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RESEARCH ARTICLE-CHEMICAL ENGINEERING

A Mechanistic Study of the Synthesis of Sustainable Carrageenan-Polylactic Acid Biocomposite

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Abstract
Environmental friendly biocomposites are urgently needed to mitigate the pollution caused by huge consumption of petroleum-based polymers. Renewable carrageenan and polylactic acid (PLA) natural polymers have the potential to replace petroleum-origin polymers. Nevertheless, the carrageenan and PLA themselves inherit poor tensile strength, hydrophobicity and stability. The aim of this study is to underpin the mechanism of synthesis of carrageenan-PLA biocomposite using van't Hoff plot, 1HNMR and density functional theorem simulation. Strong hydrogen bonding was found at 1.88 Å between O atom (carrageenan) and H atom (PLA) and was validated in ^{1}HNMR shifting at 5.3 ppm corresponding to –OH group from PLA. The interaction established in the biocomposite mixed at 50 °C leads to a stronger tensile strength of 75.37 MPa, higher hydrophobicity and thermal stability with highest activation energy of 45.39 kJ/mol. The biocomposite produced from renewable carrageenan-PLA material would be a future replacement for nondegradable plastic as a food packaging material.

Keywords Interaction energy · Tensile strength · Activation energy · Water permeability · Bioplastic

1 Introduction

Biodegradable aliphatic polyester known as polylactic acid is made from natural resources such as corn starch, tapioca root chips or starch, or sugar cane [10, 25]. Numerous industries including packaging, textiles, agriculture, and medical have potential applications of PLA [16, 17, 46], due to the low cost of the substrates, lower temperature requirements, and low energy consumption for chemical synthesis [35]. PLA is a preferable substitute to conventional petroleum-based polymers [29]. Since PLA is a brittle and stiff polyester with Tg = 60 °C, an elastic modulus of 3000 MPa, a maximum tensile strength of 50 MPa and an elongation at break of 10–15% [13], it is blended with plasticizers and modifiers to enhance the mechanical properties of higher flexibility, toughness and impact resistance [16, 17, 46]. Several compounds have been investigated as modifiers of PLA such as lactide oligomers, citrate esters, polyethers, tartaric acid, starch, and various glycerol-based modifiers [6, 7, 33]. Meanwhile, renewable

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