Contributions from industrial side streams to future protein sources

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Future protein sources

Strong impact on:
- Land-use
- Food prices
- Meat production
  → Environment, climate

Americans eat 122 kg of meat a year
Bangladeshis eat 1.8 kg of meat a year
Can we increase food production and lower CO₂ emission?
Side streams from breweries
**Side-streams from brewing**

- **90 kg Barley**
- **535 kg Water**
- **0.5 kg Hops**
- **2 kg Yeast**

- **Malt**
- **Sugary syrup** (wort)
- **BSG** 120 kg
- **Trub** 2 kg
- **Beer** 450 kg
- **Yeast** 5 kg

Preben Hansen & Tim Hobley
Fractionation is key - food chain can be kept intact

Brewing process
- 535 L
- 505 kg
- 90 kg
- 120 kg

Compact filter
- Pressed-liquid 60 kg
- Pressed BSG 60 kg

Centrifuge
- Supernatant 43 kg
- Sludge 16 kg

DTU FOOD
- Neutral taste
- Improved consistency (soft, crispy, juicy etc)
- Nutritional value (protein, fibre, antioxidants)

Meyers Madhus
- 0.3 % protein
- 0.5 % fibre
- 6 % protein
- 3.4 % fibre

DTU cantine
- 6 % protein
- 19 % fibre

DTU FOOD – Folkemødet 2016
How big is the economic potential?

• 170 breweries in Denmark
• 600 million liters beer produced in Denmark i 2017
  • Amounts to 140 million kg BSG/year in Denmark
• Approx 4% protein in BSG:
  • 5.5 million kg protein “wasted” in Denmark
  • If we assume a price of 20DKK/kg protein: 112 mill DKK
• Protein is a small fraction of the BSG, trub, yeast
Conclusion - Breweries

• Enormous resources are either wasted, burnt or used for feed world wide

• A compact filter can dewater the BSG to improve shelf life, allowing fractionation and exploitation of these resources

• Fractions of BSG can be successfully used as food ingredients with important functional, nutritional and economic benefits
Side streams from dairies
Cheese production

- Raw milk
- Pasteurization
- Standardization and filtration
- Rennet (enzyme)
- Coagulation (curdling)
- Cutting
- Stirring and cooking
- Draining of whey
- Curds
- Milling
- Salting
- Pouring into molds
- Pressing
- Draining of additional whey
- Ripening
- Fresh cheese
- (Cottage and cream cheese)
Larger dairies become food ingredient companies

Arla

Cheese process → Whey

Whey processing

Whey → UF filtration → WPC retentate protein concentrate

Processing: modification separation concentration

Application: prototyping upscaling formulation

WPC 60–90 powder
WPC specialties
Functional proteins

Lactose
~99% lactose
Permeate powder

Whey permeate → Permeate concentrate

Evolution in the whey industry

1980 → By-product from cheese making
1990 → By-product from cheese making
2015 → Product/Ingredient in its own right

Main use

1980 → FEED
1990 → FOOD/IF
2015 → IF/FOOD

Whey is more valuable - cheese is the “by-product”

Slides modified from H.J. Andersen, Arla Food Ingredients
But whey disposal is still an issue, more so in some parts of the world and for many smaller dairies

• Lactose (4%) in whey is often wasted (little or no profit)
  • Animal feed or Fertilizer
  • Dumped into the rivers/sea
  • Or even pay €€€ to get rid of

• Cheap Feedstock for fermentation

⇒ Could reduce both pollution and CO₂ emission while generating value for the dairies
Some Lactic acid bacteria ferment lactose

Lactic acid bacteria as cell factories?
Lactococci as a platform for production of biochemicals from whey and other side-streams

Cell factories >80% yield of:

- R-acetoin
- S-acetoin
- Meso-2,3-butanediol
- R,R-2,3-butanediol
- S,S-2,3-butanediol
- Diacetyl
- Pyruvate
- Ethanol

New products in focus

- Vitamins, fatty acids,
- Jetfuel precursors
- Bioactive compounds
From dairy waste to ethanol
– A spin-out from DTU Food
Conclusion - Dairies

- Larger dairies such as ARLA has created enormous revenues from side streams
- In smaller dairies and in other parts of the world these resources are underutilised
- Valuable products can also be produced via fermentation of dairy side streams for the benefit of the environment
Plant based protein and biorefining

Biorefining

Lignocellulose

Proteins

Minerals

Biowaste/side streams

Future protein sources

Traditional protein sources

Bacteria fermentation

Insect protein
Plant based “meat” products are already in the shops

Impossible burger

https://youtu.be/QB-90-LEPZ4

http://naturli-foods.dk/sortiment.aspx
Biorefining of green biomass for feed

Screw press
Can we use green biomass as a source of protein for human consumption?
Fractionation and purification is the key

1000 kg
Raj grass

310 kg
Juice

190 kg
Brew Juice

690 kg
Pulp

120 kg
Grant protein

6 kg
Hvidt protein

Ruminant feed
pig feed
food?
Amino acid profile of protein from green biomass is excellent

<table>
<thead>
<tr>
<th>Aminosyrer</th>
<th>Anbefalet indtag (% AA)(^4)</th>
<th>Soja protein (% råprotein)(^b)[16]</th>
<th>Rajgræs (% AA)(^c)[17]</th>
<th>Lucerne (% AA)(^c)[18]</th>
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<td>3,9</td>
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Test case: 5%/10% grass protein in energy bars

Grass taste:
- Significant difference
- Grass smell: No difference
- General perception: No difference
Conclusion – protein from green biomass

- Potential use as food ingredients – could contribute to future protein sources
- More research is required to make the process economically viable and to obtain approval for use in food production
Microbial production of protein via fermentation?

Future protein sources

- Traditional protein sources
- Insect protein
- Biowaste/side-streams
- Specific proteins

Bacteria fermentation

Biorefining
Microbial production of food-grade proteins

Technically feasible?

• Proteins for food ingredients
• High-quality proteins - functional, nutritional
• Drop-in protein
• Synthetic food
• Waste/side streams as feed stock

Examples of current microbial food production:
- Chymosine, transglutaminase
- Cheese, yogurt,
- Sausages, fish
- Sauerkraut, Kimchi, etc
- Beer, wine
- Bread

Consumer acceptance?

α-lactalbumin (a high-value whey protein)
Economically feasible?

Can microbes compete with cows for sustainable protein production - A feasibility study on high quality protein

Mike Vestergaard, Siu Hung Joshua Chan & Peter Ruhdal Jensen

Received: 02 June 2016
Accepted: 12 October 2016
Published: 08 November 2016

Up to 50 times value added

Figure 2. Simulation of economic yield. The plot depicts α-La fermentations at maximized productivity with yield per substrate, substrate compositions and economic return based on the substrate price of the X, Y and Z axis respectively. The global maximum represents a fermentation, which converts the initial substrate into α-La worth 52 times the value of the starting material. The fermentation is simulated to take 300 hours and require the substrate to compose of 100% sugar.
Cell factories, biorefining and industrial side-streams can help us limit greenhouse gas emissions and feed the growing population.

Researchers, politicians, industries and consumers – all of us play important roles in paving the way for future sustainable food production.