Local biomass potential for syngas production and further conversion into synthetic fuel

Monika Uler Zefikj, Risto Filkoski, Done Tashevski

Abstract

1. INTRODUCTION

The Republic of North Macedonia possesses significant biomass potential, offering a valuable resource for sustainable energy production and economic development. The country's biomass potential stems from various sources, including agricultural residues, forestry waste, energy crops, and organic municipal solid waste [1]. The gasification of waste biomass is a complex and technologically advanced process which involves proper treatment of the biomass and a series of reactions, where the raw biomass is exposed to high temperatures and is transformed into synthetic gas (syngas) [2]. The process is a good alternative to conventional waste disposal methods. This abstract will analyze the potential of wood waste and pellets to be used for syngas production through gasification by analyzing the characteristics of the waste biomass and the product parameters. Afterwards, the Fischer-Tropsch synthesis for conversion of the derived syngas into synthetic fuels will be described.

2. MATERIALS AND METHODS

In the gasification process, drying the biomass is a key step because it significantly affects the gasification efficiency and the final quality of the produced syngas. The drying was realized through heat transfer from the partial combustion zone inside the gasifier. The moisture content of the biomass, which typically ranges from 5% to 35%, decreased to around 7% in the drying zone at temperatures from 100°C to 200°C. The biomass used in this research is composed of wood pellets and waste from wood-processing industry. The pellets are of standard quality, tested by an accredited laboratory, according to the to the standard EN ISO 17225-6:2014. The test methods of each parameter are given in Table 1 below.

Table 1: Pellets characteristics

N.	Characteristic	Standard/Method	Results	Value and tolerance of the characteristic
1.	Moisture (total)	EN ISO 18134-2:2017	7.53% ± 0.15%	≤ 12%
	Moisture (analytical)	EN ISO 18134-3:2015	0.48% ± 0.01%	Not standardized
2.	Ash (on dry matter)	EN ISO 18122:2022	3.03% ± 0.06%	≤ 6.0%
3.	Sulphur (on dry matter)	ETC 7.3-4/2014	0.11% ± 0.01%	≤ 0.2 %
4.	Bulk density (on work matter)	EN ISO 17828:2015	671 ± 7 kg/m^3	≥ 600 kg/m^3
5.	Calorific value (lower, on work matter)	EN ISO 18125:2017	4.85 ± 0.02 kWh/kg	≥ 4.0 kWh/kg
		EN ISO 18125:2017	17.45 ± 0.05 MJ/kg	≥ 14.5 MK/kg

The type of gasification technique used is circulating fluid bed (CFB) gasification. A bed of inert material is suspended and circulated by an upward flow of air within a reactor chamber. The biomass waste is introduced into the reactor, where it undergoes controlled combustion reactions at elevated temperatures ranging from 700 to 1000°C. The CFB design enhances the gas-solid contact area, promoting rapid heat and mass transfer rates. This results in high conversion efficiencies and reduced emissions compared to conventional gasification processes [3].

3. RESULTS

The resulting gas mixture is itself a fuel due to the flammability of hydrogen H_2 (25-30%) and carbon monoxide CO (30-60%) of which the syngas consists largely. However, the composition of the resulting syngas can vary significantly depending on the feedstock and the gasification process involved. The coke residue consists primarily of a combination of mineral mass (ash) and almost pure carbon. The parameters of the syngas produced are given in the following Table 2.

Table 2: Composition of produced syngas

Component	Volume composition, %	Mass composition, %	Lower heating value, kJ/m^3	Lower heating value, kJ/kg
Hydrogen, H_2	19.2	1.63	10,800	141,974
Methane, CH_4	5.7	3.86	35,900	49,950
Butane, C_4H_{10}	0.5	1.23	123,552	45,720
Carbon monoxide, CO	20.0	23.73	12,600	10,132
Carbon dioxide, CO_2	7.0	13.05	0	0
Nitrogen, N_2	47.5	56.36	0	0
Oxygen, O_2	0.1	0.14	0	0
Syngas (total)	**100.0**	**100.00**	**7,257.7**	**32,361.16**

A signed agreement was made with the supplier of pellets produced from sunflower waste. The contract refers to a maximum quantity of 4,000 t/month, or maximum annual quantity of 44,000 t. From this amount of biomass waste, the amount of syngas produced is 97,680 t/annually. This amount of produced syngas is fed into a reactor containing a catalyst bed produced from iron supported on silica inert material. In the presence of the catalyst, the carbon monoxide and hydrogen molecules in the syngas undergo a series of chemical reactions known as the Fischer-Tropsch (FT) synthesis, such as polymerization and hydrogenation forming liquid hydrocarbons [4]. These hydrocarbons are then separated and purified to obtain the desired end products – synthetic fuels, such as diesel and gasoline.

4. CONCLUSIONS AND RECOMMENDATIONS

The production of syngas from biomass waste offers a promising avenue for sustainable energy production. This process helps to mitigate waste disposal issues while simultaneously producing a valuable energy resource. Synthetic fuels produced from biomass-derived syngas offer several advantages, including reduced greenhouse gas emissions, improved energy security, and the utilization of renewable resources. Despite the potential, syngas production from biomass waste faces challenges such as feedstock variability, reactor design complexities, and process optimization. The recommendations and future work are related to improving the efficiency, cost-effectiveness, and scalability of biomass gasification and FT synthesis technologies considering that it requires substantial capital investment and energy input.

References

[1] Statistical Office of the Republic of Macedonia. (2023). Statistical Yearbook of the Republic of Macedonia. https://www.stat.gov.mk/publikacii/2023/SG2023-web.pdf.

[2] Neubauer, Y. (2013). Biomass Combustion Science, Technology and Engineering. *Woodhead Publishing Series in Energy*, 106-129, https://doi.org/10.1533/9780857097439.2.106.

[3] Basu, P. (2013). Biomass Gasification, Pyrolysis and Torrefaction (Second Edition), *Academic Press*, https://doi.org/10.1016/C2011-0-07564-6.

[4] Lee, U., Cai, H., Ou, L., Benavides, P. T., Wang, Y., & Wang, M. (2023). Life cycle analysis of gasification and Fischer-Tropsch conversion of municipal solid waste for transportation fuel production, *Journal of Cleaner Production*, 382, https://doi.org/10.1016/j.jclepro.2022.135114.