Delaktivitet 3

Uppbyggnad av en fysisk infrastruktur för utvecklingsplattformen

&

Delaktivitet 4.3

Testkörning och optimering av processerna i bioraffinaderierna

Status for demonstration facilities at AU Foulum and VGN Sötåsen

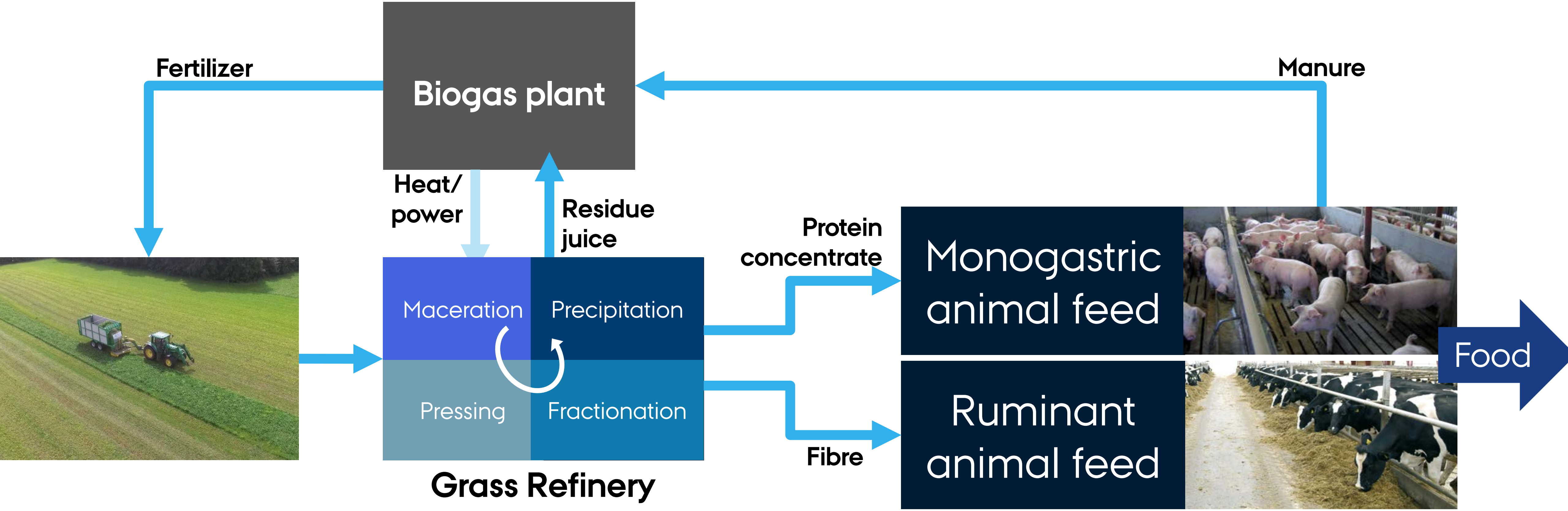
Project meeting 18.03.2020

Structure of online meeting 09:00-09:45

- Status at AU Foulum Demonstration facility
- Status at VGN Sötåsen Demonstration facility

PROTEIN FEED FROM GREEN BIOMASS

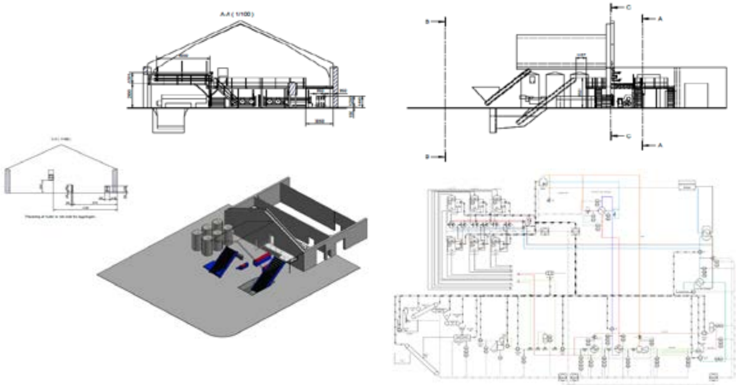
BASE CASE SCENARIO



DEMONSTRATIONSPLATFORM
TIL FORSKNING OG TEKNOLOGIUDVIKLING AF GRØN BIORAFFINERING

CBIO
AARHUS UNIVERSITY CENTRE FOR CIRCULAR BIOECONOMY

- Input: 10 ton/timen
- Fleksibelt procesdesign
- Automatisk styrring og udvidet dataopsamling
- Forbedrede processer i forhold til pilot anlægget



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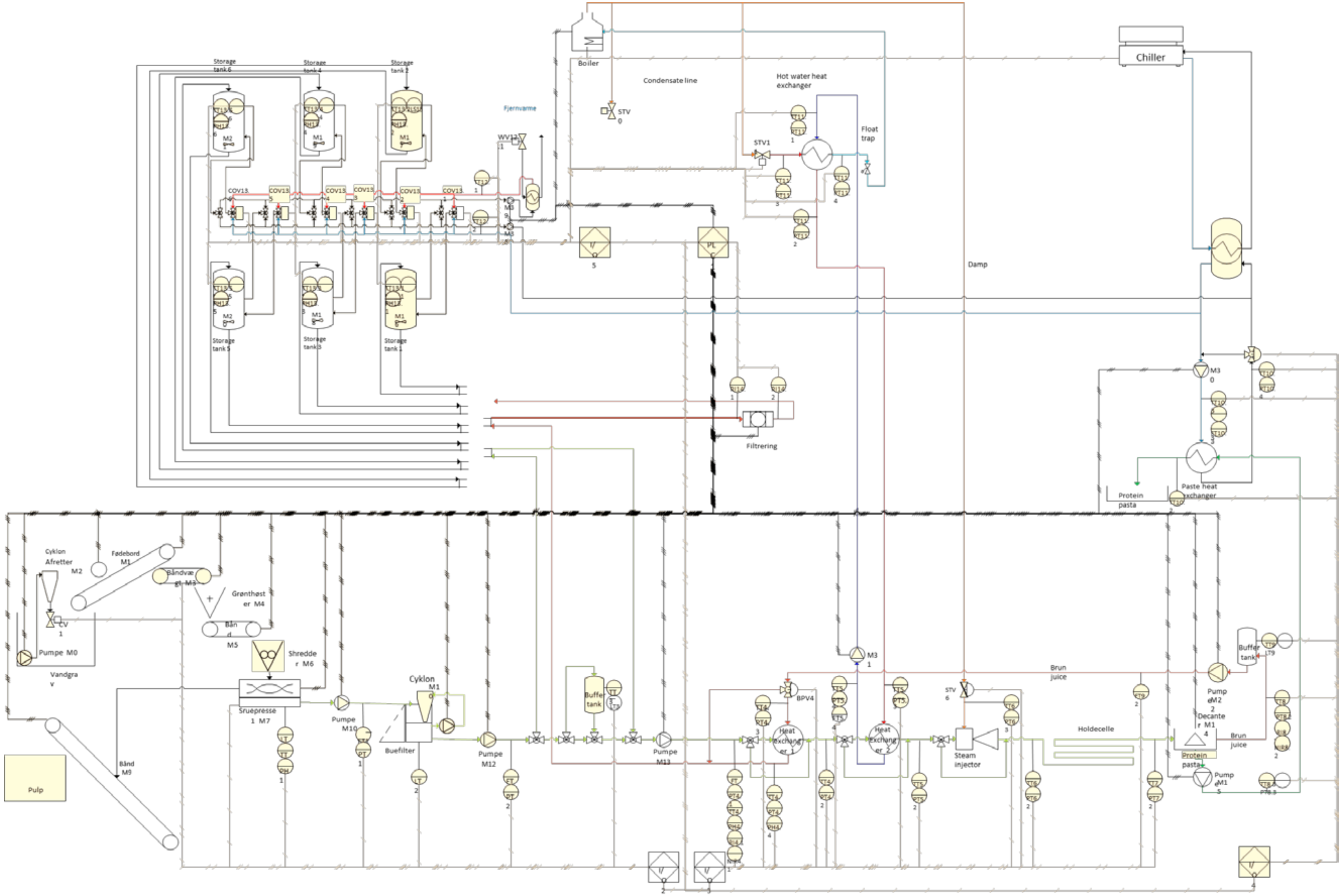
PID FOR DEMOPLATFORMEN

[Video af græsprotein produktion 2019]



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Activities at Demonstration platform at Foulum

october 2019 - march 2020

- Test, process adaptation, and production of protein concentrate
- Delivery of 2 ton dry protein concentrate, with crude protein content of 56%, for a large feeding experiments with pigs
- Processing until 12/12 2019 – possible because of the mild autumn/winter
- Jan, feb, mar, has been full of machine adjustment, deciding and ordering of new equipment and combining the old pilot equipment with the demonstration platform

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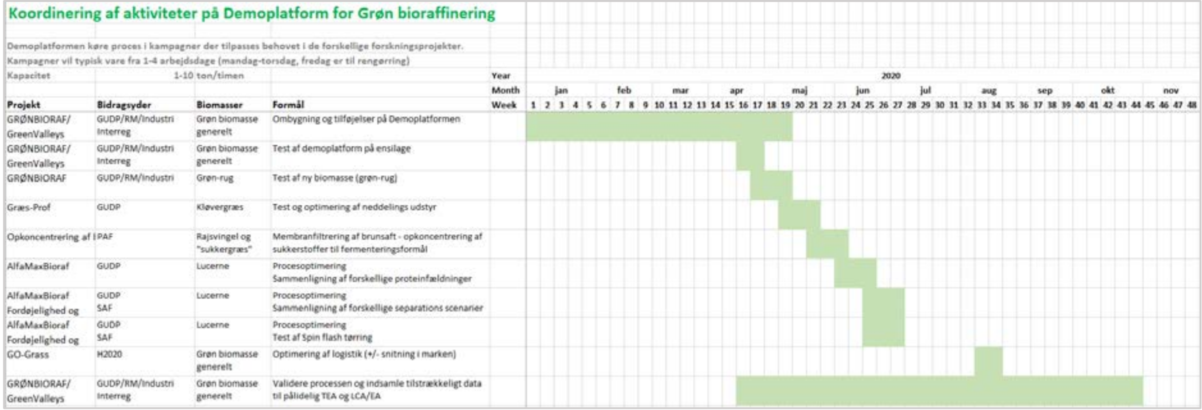
Workplan in 2020

- The demonstration platform will gather data from all experiments carried out over the entire season.
  - We are currently setting up a system for SMART data collection
  - The data is important WP 5 and 6

- In Green Valleys we will also implement and test new equipment for further separation (centrifuge and membranes) and on-site drying of the protein concentrate.



Koordinering af aktiviteter på Demoplatform for Grøn bioraffinering

Demoplatformen køre proces i kampagner der tilpasses behovet i de forskellige forskningsprojekter.
Kampagner vil typisk vare fra 1-4 arbejdsdage (mandag-torsdag, fredag er til rengørring)
Kapacitet 1-10 ton/timen

Year: 2020
Month: jan feb mar apr maj jun jul aug sep okt nov
Week: 1–48

Projekt	Bidragsyder	Biomasser	Formål
GRØNBIORAF/ GreenValleys	GUDP/RM/Industri Interreg	Grøn biomasse generelt	Ombygning og tilføjelser på Demoplatformen
GRØNBIORAF/ GreenValleys	GUDP/RM/Industri Interreg	Grøn biomasse generelt	Test af demoplatform på ensilage
GRØNBIORAF	GUDP/RM/Industri	Grøn-rug	Test af ny biomasse (grøn-rug)
Græs-Prof	GUDP	Kløvergræs	Test og optimering af neddelings udstyr
Opkoncentrering af I	PAF	Rajsvingel og "sukkergræs"	Membranfiltrering af brunsaft - opkoncentrering af sukkerstoffer til fermenteringsformål
AlfaMaxBioraf	GUDP	Lucerne	Procesoptimering Sammenligning af forskellige proteinfældninger
AlfaMaxBioraf Fordøjelighed og	GUDP SAF	Lucerne	Procesoptimering Sammenligning af forskellige separations scenarier
AlfaMaxBioraf Fordøjelighed og	GUDP SAF	Lucerne	Procesoptimering Test af Spin flash tørring
GO-Grass	H2020	Grøn biomasse generelt	Optimering af logistik (+/- snitning i marken)
GRØNBIORAF/ GreenValleys	GUDP/RM/Industri Interreg	Grøn biomasse generelt	Validere processen og indsamle tilstrækkeligt data til pålidelig TEA og LCA/EA

AGROVÄST SKIVEKOMMUNE Hushållningssällskapet SLU AARHUS UNIVERSITY CHALMERS VÄSTRA GÖTALANDSREGIONEN NATURBRUKSFÖRVALTNINGEN

Delaktivitet 4.4

Test och försök för optimal energiproduktion

B: Energioptimering och integration mellan bioraffinaderi och biogasanläggning

Project meeting 18.03.2020

Structure of online meeting
10:00-10:30

- Activities at AU ENG on modelling for optimal energy production
- Status at Hushållningssällskapet Sjuhärad on biogas experiments

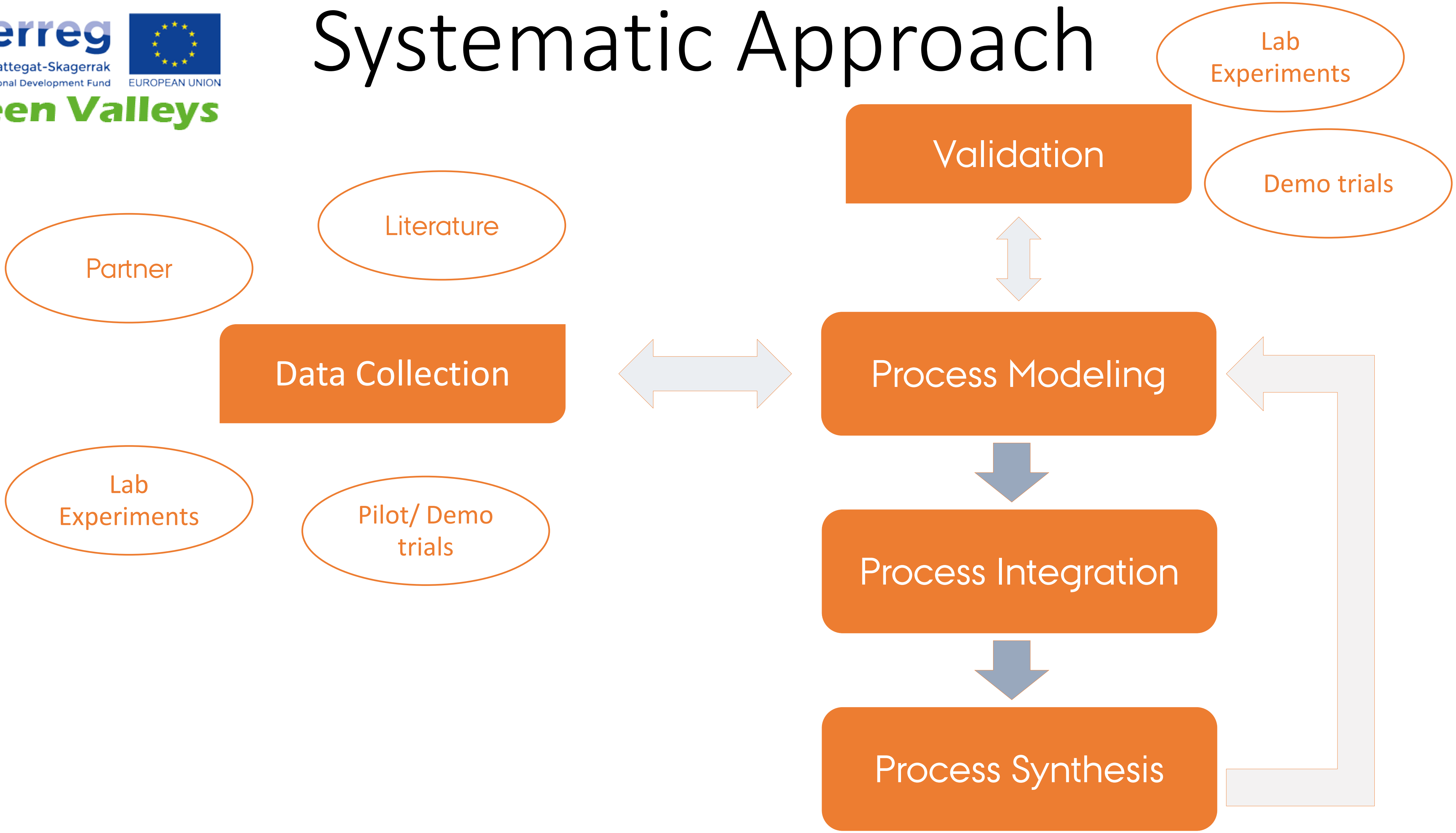
Modeling & Optimization for Green Biorefineries

Objectives

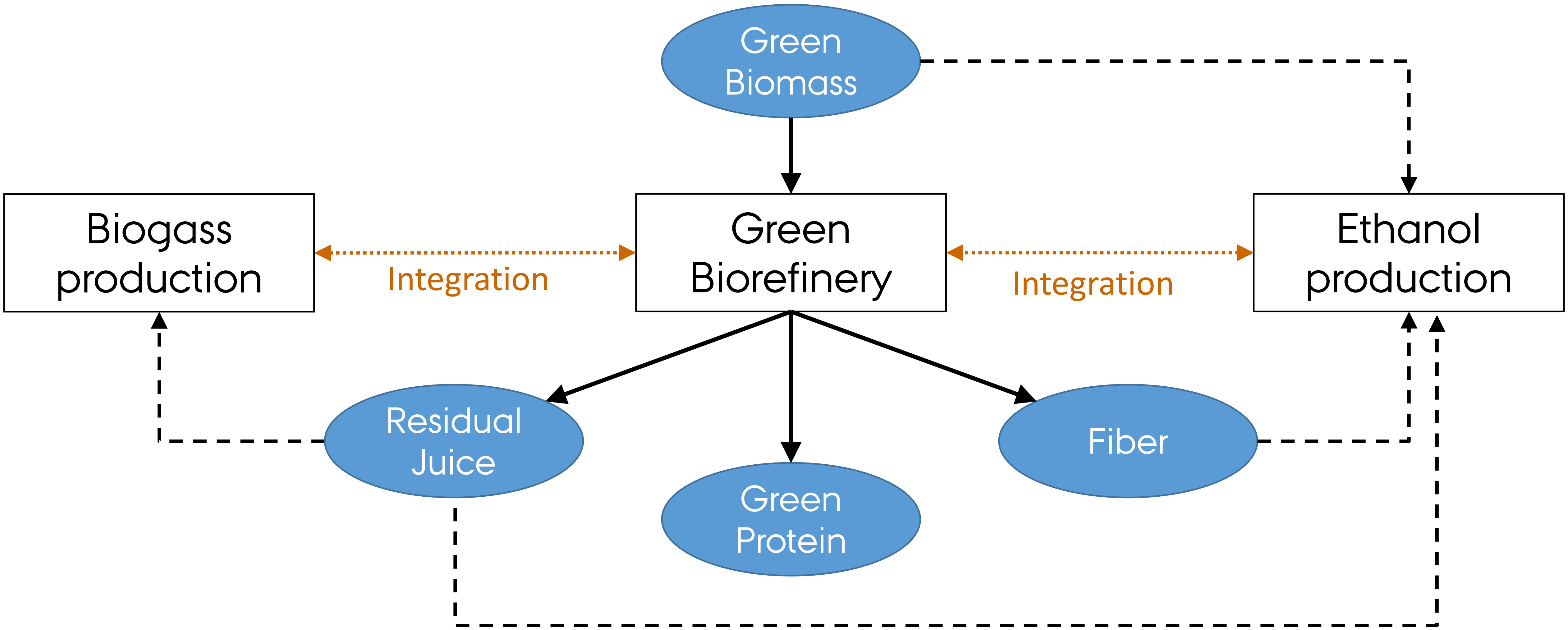
- Sustainable production of bioenergy as
  - Biogas
  - Bioethanol

- Valorization of all streams
  - Green protein
  - Fiber
  - Residual Juice

Systematic Approach



Process Integration



Delaktivitet 4.4

Test och försök för optimal energiproduktion

A: Test och optimering av biogasproduktion av pressjuicen med UASB-reaktor.

Project meeting 18.03.2020

Structure of online meeting
13:30-13:50

- Activities at AU ENG on biogas production from brown juice using a packed filter reactor (not a Up-flow Anaerobic Sludge Blanket (UASB))

BIOGAS OF BROWN JUICE USING IMMOBILIZED FILTER-REACTOR

Reactor system with Expo Net to immobilize bacteria and archea

Decreased retention time

Decreased reactor volume

No co digestion

Fast and efficient biogas production from easily digested organics in the brown juice

Approx. 1 m3 per day

80 m3 of brown juice

Running October 2019

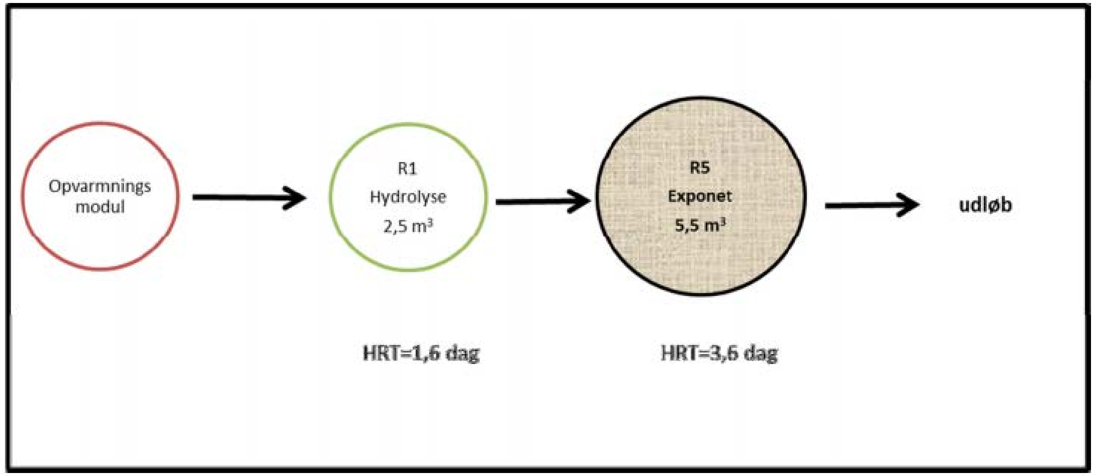


Illustration: System setup

Experimental setup

The pilot-scale AF had a total working volume of 5.5 m^3 . Filter media (BIO-BLOK® 100, EXPO-NET, Denmark) was set inside of the reactor with available surface area of 300 $m^2.m^{-3}$. The AF was operated semi-continuously at mesophilic temperature (30-32 ^oC). As shown in Fig.1, the influent BJ first entries into a tank to pre-heat to 55-60 °C in order to maintain the reactor's interior temperature (30-32 °C) as no extra heating device was installed.

The entire experiment lasted for 118 days from Oct.4, 2019 to Jan. 29, 2020, which was divided into five consecutive periods according to HRTs and feeding regimes (Table 1). The BJ was stored inside a storage tank under atmosphere temperature (ranged between -2 to 14 ^oC, average 6 ^oC. Data source: AU Foulum Climate database).

Period No.	Duration (day)	Feeding load (kg/day)	OLR (kg_{COD}/m^3 d)	HRT (days)	Feeding frequency (times per day)
1	1-19	500	1.9 (1.88)	11	1
2	20-46	250	0.9 (0.94)	22	1
3	47-67	500	1.9 (1.88)	11	1
4	68-97	500	1.9 (1.88)	11	2
5	98-118	1000	3.8 (3.75)	5.5	2

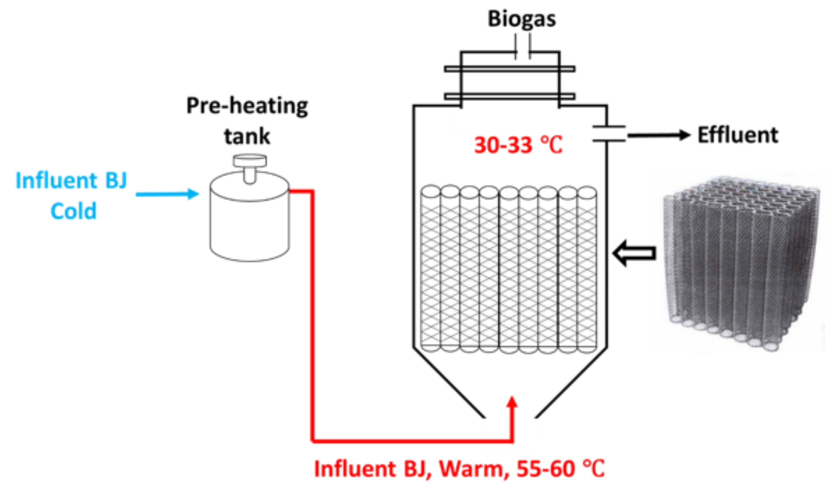


Figure 1. Illustration of anaerobic packed-filter reactor coupled with pre-heated feeding.

Brown Juice input

Table 2.Characteristics of brown juice (both raw and heated BJ)

Parameters	Total Solids	Volatile Solids	pH	VFAs	COD	BMP	BMP
Unit	($\%_{w/w}$)	($\%_{w/w}$)		(mg L^{-1})	(g L^{-1})	(NmLCH$_4$ gVS^{-1})	(NmLCH$_4$. gCOD^{-1})
BJ[1]	2.00	1.32	3.96	976	20.63	409.6	264.2
BJ[2]	2.00	1.33	3.94	1925	22.51		

1. Fresh brown juice collected at the start; 2. Brown juice collected at the last week after warm-up (heating from environmental temperature, around 15 to 60 ºC within one hour)

The ultimate CH_4 potential (BMP) of BJ following 90 days of batch digestion was 264.2 mLCH$_4$ gCOD^{-1} (409.6 mLCH$_4$ gVS^{-1}), comparable to previous result found in literature (429-539 ml CH$_4$.gVS^{-1}) (Santamaría-Fernández et al., 2018)

Conclusions of the study

- This study demonstrated that an anaerobic packed-filter reactor coupled with pre-heating tank is feasible for treating BJ to produce biogas.
- The CH_4 production was 230 mL $gCOD^{-1}$ d^{-1} corresponding to a COD removal of up to 80% at 5.5 days of HRT.
- Alteration of feeding frequency from once to twice per day enhanced the AD's stability as it narrowed the temperature variation and decreased the impact on buffer capacity.
- Investigation into microbiome changes in response to various parameters or process modelling will be useful in the future.

Delaktivitet 4.4

Test och försök för optimal energiproduktion

D: Bioraffinering av sockergräs för produktion av biogas eller bioetanol

Project meeting 18.03.2020

Structure of online meeting
13:50-13:15

- Activities at AU ENG on membrane filtration of brown juice from high sugar grasses

GREEN BIOREFINING RESIDUAL JUICE FILTRATION

GOSSAYE TIRUNEHE

1. OBJECTIVE

Objective:- To concentrate the sugar and organic fractions in the brown juice as a pretreatment step for subsequent biogas/bioethanol production.

The Pilot/ Demo scale Nanofiltration of high sugar grass brown juice.

HPLC test method used for sugars and organic acids analysis

MEMBRANES CHARACTERISTICS

Membrane name	Manufacturer	Surface polymer	MWCO (Dalton)	Permeate flow rate(m^3/d)	Salt rejection (%)
HL	GE	Polyamide	~ 150-300	3.0 (at 7.6 bar)	average 98%

PILOT SCALE NF PLANT OF 2,6 m^2 FILTRATION AREA FITTED WITH GE HL MEMBRANE

DEMO SCALE NF PLANT OF 98 m^2 FILTRATION AREA FITTED WITH GE HL MEMBRANE

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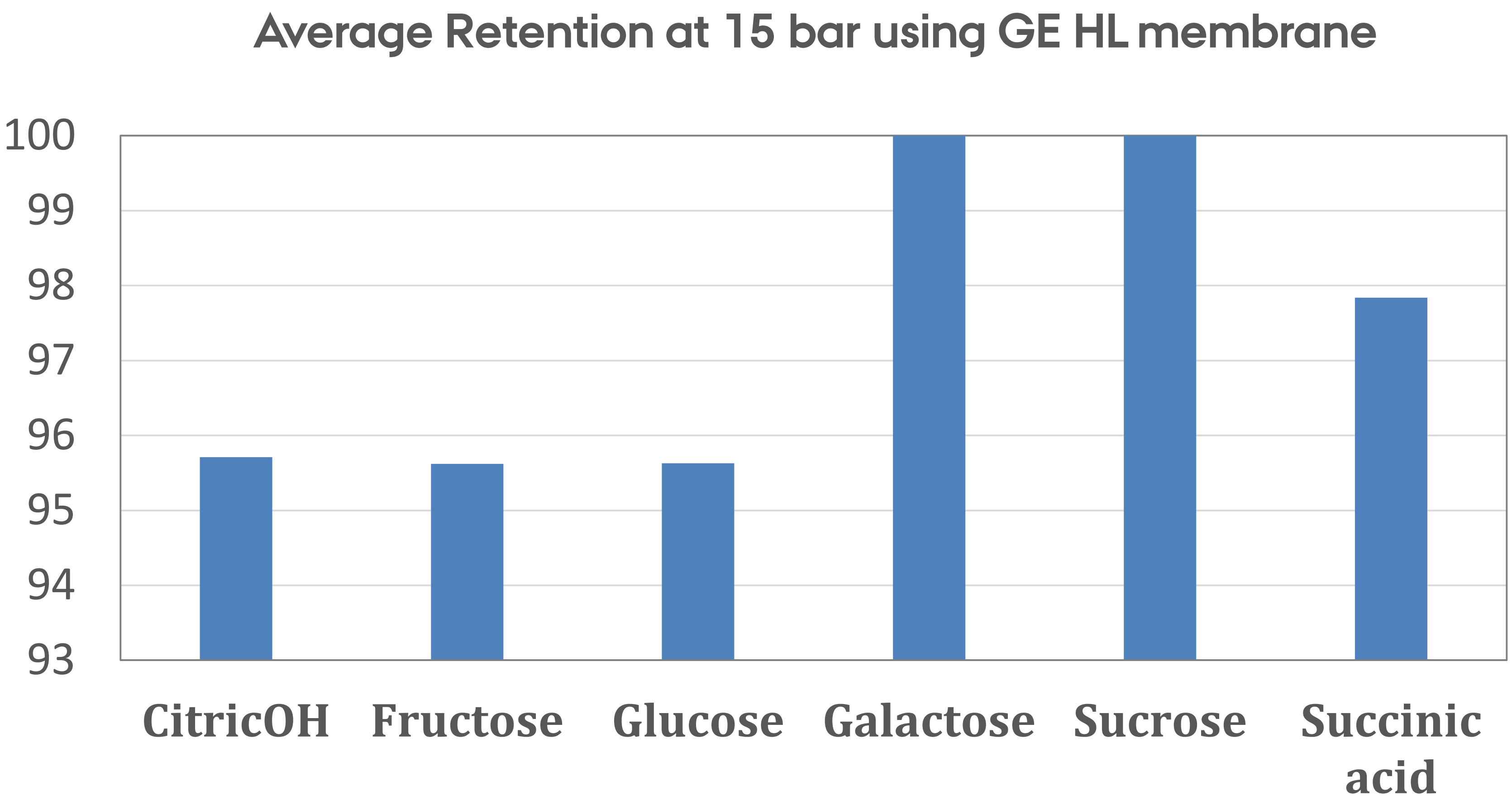
HIGH SUGAR GRASS BROWN JUICE FILTRATION USING PILOT AND DEMO PLANT

- ❑Filtration of high sugar brown juice using pilomem pilot plant at 15 bar and 25°C
- ❑Characterization of high sugar brown juice feed, permeate and concentrate

	Brix	Citric acid	Glucose	Fructose	galactose	Sucrose	Succinic acid	Lactic acid
Stream	°Bx	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
feed	4,0	1103	6938	4770	226	1871	278	nd
Permeate	1,1	98	2561	1566	0,00	0,00	9	nd
Concentrate	15,7	3467	22371	13115	272	16386	546	nd


Average Retention at 15 bar using GE HL membrane
100
99
98
97
96
95
94
93
CitricOH
Fructose
Glucose
Galactose
Sucrose
Succinic acid

- Demo scale filtration of the high sugar grass brown juice was tested using feed volume of 2,03m^3.
- The feed brix was 2,66^{o}Bx, the filtration was operated at 15 bar and 3o^{o}C using HL Nano-filtration membranes(the low feed brix is mainly due to washing water used before the grass pressing step).
- The brown juice was concentrated to 19^{o}Bx with concentrate volume of 0,12 m^3 and volume reduction factor of 16,9.

Next steps

- ❑Automation of the Filtration plant for optimal performance and membrane longevity

- ❑Evaluating the economic feasibility of brown juice Nanofiltration process based on its energy consumption, cleaning chemical use and membrane service life.

Delaktivitet 4.4

Test och försök för optimal energiproduktion

C: Produktion av bioetanol ifrån fiberfraktionen

Project meeting 18.03.2020

Structure of online meeting
14:00-14:30

- Activities at AU ENG on pretreatment, enzymatic hydrolysis and ethanol formentation of the grass fiber fraction

BIOETHANOL PRODUCTION FROM GRASS FIBER FRACTION

Biological and Chemical Engineering

Green Biorefining Group

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TOPICS FOR DISCUSSION

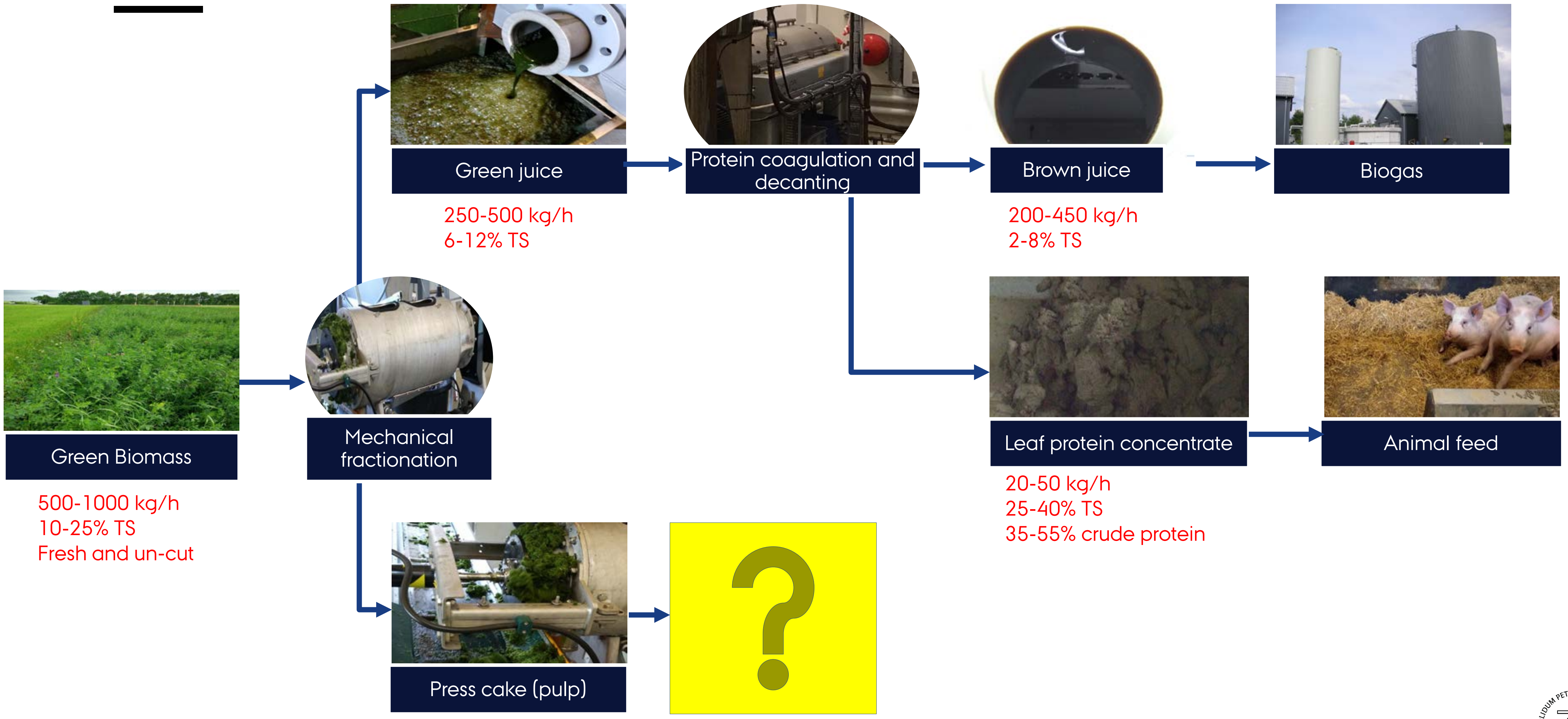
The grass fiber fraction

Pretreatment processes

Enzymatic hydrolysis of pretreated grass

Fermentation

PILOT PLANT FLOW DIAGRAM



FIBER CHARACTERIZATION

Biomass	Dry matter	%C	%H	%N	%S
Red clover	33,93	33,17	4,97	2,24	0,11
Lucerne	31,36	35,77	6,26	2,46	0,14
Ryegrass	30,02	42,29	6,91	1,84	0,17

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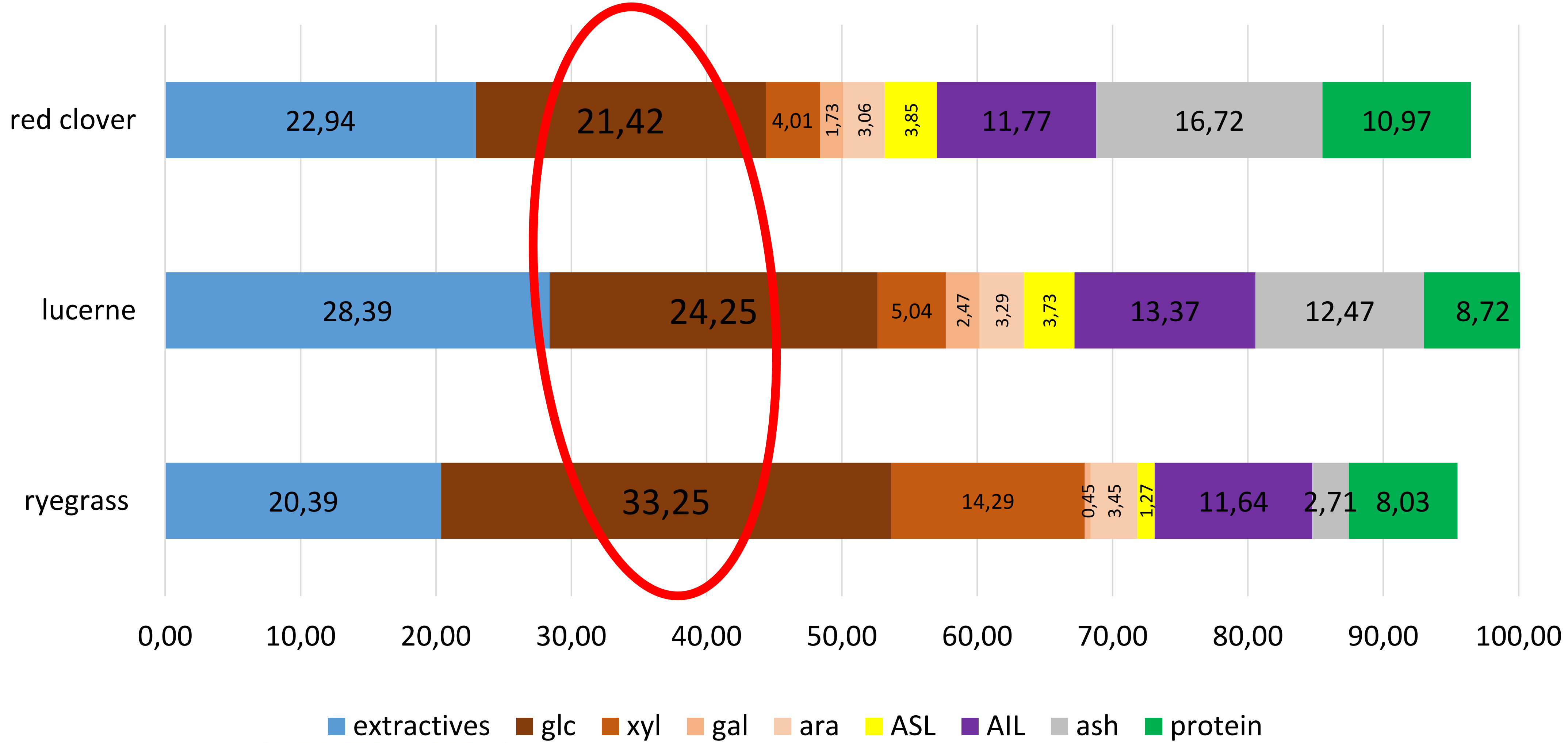
COMPOSITION OF GRASS FIBER



FEEDSTOCK FOR BIOETHANOL?

Pretreatment strategies

Silage

- Seal fiber pulp in plastic bags under vacuum; store at room temperature for 4 weeks

Organosolv (ethanol)

- Heat fiber pulp in ethanol at 70°C for 22 hours

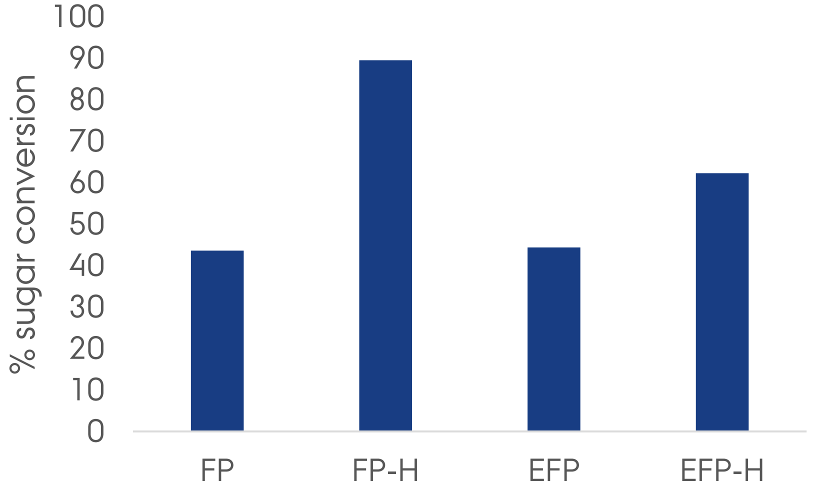
Hydrothermal

- Heat fiber pulp in water at 190°C for 10 minutes

SUGAR RELEASE FROM FIBER FRACTION

Feedstock	Pretreatment conditions	Abbr	Cellulose	Hemi-cellulose	Structural inorganics	Crude protein	Lignin
Lucerne pulp	None	FP	21.1	11.4	14.9	16.6	13.8
	190°C hydrothermal	FP-H	44.9	5.4	11.4	16.3	36.5
Lucerne pulp silage	Anaerobic environment for 4 weeks at room temperature	EFP	21.6	9.2	22.0	9.8	16.1
	190°C hydrothermal	EFP-H	46.3	7.6	9.2	13.1	35.2

* Enzymatic hydrolysis with Cellic CTec3 (Novozymes)



POTENTIAL BIOETHANOL YIELDS

85.5% glucose conversion from fresh pulp hydrothermal pretreatment

- Equivalent 0.19 g glucose produced/ g DM loading
- Expected 0.097 g ethanol produced/ g DM

FUTURE PLAN

Optimization of enzymatic hydrolysis with auxiliary enzymes (e.g. pectinases)

- Increase fermentable sugar yields

Obtain fermentation yields from hydrolyzed sugars

- HHF strategy: 48 hours hydrolysis + 120 hours fermentation

Enzymatic hydrolysis at high solids (>20% dry matter)

- Increase sugar, hence ethanol, concentrations in solution

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