Grass silage for biorefinery

Effect of additives on silage quality and liquid-solid separation of timothy and red clover silages

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General overview of the project

Introduction

Materials and Methods

Results

Conclusion

What’s coming up...
Innofeed project

Biorefining ensiled grass into inventive feed products

- Developing and testing methods to process grass silage into novel feeds
- Targets: to improve protein self-sufficiency, profitability and sustainability of agricultural production in Finland
- Project is carried out during 2015-2018 by VTT and Luke
- Funding from TEKES and companies
  - A-Rehu
  - Gasum
  - Pohjolan Maito
  - Pellon
  - Pirteää Porsas
  - Roal
  - Eastman
  - Toholammin Kehitys
  - Valio
Surplus grass biomass as raw material for green biorefineries

- Grass grows well in humid temperate areas with a capacity for high biomass production compared to annual crops

- Existing technology is available for its cultivation, harvesting and ensiling

- Due to its low lignin content, it is easier to process than wood or straw

- Grass offers a versatile raw material for feed and other purposes

Photos: ©Luke / Marketta Rinne
Potential to increase grass production from current level

- Increase production level per hectare of current grass fields
- Increase fields under intensive grass production (e.g. from fallow, peat lands)
- Traditional usage of grass as feed for ruminants & horses is not increasing - surplus grass available
- When preserved as silage, grass can be biorefined all year around
Introduction

- Timothy and red clover → excellent potential for biomass production (Boreal)
- Ensiling → all year round

Photos: ©Luke / Marketta Rinne
First step of biorefinery → liquid-solid separation

Introduction

- First step of biorefinery → liquid-solid separation
- Silage additives ↑ fermentation ↓ losses (modify the characteristics of silage as a raw material for a green biorefinery)
- High correlation: silage quality & liquid yield and composition (Franco et al., 2018)
- Silage production system can be manipulated in order to prepare a feed that best meets the requirements of a particular green biorefinery process
The objective of the current work

- Evaluate the effect of additives on chemical composition and fermentation quality of timothy and red clover silages

- Silages were mechanically separated into liquid and solid fractions. Effects of additives and silage raw material quality (plant species and wilting) on the efficiency of the biorefinery process were also evaluated through assessing of yield and composition of the liquid fraction.
materials and methods
Materials and Methods
Timothy and meadow fescue ensiled after:

• short (4 hours; G4)
• long (24 hours; G24) wilting period

Red clover (RC) ensiled after:

• 24 hours wilting
Materials and Methods

Timothy and meadow fescue ensiled after:
- short (4 hours; G4)
- long (24 hours; G24) wilting period

Red clover (RC) ensiled after:
- 24 hours wilting

Additive treatments

- **Control** without additive (C)
- Formic acid based additive – 5 l/t (FA)
- Lactic acid bacteria strains – 5 g/t (LAB)
Experimental field – Timothy

Photos: ©Luke / Marketta Rinne
Materials and Methods…

Timothy 4h and 24h wilted

Photos: ©Luke / Marketta Rinne
Experimental field – Red clover
Red clover 24h wilted
Red clover 24h wilted

Materials and Methods...
Ensiling period of 111, 110 and 97 days (G4, G24 and RC)

Samples: chemical composition and fermentation products

Liquid-solid separation: pneumatic press (in-house built equipment; Luke)
Opening the silos

Ensiling period of 111, 110 and 97 days (G4, G24 and RC)

Samples: chemical composition and fermentation products

Liquid-solid separation: pneumatic press (in-house built equipment; Luke)
Data analysis

✓ **MIXED** procedure of SAS at 5% of probability

✓ **Timothy**: additive, wilting period effects and their interaction

✓ **Red clover**: additive effect

✓ **Overall interaction effect**: additive * forage species
Chemical composition of timothy and meadow fescue (4 and 24 hours wilting; G4 and G24) and red clover (RC) herbage prior to ensiling

<table>
<thead>
<tr>
<th></th>
<th>G4</th>
<th>G24</th>
<th>RC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (DM), g/kg</td>
<td>290</td>
<td>298</td>
<td>285</td>
</tr>
<tr>
<td>Buffering capacity</td>
<td>6.40</td>
<td>6.54</td>
<td>10.10</td>
</tr>
<tr>
<td>In DM, g/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>82</td>
<td>88</td>
<td>101</td>
</tr>
<tr>
<td>Crude protein</td>
<td>98</td>
<td>103</td>
<td>197</td>
</tr>
<tr>
<td>Water soluble carbohydrates</td>
<td>153</td>
<td>109</td>
<td>89</td>
</tr>
<tr>
<td>Neutral detergent fibre</td>
<td>537</td>
<td>563</td>
<td>334</td>
</tr>
<tr>
<td>D-value</td>
<td>700</td>
<td>681</td>
<td>677</td>
</tr>
<tr>
<td>Organic matter digestibility</td>
<td>0.762</td>
<td>0.746</td>
<td>0.753</td>
</tr>
<tr>
<td>Metabolizable energy, MJ/kg DM</td>
<td>11.2</td>
<td>10.9</td>
<td>10.8</td>
</tr>
</tbody>
</table>
Dry matter (g/kg) of grass and red clover silages treated with additives

<table>
<thead>
<tr>
<th></th>
<th>Grass 4 h</th>
<th>Grass 24 h</th>
<th>Red clover 24 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>250</td>
<td>300</td>
<td>270</td>
</tr>
<tr>
<td>LAB</td>
<td>270</td>
<td>290</td>
<td>280</td>
</tr>
<tr>
<td>FA</td>
<td>290</td>
<td>310</td>
<td>300</td>
</tr>
</tbody>
</table>

Grass
- Add < 0.001
- Wilt < 0.001
- Add*Wilt < 0.001

Red clover
- Add = 0.634
- Add*species = 0.021
Ammonia (g/kg N) and pH of grass and red clover silages treated with additives

Ammonia
Grass
Add < 0.001
Wilt < 0.001
Add*Wilt < 0.001

Red clover
Add < 0.001
Add*species < 0.001

pH
Grass
Add < 0.001
Wilt = 0.004
Add*Wilt < 0.001

Red clover
Add = 0.024
Add*species = 0.012
Ash and crude protein (g/kg DM) of grass and red clover silages treated with additives

**Ash**
- Grass
  - Add < 0.001
  - Wilt = 0.062
  - Add*Wilt < 0.001
- Red clover
  - Add = 0.071
  - Add*species = 0.901

**Crude protein**
- Grass
  - Add = 0.134
  - Wilt = 0.097
  - Add*Wilt = 0.056
- Red clover
  - Add = 0.069
  - Add*species = 0.104
Water soluble carbohydrate (g/kg DM) of grass and red clover silages treated with additives

Grass
Add < 0.001
Wilt < 0.001
Add*Wilt < 0.001

Red clover
Add = 0.121
Add*species = 0.010
Fermentation quality of grass and red clover silages treated with additives

![Graph showing fermentation quality of grass and red clover silages treated with additives](graph.png)
Yield of liquid-solid separation of grass and red clover silages treated with additives

Grass
Add = 0.445
Wilt < 0.001
Add*Wilt < 0.001

Red clover
Add = 0.121
Add*species = 0.010
Dry matter retained in liquid of liquid-solid separation of grass and red clover silages treated with additives

Grass
- Add < 0.001
- Wilt < 0.001
- Add*Wilt < 0.001

Red clover
- Add < 0.001
- Add*species < 0.001
Crude protein retained in liquid of liquid-solid separation of grass and red clover silages treated with additives

- Grass: Add < 0.001, Wilt < 0.001, Add*Wilt < 0.001
- Red clover: Add < 0.001, Add*species < 0.001
Yield and retained compounds of liquid-solid separation of grass and red clover silages treated with additives

**Yield**
- **Grass**
  - Add = 0.445
  - Wilt < 0.001
  - Add*Wilt < 0.001

- **Red clover**
  - Add = 0.121
  - Add*species = 0.010

**DM ret. in liquid**
- **Grass**
  - Add < 0.001
  - Wilt < 0.001
  - Add*Wilt < 0.001

- **Red clover**
  - Add < 0.001
  - Add*species < 0.001

**CP ret. in liquid**
- **Grass**
  - Add < 0.001
  - Wilt < 0.001
  - Add*Wilt < 0.001

- **Red clover**
  - Add < 0.001
  - Add*species < 0.001
Formic acid and lactic acid bacteria strains as additives on grass and red clover forages positively impacted chemical composition and fermentation quality of the silages.

Chemical composition influenced liquid yield in liquid-solid separation of grass silages while no effect of additives on liquid yield was observed.

Shorter wilting period resulted in higher crude protein retained in liquid.

Additives increased crude protein retained in liquid for red clover.
WHAT’S COMING UP?

Nordic Feed Science Conference
June 12-13 2018

www.slu.se/nordicfeedscienceconference

- Savonen, O., Franco, M., Stefański, T., Mäntysaari, P., Kuoppala K. & Rinne, M. Grass silage from biorefinery - Dairy cow responses to diets based on solid fraction of grass silage.

Grass for biorefinery

Dairy cow responses to diets based on solid fraction of grass silage

Outi Savonen, Marcia Franco, Tomasz Stefański, Päivi Mäntysaari, Kaisa Kuoppala & Marketta Rinne

Natural Resources Institute Finland (Luke), Jokioinen, Finland

www.luke.fi
Grass silage for biorefinery – Separation efficiency and aerobic stability of silage and solid fraction

Introduction
- A green biorefinery concept involves processing of green biomass into a range of products.
- Grasses provide versatile properties as raw material for green biorefinery.
- Ensures allowing green biomass to be processed all year-round.
- Green biorefinery usually starts with mechanical separation of liquid and solid fractions.
- Solid fractions feed for ruminants, biogas, insulation boards or hydrolysed into simple sugars for further processes.
- Liquid fraction feeds for pigs and cows and raw material for extraction of lactic acid, volatile fatty acids and amino acids.

The aim of the current study was to compare three liquid-solid separation methods on liquid yield, composition and related compounds in liquid and evaluate the effect of preservatives on aerobic stability of silage and solid fraction using two indicators.

Materials and Methods
Three pressing methods:
- Farm scale twin screw press (FTS, Haarslev Industries A/S, Randers, Denmark).
- Laboratory scale twin screw press (LTS, Angel Juicer Ltd., Busan, South Korea).
- Laboratory scale pneumatic press (LPP, Luke in-house built equipment, Joensuu, Finland).

Aerobic stability 3 x 2 x 3 factorial design:
- Three types of raw material: silage, solid fraction or solid fraction with added water (to the same DM as the silage).
- Two forms of raw material: as such or as part of TMR.
- Three preservative treatments: Control without preservative (C), Formic and propionic acid based preservative at 3 l/t (FAPA), Propionic acid based preservative at 3 l/t (PA).

Aerobic stability measurement:
- Three separations, usual inspection of deterioration.

Conclusions
- Twin screw press, farm and laboratory scale, resulted in higher liquid yield and greater amount of retained compounds in liquid fraction as compared to pneumatic press.
- Preservatives extended aerobic stability of silage, solid fraction and solid fraction added with water as such or in a TMR.

Table 1: Chemical composition of original stages, and some are made Table 1.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Solid</th>
<th>Liquid</th>
<th>Solid</th>
<th>Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>40%</td>
<td>60%</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Stage 2</td>
<td>30%</td>
<td>70%</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Stage 3</td>
<td>20%</td>
<td>80%</td>
<td>10%</td>
<td>90%</td>
</tr>
</tbody>
</table>

Table 2: Effect of pressing methods on liquid yield, composition and related compounds in liquid.

<table>
<thead>
<tr>
<th>Component</th>
<th>FTS</th>
<th>LTS</th>
<th>LPP</th>
<th>FTS vs LTS</th>
<th>LTS vs LPP</th>
<th>FTS vs LPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lactic acid (g/kg)</td>
<td>0.5</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Acetic acid (g/kg)</td>
<td>0.5</td>
<td>0.3</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Figure 1: Effect of preservation on aerobic stability assessed through increasing in TVFA value. Stage 3 > Stage 2 > Stage 1 > Control (P < 0.05) Solid vs Solid in TMR vs TMR. Stage as such > Stage in TMR (P < 0.05). Solid as such > Solid in TMR (P < 0.05). Stage as such > Stage in TMR (P < 0.05). All as such vs TMR (P > 0.05).

Figure 2: Effect of preservation on aerobic stability through visual inspection. Stage 3 > Stage 2 > Stage 1 > Control (P < 0.05). Preparative in solid P < 0.05. Preparative in solid P < 0.05. Preparative in solid P < 0.05. TMR vs TMR (P > 0.05) without same letter differ (P < 0.05).
• Savonen, O., Franco, M., Stefański, T., Mäntysaari, P., Kuoppala K. & Rinne, M. Grass silage from biorefinery - Dairy cow responses to diets based on solid fraction of grass silage.

• Stefański, T., Franco, M., Kautto, O., Jalava, T., Winquist, E. & Rinne, M. Grass silage for biorefinery – Separation efficiency and aerobic stability of silage and solid fraction.


• Rinne, M., Keto, L., Siljander-Rasi, H., Stefanski, T. & Winquist, E. Grass silage for biorefinery – Palatability of silage juice for growing pigs and dairy cows.


• Franco, M., Winquist, E. & Rinne, M. Grass silage for biorefinery – A meta-analysis of silage factors affecting liquid-solid separation.
More information about Innofeed project

- Project home page:  
  https://www.ibcfinland.fi/projects/innofeed/

- Facebook:  
  https://www.facebook.com/innofeedprojekti

- Press release:  
Thank you!

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