# Effect of Chicken Type and Reactor Temperature on Biofuel Yields from Pyrolysis of Poultry Litter

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**Abstract**

Efficient management of poultry litter resulting from the ever growing agricultural industry is key to saving the global environment. In this study, effect of chicken type and reactor temperature on biofuel yields from pyrolysis of poultry litter has been studied. Samples of fresh droppings of broiler and layer chickens were collected from the poultry farm of Ladoke Akintola University of Technology, Ogbomoso, South-Western Nigeria. The samples were sun dried for two days and afterwards oven-dried at a temperature of 105 $^{o}$C for 10 minutes. Samples of 40 g each were pyrolyzed at four different reactor temperatures (300, 400, 500 and 600 $^{o}$C) for 15 minutes. The yield of pyro-oil and pyro-gas from the litter of the two chicken types increased with reactor temperature while char yield decreased with it. Pyro-oil yield from broiler litter was higher than that from layer litter at all temperatures while pyro-gas yield from layer litter was higher than that from broiler litter at all the conditions studied. The highest yield of pyro-oil (65.10% at 600 $^{o}$C) was obtained from broiler litter while the highest yields of char (42.12% at 300 $^{o}$C) and pyro-gas (25.7% at 600 $^{o}$C) were recorded for layer litter. The presence of alkali metals in different proportions in broiler and layer litter was identified to have influenced pyrolysis secondary reactions. Cellulose, hemicellulose and lignin may also be in different percentages in the two types of chicken litter.

**Keywords:** Poultry litter, pyrolysis, biofuels, global environment

## 1. Introduction

Depletion of fossil fuel resources, emission of greenhouse gases and ever increasing energy demand have brought about global concerns regarding the use of fossil fuels (Hirosaka et al., 2008). Energy experts are worried about energy supply for sustainable development. Sequel to these, alternatives to conventional fuels are being sought (Abdulrahman et al., 2016). Biomass has continued to attract interest as a viable alternative (Jahirul et al., 2012). Energy crops, agricultural residues, solid and municipal wastes have been identified as potential biomass feedstock for biofuels production through biochemical and thermochemical processes (Parveen et al., 2011). Thermochemical processes are used quite often because they are capable of giving solid, liquid and gaseous biofuels simultaneously (Di Blasi et al., 1999; ,Babu and Chaurasia, 2004).

In Nigeria, agricultural industry, especially poultry farming, is fast growing (Adeoye et al., 2015; Olumayowa and Abiodun, 2011). With this growth comes the challenge of disposing a large volume of poultry litter being generated. It has been reported that Nigeria generated 932.5 metric tons of poultry litter in 2012 (Adewumi et al., 2011). Common methods for poultry litter disposal include direct burning, burying, dumping in remote areas or being used as organic manure, and anaerobic generation of biogas (Kim et al., 2009). Many of these conventional disposal methods cause environmental and water pollution. Hence the need to devise other methods of disposing poultry litter while at the same time generate value added products and biofuels (Ezeonu et al., 2014).

Although many researchers have used pyrolysis (one of the thermochemical processes) to convert a number of biomass feedstock into biofuels (Scotts et al., 1988; Piskorz et al., 1998; Horne and Williams, 1996; Antal, 1983; Scotts and Piskorz, 1982; Di Blasi et al., 2001; Di Blasi and Branca, 2001; Lu et al., 2010; Okekunle et al., 2011; Okekunle et al., 2015, Okekunle et al., 2016), poultry manure is rarely used. Some researchers have worked on pyrolytic conversion of poultry litter (Baniasadi et al., 2016; Mante and Agblevor, 2010). In all of these, the effect of chicken type on biofuels yield spectra from pyrolysis of poultry litter has not been investigated. Therefore, in this work, the effect of chicken type and temperature on biofuels yield spectra from poultry litter pyrolysis is being investigated.

## 2. Materials and Methods

### 2.1 Sample procurement and processing

Fresh droppings of broiler and layer chickens were collected from the poultry farm of Ladoke Akintola University of Technology, Ogbomoso, South-Western Nigeria. Fresh droppings were procured to avoid contamination with other materials. The samples were sun dried for two days and then subsequently oven-dried at a temperature of 105 $^{o}$C for 10 minutes in Food Science and Engineering Laboratory of Ladoke Akintola University of Technology, Nigeria.

## 2.2 Experimental setup

Figure 1 shows the exploded view of the fixed bed reactor used for the pyrolysis process. The reactor comprises of a cylindrical retort with a bottle neck to enhance a firm closure of the lid, products collector pipe, tar collectors and a pyro-gas receiver. Carrier gas (nitrogen) was used to purge the reactor and sweep the volatiles from the reactor. The collector pipe channeled the volatiles stream into the tar collectors which were immersed in an ice- bath (tar trapper) for condensation of condensable gases and non-condensable gases passed on to the gas collector. Staged tar trappers were employed to ensure that all tarry compounds were condensed in the tar collectors.

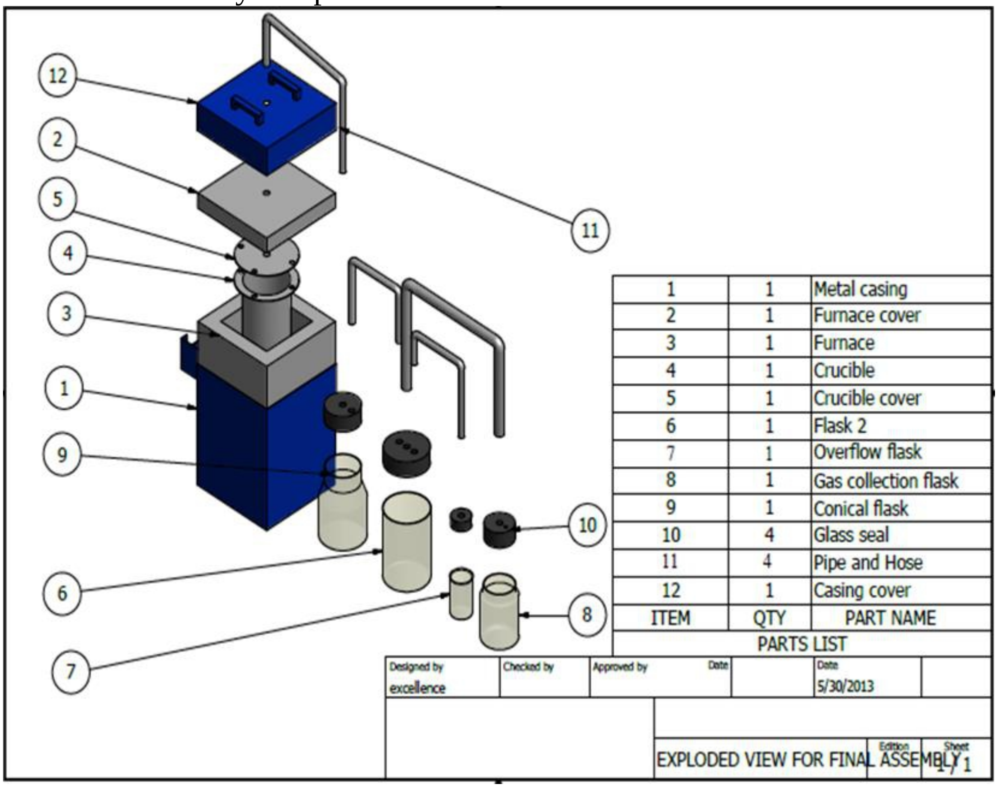


**Figure 1**: Exploded view of the pyrolysis unit

In each experimental run, 40 g of each sample of broiler and layer litter was introduced into the crucible, fastened with bolts and nuts, inserted into the furnace and covered. The weighed samples were pyrolysed at varying temperatures of 300, 400, 500 and 600 $^{o}$C for 15 minutes. The yield of char and tar (pyro-oil) were obtained and expressed as percentage of the initial weight of the sample. The yield of gas was obtained by conservation of mass.

## 3. Results and Discussion

### 3.1 Char yield

Figure 2 shows the yield of char from pyrolysis of broiler and layer litter at different temperatures. From the figure, it can be seen that layer litter char yield at 300 °C was higher than that of broiler litter. As the process temperature increased however, up to 500 °C, char yield from both chicken types were within the same range, with broiler litter char yield having higher values. At 600 °C, the difference between char yields from the litter of both chicken types was insignificant. This trend in char yield may be due to different proportions of alkali metals and lignin in their droppings. Alkali metals are reported to catalyze char formation (DeGroot and Shafizadeh, 1984) and lignin has been identified as the main source of char formation (Yang et al., 2006). For both types of chicken litter, the yield of char decreased with increase in pyrolysis temperature. This is in agreement with the pyrolysis convention. Char yield ranges for broiler and layer litter were 20.95 - 30.82% and 21.62 - 42.12%, respectively.

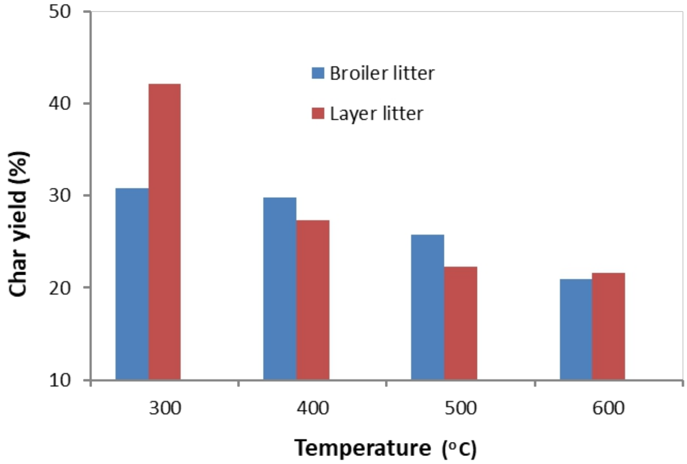


**Figure 2:** Char yield from broiler and layer litter at different temperatures

### 3.2 Pyro-oil yield

Figure 3 shows pyro-oil yield from broiler and layer litter at different temperatures. It can be seen that pyro-oil yields obtained at all temperatures from broiler litter were higher than those of layer litter. This suggests a higher presence of cellulose in broiler litter than layer litter. Cellulose has been identified as the main source of pyro-oil in biomass pyrolysis (Burhenne et al., 2013). Figure 3 also reveals that pyro-oil yield slightly increased with temperature, the phenomenon contrary to pyrolysis convention, especially above 500 °C. This trend may also be connected to the presence of metals in chicken feeds, which, mostly likely, has altered the sequence of events during secondary reactions in favour of pyro-oil yield. Further studies will be needed to fully unravel this trend. Pyro-oil yield ranges for broiler and layer litter were 59.76 – 65.10% and 41.34 – 54.05%, respectively.

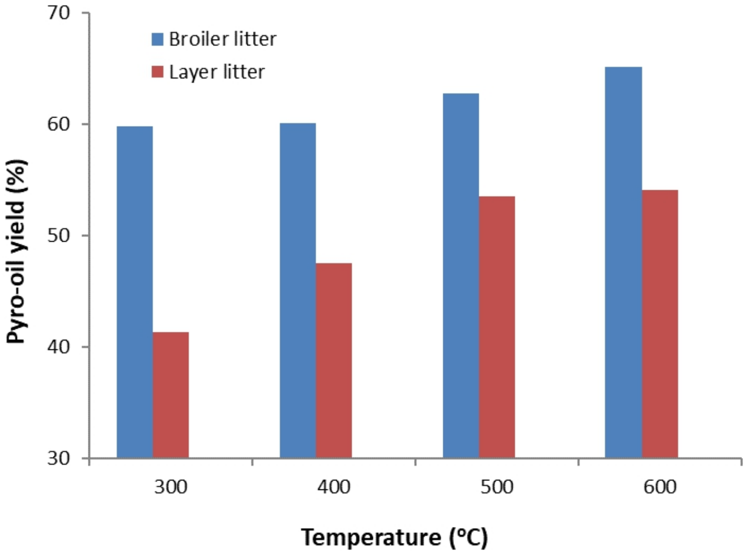


**Figure 3:** Pyro-oil yield from broiler and layer litter at different temperatures

### 3.3 Pyro-gas yield

Figure 4 shows the gas yield obtained at different pyrolysis temperatures for broiler and layer litter. From the figure, gas yields from layer litter at all temperatures were much higher than those from broiler litter. This suggests a higher percentage of hemicellulose in layer litter. Hemicellulose and cellulose have been linked with high yield of pyro-gas (Burhenne et al., 2013). Pyro-gas yield ranges for broiler and layer litter were 9.42 – 13.95% and 16.54 – 25.7%, respectively.

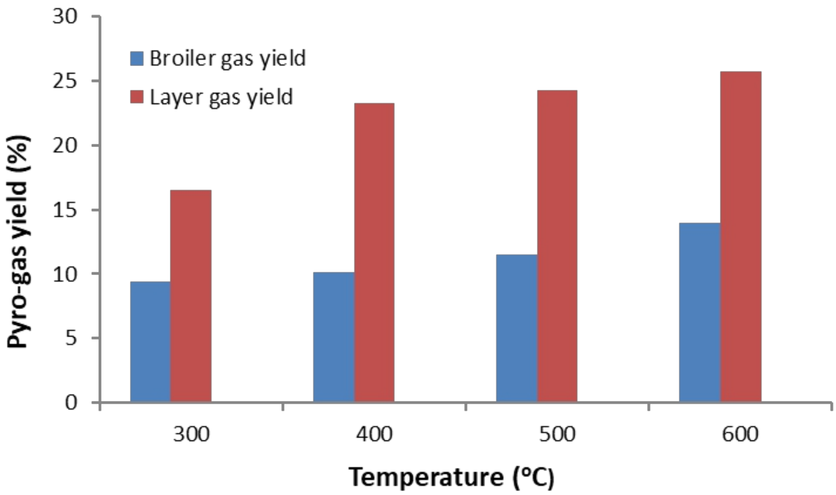


**Figure 4:** Pyro-gas yield from broiler and layer litter at different temperatures

## 4. Conclusion

Effect of chicken type and reactor temperature on the yield of biofuels from poultry litter pyrolysis in a fixed bed reactor has been studied. Findings revealed that broiler litter gave the highest yield of pyro-oil (65.10% at 600 $^{o}$C) while layer litter gave the highest yields of char (42.12% at 300 $^{o}$C) and pyro-gas (25.7% at 600 $^{o}$C). The presence of alkali metals in poultry feed was identified to have interfered with pyrolysis secondary reactions. Results also suggest that the percentage compositions of cellulose, hemicellulose and lignin in broiler and layer droppings may not be the same.

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