Silage fermentation & conservation

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Silages

- Silage is the product of anaerobic storage of high moisture forage
- Oxygen exclusion is crucial
- Storage process = fermentation or ensiling
- Contain 20-40% DM
- Form bulk of ration of dairy cow diets especially during winter
- Stored in silos (towers, trenches, bunkers, plastic bags)
Types of Silages:

- **Cereal silages** e.g. Corn, wheat and Sorghum
  - whole plant is ensiled
  - grain gives **fermentable** carbohydrate, stem gives digestible fiber (energy), palatable

- **Temperate grasses**: e.g. ryegrass & timothy
  - Good ruminant feeds; High NPN
  - High in **sugars** (15%), protein (15%), low NDF (40%)

- **Tropical grass**: e.g. bermuda & bahiagrasses
  - low sugars, high NDF (75%), poor fermentation,
  - Wilting is often necessary to improve their fermentation
Types of Silages

♦ **Legumes: e.g. peas, beans, clover, alfalfa**
  - High CP (24%),
  - Difficult to ensile due to high buffering capacity
  - Wilting, additive treatment- aid fermentation

♦ **Haylage:**
  - High DM grass silages (40-60%)
  - Difficult to pack due to maturity; ensiled in bales
  - Additive treatment may aid fermentation
Types of silos

- Bag silos
- Round bale bunker
- Mini-silo
Tower silos
Pit/trench silo
Bunker silo
Silage making in bunkers
Haylage
# Phases of silage conservation

<table>
<thead>
<tr>
<th><strong>Pre-ensiling</strong></th>
<th><strong>Ensiling</strong></th>
<th><strong>Feedout</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Aerobic</td>
<td>• Anaerobic</td>
<td>• Aerobic</td>
</tr>
<tr>
<td>• Plant respiration</td>
<td>• Sugar fermentation</td>
<td>• Fungal resurgence</td>
</tr>
<tr>
<td>• Protease activity</td>
<td>• LAB dominance</td>
<td>• Acetic bacteria, yeasts, molds</td>
</tr>
<tr>
<td>• Epiphytic organisms</td>
<td>• Lactate &amp; VFA formation</td>
<td>• pH 6 – 9</td>
</tr>
<tr>
<td>• pH 5.5-6.5</td>
<td>• pH 3.8 - 5</td>
<td>≤ 47% DM loss</td>
</tr>
</tbody>
</table>
During fermentation

1. Sugars are fermented into volatile fatty acids (VFA) like lactic, acetic, propionic & butyric acids by anaerobic microorganisms.

2. The formation of the acids reduces the pH (target = 4).

3. Low pH pickles product preventing growth undesirable microorganisms that impair the fermentation.

4. Protein is degraded into ammonia and NPN (target =<100g ammonia/kg total Nitrogen).
Chemical changes during fermentation

Scale (%)

Days

Sugars
CP
Lactate
pH
Ammonia
Acetic acid
Butyric acid

1 14 50

GRASS ——————————— SILAGE
Grass & silage protein fractions

- Grass
- Silage

Components:
- ammonia
- nitrate
- amines
- peptides
- Nucleic acids
- Free amino acids
- True Protein

(Jones, 99)
Types of fermentation

♦ Homolactic fermentation (homofermentative pathway)
  – V. desirable, common in high sugar grasses,
  – sugars fermented to lactic acid, low pH ↓ nutrient loss
  – mediated by *Lactobacillus plantarum, L acidilacti* etc.

♦ Heterolactic fermentations (heterofermentative pathway)
  – Less desirable, occurs when limited sugars are available,
  – Mediated by *Lactobacillus brevis, L. buchneri*
  – Sugars mainly fermented to acetic acid, & alcohols,
  – Less efficient than homolactic fermentation

♦ Secondary fermentation –
  – V. undesirable
  – Degradation of lactate by clostridial bacteria to Ac & Bu
  – Facilitated by high moisture contents & high pH
<table>
<thead>
<tr>
<th>Fermentation</th>
<th>Substrate (Microbe)</th>
<th>Product</th>
<th>Nutrient Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homo-fermentative</td>
<td>Glucose (L. plantarum)</td>
<td>2 x Lactic acid (Low pH)</td>
<td>Low</td>
</tr>
<tr>
<td>Hetero-fermentative</td>
<td>Glucose (L. buchneri)</td>
<td>1 x Lactic &amp; acetic acids, ethanol &amp; CO₂ (Moderate pH)</td>
<td>Moderate</td>
</tr>
<tr>
<td>Secondary fermentation</td>
<td>Lactic acid (Clostridia)</td>
<td>Butyric acid + CO₂ (High pH)</td>
<td>High</td>
</tr>
<tr>
<td>Aerobic spoilage</td>
<td>Glucose, lactic acid (Yeasts &amp; molds)</td>
<td>Ethanol, CO₂</td>
<td>V. high</td>
</tr>
</tbody>
</table>
## Ensiling losses

<table>
<thead>
<tr>
<th>Source</th>
<th>% Net energy lost</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration</td>
<td>1-2</td>
<td>Plant enzymes, aerobic bacteria</td>
</tr>
<tr>
<td>Wilting</td>
<td>2-5</td>
<td>Continued respiration</td>
</tr>
<tr>
<td>Fermentation</td>
<td>4</td>
<td>Heterofermentative bacteria</td>
</tr>
<tr>
<td>Secondary Fermentation</td>
<td>0-5</td>
<td>Clostridia</td>
</tr>
<tr>
<td>Effluent</td>
<td>5-7</td>
<td>Low DM at harvest</td>
</tr>
<tr>
<td>Surface wastage/Aerobic spoilage</td>
<td>0-10</td>
<td>Aerobic microbes</td>
</tr>
</tbody>
</table>
Aerobic spoilage

- Cause of significant loss of nutrients
- Caused by aerobic sugar & lactate utilizing yeasts & molds
- Heat production from such microbes denatures protein
- Avoided by
  - Good packing at ensiling
  - Good silo face maintenance
  - Additives
Aerobic spoilage prevention

- Proper packing
- Manage the silo face
  - Feedout quickly (12 inches/day)
  - The narrower the silo face, the better
  - Minimize silo face disturbance with a block cutter
Silage Additives

Silage additives should
1. increase DM (nutrient) recovery,
2. improve animal performance
3. decrease heating and molding during storage and feed out.

Changes in fermentation end products without quantifiable improvements in one or more of these categories is questionable. (Kung, 1999?)

http://ag.udel.edu/anfs/faculty/kung/articles/a_review_on_silage_additives_and.htm
Silage additives

- **Direct acidifiers**
  - inorganic/organic acids - ↓ pH
  - eg Sulphuric and formic acids

- **Fermentation inhibitors**
  - Immediately ↓ pH
  - Sterilents to inhibit microflora
  - eg formaldehyde, Maxgrass, Add safe, sorbic acid salts
Silage additives contd.

- **Fermentation stimulants**
  - provide substrates for fermentation eg molasses
  - enzymes - speed-up fermentation eg. cellulase
  - Inoculants - microbial cultures e.g. homofermentative lactobacilli

- **Others**
  - Specific antibiotics/ to ↑ nutritive value
    (NaCl, starch, CaCO$_3$ etc)
Organic acids

♦ Role
  – Rapidly reduce pH; hence inhibit undesirable microbes
  – Antifungal – hence enhance aerobic stability
  – Normal application rate = 3-4% fresh weight

♦ Types
  – Pure acids e.g. formic, propionic, acetic & benzoic acids.
    • Effective but caustic & hazardous
  – Buffered organic acids – Ca & Na salts of pure acids
    • Less caustic & safer to handle
Ammonia (urea)

- **Role**
  - Alkaline and antifungal in nature
  - Improves aerobic stability
  - Contributes CP
  - Apply at 1 -2% fresh weight

- **Concerns**
  - Narrow harvest window
    - If < 60% moisture – volatilization
    - If >70% moisture – N loss in effluent
  - May hinder fermentation & increase DM losses
  - V. caustic, protective clothing required
  - Ammonia poisoning
Inoculants

♦ Definition
Additives containing bacteria selected to grow quickly and dominate the bacterial population in the silage

♦ Types
1. Traditional (homofermentative) inoculants
   • e.g. Lactobacillus plantarum
   • ↑ lactic acid & ↓ pH, acetic & butyric acids
   • ↓ losses of DM (1-3%), sugar and protein

2. Newer inoculants (heterofermentative)
   – Aerobic stability enhancers
   – e.g. L. buchneri

3. Combo inoculants
Traditional inoculants

- Depended on dominance of homolactic bacteria (e.g. L. plantarum)
- Aimed to preserve nutritive value by rapid acidification
- Only focused on improving the ‘ensiling’ phase
Heterolactic Bacteria

- Ferment lactate to stronger antifungal acids like acetate & propionate

- Greater potential to inhibit spoilage yeasts

- Candidates
  - Propionic acid bacteria e.g.
    (only effective in slow fermentations)
  - Lactobacillus buchneri
Effects of L. buchneri on silage
(Driehuis et al., 1999)

(P<0.05)
Effects of L. buchneri on pH & DM loss

Higher pH due to depressed lactate production & higher DM losses

(Driehuis et al., 1999)
Using a mixture of homo- & heterolactic bacteria

♦ Rationale
  - Homolactic bacteria will improve the fermentation and prevent DM losses or pH rise
  - Heterolactic bacteria will inhibit yeasts and improve aerobic stability
Which of the two combo inoculants on the US market is more effective?

– A mixture of *P. pentosaceous* & *L. buchneri* (Lallemand)
  or
– A mixture of *L. plantarum*, *E. faecium* & *L. buchneri* (Pioneer)

(Huisden et al., 2005)
Treatments

- **CON** = Control
- **BB** = Lallemand combo inoculant
- **DBB** = 2 x BB
- **PN** = Pioneer combo inoculant
- **DPN** = 2 x PN
Treatment effects on yeasts (log cfu/g) & aerobic stability (hours)

(Huisden et al., 2006)
Treatment effects on fermentation indices (%)
Summary

- Both combo inoculants prolonged bunk life and tended to increase DM losses
- No difference between two types of combo inoculants
- No difference between normal and high rates
- Effect on performance?