Ultrasonic treatment of lignocellulosic biomass for sugar production

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Lignocellulosic materials from agro-forestry sector represent a substantial renewable source of chemicals, energy and fuels that do not compete with food production and animal feed. However, a pretreatment is necessary to separate the cellulose from hemicellulose and lignin, which is recalcitrant to further biological degradation. Ultrasound (US) provides a high energy input that destroys the lignocellulosic matrix at mild conditions, without generation of toxic byproducts or wastes streams.[1,2] In this work, different US device were tested for wheat straw and poplar wood pre-treatment.

Wheat straw

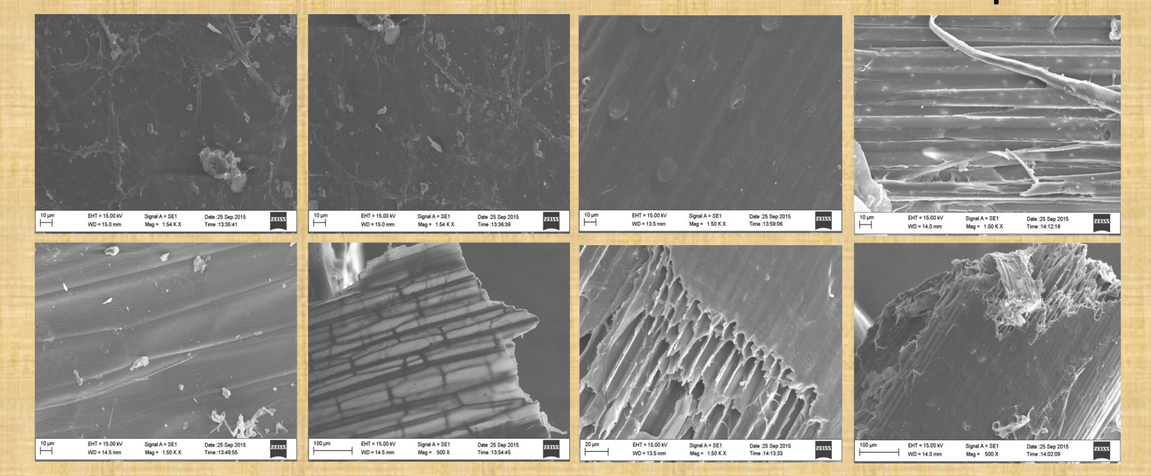
US pre-treatment processes for wheat straw: different device were tested comparing water and mixtures of water and γ-valerolactone (GVL) as solvents

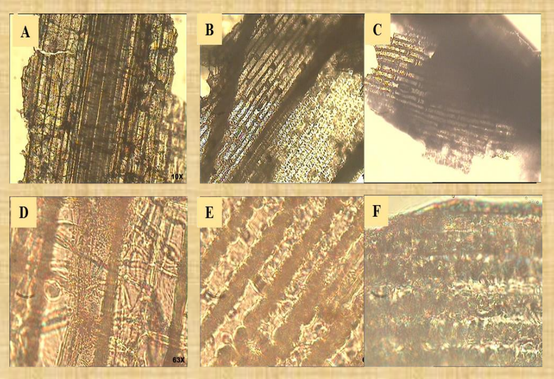
US Device	Solvents	Frequency (kHz)	Time (min.)	T (°C)	Energy consumption (kWh)	Weight loss (%)	Delignification[a] (%)
Ti horn	H_2O	20	40	58	0,12	7,5	15,50
Ti horn	H_2O	20	20	62	0,04	7,5	15,50
Ti horn	GVL/H_2O (1:1)	20	40	65	0,12	30,0	40,20
Ti horn	GVL/H_2O (1:1.5)	20	40	65	0,15	17,0	43,40
Ti horn	NH_4OH 15%	20	40	65	0,11	22,5	29,00
Weber Ultrasonic	H_2O	29	20	25	0,07	15,0	22,80
Weber Ultrasonic	H_2O	80	20	25	0,06	10,0	20,50
RSHC[b]	H_2O	-	10	40	10,00	15,0	25,00

[a]The delignification was measured by Py-GC/MS/FID (lignin proportion in the volatiles compared to untreated biomass)
[b]Large scale experiment (400 g)

SEM images of raw wheat straw

SEM images of Ti horn US treated wheat straw sample





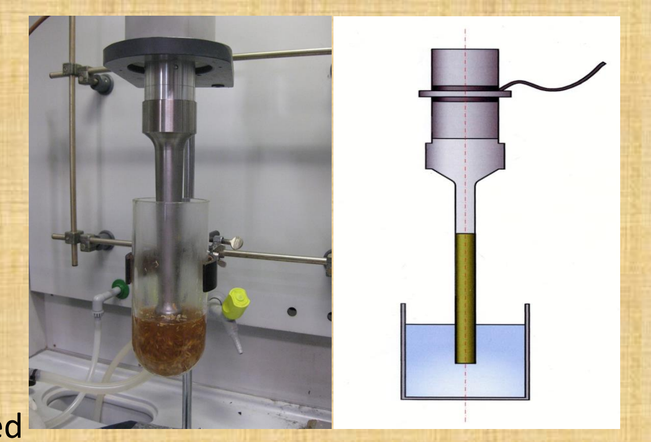
Optical microscope images of wheat straw before and after US treatment in H_2O, GVL/H_2O.

A and **D**: raw wheat straw
B, E: US treated wheat straw in water (Ti horn (20 kHz) 40 min 150 W);
C, F: US treated wheat straw in GVL/Water (Ti horn (19.5 kHz) 40 min 200 W).

US device

Titanium Horn

20 kHz/150-200 W

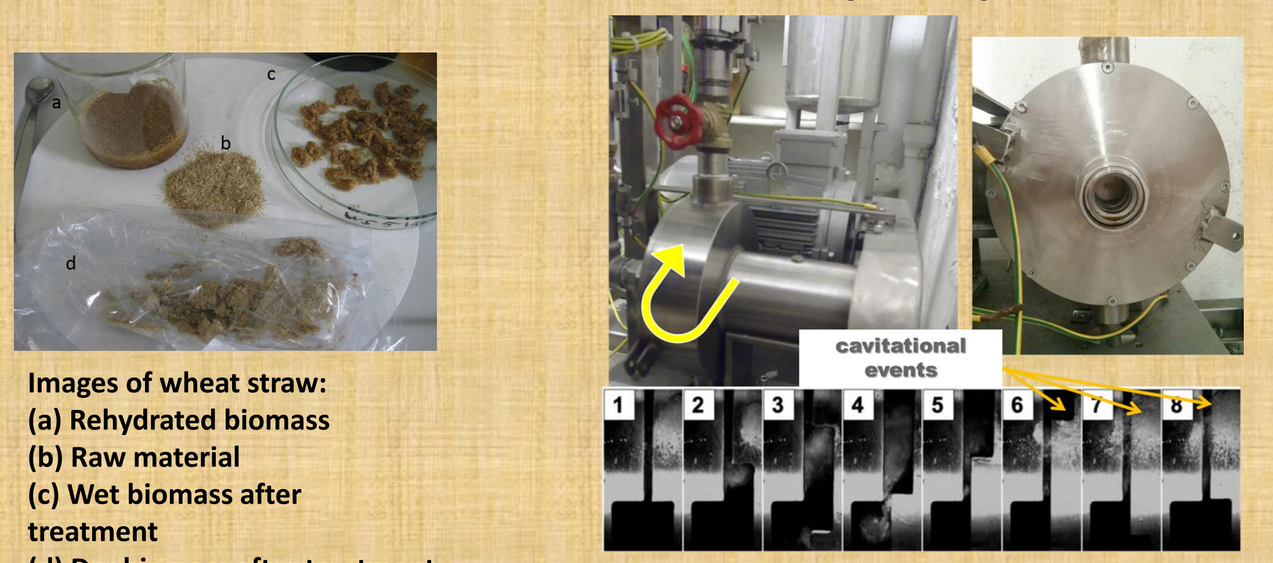


Acoustic cavitation

Weber Ultrasonic

29.0, 40.0, 80.0, 120.0 kHz/150-200 W

Hydrodynamic cavitation (RSHC)



200 W

Images of wheat straw:
(a) Rehydrated biomass
(b) Raw material
(c) Wet biomass after treatment
(d) Dry biomass after treatment

Poplar wood

US Device	Solvents	Frequency (kHz)	Time (min.)	T (°C)	Energy consumption (kWh)	Weight loss (%)	Delignification[a] (%)
Ti horn	H_2O	20	40	41	0,10	7,5	4,4
Ti horn	H_2O	20	20	42	0,07	5.0	3,6
Ti horn	GVL/H_2O (1:1)	20	40	65	0,14	4.0	4,8
Ti horn	GVL/H_2O (1:1.5)	20	40	65	0,17	8.0	8,4
Weber Ultrasonic	H_2O	29	20	24	0,06	10	10,8
Weber Ultrasonic	H_2O	80	20	25	0,06	2.0	2,4
RSHC[b]	H_2O	-	10	40	10,00	10.0	1,6

[a]The delignification was measured by Py-GC/MS/FID (lignin proportion in the volatiles compared to untreated biomass)
[b]Large scale experiment (400 g)

Raw poplar wood

RSHC pre-treated poplar wood

Conclusions

The influence of US pretreatment on the lignin constituent of biomass revealed itself in the case of poplar wood much slighter in comparison with wheat straw. The strongest decrease in the lignin content was observed for the samples obtained using the mixed solvent (GVL:H_2O) as well as 15% NH_4OH. The RSHC reactor is suitable for scale-up experiments, and yielded good results in terms of delignification (for wheat straw).

References

1. S. Tabasso, D. Carnaroglio, E. Calcio Gaudino, G. Cravotto, *Green Chem*., **2015**, *17*, 684.
2. J. Luo, Z. Fang, R. Smith Jr, *Progress in Energy and Combustion Science*, **2014**, *41*, 56.

Aknowledgements
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