Effect of temperature on the gasification of animal fat: *Preliminary results*

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Abstract

In this work, steam reforming of animal fat was studied using a fixed bed reactor. The effect of temperature was evaluated in the range of 750 and 950°C. Gas chromatography was used to analyze the gas sample and determine the gas composition. The results showed that the temperature greatly influences the gas composition and gasification process. The gasification parameters increased with the temperature rise, and the best results were obtained at the highest tested temperature.

Introduction

The leather sector is one of the prominent industries with a global trade value of USD 242.85 billion in 2022 and it is anticipated to expand from 2023 to 2030 at a compound annual growth rate (CAGR) of 6.6%. In Portugal, a total of 3096 enterprises manufactured leather in 2020. The leather sector is currently under scrutiny for the negative impacts of its unchecked pollution burden Muralidharan *et al.*, (2022). Tannery produces a vast amount of environmental pollutants in the form of solid and liquid, posing a threat to the environment if not disposed of properly Vidaurre-Arbizu *et al.*, (2021). Landfill and incineration are the two disposal methods for solid leather waste currently accessible Ayele *et al*., (2021). Publications on animal fat gasification are scarce. However, this thermochemical process can be an opportunity for waste valorization in the tanning industry. This work presents the preliminary results of the effect of temperature on the composition of the producer gas and the gasification parameters. The gasification process involves a complex reaction mechanism Tezer *et al*., (2022). The following list represents some typical gasification reactions:

Water–gas shift reaction:

$CO + H_2O \rightleftharpoons CO_2 + H_2$ $\Delta H_R^{298,15k} = -41.2$ kJ/mol (1)

Steam char reaction:

$C + H_2O \rightleftharpoons CO + H_2$ $\Delta H_R^{298,15k} = +131$ kJ/mol (2)

Methane steam reforming:

$CH_4 + H_2O \rightleftharpoons CO + 3H_2$ $\Delta H_R^{298,15k} = +206$ kJ/mol (3)

$CH_4 + 2H_2O \rightleftharpoons CO_2 + 4H_2$ $\Delta H_R^{298,15k} = +165$ kJ/mol (4)

Materials and methods

The animal fat was obtained from a technological Center for the Portuguese leather Industry. The gasification of animal fat was investigated in a downflow fixed bed reactor composed of alumina particles (6 mm in diameter). Steam was used as the gasification agent. An emulsion of 40 % (w/w d.b.) of fat and 60 % (w/w) of water was studied at temperatures ranging from 750 to 950 °C, using a mixture fixed flow of 2.0 g/min. Fat was analyzed regarding the higher heating value, proximate analysis, and ultimate analysis. Almeida et al. describe the experimental installation and test procedure in more detail Almeida *et al*., (2020).

Results and discussion

Three trials were carried out for each of the temperatures tested. Fig 1 shows the obtained results for the effect of temperature on the producer gas composition in terms of H_2, CO, CH_4, CO_2, C_2H_4, and C_2H_6. The increase in bed temperature led to increased H_2 and CO concentrations and decreased CH_4, CO_2, C_2H_4, and C_2H_6 concentrations in the producer gas. Along the temperatures that were tested, H_2 concentration increased from 28 to 60 % (v/v), and CH_4, C_2H_4, and C_2H_6 concentrations decreased from 15 to 4 % (v/v), from 26 to 4 % (v/v), and from 4 to 2 % (v/v), respectively. It should be noted that the high values of C_2H_4 were obtained at lower gasification temperatures. Concerning CO concentration, a sharp increase in its value from around 5 % to 17 % is observed for temperature values above 850 ºC. Regarding CO_2 concentration, there was a minor increase, from 18 to 19% (v/v), when the temperature rises from 750 to 850 °C and a slight drop, from 17 % to 14 % (v/v) when the temperature rises from 875 to 950 °C. Regarding CH_4, there is a decrease in its concentration in the test carried out at 875 ºC (5 %) with a subsequent increase (12 %) and a further decrease in the test carried out at 950 ºC (5 %). The water-gas shift (1) plays a well-known important role in the process up to 850 °C. From this temperature on, methane steam reforming

(2), (3), and methane dry reforming (4) become increasingly significant. The results obtained indicate that there may be a change in the reaction mechanism between 850 ºC and 950 ºC.

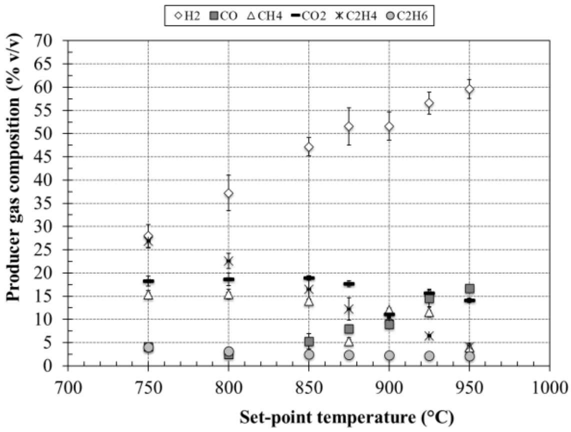

Fig. 1. Temperature effect on producer gas composition.

The temperature effect on the gasification parameters was evaluated, and the obtained results also showed a perturbation of its trend between 850 and 900 ºC. Carbon conversion efficiency increased from 29.8 to 74.9 %, hydrogen conversion efficiency increased from 56.8 to 158.3 %, cold gas efficiency increased from 19.5 to 79.5 %, and dry gas yield increased from 0.6 to 2.5 m^3/kg. Bearing in mind that the definition used for the hydrogen conversion efficiency values greater than 100 % can be obtained since this parameter quantifies the H_2 present in the gas relative to the hydrogen present in the feed, which is a mixture of fat and water. The higher heating value of the producer gas varied according to the change in the produced gas composition, with average values between 12 and 14 MJ/m^3.

Conclusion

The results of this preliminary investigation of the gasification of fat/water mixtures indicate that fat gasification may be a technically feasible option for the disposal of this waste, even though more studies are required to support the study.

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