THE IMPACT OF CO-PYROLYSIS OF PIG DUNG WITH PALM KERNEL SHELL AND EMPTY PLASTIC WATER SACHETS ON ITS BIOCHAR AND ACTIVATED CHARCOAL YIELD

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ABSTRACT

The large volumes of pig dung generated in pig farms in Nigeria constitute environmental problems that need to be addressed through better waste management approaches. This study determined the impact of the co-pyrolysis of pig dung with palm kernel shell (PKS) or empty plastic water sachets (PWS) on its biochar (BC) and activated charcoal (AC) yields. Properly sun-dried weighed pig dung (PDA) and its blends with PKS (2:1 ratio pig dung/palm kernel shell derived activated charcoal (PPA) or with PWS (2.1 ratio) (pig dung/empty plastic sachet derived activated charcoal (PWA) were pyrolysed using a simple clay pot pyrolyser at about 350 - 400^{0}C for 3-4 hours to achieve the complete carbonization and produce biochar. For AC production, the carbonization process was terminated by introduction of water to the hot biochar, thereby achieving physical activation of the chars. The products were cooled and dried at ambient temperature and thereafter weighed to determine the carbon yield and combustible material in percentages. The results showed that the AC yields from PPA< PWA and PDA were 41. 00, 19.67 and 35% respectively with PWA value being significantly lower ($p < 0.05$) than the PPA value but similar to PDA. The biochar (BC) result showed a similar, to PDA. The biochar results showed values standing at 35.56; 16.33 and 29.50% respectively. The AC yields were therefore higher than the BC yields across different materials. The pyrolysis of pig dung and its blends resulted in 59.00 - 83.67 % reductions in their weights with the production of value added products and is therefore recommended to pig farmers as an effective dung management option.

Keywords: Pig dung, biochar, activated charcoal co-pyrolysis, waste management

INTRODUCTION

Pig dung is the solid excretion of pigs and consists of the macerated undigested remains of consumed feed, such as cellulose hemicellulose, lignin and other waste products excreted by the pig (Enyiukwu *et al.,* 2021). Large volumes of pig dung are generated annually in Nigeria from commercial intensive pig producing units and have been reported to be as high as 67, 952 kg per annum from 60 small-scale units in Imo state (Ewuziem, 2021). Majority of the farms practice open dumping, flushing into water bodies, incineration, and recycling as fertilizer on the major systems of waste management (Ewuziem, 2021). These management approaches usually result in waste disposal challenges in form of unsightly environment, foul odour, nuisance flies and complaints from neighbours. The conversion of pig dung to ash by direct combustion (Sahu *et al*., 2016) or by thermo-chemical decomposition into biomass-derived charcoal are however viable options for the effective management of the large volumes of dung generated from intensive pig farms in Nigeria. The thermo-chemical decomposition option under low oxygen environment or pyrolysis could be used to produce either biochar (BC) or activated charcoal (AC) from the pig dung, thus converting the dung into value-added products for different industrial and domestic applications (Okoli, 2021a). The major drawback to the production of BC and AC from pig dung is its relative low density and poor combustion properties, which could be overcome through co-pyrolysis with high density materials, such as palm kernel shell (Ohanaka *et al*., 2021) or plastic materials (Ro *et al*.,

2014) to enhance the process. The pyrolysis of animal manures has also been shown to result in substantial reduction in their volume thereby making their disposal cost-effective management (Okoli, 2021a). This study determined the impact of the co-pyrolysis of pig dung with palm kernel shell or empty plastic water sachets on it biochar and activated charcoal yields.

MATERIALS AND METHODS

Study area:The study was carried out in Imo state, south-eastern, Nigeria, situated in the southern rain forest vegetational zone of Nigeria. It lies between latitude 5.476310, and longitude 7.025853. The area is dominated by plains 200 m above sea level except for elevations associated with the Okigwe uplands and covers an area of 5100 sq.km with a population of about 3.9 million people. The climate is marked by two main seasons: a wet (rainy) season, and a dry season. Most of the mean annual rainfall of about 2152 mm occurs during the wet season that extends from April - October, and is associated with the moisture-laden maritime southwest trade winds from the Atlantic Ocean. Average relative humidity is about 80% with up to 90% occurring during the rainy season. The mean daily maximum air temperature ranges from 28 to 35^0C, while the mean daily minimum ranges from 19 to 24^0C. Agriculture is the major occupation of people of the state.

Collection and preparation of pig dung:This phase of the study was carried out at the Teaching and Research Farm of the Federal University of Technology Owerri (FUTO), Imo State. Freshly voided pig dung were collected from the study farms at the different zones and dried as described in study 2 (plate 1). Palm kernel shell (PKS) was collected from a local palm oil mill and sieved to remove sand and other foreign materials (plate 2). A magnet was also run through the hip to remove metallic objects (Ohanaka, 2016). Thereafter, it was spread on polyethylene sheet to dry further before packing it into a polyethylene bag. Empty plastic water sachets were collected from waste dumps in FUTO and washed with clean water to remove sand and other foreign materials before drying them.

Production of biochar and activated charcoal from pig dung: *Two* types each of biochar and activated charcoal were produced from the pig blends. They included pig dung/PKS-derived biochar and activated charcoal and pig dung/plastic sachet-derived biochar and activated charcoal. For the purpose of co-pyrolysis of pig dung and PKS, the blending ratio was 2:1, also for pig dung and plastic water sachets, the ratio was 2:1, these blending materials served as flame accelerants to enhance the combustion of the pig dung. The physical method of preparation of activated charcoal which involves thermal decomposition or carbonization of the precursors, followed by steam activation as described by Gunamantha and Widana (2018) was employed in this study. The pig dung and its blend in each case was weighed using a HN 289 digital scale (Omron Co., Ltd, Japan) and then transferred into a clay pot of about 2.5 litres size for carbonization. Fire wood and local tripod stand was used as the source of heat for the carbonization process. The carbonization temperature was adjusted to range between 300 and 400^0C as earlier reported by Gunamatha and Widana (2018). Once the fire was ignited, the clay pot was covered with its lid and the set-up observed for appearance of black smoke from the small crevices of the lid for about 20 minutes. This black smoke was subsequently replaced by white smoke, which was a sign that the biomass precursors were burnt. Thereafter, the pyrolysis process was allowed to continue for about 3 – 5 hours until no more smoke was being produced. At this point the lid was opened, and water was introduced quickly to stop-cool the carbonization process and also achieve the activation process. Thereafter, the pot was closed again, brought down from the fire and left to cool down completely after which the activated charcoal or biochar product was taken out, rinsed with cold water to remove ash and any remaining debris and dried. For the biochar production, the activation step was avoided. The carbonized material was poured on a cement floor and allowed to cool down completely. The dried biochar and activated charcoal were each transferred to a wooden mortar and ground with pistol into fine powder and stored in air tight plastic containers for subsequent characterization, the char yield percentage volatile matter were determined.

***Data analysis*:**Data generated from the different treatments were subjected to one-way analysis of variance (ANOVA), and where significant difference are observed ($p<0.05$), means was separated using the Least Significant Difference (LSD) method (SAS, 2001). The mean treatment value for the biochar and activated charcoal were also compared with the aid of the student t Test statistics ($p <0.05$) (SAS, 2001).

RESULTS AND DISCUSSION

The activated charcoal (AC) and biochar (BC) yields from pig dung (PD) and its palm kernel shell (PKS), and plastic water sachet (PWS) blends are shown in tables 1 and 2. Both the activated charcoal, and biochar yields of the PKS blended dung (PPA and pig dung/palm kernel shell derived biochar (PPB) respectively) were significantly higher ($p < 0.05$) than the PWS blended ones, but similar to the yields from raw pig dung (PDA and pig dung alone derived biochar (PDB) respectively). Correspondingly, the PWA and pig dung/ empty plastic sachet derived biochar (PWB) recorded significantly higher ($p < 0.05$) percentage combustion material than PPA and PPB. The AC yield was also generally higher than the BC yields across different sample types. During the carbonization process, the carbon materials in the biomass or feedstock are rearranged into their most stable structure, which is a graphite plate. The specific arrangements of angles, spacing and gaps within the chars however vary according to the type of raw materials used in the preparation, therefore blending pig dung with PKS or plastic sachet is expected to confer varied characteristics to the end products (Okoli, 2021a). Ohanaka *et al* (2021) reported an AC yield of 46.54 % from the co-pyrolysis of pig dung, PKS and bamboo sticks using a simple pyrolysis process and which is slightly higher than the value obtained in this study, probably because of the contribution from the bamboo sticks. Eucalyptus saw dust was reported to yield a much higher (42.50 %) biochar at 380^0C pyrolysis temperature, while Lima and Marshall (2007) recorded a much lower activated carbon yield range of 17.60 – 25.30 % and attributed the variations to the effects of different flow rates, activation time and temperature. The significantly lower AC and BC yields from the PWS blended dung could be attributed to the higher energy supply (7,887.20 – 10,994.28 Kcal/kg) from the plastic material (Ro *et al*., 2014) which is about thrice the energy value range of 2754.30 – 3163.95 Kcal/kg recorded in the pig dung used in this study (Edo *et al*., 2021). Ro *et al* (2014) reported a biochar yield of 28 % from the mixed feed stock (2:1 plastic + pig manure) which is lower than the 39 % biochar yield from pig manure alone. Co-pyrolysis of pine biomass and tire wastes significantly increased the carbon yield, while co-pyrolysis with plastic wastes had no effects. These invariably result in higher peak decomposition temperature of 718 to 741 K (Ro *et al*., 2014), and therefore improves the carbonization efficiency and lowers the carbon yield. The low BC than AC yields are probably due to the extended carbonization time required for the natural cooling of the biochars, while the process was terminated by the introduction of steam during the physical activation process to produce the AC (Okoli, 2021b)

Table 1: Yields of activated charcoal from pig dung and its blends with PKS and PWS

Parameters	PPA	PWA	PDA	SEM
Activated charcoal				
Initial weight (kg)	2.00	3.00	2.00	
Final weight (kg)	0.82	0.59	0.70	
Combustible material (kg)	1.18	2.41	1.30	
Percentage activation charcoal yield (%)	41.00^{a}	19.67^{b}	35.00^{ab}	6.35
Percentage combustible material	59.00^{b}	80.33^{a}	65.00^{ab}	6.35

$^{a, b}$ Means with different superscript in the same row are significantly different ($p <0.05$)

Legend: PPA = 2:1 ratio of pig dung and palm kernel shell
PWA = 2:1 ration of pig dung and plastic water sachet, PDA = pig dung activated charcoal

Table 2: Yields of biochar from pig dung and its blends with PKS and PWS

	Biochar			
Parameters	PPB	PWB	PDB	SEM
Initial weight (kg)	2.00	3.00	2.00	
Final weight (kg)	0.71	0.49	0.59	
Combustible material (kg)	1.29	2.51	1.41	
Biochar yield (%)	35.50[a]	16.33[b]	29.50[ab]	5.68
Combustible material (%)	64.50[b]	83.67[a]	70.50[ab]	5.66

[a, b,] Means with different superscripts in the same row are significantly different ($p < 0.05$)
Legend: PPB = 2:1 ratio of pig dung and palm kernel shell
PWB = 2:1 ration of pig dung and plastic water sachet
PDB = Pig dung activated charcoal and biochar

CONCLUSIONS AND RECOMMENDATION

Waste management is one of the major challenges in livestock enterprise in Nigeria, large volumes of pig dung are generated annually in Nigeria from commercial intensive pig producing units and have been reported to be as high as 67,952 kg per annum from small-scale units in Imo state. The thermo-chemical decomposition option under low oxygen environment or pyrolysis could be used to produce either biochar (BC) or activated charcoal (AC) from the pig dung thus converting the dung into value added products for different industrial and domestic applications. It is recommended that farmers, small-scale farms in the state process their pig into biochar or activated charcoal since this approach reduces the weight of the dung by more than 65%, thus making it easier to handle and also a value added product.

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