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PRODUCING 2ND GENERATION BIOETHANOL FROM LUCERNE WITH OPTIMISED HYDROTHERMAL PRETREATMENT

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Criteria for choosing biomasses for bioethanol research

- Easy to convert (sugar cane, sugar beet, maize, wheat)
- High availability (wheat straw, sugar cane bagasse, corn stover)
- High crop yields (miscanthus, willow)

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Bioenergy and Biorefinery Program

- **Integrated system approach**
- **Sustainability assessments**
- **Agricultural research**
- **Conversion technologies**

Criteria for choosing biomasses for bioethanol research

Classic

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New

- Low input agriculture (less fossil derived inputs)
- Providing ecosystem services (reducing eutrophication, increasing soil organic carbon, sustaining nutrients)
- Reducing GHG emissions from agriculture (perennial crops)

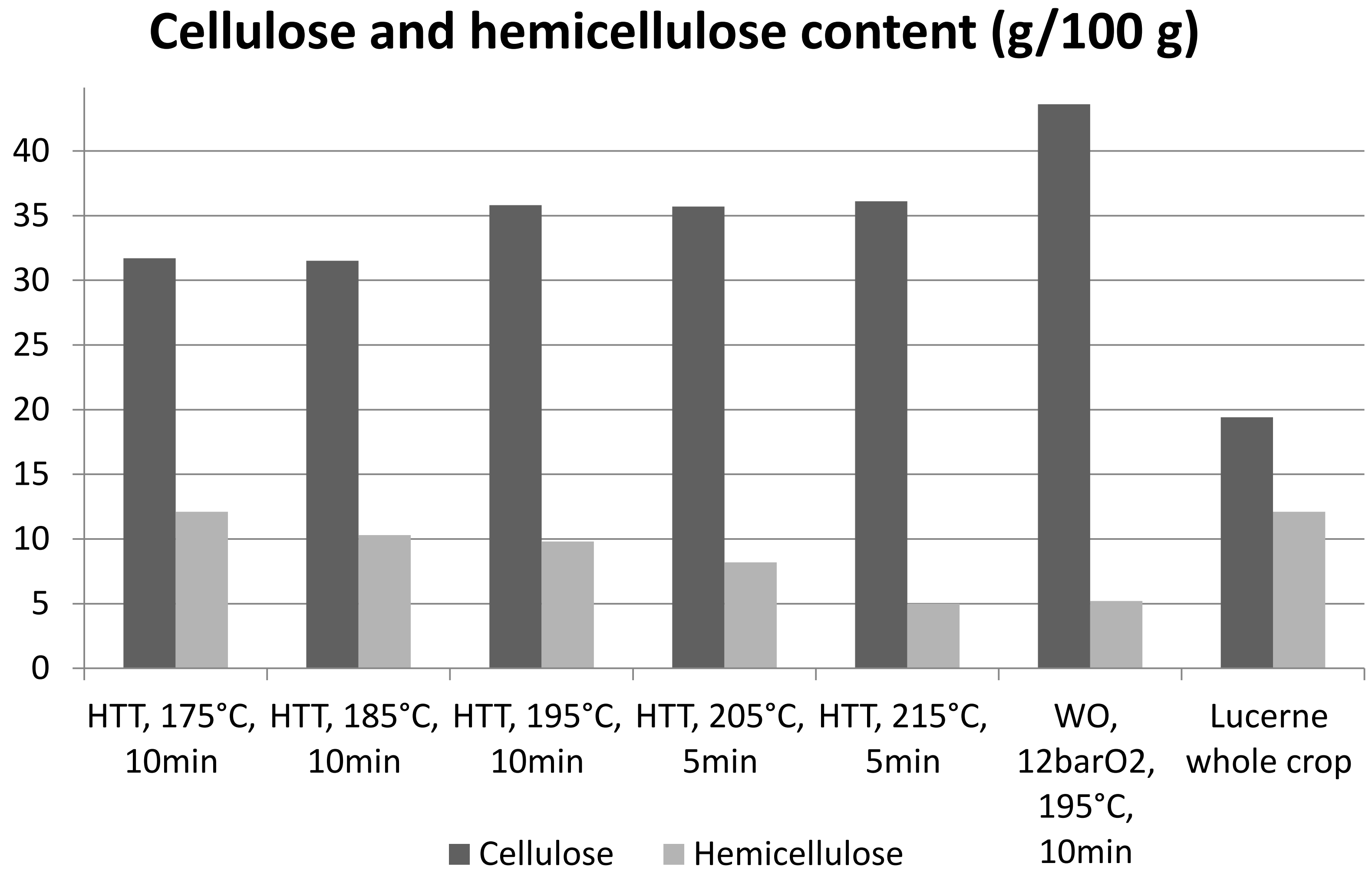
Lucerne (alfalfa, *Medicago Sativa)*

- Nitrogen fixating legume
- Natural fertiliser
- Prevent nutrient leaching
- Prevent carbon depletion
- High biomass yield
- Low energy input
- Low environmental impact during cultivation

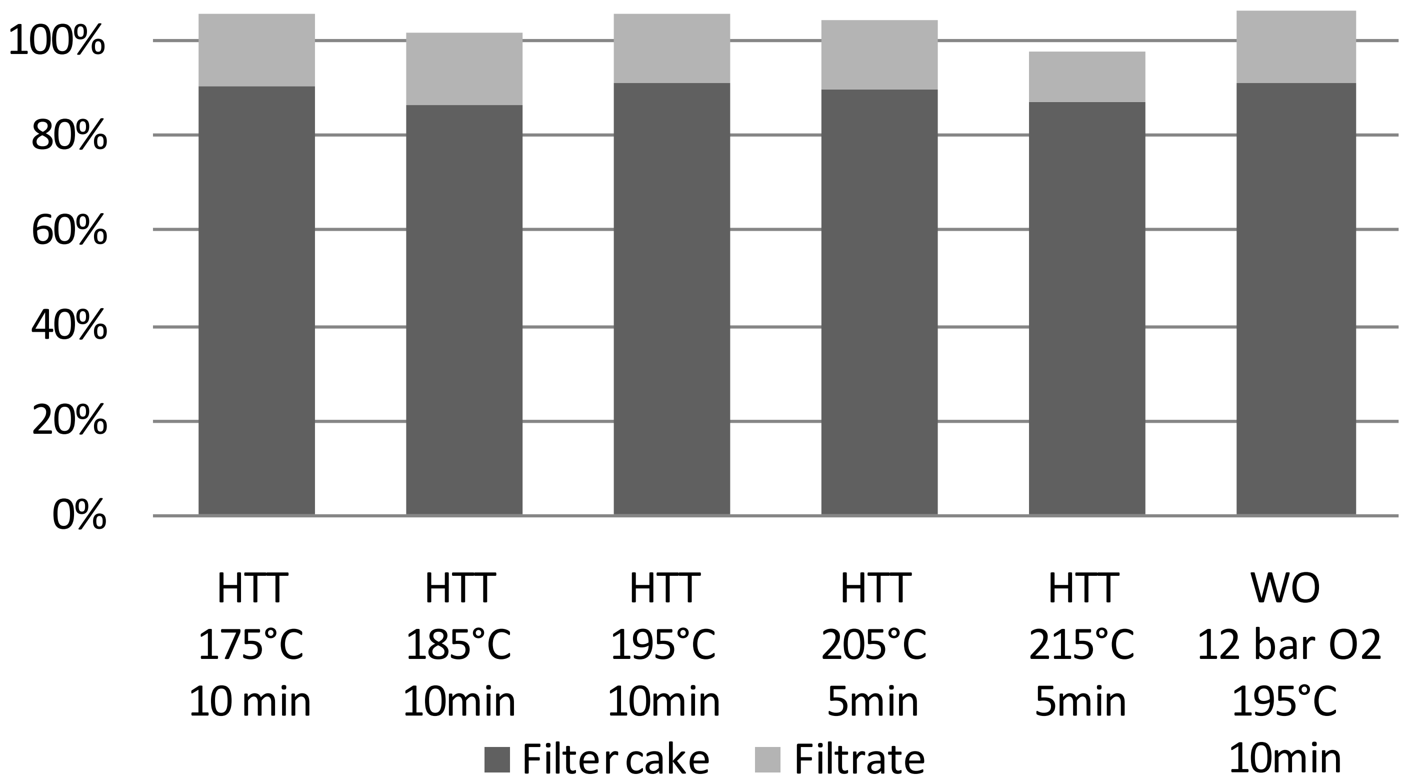
Approach

- Hydrothermal pretreatment (HTT) of lucerne hay
  - Variation of temperature (from 175-215°C)
- Assessment of HTT
  - Compositional studies
  - Sugar recovery
  - Inhibitor studies
  - Enzymatic convertibility studies
  - Simultaneous saccharification and fermentation (SSF)
  - Compare with wet oxidation (WO)

Composition of solid fraction after pretreatment

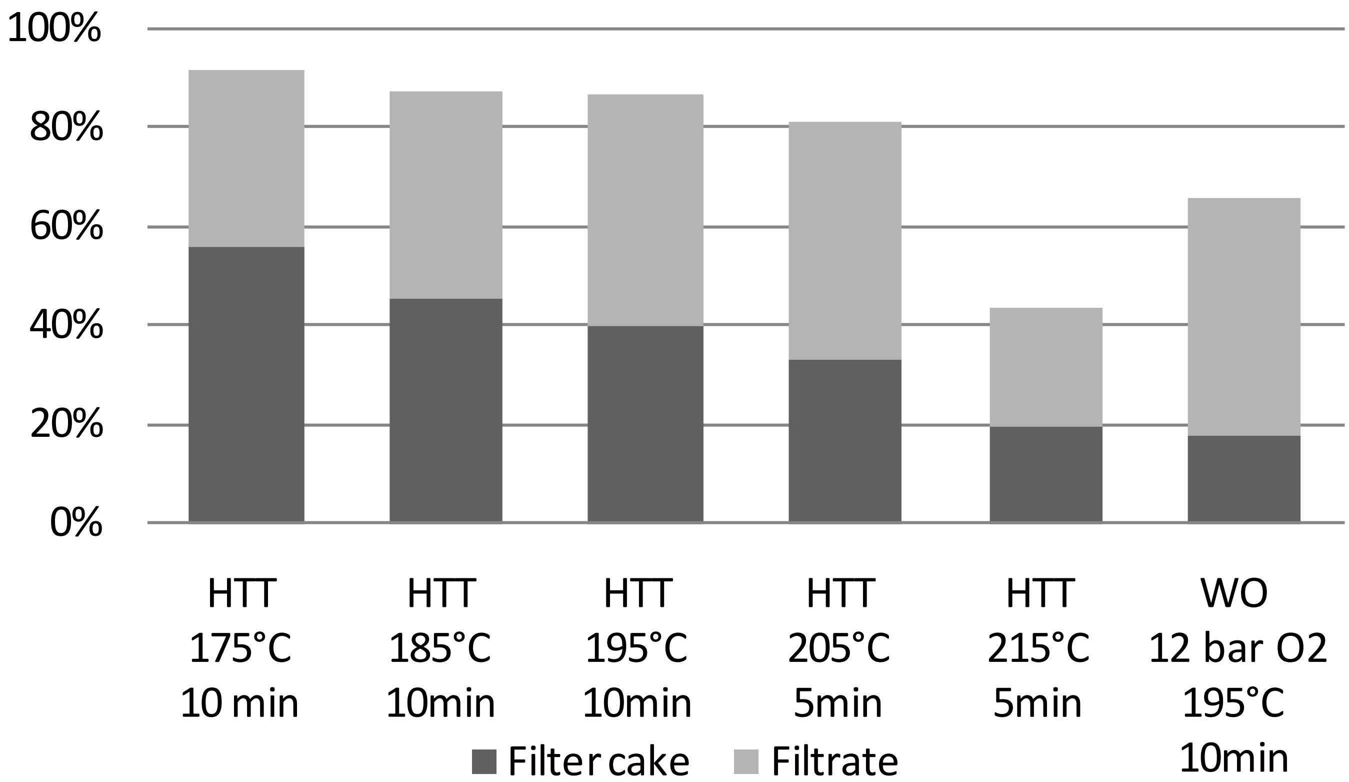


Glucose recovery
- free and polymeric glucose



g glucose in liquid and solid phases of pretreatment per g glucose in the untreated lucerne

Pentose recovery
- free and polymeric xylose and arabinose



g xylose and arabinose in liquid and solid phases of pretreatment per g glucose in the untreated lucerne

Fatty acids in liquid fraction after pretreatment

Pretreatment conditions	°C	min	Malic acid	Succinic acid	Glycolic acid	Formic acid	Acetic acid	Lactic acid
					g/L			
HTT	**175**	**10**	1.53	-	0.11	0.52	0.84	0.13
HTT	**185**	**10**	1.51	-	0.15	0.63	1.07	0.16
HTT	**195**	**10**	1.37	-	0.15	0.67	1.22	0.16
HTT	**205**	**5**	1.40	-	0.13	0.67	1.25	0.14
HTT	**215**	**5**	1.26	-	0.22	0.78	1.37	0.18
WO	**195**	**10**	0.68	0.37	0.41	1.34	2.06	-

Furans in liquid fraction after pretreatment

Pretreatment conditions	°C	min	5-HMF	Furfural	2-furoic acid
				mg/L	
HTT	**175**	**10**	-	4.27	18.50
HTT	**185**	**10**	-	8.66	24.53
HTT	**195**	**10**	-	10.41	32.28
HTT	**205**	**5**	-	10.45	31.34
HTT	**215**	**5**	-	25.97	38.44
WO	**195**	**10**	15.61	51.01	35.52

furfural (2-furaldehyde), 5-HMF (5-hydroxymethyl-2-furaldehyde)

Enzymatic convertibility and ethanol yields.

Pretreatment conditions	°C	min	Enzymatic convertibility g cellulose converted / 100g cellulose in pretreated material	Ethanol yield in SSF g ethanol / 100 g potential ethanol from pretreated material	Ethanol yield per untreated material g ethanol / 100 g DM untreated material
HTT	175	10	68	41.7	4.9
HTT	185	10	69	43.8	4.9
HTT	195	10	72	55.0	5.7
HTT	205	5	74	59.9	6.2
HTT	215	5	92	62.8	6.2
WO	195	10	81	62.8	6.5
Untreated			54	-	2.5

Conclusions

The **optimal** hydrothermal pretreatment conditions was **205°C** for 5 minutes, resulting in **pentose recovery of 81%**, and an **enzymatic convertibility of cellulose to monomeric glucose of 74%** facilitating a conversion of 6.2% w/w of untreated material into bioethanol in SSF, equivalent to **1,095 litre ethanol per hectare per year**.

Lucerne has in the presented study proven to be a potential substrate for 2nd generation bioethanol providing large annual yields per hectare.

However; The cellulose content of the lucerne seems too low for industrial production of bioethanol!

The next steps

- Fractionation of protein rich leaf fraction and cellulose rich stem fraction (*Boateng et al. 2008*)
- Optimize growth condition for optimal biomass yield instead of optimal feed conditions (done by *Lamb et al. 2007*)
- This will increase the potential ethanol yield and will conserve valuable proteins

Boateng AA, Weimer PJ, Jung HG, Lamb JFS. 2008. Response of thermochemical and biochemical conversion processes to lignin concentration in alfalfa stems. Energy Fuels 22:2810-2815.

Lamb JFS, Jung HJG, Sheaffer CC, Samac DA. 2007. Alfalfa leaf protein and stem cell wall polysaccharide yields under hay and biomass management systems. Crop Sci 47:1407-1415.

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...and

THANK YOU FOR YOUR ATTENTION