First estimation and validation of a new model to predict dry matter loss based on temperature changes

I. A meta-analysis study

S. Pires, G. Copani, J. N. Joergensen, N. G. Nielsen, K. A. Bryan, K.L. Witt

G. Copani
dkgico@chr-hansen.com
Chr. Hansen Animal Health and Nutrition. Bøge Alle 10-12 - 2970 Hørsholm, Denmark
Presentation outline

Introduction  Material & Method  Results & Discussion  Conclusion
Temperature increase during aerobic exposure of silage

Corresponding **real-time** dry matter (DM) loss during continued aerobic exposure is **difficult** to establish.

The **objective** of this meta-analysis study was to establish the regression **correlation** between DM loss and increased temperature after 24 hours of aerobic exposure.

- Sensitivity
- Over/Under estimating
- Practicality

(McDonald et al., 1991)

(Ashbell and Weinberg, 1992)
A literature review (Obs.= 9) on the **DM loss** after **24 hours aerobic challenge** was used as the basis for this meta-analysis study.

- **Different silages** (corn, alfalfa, and grass at DM ranging from 15-35%),
- **Temperature** and **DM loss measured**,  
- DM loss (%) and temperature (°C) end points after 24 hours were plotted and submitted to a regression analysis (SAS institute),
- As a reference method a stepwise assessment of DM loss (McDonald et al. 1991) was compared with the new model.
- Two others linear equations were generated and compared to the new model.

\[
\text{DM loss (\%) = 0.49 * T (°C) - 9.73}
\]

Obs. 1 from Wilkinson and Hall (1965); Obs. 2 from Henderson et al. (1979); Obs. 3 and 4 from Schukkling and Overvest (1980); Obs. 5 and 6 from Honig and Woolford (1980); Obs. 7 and 8 from Honig (1980); Obs. 9 from Rees (1982).
# Existing models overview vs. new model

<table>
<thead>
<tr>
<th>Items</th>
<th>Step logic approach (McDonald et al., 1991)</th>
<th>EQ 1 (Linear regression based on 18 study from Henderson, 1979)</th>
<th>EQ 2 (Linear regression based on 12 observations)</th>
<th>New model (Pires et al., 2018) (9 observations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>( \Delta T ) to ambient</td>
<td>( \Delta T ) to ambient</td>
<td>T max during AS</td>
<td>T max during AS</td>
</tr>
<tr>
<td>Aerobic stability (AS)</td>
<td></td>
<td>9 days</td>
<td>24 hours <strong>up to several days</strong></td>
<td>After <strong>24 hours</strong></td>
</tr>
<tr>
<td>Estimate DM losses</td>
<td>0-3-10-15% [\Delta T= 0; 0 \leq \Delta T \leq 1; 1 \leq \Delta T \leq 5 or \Delta T \geq 5]</td>
<td>More precise (Overestimate)</td>
<td>Underestimate</td>
<td>Close to DM losses measured</td>
</tr>
<tr>
<td>Equation</td>
<td></td>
<td>( \text{DM loss (%)} = \Delta T \times 0.62 + 1.05)</td>
<td>( \text{DM loss (%)} = T_{\text{max}} \times 0.14 - 1.78)</td>
<td>( \text{DM loss (%)} = 0.49 \times T - 9.73)</td>
</tr>
</tbody>
</table>

- Fit well when **T ambient is stable** e.g. mini silo trial
  - No influence of **T ambient**
  - **T ambient** is stable even during AS

- No controlled **T ambient** and **AS duration**

- More general and practical
Predicted vs. observed (meta) DM loss (%).
Two models based on Δ to ambient temperature

• The two models are over-estimating
• EQ 1 comes closer to observed DM losses (Meta data, overestimates DM loss by 1.32% on average).

Obs. 1 from Wilkinson and Hall (1965); Obs. 2 from Henderson et al. (1979); Obs. 3 and 4 from Schukkling and Overvest (1980); Obs. 5 and 6 from Honig and Woolford (1980); Obs. 7 and 8 from Honig (1980); Obs. 9 from Rees (1982).
Predicted vs. observed (meta) DM loss (%).
Two models based on recorded temperature after 24 hours of aerobic stability.

DM loss (%) estimate

- **EQ 2** is underestimating (by 0.69% points on average)
- **New model** naturally fits better to the Meta data (overestimates DM loss by 0.12% points on average)

Obs. 1 from Wilkinson and Hall (1965); Obs. 2 from Henderson et al. (1979); Obs. 3 and 4 from Schukkling and Overvest (1980); Obs. 5 and 6 from Honig and Woolford (1980); Obs. 7 and 8 from Honig (1980); Obs. 9 from Rees (1982).
### Recorded vs. Predicted DM loss with 4 different models

<table>
<thead>
<tr>
<th>Treatment</th>
<th>C</th>
<th>SSFC</th>
<th>C</th>
<th>SSFC</th>
<th>C</th>
<th>SSFC</th>
<th>C</th>
<th>SSFC</th>
<th>C</th>
<th>SSFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize (big bales) [120]</td>
<td>3.4</td>
<td>1.2</td>
<td>15</td>
<td>15</td>
<td>20.2</td>
<td>10.8</td>
<td>3.1</td>
<td>0.4</td>
<td>7.1</td>
<td>-2.3</td>
</tr>
<tr>
<td>Maize (mini silo) [90]</td>
<td>8.2</td>
<td>5.6</td>
<td>15</td>
<td>10</td>
<td>6.2</td>
<td>3.4</td>
<td>1.9</td>
<td>1.1</td>
<td>3.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Grass/legume (mini silo) [90]</td>
<td>3.1</td>
<td>1.9</td>
<td>10</td>
<td>10</td>
<td>4</td>
<td>2</td>
<td>1.8</td>
<td>1.3</td>
<td>2.6</td>
<td>1</td>
</tr>
<tr>
<td>Maize (mini silo) [8]</td>
<td>3.8</td>
<td>2.6</td>
<td>15</td>
<td>15</td>
<td>5.9</td>
<td>5</td>
<td>2.3</td>
<td>2</td>
<td>4.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Maize (mini silo) [16]</td>
<td>3.3</td>
<td>2.2</td>
<td>15</td>
<td>15</td>
<td>6.3</td>
<td>5.4</td>
<td>2.2</td>
<td>2.1</td>
<td>4.4</td>
<td>3.9</td>
</tr>
<tr>
<td>Maize (mini silo) [32]</td>
<td>2.9</td>
<td>1.8</td>
<td>15</td>
<td>15</td>
<td>7.1</td>
<td>5.2</td>
<td>2.5</td>
<td>2</td>
<td>5.1</td>
<td>3.3</td>
</tr>
<tr>
<td>Alfalfa (mini silo) [8]</td>
<td>10.8</td>
<td>5.7</td>
<td>15</td>
<td>10</td>
<td>11.4</td>
<td>4.1</td>
<td>3.4</td>
<td>1.8</td>
<td>8.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Alfalfa (mini silo) [16]</td>
<td>7.5</td>
<td>4.9</td>
<td>15</td>
<td>10</td>
<td>7.9</td>
<td>3.4</td>
<td>2.7</td>
<td>1.6</td>
<td>5.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Alfalfa (mini silo) [32]</td>
<td>7.3</td>
<td>5</td>
<td>10</td>
<td>3</td>
<td>7.1</td>
<td>4.1</td>
<td>2.4</td>
<td>1.7</td>
<td>4.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Average</td>
<td>5.6</td>
<td>3.4</td>
<td>13.9</td>
<td>11.4</td>
<td>8.5</td>
<td>4.8</td>
<td>2.5</td>
<td>1.6</td>
<td>5.0</td>
<td>1.9</td>
</tr>
</tbody>
</table>
$T_{\text{Max}}$ plot vs DM loss (recorded and predicted)

- Meta data
- Step logic approach
- EQ1
- EQ2
- New model

**Predicted DM loss, %**

- Untreated - Control
- SiloSolve®FC

**Results & Discussion**

- $R^2=0.75$ - $R^2=0.96$ - $R^2=0.99$ - $R^2=0.99$
- $R^2=0.24$ - $R^2=0.465$ - $R^2=0.906$ - $R^2=0.981$
- $R^2=0.002$ - $R^2=0.359$ - $R^2=0.906$ - $R^2=0.911$

- $\geq 30^\circ C \rightarrow 6.5$ DM losses
- Large variability
- We reduce variability
- Lower temperature recorded
- Better fit when $T$ is between 20-30 °C
Limitations of delta to ambient temperature models – from a practical point.

- Without ΔT to ambient:
  More realistic DM loss estimation during fermentation - as well as feed out

- When opening the bunker – the “damp” of hot silage raises concern – but is only reflecting the T difference to ambient – not indicating silage heating due to spoilage.

5% DM losses due to fermentation Unavoidable (McDonald et al., 1991)

≤8% DM losses after AS deterioration
The new model – Practical tool for the farmers

• We confirm that a linear correlation exists with DM loss and recorded silage temperature (independent from the ambient T)

• More practical model and related to face management

• Using a IR camera gives producers an instant indication if they should change de-facing principles

• The model has been already validated in several studies
  ✓ **WE-118**: First estimation and validation of a new model to predict dry matter loss based on temperature changes – II. Validation of maize mini silo and big scale silage
  ✓ **WE-119**: First estimation and validation of a new model to predict dry matter loss based on temperature changes – III. Validation of model in a crop with low ensilability
  ✓ **WE-120**: First estimation and validation of a new model to predict dry matter loss based on temperature changes – IV. Validation of model in a short fermentation regime
Thanks for your attention