Biofuels production from solid waste microbial oils and from pre-treated waste cooking oils

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The aim of the current research is to compare the biofuel production from two different bio-based feedstocks. The first feedstock is microbial oil produced via syngas fermentation of biogenic solid residues. Biogenic solid residues and wastes were gasified and the syngas was fermented to produce bio-based triacylglycerides (TAGs). Bio-fuels were produced via TAG hydrotreatment. The overall process, combining thermochemical, biological and thermocatalytic parts is based on the gasification of biomass and other biogenic waste in a Dual Fluidized Bed gasifier and the 2-stage fermentation of the produced syngas. Through this process the syngas is converted to acetate (1^{st} stage) and then the acetate is converted to TAGs (2^{nd} stage). The produced TAGs contained medium and long fatty acids were hydrotreated and isomerized after the necessary separation and purification and the end-products are jet- and bunker-like biofuels, respectively.

The second feedstock concerns pre-treated waste cooking oils. Waste cooking oils from restaurant and households were collected and after a mild pre-treated with the use of NaOH and centrifugation were hydrotreated and isomerized targeting gasoline, jet and bunker-like fuels. The aim of the current work is to compare the quality of the produced biofuels from the two different lipid-based feedstocks.

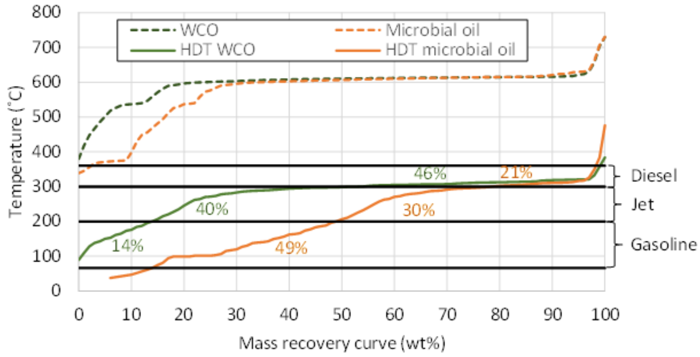
All hydrotreated experiments were performed in a small-scale pilot plant TRL 3 of CERTH. This TRL 3 pilot plant is a small industrial system which is operated to generate information about the behaviour of the system for use in design of larger facilities. The main target was to investigate the effect of the key hydrotreating parameters (Temperature, pressure, LHSV and H_2/oil ratio) during the upgrading of both lipids in terms of product quality and catalyst performance. The examined operating window for each feedstock is presented in the following table 1 via five conditions.

For the aim of the current investigation, four commercial catalysts were loaded on the reactor. The first catalyst, target to remove the heteroatoms of oxygen, sulphur and nitrogen, the second catalyst is specialized on saturation and hydrodeoxygenation reactions, the third catalyst is an isomerization and dewaxing catalyst while the fourth catalyst is specialized on hydrocracking reactions.

Table 1 Operating parameters examined for each feedstock

Parameters	Units	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5
Microbial oil						
Pressure	psi	2000	2000	2000	2000	1500
Temperature	°C	390	390	370	370	370
H2/oil ratio	scfb	5000	5000	5000	5000	5000
LHSV	hr^{-1}	0.5	1	1	0.5	0.5
Waste cooking oil						
Pressure	psi	1500	1500	1500	2000	2000
Temperature	°C	330	360	360	390	390
H2/oil ratio	scfb	5000	5000	5000	5000	5000
LHSV	hr^{-1}	1	1	0.5	0.5	0.33

The mass recovery curve from both feedstocks is shown in figure 1 while the properties from the two feedstocks are presented in table 2. According to the properties the two feedstocks looks almost similar, however by observing the distillation curves, the WCO consists of heavier hydrocarbons compared to microbial oil. For comparison reasons, the distillation curve from the product of condition 1 for microbial oil and from condition 4 from the WCO hydrogenation are also presented in figure 1 as these two conditions are identical. The results show that in case of WCO the hydrotreated product consists of 14 wt% gasoline, 40 wt% jet and 46 wt% diesel range hydrocarbons, while the hydrotreated product from microbial oil consists of 49 wt% gasoline, 30 wt% jet and 21 wt% diesel range hydrocarbons. It is easily observed that on the same operating window the microbial oil can lead to more lighter hydrocarbons in gasoline range compared to WCO. The reason is different the fatty acid composition of the oils. Figure 2 presents the fatty acid composition of both waste cooking oil and microbial oil. As it is observed, the WCO contains less palmitic acids (C16:0) which have no double bonds and more linoleic acids (C18:2) that have double bonds compared to the microbial oil. As WCO consists from more double bonds compared to microbial oil, it is more difficult to brake the molecules and produce light hydrocarbons, thus the microbial oil after hydrogenation can lead to higher gasoline yields compared to WCO.



Properties	WCO	Microbial Oil
Density at 60°C (g/ml)	0.894	0.884
S (wppm)	523	863.3
N (wppm)	46	81.7
H (wt%)	11.6	11.9
C (wt%)	77.4	76.7
Viscosity (cSt)	42.6	32.1
HHV (MJ/kg)	46.0	40.7
Water dissolved (wt%)	0.06	0.37

Figure 1 presents the mass recovery curve from both feeds and from the products of cond. 1 for microbial oil and from cond. 4 for WCO. Table 2 presents the properties from both feedstocks

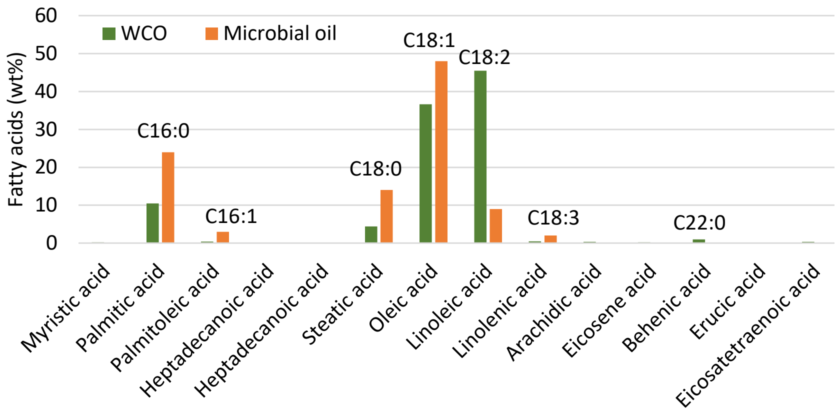


Figure 2 fatty acids composition of waste cooking oil and microbial oil

From the five operating conditions that were investigated, in case of WCO the optimum condition is cond. No. 5 leading to 30 wt% gasoline, 26 wt% jet and 44 wt% diesel range hydrocarbons with an average hydrogen consumption. In case of microbial oil, the optimum condition is No. 3 because it is characterized by high jet and diesel yields (33 and 64 wt% respectively), and average hydrogen consumption. In general, it was found that the fatty acid composition of the initial oil strongly influences the product yields. More specifically the more double and triple bonds contained in the feedstocks the heavier the resulting product is.

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References

1. S. Bezergianni, A. Kalogianni, A. Dimitriadis. Catalyst evaluation for waste cooking oil hydroprocessing. Fuel 93 (2012) 638–641
2. S. Bezergianni, A. Dimitriadis, G. Meletidis. Effectiveness of CoMo and NiMo on Co-Hydroprocessing Heavy Atmospheric Gas Oil-Waste Cooking Oil Mixtures. Fuel, volume125, Pages 129-136. 2014.