Hydrothermal carbonization of raw human excreta- effect of process severity on hydrochar properties

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Inadequate sanitation causes health and environmental problems, as well as high economic cost. 3.9 billion people around the world do not have access to safe sanitation facility (UNICEF/WHO, 2021). Hydrothermal carbonization (HTC) might be employed as an alternative and sustainable sanitation solution. HTC is a process in which wet biomass is anaerobically digested in a sealed reactor at 180-250°C for minutes to hours, after which solid hydrochar with high calorific value can potentially be used as an energy source, and nutrient-rich aqueous phase is retained. The severity of the digestion is considered to be affected by the heating temperature and the time of digestion(Funke and Ziegler, 2010). This study aimed at assessing whether the same severities, created under different time and temperature combinations, result in similar hydrochar properties.

Raw human excreta from 22 persons were collected. Using Ruyter's model (Ruyter, 1982) (equation 1.) human excreta were hydrothermally carbonized under 5 different severities, that resulted from varying combinations of digestion temperatures (180, 210, 240 °C) and time (1 min. up to 48 h). Yield, elemental analysis, calorific value, combustion profile, and the resulting gas emissions were analyzed.

Hydrochar calorific value was typically similar ($p>0.05$) between the same severity, although it was achieved by different combinations of temperature and time. It was also noted that typically, calorific value significantly increased ($p<0.05$) with increasing process severity. Yet, under all tested severities the calorific values of the hydrochar were similar to those of subbituminous and bituminous coals ranging from 23.5 to 28.6 MJ/kg (Fig.1). A similar combustion profile was also found for the same severities (Fig. 2). Gas emissions following hydrochar combustion shifted from 34.6% CO_2 at the lower severities down to 11.1% at the higher severity, whereas the percent CH_4 increased from 10.9% at the lower severity up to 44.79% in the higher severity. NO, NH_3, SO_2 and CO were found at about 10%, 6 % and <2% respectively, without significant differences between severities.

It was concluded that it is possible to predict the yield, calorific value and combustion properties of human-excreta hydrochar based on the severity of the HTC. HTC of human-excreta is an attractive sanitation treatment alternative, the hydrochar can be used as energy source with combustion properties that are close to coal, and the emitted gasses should be filtered.

$$f = 50 * t^{0.2} * e^{\frac{-3500}{T}} \quad (1)$$

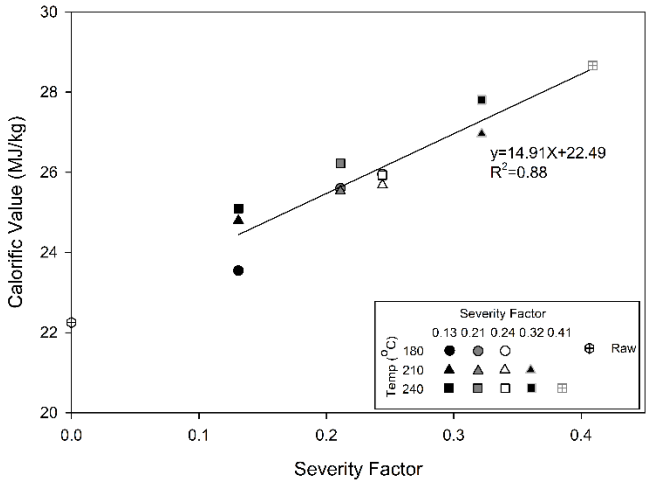

Fig. 1.Hyadrocahr calorific value in different severities

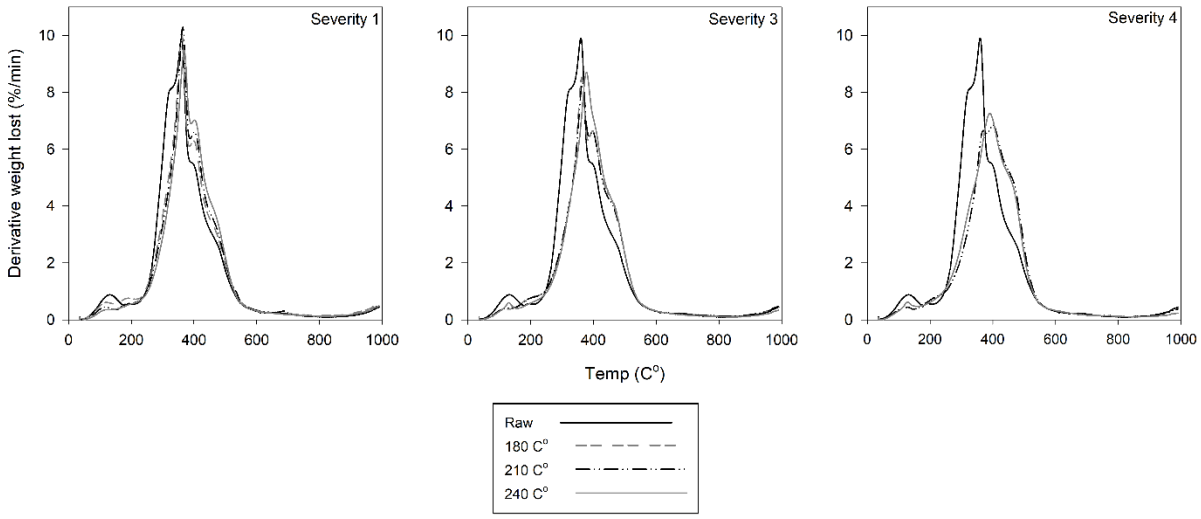

Fig. 2. Hydrochar combustion profile

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