Optimization of physical and mechanical properties for chitosan–nanocellulose biocomposites

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A B S T R A C T
Chitosan (CHT) is a biodegradable compound and has excellent performance in forming films; on the other hand, nanocellulose (NCL) crystals have low densities and are less expensive than other nanofillers. A novel and simple method was applied to develop CHT–NCL nanocomposite (NCP) from CHT powder of high molecular weight and NCL particles having two dimensions in nanoscale; a rotor stator and an ultrasound device were used to separate different nanolayers from each other and facilitate their dispersion into polymer matrix. The optimized NCP indicated superior mechanical properties compared with some synthetic films; approximate values of 47% elongation-at-break, 245 MPa tensile strength and 4430 MPa Young’s modulus were achieved. Water vapour permeability (WVP) value of the NCP was at optimal level of 0.23 × 10−11 (g/m·s·Pa) which was much less than the most biofilms’ WVP values. FESEM analyses revealed that high concentrations of CHT and NCL composed inter-connected structures justifying high elongation capability of CHT–NCL NCP.

1. Introduction
Chitosan (CHT), the cationic (1–4)-2-amino-2-deoxy-β-D-glucan, is industrially produced in various quality grades from chitin, the second most abundant polysaccharide in nature (Muzzarelli et al., 2012; Muzzarelli, 2012; Tome et al., 2013). CHT is a non-toxic and biodegradable compound and has excellent performance in forming films (Hardy, Hubert, Macquarrie, & Wilson, 2004). Molecular weight of CHT deeply affects the permeability, mechanical and thermal properties of the obtained film (Butler, Vergano, Testin, Bunn, & Wiles, 1996). CHT films have moderate water vapour permeabilities and exhibit good barrier properties against oxygen permeation (Rudrapatnam & Farooqahmed, 2003).

Cellulose, as the most abundant polymer in the environment, regards as one of the most important elements in the plant structures and guarantees the integrity of cellular structure (Righi et al., 2011). Different cellulose derivations with various applications could be obtained by physicochemical treatments on cellulose; since the aim of treatment application is grinding the long chains of cellulose polymers, hydrolysis process is applied on cellulose microfibrils and then chemical compounds and impurities are removed by washing and residuals are treated by spray drying process (Dadashi, 2011). Obtained crystals have low densities, high elongation moduli and tensile strengths (Klemm, Heublein, & Fink, 2005); besides, they have high biodegradability rates and are less expensive than other nanofillers (Hansson et al., 2013). This highlights their suitability to be applied as nano-reinforcer materials in biodegradable packaging.

Nanocomposites (NCPS) are novel polymer matrices which have been incorporated by nanoparticles (NPs) having at least one dimension in nanoscale (Petersson & Oksm, 2006). Cellulosic nanocomposites are usually used to achieve excellent strength properties (Mikkonen et al., 2011). Dadashi (2011) evaluated the effect of three different levels of the current nanocellulose (NCL) (3, 5 and 7%) on poly lactic acid matrix. Since NCL, as a polysaccharide and hydrophilic compound, is in fibrous state and its dimensions are greater than counterparts of other NPs, it was recommended to be used as a reinforcement constituent in such a way that it won’t change the matrix context. They suggested the level of 3% NCL to obtain less water vapour permeability rates and higher tensile moduli for final films. Khan et al. (2012) reported that incorporation of even 1% (w/w) NCL with 5–10 nm width could significantly increase tensile modulus of CHT film, which was equal to 43% increase compared with control CHT film. Of course, when