Effects of lipid packing and intermolecular hydrogen bond on thermotropic phase transition of stearyl glucoside

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The sugar anomer effect on the thermotropic phase transition of stearyl glucoside was investigated. Standard analysis to study the phase transition through differential scanning calorimetry (DSC), optical polarizing microscopy (OPM) was applied. In addition, small- and wide-angle X-ray scattering (SWAXS) and impedance spectroscopy (IS) were used to elucidate the phase structural information and the dielectric response of the glycolipid self-assembly system, respectively. A distinctive solid-to-liquid crystal phase transition of α- and β-stearyl glucoside was observed. At ambient temperature we observed semi-crystalline structure for the former and gel phase for the latter. α-Stearyl glucoside showed only one-step transition from semi-crystal to lamellar liquid crystal phase. In contrast, the gel phase of β-stearyl glucoside showed several distinct transition states prior to lamellar liquid crystal phase. Here the underlying reason for the observed β-stearyl glucoside polymorphism possibly involved strong intermolecular interaction originating from the combination of interlayer H-bonding and intralayer van der Waals forces.

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1. Introduction

In many consumer products including cosmetics, foods and medicines, gel-like nanostructured and structured emulsion are some examples of desired lipid architectures [1–3]. In addition, lipid self-assembly is ever-present in biological membrane structures and play important role in cell functions. Cellular membrane usually consists of planar lipid bilayer while in sub-cellular membrane (organelles), it is more of a convoluted type [4]. Using liquid crystal terminology, the cell bilayer system is commonly associated with the lamellar phase. However, some of these constituting lipid molecules like sterol-based lipid may self-assemble to form other types of liquid crystal structures [5]. Compared to phospholipids, glycolipids are minor components in cellular membrane, but they perform the role of stabilizing the membrane structure and assisting molecular recognition at the cell surface thus proves their importance to biological cell [6].

Like most polar lipids, the non-polar glycolipids can form lamellar and other curve structures such as hexagonal and cubic phases [7–10]. The phase assembly is highly dependent on the lipid molecular (CPP) proposed by Jacob Israelachvili [11]. Linear-shaped monoalkylated glycolipids are predicted to have critical packing parameter value close to 1 (CPP ≈ 1) and hence favor the formation of lamellar structure below their liquid crystal clearing temperature, Tc [12]. Meanwhile, non-lamellar structure either inverse (CPP > 1) or normal type (CPP < 1) are anticipated for many glycolipids that digress from linearity. For instance, hydrocarbon branching causes deviation from the standard CPP value i.e. CPP > 1 of the glycolipid and thus inverse hexagonal and cubic phases with more negative interfacial curvature would form [9,10,13].

In addition, these class of lipids also form gel phase (Lα) which can be found in food and personal care products. It allows different chemo-physical interactions between surfactants and other components such as carbohydrates and proteins that are present in complex functional food, pharmaceutical and cosmetic matrices [14,15]. The lamellar Lβ structure is formed when the lipids are hexagonally packed within bilayers system with tightly packed alkyl chains [14]. Due to the ordered alkyl chain array of Lβ, the head groups are forced to be closer together than that of the lamellar liquid crystal phase (Lα) [16]. Most of the am-