Techno-economic assessments of scaled–up biodiesel production using meat processing dissolved air flotation sludge as feedstock

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INTRODUCTION

We identified meat processing waste dissolved air flotation (DAF) sludge as a sustainable biodiesel feedstock. Our recent results show that DAF lipids (DSL) could be converted to a biodiesel product that satisfied American and European biodiesel standards. It was however crucial to explore the technical and economic performance of a scaled-up biodiesel production plant as a basis for future large-scale application. Technical feasibility studies will provide useful data relating to biodiesel fuel yield and energy requirements for determining the renewability of the biodiesel production process while economic feasibility studies will generate useful costing data that will enable the assessment of the unit cost of the biodiesel production process. This presentation shows our results of the technical and economic feasibility analysis of a large-scale biodiesel production system using meat processing DAF sludge as the feedstock.

MATERIALS & METHODS

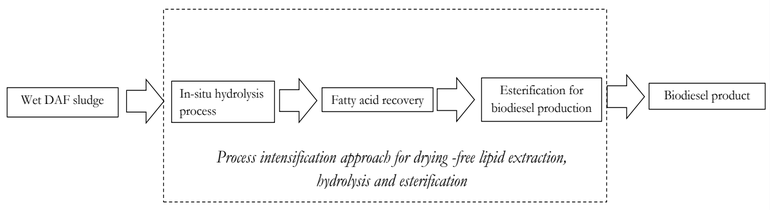


Figure 1. Process intensification strategy for biodiesel production from meat processing DAF sludge.

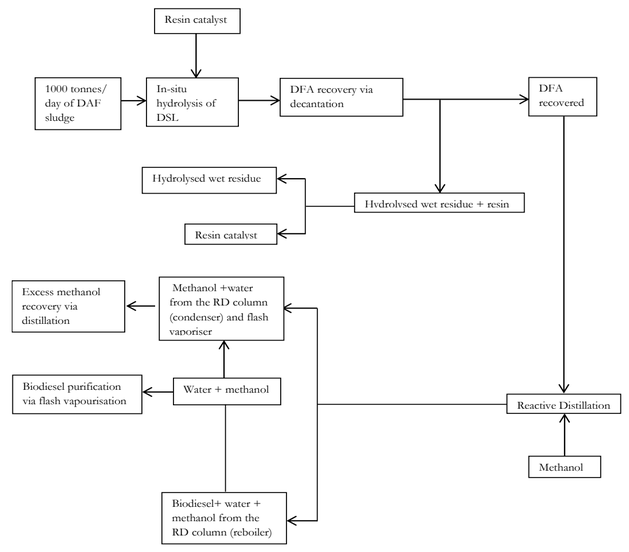


Figure 2. A simplified flow chart for the in-situ hydroesterification process for biodiesel production from meat processing DAF sludge.

MATERIALS & METHODS

- Process simulation using ASPEN plus ® V10 process simulator.
- Important thermophysical properties of the DSL modelled using chemical constituent fragment method.
- The microporous resin catalysed in-situ hydrolysis for enhanced fatty acid generation,

$$\text{DSL} + \text{water} \xrightarrow{\text{catalyst}} \text{Glycerol} + \text{DFA}$$

was modelled using our published experimental data.

- The secondary esterification reaction,

$$\text{DFA} + \text{Methanol} \leftrightarrow \text{DSME} + \text{water}$$

was modelled based on the estimated kinetic behaviour of the DAF fatty acid (DFA) and methanol mixture according to the following relation.

$$r_e = -\frac{d[DFA]}{dt} = \frac{d[DSME]}{dt} = k_f [DFA]^n [methanol]^m - k_b [DSME]^i [water]^j$$

where DSME is the DAF sludge biodiesel product.

- Renewability assessment of the biodiesel production process was undertaken using the net energy balance ratio (NER) as a surrogate measure of sustainability as follows,

$$\text{NER} = \frac{HHV_b \times P_c}{\sum_i^n E_{f,i}}$$

MATERIALS & METHODS

- Economic assessments were undertaking by considering the unit biodiesel production cost (C) as follows,

$$C = \frac{C_{AECC} + C_{AOC}}{P_c}$$

where,

$$C_{AECC} = I_t \times \left[\frac{(1+i)^n \times i}{(1+i)^n - 1}\right] \qquad I_t = 1.81 \times E_{ISBL} \quad \text{and} \quad E_{ISBL} = f_L \sum_i^n Cost_{2017,i}$$

- Major equipment purchase cost was estimated using standard mapping, sizing, and costing algorithms within Aspen Process Economic Analyser, such that 2017 costs were estimated using the CEPCI value for 2017 as follows,

$$Cost_{2017} = Cost_{2016}\left(\frac{CEPCI_{2017}}{CEPCI_{2016}}\right)$$

- Operational costs were estimated by considering existing commercial price estimates.
- Uncertainty considerations were incorporated using Monte Carlo simulations for 100,000 randomisation runs for the parameter determinants. Triangular probability distribution was utilised in line with previous studies in the area.
- Finally the sensitivities of the renewability performance and the economic performance to variations in their respective determinants were also explored.

RESULTS

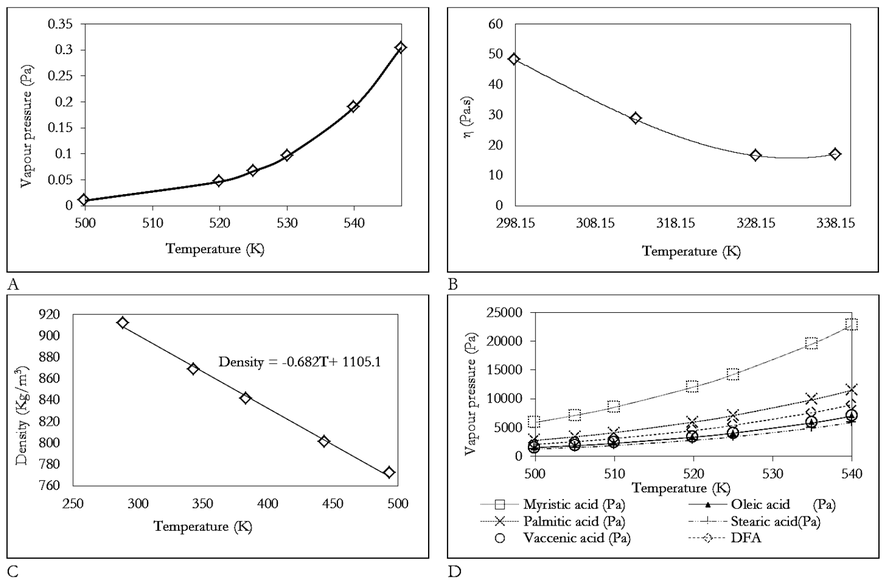


Figure 3. Estimated thermophysical properties of the DSL [A, B and C] and the vapour pressure of the DAF fatty acids (DFA) [D].

The determined molecular formula of DSL is determined as follows,
$[(CH_2COO)_2CHCOO](CH{=}CH)(CH_2)_{44}(CH_3)_3$

RESULTS

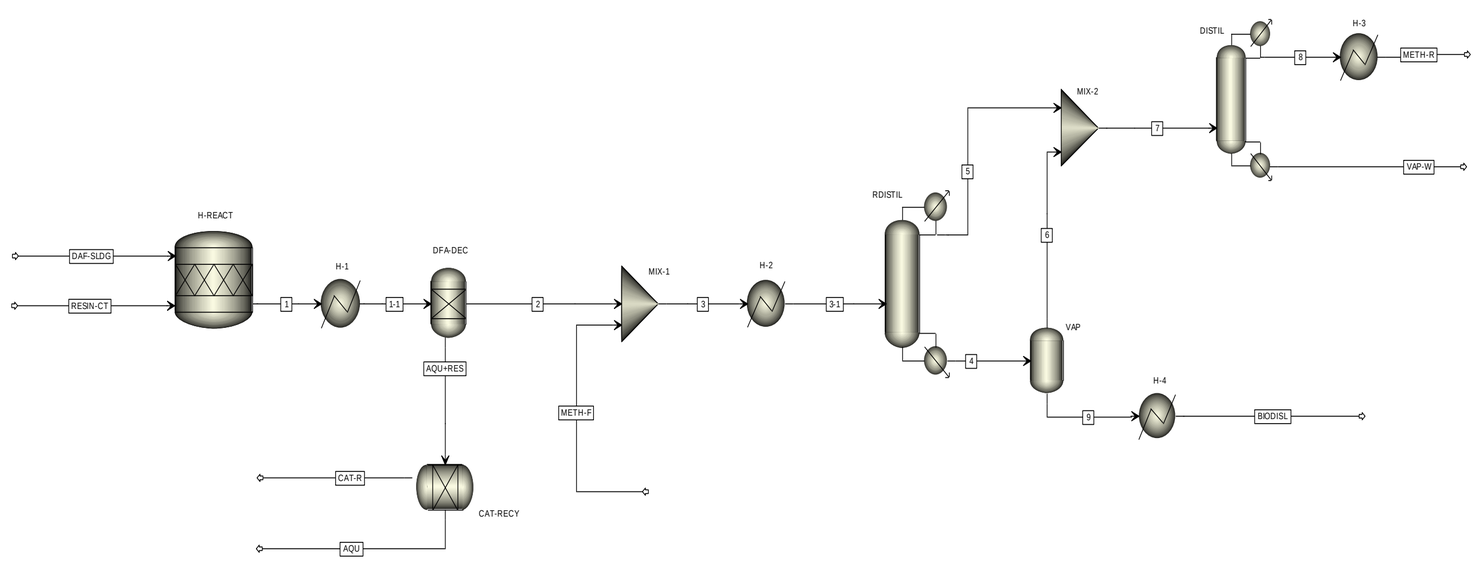
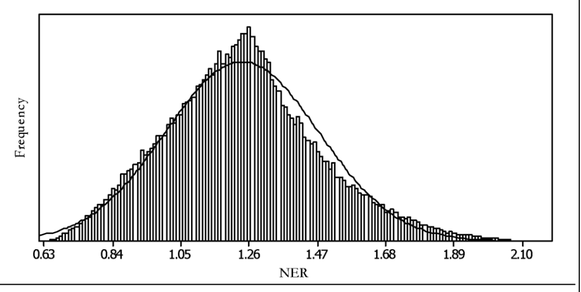
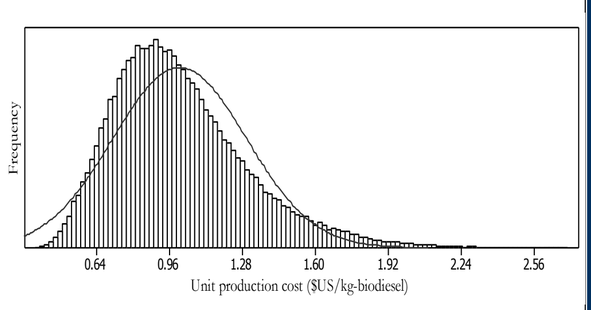


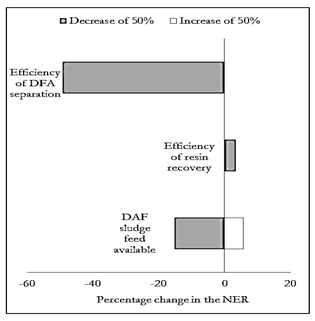
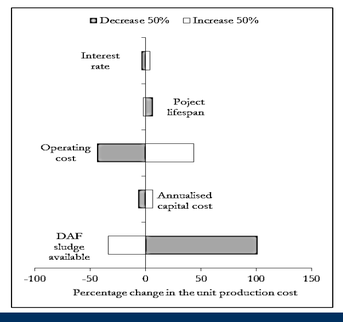
Figure 4. ASPEN simulation model output of in-situ hydroesterification of DAF sludge.

RESULTS

Monte Carlo simulation results

	Short notes	
NER	NER will range from 1 to 1.48 for a >95 % confidence interval with a mean NER value of 1.24	
C	C will range from US$0.72 to US$1.30 per kg-biodiesel for a >95 % confidence interval with a mean C of US$1.01/kg-biodiesel	

Sensitivity analysis results

NER is most sensitive to the efficiency of fatty acid recovery after the in-situ lipid hydrolysis process	
C is most sensitive to the availability of sufficient DAF sludge	

CONCLUSIONS

- The energetic performance of the biodiesel production process using DAF sludge as feed stock is always favorable (within the range considered).
- The mean unit production cost of US$ 1.01/kg-biodiesel is considerably cheaper than existing unit production costs.
- It may be more economically prudent to transport additional sludge at the expense of an increase in the operating cost if onsite supply is insufficient.
- The biodiesel production process will benefit from economics of scale.

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