Production of peat substitutes using hydrothermal carbonization

Interreg North-West Europe
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BUFFER+

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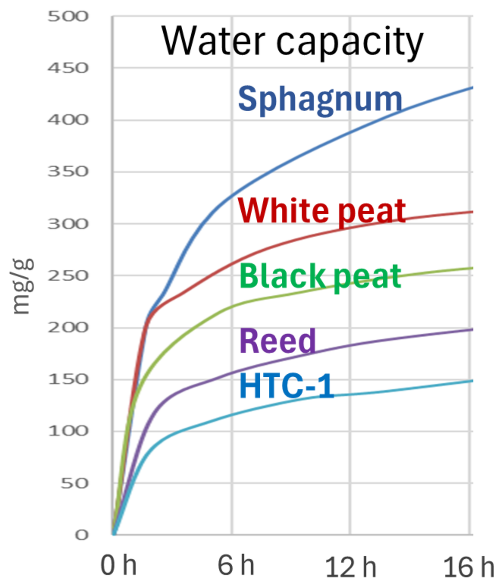
Introduction

The extraction and use of peat causes massive CO2 emissions. Reducing the amount of peat in growing media and hobby soils is therefore an effective contribution to climate protection. As part of the European peatland and climate protection project BUFFER+ (2023-2027), we are developing peat substitutes for growing media. The focus here is on processing fiber-rich plant materials using hydrothermal carbonization (HTC). With this method, moist organic source materials can be carbonized at high temperatures and pressures within a few hours. The aim is to obtain a substrate aggregate that can largely or even completely replace peat.

Results

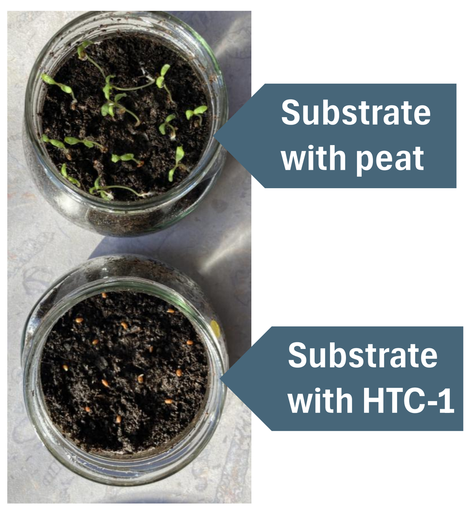
Comparison of chemical parameters

	Peat	Reed	HTC-1
Weight/volume g/l	190	210	200
pH value	4.0	5.4	3.4
Salt (as KCl) g/l	0.62	0.49	1.62
N total mg/l	42	31	32
P_2O_5 mg/l	64	139	107
K_2O mg/l	135	237	312
Humic acids g/kg	63	n.d.	168

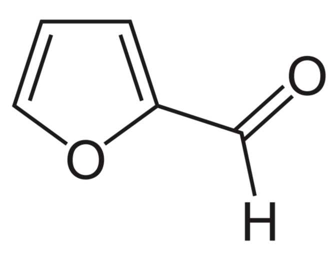


The HTC product-1 (HTC-1) has similar desirable properties to peat: it has a low volume weight, an acidic pH value and is low in nutrients, although the values for phosphorus and potassium are slightly higher than for peat. The higher salt content is probably due to the use of tap water in the HTC. HTC-1 contains significantly more humic acids than peat (n.d., not determined for reed). In addition, HTC-1 has the lowest water capacity of all samples measured.

The furfural problem...



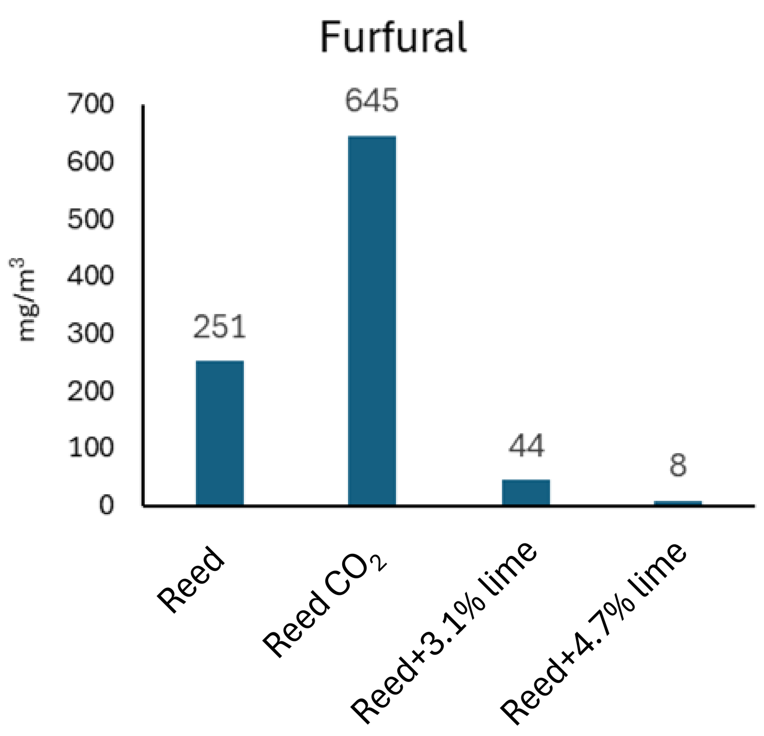
Volatiles in HTC-1	
61%	Furfural
9%	3-Methylbutanal
7%	Acetic acid
5%	2-Methylbutanal
5%	2-Butanone
1%	2,3-Butandione



Structure of furfural

HTC-1 exudes an intense sweet-smoky odor. Cress seeds do not germinate on substrate containing HTC-1, see figure on the left. Gas chromatography-mass spectrometry revealed a high content of volatile furfural in HTC-1. Furfural is a cytotoxin in high concentrations and therefore probably responsible for the inhibition of germination. Acetic acid is also formed during HTC, which causes the low pH value of the HTC product.

...and first solutions



Furfural is formed under acidic conditions and heat mainly by dehydration of pentoses, which are released during the hydrolysis of hemicellulose. Addition of 3.1% and 4.7% lime reduces the formation of furfural by 83% and 97% respectively. The HTC product had a pH value of 5.1. When the gas space above the mixture of reed and water in the reactor was filled with CO_2 instead of air, furfural formation increased. This indicates that oxygen could suppress this process.

Material and Methods

Fiber-rich plant materials

Source materials for the development of peat substitutes should be rich in fiber, available in large quantities, storable and inexpensive. Examples of candidate materials are reed grass (thatch) and hay from nature conservation areas, teek (marine flotsam) and autumn leaves. Some materials have been ensiled or composted to optimize the pH and carbon/nitrogen (C/N) ratio. Shredding and pelleting reduces transportation costs and enables maximum filling of the HTC reactor.

Hydrothermal Carbonisation

The HTC reactor with a capacity of 0.15 m^3 is located at the Lingen wastewater treatment plant. A mixture of 15 kg of reed pellets and 30 l of water was incubated at 180 °C for 4 hours. This created a pressure of approx. 20 bar. The HTC product was dark brown, see figure on the right. A longer incubation or higher temperature produces the lignite-like "hydrochar".

Further methods in brief

Humic acid: gravimetry after basic extraction and acid precipitation; water capacity: weight change at 50 °C in a water-saturated atmosphere; other parameters: Measurements by LUFA Nord-West; gas chromatography-mass spectrometry: Sensenet B.V.

Discussion

Fiber-rich plant materials such as reed straw have some peat-like properties after HTC for 4 h at 180°C and high pressure: The HTC product has a low volume weight and, an acidic pH value. Humic substances give it a brown color and the nutrient content is low. However, the poor water absorption capacity is negative. It remains to be clarified whether this problem can be solved by adjusting the HTC conditions.

Toxins can be produced during the thermal treatment of plant materials. Volatile furfural accumulated in the HTC product, which led to germination inhibition of cress seeds. The addition of 4.7% lime reduced the furfural emission by 97%. The pH value increased only slightly to 5.1 and is therefore still in a favorable range for substrates. The use of composted source materials with a basic pH could further minimize furfural formation. Future experiments will also show whether the addition of oxygen or oxygen-generating chemicals such as hydrogen peroxide can prevent the formation of furfural.

Conclusion

The HTC conditions need to be further optimized in order to develop a suitable peat substitute. More plant trials are needed to test the effects of changed HTC conditions on germination and plant growth. Overall, however, it can be stated that peat substitutes, which are of good quality, inexpensive and available regionally in large quantities, are still in short supply. The work of BUFFER+ on this topic is therefore important and well invested.

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