Refining proteins from green crops for high quality feed products for monogastric animals and dairy cows

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Introduction

• This research is based on the vision of developing sustainable farming systems based on locally produced feeds.

• This is especially important for the organic sector which has several key challenges:
  • Increased demand for organic products
  • Supply of organic protein feed for monogastric livestock
  • Need for organic fertilizers

• Improved, climate-friendly, and robust crop rotations in areas with a low density of livestock.
  • Better efficiency of the nutrients, and higher yields.
Crop rotations important – especially in organic farming
The farming system is based on "green crops"

- Alfalfa
- Red clover
- White clover
- Clover grass
- Brassica species

Harvest 3-4 times/year
The process developed in the "OrganoFinery" project

The process in laboratory scale

- Red Clover
- Clover Grass
- Alfalfa
- Oilseed Radish
Protein recoveries at lab scale

**Red clover**
- Green juice: 40%
- Protein concentrate: 20%

**Clover grass**
- Green juice: 30%
- Protein concentrate: 10%

**Alfalfa**
- Green juice: 50%
- Protein concentrate: 15%

**Oilseed radish**
- Green juice: 40%
- Protein concentrate: 20%
# Amino acid in the dry protein concentrate

<table>
<thead>
<tr>
<th>g/kg DM</th>
<th>Arg</th>
<th>Cys</th>
<th>His</th>
<th>Ile</th>
<th>Leu</th>
<th>Lys</th>
<th>Met</th>
<th>Phe</th>
<th>Thr</th>
<th>Val</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy bean*a</td>
<td>31.4</td>
<td>5.8</td>
<td>10.1</td>
<td>18.5</td>
<td>29.3</td>
<td>26.2</td>
<td>5.2</td>
<td>19.7</td>
<td>15.6</td>
<td>18</td>
<td>179.8</td>
</tr>
<tr>
<td>Red clover</td>
<td>26.8</td>
<td>2.5</td>
<td>10.8</td>
<td>23.5</td>
<td>39.4</td>
<td>26.8</td>
<td>8.5</td>
<td>26.5</td>
<td>20.1</td>
<td>28.2</td>
<td>213.1</td>
</tr>
<tr>
<td>Clover grass</td>
<td>22.9</td>
<td>2.4</td>
<td>9.1</td>
<td>20.9</td>
<td>34.3</td>
<td>23.9</td>
<td>8.2</td>
<td>23</td>
<td>17.7</td>
<td>24</td>
<td>187.2</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>20.1</td>
<td>3.4</td>
<td>9</td>
<td>21.8</td>
<td>35.4</td>
<td>21.5</td>
<td>7.8</td>
<td>25.5</td>
<td>17.6</td>
<td>24</td>
<td>186.1</td>
</tr>
<tr>
<td>Oil seed radish</td>
<td>23.4</td>
<td>4.7</td>
<td>10.1</td>
<td>21.7</td>
<td>37.3</td>
<td>25.4</td>
<td>9.1</td>
<td>25.3</td>
<td>19.2</td>
<td>26</td>
<td>202.2</td>
</tr>
</tbody>
</table>

*aSteenfeldt and Hammershøj, 2015.

Santamaria-Fernandez et al. 2017
Overall biorefining results – pr. HA (10-11 tons TS)

- **Protein**: 530 – 830 kg/ha
- **Biogas**: 980 - 1550 m³/ha
- **Fertilizer**: 147 – 230 kg N/ha
- **Residual effect**: 95 – 120 kg N/ha

Figure: Nanna K. Ytting
Process in demo-scale – protein feed production at a production facility for green feed pellets (Nybro-Tørreri)

In collaboration with
Aalborg University
Aarhus University
Nybro Tørreri
KMC
Runi
Bounum Maskinstation
SEGES
Freshly harvested organic clover grass (within few hours)
Process overview – from harvest to green juice
Process overview – fermentation of green juice

Fermentation

Transport to separation of proteins
Process overview – separation of protein concentrate

Separation of protein and drying (KMC)

Pelletizing of wet paste (Vestjysk Andel)
Process overview – preparation of silage bags of press-residue

Preparation of silage bales of the press-residue
Overall process numbers from Nybro-feed production

(NOT an optimized process)

FRESH BIOMASS
400 tons

GREEN JUICE
177 tons

PRESS CAKE
223 tons

BROWN JUICE

PROTEIN CONCENTRATE
7 tons

SILAGE BALES
COW FEEDING TRIALS

Protein content in concentrate 30-32% - which was lower than in small scale feed for trials in broilers, laying hens and pigs
Protein concentrate

- Protein: 34% of DM
Feeding trials with laying hens

• Three inclusion levels of the protein concentrate (CPC) in the diets were evaluated and compared with control diet:

A: Diet including 0% CPC (Control)
B: Diet including 4% CPC
C: Diet including 8% CPC
D: Diet including 12% CPC

Performance parameters

- Egg production, % (number of eggs)
- Egg weight, g
- Egg quality
- Feed intake (g/h/d)
- Kg Feed/kg Egg (FCR)
- Plumage quality
- Mortality
Main conclusions from feeding trials with laying hens

- Clover grass protein concentrate (CPC) - a promising substitute for organic soybean
- Partial replacement of organic soybean with CPC (4, 8, and 12 %) did not influence the egg production
- Total digestibility of dry matter was not influenced,
  - However, the digestibility of methionine and lysine decreased with higher inclusion amount.
- The yellowness of the yolk increased significantly with CPC in the diet.

Eggs from diets with 0, 4, 8 and 12 % CPC
Evaluation in broilers

• Three inclusion levels of the protein concentrate (CPC) in the diets were evaluated:

A: Diet including 0% CPC (Control)
B: Diet including 8% CPC
C: Diet including 16% CPC
D: Diet including 24% CPC
Evaluation in broilers – color of the breast meat

Content of protein concentrate

<table>
<thead>
<tr>
<th>0%</th>
<th>8%</th>
<th>16%</th>
<th>24%</th>
</tr>
</thead>
</table>
Press residues as cow feed

• Silage of press residues was compared with silage of grass clover from the same field as forage for dairy cows.
• Surprisingly, >5 % more milk was produced

<table>
<thead>
<tr>
<th></th>
<th>Press cake silage</th>
<th>Grass clover silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>In vitro digestibility</td>
<td>70.7 %</td>
<td>67.6 %</td>
</tr>
<tr>
<td>Crude protein concentration</td>
<td>16.8 %</td>
<td>13.6 %</td>
</tr>
<tr>
<td>Daily DM intake</td>
<td>23.1 (± 0.3) kg/d</td>
<td>22.6 (± 0.3) kg/d</td>
</tr>
<tr>
<td>Daily milk yield</td>
<td>37.4 (± 0.9) kg/d</td>
<td>34.6 (± 0.9) kg/d</td>
</tr>
</tbody>
</table>

Pilot Plant at Aarhus University - flow diagram

15-20% TS
Green Biomass

Input

Shredding

Fractionation
Screw pressing

Tank

Silaging

Cattle feed

Protein concentrate

Protein separation
Centrifuge

Protein precipitation
Fermentation/Heat exchange

Biogas

Power/Heat

15-20% TS

20-40% TS

0-70% recirculation

Rest juice 3-8% TS

Juice 6-12% TS

Fiber 25-35% TS

Or…
Results from pilot plant 2017

• Input capacity: 1-2 ton fresh biomass per hour
• Protein concentrate yield: 5-15 % of input TS
• Protein content: 30-55% of TS
• Optimizing yield and quality is an ongoing process
Conclusions

• Protein concentrate can be extracted from fresh grass-clover juice.
  • Robust fermentation-centrifugation method → between 60-80% of the proteins in the green juice can be concentrated
• Approximately 700 kg of crude protein/ha is realistic
  • Currently up to 45% protein content in the protein concentrate
  • Protein concentrate has a good level of essesstial amino acids
  • Protein concentrate contains lactic acid as an extra product from the proces
  • May contain probiotic lactic acid bacteria
• More nitrogen in the rotation of crops is part of the benefits
• The concentrate can substitute soy protein in the diet
• Silage of grass press cake is a valuable forage for dairy cows
• Press cake and residual juice are valuable for biogas production
• A new company for commercialization of the process
  • BiomassProtein.com
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