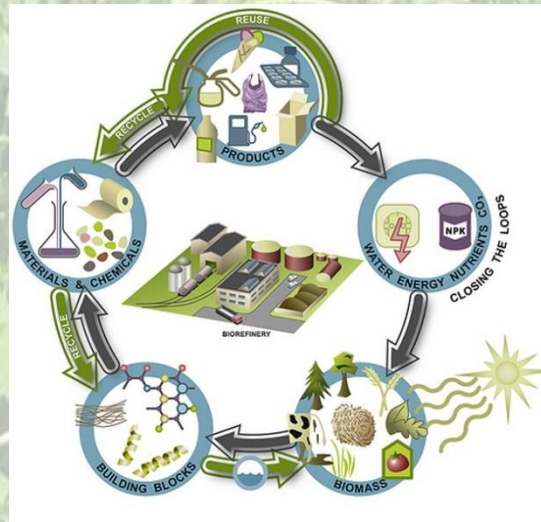
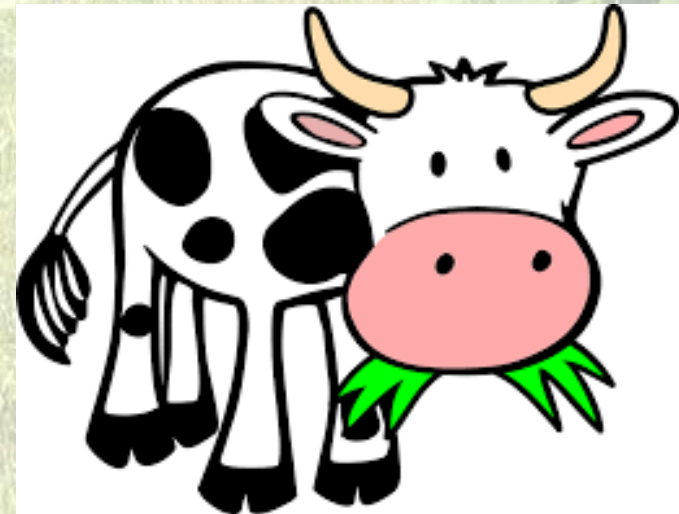


BIOREFINING OF GREEN BIOMASS FOR PROTEIN PRODUCTION

Søren Krogh Jensen

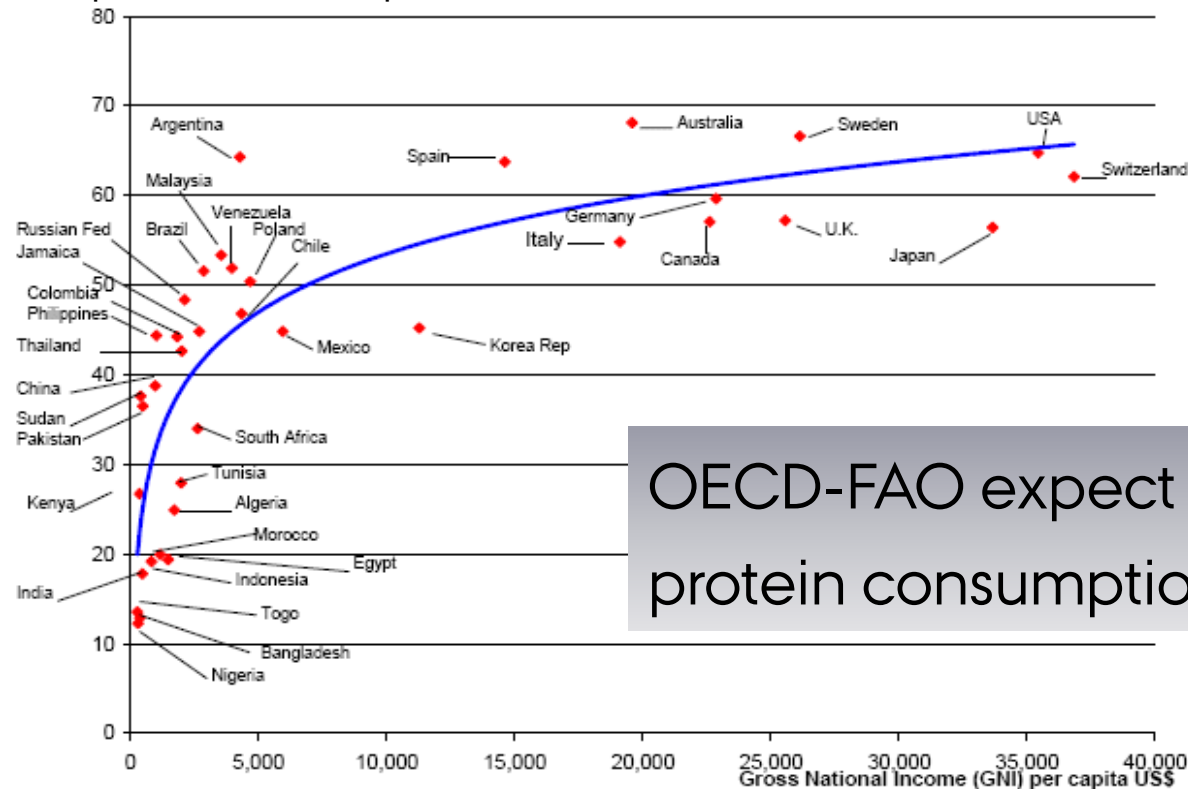
Department of Animal Science

Aarhus University, Denmark



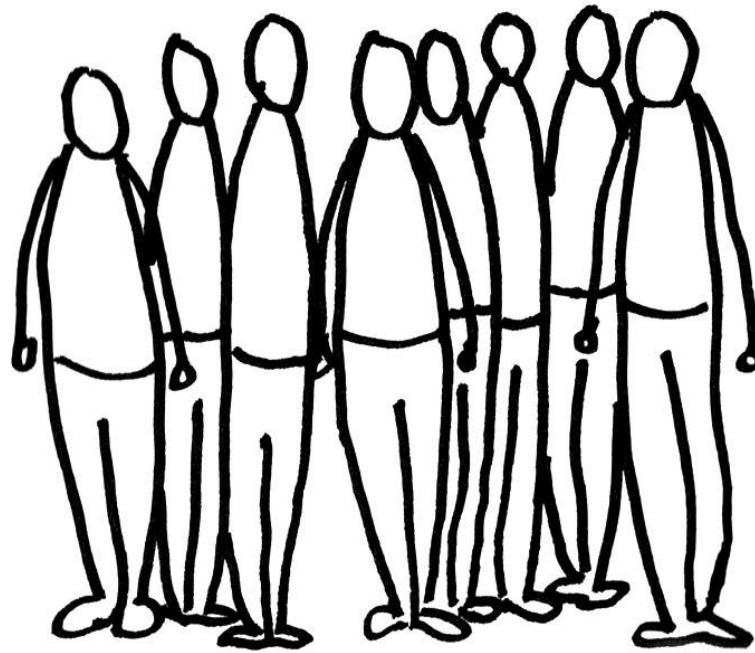
Increasing income increase animal protein consumption

% Animal protein
in % of total protein consumption



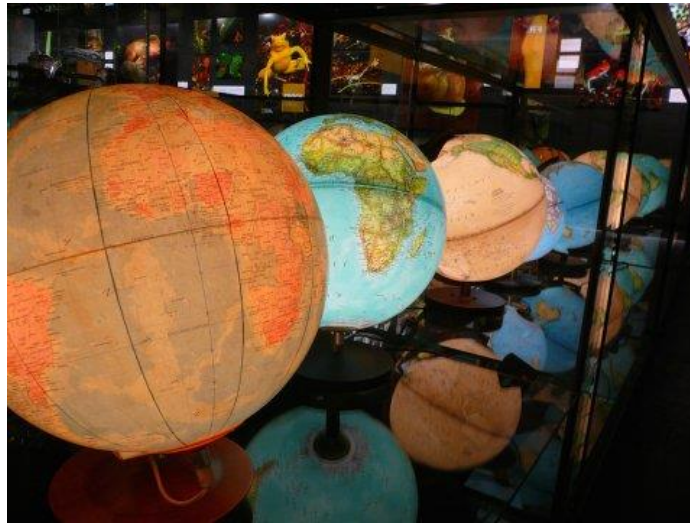
Source: Based on data through 2002 from FAO and World Bank.

Approaching 9.000.000.000



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If we continue as
today we will
need 3 globes



It's about doing more with less!

- Productivity can easily be increased by improving existing technologies and practices
- Sustainable intensification means greater yields using less

Danish animal production

Export oriented

80-90 % of production is exported

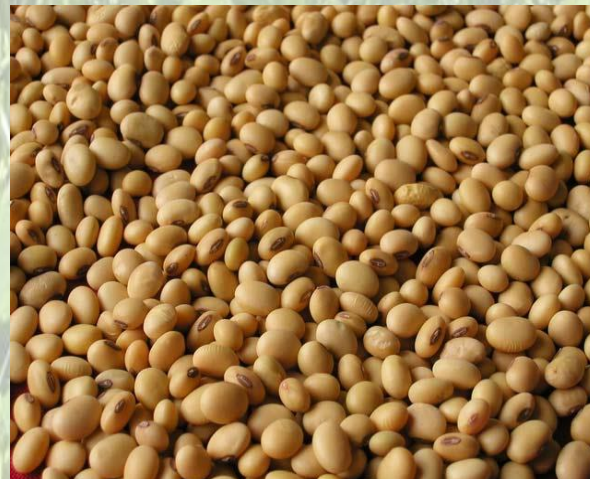
Organic production approach 10 % of production

Danish need for protein in animal production

Yearly consumption: 2,7 mill t pure protein

Production in DK: 1,7 mill t

Import: 1 mill t



Why green biomass?



Protein and amino acid yield of various crops under Danish growing conditions

	Yield, DM ton/ha	Protein %	Protein kg/ha	Lysine kg/ha	Methionine kg/ha
Soya	2	35	700	45	9
Rapeseed	5	20	1000	60	20
Faba bean	6	25	1500	90	11
Pea	6	22	1300	90	13
Wheat	9	11	1000	30	16
Corn silage	13	8	1000	27	14
Clover grass	13	20	2600	200	90
Lucerne	12	21	2600	200	90
Extensive grass	3	12	350	25	12

Protein production from green forage

Scenarie:
Clover/grass/lucerne on 400.000 ha

Yield: 11.000 kg DM/ha - 2500 kg protein



4.4 mill t DM



1 mill t protein

Processing

Raw material

Screw press

Pulp

Fiber/ Insoluble protein
Ruminants

Juice

Protein
precipitation
pH 4; 80 °C

Soluble protein/ soluble fibre
Protein fraction Protein feed - monogastric

Supernatant

Salt, sugars
Non protein nitrogen



Processing

Raw material

Screw press

Pulp

Fiber/ Insoluble protein
Ruminants

30-60 % of protein



Juice

40-70 % of protein

Protein
precipitation
pH 4; 80 °C

Soluble protein/ soluble fibre
Protein fraction Protein feed - monogastric

Supernatant

Salt, sugars
Non protein nitrogen

5-10 % of protein, 10-15 % of total N



Main products from processing line

Pulp (60-70 % of DM)

- ▶ Cattle feed
- ▶ Fiber for energy production (Biogas, Biochar, etc)
- ▶ Fiber for lignin production
- ▶ Fiber for insulation
- ▶ Fiber for production of oligosaccharides



Precipitated protein (20-30 % of DM)

- ▶ Protein concentrate as feed for monogastrics
- ▶ White protein concentrate for food purposes



Brown juice (10-20 % of DM)

- ▶ Inorganic salts / fertilizer
- ▶ Organic matter for biogas production
- ▶ Speciality compounds
(vitamins, phytoestrogens, saponins etc)



Chemical composition of pulp

	Protein % in DM	Ash % in DM	NDF % in DM	ADF % in DM	CEL + Lignin % in DM	CP in NDF % in DM
White clover	26.8	7.2	52.9	32.5	8.0	19.3
Red clover	19.8	6.6	58.9	37.9	8.2	14.8
Rye grass	16.4	5.1	69.4	34.1	3.3	11.1
Lucerne	18.4	5.8	56.9	40.6	9.5	8.2

NDF = Neutral Detergent Fibre

Damborg et al. 2017

ADF = Acid Detergent Fibre (Hemicellulose)

CEL + Lignin = Cellulose + Lignin

CP = Crude Protein

Chemical composition of protein pellet

	Protein % in DM	Lipid % in DM	Total CHO % in DM	LMW CHO [§] % in DM	Soluble NSP % in DM	Insol NSP % in DM	Klason lignin % in DM
Red clover	35.9	12.5	31.6	25.0	2.7	3.9	8.9
Rye grass	45.8	12.1	21.1	13.8	1.4	6.1	6.3
Lucerne	33.3	14.6	29.3	15.3	5.9	8.1	8.4

[§]DP < 10

Stødkilde et al. 2017

Chemical composition of protein pellet

	Protein % in DM	Lipid % in DM	Total CHO % in DM	LMW CHO ^s % in DM	Soluble NSP % in DM	Insol NSP % in DM	Klason lignin % in DM
Red clover	35.9	12.5	31.6	25.0	2.7	3.9	8.9
Rye grass	45.8	12.1	21.1	13.8	1.4	6.1	6.3
Lucerne	33.3	14.6	29.3	15.3	5.9	8.1	8.4

Aiming for > 50 %
protein in DM

^sDP < 10

Stødkilde et al. 2017

Pulp for cows

- 36 Danish Holstein cows
- Incomplete Latin square design
- 4 periods of 3 weeks each



Vinni K Damborg phd work
Animal Feed Sci and Tech, submitted
for 2. review March 2019

Pulp for cows

400 tonnes of grass clover was processed over 5 days



Vinni K Damborg phd work
Animal Feed Sci and Tech, submitted
for 2. review March 2019

Composition of pulp and clover grass silage

	Pulp silage	Clover grass silage
DM (%)	28	52
Protein (% af DM)	18	16
Ash (% af DM)	9,3	9,4
NDF (% af DM)	45	39
Sugar (% af DM)	0	8,7
<i>In-vitro digestibility</i> (% of Organic matter)	70	72

Vinni K Damborg phd work
Animal Feed Sci and Tech, submitted
for 2. review March 2019

Pulp experiment with dairy cows

	Pulp silage	Grass clover silage	Difference
DM intake, kg/day	23.0	22.7	No
ECM, kg/day	37.0	33.5	Yes
Dig. Organic matter, %	73	70	Yes
Dig. NDF, %	63	54	Yes
Dig. Protein, %	66	60	Yes

Damborg et al.2019

Pulp experiment with dairy cows

- Screw pressing increased
 - fiber and
 - protein availability in the rumen
- Milk yield increased

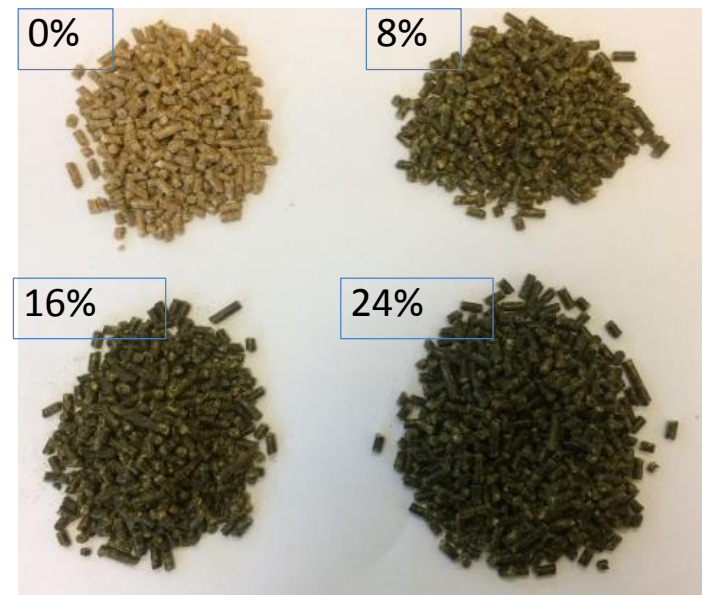


Feeding experimethn with green protein for organic broilers



Feeding experiment with green protein for organic broilers

- "Nybro protein"
- Inclusion levels
0, 8, 16, 24 % (w/w)
- Green protein substituted % of total protein:
0%, 13%, 26%, 39%
- Slaughtered at 57 days of age



Composition of green protein for the broiler experiment

Composition, g/kg DM	
Dry matter	968
Crude protein	362
Fat	138
Ash	88
Sugars ¹	0.3
Starch	-
Dietary fibers ²	324
T-NSP	103
S-NSP	20
I-NSP	83
Acid insoluble residue(lignin)	222
Fructans	0
Metabolisable energy (MJ/kg DM)	21.4



Daily weight gain and feed utilization

Daily Weight gain	Green protein, % of feed					
	0	8	16	24	SEM	P value
Day 16-57	49.8 ^a	50.2 ^a	45.7 ^b	41.8 ^c	0.56	<0.0001
Final weight (g)	2367 ^a	2389 ^a	2188 ^b	2017 ^c	25.3	<.0001
Feed utilization						
d16-57	2.29 ^c	2.34 ^{bc}	2.45 ^{ab}	2.55 ^a	0.03	<0.0001



Feeding experiment with organic slaughter pigs

- 48 Weaned piglets (7 weeks of age)



Feeding experiment with organic slaughter pigs

- Protein extracted from clover grass in 2018

Moisture	1.8	%
Protein (N*6,25)	47.0	%
Fat	11.3	%
Ash	12.3	%
EFOS svin	67.6	%

Feeding experiment with organic slaughter pigs

- 4 experimental groups
 - Control
 - 5% Clovergrass protein
 - 10% Clovergrass protein
 - 15% Clovergrass protein

Organic soybean cake,
Chinese

Organic peas

Organic faba beans

Organic barley

Organic wheat

Organic oat

- Experimental period: from weaning to slaughter
- 3 different feed mixtures per groups

Feed mixtures

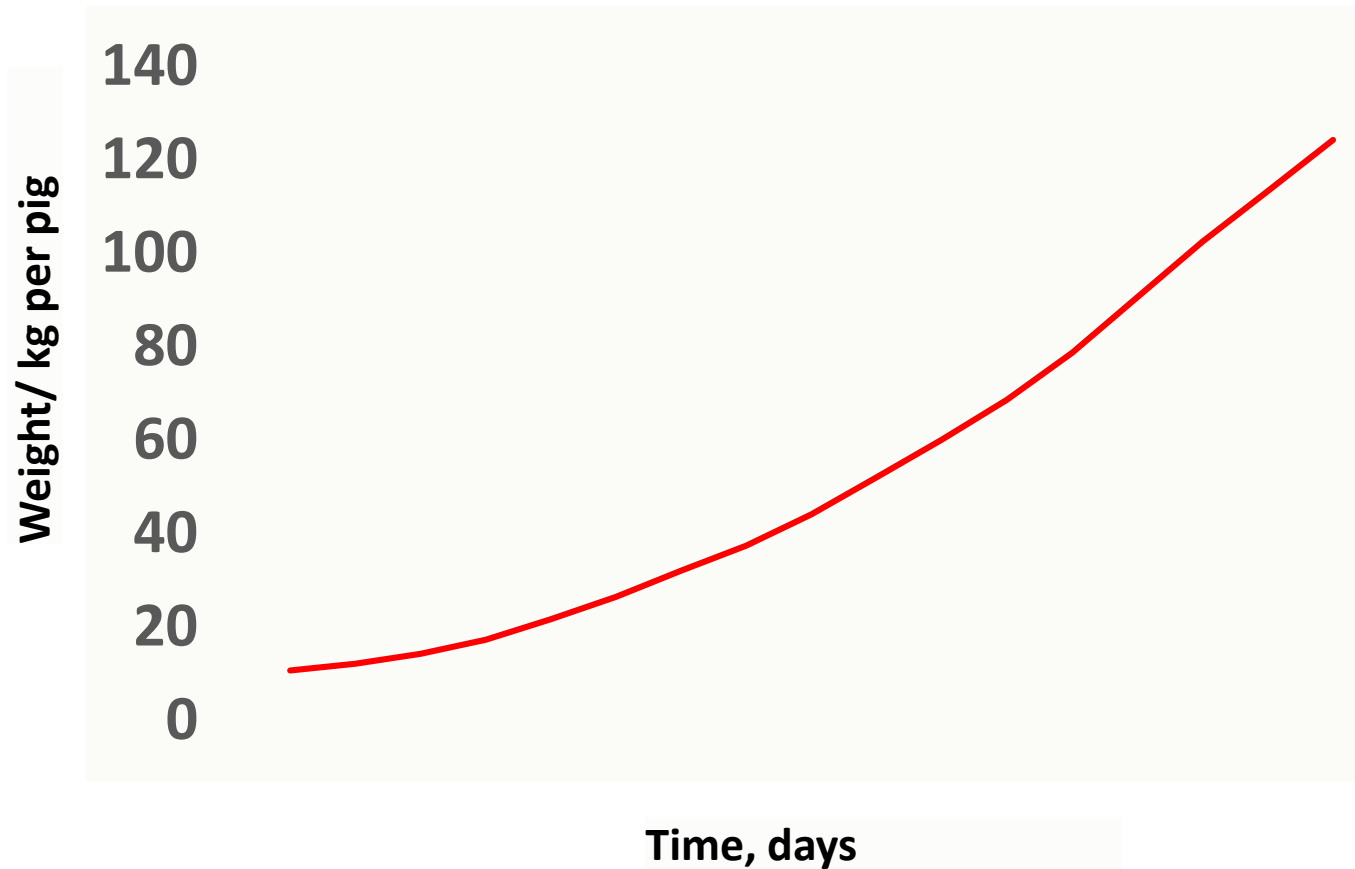
- Formulated by Vestjyllands Andel
- 100% organic
- Composition is realistic for practical feeding
- Main ingredients:
 - Barley
 - Wheat
 - Soybean cake, Chinese
 - Peas
 - Faba beans
 - GRASS CLOVER PROTEIN

Feed mixtures

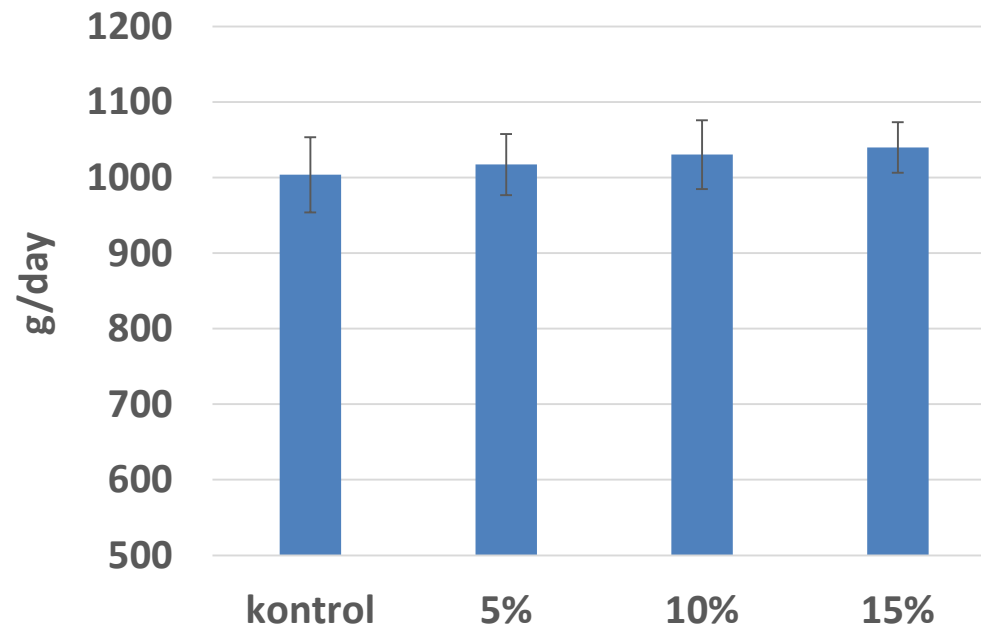
15% Group	Mix 1 Weaning - 30kg	Mix 2 30 - 65 kg	Mix 3 65 - slaughter
FEsv	1.05	1.03	0.98
Protein %	20.6	18.6	17.0
Lysine, g/kg	11.6	9.8	8.9
Methionine, g/kg	3.9	3.1	2.9



Average pig weight development



Average daily weight gain



Conclusion

- Pulp ensiled well and was palatable with a high feed consumption
- Pulp increased milk yield
- Protein concentrate with low protein content (35 %) was moderately acceptable as feed for monogastrics
- Protein concentrate with high protein content (47 %) is well suited for monogastrics