



Developing food-grade coatings for dry-cured hams to protect against ham mite infestation



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ARTICLE INFO

Article history:

Received 18 May 2015

Received in revised form 16 November 2015

Accepted 18 November 2015

Available online 19 November 2015

Keywords:

Dry-cured ham

Ham mite

Food grade coating

ABSTRACT

Dry-cured hams may become infested with ham mites, *Tyrophagus putrescentiae*, during the aging process. Methyl bromide is the only known available fumigant pesticide that is effective at controlling ham mite infestations in dry cured ham plants. However, methyl bromide will be phased out of all industries as early as 2015 due to its status as an ozone-depleting substance. Research was conducted to develop and evaluate the potential of using food-grade film coatings to control mite infestations, without affecting the aging process and sensory properties of the dry-cured hams. Cubes coated with xanthan gum + 20% propylene glycol and carrageenan/propylene glycol alginate + 10% propylene glycol were effective at controlling mite infestations under laboratory conditions. Water vapor permeability was measured to estimate the impact of coatings during the aging process. It was evident that carrageenan/propylene glycol alginate coatings were permeable to moisture, which potentially makes them usable during aging.

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1. Introduction

Many different types of dry-cured hams are currently produced around the world. Some of the most popular dry-cured hams are Iberian and Serrano ham from Spain, Corsican ham from France, country style ham from the United States, Westphalia ham from Germany, and Jing Hua ham from China. Aging, also known as ripening, is the processing step that develops the unique and characteristic aroma and flavor of dry-cured ham. Aging conditions are very different based on the type of ham and the length of the aging process varies from 3 months to 36 months (Toldrá, 2010).

Tyrophagus putrescentiae, also known as the mold or cheese mite, is a cosmopolitan species that infests stored food products such as grains, peanuts, cheese, cotton seed, and dry-cured ham. Female mites kept on wheat germ or yeast at 20 °C and 85% RH are able to lay up to 500 eggs during their life span. At 20 °C and 85% RH, depending on the type of food available, the mold mites complete one generation in 10 to 24 days (Boczek, 1991). Dry-cured ham aging temperatures usually ranges between 16 °C and 25 °C in Europe, and the relative humidity usually ranges between 65% and 80% (Toldrá, 2010). In the United States, the aging temperatures are higher, often greater than 28 °C (Rentfrow, Chaplin, & Suman, 2012). Dry-cured ham is very susceptible to mite infestations after 4–6 months of aging and the environmental conditions where hams are aged also favor mite growth and

reproduction (Rentfrow, Hanson, Schilling, & Mikel, 2008). Mold mites have been reported as a problem for dry-cured ham both in Spain (Sánchez-Ramos & Castañera, 2000) and in United States (Rentfrow et al., 2012).

Methyl bromide has been used to fumigate commodities and buildings worldwide since the 1930s (Fields & White, 2002) and is the only known fumigant that is effective at controlling ham mite infestations as of 2013 (EPA, 2013). In 1992, methyl bromide was listed as an ozone depleting substance under the Montreal Protocol, in which all developed countries agreed to reduce the amount of their application of methyl bromide by 2005 (TEAP, 2000). Since 2004, critical use exemptions have been granted in developed countries on a yearly basis if a technical and economically feasible alternative with acceptable environmental and health effects was not available. A critical use exemption of 3240 kg has been approved for dry cured pork products in the United States in 2015 (EPA, 2013). Exploring potential alternatives to control mite infestation is very important for the economic viability of the dry-cured ham industry in US.

Potential alternatives for methyl bromide fumigation include fumigants such as phosphine; physical control methods such as modified atmosphere; pesticides and bioactive compounds such as Storcide II® and limonene from pine essential oils (Abbar, Zhao, Schilling, & Phillips, 2013; Macchioni et al., 2002; Sánchez-Molinero, García-Regueiro, & Arnau, 2010; Sekhon et al., 2010). Beside the alternatives mentioned above, it has been stated that coating hams with vegetable oils or hot lard is a common practice in Spain to control mite infestations in dry-cured ham (García, 2004). Cured meat has

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been rubbed with paste of lard on the surface prior to storage to prevent flies and bacteria for over 100 years (Smith, 1923). Abbar et al. (2013) recently reported that several legal food additives applied to the surfaces of small ham cubes would inhibit mite reproduction following forced inoculation with live mites. These results on mite inhibition with food-safe additives facilitated the research reported below.

Edible coatings have been applied for different purposes on a variety of food products including fresh fruits and vegetables, confections and meat products. For meat products, edible films and protective coatings have been used to prevent off-flavor due to oxidation, discoloration, quality loss such as shrinkage, and microbial contamination (Ustunol, 2009). For example, film coatings made from k-carrageenan incorporated with ovotransferrin (a protein of avian egg's antimicrobial defense system) and EDTA were applied on fresh chicken breast and have shown inhibition against *Escherichia* and total aerobic bacteria during storage (Seol, Lim, Jang, Jo, & Lee, 2009). To be qualified as a coating for dry-cured ham, the compound must 1) be food grade; 2) be able to attach to the ham surface; 3) be able to cover the ham surface evenly; 4) be stable during the aging process; 5) be permeable to water vapor and oxygen; 6) be able to suffocate, kill, and/or repel mites and insects when applied properly; 7) not adversely affect ham flavor; and 8) be easily removed after the aging process. The objectives of this research were 1) to evaluate food grade coatings for their efficacy at controlling mite infestations under laboratory conditions; 2) to determine if coatings that are developed are permeable to moisture; and 3) to determine if the use of coatings changes the sensory properties of the dry cured ham.

2. Materials and methods

2.1. Food-grade coating materials on ham cubes

2.1.1. Materials

Lard (ConAgra Foods, Omaha, NE), mineral oil (CVS® Pharmacy Inc., Woonsocket, RI), glycerin (Essential Depot, Sebring, FL), propylene glycol (Essential Depot, Sebring, FL), and potassium sorbate (Crosby & Baker Ltd., Westport, MA) were purchased as coating materials. Ten percent potassium sorbate solution was prepared in distilled water.

2.1.2. Ham preparation

Six dry-cured hams were purchased from a commercial ham plant. From each ham, seven 1.3 cm thick slices and five 2.5 cm thick slices were obtained. The 2.5 cm slices were then cut into 2.5 cm³ cubes for the mite infestation study. Ham slices/cubes were dipped directly into mineral oil, propylene glycol, 10% potassium sorbate solution, and glycerin for 1 min and allowed to drip on a mesh colander for another min. Lard was applied directly by rubbing a thin layer to cover the entire area.

For sensory evaluation, five 1.3 cm thick slices from each ham were treated as described for the ham cubes with mineral oil, propylene glycol, potassium sorbate, glycerin and lard, respectively. Two additional slices from each ham were non-treated control slices. Slices were then vacuum-packed and stored at 4 °C for further sensory analysis. For mite bioassays, one cube from each ham was randomly selected to treat with mineral oil, propylene glycol, potassium sorbate, glycerin, and lard, respectively. Another cube from ham was also randomly selected and freeze-dried until the water activity dropped to 0.65 on the surface and 0.8 inside the cubes. Treated cubes were packaged in zip-lock bags and shipped overnight to Kansas State University, Manhattan, KS for the mite infestation study.

2.1.3. Mite infestation study

Twenty adult *T. putrescentiae* with 10 or more females per group were transferred onto each cube from a laboratory colony, and the cube was placed in a ventilated, mite-proof 130-ml glass canning jar for incubation at 25 ± 1 °C and 70% relative humidity. For the first mite infestation study with cubes dipped in pure or diluted solutions

of test material, mites were incubated for 21 days to allow for reproduction. In subsequent testing, in which propylene glycol was formulated into coatings, the mites incubation time was 14 days. Resulting mite populations on ham cubes were counted at the end of the 3-week or 2-week incubation period using a dissecting stereo-microscope (Olympus Model SZX10, Olympus Surgical & Industrial America INC.). Only adult or immature mobile stages of mites were counted as representing the level of reproduction from the initial 20 mites at the beginning of the trial.

2.2. Development of film coatings with polysaccharide and propylene glycol

2.2.1. Materials

Since initial laboratory coating tests indicated that propylene glycol was effective at controlling mite infestations, further studies were carried out to develop film coatings that contained propylene glycol and polysaccharides. Polysaccharides were utilized for two reasons. First, if no carrier is used, the propylene glycol will evaporate and lose its effectiveness within 2–3 weeks. Using the coating also decreases the effective concentration of propylene glycol, thus reducing the cost of the treatment. Preliminary tests on polysaccharides suggested that both 50% and 98% propylene glycol was effective at controlling mites with 2% carrageenan. To develop a polysaccharide gel solution with up to 50% propylene glycol, the following materials were also tested: modified food starch (INSTANT PURE-COTE, Grain Processing Corporation, Muscatine, IA52761), agar (Tic Pretested® Agar RS-100 Powder, TIC Gums, Belcamp, MD 21017), carrageenans (MBF-120i, x, INC., Waldo, ME 04915; MBF-9414, Ingredients Solutions INC., Waldo, ME 04915; Ticgel 795, TIC Gums, Belcamp, MD 21017), propylene glycol alginate (Tica-algin PGA, TIC Gums, Belcamp, MD 21017), methylcellulose (TICAGEL® HV Powder, TIC Gums, Belcamp, MD 21017), sodium alginate (TICA-algin® 400 Powder, TIC Gums, Belcamp, MD 21017), and xanthan gum (Pre-hydrated Ticaxan Rapid-3 powder, TIC Gums, Belcamp, MD 21017).

2.2.2. Solution preparation with polysaccharides and propylene glycol

To evaluate how different polysaccharides interact with propylene glycol, combinations were tested (Table 1). For cold water soluble polysaccharides, distilled water at room temperature was used. All solutions were made in glass beakers with a magnetic stir bar inside each beaker, and solutions were stirred on magnetic stir plates until homogeneous. For hot water soluble polysaccharides, boiled water was used and the solutions were stirred on magnetic stir plates with heating elements until homogeneous. Metal meat hooks were used to dip ham cubes (2.5 × 2.5 × 2.5 cm³) into the gel solutions for 10 s. Coated cubes were hung at 24 °C and 50% RH to determine the film-forming abilities of the tested combinations.

2.2.3. Ham preparation for mite bioassay

Three sets of dry-cured ham cubes (2.5 × 2.5 × 2.5 cm³) were prepared for three mite bioassays. For the first mite bioassay trial, ham cubes were coated with pure polysaccharides and no propylene glycol. Agar (Tic Pretested® Agar RS-100 Powder, TIC Gums), propylene glycol alginate (Tica-algin® PGA LV Powder, TIC Gums), carrageenan (Ticagel® 795 Powder, TIC Gums), and xanthan gum (Pre-Hydrated®-Ticaxan® Rapid-3 Powder, TIC Gums) were tested to evaluate the effectiveness of pure polysaccharide coatings at controlling mites. For the second and third trials, propylene glycol (Essential Depot, Sebring, FL) was combined with polysaccharide solutions (Table 2). Xanthan gum was solubilized at room temperature, and other polysaccharides were solubilized in boiling water on hot stirring plates and were heated and stirred until homogenous. The viscosity of the gel solutions increased as the temperature cooled. To maintain a consistent thickness of coatings on the cube surfaces, the temperatures of the dipping solutions were controlled (Table 2). Three commercially aged hams were used during each trial. Two cubes from each ham were dipped in

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