Supercritical Water Gasification of Mediterranean Biomasses Residues for Sustainable Fuel Gas Production

Cosenza A.[1], Scaturro M.[1], Tumminelli G.[2], Rizzo R.[2], Tuzzolino G.[2], Gattuso C.[2], Caputo G.[1]
[1]Dipartiment of Engineering, University of Palermo, 90128 Palermo, Italy.
[2] Qohelet Solar Italia S.p.A., Corso Umberto I, n. 211, 93100 Caltanissetta, Italy.

In this study different biomasses were characterized and studied for their valorization through syngas production via supercritical water gasification.
The continuous growth of the global population is placing increasing pressure on natural resources and ecosystems. Sustainable management of organic wastes is crucial for mitigating the environmental impacts of human activities by converting biomass and waste streams into cleaner energy carriers, including fuels, heat, electricity, and organic fertilizers. Supercritical water gasification (SCWG) offers distinct advantages over conventional thermochemical technologies by enabling direct processing of wet biomass feedstocks without energy-intensive drying and the conversion of organic matter into gaseous products in water at conditions above its critical point (374 °C and 22.1 MPa). Under these supercritical conditions, water exhibits reduced density and viscosity, which enhance mass transfer and limit transport constraints, while high temperatures accelerate reaction kinetics and promote the decomposition of complex organic compounds into lighter species. As a result, the process produces a syngas that can be effectively utilized as a fuel. To reduce the operational costs associated with gasification, the Sicilian project SUNGAS proposes the integration of Fresnel solar collectors to harness solar thermal energy. These collectors consist of a series of linear heliostats installed close to the ground, which rotate along their longitudinal axis to track the sun's movement. The mirrors reflect and concentrate solar radiation onto a thermally insulated receiver tube positioned approximately ten meters above ground level.
A lab-scale experimental campaign was carried out to mimic the operative condition of the SUNGAS process and preliminarily investigate the gasification of four different organic-contaminated wastewaters. The feedstocks were chosen among regionally relevant Mediterranean waste-derived wastes produced in Sicily (Italy): olive mill wastewater (OMW), olive leaf washing water (OLW), prickly pear cladode washing water (PPCW), and the organic fraction of municipal solid waste (OFMSW). Experiments were performed in a 200 mL tubular reactor operated in continuous mode at 420 °C, where the feedstocks were supplied as aqueous slurries and the produced gas was collected and analyzed. OMW and PPCW achieved the highest gas yields of approximately 50 wt% (dry basis) at 180 s residence time, demonstrating superior gasification performance under the investigated conditions. The resulting syngas exhibited hydrogen concentrations exceeding 55 vol% and methane concentrations up to 6.5 vol%, yielding a fuel gas with significant calorific value and potential for energy recovery applications.
These findings confirm the technical feasibility of solar-driven SCWG for the valorization of regionally abundant Mediterranean agricultural and municipal waste streams, providing the dual benefit of waste treatment and renewable fuel production while mitigating the environmental impacts associated with hazardous effluents.

The present work was carried out within the framework of the "SUNGAS" project, Action 1.1.5 of the P.O. F.E.S.R. Sicily 2014-2020.