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A kinetic study of pyrolysis and combustion of microalgae *Chlorella vulgaris* using thermo-gravimetric analysis

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HIGHLIGHTS

- ▶ Pyrolysis and combustion kinetics of *Chlorella vulgaris* are studied using TGA.
- ▶ 2nd stage of decomposition consisting of 2 subzones is the stage of devolatization.
- ▶ Combustion produces higher biomass conversion than pyrolysis due to O_2 reactivity.
- ▶ Kinetics are obtained using iso-conversional and regression methods.
- ▶ Higher energy is required for lipid decomposition than proteins and carbohydrates.

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ABSTRACT

This work uses thermo-gravimetric, differential thermo-gravimetric and differential thermal analyses to evaluate the kinetics of pyrolysis (in inert/N_2 atmosphere) and (oxidative) combustion of microalgae *Chlorella vulgaris* by heating from 50 to 800 °C at heating rates of 5–40 °C/min. This study shows that combustion produces higher biomass conversion than pyrolysis, and that three stages of decomposition occur in both cases, of which, the second one – consisting of two temperature zones – is the main stage of devolatization. Proteins and carbohydrates are decomposed in the first of the two zones at activation energies of 51 and 45 kJ/mol for pyrolysis and combustion, respectively, while lipids are decomposed in its second zone at higher activation energies of 64 and 63 kJ/mol, respectively. The kinetic expressions of the reaction rates in the two zones for pyrolysis and combustion have been obtained and it has been shown that increased heating rates result in faster and higher conversion.

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1. Introduction

Interest in converting biomass into fuel has been rapidly growing in recent years to meet the proportionate increase in its demand. According to ETP (Energy Technology Perspective) 2010 Blue Map scenario, the world's biofuel demand would reach 32EJ or 760 million tonnes of oil equivalent by 2050. Different alternatives to achieve these demands are currently being researched around the world. Commercialization of cellulosic bio-fuel or biomass derived diesel fuel continues to play an important role in fulfilling this need. But third generation bio-fuels such as algal fuels have huge potential to bridge the gap between the supply and demand of fuel and have several advantages over cellulosic biofuel technology such as high acre productivity, non-food based feedstock, potential use of non-arable land and potential CO_2 sequestration and waste water utilization from industries (Norsker et al., 2011).

Production of biofuel by esterification of microalgae has been on the rise in recent times as studied by Chisti (2007), Orta et al. (2012) and Krohn et al. (2011). But the process demands certain strains of algae rich in lipid content (40–50%) (Chisti, 2007) in order to have a good oil-yield (136.9 m^3/ha under controlled condition in photo-bioreactor compared to 99.4 m^3/ha under uncontrolled growth in race away ponds) (Chisti, 2007), thereby increasing the specificity of choosing the algal feedstock. Thermo-chemical processes like pyrolysis and combustion (Ginzburg, 1993; Agrawal and Singh, 2009) have proved to be possible alternatives in overcoming this drawback.

Combustion under controlled oxidizing environment is a process by which any carbonaceous feed can be converted into gaseous product of usable heating value leaving behind solid residue. In pyrolysis, the only difference is that it is performed under inert atmosphere. This gaseous product can be directly liquefied (Bridgwater, 2012) or converted to fuel through further

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