Air-Steam Gasification of Poultry Litter in a Bubbling Fluidised Bed Reactor

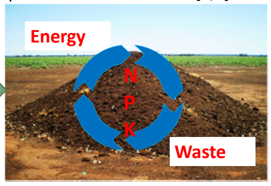
Daya Shankar Pandey[1,2*], Giannis Katsaros[2], Sanna Toumi[3], Savvas A Tassou[2]

*Daya.Pandey@anglia.ac.uk

[1] Department of Engineering and the Built Environment, Anglia Ruskin University, UK.
[2] RCUK Centre for Sustainable Energy Use in Food Chains (CSEF), Brunel University London, UK
[3] VTT Technical Research Centre of Finland.

Production of global livestock is increasing rapidly and abundantly to cater the demand of animal protein by a growing world's population. An intensive growth of livestock production systems have led to major concerns about human health and environmental issues.

1,200 million broiler chickens in EU/year (UK> 80 million).
140 to 456k tonnes of litter in UK/year with total energy potential of 1.2 to 6.5 PJ [1,3].



Equivalence Ratio (ER) the ratio between the O_2 content in the oxidant supply and that required for complete stoichiometric combustion

Combustion	Gasification	Pyrolysis
ER >1	ER = 0.1-0.4	ER = 0

Increasing Oxygen:Fuel

Proximate analysis (wt. %, Dry basis)

	Poultry litter
Moisture (ar)	9.71
Volatile matter	69.6
Ash	14.3
Fixed carbon*	16.1
Ultimate analysis (wt. % dry basis)	
Carbon	42.72
Hydrogen	5.51
Nitrogen	3.93
Sulphur	0.64
Chlorine	0.29
Oxygen*	32.59
LHV (MJ/kg)	16.78

*Calculated by difference

➢ The EU Commission have unanimously adopted EU Regulations (1069/2009) for the use of poultry litter as a fuel for energy on farm.

Key Gasification Reaction:

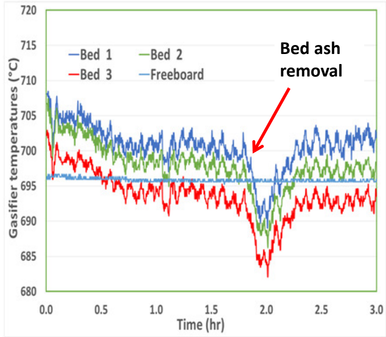
$C_{(s)} + CO_2 \leftrightarrow 2CO$ $\quad CH_4 + H_2O \leftrightarrow CO + 3H_2$

$C_{(s)} + H_2O \leftrightarrow CO + H_2$ $\quad CO + H_2O \leftrightarrow CO_2 + H_2$

$C_{(s)} + 2H_2 \leftrightarrow CH_4$

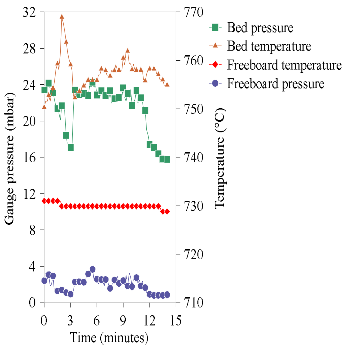
Experimental Conditions

Experimental variables	Range
Temperature	700 ≤ Tg ≤ 750 °C
Equivalence ratio	0.30
Feeding rate (kg/hr)	1.82



Bed and freeboard temperature during the gasification of poultry litter at 700°C, ER 0.30

Challenges Associated with Poultry Litter Gasification



➢The presence of inorganic elements such as phosphorous, potassium and magnesium in poultry litter ash formed compounds with lower melting temperature, causing agglomeration [2, 3].

➢Considering the high amount of moisture and ash make it difficult to gasify without continuous removal of ash.

Aim

➢The objective of the study was to investigate the technical feasibility of air steam gasification process of poultry litter with focus on energy recovery using dolomite as a bed material

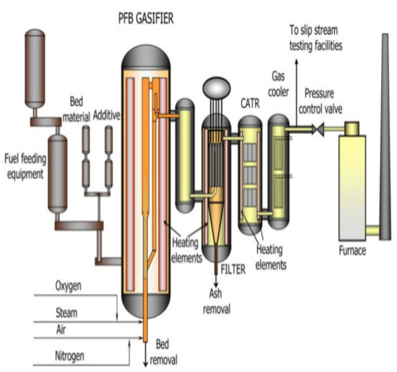
➢Investigate the effect of process parameters on composition of product gas and quality of product gas

➢Developing optimum condition for thermo-chemical conversion process using Aspen Plus

Bubbling Fluidised Bed Gasification System at VTT Finland

➢Biomass is fed through a system of screw augers into the fluidised bed reactor.

➢The fluidised bed reactor has height of 2560 mm with an internal diameter 100 mm (bed section) and 150 mm (freeboard) and is heated to the reaction temperature by electrical furnaces. The gas generated in the reactor passes through cyclones where ash and elutriated solids are collected. The gas was cooled in a heat exchanger and any tar was collected in a tar trap. The residual fly ash was collected in filters which are located before the mass flow meter. The composition of the product gas was analysed by means of micro-GC.



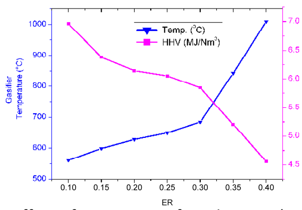
A Bubbling fluidised bed gasification system at VTT Finland. The fuel feeding point was situated 101mm above the grate. The fluidising medium (air and steam) was preheating to 320 ºC before being fed into the reactor. Dolomite was used as a bed material.

Results

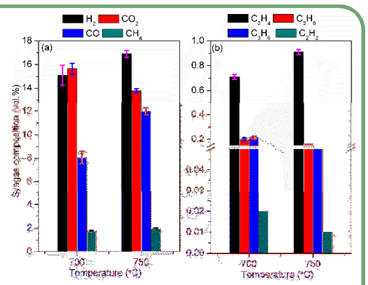
➢The effect of the gasifier temperature is illustrated (ER = 0.30). With an increase of gasifier temperature, H_2 and CO yield increased while CO_2 decreased due to improved Boudouard reaction, char conversion, char-steam and thermal cracking of tar reactions.

Mass Balance Closure, out/in

Elements	700 °C	750 °C
Carbon	0.96	1.03
Hydrogen	1.0	1.0
Nitrogen	1.0	1.0
Oxygen	1.0	0.96
Ash	0.34	0.97



Effect of ER on HHV of product gas (T_{auto})



Effect of temperature on product gas compositions

Tar, H_2O, NH_3 and H_2S concentration in product gas

Composition	700 °C	750 °C
Total Tar, mg/Nm³ (dry)	7977.6	5322.8
Identified Tar, mg/Nm³	4888.6	3882.4
Benzene, mg/Nm³	2465.3	2610.2
Naphthalene, mg/Nm³	379.8	455.2
Heavier Tar, mg/Nm³	1566.4	1062.6
H_2O, g/Nm³ (dry gas)	166.5	121.9
NH_3 concentration, g/Nm³	19.5	18.6
H_2S concentration, ppmv	180	60

Conclusions

➢The product gas from poultry litter can be used (in direct combustion) for on-form heat and electricity production. However, gas cleaning is imperative before it can be used in IC Engines.

➢ It can be concluded that the optimum condition (from model) of poultry litter gasifier should be in the temperature rage of 700-800 °C and ER of 0.25-0.30/0.30-0.35 for auto-thermal.

➢ In order to counteract fuel-ash induced in-bed agglomeration additives need to be utilised, with continuous ash removal or explore the possibility of co-gasification of poultry litter.

Simulation using a Pseudo Equilibrium Approach

➢ Modelling the gasification process is based on Aspen Plus process simulator. PR-BM equation of state was selected as the property method for the model.

➢ The steam reforming reaction is not occurring .($CH_4 + H_2O \leftrightarrow CO + 3H_2$)

➢ The amount of carbon left at the end of the gasification is considered as an unconverted carbon (Char).

References

[1] Rumsey, 2018. United Kingdom Poultry and Poultry Meat Statistics – August 2018.

[2] Pandey et al., 2016. Poultry litter gasification in a fluidized bed reactor: Effects of gasifying agents and limestone addition. *Energy & Fuels*, 30 (4), 3085 – 3096.

[3] Katsaros et al., 2019. Gasification of poultry litter in a lab-scale bubbling fluidised bed reactor: Impact of process parameters on gasifier performance and special focus on tar evolution. *Waste Management*, 100, 336 – 345.

Acknowledgments

Financial support of the experimental campaign through the European Commission BRISK2 project (grant agreement number 731101) is gratefully acknowledged. D.S. Pandey acknowledges the funding from the Global Challenges Research Fund (GCRF, R5004, UK) and the conference bursary award from the Supergen Bioenrgy Hub.