Research Note

Elimination of *Listeria monocytogenes* from Ready-to-Eat Turkey and Cheese Tortilla Wraps Using Ionizing Radiation†

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ABSTRACT

*Listeria monocytogenes* is a common postprocess contaminant on ready-to-eat foods including premade ready-to-eat sandwiches. One popular type of sandwich product is the tortilla wrap, which contains sliced luncheon meats and cheeses rolled within a flour tortilla. This study determined the radiation resistance of *L. monocytogenes* surface inoculated onto two types of commercially available wheat flour tortillas, processed cheese slices, and deli turkey meat. The D_{10} values for *L. monocytogenes* (the radiation dose required to inactivate 1 log of the pathogen) were 0.27 kGy when inoculated onto two flour tortilla types, 0.28 and 0.30 kGy when inoculated onto two types of sliced processed cheeses, and 0.58 and 0.65 kGy when inoculated onto two types of sliced deli turkey meat. When two types of tortilla wraps were assembled from the individual components and *L. monocytogenes* was inoculated into the interfaces between the individual components, the D_{10} values were 0.27 to 0.37 kGy in the tortilla and cheese interfaces, 0.33 to 0.41 kGy in the cheese and turkey interfaces, and 0.25 to 0.33 kGy in the turkey and tortilla interfaces. The ability of ionizing radiation to reduce pathogen levels on the complex tortilla, cheese, and luncheon meat product was limited by the higher radiation resistance of *L. monocytogenes* when inoculated onto the ready-to-eat turkey-meat component.

*MATERIALS AND METHODS*

Food products. Turkey, tortillas, and presliced processed and pasteurized American-style cheese were purchased from local vendors. Turkey deli meat was purchased in bulk and sliced to a

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thickness of approximately 2 mm using an automatic meat slicer. The cheese was purchased as vacuum-packaged presliced bulk packs. Tortilla packs each contained 10 to 12 wheat flour-based wraps per package. In order to investigate more than a single turkey, cheese, or tortilla product, two types of tortilla, processed cheese, and turkey meat were used in the study and were designated by number (either 1 or 2) for that product.

Tortilla 1 consisted of enriched wheat flour (wheat flour, niacin, iron, thiamine mononitrate, riboflavin, folic acid), water, shortening (partially hydrogenated soybean and cottonseed oils with mono- and diglycerides added), salt, distilled monoglycerides, sodium bicarbonate, sodium aluminum phosphate, potassium sorbate and calcium propionate (to protect flavor), sugar, dough conditioners (sodium stearoyl lactylate, calcium sulfate, sodium sulfite), fumaric acid. Tortilla 2 consisted of enriched flour (wheat flour, niacin, reduced iron, thiamine mononitrate [B1], riboflavin [B2], folic acid), water, soybean oil, salt, potassium sorbate (used to preserve freshness), guar gum, fumaric acid, baking powder (sodium bicarbonate, sodium aluminum sulfate, cornstarch, calcium sulfate, monocalcium phosphate), sodium metabisulfite (dough conditioner).

Cheese 1 consisted of cultured milk and skim milk, water, cream, sodium citrate, salt, citric acid, sorbic acid (preservative), sodium phosphate, enzymes, lecithin. Cheese 2 consisted of cultured milk and skim milk, water, cream, sodium citrate, salt, sodium phosphate, sorbic acid (preservative), citric acid, artificial color, acetic acid, enzymes, and lecithin.

Turkey 1 consisted of white turkey meat, turkey broth, salt, modified food starch, sugar, carrageenan, sodium phosphate. Turkey 2 consisted of turkey breast meat, turkey broth, 2% or less of dextrose, modified food starch, salt, sodium erythorbate, sodium nitrite, and sodium phosphate.

**Bacterial strains.** Four *L. monocytogenes* strains (H7762 serotype 4b, H7764 serotype 4b, F4249 serotype 1/2a, and F4561 serotype 1/2a) were obtained from the Centers for Disease Control and Prevention (Atlanta, Ga.). The strains were propagated on tryptic soy agar (Difco, Becton Dickinson, Sparks, Md.) at 37°C and maintained at 0 to 4°C until used. Identity of *Listeria* spp. was confirmed by Gram stain followed by analysis with gram-positive identification cards using the Vitek Automicrobic System (bioMérieux Vitek, Inc., Hazelwood, Mo.).

**Inoculation.** Each *L. monocytogenes* strain was cultured independently in tryptic soy broth (Difco) in baffled, 500-ml Erlenmeyer culture flasks at 37°C (150 rpm) for 18 h. The cultures were then combined and the cocktail sedimented by centrifugation (1,725 × g for 30 min). The *L. monocytogenes* cocktail was then concentrated by resuspension in 40 ml of Butterfield’s phosphate buffer (Applied Research Institute, Newtown, Conn.). Turkey slices, cheese slices, or tortilla quarters (approximately 60 cm²) were placed in no. 400 Stomacher bags and surface inoculated on a single side with 0.1 ml (10⁶ CFU) of *L. monocytogenes* cocktail. The inocula were then spread over the product surfaces using sterile, wet (Butterfield’s phosphate buffer) cotton swabs.

Uninoculated wraps were assembled by single layering cheese slices and then turkey slices onto an intact tortilla wrap, which was then rolled to form the final product. Two types of wraps were assembled. Wrap 1 consisted of tortilla 1, cheese 1, and turkey 1, and wrap 2 consisted of tortilla 2, cheese 2, and turkey 2. The wraps were then cut into 3- to 4-cm-long sections, placed in no. 400 Stomacher bags, and inoculated with 0.1 ml (10⁶ CFU) of *L. monocytogenes* cocktail between the meat and cheese interface, the tortilla and cheese interface, or the tortilla and meat interface using a handheld pipette and 0.2-ml needle-
radiated onto either tortillas or processed cheese (analysis of variance) \((n = 3, \alpha = 0.05)\). For both product types, cheese and tortillas, a $\geq 5$-log reduction was obtained at a radiation dose of 1.6 kGy.

In contrast with $D_{10}$-values on tortillas and cheese, the $D_{10}$-values for *L. monocytogenes* inoculated onto deli turkey meat were much higher, $0.58 \pm 0.2$ kGy for turkey 1 and $0.65$ kGy $\pm 0.3$ kGy for turkey 2 (Fig. 1). At a radiation dose of 2.0 kGy, the radiation dose at which off odors were noticed with the cheeses, a 3.1- to 3.8-log reduction of *L. monocytogenes* would be obtained. The $D_{10}$-values were statistically significantly higher than those obtained for *L. monocytogenes* on turkey as opposed to the cheese and tortilla types as determined by analysis of variance \((n = 3, \alpha = 0.05)\).

When *L. monocytogenes* was inoculated between the component layers of assembled wrap products, the microorganism retained radiation sensitivity intermediate or equivalent to that of the two individual component types. *L. monocytogenes* $D_{10}$-values were 0.37 and 0.27 kGy when inoculated between cheese and tortilla for wrap 1 and wrap 2, respectively (Fig. 2). $D_{10}$-values were 0.33 and 0.25 kGy when inoculated between turkey and tortilla for wrap 1 and wrap 2, respectively (Fig. 2). *L. monocytogenes* $D_{10}$-values were 0.33 and 0.41 kGy when inoculated onto Anthotyros cheese to be

Data obtained from irradiation of these complex food products are in agreement with previous studies that indicate that product formulation affects the radiation resistance of *L. monocytogenes*. Sommers and Thayer (17) found that the $D_{10}$-values of *L. monocytogenes* inoculated onto several types of commercially available frankfurters ranged from 0.49 to 0.71 kGy, Foong et al. (8) found that the radiation dose needed to eliminate 5 log of *L. monocytogenes* from RTE meats ranged from 2.5 to 3.0 kGy. Ennhar et al. (7) determined the $D_{10}$-values of *L. monocytogenes* inoculated onto soft and red-smear cheeses to be 0.49 and 0.41 kGy, respectively, while Tsiotsias et al. (18) found the $D_{10}$ of *L. monocytogenes* inoculated onto Anthotyros cheese to be
1.38 kGy. Bougle and Stahl (4) obtained a $D_{10}$-value of 0.50 kGy for \textit{L. monocytogenes} inoculated onto Camembert cheese. Little data are available pertaining to the radiation resistance of \textit{L. monocytogenes} inoculated onto different types of bread products.

Based on the radiation resistance on individual components for \textit{L. monocytogenes} and when the pathogen is inoculated between product layers, a radiation dose of 2.0 kGy is sufficient to eliminate $\geq$5 log of the pathogen from tortillas, cheese, and the interfaces between them. Three to 4 log CFU/g of the microorganism would be removed from the deli meat. Previous work (16) has indicated that a radiation dose of 1.5 kGy represses the postirradiation growth of \textit{L. monocytogenes} inoculated onto RTE meats for 1 to 2 weeks and that postirradiation growth of the microorganism is completely inhibited when additives such as sodium diacetate and potassium lactate mixtures are included in RTE meat-product formulations (16). Given the short shelf life of such products, $\leq$1 week, and based on the data obtained in \textit{L. monocytogenes} detection studies (5, 10, 23), a radiation dose of 2.0 kGy would eliminate the bacterium from 99.9% of RTE products and be unable to proliferate in the remainder. If additional protection were required, use of deli meats that contain additives such as sodium diacetate and potassium lactate mixtures for inclusion in the assembled RTE wrap products would ensure a minimum 3-log reduction without the possibility of \textit{L. monocytogenes} regrowth in tortilla wrap-type products regardless of shelf life. Other approaches might include the use of modified atmospheres packaging in combination with irradiation to inhibit microbial growth. Future work should include quality and organoleptic studies of an irradiated product.

While the vast majority of luncheon meats and bagged salad vegetables contaminated with \textit{L. monocytogenes} contain relatively low levels ($\leq$10² CFU/g) of the microorganism, it is not unusual that products subjected to temperature abuse (10°C) may contain $\geq$10⁴ CFU/g of \textit{L. monocytogenes} (10, 13, 23). Wilson (23) found that 15% of prepacked retail sandwiches contained \textit{Listeria} spp. and 0.3% of the contaminated sandwiches contained $\geq$10⁴ CFU/g of \textit{L. monocytogenes}. In addition, Gombas et al. (10) noted that retailers that prepared and packaged RTE foods had \textit{L. monocytogenes} detection rates in their products that ranged from 2.7 to 6.3%, much higher than those detected by products obtained directly from manufacturers (0.4 to 1.4%). Complex multicomponent products assembled for retail sale could therefore benefit from a postassembly and postpackaging pathogen-reduction treatment such as irradiation, which protects the public from foodborne illness outbreaks.

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\section*{REFERENCES}


