



## Production of 2nd generation bioethanol from lucerne with optimized hydrothermal pretreatment

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# PRODUCING 2<sup>ND</sup> GENERATION BIOETHANOL FROM LUCERNE WITH OPTIMISED HYDROTHERMAL PRETREATMENT

Sune Tjalfe Thomsen\*, Morten Jensen, Jens Ejbye Schmidt

**Bioenergy and Biorefinery Program**

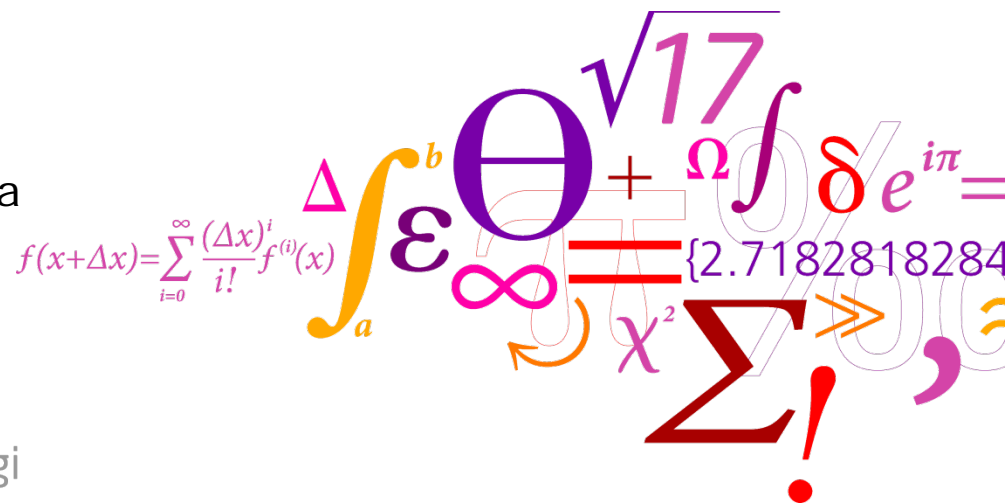
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Keywords: bioethanol, biomass, chemical composition, lucerne, alfalfa novel crops, pretreatment



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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



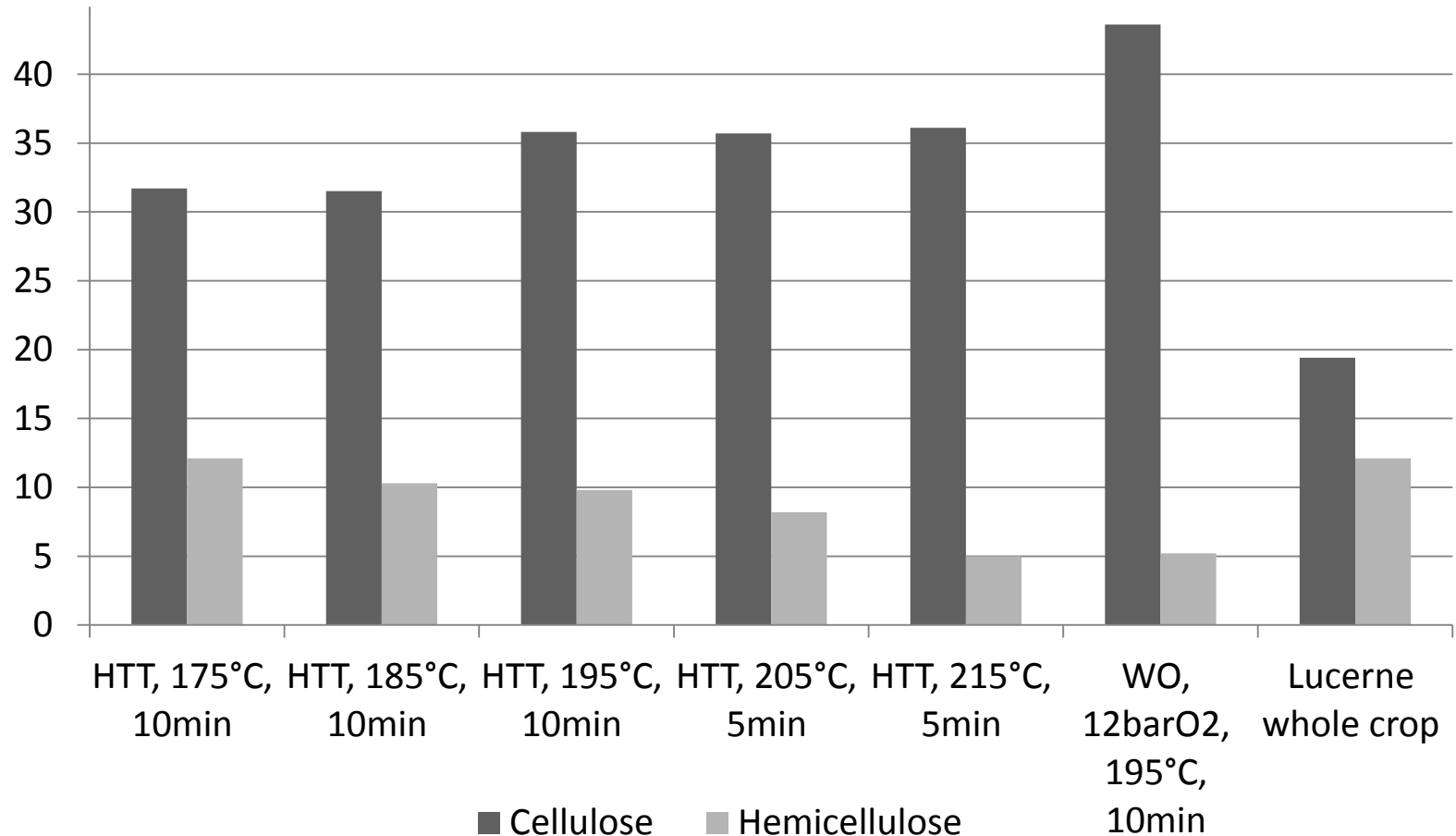
# Approach

- 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

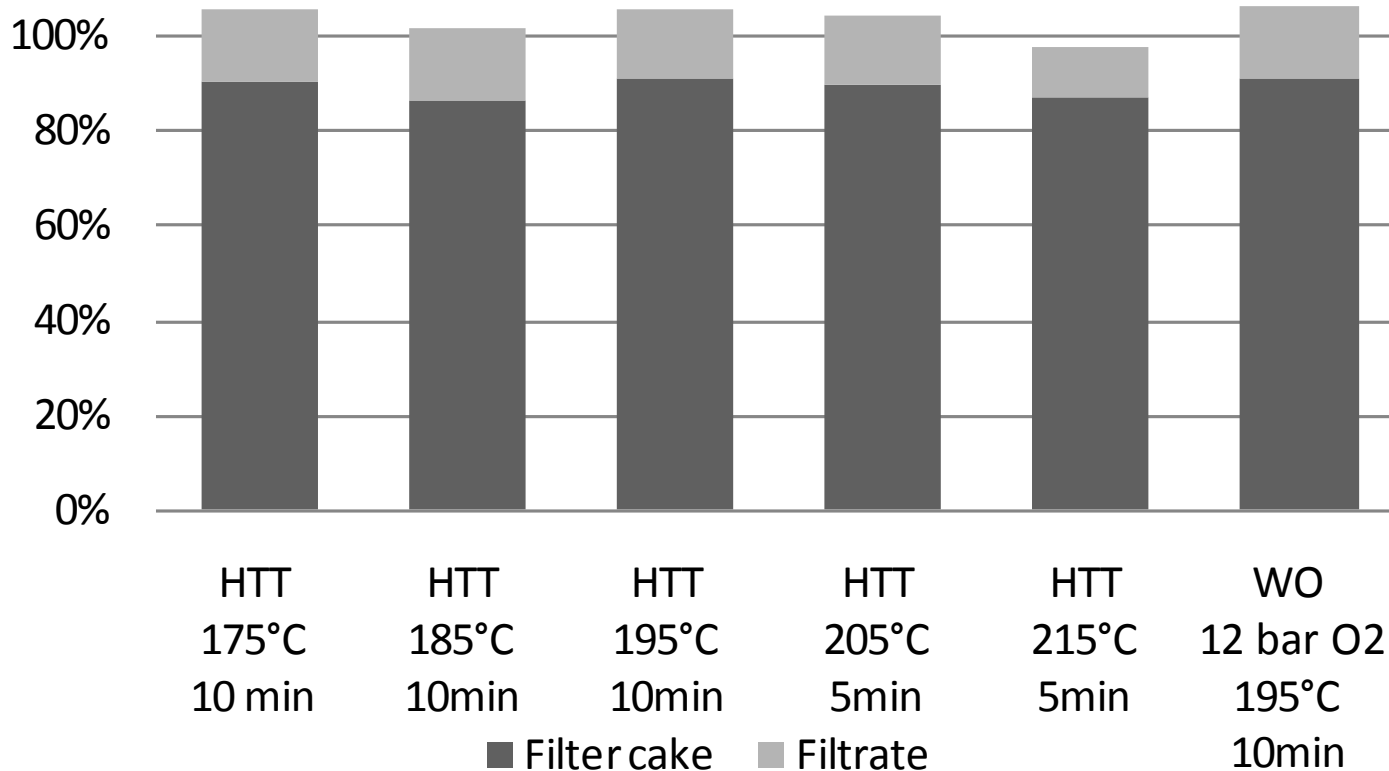
## Cellulose and hemicellulose content (g/100 g)





# Glucose recovery

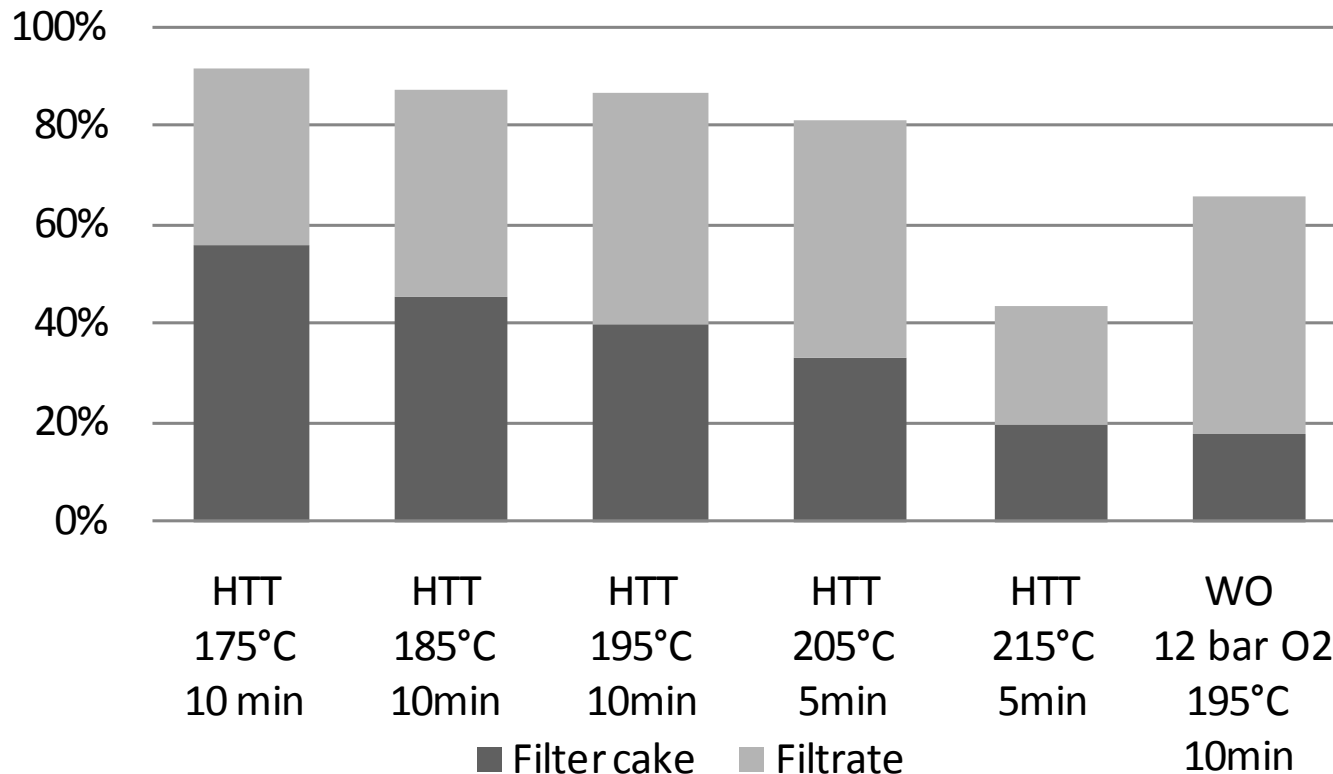
## - free and polymeric glucose



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

# Furans in liquid fraction after pretreatment

Pretreatment conditions			5-HMF	Furfural	2-furoic acid
°C	min			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			Enzymatic convertibility	Ethanol yield in SSF	Ethanol yield per untreated material
°C	min		g cellulose converted / 100g cellulose in pretreated material	g ethanol / 100 g potential ethanol from pretreated material	g ethanol / 100 g DM untreated material
<b>HTT</b>	<b>175</b>	<b>10</b>	68	41.7	4.9
<b>HTT</b>	<b>185</b>	<b>10</b>	69	43.8	4.9
<b>HTT</b>	<b>195</b>	<b>10</b>	72	55.0	5.7
<b>HTT</b>	<b>205</b>	<b>5</b>	74	59.9	6.2
<b>HTT</b>	<b>215</b>	<b>5</b>	92	62.8	6.2
<b>WO</b>	<b>195</b>	<b>10</b>	81	62.8	6.5
<b>Untreated</b>			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 2<sup>nd</sup> 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