Solid waste biomass as a potential feedstock for sustainable aviation fuel production

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Presentation Outline

- Introduction
- Purpose
- Research method
- Results and discussion
- Conclusions
Aviation sector:

• Contributes approximately 2% of total CO$_2$ emissions.

• **Sustainable Aviation Fuels (SAF)** will play a key role for early reductions of CO$_2$ emissions by 2030 and deeper reductions by 2050.

• **Non-edible** feedstocks comprise favorable choice and include municipal solid waste (MSW) and forestry residues.

• The **price** of biojet fuel depends on feedstock cost, availability, conventional jet fuels’ price volatility and commercialization feasibility of production technologies.
Introduction

SAF pathways

**FT**
- ASTM Certified 2009
- Blend limit: 50%

**HEFA**
- ASTM Certified 2011
- Blend limit: 50%

**SIP**
- ASTM Certified 2014
- Blend limit: 10%

**Co-processing**
- Lipids:
  - ASTM Certified: 2018
  - Blend limit: 5%
  - FT-liquids
  - ASTM Certified: 2020
  - Blend limit: 5%

**SPK/A**
- ASTM Certified 2015
- Blend limit: 50%

**CHJ**
- ASTM Certified 2020
- Blend limit: 50%

**HC-HEFA**
- ASTM Certified 2020
- Blend limit: 10%

**ATJ**
- ASTM Certified 2016 (isobutanol)
- Blend limit: 50%
- 2018 (ethanol)
- Blend limit: 50%

**Figure 1.** ASTM approved pathways for SAF production (IRENA, Reaching Zero with Renewables: Biojet fuels, 2021).
Purpose

- Investigation of the potential of SAF production from waste materials.
- Waste materials: MSW including food waste and waste cooking oils, plastic waste as well as agricultural and forestry residues.
- Current conversion technologies based on recent literature data.

Research method

- Systematic review by using PRISMA analysis.
## Results

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Conversion method</th>
<th>Reaction conditions</th>
<th>Obtained biofuels</th>
<th>Highlights</th>
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</thead>
</table>
| Food waste/WCO | **Hydroprocessing** | Hydroprocessing reactor  
- Temperature: 400 °C  
- Pressure: 6.07 MPa  
- H₂/oil molar ratio: 450 v/v  
- Catalyst: DHC-8 commercial Hydroisomerization reactor  
- Pressure: 8.1 MPa  
- Temperature: 480 °C  
- Catalyst: Pt/amorphous SiO₂-Al₂O₃ | Biojet  
- Yield: 47.46% | Thermally coupled distillation columns resulted in 22% of CO₂ emissions and 33% of utilities cost reduction. |
| Hydrotreated paraffins from WCO | **Hydrocracking/ Hydro-isomerization** |  
- Temperature: 380 °C  
- Pressure: 4 MPa  
- H₂/alkane molar ratio: 13.6  
- Catalyst: NiAg/SAPO-11 (5 g)  
- Time: 2.5 h | Biojet  
- Yield: 54%  
- Selectivity: 67%  
- Main components: C₁₅⁻C₁₈ alkanes | Relative poor cold flow properties.  
Catalyst performed excellent isomerization and medium cracking properties. |
| Waste oil with high viscosity | **Catalytic cracking and hydrogenation/aromatization** | Catalytic cracking  
- Base catalyst: Na₂CO₃ (100 g)  
- Amount of feedstock: 2 kg  
- Temperature increasing rate: 10°C/min  
- Column temperature: 280 °C  
- Hydrogenation  
- Catalyst: Ni/ZSM-5 | Biojet  
- Yield: up to 60%  
- Biodiesel  
- Yield: 15-30% | Two-step conversion is efficient for low quality triglycerides.  
Diesel fraction can also be obtained by adjusting operating parameters. |

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Table 1. Various waste materials as feedstock for biofuel and biojet fuel production [3-10].

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Table 1. Various waste materials as feedstock for biofuel and biojet fuel production [3-11].

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<td>Food waste/WCO</td>
<td>Catalytic cracking and aromatization and hydrogenation</td>
<td>Catalytic cracking Base catalyst: Na₂CO₃ (5 wt. %) Amount of feedstock: 1500 g Pyrolysis temperature: 350 – 450 °C Aromatization 80 g distilled aviation fuel Catalyst: HZSM-5 (5 wt. %) Temperature: 350 °C Time: 6 h Hydrogenation Catalyst: Pd/AC (5 wt. %)</td>
<td>Liquid hydrocarbons Yield: 76 ± 1.0% Biojet Yield: 29.5 ± 1.9 %</td>
<td>Biojet fuel presented similar properties to fossil based aviation fuels. The freezing point was found -48 °C indicating good fluidity in low temperature. During catalytic cracking biodiesel can also be produced.</td>
</tr>
<tr>
<td>Food waste, sewage sludge, blend of food waste and fats</td>
<td>Hydrothermal liquefaction and hydrotreatment</td>
<td>Hydrothermal liquefaction of bio-crude Catalysts: sulfided NiMo and CoMo</td>
<td>Biojet Yield: 65%</td>
<td>Carbon content increased &gt;11%. Oxygen content of bio-crude reduced &gt;90% Drawback: High nitrogen content after upgrading.</td>
</tr>
<tr>
<td>Agricultural wastes and waste frying oil</td>
<td>Pyrolysis and catalytic hydrogenation</td>
<td>Amount of feedstock: 300 g Heating rate: 20 °C min⁻¹ Temperature: 850 °C Catalyst: NiMo (200 g) 1Hydrogen pumping rate: 10 mL min⁻¹ Hydrogenation temperature: 450 °C</td>
<td>Pyrolysis oil Yield: 54% Hydrogenated bio-oil aliphatic hydrocarbons: 21% aromatics: 25% cyclic hydrocarbons: 16%</td>
<td>After hydrogenation, more than 60% of oxygenates and 12% of nitrogen compounds were removed. Hydrogenated bio-oil exhibited similar properties with conventional jet fuel.</td>
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Results

Table 1. Various waste materials as feedstock for biofuel and biojet fuel production [3-12].

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| Polystyrene (PS) waste | Thermal liquefaction and fractional distillation | Amount of feedstock: 750 mg  
Temperature: 100 – 400°C | Biojet  
Yield: 23%  
Main components  
C₆ to C₁₆ | Aromatic and aliphatic compounds in produced fuels.  
Further modification is required for commercial use. |
| Waste plastics (PE,PP,PS,PET) | Catalytic pyrolysis and fractional distillation | Catalyst: graphite  
Temperature: 350 °C – 450 °C | Biojet  
Yield: 80% | Chemical properties of biojet fuel were comparable to aviation jet fuel. |
| Waste plastic LDPE | Catalytic hydrocracking | Catalyst: Pt/Al/MCM-48 (1 wt. %)  
Hydrogen pressure: 4 MPa  
Temperature: 573 K  
Time: 4 h | Main components  
C₉–C₁₅  
Biojet  
Yield: 85.9% | Catalytic performance was not reduced after four cycles. |
| Plastic waste (PE,PP) and agricultural biomass | Co-gasification-FT synthesis and upgrading | Overall process included 6 units. | Biofuels yield  
13.06%  
Biojet  
Mass distribution:  
41.8%  
Output: 1697.45 kg/h | Plastic addition to biomass improved the volatility of mixture.  
Biojet fuel emissions: 20.14 g CO₂eq/MJ  
Minimum selling price: 1.37 €/L.  
Heat exchanger network reduced total cost of GFT synthesis. |
Discussion

- **Utilization of biomass waste materials** as feedstocks for SAF production is of great significance for future demands as well as for cost minimization and environmental protection.

- **To date**, the majority of aviation biofuels is produced from **oleochemical/lipid feedstocks** such as vegetable oils and bio-wastes.

- Obtained biofuels have the **potential** to be considered as drop-in jet fuels and used as blends with conventional jet fuels in aircraft engines without any further modification.

- Catalytic hydrogenation or **HEFA pathway** is a promising method for WCOs conversion into SAF, nonetheless pretreatment, including filtration and cleaning are still required.
Discussion

• **Agricultural wastes** are still *underutilized* as an alternative feedstock for biofuels and value added chemicals production.

• **Lignocellulosic residues** could contribute to sustainable biojet fuel production.

• **Thermal processes** can be used to convert plastics into hydrocarbon fuels which have unlimited applications in airline industries, as well as in transportation and power generation industries.

• **Co-pyrolysis** of plastic waste and biomass-based materials serves as a *promising way* to convert wastes into value added products and biofuels with high product yields and quality.
Conclusions

• **HEFA pathway** for oleochemical feedstocks will continue to dominate in near future.

• **Waste-biomass feedstocks** can contribute to scale up the production of biojet fuels.

• **Thermochemical methods** for lignocellulose-based waste materials present also high potential to contribute in global biojet fuel production.

• **Ongoing challenges** for SAF production through advanced methods are closely related to feedstock availability, high production cost and lack of policy support.


Thank you for your attention