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A PVA film for detecting lipid oxidation intended for food application

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ABSTRACT

Lipid oxidation is a big contributor to food deterioration. The objective of this study was to develop an intelligent film for visually detecting lipid oxidation, based on the colorimetric reaction of Schiff's reagent and aldehydes—the major volatile lipid oxidation products. A polyvinyl alcohol (PVA) film containing Schiff's reagent was formed, with the elasticity modulus of 0.27 MPa and the tensile strength of 19.17 MPa. The PVA film was exposed to various concentration (0–7.02 mg/L) of gaseous hexanal—the major aldehyde formed during lipid oxidation, the color change of the PVA film was measured by CIELab scale. The color of PVA film changed from colorless to purple after exposure to hexanal. As the hexanal concentration increased, the color change of the PVA film was more obvious. A linear relationship was found between the hexanal concentration and the color change. The developed PVA film could be an indicator for lipid oxidation of food when incorporated as a minor component of food packaging.

1. Introduction

Lipid oxidation is a major reason that causes the deterioration of foods. The products of lipid oxidation not only affect the sensory properties of foods, they are also potentially harmful to human health [1]. Several methods have been established to determine the extent of lipid oxidation in foods. The iodometric titration method is used to measure the primary lipid oxidation products—hydroperoxides [2]. The p-anisidine value test [3] is for the measurement of aldehydes—the secondary lipid oxidation products. The thiobarburic acid test is used to determine malonaldehyde—a minor product formed during lipid oxidation [4]. Gas chromatography and high-performance liquid chromatography have been established to quantify hexanal— a major secondary lipid oxidation product and used as the indicator for lipid oxidation [5]. Although all the aforementioned methods are commonly applied, they are unable to provide timely information on the lipid oxidation state of food due to time-consuming assays.

Schiff's reagent is a colorless aqueous solution containing pararosaniline hydrochloride and sodium sulfite. Upon reacting with aldehydes, Schiff's reagent turns from colorless to magenta. Schiff's reagent is commonly used to stain DNA in biological samples. Little attempt has been made to exploit its potential in food application. Based on the colorimetric reaction between Schiff's reagent and aldehydes—the secondary lipid oxidation products of food, it is highly possible that Shiff's reagent can be used to indicate lipid oxidation in food. A mechanism for the color formation between Schiff's reagent and the products formed during lipid oxidation of food was proposed and illustrated in Fig. 1, which was based on the work of Robins and others [6]. Polyvinyl alcohol (PVA) is a non-toxic, biodegradable polymer used in food packaging. Compounds with functions have been incorporated into PVA film for food application [7,8]. The objective of this study was to incorporate Schiff's reagent into PVA film, and develop an intelligent film for use as a minor component of food package, in order to timely detect lipid oxidation of food.

2. Materials and methods

2.1. Materials

Polyvinyl alcohol (PVA) (Mw: 85,000–124,000), hexanal, Schiff's reagent were purchased from Sigma Aldrich Inc. Glycerol (liquid chromatography grade) were obtained from the Aladdin Reagent Co., Ltd., China.

2.2. Formation of intelligent PVA film

PVA solution (3%) was prepared by dissolving 0.9 g PVA in 30 mL distilled water at 85 °C, and then cooled to room temperature. 20 mL PVA solution was mixed with 2 mL Schiff's reagent and 0.4 g glycerol to yield a mixture solution. 1 mL mixture solution was placed in a plastic plate (44 x 44 mm), and dried at 35 °C in an oven for 5 h. The PVA film formed was peeled off the plastic plate, and used for further analysis.

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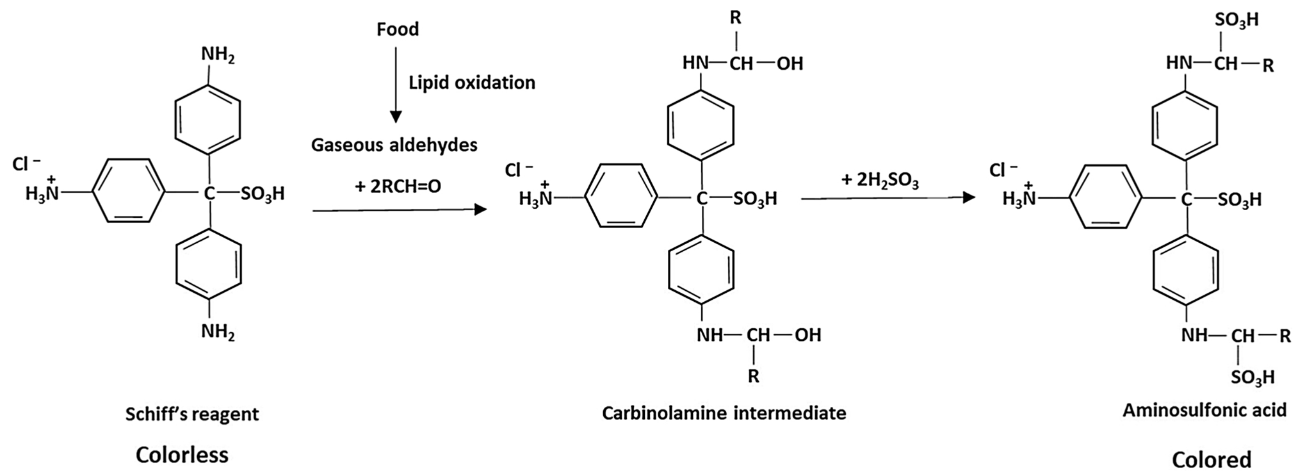

Fig. 1. Mechanism of color formation between Schiff's reagent and aldehydes produced from lipid oxidation of food.

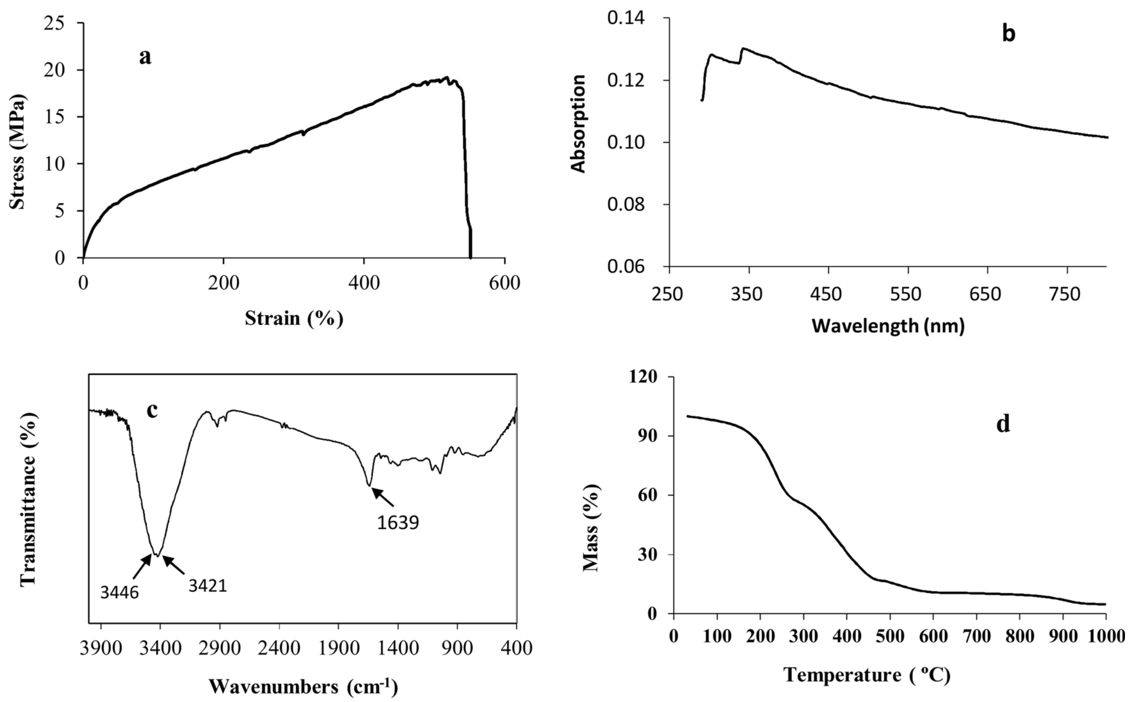

Fig. 2. Characteristics of PVA film. a. Tension-deformation curve; b. UV–vis spectrum; c. FT-IR spectrum; d. TG curve.

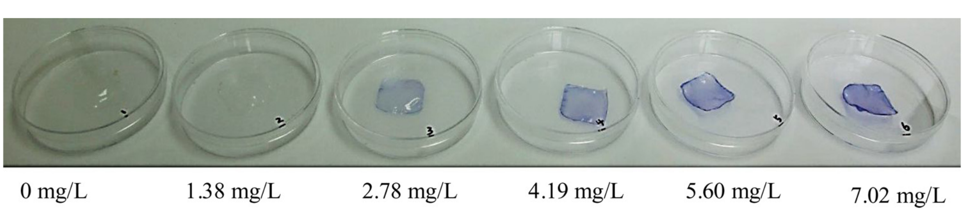

Fig. 3. PVA film after exposed to various amount of gaseous hexanal.

2.3. Characterization of the intelligent PVA film

The mechanical properties of the PVA film was determined by an Instron MicroTester, model 15,848 (MTS Systems Corp., Minneapolis, MN). The thickness of the PVA film was measured using a Mitutoyo® manual micrometer. The UV–vis absorption spectrum of the PVA films was obtained with a spectrophotometer (A590, AOE Instruments, China).The FT-IR spectrum was obtained using a Bruker spectrometer (Vetex 70). TG analysis was performed using a Netzsch thermal analyzer (STA 449 F3).

2.4. Colorimetric response of the intelligent PVA film to hexanal

The PVA films was placed in empty glass bottles (1 L), to which various amounts of hexanal was injected and vaporized. The bottles were immediately sealed, and the PVA films were exposed to gaseous hexanal for 24 h. The color parameters of the PVA film L* (lightness), a* (red-green) and b* (yellow-blue) before and after exposure to hexanal were determined using a spectrophotometer (3 nh, Model YS3010, Shenzhen 3 nh Technology Co., Ltd.). The total color change was calculated by the Eq. (1) according to CIELab: