Food Control 31 (2013) 116–124

Contents lists available at SciVerse ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Observation and relative quantification of cross-contamination within a mock retail delicatessen environment

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ARTICLE INFO

Article history:
Received 8 June 2012
Received in revised form
14 September 2012
Accepted 25 September 2012

Keywords:
Ready-to-eat food
Delicatessen meats
Deli slicer
Cross-contamination
Fluorescent compound
Food safety

ABSTRACT

Ingestion of ready-to-eat deli meats contaminated with foodborne pathogens has been linked to several outbreaks. For this study, a fluorescent compound (FC) was used to observe deli workers in cross-contamination events to visualize and quantify how potential microbial contamination can move within a mock retail deli environment. Twenty-one participants were recruited and were asked to complete a series of steps involving the slicing of deli meats in which one of the meat products was inoculated with the FC. Upon completion, 16 separate areas (5 × 5 cm) per participant were swabbed to quantify the amount of FC present. A standard curve for the FC (based on absorbance at 370 nm) was developed in order to quantify the amount of FC. For each participant, both video and image data were also collected. These data were normalized and reported as percentages of the total amount of FC collected per participant to allow the amount of FC in each area to be compared across participants. Concentrations of FC by area swabbed and participant were highly variable; even so, consistently elevated levels of FC were found on participants' gloves (18%), on the slicer's meat grip (16%), the outside wall of the carriage tray (16%) and within the collection area (13%). Video analysis revealed that high-touch areas include the deli meat, deli meat wrapper, deli paper, and plastic bags which comprised 74% (87 of 118 touches) of the total average hand contact frequency per participant. The relationship between frequency of hand contact and % FC on a particular area swabbed was analyzed, and a Pearson's *r* value of 0.37 was determined indicating a medium-strength, positive correlation. The findings in this study demonstrate that there is variability among participants within a mock retail deli environment, and thus, likely to be similar variability among workers in an actual retail deli environment. In addition, even in the presence of this variability, this study identifies both areas of elevated contamination levels as well as areas of high hand contact within a deli environment. To our knowledge, this is the first study to quantify cross-contamination events using a FC and to identify potential areas of concern with respect to cleaning and sanitizing as well as employee training.

1. Introduction

Cross-contamination of pathogens in food service environments is considered a leading factor in both sporadic and epidemic foodborne illness (Chen, Jackson, Chea, & Schaffner, 2001; Pradhan, Ivanek, Grohn, Bukowski, & Wiedmann, 2011). Ready-to-eat (RTE) foods prepared at the retail level are of particular concern since there is no further intervention or treatment prior to consumption (Lianou & Sofos, 2007). One of the major pathogens of concern with respect RTE food products is *Listeria monocytogenes*, a foodborne bacterial pathogen that causes listeriosis—a rare yet severe human disease (Lianou & Sofos, 2007). Of particular importance is the contamination of RTE delicatessen (deli) meats with *L. monocytogenes*. Contaminated deli meats are estimated to be responsible for 90% of the cases of listeriosis in the United States based on a risk assessment conducted by the U.S. Food and Drug Administration (FDA) and U.S. Department of Agriculture Food Safety and Inspection Service (FSIS) (FDA & FSIS, 2003). Moreover, it has been estimated that 83% of listeriosis cases attributable to contaminated deli meats are associated with products sliced at retail as opposed to sliced in a United States Department of

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http://dx.doi.org/10.1016/j.foodcont.2012.09.040

Agriculture (USDA) inspected plant by the manufacturer (Endrikat et al., 2010). As indicated by Sheen (2008), slicing is the last processing step thus the deli slicer can become a critical control point for preventing cross-contamination events.

Several studies have investigated as well as mathematically modeled pathways of cross-contamination of *L. monocytogenes* at the food processing plant level (Ivanek, Grohn, Wiedmann, & Wells, 2004; Lappi, Thimothe, Nightingale et al., 2004; Lappi, Thimothe, Walker et al., 2004; Schaffner, 2004); meanwhile, similar studies at the retail level are limited, not as comprehensive, and model hypothetical scenarios of cross-contamination (Peréz-Rodríguez et al., 2006; Pradhan et al., 2011). As identified in Pradhan et al. (2011), the mechanisms and critical pathways of cross-contamination at retail are influenced by several factors (e.g., source of contamination, frequency of cross-contamination, worker habits, and distribution of contamination) that, at present, are not well understood. In particular the ability to better assess worker habits and their effects on cross-contamination events at retail delis may contribute to the development of more effective Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP) (Crandall et al., 2011).

Food handlers may play a critical role in the transmission of foodborne pathogens in retail food service operations either as the primary source of the pathogen by coming to work ill or by transferring the pathogen from contaminated surfaces (slicers, refrigerator handles, or foods) to RTE products (Lianou & Sofos, 2007). Observational studies of food handling practices at retail food service operations have identified behaviors that may contribute to cross-contamination and include: inadequate hand washing, bare hand contact with unwrapped raw food, bare hand contact with salads and utensils, and the use of weighing scales with RTE foods and raw product (Angelillo, Viggiani, Rizzo, & Bianco, 2000; Clayton & Griffith, 2004; Green et al., 2005, 2006; Little & de Louvois, 1998; Sagoo, Little, & Mitchell, 2003). By identifying specific employee practices that contribute to food safety, more effective, science-based educational materials can be developed serving as a foundation for creating behavioral changes to improve sanitary and hygienic food handling (Crandall et al., 2011; Lianou & Sofos, 2007). In addition to food handlers, environmental sources, including utensils, and equipment within the deli when poor cleaning and sanitation conditions occur, may also be a source of foodborne pathogens of concern (Bryan, 1990, 2002; FDA, 1999; Sheen & Hwang, 2010). While several studies have investigated the pathways of cross-contamination of *L. monocytogenes* at the food processing level, there are several unique characteristics of the retail deli environment that differ from processing plants that may have prevented the development and application of effective control measures. These unique characteristics include the complexity, variety, and highly dynamic character of the operations, the presence of customers, display needs, slicing and repackaging of products, and dependency of part-time or temporary food handlers with a high employee turnover rate (McSwane & Linton, 2000; Mortlock, Peters, & Griffith, 1999, 2000; Reimers, 1994). Identifying potential sources and routes of contamination of RTE foods within the retail food service operation may be useful in the development of control measures throughout the food service system (Lianou & Sofos, 2007).

Several studies have used fluorescent compounds as indicators of contamination in food processing. Digestion of green plants in the gastrointestinal (GI) tract of beef cattle produces degradation products from chlorophyll that cause ingesta and feces to be highly fluorescent. Ashby et al. (2003) exploited this property to develop and construct instruments to noninvasively detect minute quantities of feces on meat samples in real time. Similarly, Burfoot, Tinker, Thorn, and Howell (2011) reported on the use of a hand-held fluorescent imaging devise to locate feces on beef and lamb carcasses contaminated within processing plants in the United Kingdom. Nieto-Montenegro, Brown, and LaBorde (2008) described the use of fluorescent lotion as a training tool for teaching Hispanic workers in the mushroom industry proper hand washing techniques. Using fluorescent compounds within a mock deli environment can help researchers identify contamination "hot spots" within the workspace, visualize how employees may transfer pathogens and contribute to cross-contamination of utensils and equipment. This data may then be utilized to develop risk-based, scientific training materials specifically for deli employees.

The objectives of this research were to visualize and quantify how potential microbial contamination can move within a mock retail deli environment by utilizing a fluorescing compound (FC). This research addresses a two-fold primary goal to 1) help understand the "worker effect" and 2) identify critical areas of contamination within a simulated deli environment.

2. Materials and methods

2.1. Study participant recruitment

For the scope of this study, we aimed to recruit 21 participants from the Food Science Department at the University of Arkansas (UA), Fayetteville. Prior to recruitment, the UA Institutional Review Board (IRB) approved the observational study design and recruiting method (IRB Protocol #11-04-594). The online survey tool SurveyMonkey® (SurveyMonkey.com, LLC, Palo Alto, CA) was used to create a questionnaire that was emailed to faculty, staff, and students in the Department of Food Science. The online questionnaire was used to both recruit and pre-screen participants by asking questions regarding age (i.e. required age of 18 or older for participation), previous experience in the food service industry (yes/no), and availability for participation in the current study. As an incentive, participants were offered a $25 gift card upon completion of the set of tasks outlined in the subsection "Participant Training and Tasks".

2.2. Participant Training and Tasks

Each participant ($n = 21$) was assigned a date and time for participation in the study and, on their assigned day, the participants received training from an experienced, industry professional on how to operate the deli meat slicer. A gravity-fed mechanical slicer (PrepSaver™ Model 4510, Univex Corporation, Salem, NH) was used for slicing deli meats. The slicer was equipped with a 254-mm (10-inch) diameter hollow ground, chrome plated high carbon, hardened steel blade and operated at 650 revolutions per minute (rpm). Following training, the participants were given a set of tasks to complete (Table 1) in the mock deli environment. Due to the specifics of the tasks and that the participants worked independently, the researchers believe that potential Hawthorne effects (Diaper, 1990) and halo errors (Murphy, Jako, & Anhalt, 1993) were minimized. Briefly, the set of tasks involved preparing 5 slices (2 mm thick) of 3 separate chubs of deli meat—101 to 127 mm in length and approximately 127 mm in diameter—labeled A, B, and C. The deli product used throughout the study was bologna meat (Land O'Frost, Searcy, AR) containing approximately 62% moisture and 19% fat content.

For each participant, the chub of bologna labeled "A" was evenly coated with the FC powder (DMA International, Moab, UT) using a slightly damp sponge while meat "B" and "C" remained uncoated. The FC powder is comprised of 5-μm melamine copolymer resin beads that fluoresce under black light. Once the participant entered the mock deli, he or she was asked to put on a disposable