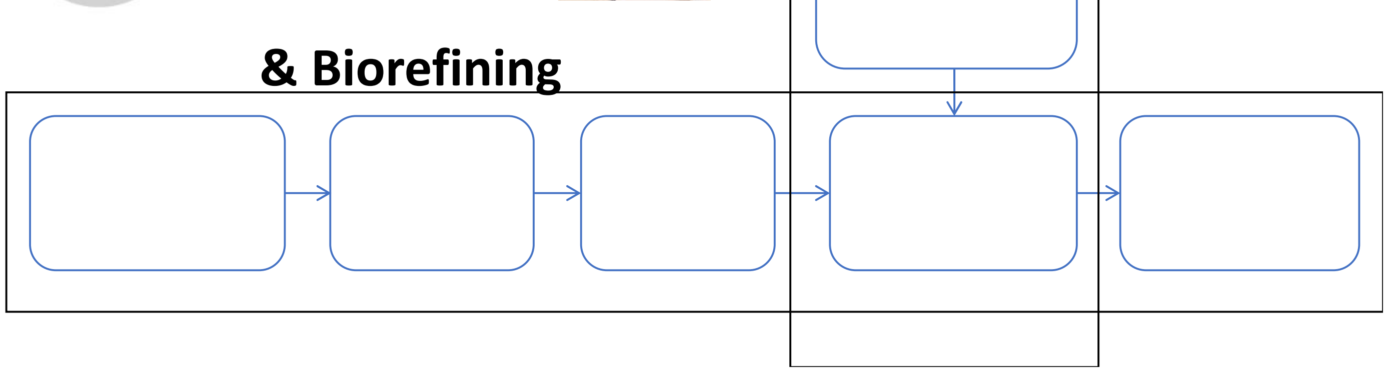
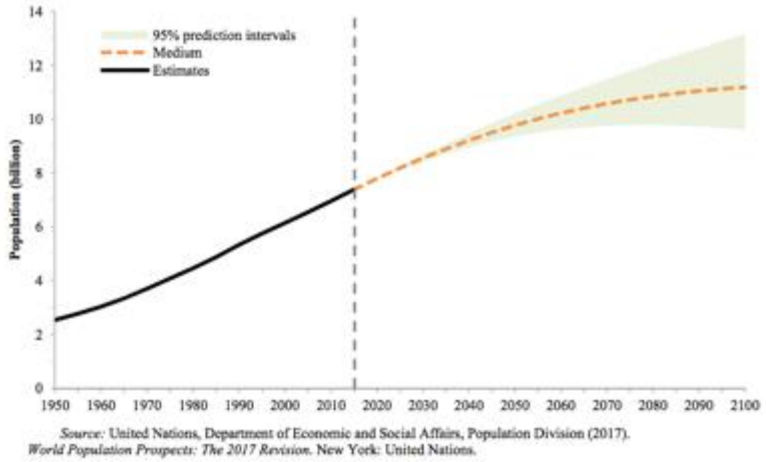
Contributions from industrial side streams to future protein sources

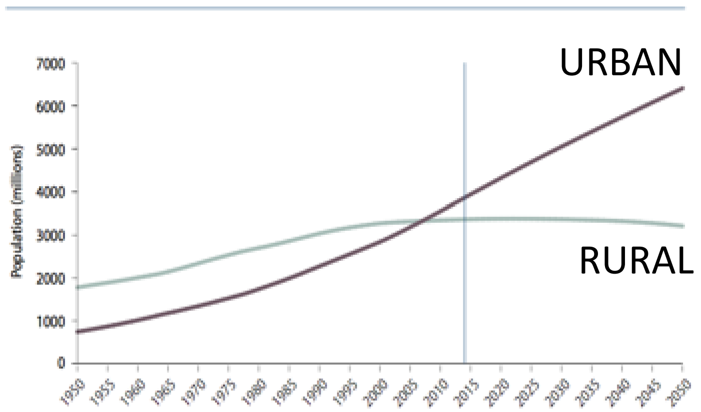
Peter Ruhdal Jensen

National Food Institute, Technical University of Denmark





Future protein sources

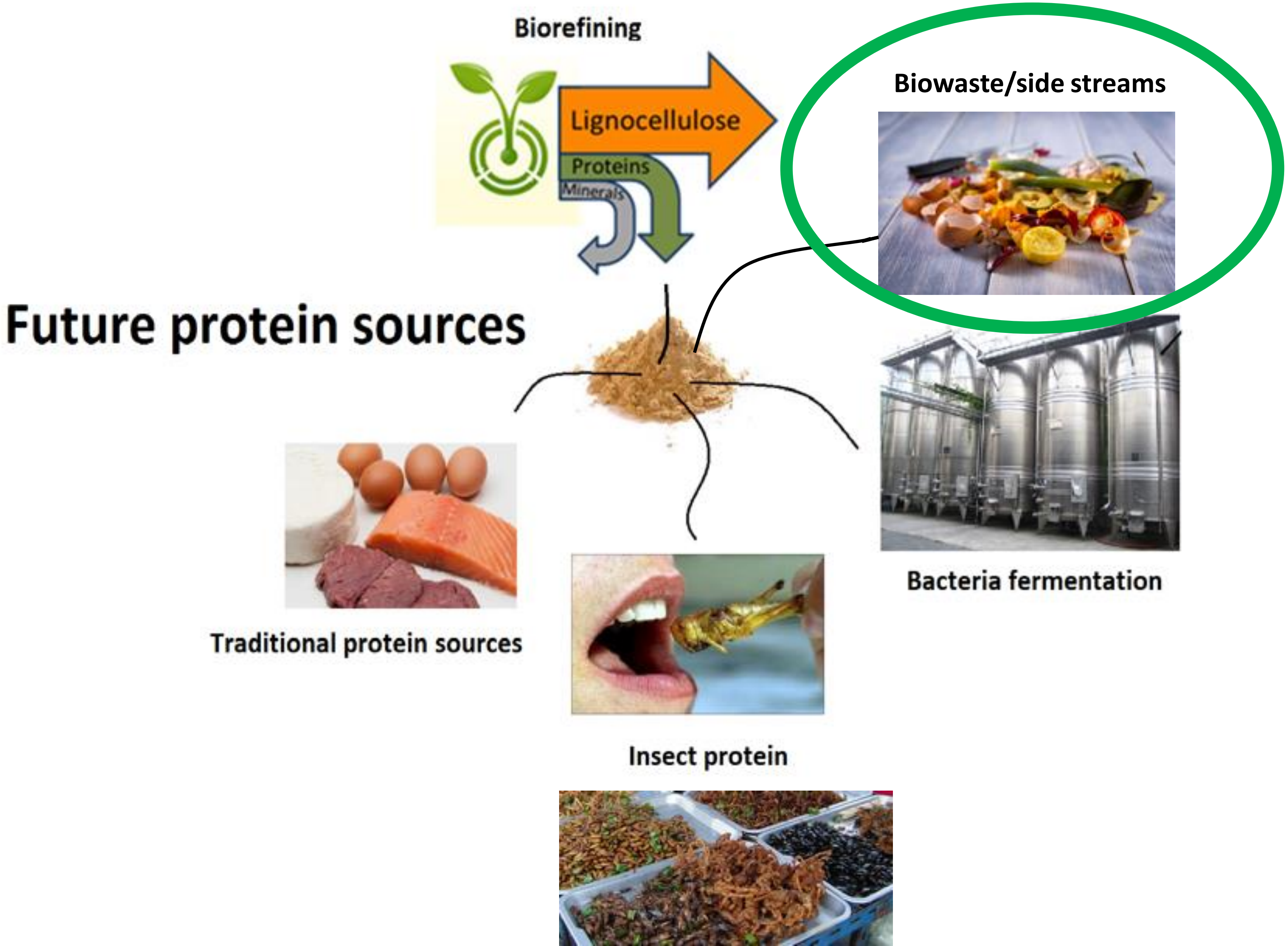


Americans eat 122 kg of meat a year
Bangladeshis eat 1.8 kg of meat a year

Strong impact on:
- Land-use
- Food prices
- Meat production

→ Environment, climate

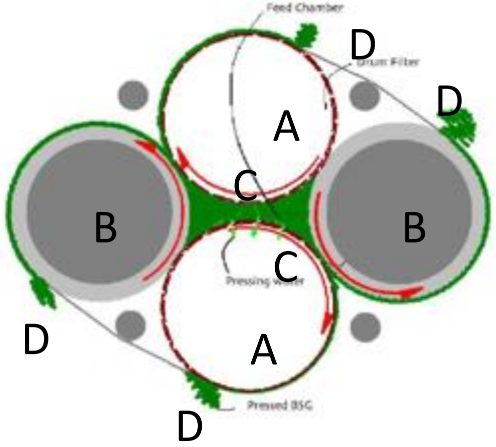
Can we increase food productionen **and** lower CO_2 emission?



Side streams from breweries

Side-streams from brewing

Preben Hansen &Tim Hobley



140mill kg/year in DK

90 kg Barley → Malt

535 kg Water → Malt

Malt → BSG 120 kg

Malt → Sugary syrup (wort)

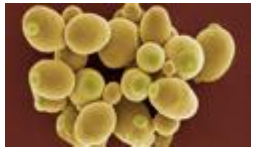
0.5 kg Hops → Sugary syrup (wort)

2 kg Yeast → Sugary syrup (wort)

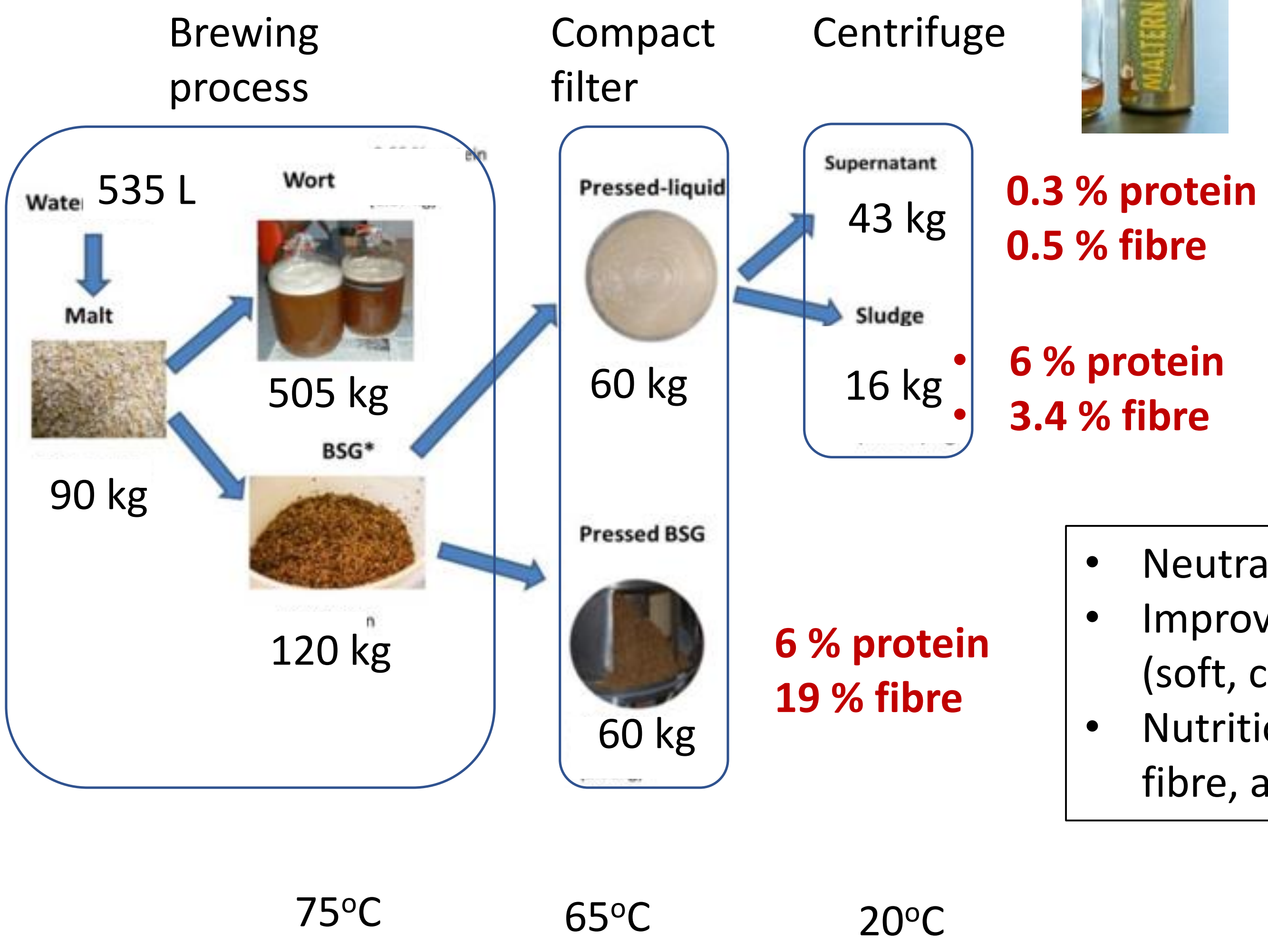
Sugary syrup (wort) → Trub 2 kg

Sugary syrup (wort) → Beer 450 kg

Beer 450 kg → Yeast 5 kg



Fractionation is key - food chain can be kept intact



Meyers Madhus

DTU FOOD

DTU cantine

DTU FOOD – Folkemødet 2016

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

How big is the economic potential?

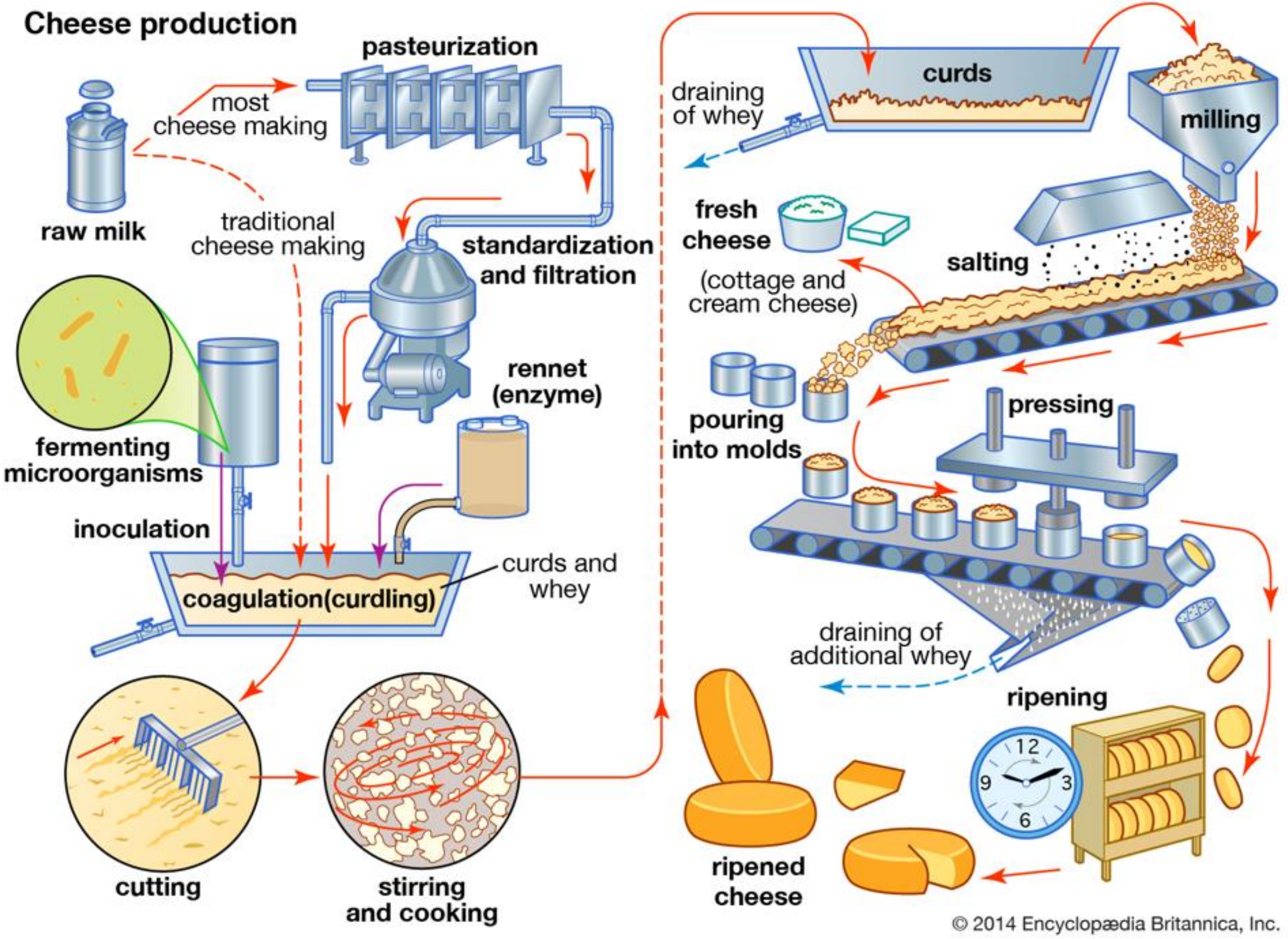
- 170 breweries in Denmark
- 600 million liters beer produced in Denmark i 2017
    - Amounts to 140 million kg BSG/year in Denmark
- Approx 4% protein in BSG:
    - 5.5 million kg protein ”wasted” in Denmark
    - If we assume a price of 20DKK/kg protein: 112 mill DKK
- Protein is a small fraction of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

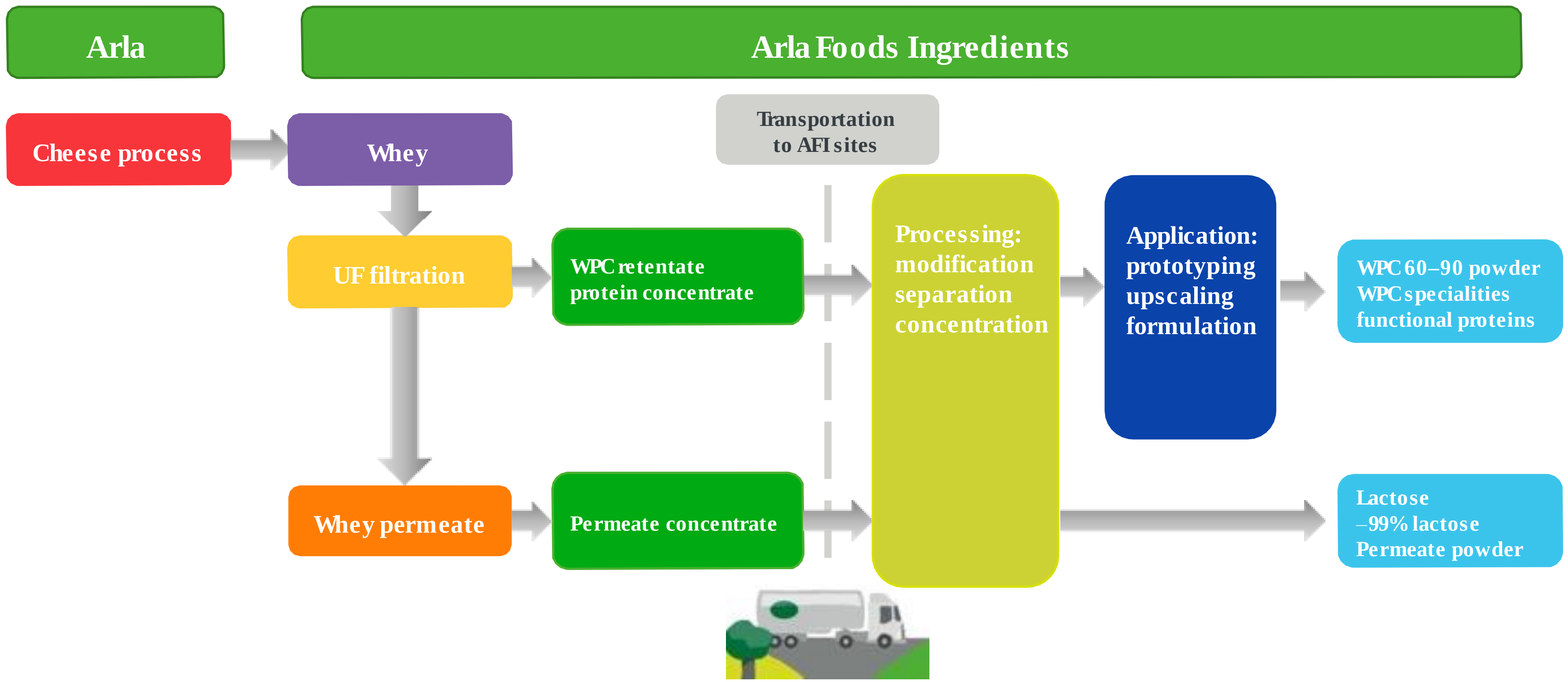
Side streams from dairies

Cheese production



Larger dairies become food ingredient companies

Whey processing



Evolution in the whey industry

	1980 →	1990 →	2015 →
	By-product from cheese making	By-product from cheese making	Product/Ingredient in its own right
Main use	FEED	FOOD/IF	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

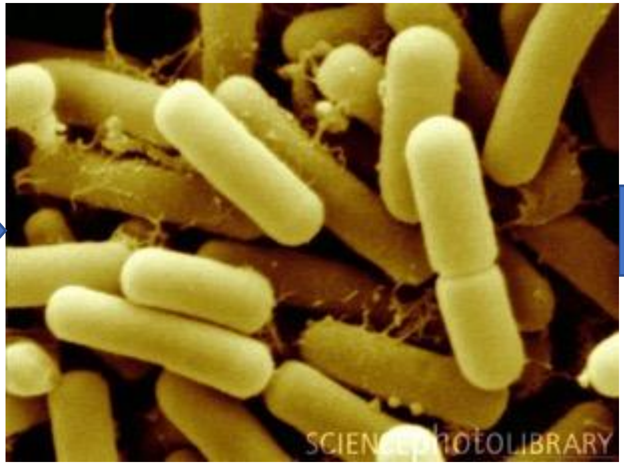
- Lactose (4%) in whey is often wasted (little or no profit)
  - Animal feed or Fertilizer
  - Dumped into the rivers/sea
  - Or even pay €€€ to get rid of

- Cheap Feedstock for fermentation

⇒ **Could reduce both pollution and CO_2 emission while generating value for the dairies**

Some Lactic acid bacteria ferment lactose

lactose



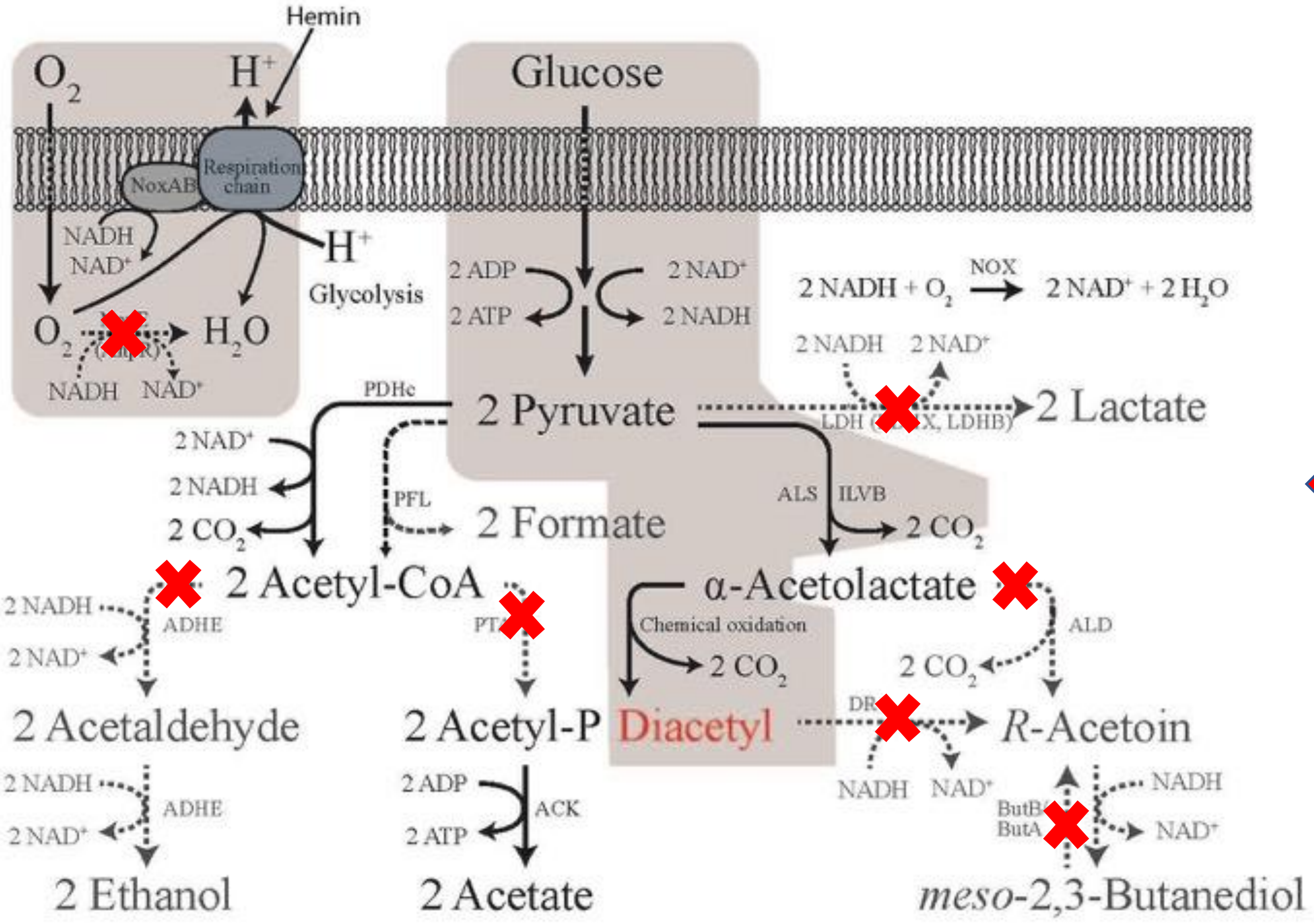
lactic acid

Lactic acid bacteria as cell factories?

Lactococci as a platform for production of biochemicals from whey and other side-streams

Jianming Liu

Christian Solem



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

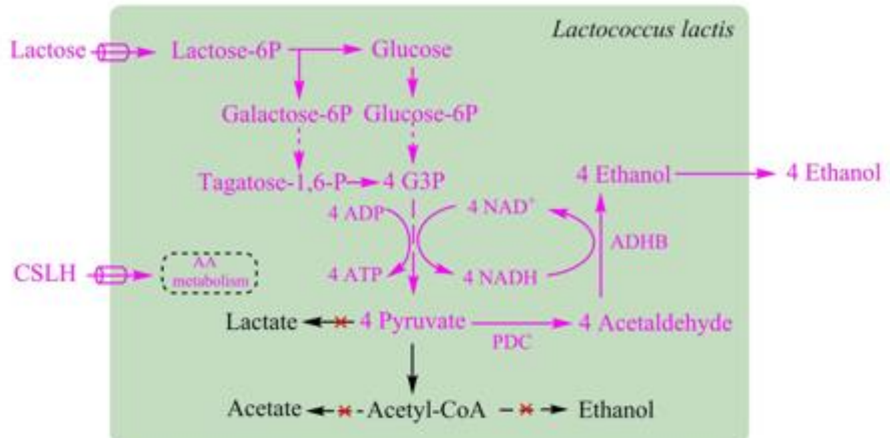


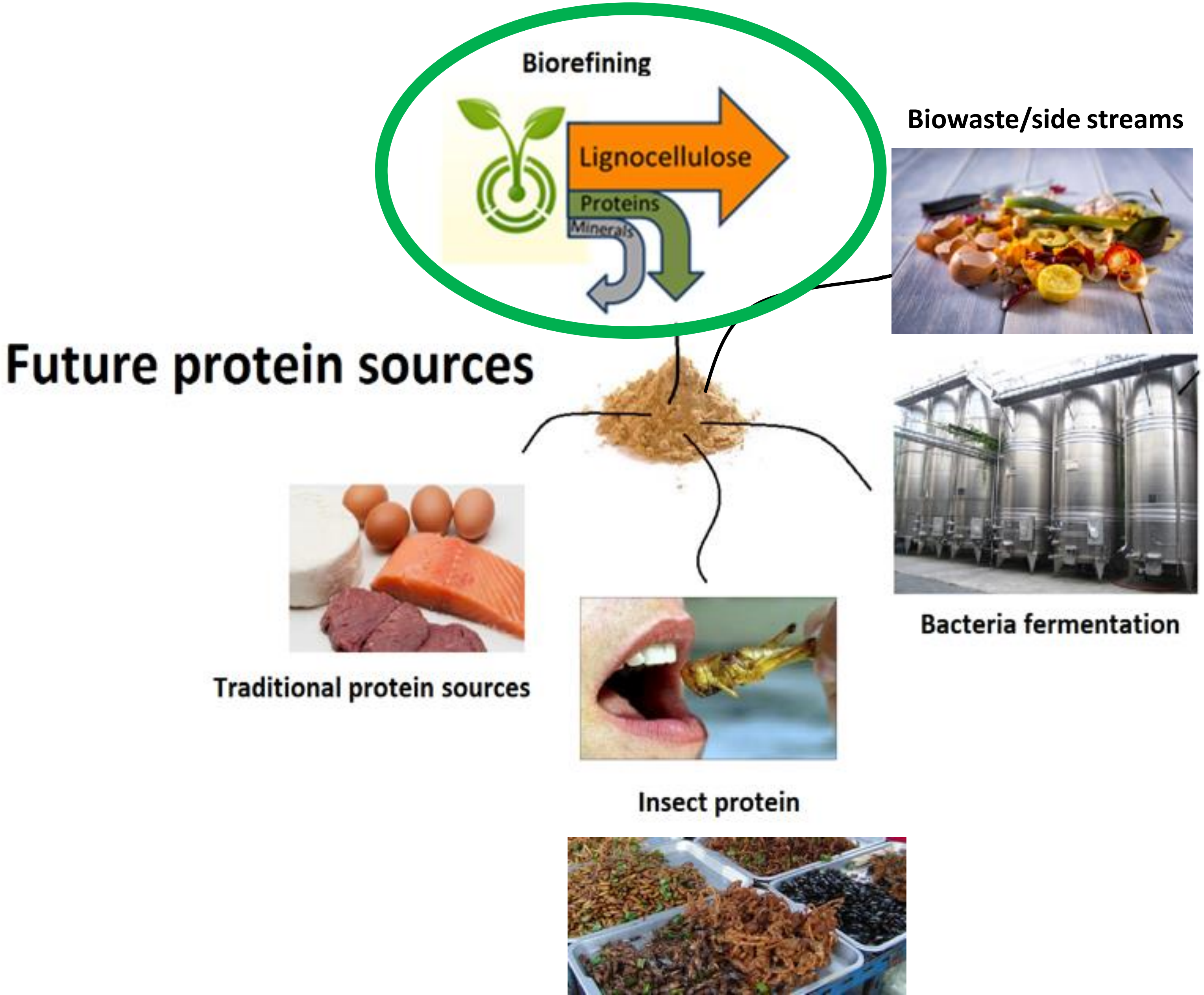
Fig. 1 Efficient cell factory for ethanol production. The incorporation of heterologous ethanol-producing pathway enables complete cofactor recycling. Competitive pathways have been inactivated (indicated with *red mark*). *G3P* glyceraldehyde 3-phosphate, *PDC* pyruvate decarboxylase from *Zymomonas mobilis*, *ADHB* ethanol dehydrogenase from *Z. mobilis*, *AA* amino acids, *CSLH* corn steep liquor hydrolysate

ALCOWHEY

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



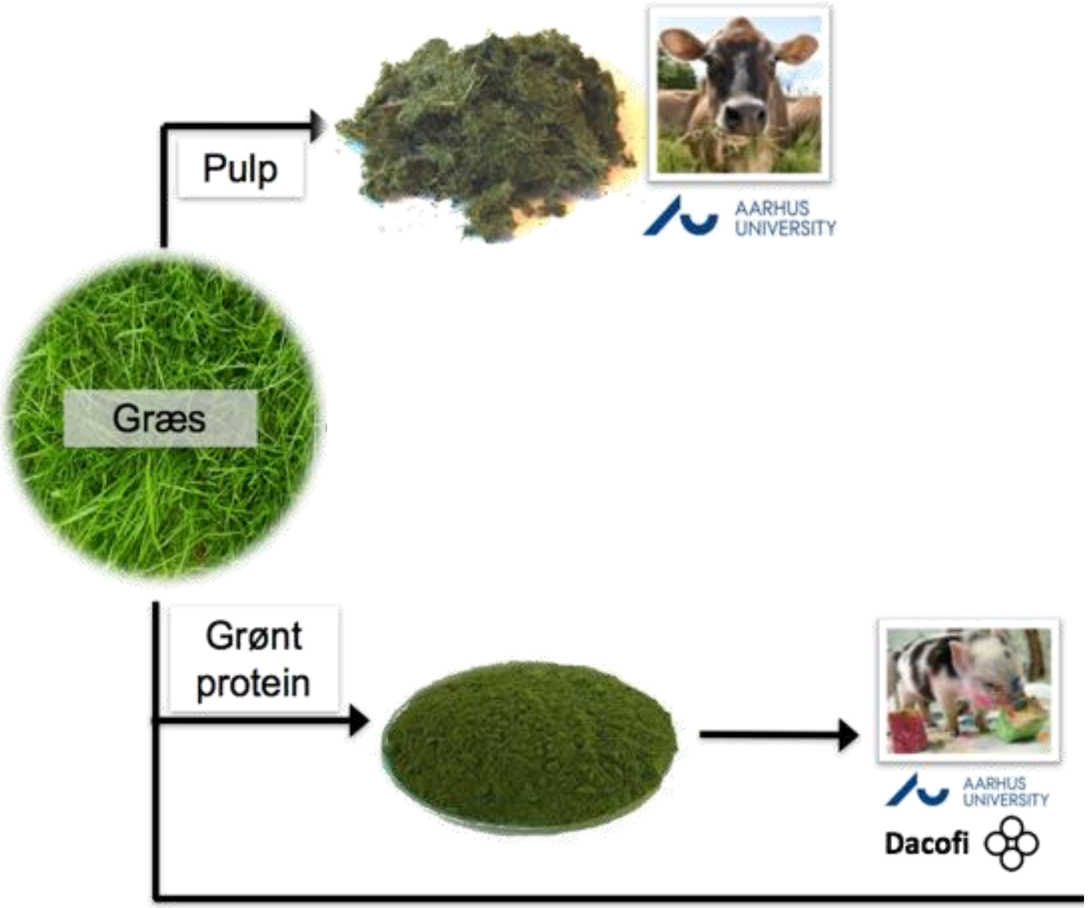
Plant based “meat” products are already in the shops

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

http://naturli-foods.dk/sortiment.aspx

Biorefining of green biomass for feed

Screw press

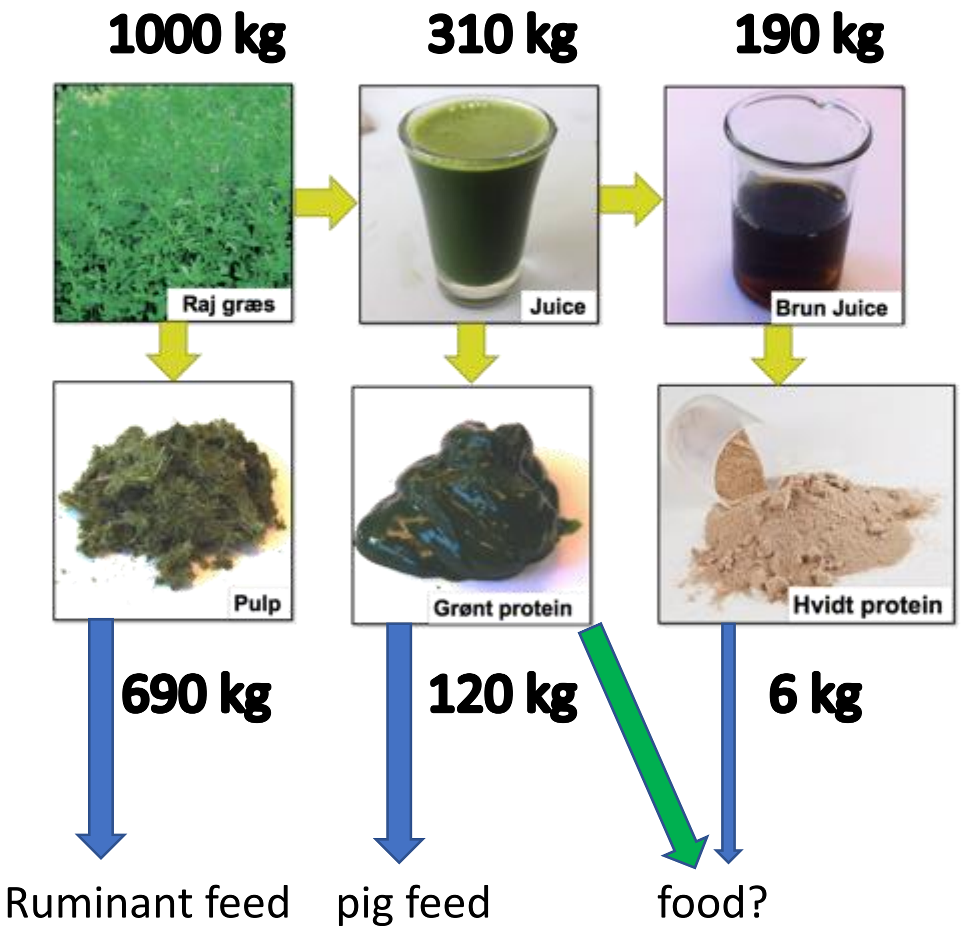


Can we use green biomass as a source of protein for human consumption?

Daniel Nørgaard

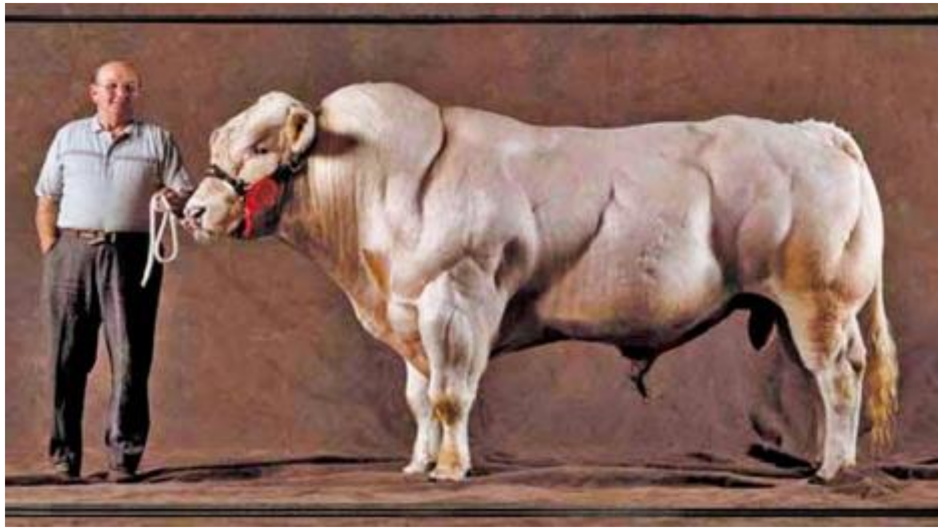
Mikkel Stærmose

Fractionation and purification is the key

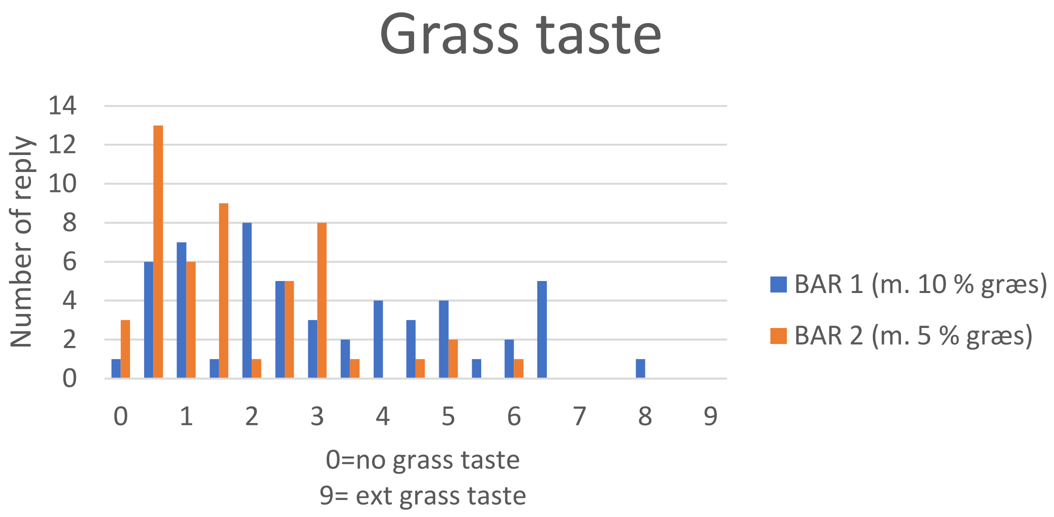


Amino acid profile of protein from green biomass is excellent

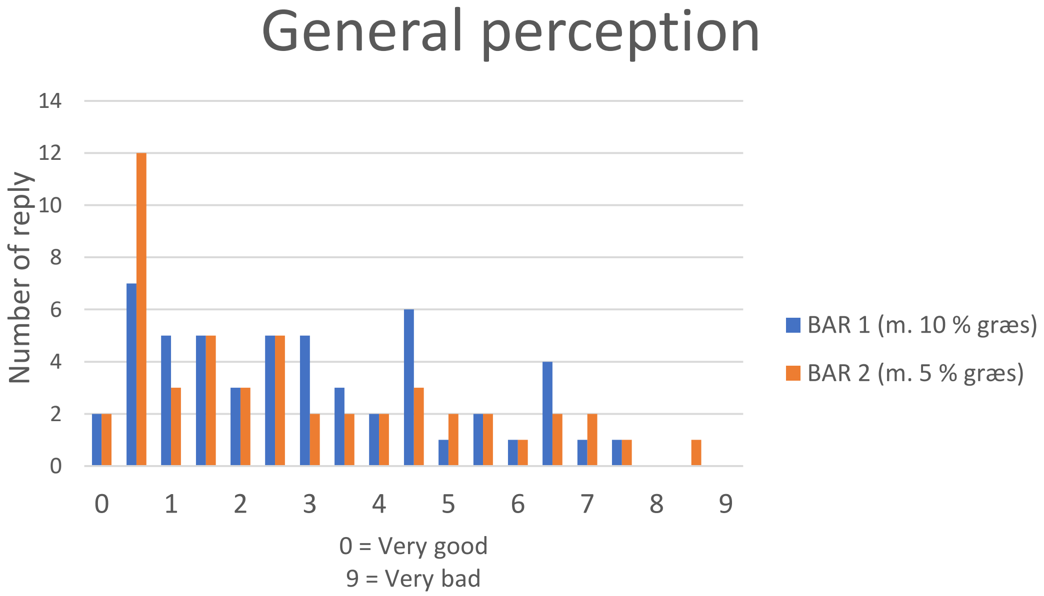
Aminosyrer	Anbefalet indtag (% AA)[a][4]	Soja protein (% råprotein)[b][16]	Rajgræs (% AA)[c][17]	Lucerne (% AA)[d][18]
Alanin	-	3,9	7,8	6,3
Arginin	-	7,8	6,0	6,2
Asparagin	-	11,9	10,4	10,4
Cystein	0,6	1,2	1,4	1,3
Glutamin	-	20,5	12,3	11,2
Glycin	-	4,0	6,2	5,2
Histidin	1,5	2,5	2,2	2,4
Isoleucin	3,0	4,9	4,7	5,2
Leucin	5,9	7,7	9,4	8,9
Lysin	4,5	6,1	5,6	6,3
Methionin	1,6	1,1	2,2	2,0
Fenylalanin	3,8[f]	5,4	5,7	5,8
Prolin	-	5,3	6,0	4,7
Serin	-	5,5	5,0	4,4
Threonin	2,3	3,7	5,2	5,0
Tryptofan	0,6	1,4	-	1,7
Tyrosin	-	3,7	3,4	4,6
Valin	3,9	4,8	6,5	6,4



Test case: 5%/10% grass protein in energy bars



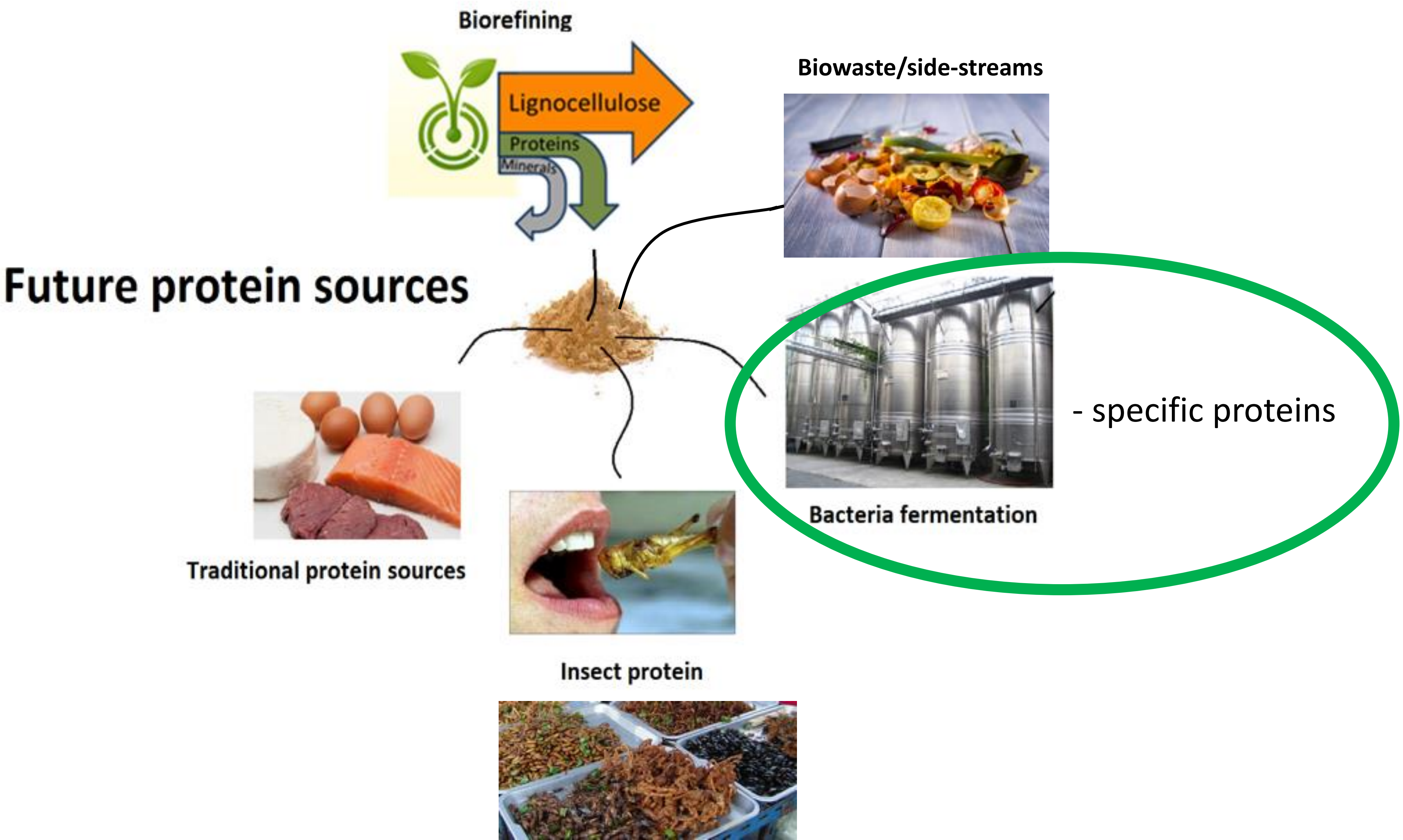
Grass taste: **Significant difference**
Grass smell: **No difference**
General perception: **No difference**



Conclusion – protein from green biomass

- Potential use as food ingredients – could contribute to future protein sources
- More research is requires to make the process economically viable and to obtain approval for use in food production

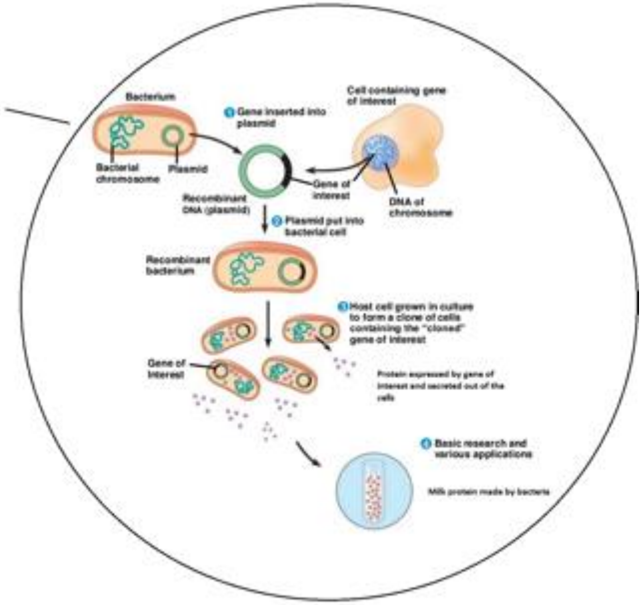
Microbial production of protein via fermentation?



- specific proteins

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

α-lactalbumin (a high-value whey protein)

Consumer acceptance?

Examples of current microbial food production:

- Chymosine, transglutaminase
- Cheese, yogurt,
- Sausages, fish
- Sauerkraut, Kimchi, etc
- Beer, wine
- Bread

Ecomically feasible?

Mike Vestergaard

Joshua Chan

OPEN

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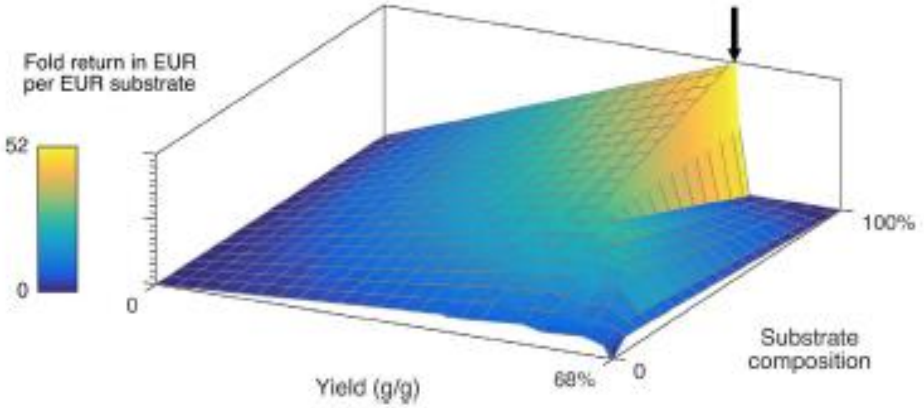
Can microbes compete with cows for sustainable protein production - A feasibility study on high quality protein

Mike Vestergaard, Siu Hung Joshua Chan & Peter Ruhdal Jensen



Up to 50 times value added

Figure 2. Simulation of economic yield. The plot depictures α-La fermentations at maximized productivity with yield per substrate, substrate compositions and economic return based on the substrate price on 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

$O_2 + C \rightarrow CO_2$

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