Meat processing DAF sludge transformation to biofuels via hydroesterification

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Motivation and background of the biorefinery research focus focusing on using meat processing waste

- Global challenges with respect to sustainability issues (GHG emissions, environmental concerns, resource depletion) are increasing
- DAF sludge contains useful proteins, carbohydrates and lipids and therefore constitutes an undisputed and sustainable source of ever increasing biomass feedstock. It is however usually disposed of in landfills or incinerated in boilers
- Underwhelming low return on investments in stand-alone biomass-to-fuel facilities
- Absence of associated costs of cultivation, harvesting or agricultural land use for biomass generation

Research progress: investigating the possibility of DAF sludge lipid to biodiesel

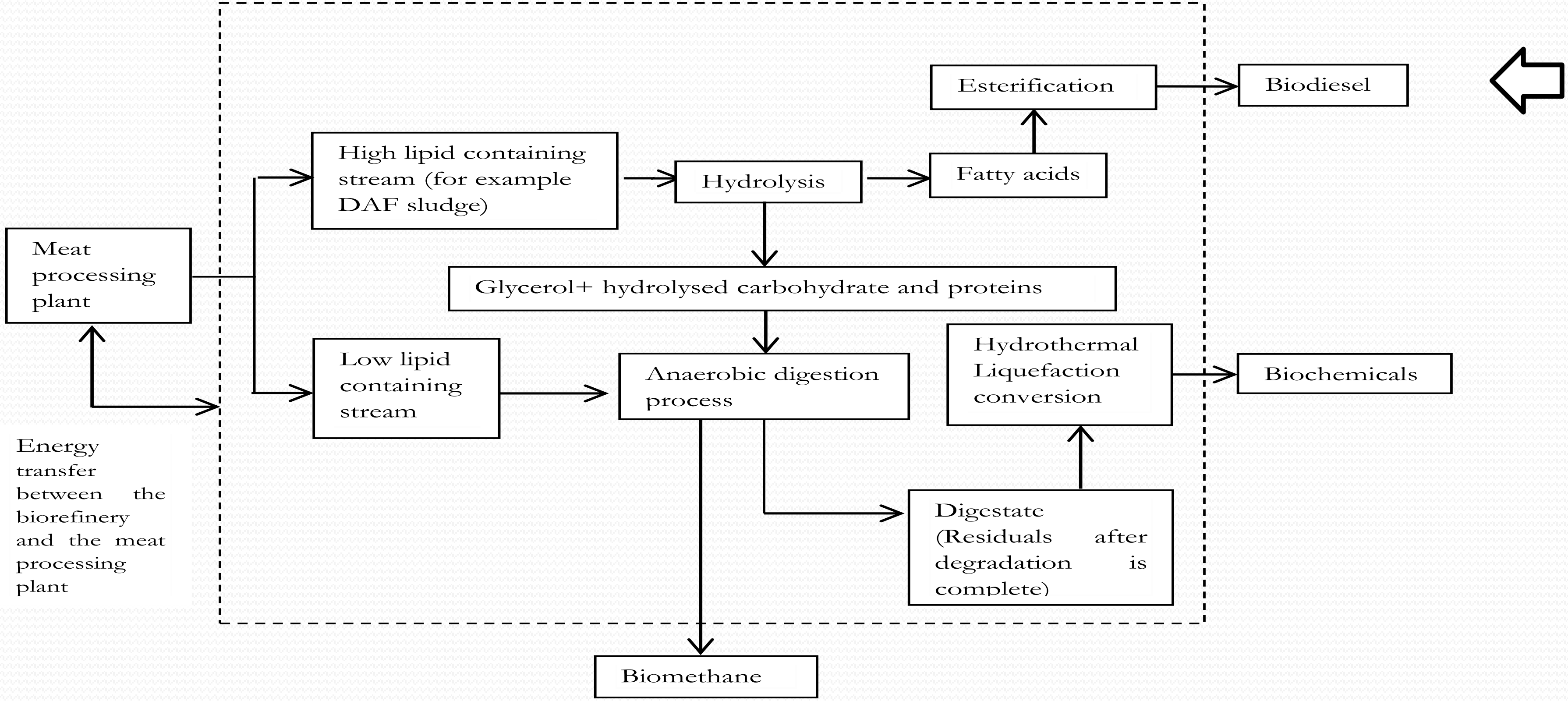

Figure 1: Proposed bio refinery configuration.

Quality and composition of the DAF sludge derived oils

1. The quality of extracted lipids from DAF sludge was investigated by determining the free fatty acids of the extracted lipids using standard titrimetric methods.
2. The moisture content of the fresh DAF sludge was also determined to establish the high energy demand required for drying in the traditional transesterification process.
3. The fatty acid distribution of the extracted lipids (tri-, di-, mono-, glyceride and free fatty acids) was determined using FAME analysis.

Quality and composition of the DAF sludge derived oils

The following results were obtained:

- Free fatty acid content and moisture content was established as 22.3g of FFA/100 g of oil extracted and 2900 kg-water/kg-dry sludge respectively.

This implied that,

- DAF sludge lipids were low grade oils since the value of 22.3% FFA content exceeds the maximum (0.5%) permitted in conventional transesterification processes.
- This suggests that the conventional transesterification process will be insufficient, due to the unwanted saponification reaction when an alkali catalyst is used.
- The high moisture content suggested the requirement of a high energy input requirement for the preliminary drying required in conventional transesterification processes.

Fatty acid distribution of the DAF sludge derived lipids

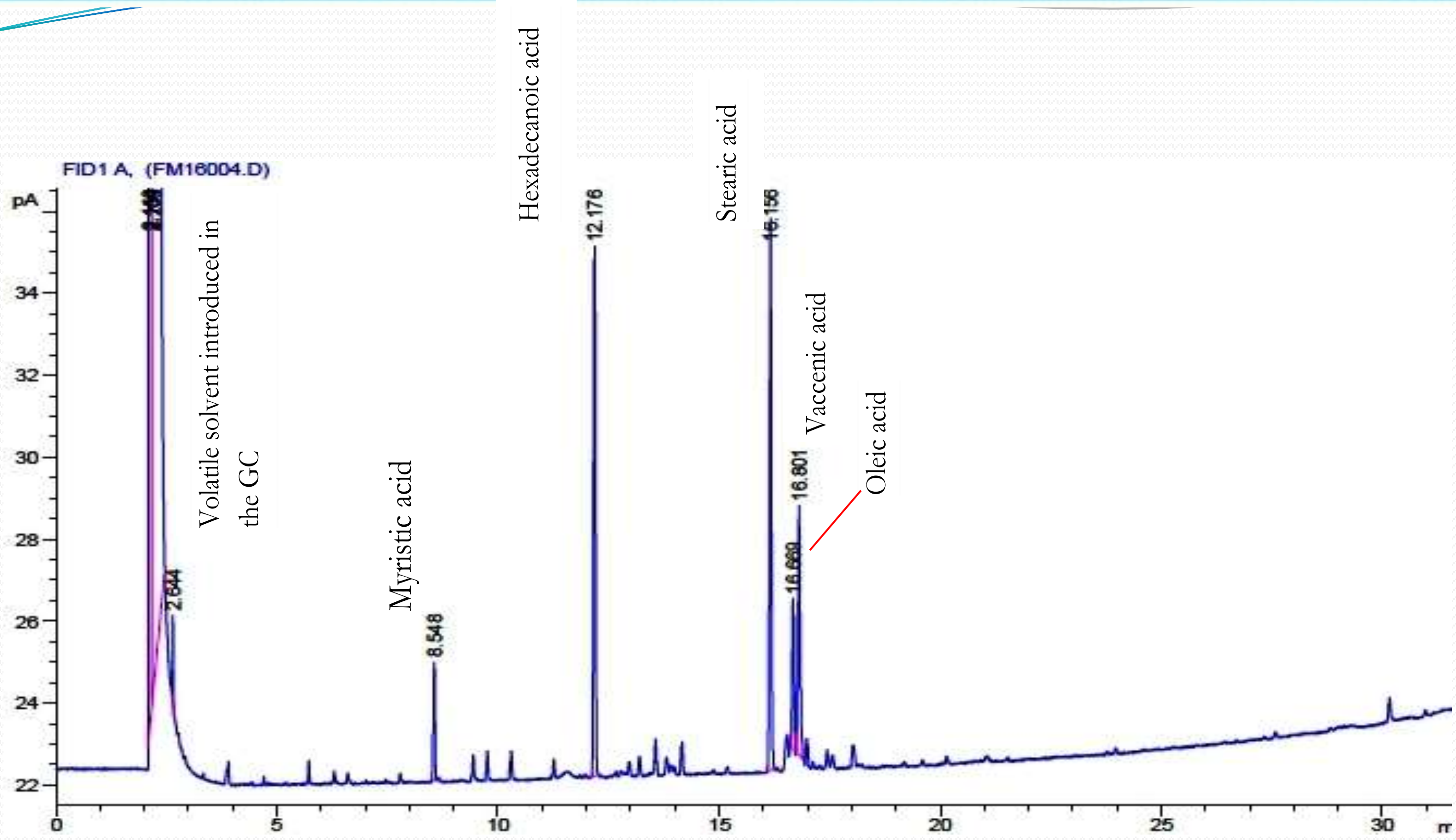

Figure 2: Gas chromatographic output.

Average fatty acid distribution of DAF sludge derived lipid

Table 1: The relative composition of the major fatty acids in DAF sludge.

Major fatty acid	Common name	Compound ID	Mole fractions
Saturated fatty acids			
Tetradecanoic acid	Myristic acid	C14:0	0.0598
Hexadecanoic acid	Palmitic acid	C16:0	0.3162
Octadecanoic acid	Stearic acid	C18:0	0.3504
Total			**0.7264**
Unsaturated fatty acids			
11-Octadecenoic acid	Vaccenic acid	C18:1	0.0941
Cis-9-Octadecenoic acid	Oleic acid	C18:1	0.1795
Total			**0.2736**

Estimated molecular formula of the DAF sludge triglyceride, hydrolysis product and FAME product

Using Espinosa's method, the DAF sludge triglyceride was determined as follows,

$$[(\mathrm{CH_2COO})_2\mathrm{CHCOO}](\mathrm{CH=CH})_\mathrm{m}(\mathrm{CH_2})_\mathrm{n}(\mathrm{CH_3})_3 \text{ with } n = \sum_{i=1}^{N} n_i x_i \text{ and } m = \sum_{i=1}^{N} m_i x_i$$

where, x_i, m_i and n_i represent respectively the fatty acid mole fraction, the numbers of the functional groups of CH=CH and CH_2 present in the pseudo triglyceride.

Estimated molecular formula of the DAF sludge triglyceride, hydrolysis product and FAME product

Using Espinosa's method, the DAF sludge triglyceride was determined as follows,

Table 2: Distribution of the fatty acids in the DAF sludge derived lipids and the corresponding functional groups

Common name	*Mole fractions*	n_i	m_i	n_i ×*Mole fraction*	m_i × *Mole fraction*
Myristic acid	0.0598	36	0	2.1528	0
Palmitic acid	0.3162	42	0	13.2804	0
Stearic acid	0.3504	48	0	16.8192	0
Vaccenic acid	0.0940	42	3	3.948	0.282
Oleic acid	0.1794	42	3	7.5348	0.5382
Pseudo triglyceride				43.7352	0.8202

Estimated molecular formula of the DAF sludge triglyceride and FAME product mixture

DAF sludge triglyceride molecular formula was therefore estimated as,

$$[(CH_2COO)_2CHCOO](CH = CH)(CH_2)_{44}(CH_3)_3$$

- Indicating a triglyceride (16:0/18:0/18:1) implying the pseudo triglyceride contains palmitic, stearic and oleic acid groups
- Other possible triglyceride with a similar molecular formula such (16:0/16:1/20:0) and (16:0/16:0/20:1) does not exist based on the fatty acid distribution shown in Table 1.

Based on functional group contribution methods the FAME product of DAF sludge derived lipids was estimated as,

$C_{18.666}H_{35.99}O_2$ which is very similar to the formula for methyl oleate.

Hydroesterification as an alternative biodiesel production pathway

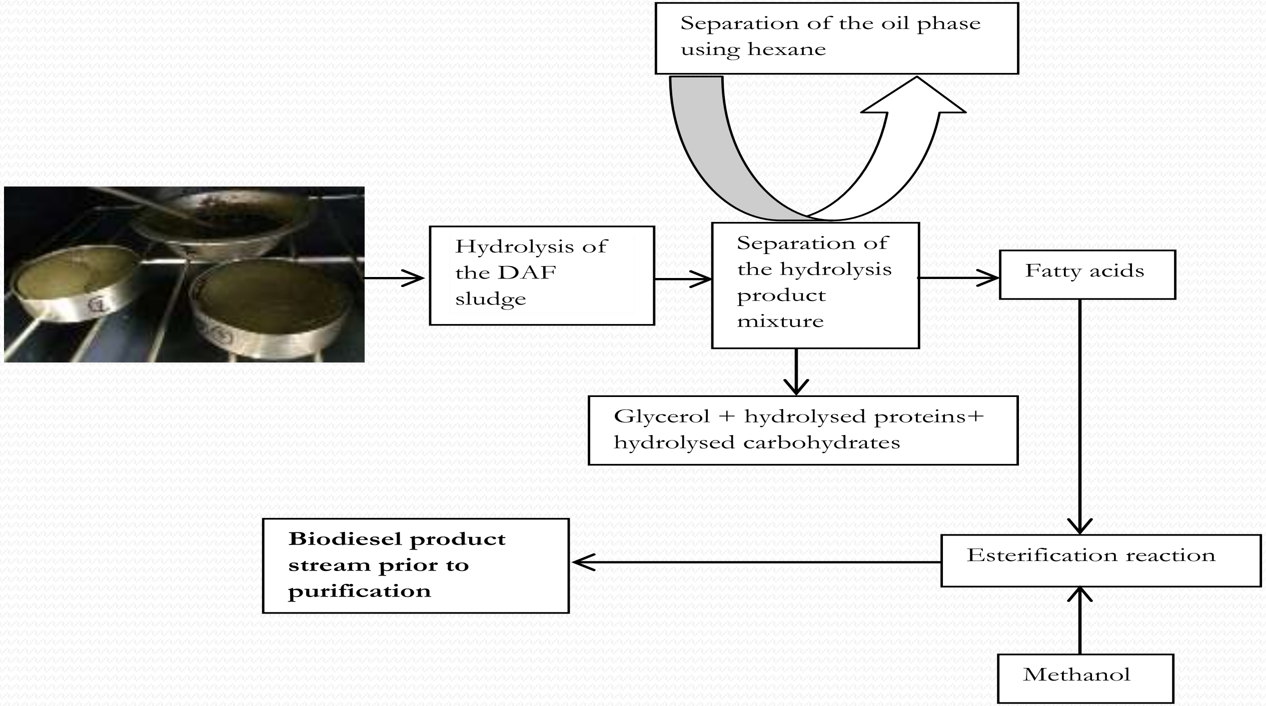

Figure 2: Process flow diagram for hydroesterification of locally sourced DAF sludge for biodiesel production

Major fuel properties predicted

Biodiesel is composed of a mixture of methyl or ethyl esters implying that the major biodiesel fuel properties can be estimated as a function of the properties of each individual ester.

Thermodynamic, regression and correlation based models can facilitate the prediction of the fuel properties of the hydroesterification product from the fatty acid profile. These properties include:

- Cetane number,
- Cold flow properties,
- Dynamic viscosity,
- Higher heating value (HHV) and
- The oxidative stability

Major fuel properties of DAF sludge derived biodiesel

Table 3: Comparative assessment of the predicted DAF sludge derived fuel properties with European standards for biodiesel(vehicular use).

DAF sludge biodiesel compared with European standards	Cetane number (CN)	Cloud point(^{o}C)	Cold filter plugging points (^{o}C)	Kinematic viscosity (ʋ) mm^2/s at 40^{o}C	HHV (MJ/kg)	References
DAF sludge	70.79	5.27	2.43	4.90	40.12	This work
EN 14214 (Vehicle -use) standards	>51	Country specific	Country specific	$3.5 \leq ʋ \leq 5.0$	>35	Knothe, (2006)

Limitations of DAF sludge derived biodiesel

DAF sludge derived biodiesel is expected to possess suitable fuel properties with the exception of the cold flow and the cold filter plugging properties (See Table 2).

- ❑ Poor cold flow properties suggests that difficulties in the utilisation of DAF sludge derived biodiesel in temperate climates

- ❑ This challenge may however be resolved via;
- ✓ Product blending
- ✓ Winterisation
- ✓ Use of industrial additives such as BioFlow 875, Flozol 503 and MCC P205

Conclusions of this study

- DAF sludge derived biodiesel will be characterised by a high oxidative stability, higher heating values and cetane number as well as a viscosity that satisfied the requirements according to European standards
- Cold flow challenges of the DAF sludge derived biodiesel can be overcome using the existing methods discussed earlier
- The utilisation of DAF sludge as a biodiesel feedstock will significantly improve the economics of overall biodiesel production processes since the feedstock is obtained freely
- Further investigations into the utilisation of the process residuals via the application of the biorefinery concept must be undertaken to further improve the economic performance

Thank you

Questions