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Effect of addition of nanoclay, beeswax, tween-80 and glycerol on physicochemical properties of guar gum films

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ABSTRACT

Effect of addition of nanoclay (nanofil-116), beeswax, tween-80 and glycerol on physicochemical properties of guar gum (GG) films was studied using response surface methodology (RSM). Beeswax produced reduction in water vapor transmission rate (WVTR) and tensile strength (TS). An improvement in TS with reduction in WVTR was observed due to nanoclay. Concentrations of various additives were optimized to prepare films with improved properties. Optimized concentrations (beeswax: 0.63%; nanoclay: 2.5%; tween-80: 0.63%; glycerol: 11.87% w/w GG) resulted in TS of 98 MPa and WVTR of 89 g/m^2/d. Compatibility between GG and beeswax was further increased using gamma irradiation. RSM study with 50 kGy irradiated beeswax was performed and optimum concentration of tween-80 (0.88%), irradiated beeswax (50 kGy) (1.21%), glycerol (13.91%), nanoclay (3.07%) w/w of GG resulted in films having TS of 122 MPa and WVTR of 69 g/m^2/d. Guar gum based films with improved mechanical and barrier properties were successfully prepared.

1. Introduction

Conventional packaging is synthesized from non-renewable petroleum based resources and thus poses environmental hazards due to their non-biodegradability. It is therefore of interest to develop newer packaging materials that can address the limitation of petroleum based conventional packaging. Biopolymers such as polysaccharides, proteins and lipids are potential candidates for developing biodegradable films due to their biodegradability, edible nature and natural origin. Among these, polysaccharides have excellent film forming properties and are suitable materials for the development of biodegradable films (Perez-Gago and Krochta, 2005).

Bioplastics however have some drawbacks compared to their commercial petroleum based counter parts. These include poor mechanical properties and high water vapor transmission rate (WVTR). Many physical and chemical treatments have been proposed in the past to overcome these shortcomings. Among the physical treatments, thermal processing (Micard et al., 2000), UV curing and more recently gamma irradiation (Ibrahim, 2011; Saurabh et al., 2013) have been used to improve the mechanical and barrier properties of bio-based films. Chemical treatments involving modification of functional groups (Das et al., 2011) or cross-linking by addition of agents such as formaldehyde (Micard et al., 2000) and glutaraldehyde (Parra et al., 2004) have also been successfully demonstrated. Another approach for improving the properties of biopolymer based film is the incorporation of various additives into the films. Each additive individually or in combination with other additives affects one or more properties. Among the additives generally used, addition of nanoclays to bio-polymeric matrixes often results in improved mechanical properties (Avella et al., 2005; Rhim et al., 2006; Saurabh et al., 2015). Lipid and waxes are other important additives for reducing WVTR because of their hydrophobic components. Beeswax has been successfully used by several authors to reduce the water vapor permeability of biodegradable films (Soazo et al., 2011; Monedero et al., 2009). Incorporation of wax to form either bilayer or emulsion films has been reported (Debeaufort et al., 1993). It has been proven that emulsion composite films are simpler and more feasible to prepare than bilayer films (Cheng et al., 2008). However, the effectiveness of beeswax in emulsion films for reducing WVTR is strongly dependent on the presence of emulsifier (Debeaufort and Voilley, 1995). Emulsifier possesses both hydrophilic and hydrophobic groups and thus reduces the surface tension of the film forming solution (Maran et al., 2013a). Emulsifiers with higher hydrophilic/lipophilic balance (HLB) allow a greater association of their hydrophilic fraction with the hydrophilic film

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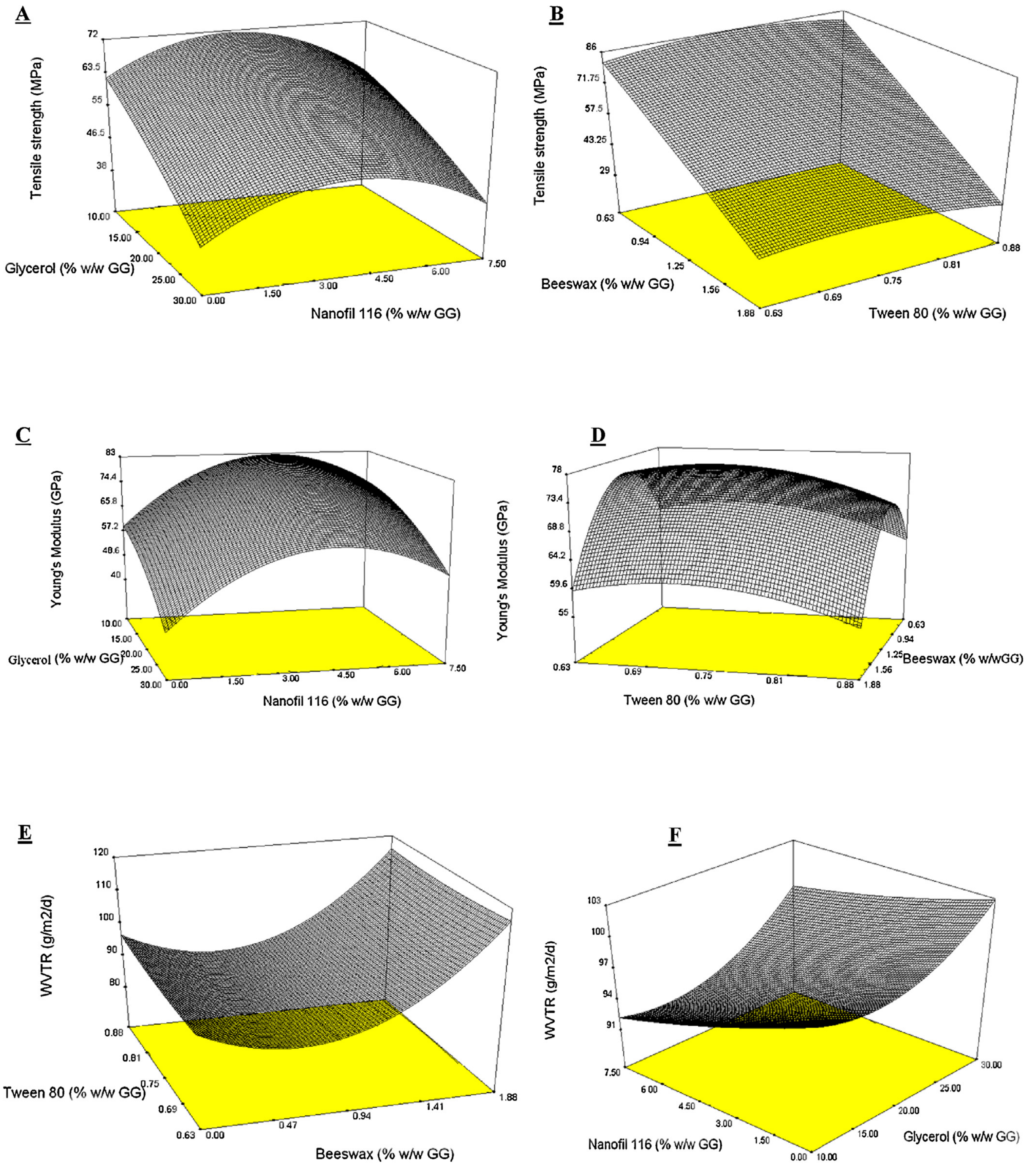

Fig. 1. Response surface curves: (A) Tensile strength V/s nanoclay and glycerol at center point of beeswax and tween-80; (B) Tensile strength V/s beeswax and tween-80 at center point of nanoclay and glycerol; (C) Young's modulus V/s nanoclay and glycerol at center point of beeswax and tween-80; (D) Young's modulus V/s beeswax and tween-80 at center point of nanoclay and glycerol; (E) WVTR V/s beeswax and tween-80 at center point of nanoclay and glycerol; (F) WVTR V/s nanoclay and glycerol at center point of beeswax and tween-80.

matrix. Besides emulsifier irradiation is also reported to induce the compatibility in biopolymer based composite films (Senna et al., 2010).

Guar gum (GG) is a high molecular weight biopolymer obtained from a legume plant *Cyamopsis tetragolonoba*. Its wide availability compared to other biopolymers makes it a suitable candidate for developing biodegradable films. Chemically it is a galactomannan having a backbone made up of 1, 4-linked β-D-mannose residues to which α-galactose residues are 1, 6-linked at every second mannose, forming short side-branches