

### ***Escherichia coli* O157:H7 survival in needle-tenderized dry cured Westphalian ham**

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Dry cured Westphalian ham is a traditional ready-to-eat (RTE) product that is manufactured without thermal processing. These value added hams are preserved through the development of a naturally occurring microflora, low water activity ( $a_w$ ) and with the addition of cure agents including salt, nitrite/nitrate and spices. Lengthy production times (< 3 months) which involve substantial inventory and labour investment, have led to increased producer interest in manufacturing procedures which can accelerate traditional dry curing practices. One acceleration method includes mechanical tenderization (blade and/or needle) of raw hams prior to cure application. Mechanical tenderization functions to create multiple cure penetration points which allows for a more rapid diffusion of cure adjuncts throughout the whole ham muscle piece which can significantly shorten the Westphalian ham ripening period. However, blade tenderization has been previously demonstrated to transfer surface bacterial organisms (1 to 2 log CFU/g) to the inside of previously sterile, deep muscle tissues (5, 6). The raw meat surface harbours many bacteria that are deposited during slaughter, some of which may include human pathogens such as *Escherichia coli* O157:H7 (1). The threat of *E. coli* O157:H7 on RTE meat products is particularly troublesome due to this organism's low infectious dose (estimated at < 100 cells), acid resistance and ability to cause serious illness, particularly in the very young and old (2). As such, strict guidelines governing the manufacture of RTE fermented meats exist in both Canada (3) and the United States (7), and require that a 5 log CFU/g reduction of *E. coli* O157:H7 be achieved during product manufacture. Fermented meat establishments that handle only pork are not currently required to meet the 5 log CFU/g reduction of this organism but must ensure that no *E. coli* O157:H7 and *Salmonella* are present in the finished product (3). Although *E. coli* O157:H7 is usually associated with beef (2), it is highly significant that *E. coli* O157:H7 was recently isolated from 8.9% of swine samples tested (4). Since Westphalian ham is produced without a thermal kill step, surface or internalized pathogens may survive commercial production. A study was therefore conducted to examine *E. coli* O157:H7 survival during Westphalian ham manufacture with needle tenderization.

Freshly fabricated hams composed of the leg outside, eye and partial tip muscles were obtained from a federally registered processing facility. Hams with internal pH values ranging from 5.6 to 5.8 were deemed suitable for dry cured ham manufacture (Fig. 1). Hams were evenly trimmed to between 3 and 3.5 kg and then immersion inoculated with a five strain cocktail of *E. coli* O157:H7. Hams were then passed through a manually operated tenderizer unit with the needle bank consisting of 3 mm diameter solid needles arranged in a diamond pattern spaced 20 mm beside and 32 mm above and below. A proprietary Westphalian ham cure blend was then vigorously hand-rubbed over the entire surface before hams were vacuum tumbled for 2 d at 4°C. Following tumbling, hams were shaped, netted and then pressed for 14 d under refrigeration. Hams were then strung with butcher's twine and hung for an additional 7 d to allow salt to fully equilibrate throughout the pieces before being transferred into a fully automated, climate controlled, single rack smokehouse. Hams were then fermented (< 25°C/20 h) and intermittently cold smoked (10 h total) over an 8 d period before being placed into a drying chamber where constant temperature and relative humidity conditions (14°C and 74% relative humidity) were maintained until tests were ended.

Hams were sampled before inoculation to ensure the absence of *E. coli* O157:H7 and then again after inoculation and tenderizing. Hams were then tested on days 3, 10, 17, 24, 33, 40, 47, 64, and 112 of ripening to ensure samples were taken during or after the completion of each manufacturing step. Different hams were used for sequential testing of

*E. coli* O157:H7 cells, pH and surface and interior  $a_w$ . Surface shavings ( $\leq 2$  mm depth) were cut from areas of little or no visible fat while two core samples were removed from the leg outside portion of the ham using a 47 mm diameter sharpened stainless steel pipe to ensure that 4 to 8 needle injection sites were included in the sample. The ends of the core sample (1 cm) were removed before sterilization by searing using a hand-held propane torch. A 25 g sample was taken from both the surface and interior cores, diluted with 225 mL of 0.1% peptone water and homogenized by blending. *E. coli* O157:H7 organisms were recovered using Sorbitol MacConkey Agar containing cefixime and tellurite supplement, while injured *E. coli* O157:H7 cell recovery was conducted by plating sample homogenate onto Tryptic Soy Agar plates that were initially incubated at 35°C for 3 to 4 h before being overlaid with ctSMAC Agar and re-incubated at 35°C for 72 h.

Hams were initially inoculated with 7.3 and 4.6 log CFU/g *E. coli* O157:H7 on the surface and inside, respectively (Fig. 2). Results demonstrated that needle tenderization acted as a vehicle to transfer surface organisms to the inside of previously sterile deep tissues. Over the next 24 d of processing, reductions of surface and interior *E. coli* O157:H7 were minimal with 2.3 and 1.2 log CFU/g reductions being achieved, respectively. Low reductions were expected since *E. coli* O157:H7 survival is enhanced by cooler temperatures (8). The harsh surface conditions created during fermentation and smoking rapidly decreased surface  $a_w$  values from 0.94 to 0.89 (Fig. 1). Decreases of 2.1 log CFU/g of surface *E. coli* O157:H7 numbers were recorded over this processing step while internalized *E. coli* O157:H7 appeared unaffected as cell numbers remained static. Considering the high fermentation temperatures to which these organisms were exposed, greater reductions in both surface and internalized cells were expected. Over the course of the controlled drying period, a 5 log CFU/g destruction of surface *E. coli* O157:H7 cells was achieved following 64 d of production. Surface *E. coli* O157:H7 continued to decrease over the ripening period and was below the detection limit ( $< 0.4$  log CFU/g) after 112 d while injured cells were not detected following enrichment. Over 112 d, which included 79 d drying, internalized *E. coli* O157:H7 cells were still recovered using direct plating procedures. Internalized *E. coli* O157:H7 survived well when challenged with the multiple stresses of fermentation, exposure to cure ingredients and continuous desiccation which resulted in a final internal  $a_w$  value of 0.87.

Provided Westphalian ham pieces are otherwise intact and not needle-tenderized, current manufacturing procedures would be in compliance with federal requirements in Canada and the United States which mandate a 5 log CFU/g reduction of *E. coli* O157:H7 during fermented meat manufacture. If the same 5 log CFU/g reduction were also required for internalized *E. coli* O157:H7, the needle-tenderized product would not be acceptable. Needle tenderizing raw hams to accelerate the dry curing process should be avoided in these RTE products since this practice served to internalize surface *E. coli* O157:H7 and promote its survival.

### Acknowledgments

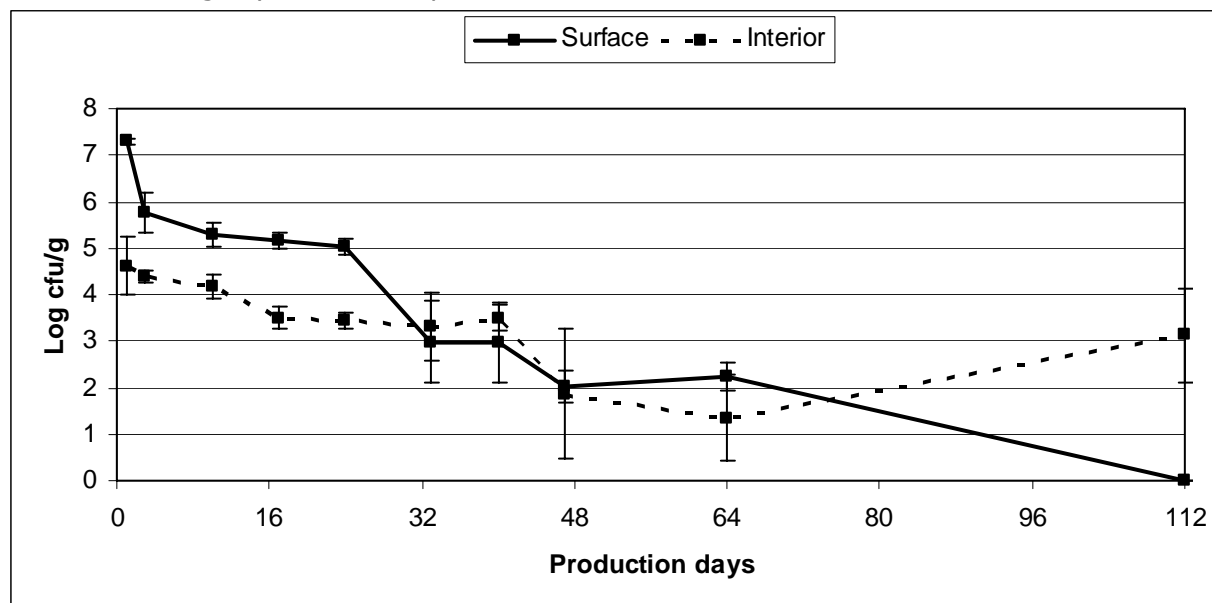
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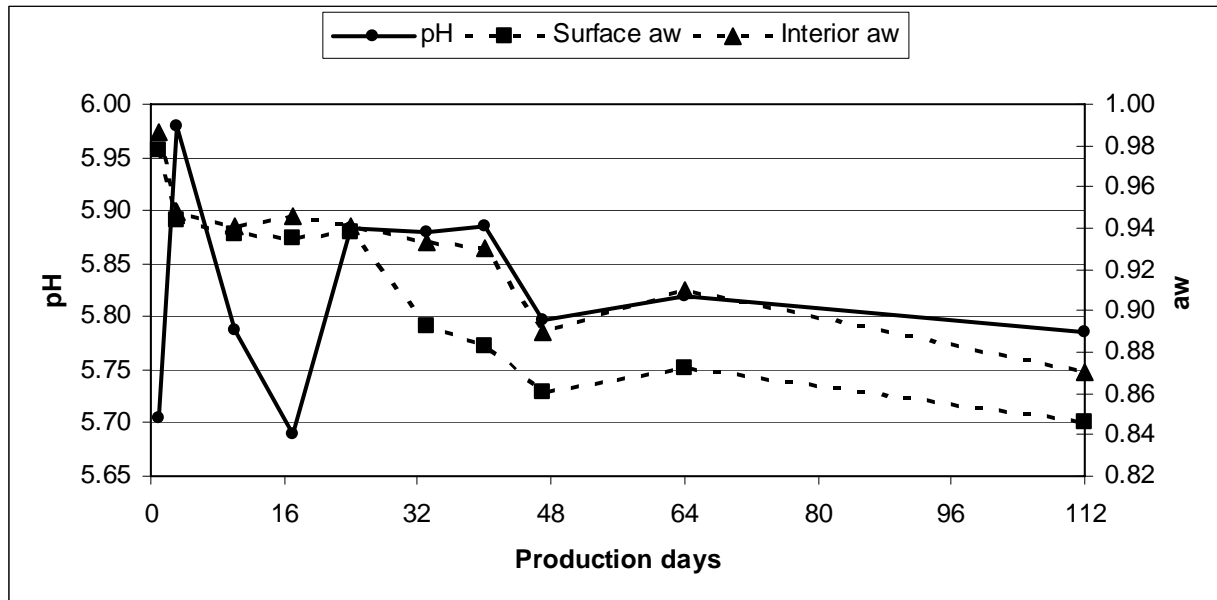
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**Figure 1.** Reductions in numbers (log CFU/g)\* of surface and internalized *Escherichia coli* O157:H7 during dry cured Westphalian ham manufacture.



\*Values represent the mean of two trials replicated four times.

**Figure 2.** Changes in Westphalian ham pH and surface and interior water activity (aw) values\* during manufacturing.



\* Values represent the mean of two trials replicated four times.

**Photo:** Westphalian ham: post fermentation and smoking.

