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Development and characterization of edible films based on flaxseed gum incorporated with *Piper betle* extract

Arshied Manzoor [a], Saghir Ahmad [a], Basharat Yousuf [b,c,*]

[a] Department of Post-Harvest Engineering and Technology, Faculty of Agricultural Sciences, A.M.U., Aligarh, U.P, India
[b] Department of Food Science & Technology, School of Applied Sciences & Technology, University of Kashmir, Srinagar 190006, J&K, India
[c] Department of Food Technology, School of Engineering & Technology, Islamic University of Science & Technology, Awantipora 192122, J&K, India

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ABSTRACT

There has been a shift from use of petroleum-based plastics, causing serious environmental pollution, towards innovative and biodegradable edible packaging. The present study documents the development of composite edible films based on the flaxseed gum (FSG) modified by the incorporation of betel leaf extract (BLE). The films were assessed for physicochemical, mechanical, morphological, thermal, antimicrobial and structural characteristics. Scanning electron microscopy images indicated that the roughness decreased with an increase in BLE concentration. The water vapor permeability of the FSG-BLE films ranged from 4.68 to 1.59 $\times$ 10^{-9} g s^{-1} m^{-2} Pa^{-1}, lower than that of the control sample (6.77 $\times$ 10^{-9} g s^{-1} m^{-2} Pa^{-1}). The BLE4 (containing 10 % BLE) films had the highest tensile strength of 32.46 MPa compared to the control sample (21.23 MPa). Similarly, EAB and seal strength of the films incorporated with BLE were ameliorated. X-ray diffraction pattern and FTIR illustrated the shift of amorphous to crystalline behavior and a significant interaction among the BLE and FSG functional groups. Furthermore, the thermal stability of the treated films was not affected significantly however, they showed improved antimicrobial activity with the highest diameter of inhibition zone in the BLE4 sample. This study concluded that the FSG-BLE composite films (BLE4 in particular) can be considered as novel packaging material for food conservation coupled with a potential to enhance the shelf life of perishable food products.

1. Introduction

The survival of living beings is under severe threat because of the accumulation of non-biodegradable materials in the environment which is creating havoc by generating toxicity, hence causing limitless obliterations to the living world. This serious issue is further provoked by the prevalent use of non-biodegradable conventional packaging materials (films/coatings) manufactured and used in the packaging industries [1,2]. Moreover, consumer safety is at risk by using harmful synthetic packaging materials. Giving credibility to the aforementioned concerns, scientific research has shifted the focus on the exploration, development and usage of edible films/coatings from different natural materials with biodegradable and eco-friendly features. Yousuf, Qadri, & Srivastava [3] have reported that polysaccharides, being a larger group (among lipids, polysaccharides and proteins), have found major exploration in the field of edible film fabrication for food packaging in the past few years. Edible polymers are high-quality, biocompatible and biodegradable alternatives to low-quality and non-biodegradable products and packages used in different food industries [4].

Another group of plant-based polysaccharides called natural gums are proclaimed as readily available with eco-friendly nature and generally recognized as safe (GRAS) status. Hence, natural gums are being explored immensely instead of synthetic materials for food applications focused on film/coating formulations as the former ones exist abundantly at low cost and are devoid of toxicity [5]. Seed gums are bestowed with exceptional film-forming properties such as physical, mechanical and barrier properties. In this regard, flaxseed (*Linum usitatissimum* L.) gum (FSG), extracted by an aqueous extraction process from flaxseed (of which 8–10 % total seed weight constitutes FSG) could be used for the development of films/coatings with excellent functional properties in general, and rheological properties in particular [6]. FSG is mostly found in the outermost flaxseed coat and the nutritional (50–80 % carbohydrates, 4–20 % of proteins and ash) and health benefits of FSG make it a potential candidate for exploration in food industries. FSG has

* Corresponding author at: Department of Food Technology, Islamic University of Science & Technology, 192122, J&K, India.
E-mail address: yousufbasharat@gmail.com (B. Yousuf).

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