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Clean solid biofuel production from high moisture content waste biomass employing hydrothermal treatment

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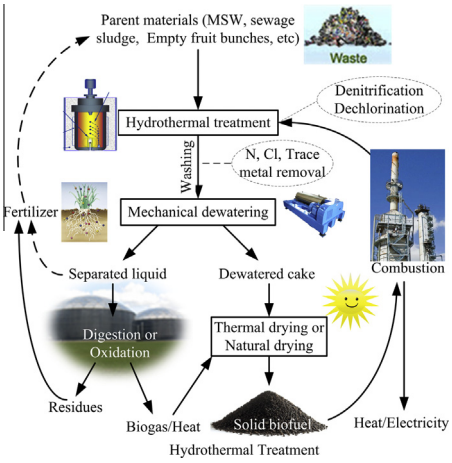
HIGHLIGHTS

- Clean solid biofuel was produced from wet waste biomass by hydrothermal treatment.
- Waste biomass resources and fuel production processes were discussed.
- The upgrading, dechlorination, denitrification, and coalification was illustrated.
- Fuel combustion performances, energy and mass balances and economics were reviewed.
- The newest results and perspectives for further developments were discussed.

GRAPHICAL ABSTRACT



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ABSTRACT

Our society currently faces three challenges, including resource depletion, waste accumulation and environmental degradation, leading to rapidly escalating raw material costs and increasingly expensive and restrictive waste disposal legislation. This work aims to produce clean solid biofuel from high moisture content waste biomass (bio-waste) with high nitrogen (N)/chlorine (Cl) content by mild hydrothermal (HT) conversion processes. The newest results are summarized and discussed in terms of the mechanical dewatering and upgrading, dechlorination, denitrification and coalification resulting from the HT pretreatment. Moreover, both the mono-combustion and co-combustion characteristics of the solid fuel are reviewed by concentrating on the pollutants emission control, especially the NO emission properties. In addition, the feasibility of this HT solid biofuel production process is also discussed in terms of "Energy Balance and economic viability". As an alternative to dry combustion/dry pyrolysis/co-combustion, the HT process, combining the dehydration and decarboxylation of a biomass to raise its carbon content aiming to achieve a higher calorific value, opens up the field of potential feedstock for lignite-like solid biofuel production from a wide range of nontraditional renewable and plentiful wet agricultural residues,

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sludge and municipal wastes. It would contribute to a wider application of HT pretreatment bio-wastes for safe disposal and energy recycling.

Contents

1. Introduction

Until now, the fossil fuel, which is regarded as non-renewable and the main energy source all over the world, is diminishing fast [1,2]. At the same time, the worldwide fuel demand keeps increasing dramatically (29.75 billion barrels oil in 2011 and projected to be 34.90 billion barrels in 2030 [3]) and correspondingly the fossil fuel reserve (about 1653 billion barrels oil at the end of 2011 [3]) decrease rapidly [4,5]. These historical and anticipated increases in primary energy consumption have amplified concerns about the environmental consequences of continued fossil fuel extraction and use [6]. Therefore, more and more attention has been given to extract energy from the alternative cheap and renewable energy resources with little or no environmental impact [7]. The status/challenge of energy demand, development of the renewable energy and environment of the global and some specific countries or region have been summarized by many researchers, including Dincer [8], Kaygusuz [9], Omer [10], Asif [11], Panwar et al. [12], Bugaje [13], Chang et al. [14], Budzianowski [15–17], etc. They clearly show that among renewable energy, biomass energy seems to be one of the most efficient and effective solutions to energy shortage and some energy-related problem, e.g. CO_2 emission reduction because of its carbon–neutral nature.

However, the heterogeneity of biomass causes difficulties in energy recovery technologies such as anaerobic digestion and combustion [18]. Direct combustion and co-combustion of biomass with low rank coals is widely accepted as less risky, less expensive, time-saving options to utilize biomass energy [19]. Several experts indicated that direct combustion is not so satisfying because of some inherent drawbacks of biomass, including the high moisture and oxygen contents, and high alkaline earth metal content [19–21]. Moreover, biomass are always of low bulk densities ($\sim$150 kg/m^3), which accounts for its low volume-based heating value, requirement of huge storage, expensive transportation, feeding control [19]. On the other hand, the intensified use of biomass from crops is limited because the finite agricultural land would generate competition between food supply and bioenergy production [22–24], finally resulting in increasing in food prices or even food shortage [18]. Therefore, comprehensively considering the challenges–resource depletion, waste accumulation and environmental degradation, energy recycling from biomass waste (bio-waste) has received more and more attractive recently because it provides a large volume reduction, hazard reduction, and heavy metals controlling and the release of the environmental burden. Just taking sewage sludge as an example, the publications related on sewage sludge utilization have been grown exponentially in Elsevier from 2000 (S1) [264].

These wastes are generally generated from industrial activities such as sewage sludge from wastewater treatment plants, mycelia wastes from medicine production, empty fruit bunches (EFB) from the production of palm oil, and distilled spirits lees from beverage production or agricultural residual such as driftwood, or material from households, like kitchen residues and garden cuts [18,25], as well as waste from municipal, including the municipal solid waste (MSW), hospital wastes. However, these bio-wastes are usually of high moisture content (around 56 wt.% for MSW and 80 wt.% for sewage sludge), high nitrogen (N) (e.g. sewage sludge: 1.0–10.0 wt.% at dry basis (db) [26–31]; mycelial waste: 2.0–9.0 wt.%