

HTL of Wheat Straw and Biocrude Refinement for Petroleum Compatibility

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The growing global demand for sustainable energy solutions has accelerated interest in converting biomass into renewable fuels. Among various biomass conversion methods, hydrothermal liquefaction (HTL) has emerged as a promising technology due to its ability to process wet feedstocks like agricultural residues, algae, and sewage sludge without the need for energy-intensive drying. HTL operates under moderate temperatures and high pressures to produce biocrude, a potential substitute for fossil fuels. Wheat straw, a lignocellulosic agricultural by-product, represents an abundant and low-cost feedstock with significant potential for biofuel production. However, raw HTL biocrude often exhibits challenges such as high oxygen content, poor stability, and limited compatibility with petroleum-derived fuels. Addressing these limitations, upgrading through hydrotreatment plays a pivotal role in improving biocrude properties, enhancing its miscibility with refinery streams, and enabling its integration into existing fuel infrastructure. This study investigates the conversion of wheat straw to biocrude via HTL, optimizing the process conditions to maximize yield and quality, and explores hydrotreatment as a critical step for producing a refinery-compatible intermediate product. The potential valorization of crude glycerol was also examined in the HTL in an attempt to reduce wastes from the biodiesel refineries.

Experiments determined that optimal HTL conditions include a temperature of 300°C (from 4 sets of temperature in the range of 280 – 350°C), a residence time of 20 minutes, and a crude glycerol-to-straw ratio of 50%. Crude glycerol, a by-product of biodiesel production, was utilized as a co-feedstock to enhance the process efficiency and align with zero-waste principles. The presence of glycerol improved the liquefaction of lignin, a major component of wheat straw, leading to a biocrude yield of 36.65 wt.% and a more fluid product with reduced viscosity, which is advantageous for downstream processing. This approach also valorized a waste stream, further contributing to the sustainability of the process.

Despite these advancements, raw HTL biocrude exhibits inherent limitations that hinder its direct application as a transportation fuel. Its high oxygen and heteroatom content result in poor miscibility with petroleum fractions, low stability during storage, and suboptimal fuel properties. To address these challenges, hydrotreatment was employed as an upgrading step. The process was conducted in a continuous-flow reactor using a NiMo/Al₂O₃ catalyst under optimized conditions of 360°C and a hydrogen-to-oil ratio of 5000 scfb. This step effectively removed oxygen and sulfur, transforming the biocrude into a highly paraffinic product with a significantly improved higher heating value (HHV) of 45.86 MJ/kg.

Hydrotreatment not only improved the fuel properties but also enhanced the miscibility of the biocrude with refinery streams such as atmospheric gas oil (AGO), light vacuum gas oil (LVGO), and light cycle oil (LCO). These refinery-compatible blends exhibited homogeneity without phase separation, demonstrating the potential for co-processing the upgraded biocrude with fossil fuels. Additionally, storage stability studies revealed that hydrotreated biocrude maintained its chemical integrity over extended periods, with minimal changes in key parameters such as acidity, water content, and density. This stability further underscores its viability for long-term storage and transportation. On the contrary, the analysis on the raw biocrude showed that it had significant limitations both in storage stability and miscibility with the aforementioned petroleum fractions.

Therefore, by combining optimized HTL conditions with hydrotreatment, this study highlights the potential of integrating biocrude derived from wheat straw into existing petroleum refinery infrastructure. This approach not only offers a pathway to reduce dependency on fossil fuels but also leverages agricultural residues to create a sustainable energy source. The findings demonstrate that HTL and subsequent upgrading represent a viable strategy for producing high-quality biofuels, supporting the global transition toward renewable energy and circular economy principles. In Figure 1, the holistic approach of the study is presented in a general chart along with the major conclusions drawn by the conducted analyses.

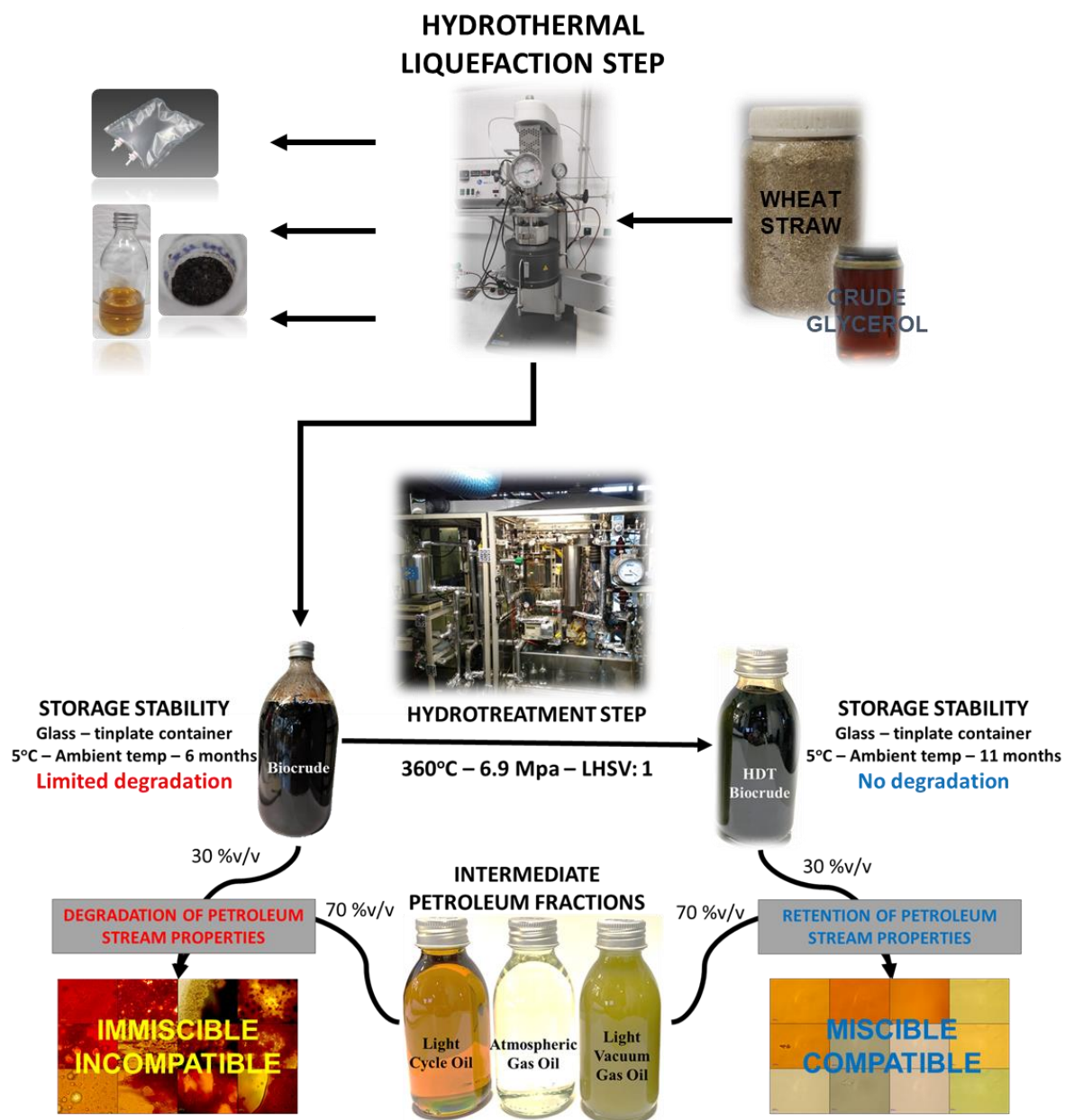


Figure 1. Process flow and conducted analyses