ASPEN PLUS MODELLING AND SIMULATION OF SUPERCRITICAL STEAM AND POULTRY LITTER GASIFICATION FOR THE PRODUCTION OF HYDROGEN FUEL AND ELECTRICITY

By

Ahmed Mohammed INUWA
Isaac JATO
Saidat Olanipekun GIWA

Department of Chemical Engineering
Faculty of Engineering and Engineering Technology
Abubakar Tafawa Balewa University Bauchi

April, 2023

1.0 INTRODUCTION

Figure 1: *Fossil Fuel Exploration and Refining (Source:* Martínez et al. 2020*).*

Fossil fuel: hydrocarbon -containing materials such as coal, oil and natural gas formed naturally in the earth.

Climate change: this long time shifts in temperature and weather pattern, which causes by burning fossil fuel and other impurities to the atmosphere.

INTRODUCTION CONT…

Figure 2: *Poultry Litter (Source: Singh et al. 2022).*

Renewable and sustainable energy: Energy sources that has less environmental effect, cheap and abundantly.

Local content: waste poultry biomass, utilized to reduced environmental problems via producing hydrogen fuel and electricity.

2.0 MATERIALS AND METHODS

2.1 Materials

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
1. **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

The process consists of four sections, the dryer, decomposition, steam thermal gasification/electric generation, and hydrogen production as illustrated in figure 3.

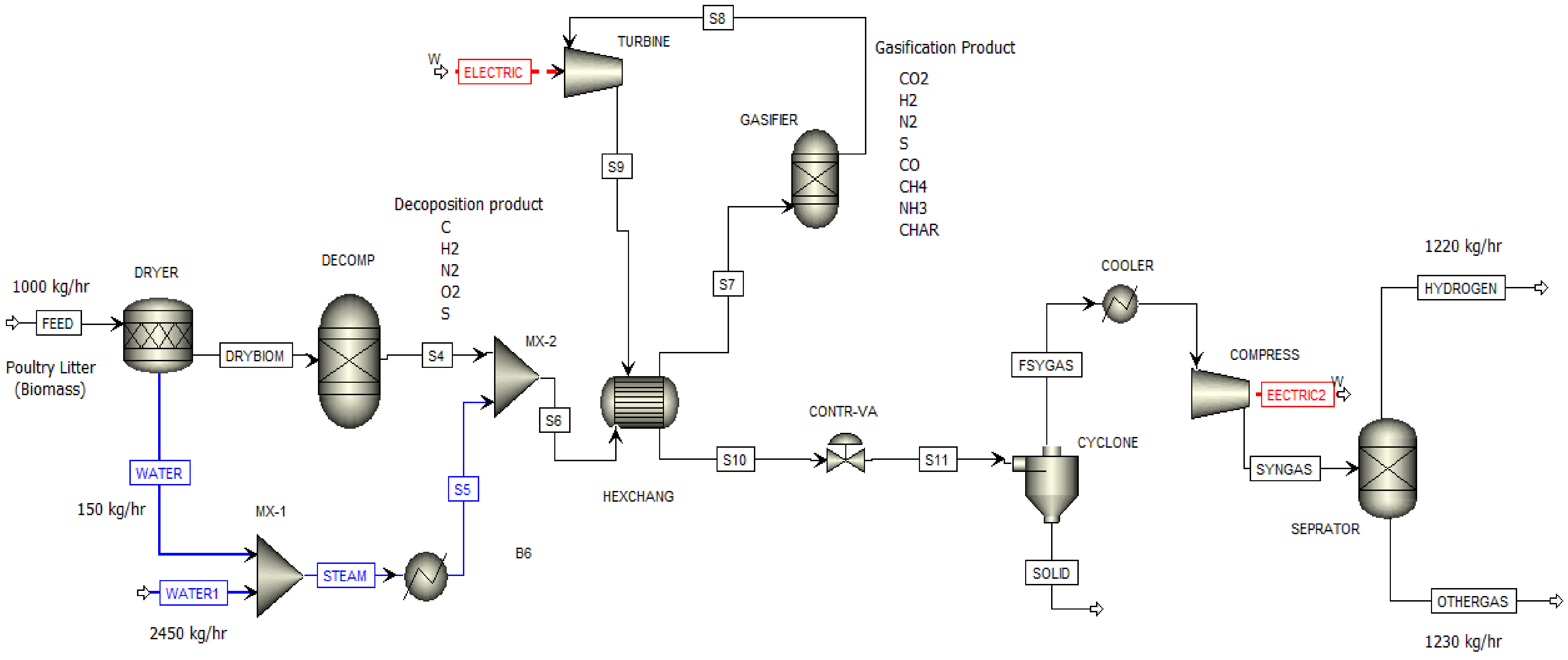

Figure 3: *Aspen Plus Design Process Flow Diagram for The Production of Hydrogen and Electricity Using Poultry Litter Biomass*

2.2.2 Modelling and Simulation

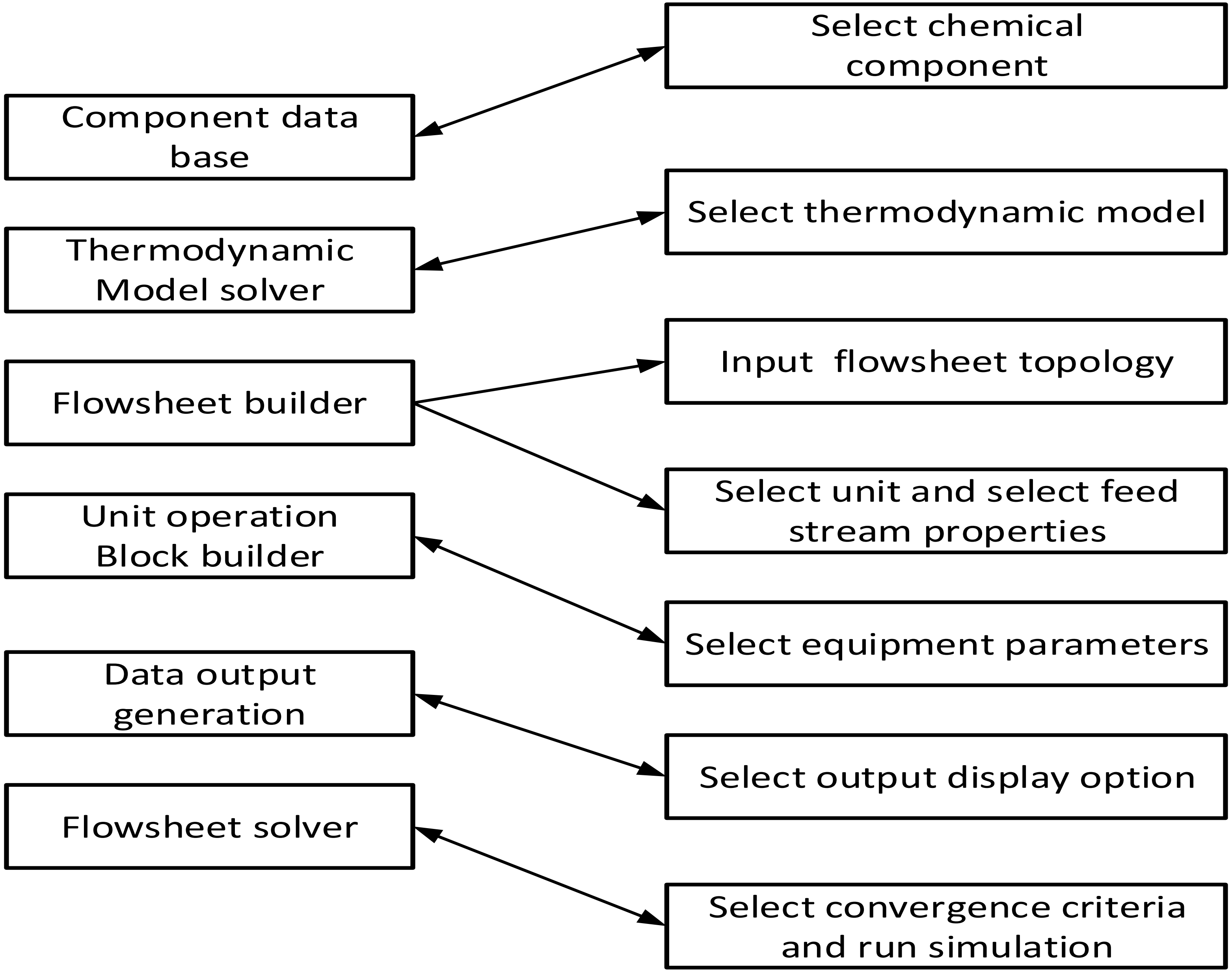

Figure 4: *Basic Modelling and Simulation Steps (Source: Inuwa et al. 2023).*

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
Proximate analysis (wt. %)	
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 ^{0}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 ΔH(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_2S 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 DISCUSSSION

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. 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 ^{o}c. According to Mohammadidoust et al. (2022), they found that as the temperature climbed, CO and H2 concentrations rose while CO and CH4 concentrations fell. Additionally, the target products' results revealed in Table 5 that at a gasification temperature of 850 ^{O}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.

Table 5: Target products of the poultry litter steam gasification

Product	Amount
Hydrogen gas	1220 kg/h
Electricity Generated	2500 kWh

4.0 CONCLUSION

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 ^{o}c, gives the best yield of Hydrogen 1220 kg/h and 2500 kWh of electricity generated.

5.0 CONTRIBUTIONS TO KNWOLEDGE

The following are the knowledge gained from this research work

i. 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

ii. 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)

REFERENCES

Al-Qahtani, A., Parkinson, B., Hellgardt, K., Shah, N., Guillen-Gosalbez, G. 2021. Uncovering the true cost of hydrogen production routes using life cycle monetisation. *Applied Energy*, **281**, 115958.

Hussain, M., & Multan, T. (2018).*A kinetic-based simulation model of palm kernel shell steam gasification in a circulating fluidized bed using Aspen Plus ® : A case study* https://doi.org/10.1080/17597269.2018.1461510

Khan, M.A., Al-Shankiti, I., Ziani, A., Idriss, H. 2021. Demonstration of green hydrogen production using solar energy at 28% efficiency and evaluation of its economic viability. *sustainable energy and fuels*, **5**(4), 1085-1094.

Mansoori, G.A., Agyarko, L.B., Estévez, L., Fallahi, B., Gladyshev, G., Gonçalves, R., Niaki, S., Perišić, O., Sillanpää, M., Tumba, K., Yen, J. 2021. *Fuels of the Future for Renewable Energy Sources (Ammonia, Biofuels, Hydrogen)*.

Martínez-Rodríguez, A., Abánades, A. 2020. Comparative Analysis of Energy and Exergy Performance of Hydrogen Production Methods. *Entropy*, **22**(11), 1286.

Mohammadidoust, A., Branch, K., & Omidvar, M. R. (2022). *Simulation and modeling of hydrogen production and power from wheat straw biomass at supercritical condition through Aspen Plus and ANN approach* https://doi.org/10.1007/s13399-020-00933-5

Oruc, O., Dincer, I. 2021. Assessing the potential of thermo-chemical water splitting cycles: A bridge towards clean and sustainable hydrogen generation. *Fuel*, **286**, 119325.

Singh, D. K., & Tirkey, J. V. (2022). Process modelling and thermodynamic performance optimization of biomass air gasification fuelled with waste poultry litter pellet by integrating Aspen plus with RSM. *Biomass and Bioenergy*, *158* (February)106370.https://doi.org/10.1016/j.biombioe.2022.106370

Inuwa, A. M., Giwa, S. O., & Joel, A. S. (2023). Optimization of Linear Alkyl Benzene Yield through Modelling and Simulation *ABUAD Journal of Engineering Research and develop. 2(5),62-73*