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Assessment of the production of biodiesel from urban wastewater-derived lipids

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Abstract: By adopting a Circular Economy Package in 2015, European Commission aimed at stimulating transition towards a stronger and more circular economy where waste (including sewage) is no longer recognized as waste, but as a valuable resource of raw materials. This review study assesses the existing methodologies to produce biodiesel from wastewater-derived lipids. Depending on the stage of wastewater treatment where biodiesel would be extracted, it may cover up to 20% of the current European biodiesel demand. Further studies in regards to the biodiesel quality, legislative conditions and techno-economic assessment towards respective transition are needed.
Keywords: Wastewater derived lipids; biodiesel; wastewater valorization

1. Introduction

Due to growing population and increasing prosperity, resources are getting scarce and the necessity for efficient reuse of raw materials increases. Production of biodiesel will remain one of the most important European targets in terms of renewables in transport fuels for future (1).

Industrially today, biodiesel (fatty acid methyl esters; FAMEs) is produced by processing vegetable oil or animal fat. These feedstocks are expensive and to some extent part of the ongoing food vs. fuel discussion. The current recovery and reuse of wastewater-derived lipids (fat, oil, grease; FOG) is limited to biogas production in digesters. The residual (majority) of the lipid potential in sewage is currently not utilized, it is dissolved and gets partially degraded or is being disposed (incineration or deposition in landfill), which brings additional cost to the wastewater treatment plants (WWTPs).

Biodiesel processes commonly use base-catalysed transesterification, where triacylglycerol reacts with 3 molecules of methanol to form three FAME molecules (2) it requires low operating temperature achieving high conversion within couple of hours. However, if the free fatty acid content exceeds 1%, acid-catalyzed transesterification takes place. Although it is much slower, it prevents soaps formation hindering otherwise transesterification and downstream purification (3). Generally, highly unsaturated fats are expected to be more prone to oxidation, hydrolysis and lower gel formation than their saturated counterparts. Longer saturated fatty acids are excellent for biodiesel production, whereas unsaturated fatty acids are great for cold weather biodiesel production, therefore mixture is desirable (4).

2. Materials and methods

Articles reporting biodiesel extraction from urban wastewaters were reviewed (5–14). It is important to highlight the scarcity of literature presenting both the biodiesel yield and its acid composition. The maximum extraction yields at different stages of wastewater treatment were compared. The assessment of potential supply by biodiesel from urban wastewater-derived lipids was calculated based on facts that i) 30-40% of COD (120 g/d/PE) in urban wastewater influent is FOG (15), ii) population number (EU-28) in 2018 was estimated to 512,710,966 (16), iii) 80% of population (EU-15) is connected to WWTPs (17), and iv) considering the average possible biodiesel production at different stages of wastewater treatment.

3. Results and conclusions

As lipids are readily removed by mixed microbial populations in WWTPs, total FAME yield showed decreasing trend along the treatments: almost 60% originated from EWC (sludge from oil-water separator, considered as hazardous material), 9-15% primary sludge, 6-23% scum from floatation tank, and 0.5-6% from the secondary sludge. At the first glance, fatty acid composition collected from various WWTPs in different countries and stages of treatment did not propose a substantial difference; the content of palmitic (C16:0) and oleic acid (C18:1) were maximal, with stearic (C18:0) and palmitoleic acid (C16:1) behind. However, analysis of variance revealed the type of wastewater, meaning the stage of treatment samples were taken, to be highly significant for some acids (Figure 3.1).

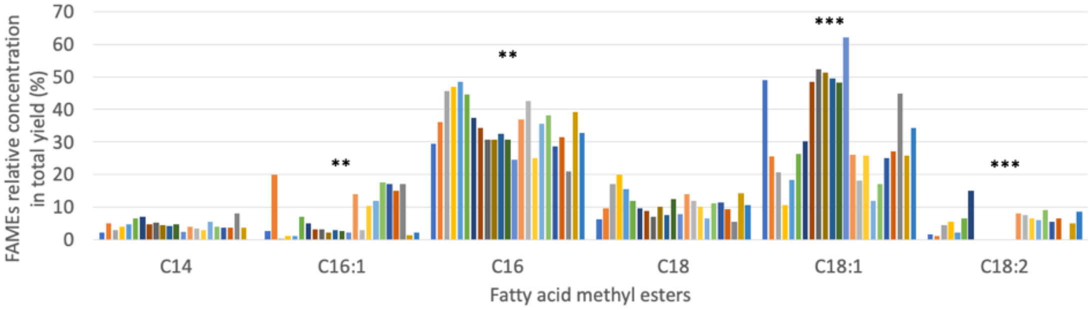

Figure 3.1 Composition of fatty acids in total FAMEs yield in samples collected at different stages of urban wastewater treatment (EWC from oil-water separator, primary sludge, scum and secondary sludge, 1., 2.-3., 4.-10., 11.-16. column respectively). ANOVA significance levels <0.01 and <0.001 are depicted with two and three asterisks, respectively.

The assessment results on potential annual market supply indicated 2.6 – 310.4 10^4 tons (min for secondary and max for EWC sludge) of extractable biodiesel from wastewater. Considering the expected biodiesel demand 14.8 10^6 tons (18), and prospect to transform WWTPs into biorefineries, we may cover in average by 1.2, 5.3, 4.4 and 20.9% (from secondary, scum, primary and EWC sludge, respectively) the European biodiesel market from the wastewater-derived lipids. Such amount cannot be ignored, and if efficiently implemented, it could represent an exploitable resource for biofuel production, an important and desired step towards the circular economy (19, 20).

This study addresses challenges and potential of transition in the urban water cycle; from a linear approach where drinking water is produced, consumed and discharged as wastewater, to a circular approach where lipids are recovered from WW and used as bio-based products. The circular use of raw materials from wastewater demands from the WWTP operators a different way of thinking and working. Within the Interreg-NWE WOW! project (12 partners from 6 countries) we are trying to optimize recovery of carbon-based products and scaling up to real conditions (supported by pilot-plant investigations), equally important is to involve the industry and market parties to use recovered material for bio-based products.

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