An Improved Slow Pyrolysis Reactor in Dar es Salaam, Tanzania

Research on producing char from biowaste, using an improved vertical small scale slow pyrolysis reactor, shows very promising results with regard to char quality and energy balance. The results showed that feedstock with moisture content higher than 20 % limits the performance. Imanol Zabaleta[1], Benjamin Pfyffer[2], Hassan Mtoro Rajabu[3], Christian Zurbrügg[1]

Introduction

Finding affordable, reliable and sustainable cooking fuel for urban households in low- and middle-income settings is a challenge. At the same time, solid waste management services are often inadequate, and the municipal solid waste – consisting mainly of biodegradable waste – severely impacts the environment. Producing char from biowaste can contribute towards energy needs, as well as provide an appropriate solution for biowaste management. In collaboration with the University of Dar es Salaam, a slow pyrolysis reactor was built in 2015 and has been iteratively improved in the course of this project.

Reactor system

The vertical slow pyrolysis reactor system comprises a furnace, two oil-barrels stacked on top of each other, and a chimney (Figure 1). Seven metal pipes, which are welded together and sealed at one end, are filled with waste, then closed with metal lids and inserted into each barrel. Heat from the furnace fuelled by LPG (HHV=50 MJ/kg) carbonises the waste in the pipes of the bottom barrel, and pyrolysis gas exits the pipe lids and burns, generating additional heat. Excess heat from the bottom barrel heats the upper barrel, drying the feedstock within it. The supply of secondary air is controlled by shutters in the furnace and chimney. This allows the oxygen supply to the furnace and the draft through the reactor to be controlled to better manage heat loss.

The waste is converted to char in the reactor. The aim is that the reactor should be energy efficient and generate high quality char with good burning properties. Its energy efficiency is determined by the energy ratio (ratio of the energy in the generated char to the energy consumed in the furnace), which should be higher than one.

Study variables

Several different biowaste feedstocks were tested, such as sawdust, briquetted sawdust and coffee husks. Experiments were conducted in triplicate with different moisture contents (MC) (6 %, 10 %, 20 % and 40 %) and different particle sizes (PS) (sawdust < 0.5 cm and sawdust briquettes of 3x6 cm and 6x6 cm) to assess their influence on energy ratio, char production and char quality. These experiments were conducted only with the bottom barrel and the assessments were based on: the higher heating values (HHV), char yield, moisture content (MC), volatile solids (VS), fixed carbon (FC) and ash content. The results, i.e. energy performance, were compared to experiments with the two barrel system, which used sawdust as feedstock.

Experiment	MC (%)	N° of barrels	Energy ratio	Char yield (%)	FC yield (%)
A	6.0	1.0	6.0	32.0	27.0
B	10.0	1.0	4.6	31.3	26.0
C	40.0	1.0	0.5	15.0	13.0
D	10.0	2.0	7.0	35.3	30.3

Table 1: Average energy ratios, char yields and fixed-carbon yields of experiments with different MC using sawdust.

Results

All carbonised feedstock types showed very similar and satisfactory high heating values (30.9 ± 0.7 MJ/kg), char yields (30–32 %), proximate analysis (MC: 1.9 ± 1.2 %; VS: 12.1 ± 1.7 %; FC: 82.1 ± 1.3 %) and ash content (5.9 ± 2.9 %). As expected, feedstocks with lower MC achieved higher energy ratios and higher char yields (Table 1). Energy ratios were < 1 when the MC was higher than approximately 20 %. Results also showed that the density of the feedstock, i.e. the mass of feedstock per pipe volume, influences the energy ratio more than PS. In experiments using small PS (sawdust), only 20 kg_{db} (dry basis) could be filled, and the resulting average energy ratio was 3.6. Comparatively, in larger PS experiments with sawdust briquettes, 60 kg_{db} could be filled into one barrel, resulting in an average energy ratio of 5.9. The LPG is used more efficiently by the two barrel system, and results in higher energy ratios, char yields and fixed-carbon yields (B versus D in Table 1).

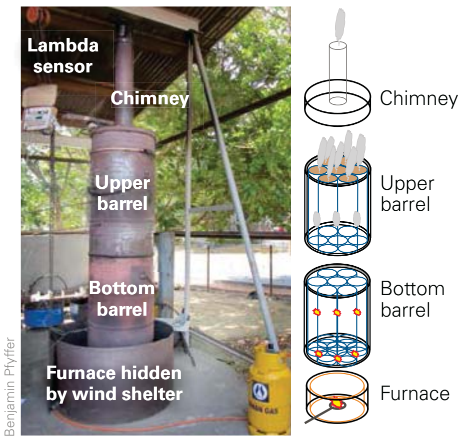

Figure 1: Scheme of vertical experimental slow pyrolysis reactor.

Conclusion

Further research is underway to test the drying capacity of the upper barrel as well as to develop a furnace fuelled by char briquettes. This could limit the need for and costs of external fuel and might allow the process to function on self-produced fuel. Lowering capital investment costs (now 950 USD) and improving the overall financial sustainability of this biowaste treatment method are other research objectives.

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