Energetic and material valorization of digestate via hydrothermal liquefaction

Influence of input material and process parameters

PyroLiq II | May 8 – 12, 2023 | Schloss Hernstein, Austria | © Christian Klüpfel

Im Auftrag des:
Bundesministerium für Digitales und Verkehr

The DBFZ

- located in Leipzig, Germany
- German Federal Ministry of Food and Agriculture (BMEL) as sole shareholder
- approx. 300 people dealing with all aspects of biomass related research and political advice
- more than 100 on-going projects

Pilot-SBG

Project:	PILOT-SBG | Bioresources and hydrogen to methane as a fuel – conceptualization and realization of a pilot plant
Duration:	09/2018 – 12/2022 (Phase 1a)
On behalf of:	Federal Ministry for Digital and Transport

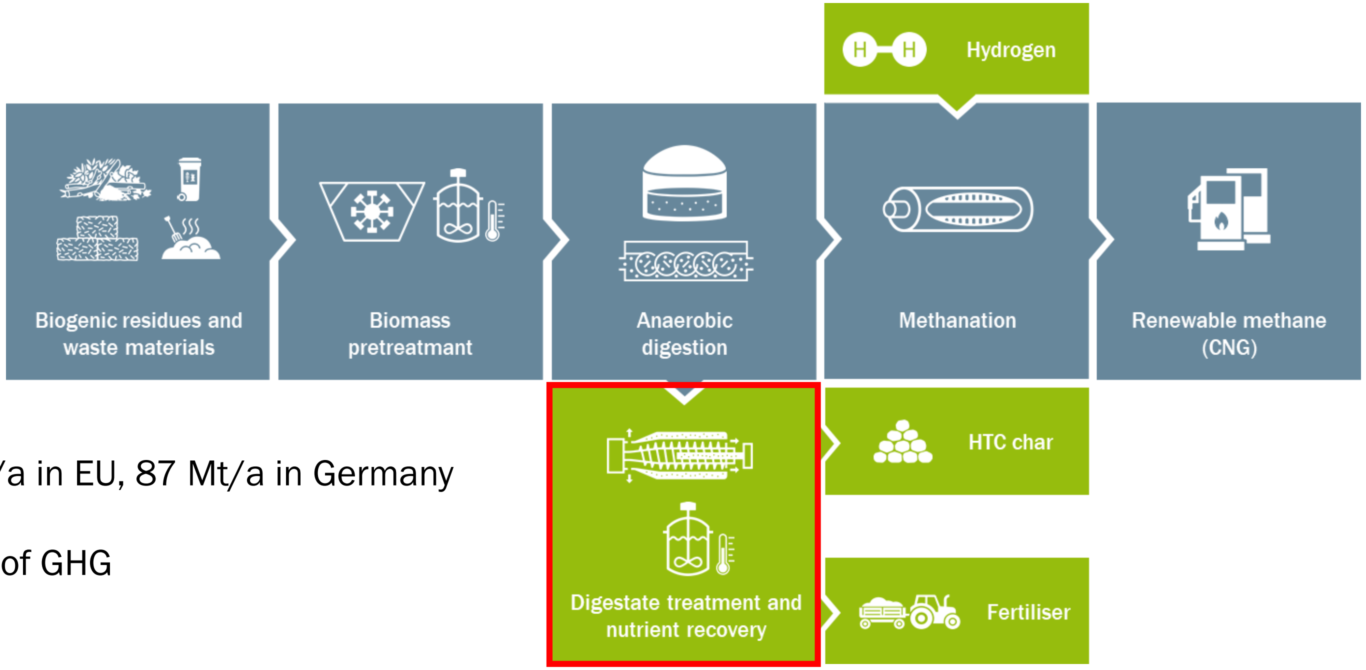
Financed by:
Federal Ministry for Digital and Transport

Objective:

- Provision of advanced methane as fuel for the transport sector in a pilot plant and development of concepts for the commercial scale

Methods:

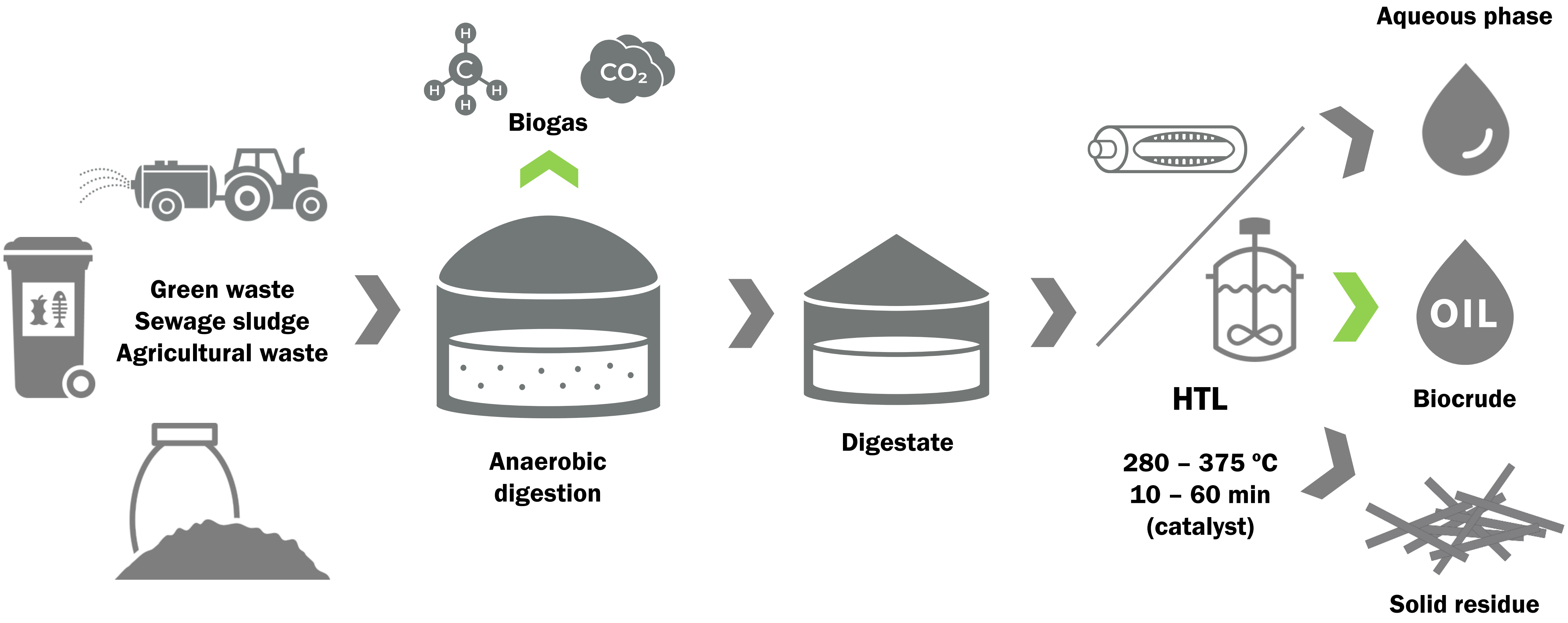
- Process and technology development with combination of innovative plant components for higher methane yields, incl. utilization of CO2 from the biogas and expanding the product portfolio
- Construction, installation and operation of a pilot plant
- Techno-economic and environmental assessment for possible plant concepts in a commercial scale



Background for digestate treatment:

- Nutrient rich by product, currently used as fertilizer (180 Mt/a in EU, 87 Mt/a in Germany (EC, 2019))
- Land application leads to overfertilization, storing, emission of GHG
- Research into suitable treatment technologies

Anaerobic digestion & hydrothermal liquefaction

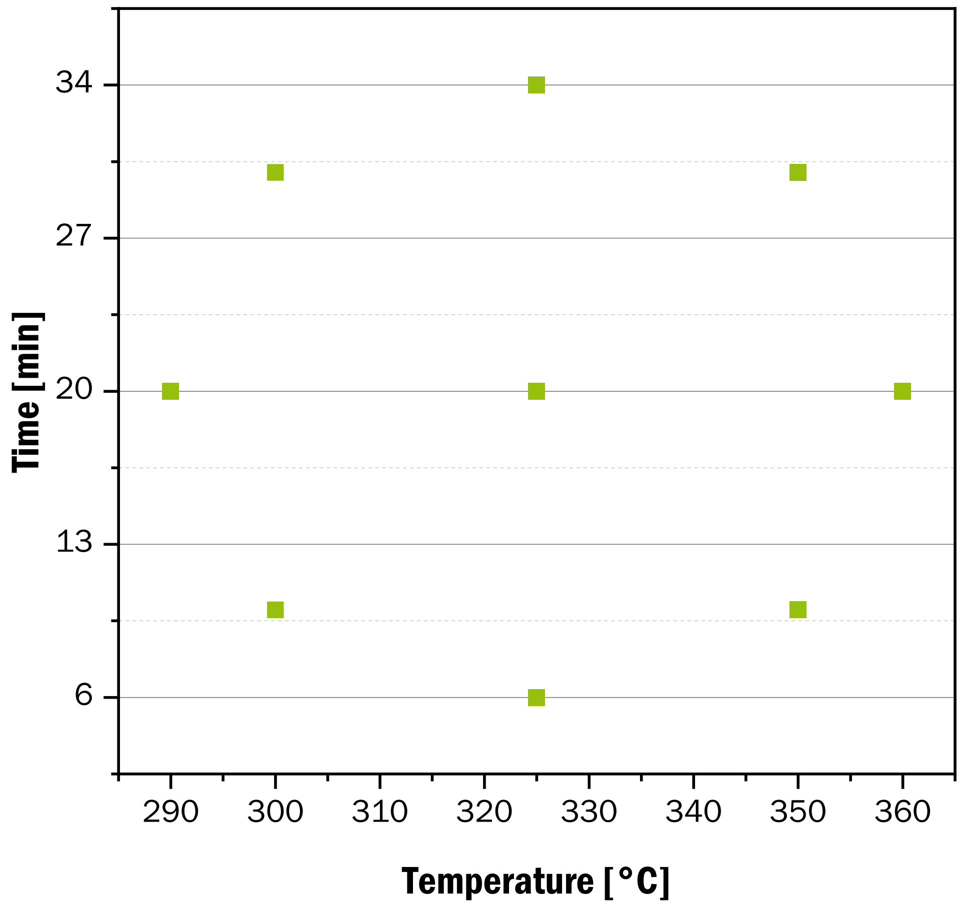


Experimental procedure

- Experiments in 20 mL mini-autoclaves, heated in a fluidized sand bath
- Separation of products by centrifugation, followed by DCM extraction
- Three digestates: digested biogenic waste (DBW), straw/manure-digestate (SMD) (18.75 % straw, 81.25 % manure), digested sewage sludge (DSS)

Design of experiments

- Central composite design of experiments in duplicates (α = 1.4)
- Elemental analysis of biocrude oil and hydrochar, ICP of hydrochar & GC-MS of biocrude



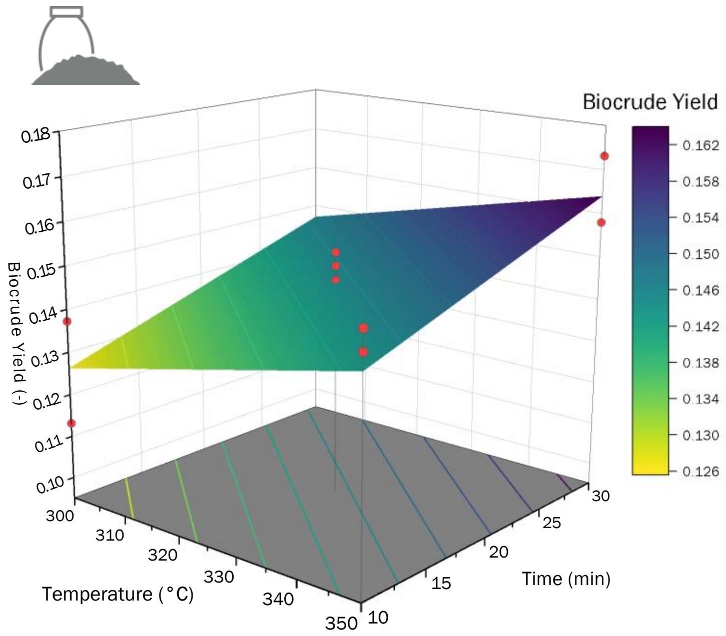
Analysis of educts

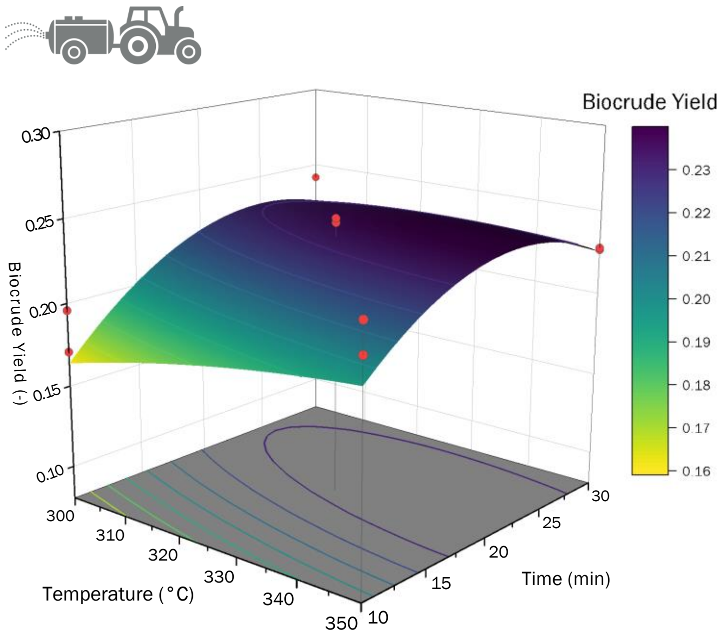
	N	C	H	S	O	P	HHV	Ash	Protein	Fat	Carbohydrate
	[$\%_{TS}$]	[$\%_{TS}$]	[$\%_{TS}$]	[$\%_{TS}$]	[$\%_{TS}$]	[mg/kg_{TS}]	[MJ/kg]	[$\%_{TS}$]	[$\%_{TS}$]	[$\%_{TS}$]	[$\%_{TS}$]
DSS	4.15	31.53 ↓	4.48	1.43	16.07	22,300	13.81	38.74 ↑	18.80 ↑	7.06 ↑	35.40 ↓
SMD	1.71	43.80 ↑	5.44	0.37	30.43	4,990	18.18	16.04 ↓	12.43	4.09	67.44 ↑
DBW	2.18	36.47	4.35	0.32	21.22	5,700	14.91	35.48 ↑	16.19	3.68 ↓	44.65 ↑

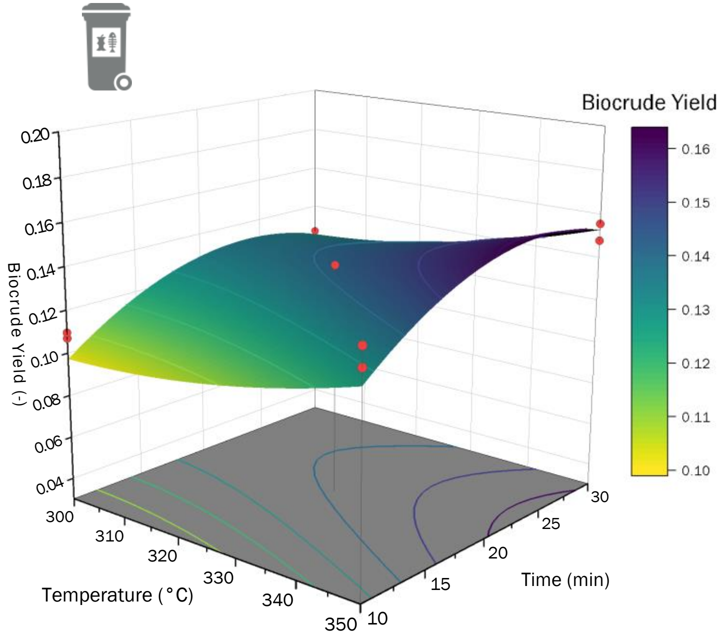
- DSS high in ash, protein and P, low in carbon
- SMD high in carbon and carbohydrates, low in ash
- DBW low in fat, high in ash and carbohydrates

Results

Biocrude yield

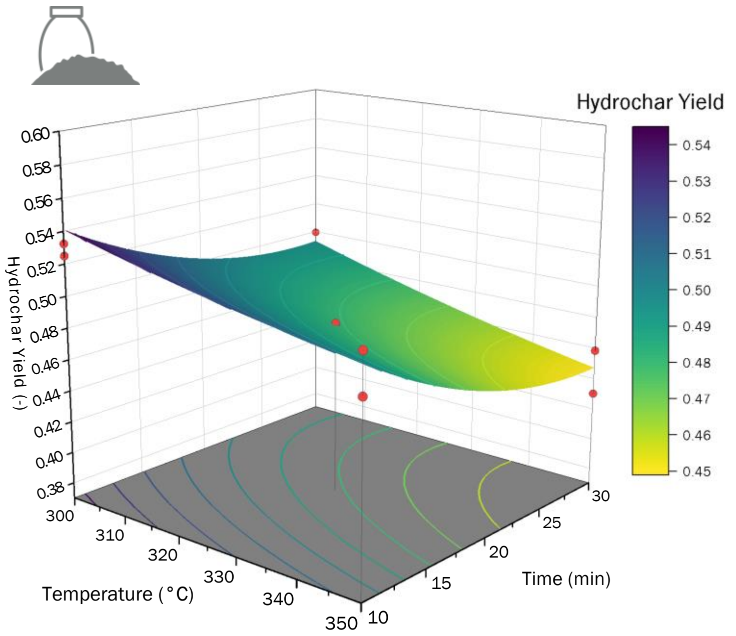


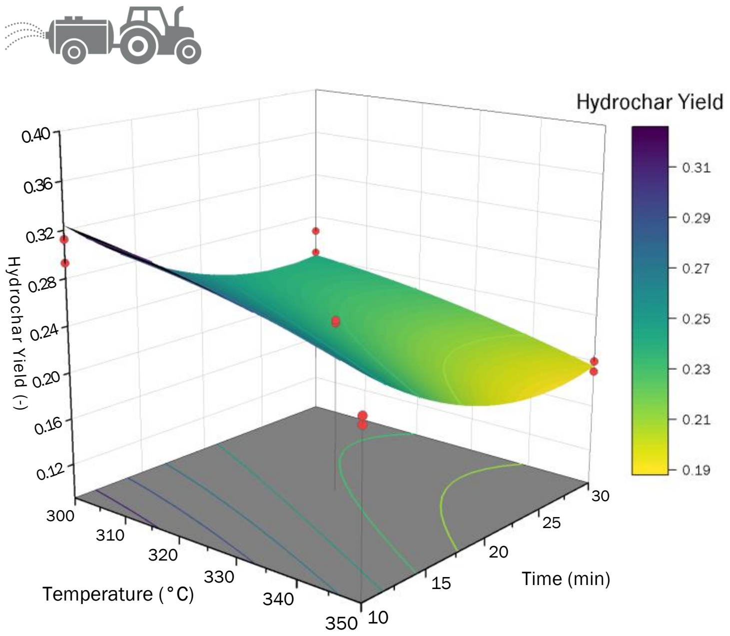


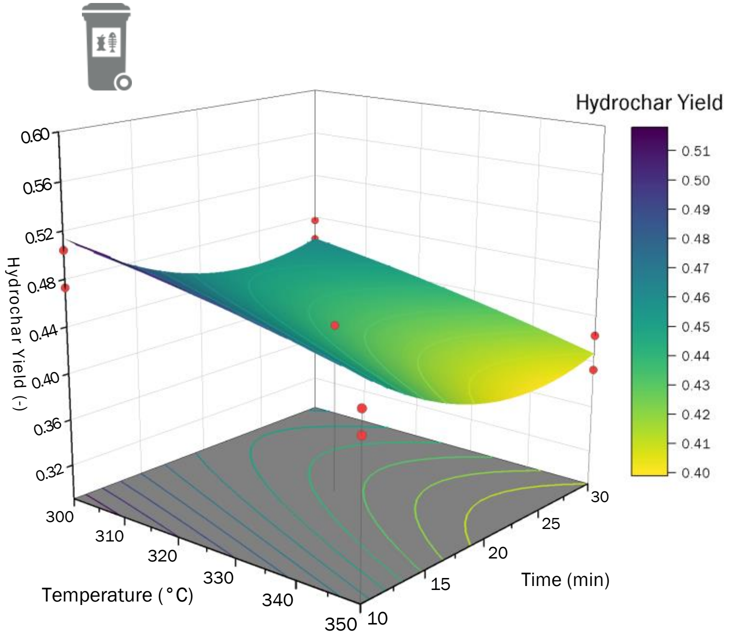


- Biocrude yield increases as reaction severity increases
- Time is generally more significant than temperature

Hydrochar yield

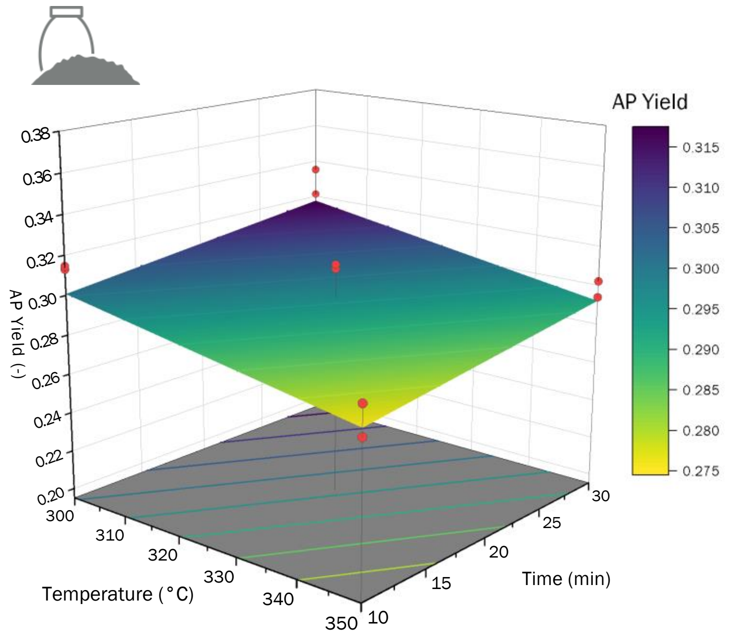


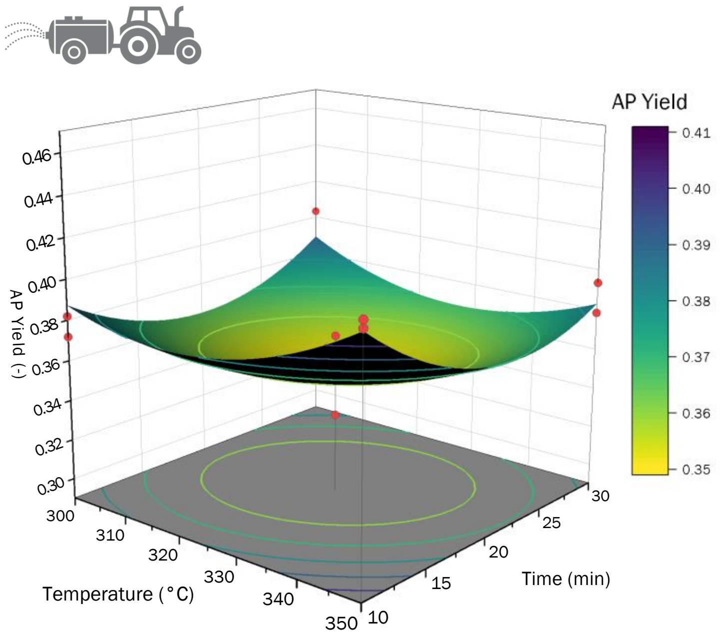


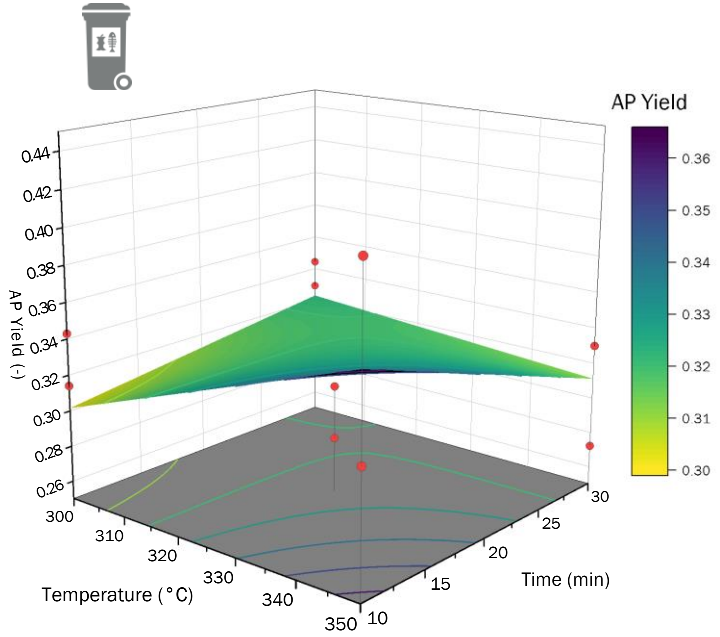


- Harsh conditions decrease solid yield
- Time & temperature significant

Aqueous product yield

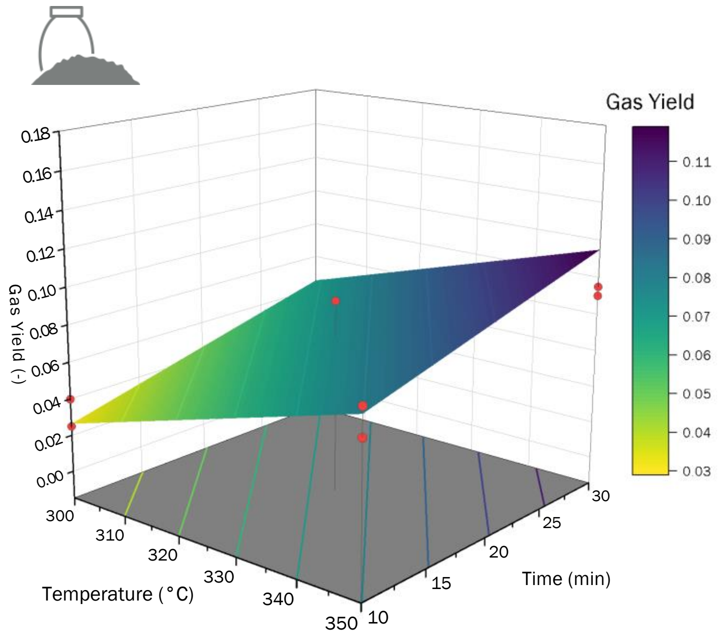


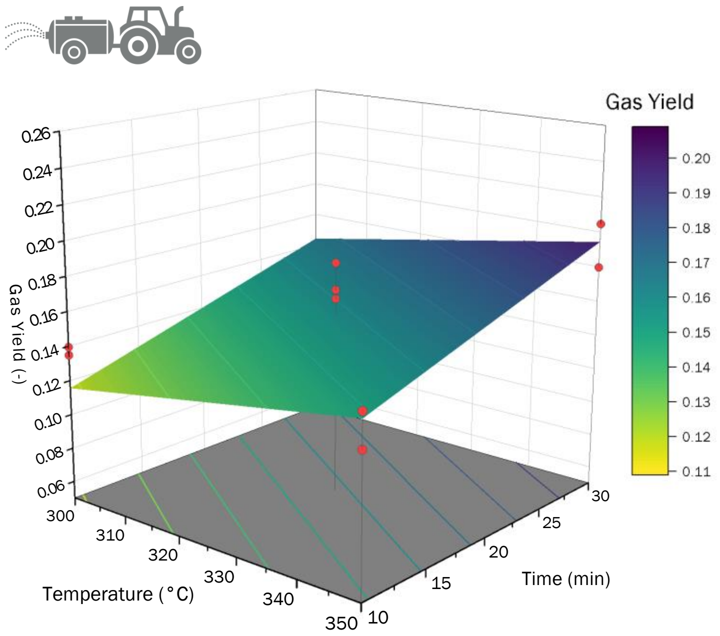


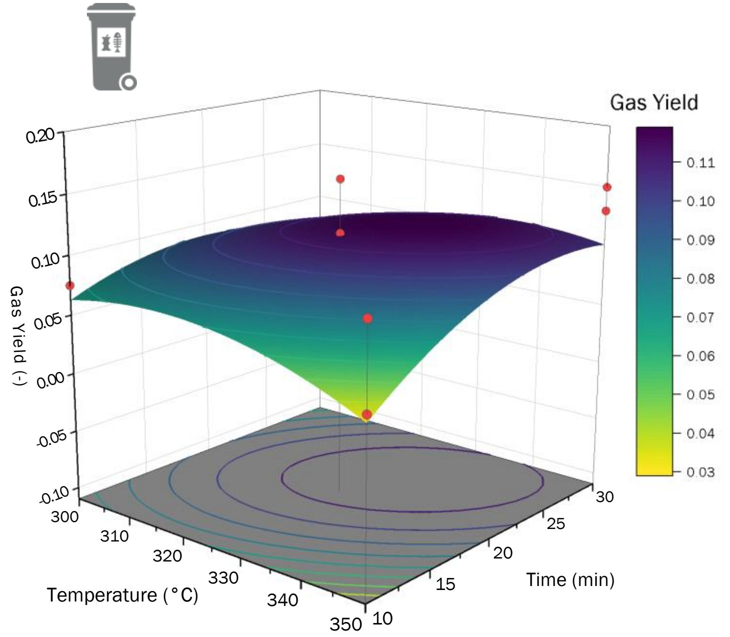


- Conflicting results
- Mathematical determination of aqueous products

Gas yield

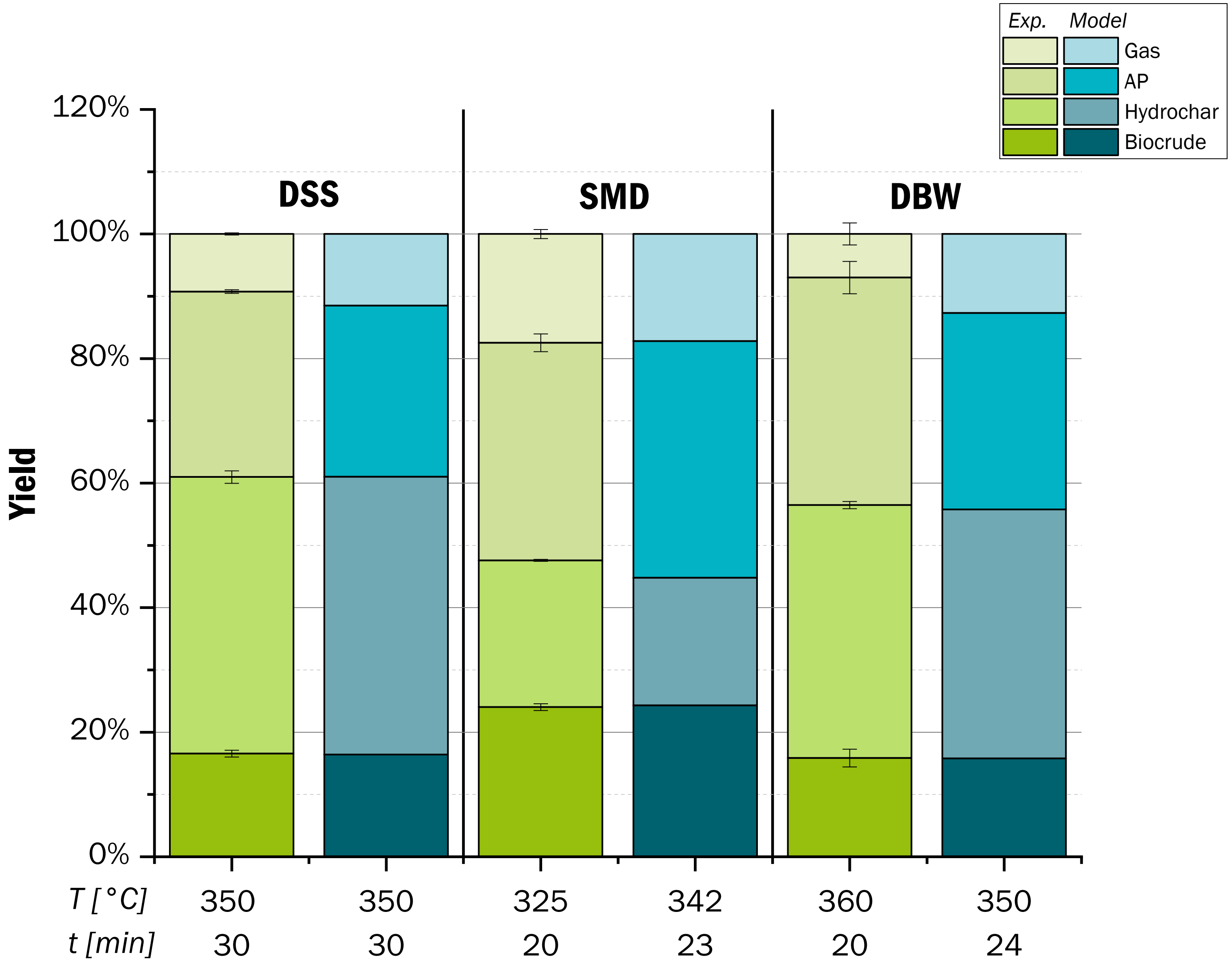




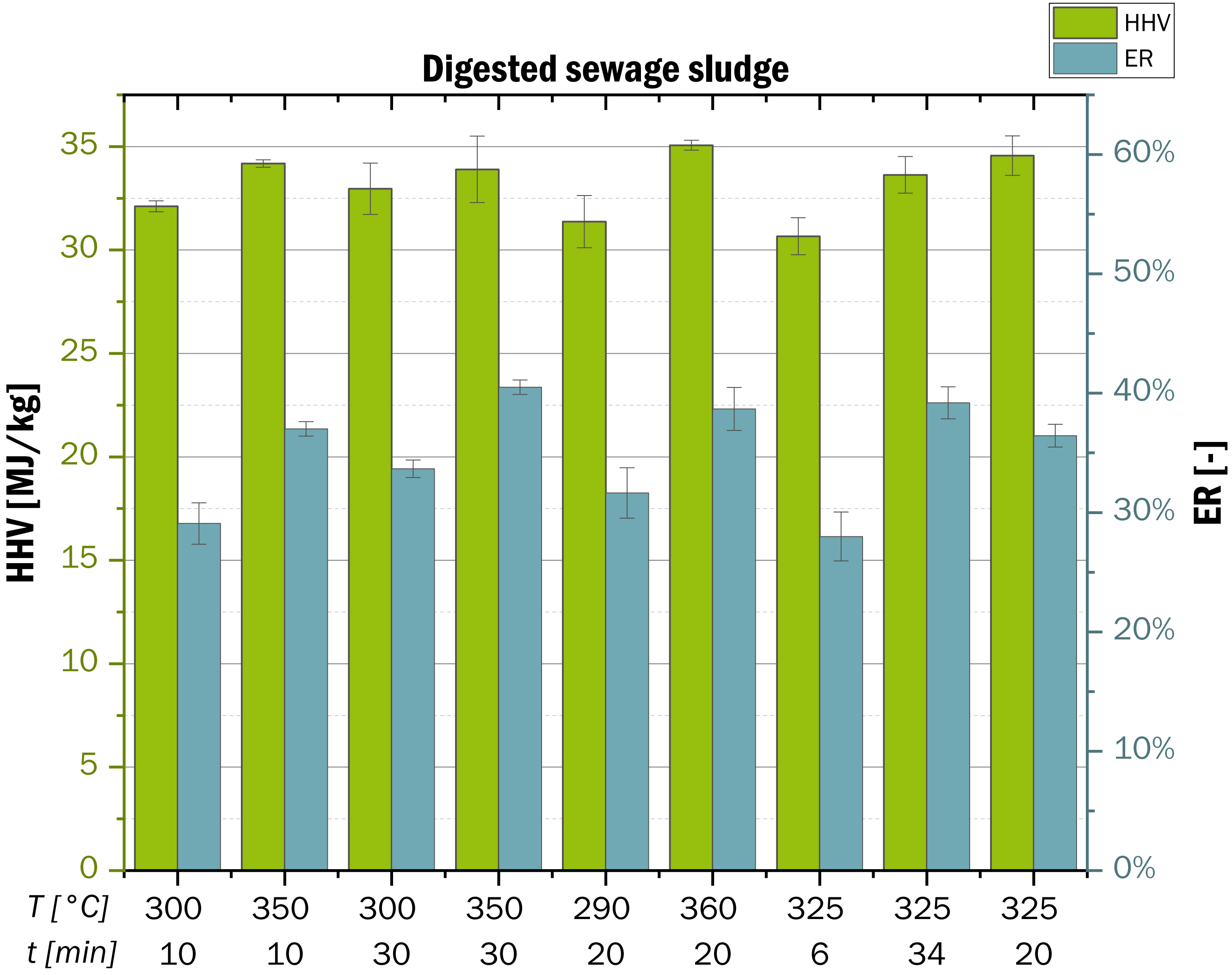


- ➢ Increasing gas yield for increasing reaction severity

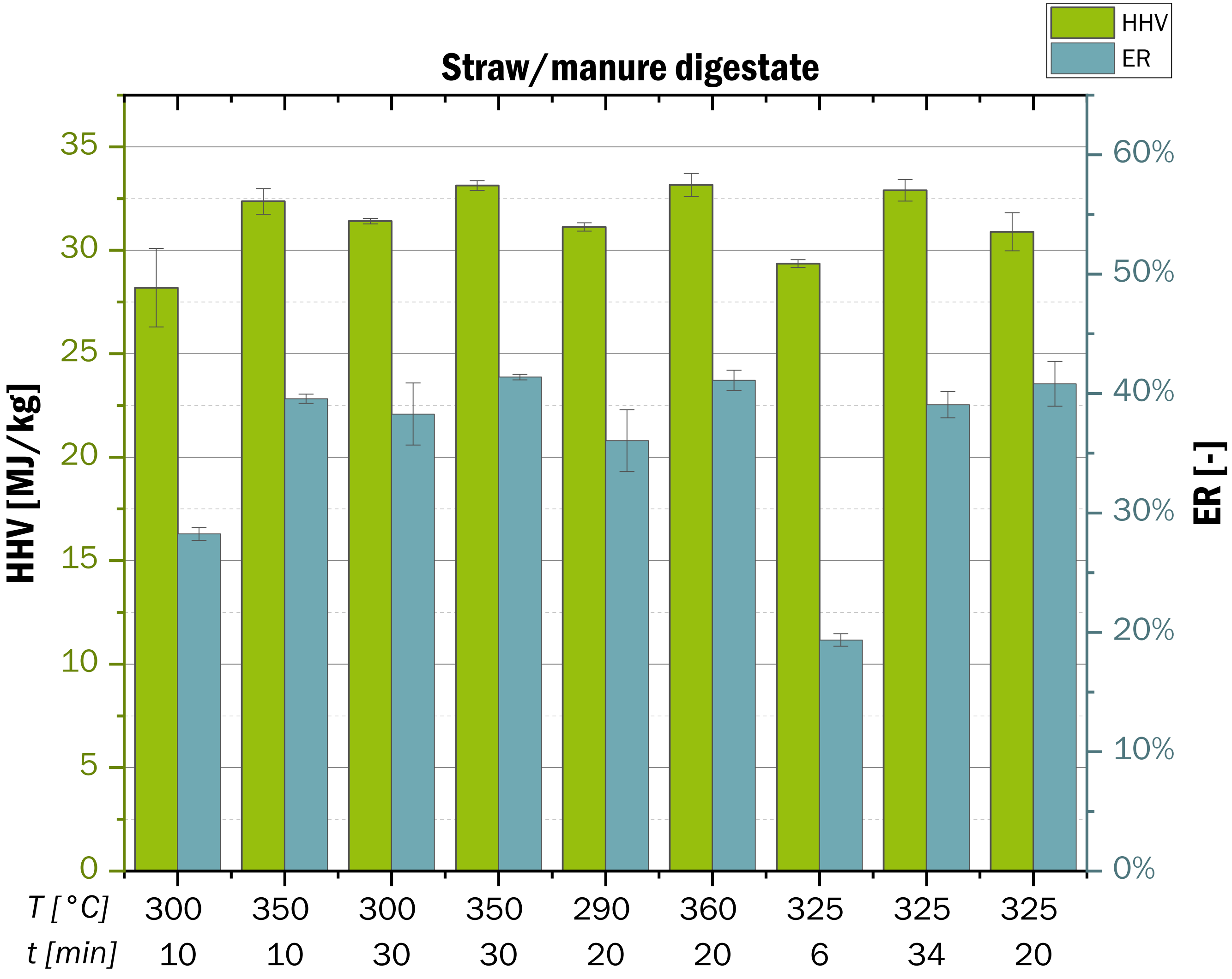
Yield comparison



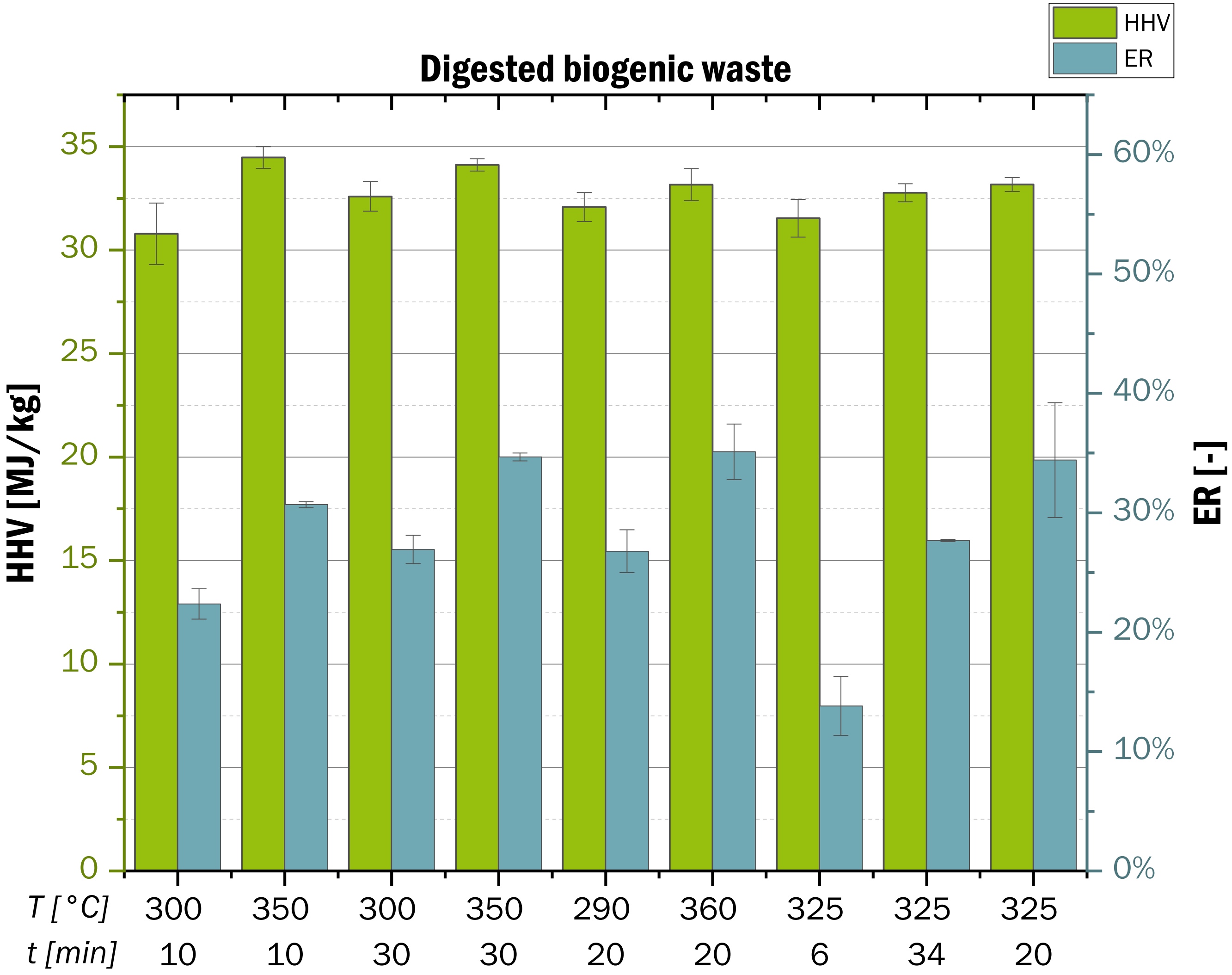
Energy recovery



Energy recovery

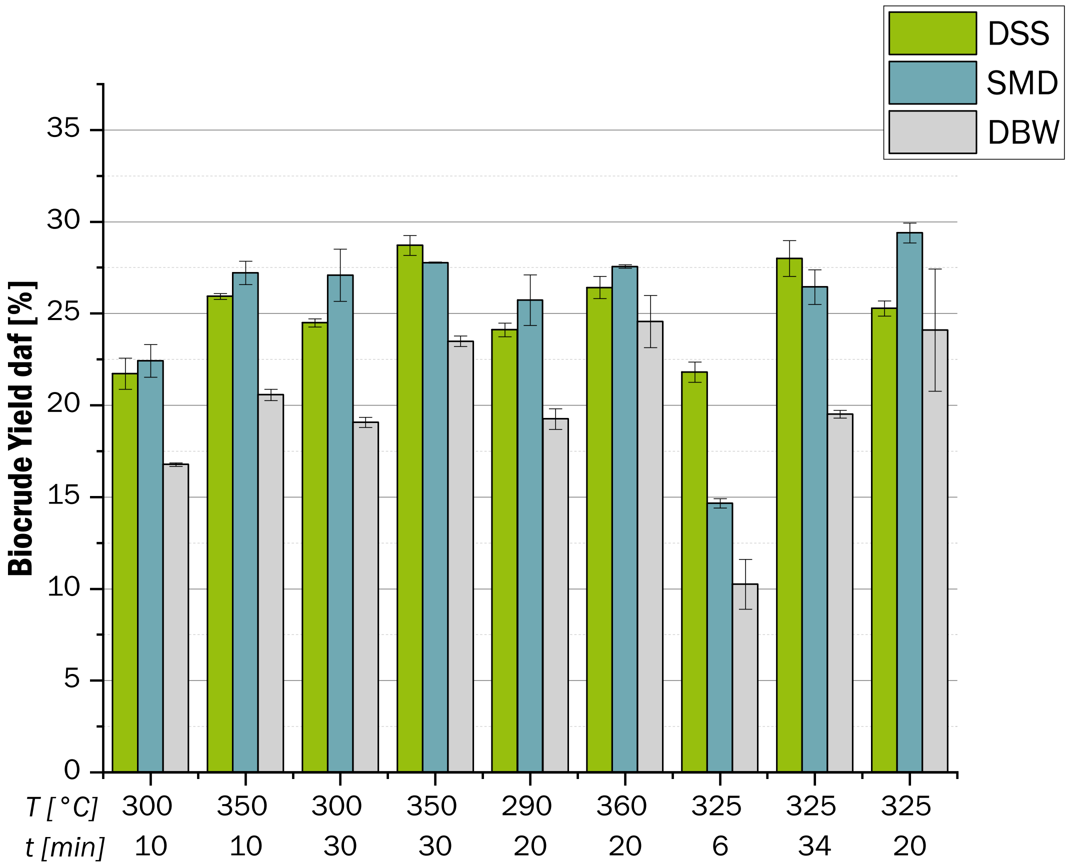


Energy recovery



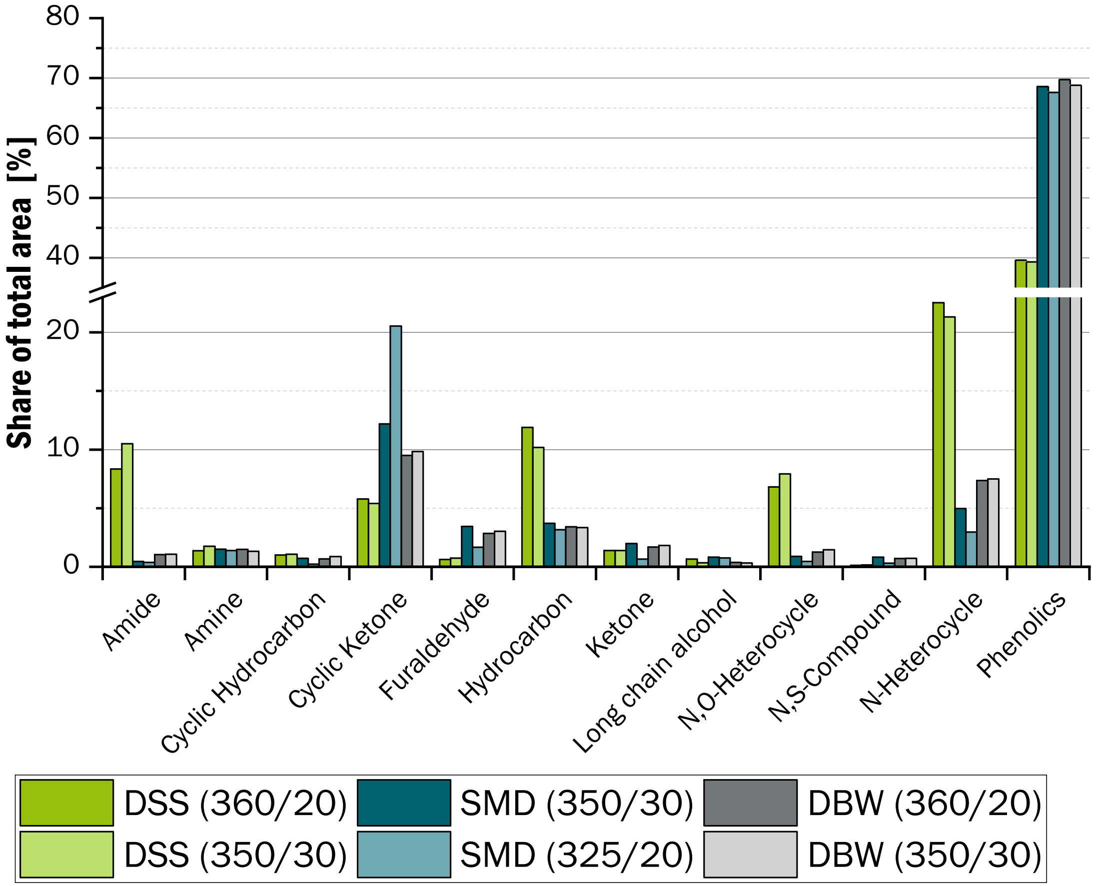
Influence of biochemical composition

- Positive influence of carbohydrate and fat
- Negative influence of lignin
- Linear influence of protein is negative, quadratic term is positive
- Synergy of carbohydrate and protein



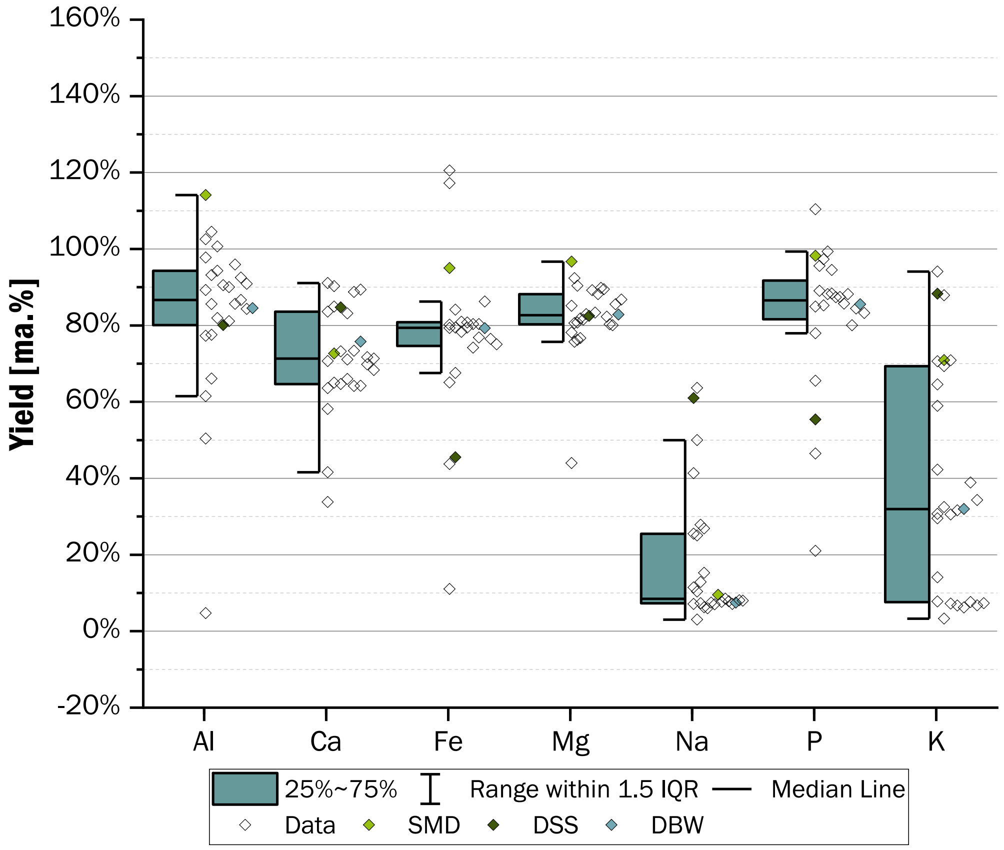
Biocrude composition

- Highest share of N-containing compounds for DSS
- Areas for ketones and phenolics higher for DBW and SMD
- Amount of hydrocarbons follows the trend of fat content in biomass



Nutrient recovery

- Around 60–100 % of Al, Ca, Fe, Mg and P can be found in the solid residue
- Processing conditions not significant towards elemental yield
- Na presumably in the aqueous phase
- Saturation of K in the hydrochar
- Values corresponding to maximum ER for each biomass highlighted by colour



Conclusion

- Biocrude oil can be produced from various digestates in quality and quantity comparable to other waste biomass
- Severe reaction conditions are required for high biocrude yield
- Digestate influences optimum reaction conditions and quality of the biocrude
- Vital nutrients fractionate to the solid residue in substantial amounts and can thus be recovered

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Federal Ministry for Digital and Transport

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