Sustainable production of biofuel: experimental design and process simulation

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1. INTRODUCTION

Waste oils are considered a promising and sustainable source of raw materials in the biofuel industry. In recent years, research has been focused on the conversion of free fatty acids (FFAs) in fish oil to fatty acid methyl esters (FAMEs) mainly through the transesterification reaction. The biodiesel produced from salmon wastes provides an alternative source of raw material for sustainable energy production, meeting the growing energy demand without damaging the environment [1]. This work aims to investigate biodiesel production from salmon oil through a complete experimental design of the transesterification process. The process is simulated through Aspen Plus® simulation software to investigate the potential scale-up of the process.

2. MATERIALS and METHODS

The salmon oil was first analysed for moisture content and FFA value. The salmon-derived biodiesel was prepared in the lab using 2 litres of salmon oil. The salmon oil was stirred and heated under reflux to 65°C, and then methanol was added at a ratio of 5:1 (salmon oil: methanol ratio). Finally, a calculated amount of 32% potassium methylate was added to the mixture and left to react for 1 hour at a constant temperature before increasing the temperature to 85°C and leaving it vigorously stirring for more than 30 mins to evaporate the unreacted methanol. After the evaporation, the sample was then placed into a conical separation flask and left to phase separate into two layers, the bottom glycerol layer, and the top salmon-derived biodiesel layer. The glycerol layer was decanted off and discarded, whilst the salmon-derived biodiesel layer was placed into a storage vessel for future analysis.

Aspen Plus® simulation software was used to model the production of FAMEs from salmon oil. The initial step in building any simulation model involves defining the components that would be used through its steps. In the present work, methanol, water, glycerol and salmon oil represented the primary components. Whilst some of the multiple constituents of salmon oil were readily predefined in the Aspen Plus® datasets, others required data entry into the software.

Experimental analysis of the oil sample indicated the presence of 18 different triglycerides (TGs); 11 of which were available in the software data bank, while 7 needed to be manually defined.

3. RESULTS and DISCUSSION

Salmon oil and methanol were heated separately to 65° C. Throughout the process, temperature and pressure were specifically modulated to obtain the necessary temperature of the streams. This prevents thermal shock between the streams, allowing for a more controllable operation. As presented in Fig. 1, The reactor operates at a temperature of 65° C and a pressure of 1 bar. The 18 reactions occur simultaneously in the reactor.

The glycerol produced was then separated in a decanter at 55° C. Decantation stages allow the separation of light and heavy phases formed during the preceding reactions. At this stage, most of the glycerol was removed from the biodiesel phase. Further purification stages were needed to obtain biodiesel that would meet ASTM regulations. To separate the FAMEs from the unreacted methanol, the glycerol-free mixture was then sent to a flash separation column that

operated at 95° C. The unreacted methanol was then recycled and mixed with the fresh methanol.

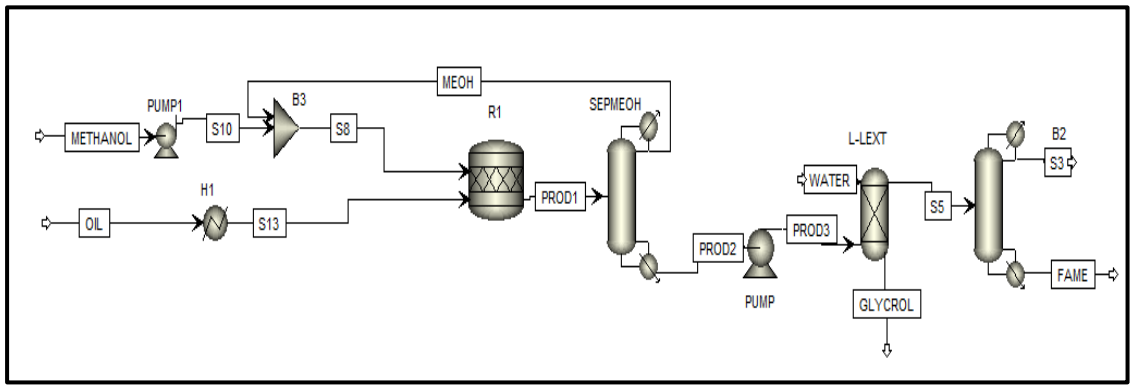

Fig. 1: Aspen Plus model for transesterification of salmon oil

After modelling the transesterification process of salmon oil components into FAMEs, the model was compared with the results of the experimental setup to validate the use of the developed model in the potential scaling up of the process. Two main aspects were considered: (i) process unit operation and operating conditions and (ii) the composition of FAMEs as presented in Fig. 2. The simulation results were in good agreement with the experimental results.

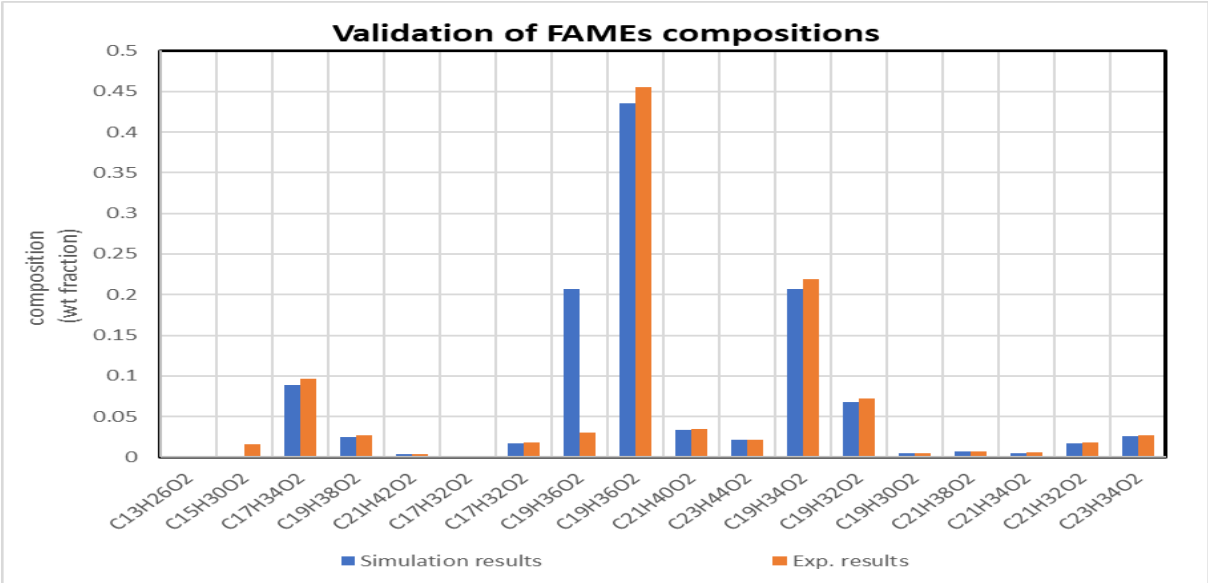

Fig.2: Validation of FAME composition

The biodiesel was produced by a homogeneous alkaline transesterification process using methanol and potassium methylate as a catalyst. The salmon oil was transesterified and then the FAMEs content was estimated using the peak areas of several FAMEs peaks observed in the chromatogram using GC-MS/FID analysis. The experimental results were modelled through Aspen Plus® software, where the salmon oil was reacted with methanol in the presence of a catalyst and the results were validated against the experimental data. This study demonstrated that the oil produced from salmon wastes showed suitable characteristics and is a promising source for sustainable biofuel production.

4. REFERENCE

1. Cardoso LDC, Almeida FNC, Souza GK, Asanome IY and Pereira NC. Synthesis and optimization of ethyl esters from fish oil waste for biodiesel production. *Renewable Energy*. **133**: 743-748 (2019).