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Investigation of microwave dielectric properties of biodiesel components

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HIGHLIGHTS

- ▶ Dielectric properties of biodiesel precursors were measured.
- ▶ The effect of temperature and frequency on the dielectric properties was studied.
- ▶ Temperature and frequency has significant effect on the dielectric properties.
- ▶ The effect varies with the polarity and conductivity of substance.
- ▶ Catalyst has a significant effect on dielectric properties.

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ABSTRACT

Advanced microwave technology has the potential to significantly enhance the biodiesel production process. Knowledge of dielectric properties of materials plays a major role in microwave design for any process. Dielectric properties (ε' and ε'') of biodiesel precursors: soybean oil, alcohols and catalyst and their different mixtures were measured using a vector network analyzer and a slim probe in an open ended coaxial probe method at four different temperatures (30, 45, 60 and 75 °C) and in the frequency range of 280 MHz to 4.5 GHz. Results indicate that the microwave dielectric properties depend significantly on both temperature and frequency. Addition of catalyst significantly affected the dielectric properties. Dielectric properties behaved differently when oil, alcohol and catalyst was mixed at room temperature before heating and when the oil and the alcohol catalyst mixture was heated separately to a pre-determined temperature before mixing. These results can be used in designing microwave based transesterification system.

1. Introduction

Microwave dielectric heating is a well-established procedure used in industrial processing of food and other materials, such as, ceramics, rubbers, and plastics (Meredith, 1998; Metaxas and Meredith, 1993) as well as for home cooking and heating. Major advantages of microwave processing include rapid heating, safety and, in certain applications, improved energy efficiency. The advantages stem from the direct molecular level interaction leading to volumetric heating. The interaction of electromagnetic waves with matter are characterized by two physical quantities – complex dielectric permittivity, ε and complex magnetic susceptibility, μ (Stuerga, 2008). The latter is relatively unimportant in relation to most biological and agricultural materials that exhibit little magnetic susceptibility. Thus, dielectric heating is induced by the electric field via two mechanisms: dipolar rotation and ionic conduction.

For the first mechanism, a dipole, when exposed to an electric field, will try to align itself with the corresponding field polarity. When the applied field is rapidly changing, the dipolar molecules try to realign to the new direction (also rapidly) and at certain frequencies, the dipole ends up spinning around. In this effort of alignment, the molecules rasp with each other causing friction and subsequent heating. In ionic conductance, charged ions oscillate through the solution under the influence of the same applied electric field. As the electric field direction changes, the ions slow down and change direction. In the process, this motion causes collisions resulting in conversion of kinetic energy into heat energy. The interaction phenomena induced between the electromagnetic waves and a dielectric substance can be divided into two major factors: dielectric constant ε' – the storage of electromagnetic energy in the material, and dielectric loss factor ε'' – the thermal conversion of electromagnetic energy occurring as explained above. The relation between permittivity ε, ε' and ε'' is given by the complex equation (Gabriel et al., 1998):

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