ARTICLES

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Implementing Targeted Good Manufacturing Practices and Sanitation Procedures to Minimize *Listeria* Contamination of Smoked Seafood Products

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SUMMARY

The Smoked Seafood Working Group (SSWG), a collaboration of two national industry trade organizations, smoked seafood processors and academia, developed guidelines to minimize *Listeria monocytogenes* contamination of finished products in smoked seafood operations. The SSWG identified five elements required for a complete *Listeria* control program: (1) *Listeria* specific Good Manufacturing Practices (GMPs) and sanitation procedures, (2) employee training, (3) environmental microbiological monitoring and testing, (4) raw material controls, and (5) temperature controls for finished product. This manuscript describes specific GMPs and sanitation procedures to minimize *Listeria* contamination in smoked seafood operations. Targeted procedures that need to be implemented include GMPs to prevent cross contamination caused by improper design and layout of processing operations, the movement of people and equipment in the plant, and inadequate employee hygiene and food handling practices. In addition, cleaning and sanitation procedures for equipment and the processing plant environment that are designed to target *Listeria* contamination specifically need to be in place.

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INTRODUCTION

Since 2001, a collaborative effort between two national industry trade associations, representatives from smoked seafood processing companies across the US, and academia has been under way to develop guidelines for the control of the foodborne pathogen *Listeria monocytogenes* in smoked seafood manufacturing plants. The intent of this manuscript is twofold: to summarize and communicate current information on *L. monocytogenes* and appropriate measures to reduce its prevalence in smoked seafood products, and to provide guidelines for processors of smoked seafood products to help them evaluate and implement effective *Listeria* controls in their operation.

The individuals and organizations involved in this effort are working together as the Smoked Seafood Working Group (SSWG) of the National Fisheries Institute and the National Food Processors Association. Representatives of both national industry trade organizations, individuals from at least 10 smoked seafood firms, and food safety or seafood specialists from Cornell University and the Sea Grant programs in New York, Virginia and Delaware are participating in SSWG activities. The guidance developed by the SSWG is based on general guidelines for *Listeria* control in food processing plants developed by Tompkin et al. in 1999 *(41)* and the specific guidelines for smoked fish processors outlined in the Appendix of a United Nations Food and Agriculture Organization (UN/FAO) consultation report in 1999 *(17)*. The SSWG convened a series of meetings and discussions that utilized the experience and expertise of industry, the trade associations, and academic participants to evaluate and adapt existing information on *Listeria* control from Tompkin et al. *(41)* and FAO *(17)* and to incorporate new information from studies in progress *(26, 39)* to produce this set of working guidelines for smoked seafood processors. Information and experiences from pilot studies on *L. monocytogenes* contamination patterns and controls in smoked seafood processing environments conducted by members of the SSWG *(21, 26, 33, 34, 39)* were also used to develop these guidelines. This initiative was also part of a Cornell University project to develop "control strategies for *Listeria monocytogenes* in food processing environments," funded under the National Food Safety Initiative in 2000 by the Cooperative State Research, Education and Extension Service of USDA, Project Number 00-51110-9768.

L. monocytogenes is a Gram-positive foodborne pathogen that can grow in the range of 1 to 45°C (34° to 113°F) and between zero and 10% water phase salt (NaCl). Under current US regulatory policy, if any *L. monocytogenes* is detected in a 25 gram sample of a Ready-To-Eat (RTE) seafood product, including smoked seafood, the product is considered adulterated. Detection of *L. monocytogenes* in smoked fish and other RTE food products has resulted in numerous product recalls and economic loss. *L. monocytogenes* is widespread in the environment, and has been found in soil, water, sewage, and decaying vegetation. It can be readily isolated from humans, domestic animals (including pets), raw agricultural commodities, food processing environments, and the home *(37)*. The organism is found in a wide variety of foods, including meats, poultry, vegetables, dairy products, and fishery products *(10, 19, 31, 37)*. It has frequently been isolated from smoked seafood *(7, 11, 19, 23, 29)*. A reported prevalence of 6–36% in RTE cold smoked salmon and cooked fishery products has raised concern about the public health impact associated with the presence of *L. monocytogenes* in these foods *(3)*. While *L. monocytogenes* present in raw fish may survive process treatments typical for many minimally processed seafoods, such as cold-smoked products *(13)*, contamination from the processing plant environment during or after processing appears to be the major source of finished product contamination for smoked seafood, as well as for other RTE foods *(2, 21, 26, 33, 39, 40)*.

Because *L. monocytogenes* is ubiquitous, there can be constant reintroduction of the organism into the plant environment. Contamination of smoked seafood that supports growth of *L. monocytogenes*, even with small quantities of this organism, is a particular concern because of its ability to multiply at refrigeration temperatures during storage. Farber *(15)* reported that moderate to severe temperature abuse of contaminated fish products may greatly enhance the growth of *Listeria* spp. on fish and indicated that, because of the low naturally-occurring levels of *L. monocytogenes* found on fish, combined with the relatively short shelf life of seafood, *Listeria*-contaminated fish stored at temperatures ≤ 4°C present little risk of serious health consequences.

Although *L. monocytogenes* is frequently isolated from RTE seafood, seafood products, including smoked seafood, have rarely been implicated as a source of human listeriosis. RTE fish products have occasionally been linked to sporadic cases of listeriosis, and epidemiological evidence suggests that listeriosis has been caused by smoked mussels *(4)*; "gravad" trout *(14)*; and smoked trout *(30)*. At least some *L. monocytogenes* subtypes present in RTE foods may have limited pathogenic potential for humans *(34, 40)*. However, because of the potential for serious illness, and even death, in susceptible individuals, it is prudent for industry to take measures to minimize the potential for *L. monocytogenes* contamination of RTE smoked seafood.

LISTERIA IN THE PROCESSING PLANT ENVIRONMENT

L. monocytogenes can survive in non-host environments, including processing plants. *L. monocytogenes* may be introduced into processing plants via a variety of routes, including raw materials, employees' shoes or clothes, containers (e.g., boxes, crates, carts, pallets) and equipment. *L. monocytogenes* tolerates and can grow in conditions (e.g., refrigeration temperatures and high salt levels) that prevent the growth of many other foodborne pathogens. *L. monocytogenes* also has the tendency to establish persistent resident populations that colonize niches in the plant *(21, 26, 39, 40)*. Routine sanitation procedures and general-purpose cleaners and sanitizers do not easily eliminate these resident populations.

Eklund et al. *(12)* identified incoming product as the primary source for *L. monocytogenes* contamination in smoked fish, but others report that the primary source for contamination is the equipment and processing environment *(2, 35, 42)*. Recent in-plant studies using molecular subtyping also indicate the processing plant environment, more often than raw materials, seems to be responsible for most incidences of finished product contamination for both hot and cold smoked products *(2, 8, 26, 31, 39, 42)*. For example, Rørvik et al. *(35)* and Autio et al. *(2)* reported a low prevalence of *L. monocytogenes* on incoming raw fish, with approximately one-third of finished product and environmental samples testing positive for *L. monocytogenes*. Similarly, Vogel et al. *(42)* found that although no *L. monocytogenes* was detected on any incoming raw fish, the pathogen was isolated from product collected immediately after slicing. In addition, an Institute of Food Technologists (IFT) expert panel concluded that reduction of *L. monocytogenes* in the processing plant was directly dependent on adherence to Good Hygienic Practices (GHPs) and Good Manufacturing Practices (GMPs) *(22)*. Areas in the processing plant that were identified as requiring particular attention include the brine, injection needles, and slicing equipment.

Studies using molecular fingerprinting techniques have improved our understanding of the ecology, sources, and spread of *L. monocytogenes* and *Listeria* spp. in processing plant environments. A variety of different *L. monocytogenes* strains are found in most processing plants (including seafood plants), and individual processing facilities often harbor unique *L. monocytogenes* populations and strains. These resident populations and strains can persist for months or years in a plant, or on its products, despite sanitation protocols designed to eliminate them *(2, 8, 21, 26, 33, 36, 39, 43)*. Patterns of persistent *L. monocytogenes* processing plant contamination have been reported for a variety of food processing environments, including smoked seafood, poultry, meat and dairy foods *(1, 26, 27, 32, 33, 35, 39)*. These studies also indicated that, even though a variety of different *L. monocytogenes* may be introduced (probably daily) into the plant environment from different sources, most are eliminated by routine cleaning and sanitation. Some subtypes appear to colonize specific niches in the plant environment and persist in these niches for long periods of time. Persistent *L. monocytogenes* contamination in processing plants is a major concern for the industry and for public health. Studies using molecular subtyping of *L. monocytogenes* isolates specifically showed that subtype(s) that persisted in a plant over time were responsible for the majority of finished product contamination incidents *(26, 31)*. Another study has shown that eradication of persistent strains in a plant will reduce the risk of finished product contamination from environmental sources *(2)*. Environmental post-processing contamination is believed to have been the source of a 1998/99 multi-state listeriosis outbreak linked to the consumption of contaminated hot dogs and deli meats. An increased level of environmental *Listeria* contamination (possibly associated with a construction event in the implicated plant) coincided with the time when product contamination with the outbreak strain first occurred. Apparently, environmental contamination was responsible for finished product contamination over an extended time period (> 4 months), thus leading to a large outbreak *(5, 6, 25)*.

Employees and processing personnel represent a potential source for the introduction of *L. monocytogenes* in the processing plant environment. Employees can serve as an indirect source of *L. monocytogenes* contamination (e.g., shoes, clothing, hands) as well as a direct source of contamination during post-processing handling of products. It has been estimated that 1–10% of healthy adults have *L. monocytogenes* present in their feces *(16, 38)*.

To verify *L. monocytogenes* controls, plants should implement a *Listeria* specific environmental monitoring program, using *Listeria* spp. as an indicator for possible *L. monocytogenes* contamination *(40, 41)*. Each plant-specific monitoring plan should identify areas to be sampled for *Listeria* spp., frequency of sampling, and actions to be taken when *Listeria* spp. is detected. This aspect of a *Listeria* control program will be covered in a subsequent manuscript in this series.

DEVELOPING AND IMPLEMENTING A *LISTERIA* CONTROL PROGRAM

Implementation of an effective *Listeria* control program is a long-term commitment. The SSWG identified at least five key elements that need to be included in an effective *L. monocytogenes* control program for RTE seafood products. These elements are:

(1) Targeted GMPs and Sanitation Procedures for *Listeria*
(2) Training of Plant Personnel
(3) Environmental Monitoring and Testing
(4) Raw Material Controls
(5) Refrigeration of Finished Products (preferably below 38°F (3°C)

Each plant should decide how to implement these control elements over time and refine them as experience is gained. Developing and implementing an effective *Listeria* control program requires a long-term commitment by both plant management and all employees. For most processing plants, components of all five elements of the control program suggested by the SSWG will be needed to effectively minimize *Listeria* contamination and growth in finished products. It is important to establish both an immediate and a long-term strategy for the development and implementation of a *Listeria* control program in each plant.

GMPs that include effective sanitation procedures and procedures to prevent cross contamination are the foundation of an effective *Listeria* control program. As a first step in the process of developing and implementing a *Listeria* control program, a team of employees from a plant should evaluate the operation and identify where *Listeria* contamination problems are most likely to occur and what improvements or changes are needed to prevent product contamination. If the team has insufficient expertise to make this evaluation, outside experts may be needed to assist. A plan should be developed outlining specific changes that are needed in the process flow, facility design and layout, processing procedures, and equipment to adequately control *Listeria* contamination. A realistic timetable to implement these changes should be developed. An environmental *Listeria* monitoring and testing program should also be developed and implemented before *Listeria* controls are implemented and finalized. Data collected during this monitoring phase will help the plant's team evaluate the impact of the proposed changes as they are implemented and ensure that any necessary adjustments are made to focus control efforts on higher risk areas of the operation and/or areas that have existing *Listeria* contamination problems.

CROSS CONTAMINATION PREVENTION

Raw seafood may contain *L. monocytogenes*, although the presence of the organism and the levels of contamination can vary widely *(21, 26, 31, 39)*. Raw products should be treated as though they are contaminated, and steps should be taken to prevent cross-contamination from raw product and raw product handling areas to areas where exposed finished product is handled, in order to eliminate or reduce the potential for finished product contamination.

The following key control measures adapted from Tompkin et al. *(41)* and FAO Fisheries Report No. 604 *(17)* should be evaluated in each plant's unique environment to minimize the potential for movement of environmental *Listeria* contamination within the plant and to prevent cross contamination of products and product contact surfaces.

DESIGN AND LAYOUT OF PROCESSING OPERATIONS

Processing zones

Processors should consider how to establish successively "cleaner" zones, or zones with decreasing levels of contamination, within the processing plant as the product moves through the entire process. Areas where raw products are received, stored and processed should be considered the "dirtiest" zones, where potential environmental contamination levels are highest, with decreasing levels of environmental contamination for intermediate processing steps. Areas where exposed finished products are handled (e.g., storage after smoking, slicing, weighing, packing) should be the "cleanest" zones, where environmental contamination levels are lowest.

Product and traffic flow

A linear flow of product through the operation, from the raw ingredients to the finished product, should be established to the extent possible. The location of each processing step and the equipment used at that step should be evaluated and the process flow should be rearranged (e.g., by re-locating equipment) to ensure adequate separation of raw from RTE smoked seafood. Separation of operations involving raw, semi-finished and finished products and control of traffic flow patterns between these areas of the operation are needed to prevent *L. monocytogenes* from being transferred from the "dirty," or "raw," side of the operation to the "clean," or RTE side. Using a designated color code for employee attire and equipment in the raw area and a different color code for the RTE area can facilitate monitoring and control of traffic in the plant. Raw or in-process products and exposed (unpackaged) finished products should not be handled in the same area at the same time. If raw or in-process products are handled in or near areas where exposed finished product will be handled, a procedure should be established to ensure that the area will be thoroughly cleaned and sanitized before exposed finished products are handled. Another alternative would be to establish physical barriers, or separate processing rooms if necessary, to prevent contamination. The potential for

L. monocytogenes to be brought back into a clean environment where finished products are handled should be a primary concern. This may occur as a result of traffic into and out of the raw product and finished product handling areas as people and equipment, such as trolleys and forklifts, enter from more contaminated points in the operation, or as a result of non-routine activities such as unscheduled equipment maintenance.

Wet processing environments

Efforts to control the movement of *Listeria* from one area of the plant to another can be more difficult if the plant environment is wet. When processing fishery products, at least some processing steps may require significant amounts of water. In a smoked fish operation, these steps could include thawing frozen raw materials, as well as raw material preparation steps such as filleting, trimming, brining, rinsing, and hanging or racking wet brined fillets or whole fish for smoking. The areas in which these operations occur are likely to be areas where floors are wet and the humidity is high during production. These wet and humid areas of the plant should be isolated to the extent possible from areas of the plant where exposed finished RTE products are handled and processed. Processing steps such as slicing and packaging finished products should be conducted in an environment that is as dry and clean as possible to help minimize the risk of finished product contamination.

Product movement at the smoking step

The smoking step is one point in a smoked fish operation where raw and finished products are likely to be in close proximity when they are moved into and out of the smoking chamber. The movement of raw product into and out of the smokehouses and the coolers should be monitored to assess the potential for cross contamination. Standard Operating Procedures (SOPs) should be established to ensure that raw products being moved into the smokehouse or out of refrigerated storage do not contaminate finished products that are being moved out of the smoking chamber(s) and into refrigerated storage. Separation may be temporal (e.g., by ensuring that raw and finished products are not handled or moved at the same time) or physical (e.g., by separating raw and finished product areas by distance or by using barriers such as walls or controlled entries and exits) to prevent cross contamination.

PROCEDURES TO PREVENT CONTAMINATION IN RTE AREAS

Contamination sources in RTE areas

Potential contamination sources and vehicles for the entry or movement of *Listeria* into areas where exposed RTE finished products are handled should be evaluated. Any direct entry from the exterior of the plant to any RTE area should be eliminated or prohibited from use to minimize the introduction of microorganisms such as *L. monocytogenes* from outside the plant into RTE areas. Pallets, boxes or other items from outside the facility should not be brought into RTE areas of the plant. Where possible, overhead fixtures or other structures should be removed from areas where RTE products are handled, particularly if these structures are located over exposed product and food contact surfaces. Dust and condensate can collect on these structures and contaminate food contact surfaces or RTE products directly. If these structures cannot be avoided, the product and/or the line should be shielded, and overhead fixtures and pipes should be cleaned and sanitized regularly (at least weekly) to prevent them from becoming a source of contamination. Trench drains should be avoided when possible. If trench drains are used, there should be no connection between trench drains from the "dirty" or "raw" side of the plant and those in the "clean" or RTE side.

Equipment movement between raw and RTE areas

The movement of equipment into and out of areas where exposed RTE products are handled should be monitored and managed to prevent the spread of *Listeria* contamination during the workday. Separate equipment, utensils, trash barrels, and cleaning tools that are labeled or color-coded (e.g., to facilitate monitoring and ensure that they are used in their assigned areas) should be used in RTE areas of the plant. Containers, tubs, or totes used for storing or transporting finished products should be designated for that use only and should not be used in other ways. These portable items should also be appropriately labeled or color-coded, and cleaned and sanitized after each use. Using separate color-coded or labeled carts, racks, totes, or other portable items that are used only in RTE product areas can minimize the potential for errors that could lead to contamination of exposed finished products. If any of these items move from one area to another, proper controls must be in place to prevent the transfer of contamination from one area to another. Controls may include using chemical foam or other barriers for carts and racks at the entrance to RTE areas, the use of sanitizer sprays on cart or rack wheels, and special procedures to clean and sanitize racks, tubs, totes or other equipment used in raw areas and then moved to RTE areas of the plant.

Preventing contamination during production

Finished product areas should be routinely monitored throughout the workday to ensure that conditions are adequate to prevent finished product contamination. Standing water in all areas of the plant, and particularly in the RTE areas, should be removed as soon as possible to prevent transfer of bacterial contamination to product from carts and shoes that have tracked contaminated water through the plant. Hoses should be hung, stored properly, or removed in areas where RTE products are exposed before start of operation each day. Plants should have washing areas and systems designated for equipment used in the RTE area, and these systems should not be used for equipment from the raw processing area. If only one equipment washing and cleaning area is available in a plant, equipment from the raw and RTE areas of the plant should not be handled or stored in this area at the same time, and the washing area must be cleaned and sanitized before any RTE equipment is handled, cleaned and sanitized in this area.

Chemical barriers and footbaths

Chemical foam barriers or footbaths can be used to minimize the spread of contamination from raw areas to RTE areas of the plant. Footbaths or foam barriers should be properly installed, maintained, and monitored or they will not be effective and can even become a source of contamination. These chemical barriers should be located at all entrances to RTE areas of the plant. It is important to monitor and maintain proper sanitizer concentrations in footbaths and foam barriers to ensure that they are effective. Quaternary ammonia sanitizers (quats), iodophors, or other products especially formulated for *Listeria* control should be used. Manufacturer recommendations for this use (foot baths or foam barriers) should be followed when determining the proper concentration, monitoring frequency, and timing of application for foam barriers. Chlorine is not recommended since it can quickly become inactivated. Shoes or boots should be kept clean, since footbaths or foam barriers will not be ineffective if boots or shoes are carrying large amounts of organic material (e.g., compacted dirt or seafood waste).

EMPLOYEE POLICIES TO PREVENT CONTAMINATION OF RTE AREAS

Personnel policies and training

Smoked seafood processors should establish personal hygiene practices and policies with *L. monocytogenes* control as a major objective. Employee training in GMPs is necessary; along with specific controls or policies related to employee movement in the plant and procedures to minimize the potential for employees to bring contamination into RTE areas. Control measures for employee hygiene and traffic management are likely to be most stringent in areas where exposed finished products are handled or processed. All company policies and procedures related to employee hygiene, food handling practices, and employee movement in the plant need to be included in employee training programs for *L. monocytogenes* control. Employees not directly involved in processing (e.g., maintenance staff, equipment technicians, the cleaning and sanitizing crew, managers, sales staff, and other office personnel) should be included in training programs, since they can cause significant problems if they do not understand and follow GMPs and company policies and proper practices designed to prevent *Listeria* contamination.

Employee attire

Personnel policies and procedures should be developed and implemented to ensure that employee attire does not contaminate RTE products. Employees who handle RTE products must use clean gloves, smocks, and aprons to minimize product contamination. Disposable gloves, aprons, arm covers, hair covering and/or beard covers should be used in RTE areas. All disposable items should be discarded when leaving the work area and replaced with new items when returning. Personnel procedures should also ensure that all employees and visitors who enter areas where exposed finished products are handled wash and sanitize their hands and put on clean outer garments such as disposable smocks or aprons, hair covering, and shoe covers or work boots.

Employee traffic

The movement of employees into and out of areas where exposed RTE products are handled should also be monitored and managed to prevent the spread of *L. monocytogenes* contamination during the workday. The movement of employees into and out of RTE areas should be limited where possible, and when movement is necessary, appropriate precautions must be taken to prevent the spread of contamination. Precautions may include changing outer garments, washing hands, and changing into clean smocks, gloves, and boots before entering the RTE area. Color-coding of employee attire can be useful to facilitate monitoring and to help manage the movement of employees into and out of RTE areas. Maintenance personnel, sales, office or other non-production staff must also follow these procedures that prevent the inadvertent transfer of *L. monocytogenes* from the raw to the RTE side of the operation.

Hand washing and other employee facilities

An adequate number of easily accessible and properly equipped and maintained hand washing and sanitation stations should be available in all areas of the plant. It is particularly important to locate hand-washing facilities in areas where exposed finished products are handled, as well as at all entrances to RTE finished product areas. Policies that ensure that hands are washed and sanitized properly or gloves are changed when an unclean surface is touched must also be implemented and monitored. All employees (including those not directly involved in processing activities) should be trained to ensure that they understand the importance of proper hand washing, how to wash their hands and/or gloves properly, as well as when to wash their hands and/or gloves. Plant management must also provide restrooms and break rooms that are easily accessible and located in areas that minimize the potential for contamination of food processing or handling areas. Policies, including appropriate monitoring procedures, should also be developed to ensure that personal items are not allowed at work stations and that equipment, soiled clothing, or food is not stored in lockers.

TARGETED SANITATION PROCEDURES

Sanitation procedures targeting *Listeria* should focus on the most likely sources of direct product contamination. Processors will need to assess where exposed products are likely to become contaminated along the product flow. The highest potential risk is likely to occur in areas where exposed finished products are handled. Many different areas in the processing plant environment can become indirect sources of *Listeria* contamination. Such areas can harbor the organism and, under certain conditions, can contaminate product contact surfaces or the product itself. Minimizing the presence of *L. monocytogenes* in the environment can reduce the risk that finished RTE products or product contact surfaces will become contaminated. The importance of different areas of the processing plant as a potential *L. monocytogenes* contamination source will vary depending upon the age and condition of the facility, the type and location of processing procedures conducted, the temperature and humidity of the plant environment, and the raw materials used.

It is possible to have random isolated contamination with *L. monocytogenes* from the environment even if a plant has an effective control program *(26, 40)*. However, contamination is more likely to occur after the organism has become established in a niche, where it is not easy to eliminate with routine cleaning and sanitizing procedures *(21, 26, 39)*. If equipment that contains a niche harboring *L. monocytogenes* is operated, bacteria may be dislodged from the niche and become deposited on equipment or other surfaces. As product moves over or through the equipment, it can become contaminated. Identifying *L. monocytogenes* niches and eliminating them can correct this situation.

Identifying and eliminating *Listeria* contamination sources

A number of studies have identified sites likely to be potential persistent reservoirs of *L. monocytogenes* in the processing plant environment of smoked seafood and other RTE foods *(9, 17, 21, 23, 26, 33, 35, 39, 40, 41)*. Table 1 provides a list of sites, equipment, or materials that have been found to be frequent or intermittent sources of *L. monocytogenes* contamination. This list of contamination sources and the following procedures for equipment design and maintenance were developed using information from Tompkin et al. *(41)*, FAO Fisheries Report No. 604 *(17)*, and Lappi et al. *(26)*.

Equipment design and maintenance

Each processing facility must examine and evaluate the equipment used in the facility, its location, its condition, and how easy it is to clean and sanitize to prevent persistent *L. monocytogenes* contamination sources from becoming established, and to ensure that sporadic contamination is eliminated with routine cleaning and sanitizing procedures**.** The design of any new or replacement equipment should be evaluated from a microbiological and sanitation viewpoint. Quality control and sanitation personnel should be included in equipment design and purchase decisions to ensure that sanitation considerations are evaluated before purchasing decisions are made.

All equipment should be evaluated to ensure that there are no crevices, cracks, rough seams, unsealed joints, pitted or corroded surfaces, or hollow areas where water and food debris can collect and serve as harborages for *L. monocytogenes.* Equipment design should minimize the use of nuts, bolts, and threads, as they can be a particular problem with respect to niches for *L. monocytogenes.* Properly designed equipment should not contain nuts and bolts in any location that could directly or indirectly contaminate products during operation. Nuts and bolts that could be an indirect contamination source should be routinely removed for cleaning and sanitizing. Equipment, platform framework, table legs, machine platforms, or conveyor rollers that are hollow should be avoided because hollow areas provide an opportunity for water and food particles to collect and harbor *L. monocytogenes.* Hollow rollers on conveyors and any

TABLE 1. Potential sources of *L. monocytogenes* contamination in smoked seafood plants*

Air curtains
Air filters through which compressed air must pass (especially if poorly maintained)
Brining solutions and brine injection equipment
Ceilings and overhead structures
Cleaning tools (e.g., sponges, brushes, floor scrubbers)
Condensate
Containers (e.g., bins, tubs, baskets, totes) used for raw or RTE products
Conveyances (e.g., trolleys, carts, hand trucks, pallet jacks) including their wheels
Conveyor belts, especially if porous, frayed or in poor condition
Conveyor rollers that are hollow
Drains
Employee attire (e.g., gloves, aprons, shoes)
Floors and floor mats
Framework (metal or plastic) especially if wet, rusting, hollow, pitted or corroded
Ice and ice makers
Implements with hollow handles or other components including box cutters
Insulation in walls, around pipes, or in coolers that has become wet
Maintenance tools
Mixers and meat-bone separators
Motor housings
Nuts, bolts, screws and crevices in or on equipment
On/off switches
Open bearings within equipment
Packaging equipment
Pallets (plastic or wooden)
Racks for transporting raw fish and finished product
Raw fishery products
Rubber seals around doors
Scales
Slicers
Skinning machines
Standing water on poorly drained floors in processing areas and coolers
Trash cans and waste receptacles
Utensils (e.g., hand tools, knives, scrapers) that contact exposed finished product
Walls that are cracked and can retain moisture

*Adapted from Tompkin et al. *(41)*, FAO Fisheries Report No. 604 *(17)*, and Lappi et al. *(26)*

other equipment that has hollow areas where water could collect should especially be avoided in areas where exposed finished products can become contaminated. Portable equipment (e.g., smoking racks, carts, dollies, slicers, tubs, totes) used for exposed product should be designed to avoid the possibility that splashing water or other residue from the floor, a likely source of *L. monocytogenes*, may contaminate products. Racks used for transporting exposed RTE product should have cover guards over the wheels to prevent spray from the wheels from contaminating the rack and product as the racks are moved.

Non-routine activities or changes in processing operations may lead to the introduction of a new contamination source. Examples include plant construction; moving or modifying a processing or packaging line; installing new equipment; or adjusting or repairing equipment during production. During construction or line re-configuration, procedures should be established to separate the construction area and to enhance sanitation efforts and environmental monitoring procedures. It is important to thoroughly disassemble, and clean and sanitize (using rigorous procedures for eliminating niches if necessary) used equipment from storage or another plant before it is brought into the processing plant environment *(28)*.

Procedures and schedules for regular visual inspection and maintenance should be developed and implemented to minimize the likelihood that *Listeria* will colonize a piece of equipment, and to reduce the number of unscheduled repairs which could contaminate equipment. When visual inspections reveal that equipment is in poor condition (e.g., damaged, pitted, corroded, or cracked) it should be repaired or replaced. Maintenance personnel should follow the same procedures described earlier for washing hands and changing outer

garments before moving from raw material or other areas of the plant into RTE areas. Tools used for the maintenance or repair of equipment in RTE processing areas should be dedicated for that use and stored in that area. If this is not possible, maintenance or repair tools should be cleaned and sanitized prior to their use in RTE areas. All equipment should be cleaned and sanitized after maintenance or repair work is complete.

Developing effective cleaning and sanitizing procedures

The development and implementation of effective cleaning and sanitation procedures is essential for control of *L. monocytogenes*. Routine cleaning and sanitizing procedures provide the primary defense to eliminate day-to-day *Listeria* contamination from raw materials, people, conveyances, packaging and other sources. Processors should consider the type of activities conducted at each specific location, the nature and volume of the products handled in each area of the plant, and microbiological monitoring data to identify where problems are likely to occur and to help determine the required frequency for cleaning and sanitizing. Routine microbiological testing for *Listeria* can be used to determine trends, to detect a developing sanitation problem, and to demonstrate that sanitation procedures are effective.

Different cleaning and sanitation procedures may be needed for: (1) different areas of the plant such as raw material areas, finished product areas, and drains; (2) equipment such as slicers, conveyors, skinning machines, smoking ovens, coolers, and freezers; (3) conveyances such as smoking racks, trolleys, forklifts, and pallet jacks; and (4) utensils and portable items such as knives, tubs, and totes. Special procedures to clean and sanitize floor mats, as well as the wheels of carts, trolleys, and other conveyances, may also be needed since these items have been identified as a source of *L. monocytogenes* contamination *(26)*. In addition, intensive rigorous cleaning and sanitizing procedures will be needed to eliminate *L. monocytogenes* that persist in niches where the organism may have developed biofilms or communities that are attached to equipment or other surfaces, which may be difficult to eliminate. Written Sanitation Standard Operating Procedures (SSOPs) will help to ensure that sanitation procedures are adequate and clearly understood by all personnel. Written pre-operational checklists can help to ensure that all daily and periodic sanitation procedures are consistently and effectively completed.

The following specific cleaning and sanitation procedures for *Listeria* control were adapted from Tompkin et al. *(41)* and FAO Fisheries Report No. 604 *(17)*.

Cleaning and sanitizing steps

Routine cleaning and sanitizing procedures for specific areas of the plant may include the following steps: (1) remove all exposed finished products (2) dry clean to remove excess food debris, sweep, and remove trash as necessary (3) pre-rinse the equipment, (4) visually inspect equipment, (5) foam and scrub equipment, (6) rinse equipment, (7) visually inspect equipment, (8) clean the floors, (9) sanitize equipment and floors, (10) conduct post-sanitation verification, (11) dry the floors, (12) clean and put away supplies. Wet cleaning should never begin until all exposed products have been removed from the area and properly stored. Variations in a basic procedure may be needed for different processing areas (e.g., RTE product handling areas, raw product handling areas, and storage areas) depending on the activities and equipment in each area. These variations may include modifications in the timing of cleaning and sanitizing activities, the types of cleaners and sanitizers that are used, and special procedures for equipment, utensils or portable items that have a history of contamination problems or pose a higher risk of product contamination. Consistency and attention to detail are important to ensure that cleaning and sanitation procedures are effectively and efficiently controlling *L. monocytogenes* contamination.

Practices to avoid

Because *Listeria* is likely to be present in most plant environments, especially on floors and in areas where raw products are handled, the following activities should be avoided.

- Wet cleaning and sanitizing procedures should never be started before all exposed products are removed from the area. Floors, drains, walls, ceilings should not be cleaned during production. In plants with multiple processing lines, cleaning should not be started if another line is still operating.
- High-pressure hoses should be avoided because they are likely to generate aerosols and spread contamination of *L. monocytogenes* and other pathogens via water droplets.
- Equipment, equipment parts, tubs, racks, screens and other portable items should never be cleaned or sanitized on the floor, since floors should always be considered contaminated.
- Mid-shift wet cleanups should be eliminated, since they are likely to be counter-productive and may increase rather than decrease the risk of *L. monocytogenes* contamination. Mid-shift or periodic wipe-downs may be needed to remove product residue and keep work areas clean.

- Using compressed air to remove debris from equipment during production should also be avoided. Compressed air can be a source of *L. monocytogenes* if in-line filters are not maintained or replaced on a regular basis. If it is necessary to use compressed air to remove product or other residue from equipment like packaging machines, it should be used only at the end of production, after all exposed finished products have been removed, and before cleaning begins.

Cleaning procedures

Effective cleaning procedures using appropriate cleaning agents to remove soil, protein, fat, residues, and smoke or soot need to be developed and implemented. Foam application of cleaning agents can enhance effectiveness, and enzymatic cleaners may be needed to remove organic materials prior to sanitizing. Manufacturers' instructions should be followed when determining the strength, contact time, and any special precautions (e.g., face or skin protection and the potential for equipment corrosion) that may be needed when using cleaning agents. Thorough scrubbing of all surfaces is an essential part of the cleaning process that cannot be overlooked. Consideration should be given to selecting the proper cleaning tools. Brushes, scrapers or other tools should be designed for use in food establishments and be easy to clean and sanitize. Special tools that are properly sized (e.g., long handles, properly sized brush heads) may be needed to ensure that difficult-to-reach areas or parts of equipment can be thoroughly scrubbed during the cleaning process. Special cleaning tools may also be needed for specific uses. Brushes or other tools used for equipment and food contact surfaces should not be used to clean floors or other more contaminated areas in the processing plant environment. Using color-coded cleaning tools can help facilitate monitoring and decrease the likelihood that cleaning tools could contaminate equipment or surfaces that come into contact with food products. Sponges, mops, rags or other cleaning aids that can become contaminated during production and are difficult to clean and sanitize properly should be avoided. The cleaning and sanitation crew should be trained to ensure that the proper cleaning tools and procedures are used.

Sanitizers for *Listeria* control

Quaternary ammonium compounds (quats) and peracetic acid or peroctanoic acid (peracid) sanitizers, available from a number of different manufacturers, have been found to be effective against *L. monocytogenes*, including when the organisms are present in biofilms *(18, 24)*. Some products (e.g., quats) leave a germicidal film on surfaces, which provides residual sanitation after the initial application. Areas that may need to be sanitized with quats, peracid or other sanitizers specifically formulated for *Listeria* control include drains, floors, floor mats, smoker racks, waste and storage containers, walls, coolers, freezers and condensate drip pans. These sanitizers are also likely to be useful for sanitizing equipment such as slicers, mixers, and de-boners. When possible, nuts, bolts or other parts should be soaked overnight in sanitizer. Caution should be used when soaking equipment parts or cleaning tools in sanitizer for extended periods of time or at higher concentrations since these treatments may cause corrosion or other damage. Rotating different sanitizers periodically can help to ensure that sanitation chemicals continue to be effective over time. Special attention is required to ensure that cleaning tools such as brushes, squeegees, wipes, etc. are properly cleaned and sanitized after they are used to ensure that they do not become a contamination source. Cleaning tools, especially those tools used for more contaminated areas of the plant such as floors and drains, may need to be sanitized with a stronger concentration of sanitizer (e.g., 600–1000 ppm quat). When higher concentrations of sanitizer are used, cleaning tools should be routinely inspected and replaced as necessary, because they may deteriorate or become pitted or corroded more quickly. After sanitization, cleaning tools should be air-dried and stored properly, or stored in fresh sanitizer until they are used again. The cleaning and sanitation crew should be trained to ensure that sanitizers are used properly at the proper concentration and that sanitation procedures are conducted correctly.

Sanitizing with heat or steam

Hot water or steam sanitation is an alternative to chemical sanitation when equipment is difficult to clean or has been colonized by *L. monocytogenes*. When using heat to sanitize, it is essential that the equipment be thoroughly cleaned first so the heat does not bake the soil, protein, and fat onto the surface, making it more difficult to remove, and potentially creating an additional contamination problem in the future. If steam is used, caution should be taken to avoid the creation of aerosols containing *Listeria* and other microorganisms, which can condense on surfaces. If steam is used as a final sanitation step on equipment that is difficult to clean, the equipment should be covered before injecting steam to protect the surrounding area from contamination. Equipment can also be steamed in an oven or other cham-

ber, and equipment parts can be boiled in water. The equipment and/or parts should reach a temperature of at least 160°F (71°C) throughout for at least one hour. Lower temperatures, from 145 to 160°F (63 to 71°C), may require a significantly longer holding time.

Cleaning and sanitizing equipment

Special consideration should be given to the development of effective procedures for cleaning and sanitizing equipment and portable items that come in contact with products (food contact surfaces). Equipment may need to be disassembled prior to cleaning and sanitizing, and may need to be re-sanitized after re-assembly. It is important that all areas of equipment be thoroughly cleaned and sanitized properly after disassembly to prevent *L. monocytogenes* niches from becoming established. The application of foam detergents to provide adequate contact with equipment surfaces and vigorous scrubbing can facilitate the cleaning process. Special sanitizers may also be needed for equipment that is difficult to clean or has a history of contamination problems. Equipment parts and portable items such as utensils, trays and tubs, can be soaked and scrubbed, rinsed, and sanitized in a multi-compartment sink. Equipment parts and portable items, and utensils should never be placed or stored on the floor after cleaning, since floors are likely to be contaminated. Consideration should also be given to when equipment and portable items that come into contact with food products are cleaned and sanitized, and how and where they are stored to ensure that subsequent cleaning of floors, walls or other areas do not re-contaminate them. In some situations it may be necessary to re-clean and sanitize these items before they are used if subsequent cleaning activities may have re-contaminated them.

Cleaning and sanitizing floors

Special attention should be given to the development and implementation of effective procedures for cleaning, sanitizing, and maintaining floors. Special caustic or hydrogen peroxide-based cleaners may be particularly effective for cleaning floors. Dedicated, color-coded brushes, squeegees, etc. should be used for cleaning floors. After an initial dry cleaning, floors need to be thoroughly rinsed, using a low-pressure hose, and then sanitized. Powdered hydrogen peroxide-based cleaners or citric acid applied to certain areas of the floor (e.g., in RTE product handling areas) can be effective for controlling *L. monocytogenes* during processing, if the floor has been properly cleaned and dried first. If citric acid is used, the surface of the floor should be maintained at pH 5.0 or below for maximum effectiveness. However, these acidic conditions can cause floor deterioration that eventually will necessitate replacing the floor. Hydrogen peroxide-based materials do not have this corrosive effect.

Cleaning and sanitizing floor drains

Research and experience has shown that floor drains can be the most highly contaminated sites in the processing plant environment *(20, 21, 26, 33, 39). Listeria* present in the plant environment in the vicinity of a drain are likely to end up in that drain. In addition, drains are likely to be areas that *Listeria* can colonize and where *Listeria* can persist over time. Floor drains should be cleaned and sanitized in a way that prevents contamination of other surfaces in the room. Floor drains should never be cleaned during production or before all food products have been removed from the area and properly stored. Floor drain brushes should be smaller than the diameter of the drain opening to prevent the brush from splashing as it is removed during cleaning; alternatively, a splashguard could be used. Utensils for cleaning drains must be dedicated to that purpose to minimize potential for contamination of other areas of the plant. Consideration should also be given to determining when to clean drains. If floor drains are cleaned first, it may be necessary to clean and sanitize them again after cleaning and sanitizing adjacent areas. Bactericidal drain rings should be used when feasible to provide additional residual sanitation after cleaning. High-pressure hoses should not be used to clean drains or to clear a backed-up drain. Using high pressure can create aerosols that contain *Listeria* and spread this contamination throughout the processing area. Floor drains should also be designed and maintained to prevent backups. If a drain backup occurs, production must cease, the drain cleared, and the area carefully cleaned, rinsed, and sanitized. The floor should be dry before production resumes.

Cleaning and sanitizing smoker racks and trolleys

Smoked seafood and other RTE processing operations use a large number of portable racks and trolleys to transport products into and from the smoking chambers and from one area of the plant to another. Cleaning, sanitizing and storing these items is a challenge for many plants. Special cleaners formulated to remove protein, fat residue, and soot from the smoking process may be needed. Application of foam cleaners may be required to ensure adequate coverage and contact time. Sanitizing racks and trolleys may also be difficult. Chemical sanitizers can be difficult to apply and foam or fog application may be useful to ensure adequate concentrations and contact times. Manufacturers' instructions should be

followed when using chemical sanitizers. The application of heat may be an alternative to chemical sanitation. When sanitizing racks or other conveyances with heat, a special chamber or rack washer will be needed. Heat can be applied by hot water, steam, or moist heat in a rack washer, cabinet or oven. Sufficient heat should be applied for a sufficient period of time to raise the temperature of the rack to 160°F (71°C) or higher (see Sanitizing with heat or steam). When cleaning carts, trolleys, and other conveyances, additional sanitation measures may be needed for the wheels, as they have been shown to be a source of *L. monocytogenes* and a vehicle for moving contamination around the plant environment *(26, 39)*.

Cleaning and sanitizing coolers and freezers

Infrequent cleaning of coolers used for holding RTE products may increase *L. monocytogenes* contamination problems. Coolers should be emptied and cleaned at least once a week. All exposed RTE products should be removed and/or placed in tightly sealed containers before the cleaning and sanitizing process is started. Simply covering product in the cooler will not provide adequate protection from contamination during the cleaning and sanitizing process. Keeping cooler floors, ceilings, air blower fixtures, and walls dry is also important since splashing water or condensation can be a potential source of *L. monocytogenes* contamination. Drip pans, blowers, racks and other equipment in coolers should also be cleaned and sanitized regularly. Solid forms of sanitizers (e.g., blocks or donuts of quaternary ammonia sanitizer) may be placed in the drip pan to control microbial growth after cleaning. Condensate that accumulates in drip pans of refrigeration units should be routed to a drain with a hose. Infrequent defrosting, cleaning, and maintenance of freezers used to freeze or store unpackaged product is also a potential source of *L. monocytogenes* contamination. Freezers should be cleaned at least twice a year depending on production volume, use, and maintenance.

Intensive cleaning and sanitizing to eliminate persistent *L. monocytogenes* niches

When bacteria such as *Listeria* have colonized a particular location, they are difficult to remove and are more resistant to common sanitizers. To the extent possible, equipment should be disassembled, including removing parts, nuts, and bolts to ensure that all areas can be cleaned and sanitized. Small parts should be soaked in sanitizer overnight. As noted earlier, special cleaners and quaternary ammonia and hydrogen peroxide-based sanitizers, as well as peracid sanitizers, may be more effective and should be used for eliminating persistent *Listeria* communities that are attached to surfaces, particularly when biofilms have formed. Hot water or steam sanitation is particularly useful for eliminating *L. monocytogenes* from niches (see "Sanitizing with Heat or Steam").

Sanitation personnel and monitoring

Because of the importance of sanitation in *L. monocytogenes* control, trained and reliable personnel should be assigned to conduct sanitation activities, especially in areas where RTE products are handled and packaged. The sanitation crew should receive special training to ensure that they understand the procedures necessary to control *L. monocytogenes* and how to conduct them properly. Routine monitoring of sanitation activities and their effectiveness is necessary to ensure that all procedures are conducted properly and at the appropriate times. Supervisory personnel should themselves conduct routine inspections to ensure that sanitation procedures are effective and conducted properly. At a minimum, such an inspection should be conducted each day before production begins (Pre-Op) to ensure that cleaning and sanitation tasks have been completed and the facility is ready for processing. If deficiencies or problems are found in the Pre-Op inspection, they can be corrected before processing begins and minimize the potential for product contamination. Post-Op inspections, conducted after the cleaning and sanitation crew has completed its tasks, can be used to monitor the performance of the sanitation crew and as a tool to correct procedures or performance. Daily checklists completed by supervisory personnel can also help to facilitate monitoring. Microbiological or other testing procedures can provide objective measurements that can be used to further evaluate the effectiveness of cleaning and sanitation procedures and the performance of the sanitation crew.

SUMMARY

The development and implementation of an effective *Listeria* control program requires a long-term commitment, consistency and tenacity. Elements of a complete *Listeria* control program are likely to include sanitation, employee hygiene and food handling procedures specifically targeted to control *Listeria,* as well as employee training, environmental monitoring and testing, and raw material and finished product controls. Targeted *Listeria* control procedures should ensure that (1) the overall plant design and process flow minimizes the potential for cross contamination; (2) traffic control procedures for people and equipment are in

place to minimize the spread of *Listeria* throughout the plant; and (3) policies and procedures for employee hygiene and food handling practices prevent contamination of finished products; (4) effective cleaning and sanitizing procedures are implemented; and (5) equipment does not contribute or harbor contamination. Smoked seafood processors can use the specific guidelines provided by the Smoked Seafood Working Group in this manuscript to assess their operation, evaluate what control measures are needed for their operation, and implement effective controls.

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