PROCESS DESIGN & TECHNOLOGICAL ASSESSMENT OF MICROALGAL DERIVED BIODIESEL VIA THE IN-SITU PROCESS.

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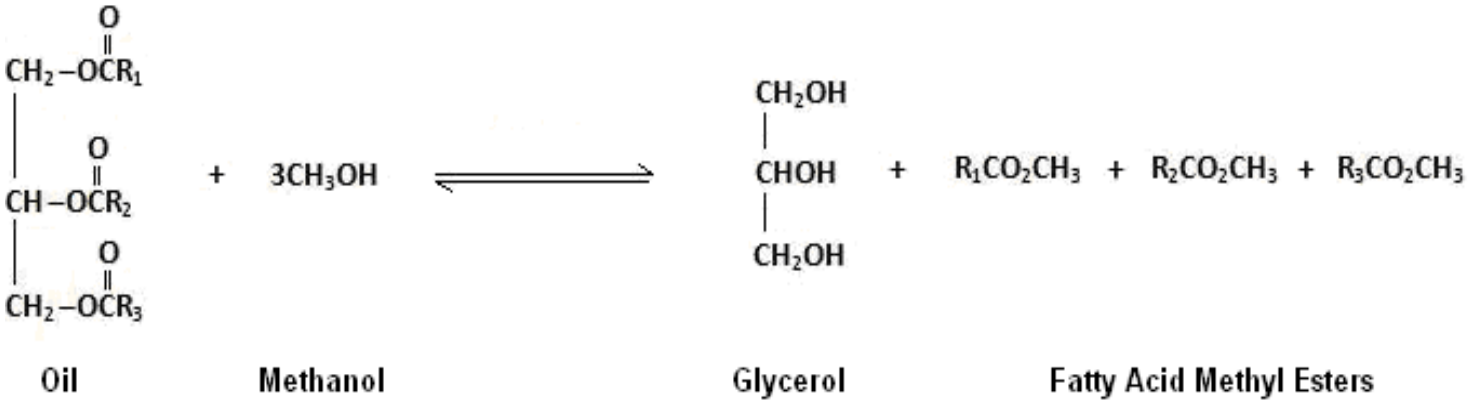
Introduction

Methods employed for the enhancement of of biomass oils to produce suitable petro-diesel replacements*:

- Blending
- Micro-emulsification
- Pyrolysis (thermal cracking)
- Transesterification

* Meher et al (2006). Renewable & Sustainable Energy Reviews 10: 248

Transesterification



The transesterification reaction can be facilitated using:

- Inorganic catalysts (acids or bases)
- Use of enzymes (lipases)
- Non-catalytic methods (using supercritical alcohol)

Inorganic Catalysis

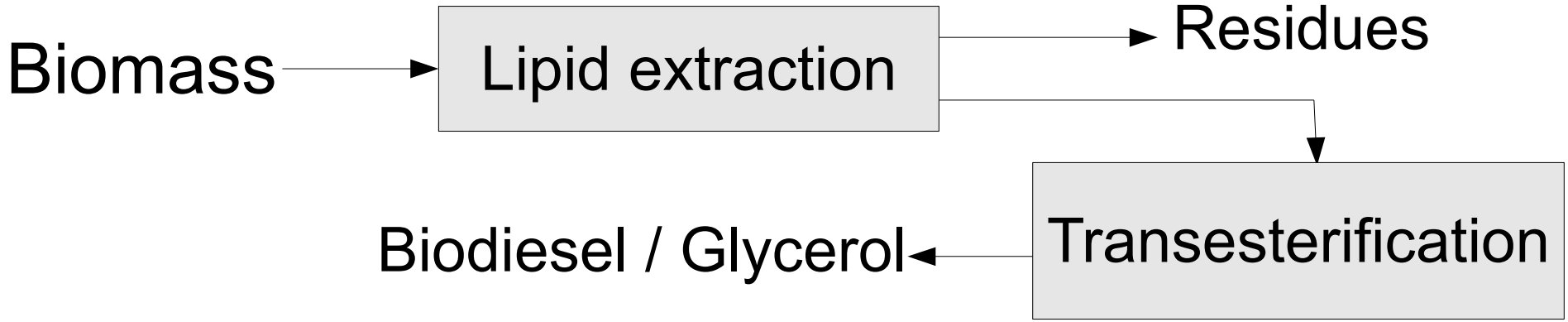
Choice of acid or alkaline catalysts for the transesterification process is mainly dependent on the oil purity and free fatty acid (FFA) content*

	Alkali catalysis	**Acidic Catalysis**
Water Content	Anhydrous Oil	Allows for moisture
FFA content	< 0.5 % w/w	> 2% w/w

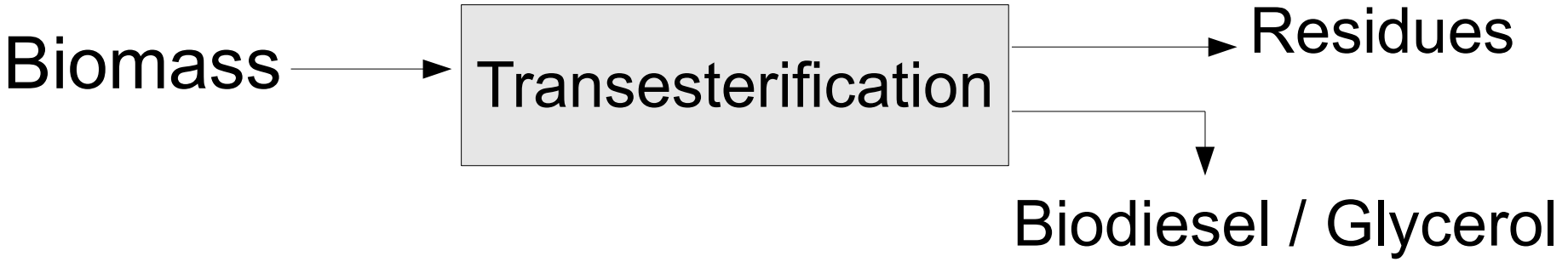
* Al-Zuhair (2007). Biofuels, Bioprod & Biorefining 1:57

Acidic Catalysed Routes

Conventional process:



In-situ process:



Merits of the In-situ Process?

- Process simplification
- Improved product yield
- Process waste reduction
- Reduced energy and material demand
- Improved Process economics

Biomass Feedstock

Microalgae considered as the study feedstock

- Increasing interest for biofuel applications
- Non-requirement of arable land
- Characteristic high FFA lipid content

Process Assumptions

- Biodiesel plant with production capacity of 8000MT biodiesel/annum.
- Microalgae biomass (*Chlorella*) assumed to be completely dried & contaminant free.
- Triolein and oleic acid alone are used as the representative glyceride and fatty acid of the microalgae lipids.
- Sulphuric acid (H_2SO_4) as the process catalyst.

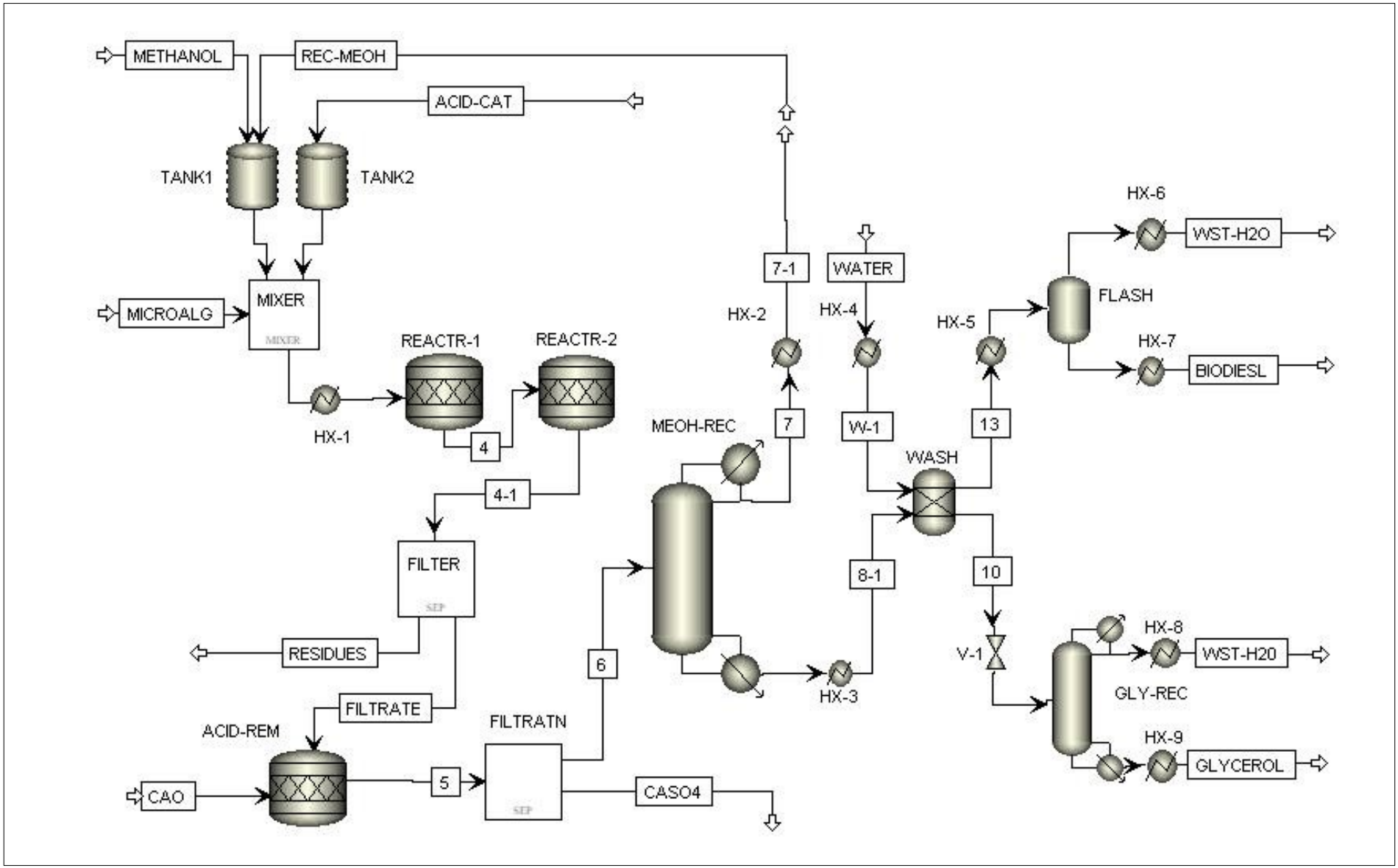
Modelling Tools

- The process simulation software Aspen Plus® version 11.1.1 was used in the design of the reaction separation units of the industrial scaled transesterification process.
- Reaction inputs & process assumptions based on results from laboratory experiments, literature as well as industrial practices.

In-situ Process Assumptions

- Microalgae contains 26.7% lipids with FFA content of 2.8% w/w.
- Molar ratio of reacting methanol to oil 340:1
- Molar ratio of H_2SO_4 catalyst to oil 1:1
- 90% conversion efficiency of microalgae oil to biodiesel at 60°C and 1 bar and a reaction time of 4 h

In-situ Process Flowsheet



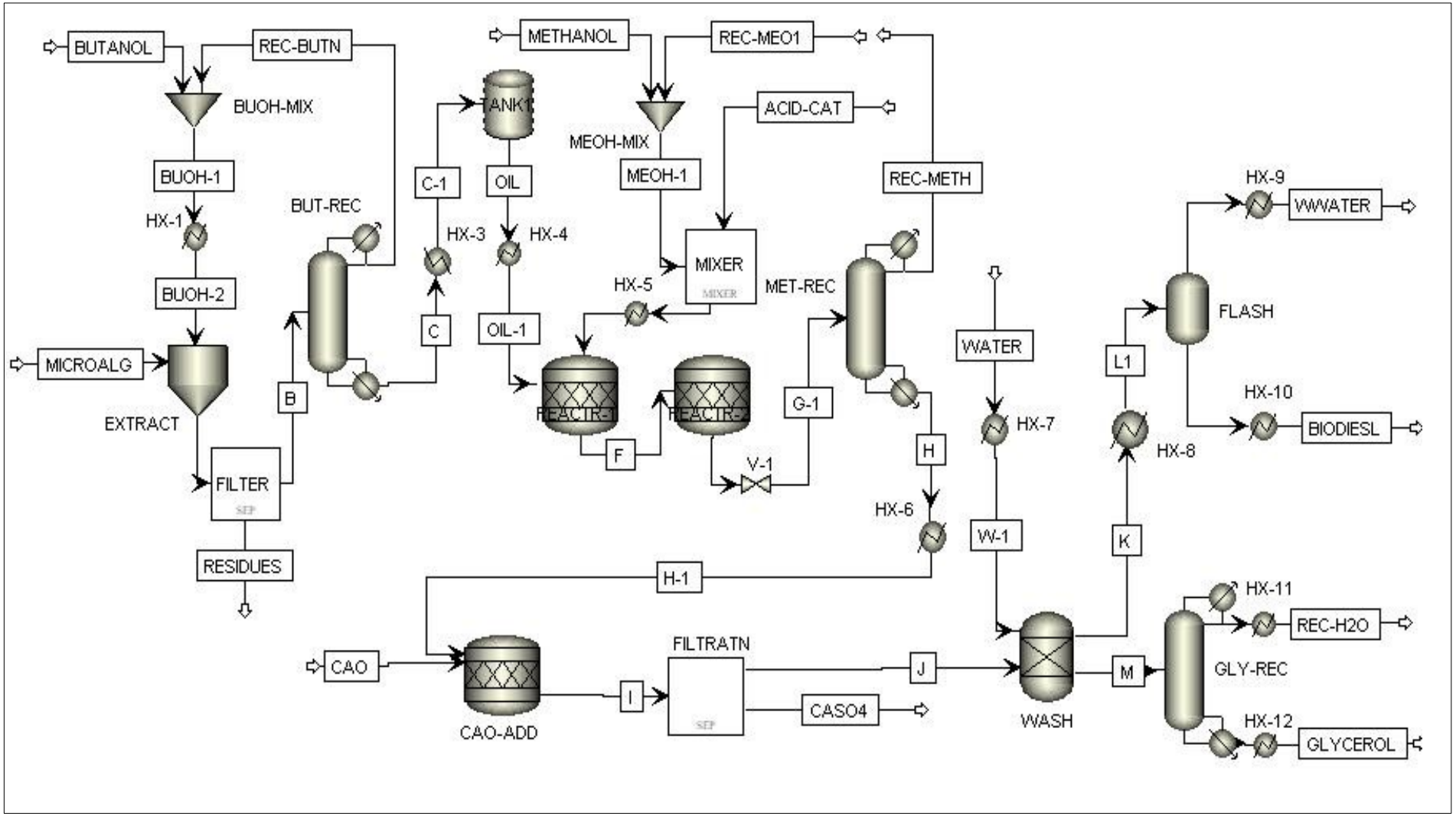
The conventional acid catalysed transesterification process was also simulated in this study to provide a suitable comparison means for the investigation of the discussed merits of the use of the in-situ process.

Conventional Process Assumptions

- Oil extraction step with butanol
- Molar ratio of reacting methanol to oil 50:1*
- 97% conversion efficiency of biomass oil to biodiesel at 60°C and 4 bar with a reaction time of 4 h*

*Zhang et al (2003) Bioresour. Technol. 89:1

Conventional Process Flowsheet



Process Model Results

The in-situ route can be observed to lead to a simplification of the process due to reduced processing steps.

Improvement in the biodiesel production rates compared to the conventional process:1169 kg/h and 1062 kg/h for the in-situ & conventional methods respectively.

Operational Time

A reduction in the operational time was demonstrated via the in situ method over the conventional.

Operational Time for 8000MT biodiesel prod. (h)	
In-Situ	Conventional
6845	7536

Energy Requirements

The minimum process heat and cooling external demands were determined after considering the maximum energy recovery from the hot and cold process streams (using pinch analysis).

Transesterification method	Hot Utility (before integration) kW	Cold Utility (before integration) kW	Minimum Hot Utility (after integration) kW	Minimum Cold Utility (after integration) kW
In-situ	5920	5899	5266	5245
Conventional	2648	2628	2317	2312

Process Material Demands

The input H_2SO_4 as well as CaO were not considered for this analysis since equal amounts were utilised for both processes.

	Transesterification process	
	In-situ	Conventional
	Raw materials annual consumption (MT)	Raw materials annual consumption (MT)
Butanol	-	76.82
Methanol	2260.85	872.79
Water	1601.73	1559.95

Conclusions

The use of the in-situ transesterification method although leading to a reduction in the processing steps and improvement in the biodiesel yields over the conventional process (as discussed by Haas et al. 2007) however has the accompanying demerit of an increased energy and material consumption.

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