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Investigation of different coating application methods on the performance of edible coatings on Mozzarella cheese

Yu Zhong [a], George Cavender [b], Yanyun Zhao [b,a,*]

[a] Department of Food Science & Technology, School of Agriculture and Biology, Shanghai Jiao Tong University, Shanghai, China
[b] Department of Food Science and Technology, Oregon State University, Corvallis, OR, USA

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ABSTRACT

The performance of edible coating is influenced by the properties of coating materials and execution methods. In this study, three different coating materials (chitosan, sodium alginate, and soy protein isolate) and four different coating application methods (dipping, enrobing, spraying and electrostatic spraying) were investigated on their performance for coating Mozzarella cheese. The properties of coating solutions, morphology and basic quality changes of the cheese during storage at 4 °C were evaluated. Results showed that sodium alginate solution was the most viscous ($\eta = 0.155$ Pa s) and had small contact angle on hydrophobic substrate surface indicating its better spreadability on cheese. Film thickness displayed obvious differences based on the coating methods (ranging from 30.6 to 83.3 μm), with two spraying methods leading to thinner coatings. Sodium alginate coated cheese possessed the best overall physicochemical properties during storage whereas the preservation effects were not significantly different among four coating methods. This study provided valuable new information about the effective coating application methods for different coating materials.

1. Introduction

Edible coatings have attracted great attentions nowadays, mainly due to the need of relieving the environmental pressure and improving the food quality and safety. Edible coatings can be applied on or even within foods by various methods, and different coating methods possess their own advantages and disadvantages. Dipping is the most common lab-scale way due to its simplicity, low cost, and good coverage on uneven food surface. However, dipping method has obvious disadvantages, e.g. it leads to coating-solution dilution and residual of high quantity of coating materials, and often results in microorganism growth in the dipping tank (Andrade, Skurtys, & Osorio, 2012; Hirlekar, Patel, Jain, & Kadam, 2010). Moreover, processing control and automation of continuous production are the major challenges. Enrobing technology is prevalent in chocolate manufacturing and meat industry (Bhat, Kumar, & Kumar, 2013; Karnjanolarn & McCarthy, 2006). During enrobing process, the sticky coating solution flows vertically to the treated food items, and the products are coated by viscous and gravitational forces. For good product quality and accurate weight control, coating solution viscosity is a key parameter and the surface of food should better be flat. Spraying is another widely used way for applying coatings. This technique offers uniform coating, thickness control, and the possibility of successive applications which does not contaminate the coating solution (Andrade et al., 2012). It has been reported that bovine gelatin is successfully spray-coated onto fresh meat including beef tenderloins, pork loins, salmon fillets, and chicken breasts to improve their storage qualities (Antoniewski, Barringer, Knipe, & Zerby, 2007). Recently, there is a growing effort to adapt electrostatic spraying technology in food industry. Electrostatic spraying, beginning in the paint industry, has a series of superiorities than traditional spraying technique. This method can control the droplet size, increase the droplet coverage and deposition, produce homogenous distribution, and reduce wastage. It has been reported that the application efficiency can be increased up to 80% with 50% less spray dosage by using electrostatic spraying (Maski & Durairaj, 2010). Nam, Seo, Jo, and Ahn (2011) indicated that electrostatic spraying of ascorbic acid at 500 mg/kg could efficiently prevent both lipid oxidation and color change in ground beef (Nam et al., 2011). Ganesh, Hettiarachchy, Griffis, Martin, and Ricke (2012) pointed out that electrostatic spray of food-grade acids and plant extracts are more effective compared with conventional spray in decontaminating Escherichia coli O157:H7 on spinach and iceberg lettuce (Ganesh

* Corresponding author. Department of Food Science and Technology, Oregon State University, Corvallis, OR 97331, USA. Tel.: +1 541 737 9151; fax: +1 541 737 1877.
E-mail address: yanyun.zhao@oregonstate.edu (Y. Zhao).

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et al., 2012). The selection of an appropriate coating method not only impacts the preservation effect of the coatings formed on the food items, but also determines the production cost and process efficiency. Unfortunately, a very few studies have compared the performances of these different coating methods on the same food product.

To evaluate the behavior of edible coatings, coating thickness is an important parameter since it can influence the morphology, opacity, mechanical property, and barrier ability of resulted films. Generally, a micrometer is used to measure the thickness of edible films. However, this method can't directly reflect the thickness of coatings applied on food surface. Hsu, Weng, Liao, and Chen (2005) chose Near-infrared Fourier transform Raman technology to determine the thickness of zein coatings on apples by correlating the Raman intensity ratio of characteristic peaks versus the film thickness (Hsu et al., 2005). Unfortunately, this method needs long analytical process, expensive instrument, and professional spectral analysis skills. In this study, a rapid and easy optical method was developed to observe the coating thickness without employing expensive instruments.

The performances of edible coatings not only depend on the coating methods employed, but also the properties of the coating materials (type, amount, density, viscosity, and surface tension). Many natural materials have the potential to make well performing edible coatings, including proteins, polysaccharides, and lipids (Al-Hassan & Norziah, 2012). Among these nature biopolymers, chitosan, sodium alginate and soy protein isolate are the three most promising coating materials (Janjarasskul & Krochta, 2010). Chitosan obtained by the deacetylation of chitin has good film-forming ability, excellent biocompatibility and wide antibacterial spectrum. Sodium alginate, a natural linear polysaccharide, has good moisture-retention capacity, gel-forming and biocompatibility. Soy protein isolate is digestible and nourishing, and has shown excellent oxygen barrier property (Skurtys et al., 2010). The applications of these three materials as edible coating on various food products have been widely discussed (Elsabee & Abdou, 2013; Pizato, Cortez-Vega, de Souza, Prentice-Hernandez, & Borges, 2013; Ramos, Fernandes, Silva, Pintado, & Malcata, 2012). Hence, it is worthy to study the responses of these different coating materials to the above mentioned coating methods, and their behaviors on a given food item.

For the same coating material and coating method, the protection effect of an edible coating will also depend on the composition, surface morphology, size, and shape of the product matrix to be coated. Cheese, a widely consumed food mainly consisting of casein, fat, and water, is an ideal food model to study the diversity of coating process due to its smooth surface, uniform texture, and regular shape. Hence, in the present study, four different coating methods including dipping, enrobing, spraying and electrostatic spraying were studied by employing three kinds of coating solutions (chitosan, sodium alginate, and soy protein isolate) to evaluate the comprehensive coating performances of these methods, especially their impacts on film morphology and their preservation effects, and consequently guide the smart selection of coating materials and successive industrial applications of edible coatings.

2. Materials and methods

2.1. Materials

Chitosan with 300 kDa of molecular weight and 88% of degree of deacetylated was purchased from Primex (Siglufjordur, Iceland). Sodium alginate (TICA-algin® 400 powder) was obtained from TIC Gums (Belcamp, MD). Soy protein isolate (with 90% protein) was acquired from Cargill Inc. (Minneapolis, MN). Glycerol from IBI Scientific Inc. (Peosta, IA) and acetic acid from Fisher Scientific Inc. (Fair Lawn, NJ) were used as plasticizer and acid solvent, respectively.

Low-moisture Mozzarella cheese (Tillamook County Creamery Assoc., Tillamook, OR) was obtained from a local supermarket in Corvallis, OR, USA, and stored in a refrigerator (4 °C) before using. Cheese bricks were carefully cut into square pieces of 40 × 40 × 4 mm (approximately 9 g) by a cheese slicer.

2.2. Preparation of coating solutions

Three different coating solutions were prepared according to the procedures described in the literature (Kanatt, Rao, Chawla, & Sharma, 2013; Shon, Eo, & Eun, 2010; Sipahi, Castell-Perez, Moreira, Gomes, & Castillo, 2013) and our preliminary experiments: (1) 2 g/100 g chitosan and 0.5 g/100 g glycerol (as plasticizer) (chitosan: glycerol = 1:4) were dissolved in 1 g/100 g acetic acid (CA); (2) 1 g/100 g sodium alginate and 0.25 g/100 g glycerol (sodium alginate: glycerol = 1:4) were dissolved in DI water (SA); and (3) 5 g/100 g soy protein isolate and 1.25 g/100 g glycerol (soy protein isolate: glycerol = 1:4) were dissolved in DI water and heated at 80 °C water bath for 45 min (SP). All coating solutions were filtered through nylon mesh to remove insoluble particles.

2.3. Coating methods

Four different coating methods were chosen: (1) dipping (D); (2) enrobing (E); (3) spraying (S); and (4) electrostatic spraying (ES). In order to get thin films and control film thickness, the operation time was fixed. Generally, the coating time was set to 30 s for CA and SA, and 20 s for SP except for dipping method. During dipping process, the coating time was 15 s for SP and 20 s for CA and SA. After coating process, all of the samples were drained on stainless steel screens and air-dried in a laminar airflow bench for 1 h, and then were put into plastic "clam-shell" containers with four samples in each box (Industry standard, 9756Z, Pactiv Corp., Mexico) and stored at 4 °C for 14 d.

Concerning dipping method, each sample was directly dipped into coating solution for the given time mentioned above. For enrobing method, each coating solution was pumped up by a peristaltic pump through a 6 mm inner diameter plastic tube. Dripping speed was controlled at 50 mL/min, and the dripping nozzle ca. 2 cm above each sample was moved around by hand to promote fully coating.

Both spraying and electrostatic spraying processes were carried out by an SC-ET Sprayer (Electrostatic Spraying Systems Inc., Watkinsville, GA). The spray gun was perpendicularly fixed ca. 50 cm over a metal tray with 3 samples laying out as triangle on it. During the spraying process, spray rate and feeding pressure were set at 3.8 L/h and 1.8 kg/cm^2, respectively. For electrostatic spraying, voltage was set as 7.5 kV and load current of 60 mA.

2.4. Properties of coating solutions (CS)

Total soluble solid content (TSS) was measured at room temperature in triplicate by an RA-250 HE digital refractometer (Kyoto Electronics Manufacturing Co. Ltd., Kyoto, Japan).

Viscosity was measured using a model DV-III programmable rheometer (Brookfield Engineering Laboratories, Middleboro, MA) with a 91 spindle at steady shear rate (30 rpm), and each solution was measured for six times at room temperature. Density was calculated by the weight of each solution divided by its volume (fixed to 25 mL) and was expressed as g/mL.