ACTIVE GALLIC ACID RELEASING FILMS: RELEASE KINETICS AND PHYSICOCHEMICAL PROPERTIES

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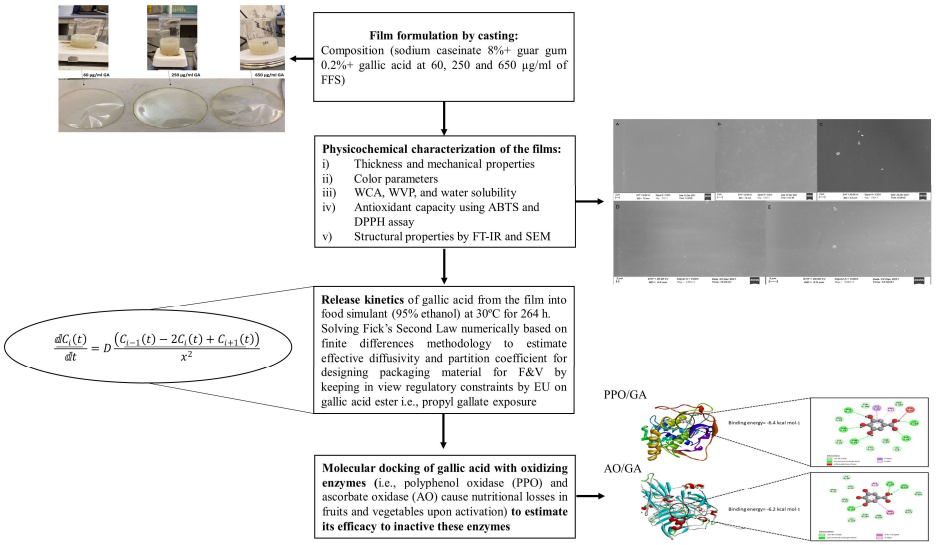
1. INTRODUCTION

Due to the non-biodegradable nature and disposal problems of plastics, the screening of natural biodegradable alternatives is at the rise in the past decade. Biopolymers derived from agro-livestock resources can provide an effective solution to this problem. For instance, casein is a milk protein with an excellent tendency for degradation, emulsification, carrier of bioactive compounds, and high thermal stability, making it a highly desirable macromolecule [1]. However, the hydrophilic nature of caseinate restricts its application in food packaging. Several strategies have been employed to counter this problem i.e., blending with other biopolymers. Nevertheless, the possibility of cross-linking phenolic compounds can provide the solution to this problem since certain polyphenolic compounds can improve physicochemical properties by modifying the structure of the polymeric matrices upon interaction and their release into the food matrices can be modulated which can have a significant impact on the shelf-life of the product. Gallic acid has only been utilized for the development of food packaging with certain polymeric materials (i.e., chitosan) because of its acidic pH and solubility issues [1]. However, these issues can be resolved by mixing the biopolymer and the gallic acid in a buffer. Although several studies have been conducted to elucidate the release of bioactives from the packaging materials into different matrices, still to the best of our knowledge, the approach to elucidate the influence of gallic acid on its release from caseinate/guar film with mathematical modeling has never been carried out. Previously, the research was focused to design packaging materials to restrict lipid oxidation in food products of animal origin [2], whereas loss of nutritional quality in minimally processed fruits and vegetables (F&V) due to oxidation reactions has not been given much attention. One of the reasons of the oxidation of essential nutrients is the activation of oxidizing enzymes i.e., polyphenol oxidase (PPO) and ascorbate oxidase (AO) due to various factors. Several studies have been employed for the inactivation of oxidative enzymes i.e., by using light (i.e., pulsed) and temperature (i.e., conventional heating and microwave), however, inactivation of oxidizing enzymes by using phenolic compounds is still a new concept, especially in food packaging. Thus, the objective of this study was to investigate the influence of gallic acid on the film structure, quantify its antioxidant properties, and describe the release mechanism by mathematical modeling.

2. METHODOLOGY



3. RESULTS AND DISCUSSION

WVP of films decreased up to 21% after the incorporation of gallic acid in the film. However, the hydrophobicity of the films decreased. The gallic acid released from the films GAI$^{*60\ ug/ml}$, GAII$^{*250\ ug/ml,}$ and GAIII$^{*650\ ug/ml}$ was 67 %, 32 %, and 30 % respectively. Similarly, the diffusion coefficient was also affected by an increase in the concentration and was: 8.10 $\times 10^{-12}$ m^2s^{-1}, 6.23 $\times 10^{-12}$ m^2s^{-1}, and 4.5 $\times 10^{-12}$ m^2s^{-1} for GAI, GAII, and GAIII films respectively. The neat caseinate films were smooth surfaced, without any cracks, and homogenous. A low degree of heterogeneity was observed in the film sample with the highest level of gallic acid as compared to the films with lower levels of gallic acid [3]. The incorporation of gallic acid imparted changes in the FT-IR spectra mainly in the amide-I region. Additional peaks at 3074-3075 cm^{-1} were observed in the samples after release, indicating stretching of the aromatic C-H group and confirming the release of gallic acid from the films. Despite the hydrophilic nature of the packaging material, the high antioxidant potential (~80 % DPPH inhibition) of the films (with higher gallic acid content) can make them useful for packaging purposes. Furthermore, molecular docking suggested the potential inactivation of oxidative enzymes due to the binding of gallic acid near their active sites.

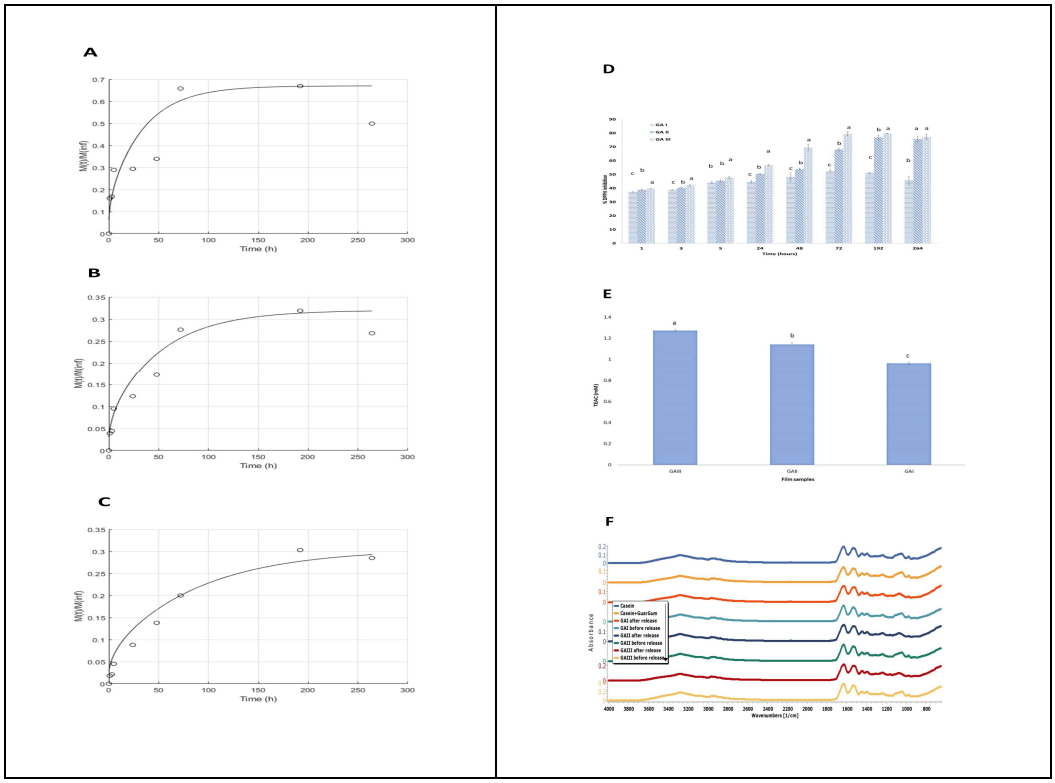


Figure .1. Release kinetics and mathematical modelling of release behavior of gallic acid (Where A= sodium caseinate + guar gum + GA I, B= sodium caseinate + guar gum + GA II, and C= sodium caseinate + guar gum + GA III; also "o" represents experimental while the solid line "-"represents predicted values). Antioxidant activity of the D= food simulant solutions and E= films (Different superscript letters (a-c) above bars show significant differences ($p < 0.05$) among mean observations. Whereas F represents, chemical fingerprinting of neat and composite films.

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