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Review

Controlling pests in dry-cured ham: A review

Y. Zhao [a], S. Abbar [b], B. Amoah [b], T.W. Phillips [b], M.W. Schilling [a,*]

[a] Department of Food Science, Nutrition and Health Promotion, Mississippi State University, MS, United States
[b] Department of Entomology, Kansas State University, Manhattan, KS 66506, United States

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ABSTRACT

Dry-cured hams can become infested with ham mites, red-legged beetles, cheese skippers, and larder beetles during the aging process. Though other methods may be used for beetles and cheese skippers, methyl bromide is the only available fumigant that is effective at controlling ham mites in dry-cured ham plants in the United States. However, methyl bromide will be phased out of all industries by approximately 2015. This paper will review and explore potential alternatives that have been investigated to determine their feasibility for replacing methyl bromide to control pest infestations in dry-cured ham plants in the United States. Potential alternatives include: 1) fumigants such as phosphine and sulfuryl fluoride; 2) physical control approaches through cold treatment, modified atmosphere, inert dusts, etc.; 3) pesticides and bioactive compounds; 4) food-grade processing aids. The most promising potential alternatives to date include the use of propylene glycol on the ham surface, the exploration of alternative fumigants, and implementation of an integrated pest management plan.

Contents

1. Manufacturing of dry-cured ham

Many types of dry-cured hams are 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 (Toldrá, 2010). American dry-cured ham, also known as country ham, is produced from the hind leg of a pork carcass by rubbing salt and other ingredients that draw out the moisture. A typical American dry-cured ham is treated with salt, nitrate and/or nitrite and loses at least 18% of its original weight during processing. The majority of American dry-cured ham facilities are located in the southeastern states, including Virginia, Kentucky, North Carolina, Tennessee, Georgia, and Missouri (Rentfrow, Chaplin, & Suman, 2012).

Salt, nitrate and/or nitrite are the major ingredients in the cure mix. Salt inhibits the growth of spoilage microorganisms by reducing the water activity and solubilizing some of the myofibrillar proteins. Nitrate

* Corresponding author.
E-mail address: schilling@foodscience.msstate.edu (M.W. Schilling).

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is reduced to nitrite and then nitric oxide by nitrate reductase, a natural enzyme in the ham. The typical red/pinkish color of ham is due to the reaction of nitric oxide and myoglobin which forms nitrosyl myoglobin (Toldrá, 2002). Other ingredients such as sugar and black pepper are optional for flavor enhancement. A typical curing mix contains 8 kg of salt, 2 to 3 kg of sugar, and 90 to 250 g of sodium nitrate for each 100 kg of fresh ham (Ockerman, Basu, Crespo, & Sánchez, 2002). The curing mix is applied on the surface of hams by evenly spreading or hand rubbing at one time or by multiple applications at certain intervals based on the processors' experience and preference (Ockerman et al., 2002). The duration of the ham in the curing mix is typically 6 weeks at 2–4 °C but varies depending on the weight of the fresh ham, the processor's preference and meeting USDA requirements (USDA FSIS 9 CFR 318.10). Salt penetrates hams at an approximate rate of 2.54 cm of cushion depth per week (Marriott & Schilling, 2004). The excess curing mix on the ham surface is removed by washing and soaking hams in water after the curing period. Hams are then transported to a warmer environment (approximately 10–13 °C) for approximately 2 weeks for the salt equalization step (Ockerman et al., 2002; Rentfrow et al., 2012).

Aging, also known as ripening, is the processing step that develops the unique and characteristic aroma and flavor of country ham. The intensity of the dry-cured aroma and flavor is a result of extensive lipolysis and proteolysis that are proportional to the length of the aging time. Aging conditions vary based on the country of origin (Andres, Ventanas, Ventanas, Cava, & Ruiz, 2005) and individual producers. Aging temperatures usually range between 16 °C and 25 °C in Europe with relative humidity between 65% and 80% (Toldrá, 2010). In the United States, the aging temperatures are higher, often greater than 28 °C (Rentfrow et al., 2012). More than 50% of country hams are aged for 3–6 months (Rentfrow et al., 2012), but there are many companies that age hams between 6 and 24 months to develop intense and desirable flavor characteristics. Hams produced in the Mediterranean area such as Iberian hams are aged for a minimum of 18 months (Ockerman et al., 2002). When aging for a long period, applying a layer of lard on the lean area is a common practice to avoid excessive drying and to prevent cracking and hollow defects (Fulladosa et al., 2010). In addition, minimizing mold growth, covering cracks and holes on the ham with fat and relative humidity control can be used as part of an integrated pest management plan to help control mites.

2. Pest infestations in dry-cured ham

Dry-cured hams are susceptible to several arthropods, insects and mites during the aging process: ham mites *Tyrophagus putrescentiae* (Acarina: Acaridae), red-legged ham beetles, *Necrobia rufipes* (Coleoptera: Cleridae), cheese skippers *Piophila casei* (Diptera: Piophilidae) and larder beetles, *Dermestes lardarius* (Coleoptera: Dermestidae).

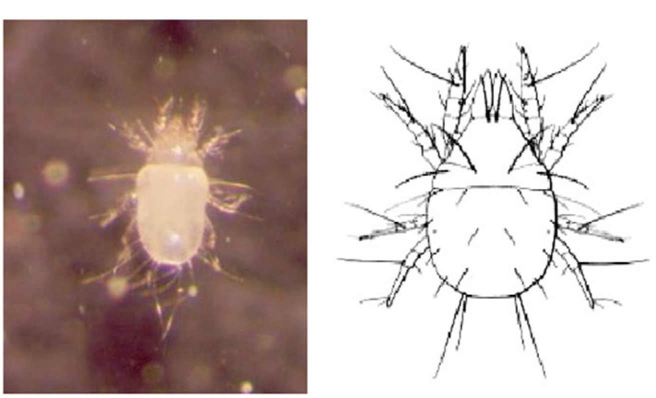

Fig. 1. *Tyrophagus putrescentiae* photo of adult, left (http://www.horticom.com/pd/imagenes/56/475/56475.html) and drawing of adult, right (USDA, 2015).

T. putrescentiae (Schrank) (Fig. 1), also known as the mold or cheese mite, is a universal species that infests stored food products that have high fat and protein content (Gulati & Mathur, 1995). These products include dried fruits, spices, cultured cheeses (Rentfrow, Hanson, Schilling, & Mikel, 2008), pet food (Brazis, Serra, Dethioux, Biourge, & Puigdemont, 2008; Thind, 2005), and cereal-based food products (Thind & Clarke, 2001). In dry-cured ham, there is little or no infestation when aging is done for less than three months. However, aging times longer than six months is necessary to obtain the desired flavor and product quality that meets a niche high dollar market. The risk of mite infestation increases when ham is aged for more than five months. However, aging for less than five months does not assure processors that infestation problems will not occur (Rentfrow, Hanson, Schilling, & Mikel, 2006). Most mite infestations occur on the surface of food products. However, mites may penetrate inside the product and thus cause more severe economic loss (Zdárková, 1991). The infested surface sometimes appears to move when observed by the naked eye due to the massive population of mites, and mite dust may appear around an infested food product.

At 60–80% relative humidity and 20–30 °C, the mold mite can complete one generation in 8 to 21 days, and the length of the life cycle increases when the temperature drops (Mueller, Kelley, & VanRyckeghem, 2006). The optimal temperature for females to lay eggs is between 22 °C and 26 °C. At 20 °C and 85%RH, female mites start laying eggs within the first 24 h of mating and are able to lay up to 500 eggs throughout their lives (Boczek, 1991). Once the temperature drops below 10 °C, the mites cannot develop, but they are able to survive at 0 °C in an inactive state (Mueller et al., 2006). Eggs are more tolerant to adverse conditions such as fumigation since mites are more

Fig. 2. Adult red-legged ham beetle (http://commons.wikimedia.org/wiki/File:Necrobia_rufipes.jpg).