Catalytic conversion of microalgae into tar free methane- and hydrogen- rich syngas using millisecond steam gasification

Pratik Gholkar,[a] Akshat Tanksale,[b*] Yogendra Shastri,[c] Suman Majumdar[d]

[a] *IIT-B Monash Research Academy, Mumbai, India 400076*
[b] *Monash University, Clayton, Melbourne, Australia 3800*
[c] *Indian Institute of Technology Bombay, Mumbai, India 400076*
[d] *JSW Centre, Mumbai, India 400051*
**Corresponding author:* akshat.tanksale@monash.edu

Abstract: Catalytic Reactive Flash Volatilization (RFV) is a single step char- and tar- free alternative to the gasification processes at low temperatures (600°C – 800°C). Microalgae exhibits various operational challenge due to its composition. Here we report tar free syngas production with tunable composition to make it rich in methane or hydrogen by varying catalyst and operating parameters. Selectivity of carbon towards gas phase was observed to be more than 93%, after 13 hours of the experiment.

Keywords: Microalgae, Reactive Flash Volatilization, Methane, Hydrogen, Catalyst.

1. Introduction

Microalgae has gained significant attention in the literature of late as the potential renewable energy feedstock. However, efforts towards harnessing the stored energy were unidirectional and, mostly focused on microalgal lipid conversion. This resulted in the poor overall carbon conversion efficiency. Salge *et.al*[1] first described the catalytic Reactive Flash Volatilization (RFV) of Soy oil and Glucose in the presence of rhodium cerium catalyst as a char and tar free alternative to the gasification technology, with more than 95% carbon conversion efficiency and tunable CO to H_2 ratio in the product. Chan F.L *et al* [2,3] demonstrated that the lignocellulosic biomass could also be converted into char and tar free syngas in the presence of nickel based catalysts and analysed the reaction kinetics of the cellulose RFV. In this work, two major hypotheses were studied – a) low temperature catalytic steam gasification can be used to produced tar free syngas from microalgae b) operating parameters can be varied to tune the composition of the syngas. Microalgae exhibits major operational challenges, such as high nitrogen content (9%-11% w/w) compared to the lignocellulosic biomass and low melting point (slagging) ash. Gasification of microalgae and the effect of nitrogenous compounds on the gasification reactions is rarely reported. This work is an attempt to study the RFV of microalgae and effects of nitrogenous compounds. In the following sections we have discussed, in brief, the operating conditions and the catalysts used to convert microalgae into syngas predominantly char and tar free.

2. Materials and Methods

The experiments were performed in the reactor setup explained in detail by Chan, F.L *et al* [1]. A bimetallic (Ni/Rh) and a trimetallic (Ni/Cu/Pd) nanocatalyst consisting of; transition metals impregnated on alumina support was prepared using wet impregnation method. The catalysts were characterised by its chemical state, elemental composition, size, shape, also TPR and TPD profiles. The catalyst was reduced *in-situ* and the millisecond steam gasification was performed by feeding 7 g/h of dried microalgal strain of *Scenedesmus sp*. Effects of carbon to steam ratio and temperature were analysed.

3. Results and discussion

Under the oxygen-steam RFV conditions reported earlier[3] the nitrogenous compounds present in microalgae could not be gasified, resulting in nitrogen rich tar (~72% N composition). In this work only, steam was used as a gasifying agent. Figure 1 shows the effect of carbon to steam ratio (CSR) on the gas distribution. As the CSR is increased, we observe a gradual increase in hydrogen and CO composition when using Rh-Ni catalyst (Fig 1a) and increase in methane composition when using Pd-Ni-Cu catalyst at 600°C. The latter catalyst promotes CO methanation resulted in methane rich syngas (16% (v/v) CH_4). Figure 2 shows the effect of temperature using the two catalysts used in this study. As the temperature is increased, both the catalysts exhibit drop in methane composition in favour of hydrogen production. At 650°C, the methane composition is only 4% with Rh-Ni catalyst and 8% with Pd-Ni-Cu catalyst, which indicates that high temperatures are not favourable for methanation. However, steam reforming is favourable at high temperatures, resulting in 65% (v/v) hydrogen at 650°C. The reaction was run for up to 13 hours during which no significant loss in activity was observed.

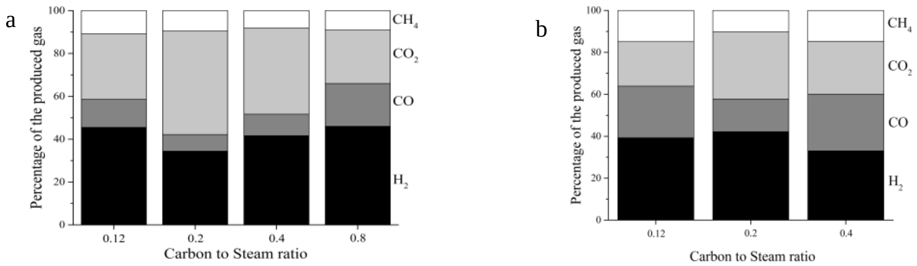

Figure 1. Effect of carbon to steam ratio on the distribution of components in the syngas gas using a) Rh-Ni/alumina b) Pd-Ni-Cu/alumina as catalysts at 600°C

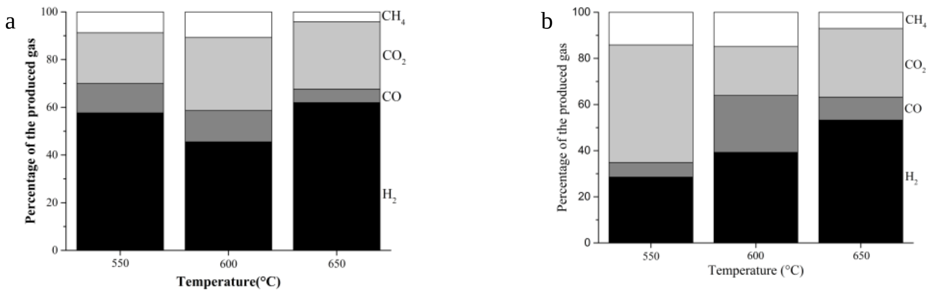

Figure 2. Effect of temperature on the distribution of components in the produced gas. a) Ni/alumina b) Pd-Ni-Cu/alumina as catalyst at CSR = 0.12

4. Conclusions

Tar free conversion of microalgae into syngas with the tunable composition was achieved using millisecond steam gasification by varying the catalyst and operating parameters. The composition of the gas phase can be tuned to increase, the selectivity towards either hydrogen or methane, depending on the catalyst and the reaction temperature. Hydrogen rich syngas (65% (v/v)) was obtained by using Rh-Ni/alumina catalyst at 650°C whereas, methane rich syngas (16% (v/v)) was observed in the presence of Pd-Ni-Cu/alumina catalyst at 600°C, both with more than 93% gas phase carbon selectivities. To the best of our knowledge this is the highest reported literature methane composition with high carbon selectivity for a single step tar free gasification conversion processes.

References

1. Salge, J.R., Dreyer, B.J., Dauenhauer, P.J. and Schmidt, L.D., 2006. *Science*, *314*(5800), pp.801-804.
2. Chan, F.L. and Tanksale, A., 2014. *ChemCatChem*, *6*(9), pp.2727-2739.
3. Chan, F.L. and Tanksale, A., 2016. *Applied Catalysis B: Environmental*, *187*, pp.310-327.
4. Colby, J.L., Dauenhauer, P.J. and Schmidt, L.D., 2008. *Green Chemistry*, *10*(7), pp.773-783.