Major contributions in 45 years of International Silage Conferences

1970 - 2015

Roger Wilkins and Mike Wilkinson
We will:

• Outline the state of knowledge in 1970
• Highlight contributions to increase UNDERSTANDING of PRESERVATION and FEEDING VALUE
• Highlight contributions on INCREASING SILAGE EFFICIENCY
• Discuss future challenges
### Papers presented and cited

**Silage Conferences, 1970-2012**

<table>
<thead>
<tr>
<th>Papers and posters presented</th>
<th>1399</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cited in our written paper</td>
<td>119</td>
</tr>
<tr>
<td>Referenced in oral presentation</td>
<td>52</td>
</tr>
<tr>
<td>With data in presented slides</td>
<td>7</td>
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State of Knowledge, 1970

• Major biochemical pathways for fermentation identified
• Importance of dry matter %, water-soluble carbohydrates and buffering capacity realised
• Sources of loss identified
• With good technique, digestibility of silage similar to crop before ensiling
• Reduced voluntary intake often limits performance
Major contributions

• Understand preservation

• Understand feeding value

• Improve silage efficiency
UNDERSTANDING PRESERVATION

• Silage fermentation

• Aerobic deterioration

• Animal and human health
Silage fermentation: the organisms involved

Papers showing role of:

Yeast - Weise, 1972
Enterobacteria - Lindgren, 1984; Spoelstra, 1984
Acetic acid bacteria - Spoelstra, 1987
Epiphytic lactic acid bacteria - Pahlow, 1987; Muck, 1987
Silage fermentation: plant components

- Some bacteria have limited capacity to ferment fructans, *Seyfarth, 1993*

Silage fermentation: effect of nitrate content on ensiling potential (Kaiser, 2002)

Calculated minimum nitrate content required for butyric acid-free silages depending on:

- Dry matter (DM) content
- Water-soluble carbohydrate (WSC)/buffering capacity
- Clostridia spore count

Validated for different forages by Pahlow, 2002
Aerobic deterioration

Not mentioned, except surface wastage, in 1970

Magnitude of losses (up to 30% in affected areas) quantified by Honig, 1974

Organisms highlighted:

- Yeasts, Weise, 1972
- Bacilli, Woolford, 1976
- Acetic acid bacteria, Spoelstra, 1987

Pahlow and Muck, 2009, conclude ‘Most often yeasts utilise lactic acid and raise pH allowing others, such as bacilli, to develop’
Aerobic deterioration

Large effects on deterioration of:

• Extent of air permeation into exposed silo face, *Honig, 1974*

• Silage composition (reduced by high levels of undissociated acetic acid), *Wolthusen, Rostock, 1989*
Aerobic deterioration model, *Williams, 1993*

Driven by:

- **Microbial growth**, including inhibitory factors
- **Gas movement**
- **Heat transfer**
Effect exposure of maize silage to air (days) on feed preference by goats, *Gerlach, 2012*

![Graph showing the effect of exposure of maize silage to air (days) on feed preference by goats. The x-axis represents days (0, 2, 4, 6, 8), and the y-axis represents DM Intake (g/3h). The graph shows a decrease in DM Intake as the exposure to air increases.](image-url)
Risks to animal and human health

First reports:

• *Listeria monocytogenes* in big bale silage, *Fenlon, 1987*

• *Penicillium roquefortii* prevalent, *Auerbach, 1993*
Risks to animal and human health

Reviews by *Wilkinson, 1999,* and *Dreihuis, 2012* highlighted:

- *E.coli*
- *L. monocytogenes*
- *P. roquefortii*
- *Clostridium botulinum*

and prevalence of mycotoxins
UNDERSTANDING EFFECTS ON FEEDING VALUE

• Intake

• Nitrogen utilisation
Feed intake

Limited by:

• Protein breakdown *Barry, 1976; Wilkins, 1978*
• Total acids *Wilkins, 1978*
• Physical factors (chop length) *Dulphy, 1976; Deswysen, 1978*

Model for prediction by *Huhtanen, 2002*, from:

• Ammonia N
• Total acids
• Digestibility
Nitrogen utilisation

Poor N utilisation from silage leads to:

• Low N retention by animal

• Increased fat in carcases, *Waldo, 1978*

• Increased loss of N to environment, *Misselbrook, 2012*
Limitations to N utilisation

Low production of microbial protein

Resulting from large quantity of non protein nitrogen and low quantity of readily available carbohydrates

Sucrose supplementation increased N retention, *Syrjala, 1972*

and microbial protein, *Huhtanen, 1987; Chamberlain, 1993*
Effect sucrose infusion on microbial N, *Huhtanen, 1987*

<table>
<thead>
<tr>
<th></th>
<th>No infusion</th>
<th>Sucrose infusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumen ammonia-N</td>
<td>8.3</td>
<td>5.0</td>
</tr>
<tr>
<td>Microbial N at duodenum</td>
<td>43</td>
<td>59</td>
</tr>
<tr>
<td>Microbial N, g/kg OM apparently digested in rumen</td>
<td>24</td>
<td>32</td>
</tr>
</tbody>
</table>
INCREASING SILAGE EFFICIENCY

• Control or monitor crop composition
• Improve drying rates
• Use effective additives
• Improve N utilisation
• Improve silo management and sealants
• Reduce environmental impact
Improve drying rates: plastic elements for crop conditioning, *Klinker, 1981*
Additives to improve preservation and feeding value

Initial concentration on chemical additives

Technique for assessing anti-microbial spectra, *Woolford, 1972*

Clarified mode of action of formic acid
Microbial additives 1

- Importance of high application rate ($10^6 / \text{g FM}$), *Lingvall, 1972*
- Positive effects of *L. plantarum* on fermentation and feed intake, *summarised by Wilkins, 1996*
- But could reduce aerobic stability
Microbial additives 2

Heterolactic *L. buchneri* increased acetic acid and aerobic stability, *Driehuis, 1996*

<table>
<thead>
<tr>
<th></th>
<th>No additive</th>
<th>With <em>L. buchneri</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aerobic stability (hours)</td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td>130</td>
<td>&gt; 320</td>
</tr>
<tr>
<td>Maize</td>
<td>43</td>
<td>792</td>
</tr>
<tr>
<td>Wheat</td>
<td>125</td>
<td>250</td>
</tr>
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</table>
Additives to increase digestibility

- Session in 1976 on cellulases - Increased lactic acid, but no effect on DM digestibility
- In 2009 L buchneri PTA 6138 with ferulic esterase activity increased fibre and DM digestibility, but by only 1 % unit, Bruesermeister, 2009; Dupon, 2012
- Romero, 2012, screened 18 enzymes and the best increased NDF digestibility of Cynodon dactylon (Bermuda grass) from 31% to 40%
## Treatments to improve N utilisation 1:
Suppress fermentation in silo, *Jaakola, 1993*

<table>
<thead>
<tr>
<th>Formic acid (l/t)</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>WSC in silage</td>
<td>3</td>
<td>19</td>
<td>37</td>
<td>92</td>
</tr>
<tr>
<td>(g/kg DM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microbial N</td>
<td>49</td>
<td>57</td>
<td>58</td>
<td>65</td>
</tr>
<tr>
<td>duodenum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(g/day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microbial N</td>
<td>12.7</td>
<td>15.4</td>
<td>16.4</td>
<td>18.5</td>
</tr>
<tr>
<td>(g/kg DMADR)</td>
<td></td>
<td></td>
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## Treatments to improve N utilisation: 2

Plant polyphenol oxidase, *Jones, 1993*

<table>
<thead>
<tr>
<th></th>
<th><em>Trifolium pratense</em> (Red clover)</th>
<th><em>Medicago sativa</em> (Lucerne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non protein nitrogen (NPN), % total N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbage</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Ensiled, 3 days</td>
<td>34</td>
<td>52</td>
</tr>
<tr>
<td>Ensiled, 7 days</td>
<td>47</td>
<td>79</td>
</tr>
</tbody>
</table>
## Treatments to improve N utilisation 3

### Plant tannins, *Hymes Fecht, 2005*

<table>
<thead>
<tr>
<th></th>
<th>Medicago sativa (Lucerne)</th>
<th>Lotus corniculatus (Birdsfoot trefoil)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low tannin</td>
</tr>
<tr>
<td>3.5% fat corrected milk (kg/day)</td>
<td>31.4</td>
<td>33.8</td>
</tr>
<tr>
<td>Milk protein (kg/day)</td>
<td>0.94</td>
<td>1.04</td>
</tr>
</tbody>
</table>

The table above compares the effects of low and normal tannin levels in *Medicago sativa* (Lucerne) and *Lotus corniculatus* (Birdsfoot trefoil) on milk production and milk protein content in dairy cows. The data shows that the inclusion of low tannin forage can increase milk production and milk protein content compared to normal tannin levels.
Improve silo management and sealants

High oxygen barrier films (eg ‘Silostop’):

- Reduced surface wastage, *Delgano, 1999*
- Reduced yeasts, moulds and clostridia, *Borreani, 2005*
Oxygen barrier film, no tyres
Effects of high oxygen barrier stretch film, *Borreani, 2012*

<table>
<thead>
<tr>
<th></th>
<th>Standard polyethylene</th>
<th>High oxygen barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen permeability</td>
<td>7989</td>
<td>32</td>
</tr>
<tr>
<td>(cm$^3$O$_2$/m$^2$ per 24h)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bale surface covered by moulds (% of total area)</td>
<td>3.3</td>
<td>0.3</td>
</tr>
<tr>
<td>DM loss (g/kg)</td>
<td>63</td>
<td>34</td>
</tr>
</tbody>
</table>

Bales wrapped with 6 layers; mean for *Lolium multiflorum* (Italian Ryegrass) and *Trifolium pratense* (Red Clover)
Silage systems

• Farm-scale systems, eg Lingvall, 1972; Morrison, 1982; Gordon, 1984

• Economic models, eg Witney, 1974; McGechan, 1990; Bolsen, 2012
Impact on environment

• Early meetings only concern was effluent with high biological oxygen demand (BOD)
• First paper on methane in 1999, Takahashi
• First papers on volatile organic compounds in 2009, Mitloehner; Montes; Hafner

Surprisingly few contributions on environmental losses of N compounds
FUTURE CHALLENGES

• Improve silage management precision – sensors and decision support models
• Effective edible sealants
• Enhance digestibility during ensiling
• Incorporate protein protection in grasses and lucerne
• Control mycotoxins
• Ensure high hygienic quality and silo safety
CONCLUSIONS 1

Benefits from Silage Conferences:

• Rapid communication of new findings
• Multidisciplinary participation
• Building confidence and awareness leading to enhanced collaboration
CONCLUSIONS 2

Great progress that has

IMPROVED PRACTICE FOR BENEFIT OF MANKIND

New challenges have emerged. They require sustained investment in silage R & D

and continuation of Silage Conferences!