Stabilizing oil-in-water emulsion with amorphous cellulose

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Abstract

Non-derivative cellulose is usually not considered an amphiphilic biopolymer with emulsion stabilization ability. In this study, we have demonstrated, using a dissolution and regeneration process, that the obtained non-derivative amorphous cellulose can effectively stabilize oil-in-water emulsions. Freshly prepared emulsions with cellulose contents of 0.07–0.56% are not stable against creaming. After increasing the cellulose content to 0.83%, the emulsions remain completely stable for months. All previously gravitationally unstable liquid-like emulsions were transformed into stable gel-like emulsions by increasing the cellulose content to 0.83%, the emulsions remain completely stable for months. All previously gravitationally unstable liquid-like emulsions were transformed into stable gel-like emulsions. Attractive emulsions with typical shear-thinning gel characteristics. The underlying emulsion stabilization mechanism is a combination of Pickering and network mechanisms. The findings of this research explore a more practical way of utilizing non-derivative cellulose in the food industry as a novel food ingredient.

1. Introduction

Food emulsions are usually stabilized by small molecular surface active emulsifiers, amphiphilic biopolymers, including proteins and polysaccharides, and nano/micro-particles (Dickinson, 2009). A number of naturally occurring polysaccharides, such as gum arabic, pectin, chitosan, and galactomannans, are capable of stabilizing emulsions, although there is debate regarding the underlying mechanisms and whether they involve surface activity or thickening effects (McClements, 2005). Traditionally, natural starches and cellulose are not considered amphiphilic biopolymers with good emulsion stabilization ability, unless chemical modifications are made to introduce surface active groups (McClements, 2005; Xhanari, Syverud, & Stenius, 2011). Starches are essentially hydrophilic molecules with poor surface activity, whereas cellulose is hydrophilic as well, but it is insoluble in water because of strong intermolecular hydrogen bonds (McClements, 2005).

Recently, the role of hydrogen bonding in the solubility and insolubility properties of cellulose has been challenged (Glasser et al., 2012; Medronho, Romano, Miguel, Stigsson, & Lindman, 2012). It is believed that the properties of cellulose are also significantly influenced by hydrophobic interactions, and the surface of crystalline cellulose has both hydrophobic and hydrophilic planes (Cho, Gross, & Chu, 2011; Glasser et al., 2012; Medronho et al., 2012; Parthasarathi et al., 2011; Yamane et al., 2006). As a result of this amphiphilic character, it is not surprising to see that crystalline cellulose is capable of forming stable emulsions if they are dispersed well. Earlier studies have found colloidal microcrystalline cellulose (MCC) (11% MCC + 1% sodium carboxymethylcellulose) can stabilize oil-in-water emulsions and water-in-oil-in-water (w/o/w) multiple emulsions by forming a network around the emulsified oils (Oza & Frank, 1986, 1989). The function of MCC is to orient at the oil-in-water interface thus providing a mechanical barrier to droplet coalescence, whereas the sodium carboxymethylcellulose functions as a dispersing and protective colloidal for the MCC (Oza & Frank, 1986). Recent studies have demonstrated that cellulose nanocrystals, without any dispersing agent, can also effectively stabilize oil-in-water emulsions (Kalashnikova, Bizot, Cathala, & Capron, 2011, 2012). Moreover, high internal phase emulsions (HIPEs) with oil volume fractions more than 0.9 can be stabilized by less than 0.1% cellulose nanocrystals (Capron & Cathala, 2013). These nanocrystals are needle- or rod-shaped crystalline cellulose with widths of a few nanometers and lengths varying from tens of nanometers to several micrometers. They are...