Quality requirements and nutritional value of protein products for feed from biorefined biomass

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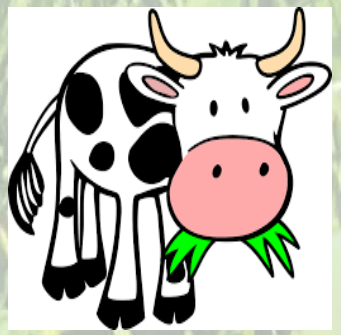
Lab scale

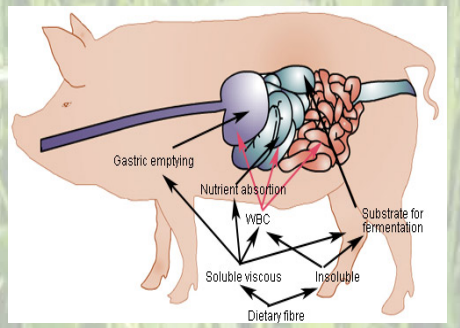
Pilot-scale

Semi-production-scale

Lab analyses

Feeding experiments





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Why a Danish protein production?

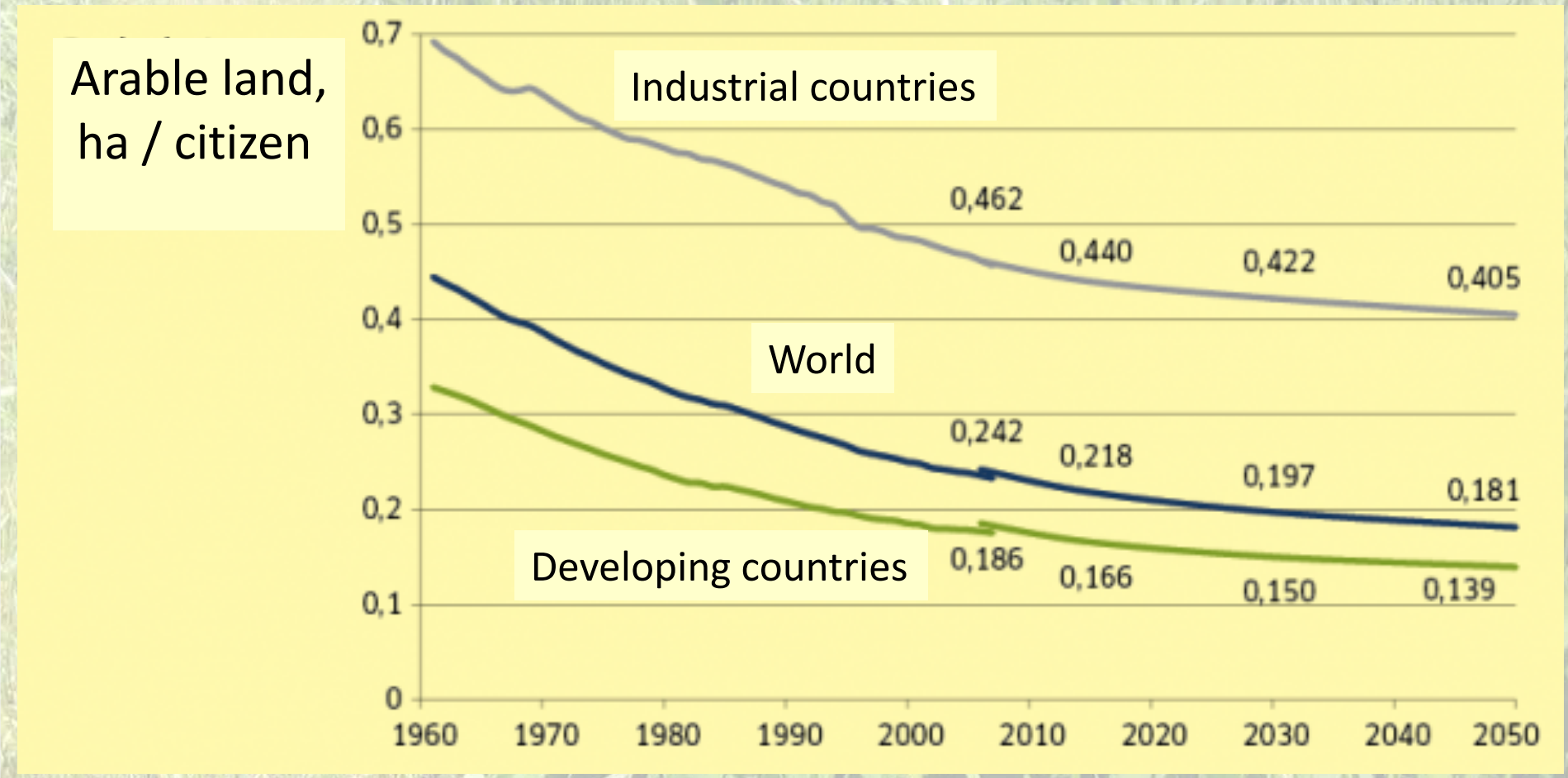
- **Large import of soya protein**
  - Sustainability and carbon footprint is questioned
- **Grass and forage legumes has a high protein content**
  - Environmental friendly production (nitrate, pesticides, carbon in soil)
  - High yield
- **Perspectives in relation to biorefining**
  - Protein for mono gastrics
  - Protein/fiber for ruminants
  - Sidestreams for bioenergy / materials

Increasing income increase meat consumption

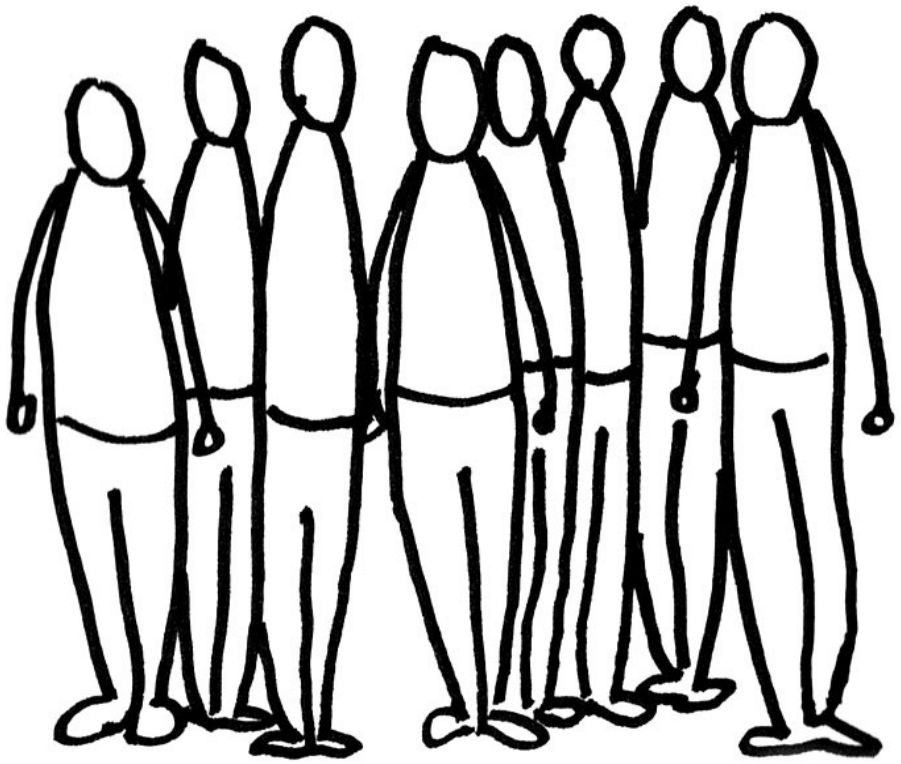
OECD-FAO expect 70 % increase in meat consumption over the next decade

Meat consumption, kg per capita per year			
	1964-1966	1997-1999	2030 (estimated)
World	24.2	36.4	45.3
Developing countries	10.2	25.5	36.7
Developed countries	61.5	88.2	100

Increasing population decrease the arable area per capita



Towards 9.000.000.000



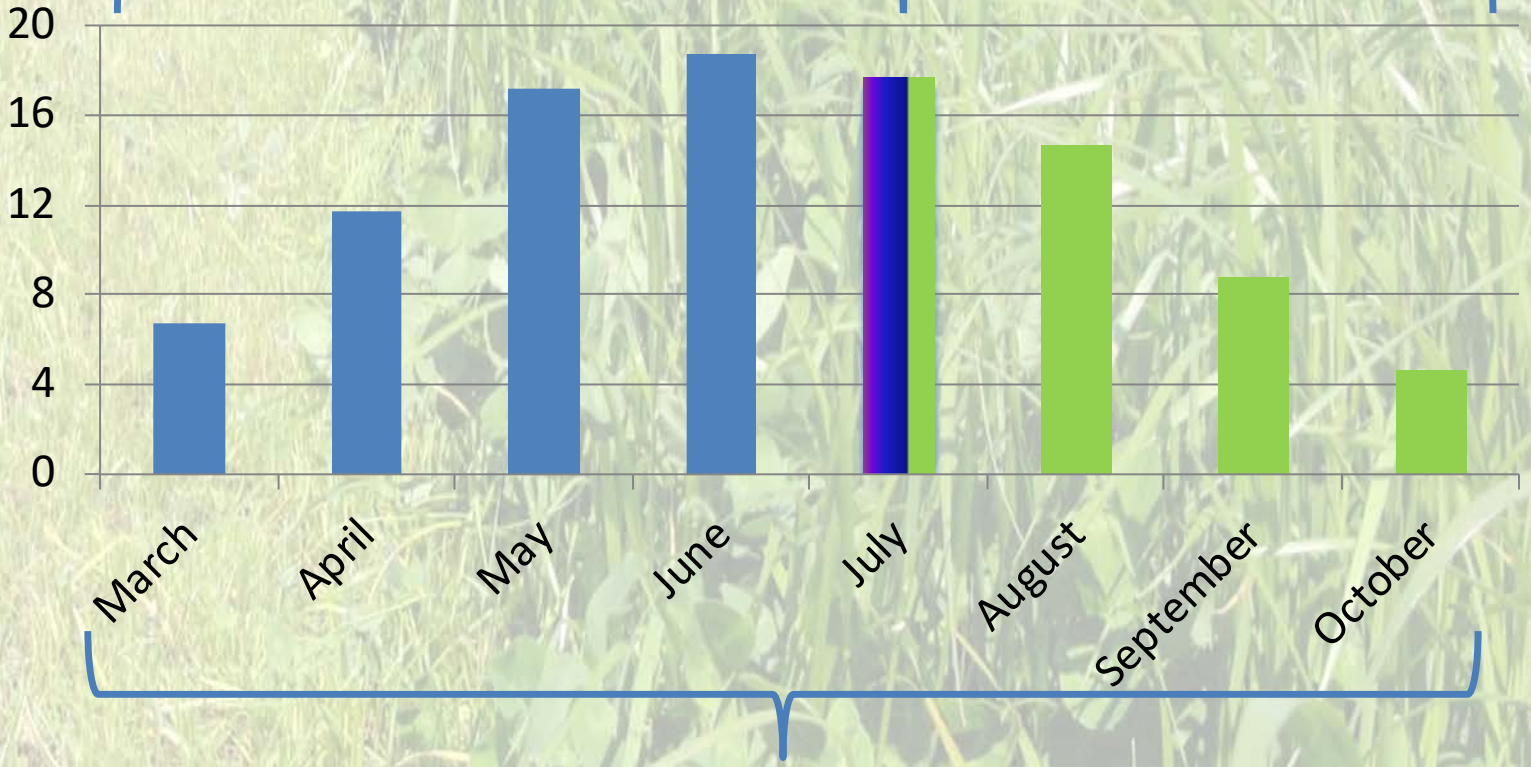
If we continue as today we will need 3 globes

Why green biomass?

Relative Sun insolation

70 % of sun energy *can be utilized by grain and seed legumes*

30 % af sun energy



100 % can be utilized by clover, grasses and lucerne

Protein and amino acid yield under Danish growing conditions

	Yield DM ton/ha	Protein %	Protein kg/ha	Lysine kg/ha	Methionine kg/ha	N leaching
Soya	2	35	700	43	9	Large
Rapeseed	5	20	1000	60	20	Large
Wheat	9	11	1000	30	16	Large
Faba beans	6	25	1500	92	11	Large
Peas	6	22	1300	92	13	Large
Corn silage	13	8	1000	27	14	Large
Grass clover	13	20	2600	200	90	Small
Lucerne	12	21	2600	200	90	Small
Potato	14	9	1300	90	27	Small

Cultivation of forages

- **Challenges and perspectives**
  - Cultivation is easy
  - Yield is high
  - Growing season is long
  - Environmental impact is low
  - Optimizing harvest in relation to maximal protein content
- **Challenges are**
  - Logistic
  - Persistence of the harvested biomass
  - The low dry matter content

Biorefining - Processing

Screw press

Pulp: Fiber/insoluble protein: ruminants

Juice

Protein precipitation pH 4; 80 °C

Protein fraction: Soluble protein/fibers Proteinfeed - monogastrics

Braun juice
Salt, sugar, Non-protein N


CBT
Center for
Biorefinery Technologies
Aarhus University
Department of Engineering
SoRoto
3.3m
ALFA LAVAL

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)

Biorefining

- **Protein yield depends on**
  - Effective screw pressing
  - Effective precipitation of protein from the juice
  - adequate separation of protein and fiber
- **Challenges:**
  - Maintain the nutritional quality of the protein
  - avoid oxidation and crossbinding between proteins
    - Cause decreased digestibility
  - Avoid hydrolysis of the proteins with proteases before protein precipitation
    - Cause too little protein yield

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
ADF = Acid Detergent Fibre (Hemicellulose)
CEL + Lignin = Cellulose + Lignin
CP = Crude Protein

Damborg 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
J. Dairy Sci. 2019, Accepted

Pulp for cows

400 tonnes of grass clover was processed over 5 days

This huge production experiment was a cooperation with OrganoFinery, Biovalue and Biobase

Vinni K Damborg phd work
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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
In-vitro digestibility (% of Organic matter)	70	72

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Pulp experiment with dairy cows

	Pulp silage	Grass clover silage	Diffe-rence
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

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Pulp experiment with dairy cows

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

Protein produced from grass clover in 2018 at Foulum Pilot Plant

Batch #	Wet amount, kg	Precipitation method	Ash % of DM	Protein % of DM
1	168	Fermentation	14.6	38.4
2	229	Fermentation	18.3	43.0
3	**694**	**Heat**	**7.5**	**49.4**
4	**386**	**Heat**	**10.2**	**54.2**
5	39	Fermentation	12.1	38.4

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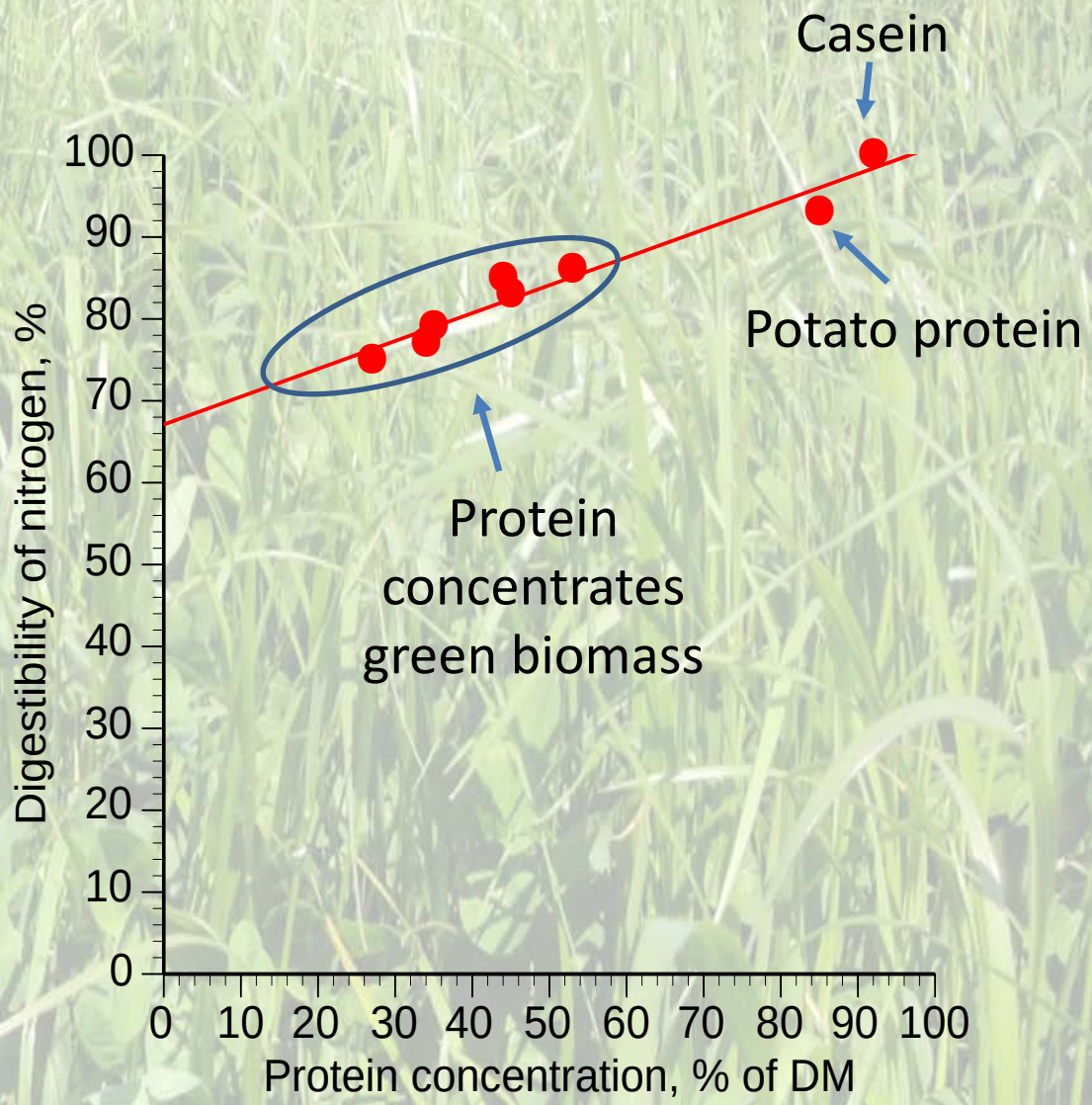
Relationship between protein content and protein digestibility



Feeding experimetn with green protein for organic broilers

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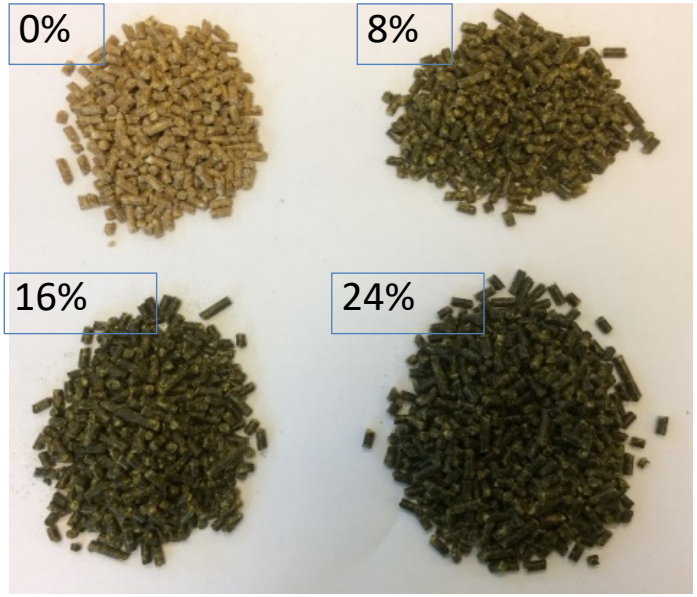
Feeding experimetn with green protein for organic broilers

- ”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



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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

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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

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Ileal digestibility with pigs
The products and diets

	Enzyme	Precipitation	Prod. Date	CP product (% of DM)	Inclusion in diet (%)	CP in diet (% of DM)
Rye grass	-	Heat	22/08-16	33.0	30	10.7
	+	Heat	25/08-16	33.4	30	10.9
Red clover	-	Fermentation	23/08-16	33.3	30	10.2
	+	Fermentation	29/8-16 + 26/9-16	33.7	30	10.7

CP = crude protein

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Results – Ileal digestibility

	Rye grass	Rye grass	Red clover	Red clover			
	-	+	-	+	SEM	P-value	*SBM*[1]
Organic matter	24[b]	27[b]	13[c]	38[a]	5.1	**0.004**	
Standardized ileal digestibility, % - CP and indispensable amino acids							
Crude protein	61	62	55	63	6.2	0.17	85
Arg	78	80	72	80	6.0	0.12	92
His	70	73	67	70	2.3	0.25	86
Ile	74	78	71	75	1.9	0.18	88
Leu	77	81	74	76	1.9	0.17	86
Lys	74	77	72	71	1.8	0.067	88
Met	76[b]	81[a]	74[b]	75[b]	1.7	**0.040**	89
Phe	76	80	73	75	2.0	0.19	87
Thr	70	72	66	70	2.7	0.41	83
Trp	70	70	68	68			90
Val	73	76	70	73	2.0	0.26	84

[1] Soy bean meal, solvent extracted (NRC 2012)

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Results – Ileal digestibility

	Rye grass	Rye grass	Red clover	Red clover			
	-	+	-	+	SEM	P-value	*SBM*[1]
Standardized ileal digestibility, % - dispensable amino acids							
Ala	71[ab]	76[a]	66[b]	73[a]	3.3	**0.028**	79
Asp	72	74	69	70	2.3	0.34	83
Cys	29	37	22	26	5.3	0.23	76
Glu	71	73	67	69	2.4	0.22	86
Gly	58	60	47	64	12.9	0.10	70
Ser	64	66	61	65	3.5	0.46	81
Tyr	70	72	67	69	2.9	0.69	83

[1] Soy bean meal, solvent extracted (NRC 2012)

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Feeding experiment with organic slaughter pigs

- 48 Weaned piglets (7 weeks of age)

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Feeding experiment with organic slaughter pigs

- Protein extracted from grass clover in 2018

Moisture	1.8 %
Protein (N*6,25)	47.0 %
Fat	11.3 %
Ash	12.3 %
EFOS svin	88.8 %
FEsv	1.08 pr kg

Amino acids, g/16 g N		
	Grass clover	Soya
Lys	6.04	5,98
Met	2.24	1,31
Cys	0.70	1,43
Thr	4.71	3,92
Trp	2,17	1,36
Ile	5.19	4,91
Leu	8.82	7,68
His	2.26	2,61
Phe	5.84	5,06
Val	6.41	5,19
Arg	6.02	7,23
Glu	11.04	17,78
Gly	5.45	4,22
Ala	6.70	4,34
Ser	4.38	4,97
Asp	9.63	11,36
Pro	4.68	5,54

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Feeding experiment with organic slaughter pigs

- 4 experimental groups
  - Control
  - 5% Grass clover protein
  - 10% Grass clover protein
  - 15% Grass clover protein

- 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, Chinesee
  - Peas
  - Faba beans
  - GRASS CLOVER PROTEIN

Feed mixtures

15% Group	Mix 1 Weaning – 30 kg	Mix 2 30 - 65 kg	Mix 3 65 - slaughter
FEsv	1.10	1.09	1.04
Protein %	21.4	19.5	17.6
Lysine, g/kg	10.5	9.2	8.4
Methionine, g/kg	3.5	2.9	2.7

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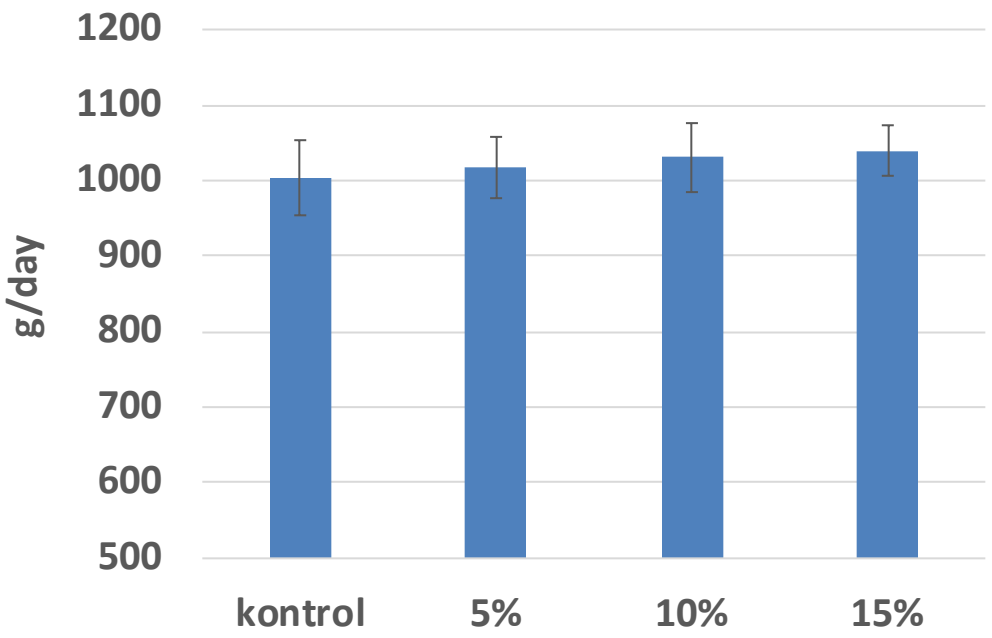
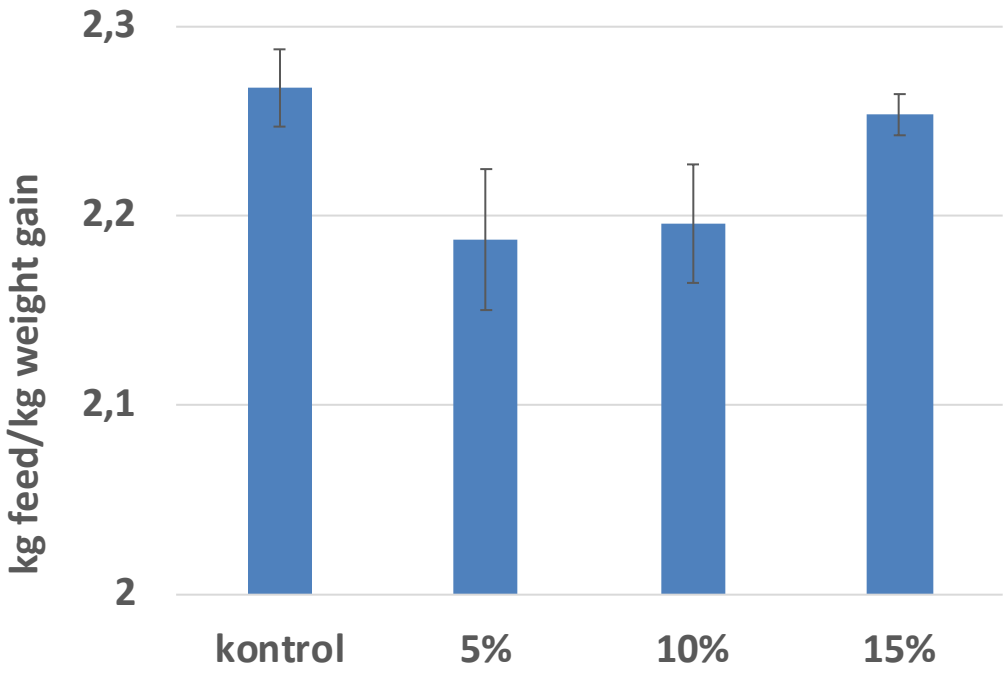
Average daily weight gain



Average daily feed utilization



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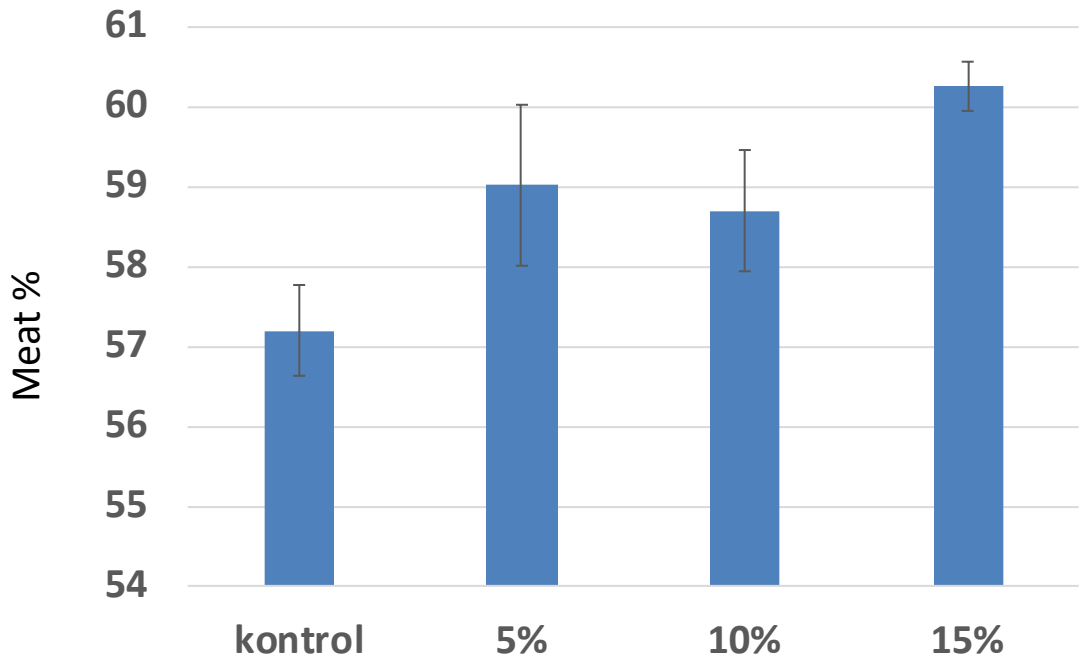
Average meat % at slaughter



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
- Exact digestibilities is highly needed.

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Thanks to the collaborators

- **AU-ANIS**
  - Knud Erik Bach knudsen
  - Søren Krogh Jensen
  - Helle Nygaard Lærke
  - Lene Stødkilde
  - Vinni Kragbæk Damborg
  - Martin Riis Weisbjerg
  - Jan Værum Nørgaard
- **AU-ENG**
  - Morten Ambye-Jensen
  - Carmen Hsieh
  - + several more

- Participants
  - **AU-FOOD**
    - Trine Kastrup Dalsgaard
    - Marianne Danielsen
    - Bashar Amer