Short and long term storage of wet by-products fed to ruminants

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Outline

1. Importance of wet by-products as feedstuffs, volume produced worldwide.
2. General description of diversity, industrial processes, nutritive value.
3. Short term storage
   - top vs. inner subsurface layer
   - treatments.
4. Long term storage
   - ensiling characteristics,
   - aerobic stability,
   - mixtures,
   - additives,
   - silo types.
5. Opportunities for research work in the future
The Swill Milk Scandal was a major adulterated food scandal in New York in the 1850s.

Cows were fed swill which was residual mash from nearby distilleries.

**MESSAGE FOR THE XXI CENTURY:**

**BENEFITS:**

- AVAILABLE FEED SOURCE IN HIGH VOLUME
- ECONOMICAL AND ENVIRONMENTAL ASPECT

**HAZARD:**

- ANIMAL HEALTH RISK
- STORAGE CHALLENGES
- FOOD SAFETY (eg. AFLATOXIN)
Importance of wet by-products: SUPPLY approx. 1000 million ton/year for feeding

Main wet by product sources and producers

1. Sugar factory
   - sugar beet pulp (USA, EU: GE, RU)
   - sugar cane by-products (Brazil, China, India)
   - sorghum by-products (USA, Africa, Australia)

2. Fruit by-products: citrus pulp (Brazil)

3. Brewers’ by-products: brewers’ grain (Brazil, China, USA)

4. Distillers’ by-products: DDGS (corn: USA; wheat: EU)

5. Starch or ethanol prod.: CGF (USA, EU, Asia)
Types of wet by-products from sugar industry

Wet sugar beet pulp (247 million ton/year: for feed and biogas)

- DM: 20-25% (perishable)
- Sugar: 5%DM (palatable)
- dNDF: 20-25%DM (hemicellulose) for cattle
- Heat-stress TMR ingredients in dry continental region: DMI and milk fat%.
- Good fermentability: 'Sausage' (successfull story)
- 1993/94: more than 1 million tonnes of pressed sugar beet pulp across Europe have been stored in plastic tube silos (Budissa Bag Technologies)

<table>
<thead>
<tr>
<th></th>
<th>Dry matter</th>
<th>Crude protein</th>
<th>Crude fiber</th>
<th>NDF</th>
<th>ADF</th>
<th>lignin</th>
<th>Total sugars</th>
<th>OMd</th>
<th>ME</th>
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<td>%DM</td>
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Washing
Shredding
Slicing into V-shaped strips (2 mm wide)
Passing into a rotating diffuser drum immersed in water at 72°C
Types of wet by-products from sugar industry

Sugarcane by-products (200 million ton/year for feed)

Field: sugarcane tops (DM: 30%, CF: 35%DM, ADL: 6%DM, CP: 5-7%DM)

Process:
- sugarcane bagasse (DM: 45%, CF: 45%DM, ADL: 12% DM, CP: 2%DM)
  - ‘Factory’ bagasse: poor dig, fibrous forage
  - ‘Farm’ bagasse: higher sugar content, higher nutritive value
- sugarcane mud

Heuzé et al, 2014
Types of wet by-products derived from breweries

**wet brewers’ grains:**
*barley, wheat, maize, rice and sorghum*  
(high protein -seasonal product)

<table>
<thead>
<tr>
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<th>wet brewers grain, fresh (barley)</th>
<th>wet brewers grain, ensiled (barley)</th>
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<td><strong>Dry matter</strong></td>
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<td>%DM</td>
</tr>
<tr>
<td>Crude protein</td>
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<td>Crude fiber</td>
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<td>Lignin</td>
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<td>Starch*</td>
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<tr>
<td>Total sugars</td>
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</tr>
<tr>
<td>OMD</td>
<td>%</td>
<td>%DM</td>
</tr>
<tr>
<td>ME</td>
<td>MJ/kg DM</td>
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<td>N dig. ruminants</td>
<td>%</td>
<td>%DM</td>
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<table>
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<td>ME</td>
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<td>N dig. ruminants</td>
<td>76,5</td>
<td>78,3</td>
</tr>
</tbody>
</table>

Heuzé et al, 2015
Corn distilleries produce:
- alcoholic beverages,
- industrial ethanol
- ethanol as biofuel (corn-based: USA)

**Dry-milling distillery -ethanol production**
(40 million ton/year):
- spent grains, wet grains,
- wet distillers grain (WDG),
- wet distillers grain with solubles (WDGS),
- distillers wet grains with solubles (DWGS),
- dried distillers grain (DDG),
- condensed distillers solubles - syrup (CDS),
- dried distillers solubles (DDS)
- dried distillers grain with solubles (DDGS: CP: 40% M, STARCH <8%DM, low lysine, UDP-source)
By-products from starch or ethanol production: ‘wet-milling’

Wet-milling products:
1. maize starch,
2. maize germ oil meal,
3. maize steep liquor,
4. corn gluten meal,
5. corn gluten feed
   (meal + CGF: 15 million ton/year)

Corn gluten feed (WET OR DRIED)
- maize bran + maize steep liquor
  + distillers solubles, + germ meal,
  + cracked maize screenings.
- NUTRITIVE VALUE:
  - DM: 40%
  - starch: 24-28% DM
  - CP: 20-25% DM (70% dg.)
  - acidic (pH approx. 4.0-4.5), but perishable
  - mycotoxin hazard: aflatoxinB1, DON, T2 F2
  - corn gluten meal 65%CP ≠ corn gluten feed 20-25% CP
Fruit wet by-products: citrus by-products

The main producer of citrus fruit for processing is Brazil 2010: 47% of the world production, followed by the USA (29%).

Citrus pulp
• solid residue that remains after fresh fruits are squeezed into juice.
• 50-70% of the fresh weight of the original fruit:
  • peel (60-65%),
  • internal tissues (30-35%)
  • seeds (0-10%)
• nutritive value:
  • DM: 20%
  • soluble fibre (pectins): 40% DM
  • high energy content and good digestibility in ruminant species
  • palatable to cattle
  • health risk: rumenparakeratosis, unbalanced Ca: P ratio
• stability and fermentation:
  • fresh: natural acidity, but still quite perishable
  • aerobically unstable - quick deterioration

WORLDWIDE: 135 million TON/YEAR
Short term storage: aerobic spoilage on the surface and subsurface processes of wet by-products

Periodic delivery of fresh material from the factories to farms (20-40 ton/week):

Achilles ’hill’

What is happening inside and outside?
How can we protect?
FOOD SAFETY AND ANIMAL HEALTH RISK: MYCOTOXIN CONTAMINATION

Toxigenic fungi: wet by-products are particularly at risk

1. in the field
   the grain can be infected by molds and contaminated by mycotoxins before harvest (AFLA B1, DON, T2, F2)

2. during the industrial process
   mycotoxin concentration will be increased in the by-product due to starch and protein extraction (mycotoxins in the bran),

3. on farm, during the short term storage
   in open-air (often non-covered) horizontal piles before feeding: aerobic spoilage (roquefortin)
Short term storage: aerobic spoilage on the surface and subsurface processes of wet CGF (Hungary, 2007)
Temperature changes in *wet CGF* compared to the ambient temperature at depth of 10 cm - *aerobic top layer* \((n=5)\)
Short term storage: aerobic spoilage on the surface and subsurface processes of wet CGF (Hungary, 2007)

The surface: visible spoilage after 14 aerobic days

Untreated: TOP 10 cm

Untreated: 50 cm
Wet CGF temperature at depth of 10 cm and 50 cm on the 14th day of aerobic storage (ambient temperature: 22°C, n=5)

Different letters indicate significant difference, p<0.05

Temperature (°C)

47.4a

22.1d

pH: 5.5 vs. 4.1

Anaerobic conditions?
Surface and subsurface processes in wet brewers’ grain under aerobic and anaerobic conditions after 10 days storage (n=5, 0.3% PA:FA 1:1, 0.5% PA:FA 1:1, buffered 0.5% PA:FA 1:1)

Different letters show significant differences p< 0.05
Changes in wet brewers’ grain under aerobic and anaerobic conditions after 10 days storage
(n=5, 0.3% PA:FA 1:1, 0.5% PA:FA 1:1, buffered 0.5% PA:FA 1:1)

Different letters show significant differences p< 0.05

<table>
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<th>Aerobic</th>
<th>Anaerobic</th>
<th>Control</th>
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</thead>
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<tr>
<td><strong>Propionic acid</strong></td>
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</tr>
<tr>
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<td>0.4a</td>
<td>0.4a</td>
<td>0.3a</td>
</tr>
<tr>
<td>0.5% PA:FA 1:1</td>
<td>6.7b</td>
<td>6.7b</td>
<td>1.6b</td>
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<tr>
<td>0.5% PA:FA 1:1, buffered</td>
<td>1.4a</td>
<td>1.4a</td>
<td>1.3a</td>
</tr>
<tr>
<td><strong>Acetic acid</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3% PA:FA 1:1</td>
<td>5.9b</td>
<td>5.9b</td>
<td>4.6c</td>
</tr>
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<td>0.5% PA:FA 1:1</td>
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<td>5.3c</td>
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<td><strong>Lactic acid</strong></td>
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<td>2.1c</td>
<td>2.1c</td>
</tr>
<tr>
<td><strong>Ethanol in control WBG:</strong></td>
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<tr>
<td>aerobic: 0.30% g/kg DM</td>
<td>0.8a</td>
<td>0.8a</td>
<td>0.3a</td>
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<tr>
<td>anaerobic: 1.84 g/kg DM</td>
<td>1.4a</td>
<td>1.4a</td>
<td>1.3a</td>
</tr>
</tbody>
</table>

**Different letters show significant differences p< 0.05**
Inhibitory effect of different treatments on deterioration of wet by-products during short term storage

Additives: mould and enterobacteria inhibitors

• propionic acid
• propionic salts: the propionate solution at pH 4.86 was as effective as pure propionic acid (pH = 1.70), so does have considerable antimicrobial activity.
• formic acid and its salts,
• propionic acid/salt and formic acid/salt mixtures,
• buffered acids by ammonia,
• sodium benzoate
• potassium sorbate
Temperature changes in wet CGF compared to the ambient temperature at depth of 10 cm - *aerobic top layer* (n=5)
Inhibitory effect of different treatments on deterioration of wet brewers’ grain during short term storage in under aerobic and anaerobic conditions after 10 days storage (n=5, 0.3% PA:FA 1:1, 0.5% PA:FA 1:1, buffered 0.5% PA:FA 1:1)

Different letters show significant differences p< 0.05
Inhibitory effect of different treatments on deterioration of wet brewers’ grain during short term storage under aerobic and anaerobic conditions after 10 days storage (n=5, 0.3% PA:FA 1:1, 0.5% PA:FA 1:1, buffered 0.5% PA:FA 1:1)

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</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.3a</td>
<td>0.4a</td>
</tr>
<tr>
<td>0.30%</td>
<td>1.4a</td>
<td>1.3a</td>
</tr>
<tr>
<td>0.50%</td>
<td>0.2a</td>
<td>0.8a</td>
</tr>
<tr>
<td>0.5% buff.</td>
<td>1.4a</td>
<td>1.6b</td>
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</tbody>
</table>

Different letters show significant differences p< 0.05
Inhibitory effect of different treatments on deterioration of wet brewers’ grain during short term storage in under aerobic and anaerobic conditions after 10 days storage

(n=5, 0.3% PA:FA 1:1, 0.5% PA:FA 1:1, buffered 0.5% PA:FA 1:1)

Different letters show significant differences p< 0.05
Short term storage: aerobic spoilage on the surface and subsurface processes of wet by-products

Statements:
• inner layers are more stable than the top,
• top surface treatments,
• dose of top surface treatment: DOSE (PA:FA 0.5% vs 0.3%)
• storage time: 7-10-14 days
• covering the piles: acids will volatilize

Further investigations are needed.....
• How many kg acid/m² top?
• Dose (kg acid/m² surface) and concentration (l/t) interaction?
• Salt kg/m² top?
• Storage time and acid treatment interactions?
Short term storage: ’solutions’ for the PRACTICE

1. **Surface/volume ratio**
   (WALLS, 1 m deep concrete TRENCH, temporary store in small CLAMP)

2. **Surface protection: against sunshine and rain** (roof)

3. **Surface protection: against OXYGEN**
   (oxygen barrier film)

4. **Top treatment: acid and/or salt**

5. **Feeding regime: 7-10 (-14?) days**

Further investigations are needed.....
Long term storage of wet by-products: fermentation profile, aerobic stability and effect of mixing/treatments

MIXING AND ADDITIVE APPLICATION
1. Effluent production (DM 15-40%)
   - nutrient losses
   - acidic effluent - damage (concrete)
   - environmental aspects
2. Fermentable carbohydrate - variable
3. Modified natural microflora
4. Structure: ground wet material (baling/consolidation difficulties)
5. Aerobically unstable wet materials

NEI, NEm NEg, ME!
Long term storage of wet by-products: fermentation profile and effect of mixing

Fermentation profile of tomato pulp silages
(2008, n=5, 100 days fermentation, barrels)

Different letters show significant differences $P < 0.05$

(T1) tomato pulp
(T2) tomato pulp covered with 1 kg/barrel salt (NaCl)
(T3) tomato pulp + dried whole seed wheat (20%)
(T4) mixture of tomato pulp + dried whole seed wheat (20%) treated with a silage inoculant (homof. LAB)
Long term storage of wet by-products: fermentation profile and effect of mixing

Fermentation profile of baled tomato pulp silages (2009, n=5, 70 days fermentation)

(T1) tomato pulp + 20% dried ground corn
(T2) tomato pulp + 20% dried ground corn + 0.5% salt (NaCl)
(T3) tomato pulp + 20% dried ground corn + inoculant (homof.LAB)

Lactation net energy content is similar to maize silage harvested with approx. 30-35% starch content
Long term storage of wet by-products: fermentation profile and effect of blending of wet corn gluten feed with wilted lucerne

<table>
<thead>
<tr>
<th>n=3 baled silage</th>
<th>pH</th>
<th>Lactic acid</th>
<th>Acetic acid</th>
<th>Propionic acid</th>
<th>Butyric acid</th>
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<tr>
<td></td>
<td>g/kg DM</td>
<td>g/kg DM</td>
<td>g/kg DM</td>
<td>g/kg DM</td>
<td>g/kg DM</td>
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<tr>
<td>70%WCGF: 30% L</td>
<td>4.3a</td>
<td>62.7a</td>
<td>20.8a</td>
<td>2.2a</td>
<td>0a</td>
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<td>60%WCGF:40% L</td>
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<thead>
<tr>
<th>Ethanol</th>
<th>LA:AA</th>
<th>NH3-N/total N</th>
<th>Aerobic bacteria</th>
<th>Mould</th>
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<tr>
<td></td>
<td>g/kg DM</td>
<td>g/g</td>
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<td>lg_{10} CFU/g</td>
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<tr>
<td>70%WCGF: 30% L</td>
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<td>60%WCGF:40% L</td>
<td>7.2a</td>
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<td>3.88b</td>
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Long term storage of wet by-products: fermentation profile and effect of mixing of wet brewers’ grain with wilted lucerne

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<tr>
<td></td>
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<td>g/kg DM</td>
<td>g/kg DM</td>
<td>g/kg DM</td>
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<td>40%WBG: 60% L</td>
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<tr>
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<td>g/g</td>
<td>%</td>
<td>lg\textsubscript{10} CFU/g</td>
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<td>40%WBG: 60% L</td>
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<td>31.6b</td>
<td>5.03b</td>
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Long term storage of wet by-products: fermentation profile and effect of mixing

Changes in fermentation profile of wet CGF and of wCGF + 10% AF dry corn (n=5)

- Ethanol
- Acetic acid
- Lactic acid

<table>
<thead>
<tr>
<th></th>
<th>Ethanol</th>
<th>Acetic acid</th>
<th>Lactic acid</th>
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<td>wCGF Day 4</td>
<td>7,9a</td>
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<tr>
<td>corn 10% Day 4</td>
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<td>wCGF Day 14</td>
<td>21,0c</td>
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<td>corn 10% Day 14</td>
<td>26,8d</td>
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<td>1,2b</td>
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<td>wCGF Day 30</td>
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<td>6,6d</td>
<td>1,7c</td>
</tr>
<tr>
<td>corn 10% Day 30</td>
<td>23,4e</td>
<td>9,3e</td>
<td>2,9d</td>
</tr>
</tbody>
</table>

No positive results: +20% maize silage.
Significant but not considerable: LAB INOC, or LAB+SALT
Efficient: 4-5-6 kg/ton PA-FA
Long term storage of wet by-products: aerobic stability and effect of blending

Changes in temperature of the aerated wet CGF at 10 cm depth compared to the ambient (10 aerobic days, n=5)

Temperature changes °C

39 vs. 84 hours

Aerobic hours

- wet CGF
- wet CGF + 10% corn
Long term storage of wet by-products: aerobic stability and effect of mixing

Changes in temperature of the aerated wet CGF at 10 cm depth compared to the ambient (10 aerobic days, n=5)

49 vs. 28 hours

Temperature changes °C

Aerobic hours

- wet CGF
- wet CGF + 20% maize silage
Long term storage of wet by-products: aerobic stability and effect of additives

Aerobic stability of control and treated wet CGF on the 10th aerobic days (n=5)

Mix of formic- and propionic acids (60% formic acid, 20% propionic acid), at dose of 5 litre/ton is recommended to apply for ensiling of WCGF to improve aerobic stability after silo-opening.
Long term storage: silotypes

1. Plastic tube
2. Special, high-density bales
3. Bunker silo/clamp

New options for small farms, high quality by-product, suppliers

Highly recommended silotype

Management- and size challenges
Conclusion and future research needs

LACK of COHERENT INFORMATION about fermentation and aerobic stability OF WET BY-PRODUCT STORAGE. Mostly nutritionally focused publications.....

Further investigation is needed on the followed area:

SHORT TERM STORAGE

• adequate TEMPORARY sylotypes and 'best practice’
• undesirable microflora (aerobic instability, fermentation-inhibition)
• contaminants (soil, heavy metals, acids and salts)
• mycotoxin prevention and risk assessment
• additive treatments: acids, salts, inoculants, combinations, dose, top and/or entire bulk treatment for the different by-products

LONG TERM STORAGE

• mixtures: hygroscopic materials
• adequate silotypes and 'best practice’
• additives: acids, salts, inoculants, combinations
Message

By-products offer a massive feed resource providing the opportunity to save more land and water for the production of food, feed and biofuel.

IMMORAL, as ‘silage scientists’ not to make considerable efforts in maximising the use of these nutrients by optimal preservation, storage and feeding.
Thank you for your attention!
Obrigado pela sua atenção!