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Understanding starch gelatinization and rheology modeling of tapioca starch– NaCl/$CaCl_2$ blends: Thermodynamic properties and gelatinization reaction kinetics during pre- and post-ultrasonication

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ABSTRACT

The presence of salt can impact the fluid phase and gelatinization process of starch granules. The variation in viscosity and rheology models including the Herschel-Bulkley, the Casson model, and the power law, were determined by adding salts before and after starch ultrasonication. Non-isothermal kinetics can be utilized for the mathematical modeling of the gelatinization process and the evolution of the reaction. Unlike Na^{+} ions, Ca^{+2} ions notably elevate viscosity. The Casson model accurately predicts viscosity data. Results indicate that the addition of Na^{+} ions decreases yield stress by up to 60.4 %, while Ca^{+2} ions increase by up to 100.8 %. Adding Na^{+} ions decreases the required thermal energy by as much as 49.6 %, while the presence of Ca^{+2} ions can lead to a substantial increase of up to 337.1 % compared to control samples. The positive ΔG indicates a non-spontaneous gelatinization process. The addition of NaCl promotes a spontaneous reaction, while the addition of $CaCl_2$ increases the Gibbs energy. The changes in entropy are minimal, implying minimal changes in starches' disorder structure.

1. Introduction

The utilization of ultrasonication as a means of physically modifying starch provides numerous benefits, such as minimizing the need for chemicals and reducing processing time. Additionally, ultrasonication offers high selectivity and quality, making it an environmentally friendly processing method. Sonication of starch has been found to influence various physicochemical characteristics, including swelling power, solubility, gelatinization temperature, enthalpy, depolymerization or polymerization, and pasting properties [1–3].

Salts are used to enhance flavor perception and play a functional role in processing cereal-based products [4]. The literature indicates that salts can impact polysaccharides during processing, even if the polysaccharides do not possess significant ionic groups. It has been observed that small molecules with a molecular weight of up to approximately 1000 g/mol, can easily penetrate starch granules when they are immersed in water. This highlights salts' potential influence on polysaccharides' behavior and properties during processing [5,6]. Once inside the starch granule, the presence of salt can affect the plasticizing and solvent properties of the fluid phase within the granule. The presence of salt can alter these transitions by modifying the properties of the fluid phase within the granule. Moreover, the presence of salt can influence the water absorption, gelatinization, and starch retrogradation. Therefore, salt has a significant impact on the food product's structure, physical properties, microstructure, texture, viscosity, sensory characteristics, and overall quality of the finished products [5,6].

The sonication treatment involves several phenomena, such as flow streaming, the creation of an oscillation pressure field, and mass transfer between vapor and liquid phases due to the formation and explosion of nanobubbles. To better understand and determine the necessary process specifications, it is crucial to simulate the flow and acoustic pressure fields [7]. Furthermore, the fluid's viscosity fluctuates during the

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