

# ASPEN PLUS MODELLING AND SIMULATION OF SUPER-CRITICAL STEAM AND POULTRY LITTER GASIFICATION FOR THE PRODUCTION OF HYDROGEN FUEL AND ELECTRICITY

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**ABSTRACT:** Since more than 75% of the world's energy needs are currently met by fossil fuels, the growing worry about climate change as well as the depletion of hydrocarbon resources has compelled scientists worldwide to discover alternative sources of renewable and sustainable energy. Hence, it has become necessary to reduce depilation of poultry manure in addition to meeting energy demands. By extracting energy from the feedstock through the thermal gasification process, this research aims to address waste management and reduce environmental impact. High-hydrogen feedstock is widely available. Waste poultry (biomass) and steam were used as the gasification agent in Aspen PLUS<sup>®</sup> version V 11.0 software modeling and simulation of the process. According to the outcome, 1000 kg/h and 2500 kg/h of the poultry litter and steam were able to yield 1220 kg/h of hydrogen and electricity of 2,500kwh, this identified that a poultry litter as a promising candidate to reduce fossil fuel dependency.

**Keywords:** Aspen plus<sup>®</sup>, Modelling; Simulation; Hydrothermal Gasification; Poultry litter; Hydrogen and Electricity

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## 1.0. INTRODUCTION

Unsettling sustainable energy issues are brought on by an increase in energy demand, the quick depletion of non-renewable energy sources and harmful environmental issues brought on by greenhouse gas emissions (GHE). aims for development. Projections of the world's energy needs show an expanding pattern. According to estimates, annual consumption amounts from 2035 to roughly 778 EJ (Singh & Tirkey, 2022). These issues encourage scientists all over the world to focus on alternate energy sources rather than traditional fossil fuels. The earlier inquiry shows that several novel technologies were developed, many of which can convert used biomass into heat, electricity, and chemicals with additional value (Martínez et al., 2020) and (Khan et al., 2021). Biomass gasification is one of the finest methods for converting biomass into syngas (mostly CO and H<sub>2</sub>) among all of these novel approaches (Singh et al., 2015) and (Oruc et al., 2021). The thermochemical conversion of biomass into gaseous fuels is known as gasification (Mohammadidou et al., 2022) and (Al-Qahtani et al., 2021). CO, H<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>, and water vapor are among the components of the producer gas produced by the gasification (H<sub>2</sub>O). The four stages of the gasification process include drying, pyrolysis, combustion, and reduction zone.

## 2.0. MATERIALS AND METHODS

### 2.1. Materials

The materials used for this research work are as follows:

**Table 1.** Materials and Their Uses in This Research Work.

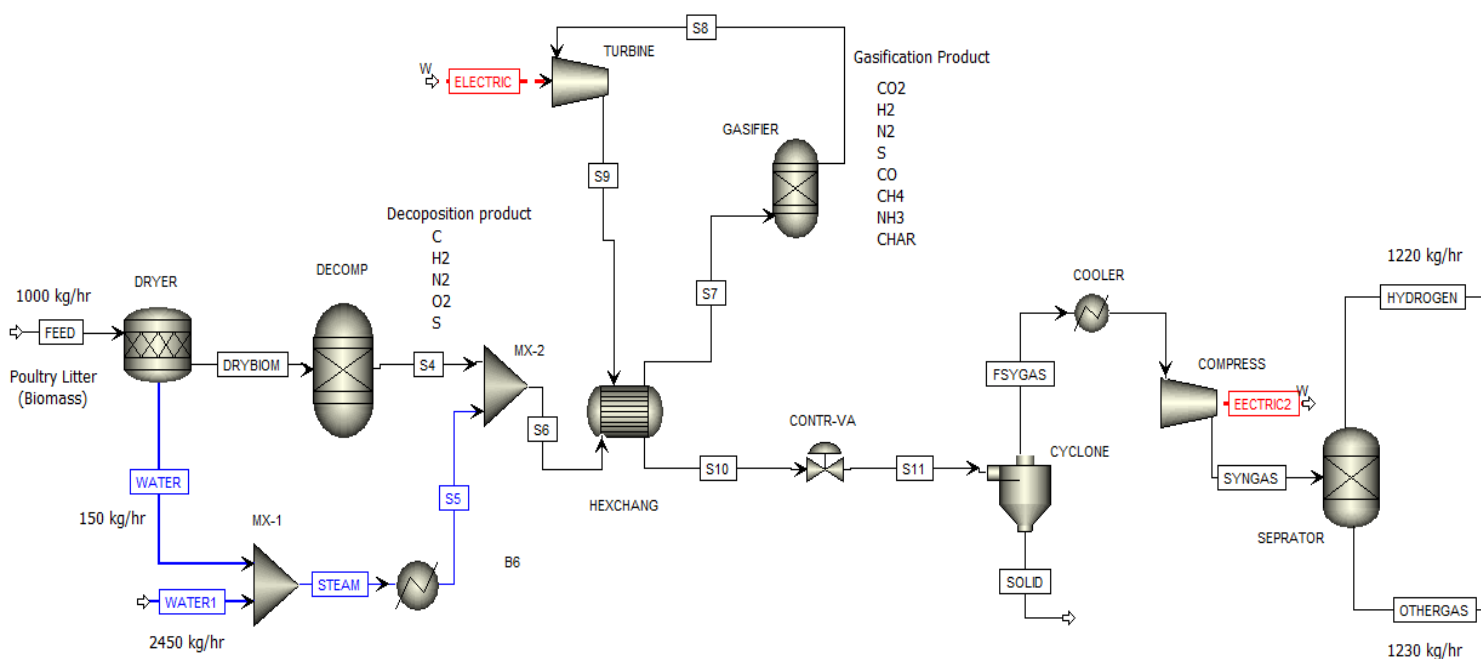
Materials	Uses
1. Aspen plus version 11.0	Aspen plus is a chemical engineering simulator used for the modelling and simulation of the design process
2. Data sheet of poultry litter	This consist of the feed specifications,3 ultimate, proximate and composition analysis of poultry litter from online literature review

2.2 . Methods

Modelling and simulation is an integrated tool used by process engineers to design and gain insight into an existing or expected system. Aspen plus version 11.0 was used to model and simulate the abundant poultry litter biomass via drying, decomposition and steam gasification to produce hydrogen fuel and electricity.

2.2.1. Process description

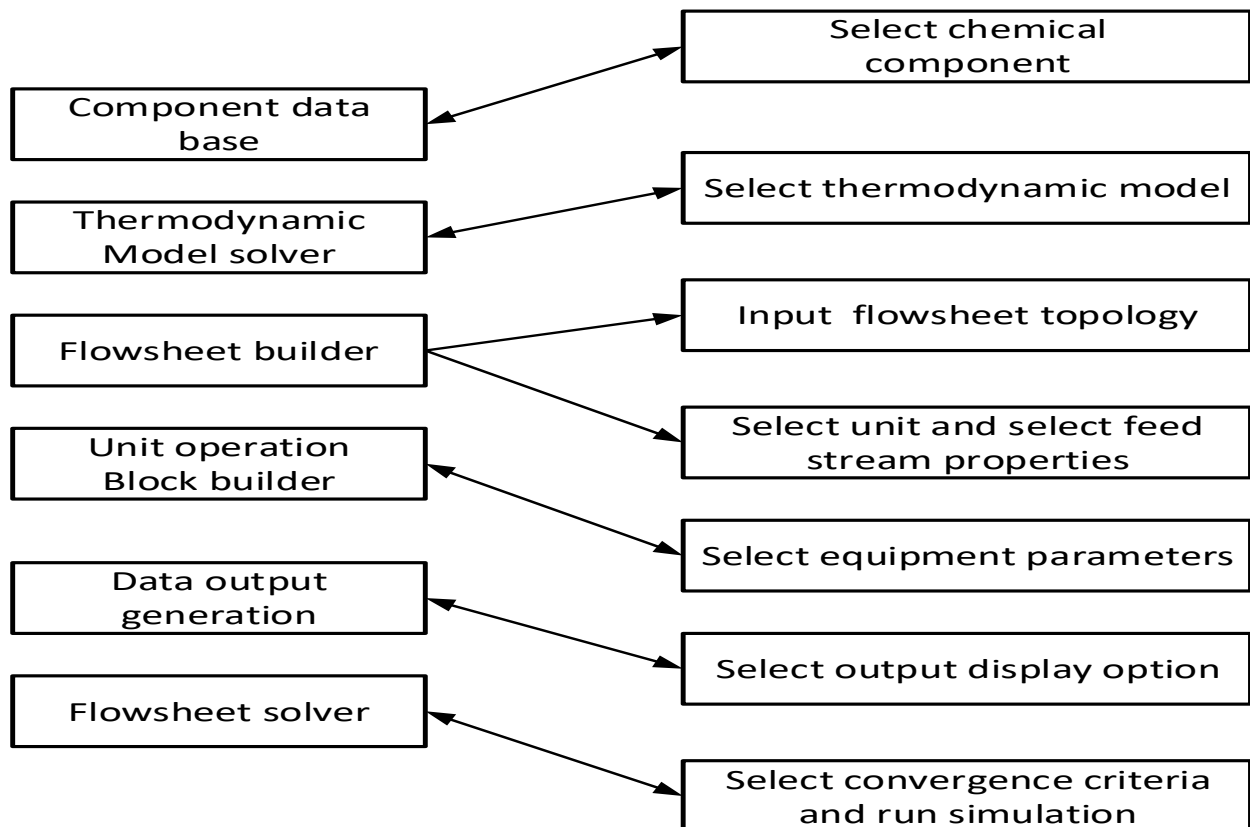
Poultry litter (biomass) processing using the Aspen Plus design model and simulation to create hydrogen and power as shown in Figure 1, the procedure is divided into four parts: the dryer, decomposition, steam thermal gasification/electric generation, and hydrogen production. To reduce the moisture content, the wet poultry letter was put into a dryer. The dry biomass was then transferred to a pyrolizer, where decomposition took place and produced the breakdown products C, H, N, S, and O. To raise the temperature of the gasification process by passing via the heat exchanger's tube, the disintegrated product was combined with steam. The syngas-and-other-solid-particle-containing gasification product travels through the gas turbine to produce electricity before returning to the heat exchanger's shell and passing via a valve to the cyclone, where the fine syngas is separated from the solid. After cooling and compressing the syngas, hydrogen was extracted from the other gases using a separator.



**Figure 1.** Aspen Plus Design Process Flow Diagram for The Production of Hydrogen and Electricity Using Poultry Litter Biomass.

3.2.2. Modelling and Simulation

Modelling and simulation was carried out using the following steps as it was depicted in Figure 2. Also, Table 1, 2 and 3 showed the ultimate and proximate analysis of poultry litter biomass, feed entering specification and reaction involved in the gasifier respectively.



**Figure 2.** Basic Modelling and Simulation Steps (Source: Inuwa et al. 2023).

**Table 2.** Ultimate and Proximate Analysis Results of Waste Poultry Litter (Singh et al., 2022).

Ultimate analysis (wt. %)	Poultry litter
Carbon	43.98
Hydrogen	5.16
Nitrogen	4.63
Oxygen	31.98
Sulphur	0.75
<b>Proximate analysis (wt. %)</b>	
Volatile matter	63.6
Fixed carbon	15.3
Moisture content	7.6
Ash	13.5

**Table 3.** Feed Entering Specifications.

Feed	Amount
Biomass (Poultry litter)	1000 kg/h
Temperature	25 °C
Pressure	1 atm
Steam	2000 kg/h

**Table 4.** Chemical Reaction Involved in The Poultry Litter Biomass Steam Gasification (Hussain et al., 2018).

Reaction no	Reaction name	Reaction equation	Heat of reaction $\Delta H(\text{KJ/mol})$
1	Combustion reaction	$C + O \rightarrow CO$	-111
2	Combustion reaction	$C + O_2 \rightarrow CO_2$	-283
3	Bourdouard reaction	$C + CO_2 \rightarrow 2CO$	+172
4	Methanation reaction	$C + 2H_2 \rightarrow CH_4$	-75
5	Methanation reaction	$2C + 2H_2O \rightarrow CH_4 + CO_2$	+103
6	Water gas shift reaction	$C + H_2O \rightarrow CO + H_2$	+131
7	Water gas shift reaction	$CO + H_2O \rightarrow CO_2 + H_2$	-41
8	H <sub>2</sub> S formation reaction	$H_2 + S \rightarrow H_2S$	-170.5
9	Steam reforming	$CH_4 + H_2O \rightarrow CO_2 + 3H_2$	+206

### 3.0. RESULT AND DISCUSSION

A hypothetical process model for the creation of hydrogen and energy utilizing poultry litter as feedstock was successfully created using Aspen PLUS® version V 11.0 software, as illustrated in Figure 1. The most persuasive parameters are the high rate of syngas composition and the temperature of gasification. The consistency of the syngas depends on the temperature at which gasification takes place. However, the results of a different study by Singh et al. (2022) are consistent with the findings of the current study on gasification temperatures of 850 °C. According to Mohammadidoust et al. (2022), they found that as the temperature climbed, CO and H<sub>2</sub> concentrations rose while CO and CH<sub>4</sub> concentrations fell. Additionally, the target products' results revealed that at a gasification temperature of 850 °C, 1000 kg/h of poultry litter (biomass) and 2500 kg/h of steam, respectively, were able to produce 1220 kg/h (99.43%) of hydrogen in contrast to the highest optimum hydrogen yield obtained by Singh et al. (2022), which is 93.2%, and 2,500 kWh of electricity. This identified chicken litter as a promising candidate to lessen reliance on fossil fuels.

### 4.0. CONCLUSIONS

The results obtained from the modelling and simulation of the production of hydrogen and electricity using poultry litter as feed stock production process revealed that the developed model was successful and was able to converge when simulated with Non-Random Two Liquid as fluid package and gasification temperature 850 °C gives the best yield of Hydrogen 1220 kg/h and 2500 kWh of electricity generated.

**CONFLICT OF INTEREST:** The authors declare no conflicts of interest regarding the publication of this article.

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**CONTRIBUTIONS TO KNOWLEDGE:** The following are the knowledge gained from this research work

The results obtained from this work showed that a commercial-scale plant design that will convert poultry litter to hydrogen and electricity is a possibility

The work established that the hydrogen and energy yields of 1220 kg/h and 2500 kWh respectively can be obtained with biomass to steam ratio of 1:2 (1000 kg/h:2000 kg/h)

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