders

- start of dry-off period - 60th day in lactation
- energy intake lower than energy requirement: negative energy balance
- increased risk for disorders:
  - milk fever
  - ketosis
  - left displaced abomasum
- monitoring necessity: detection model for early warning based on sensor measurements
Material & methods: literature study

<table>
<thead>
<tr>
<th></th>
<th>milk fever</th>
<th>ketosis</th>
<th>left displaced abomasum</th>
</tr>
</thead>
<tbody>
<tr>
<td>milk yield</td>
<td>?</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>feed intake</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>rumination</td>
<td>++</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td>body weight</td>
<td>-</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>activity</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

++ good indicator

+ indicator

? varying results found

- not useful as indicator
Material & methods: data collection

- commercial farm: 300 cows, 4 milking robots (AMS)
- sensor data: 15 months
- reference data: 26 metabolic disorders (mostly milk fever)

<table>
<thead>
<tr>
<th>variable</th>
<th>measurement method</th>
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<tbody>
<tr>
<td>milk yield</td>
<td>AMS</td>
</tr>
<tr>
<td>milk fat &amp; protein</td>
<td>AMS</td>
</tr>
<tr>
<td>milking visits</td>
<td>AMS</td>
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<tr>
<td>concentrates intake</td>
<td>AMS/concentrates feeder</td>
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<tr>
<td>concentrates leftover</td>
<td>AMS/concentrates feeder</td>
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<tr>
<td>feedings</td>
<td>AMS/concentrates feeder</td>
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<td>feeding visits</td>
<td>AMS/concentrates feeder</td>
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<tr>
<td>activity</td>
<td>collar sensor</td>
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<tr>
<td>rumination activity</td>
<td>collar sensor</td>
</tr>
<tr>
<td>body weigth</td>
<td>AMS/concentrates feeder</td>
</tr>
</tbody>
</table>
Material & methods: model formulation

- **level alert:**
  - daily value differs from expected value (based on moving average + standard deviation)
  - one day / two successive days
  - ketosis alert based on fat & protein percentage

- **trend alert:**
  - decrease in milk yield in first four weeks of lactation
  - strong decrease in body weight in first 80 days

- **index alert:**
  - activity/rumination deviating on day of calving
  - body weight deviating at start/end of dry period
Material & methods: model formulation

- SumAlert: number of alerts per day per cow
- SmartSumAlert: number of selected alerts per day per cow

<table>
<thead>
<tr>
<th></th>
<th>disease</th>
<th>no disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>alert</td>
<td>True Positive (TP)</td>
<td>False Positive (FP)</td>
</tr>
<tr>
<td>no alert</td>
<td>False Negative (FN)</td>
<td>True Negative (TN)</td>
</tr>
</tbody>
</table>

- sensitivity = percentage of detected cases
  \[ \frac{TP}{TP + FN} \]

- specificity = percentage of healthy cows without alert
  \[ \frac{TN}{TN + FP} \]
Results: one day level alerts

- ROC curve, e.g.:
  - for activity a: sensitivity 86%
  - specificity 97%
Results: ... + two days level alerts

- ROC curve, e.g.:
  - for activity a:
    - sensitivity 36%
    - specificity 99.6%
Results: ... + trend alerts

- ROC curve, e.g.:
  - for weight one day \textit{w1}:
    - sensitivity 56%
    - specificity 95.9%

```plaintext
Sensitivity (%)  100
0  10  20  30  40  50  60  70  80  90  100

100 - Specificity (%)
0  10  20  30  40  50  60  70  80  90  100
```

LIVESTOCK RESEARCH
WAGENINGEN UR
Results: ... + index alerts

- ROC curve, e.g.:
  - for activity at calving day ac:
    - sensitivity 75%
    - specificity 92%
Results: sum alerts

- different sums: 1, 2, 3, 4, 5
- different periods: 0 days, 2 days, 4 days and 10 days
Discussion

- Difference in performance of variables
- Double alert not applicable
- Milk yield difficult for milk fever
- Performance of variables differs sometimes from literature
- Combination of variables needed to increase specificity
- Higher sensitivity = lower specificity (and vice versa)
Conclusions

- Detection of metabolic disorders based on sensor data possible
- But high sensitivity difficult if specificity at least 99%
- Combination of (selected) variables worthwhile!
- Detection up to 4 days prior to diagnosis
- Real-time model started recently
Questions?