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Conventional and microwave induced pyrolysis of coffee hulls for the production of a hydrogen rich fuel gas

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Abstract

This paper describes the conventional and microwave-assisted pyrolysis of coffee hulls at 500, 800 and 1000 °C. The influence of the pyrolysis method and temperature on the product yields and on the characteristics of the pyrolysis products is discussed. It was found that the pyrolysis of this particular residue gives rise to a larger yield of the gas fraction compared to the other fractions, even at relatively low temperatures. A comparison of microwave-assisted pyrolysis and conventional pyrolysis showed that microwave treatment produces more gas and less oil than conventional pyrolysis. In addition, the gas from the microwave has much higher H_2 and syngas (H_2 + CO) contents (up to 40 and 72 vol.%, respectively) than those obtained by conventional pyrolysis (up to 30 and 53 vol.%, respectively), in an electric furnace, at similar temperatures. From the pyrolysis fraction yields and their higher heating values it was found that the energy distribution in the pyrolysis products decreases as follows: gas > solid > oil. Moreover, the energy accumulated in the gas increases with the pyrolysis temperature. By contrast, the energy accumulated in the char decreases with the temperature. This effect is enhanced when microwave pyrolysis is used.

Keywords: Microwaves; Pyrolysis; Coffee hulls; Hydrogen; Syngas

1. Introduction

World energy demand is expected to increase over the next few decades as a result of population growth and the increase in the standard of living of developing countries. General concern over the global climate change caused by CO_2 emissions requires that the demand for energy be met in an environmentally sustainable manner. For this reason, greener sources of energy will be required to replace or to minimize the consumption of fossil fuels [1].

Biomass is recognized as a potential source of renewable energy with a net zero CO_2 impact [2]. Biomass conversion technologies can be divided into biological methods (anaerobic/aerobic digestion and fermentation) and thermal methods [3]. Thermal conversion processes include direct combustion to provide heat and electricity [4], gasification to produce mainly syngas [5] which can also be used as fuel to generate electricity or steam, or be used in basic chemical processes [6] and pyrolysis. Pyrolysis can be described as the thermal decomposition of the organic components in an oxygen-free atmosphere to yield char, oil and gas. The pyrolysis of biomass is a very versatile process since conditions such as temperature, heating rate, residence time, etc. can be optimised to maximize the production of char, oil or gas depending on which product is required [7–13]. In conventional pyrolysis a high yield of hydrogen-rich gas is obtained working at high temperature and for a long residence time [14,15], whereas char production is increased by using low temperature and a low heating rate [16]. Another possible pyrolysis alternative called, flash or fast pyrolysis has been applied to maximize the yield of liquid. In this case, a very high heating rate, low residence time and temperatures of around 500 °C are used [17–19].

The processes based on the microwave heating of biomass and wastes include: the pyrolysis of scrap tyres and plastic waste [20], the preparation and regeneration of activated carbons [21], the pyrolysis of oil shales [22], wood [23], sewage

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