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Persistent and Nonpersistent *Listeria monocytogenes* Contamination in Meat and Poultry Processing Plants

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ABSTRACT

Contamination analysis of persistent and nonpersistent *Listeria monocytogenes* strains in three meat processing plants and one poultry processing plant were performed in order to identify factors predisposing to or sustaining persistent plant contamination. A total of 596 *L. monocytogenes* isolates were divided into 47 pulsed-field gel electrophoresis (PFGE) types by combining the restriction enzyme patterns of *Asc*I (42 patterns) and *Apa*I (38 patterns). Persistent and nonpersistent strains were found in all plants. Nonpersistent PFGE types were found mostly at one sampling site, with the processing environment being the most common location, whereas the persistent strains were found at several sampling sites in most cases. The processing machines were frequently contaminated with persistent *L. monocytogenes* PFGE types, and it was of concern that surfaces having direct contact with the products were contaminated. The role of the processing machines in sustaining contamination and in contaminating the products appeared to be important because the final product of several processing lines was contaminated with the same *L. monocytogenes* PFGE type as that found in the processing machine. The proportion of persistent PFGE types in heat-treated products was eight times higher than in the raw products, showing the importance of the persistent PFGE types as contaminants of the final heat-treated products. The contamination status of the processing lines and machines appeared to be influenced by the compartmentalization of the processing line, with poor compartmentalization increasing *L. monocytogenes* contamination. The separation of raw and post–heat treatment areas seemed especially important in the contamination status of post–heat treatment lines.

Meat and poultry processing plants can be contaminated with *Listeria monocytogenes (5, 7, 8, 16, 20, 25)*, and contamination analyses have shown that *L. monocytogenes* can survive in food processing plants for extended periods. Some *L. monocytogenes* strains can persist in food processing facilities, whereas other strains are nonpersistent *(8, 9, 16, 20)*. The persistent strains predominate in the plants and cause continuous contamination pressure on the products. The phenomenon of persistent contamination has been observed not only in the meat and poultry industries but also in the fish *(4, 11, 22, 23)* and dairy industries *(19, 26)*.

Some factors influencing the survival of *L. monocytogenes* strains in food processing plants are recognized. Processing machines play an important role in *L. monocytogenes* contamination *(4, 16, 19)*, especially machines with complex structure and poor hygienic properties *(4, 16)*. The persistence of *L. monocytogenes* might be influenced by strain-specific properties, such as differences in adherence to stainless steel surfaces *(18)* and susceptibility to disinfectants *(1, 17)*. However, the causes of persistent *L. monocytogenes* plant contamination are still not fully understood, and further research is needed to identify those factors present in food processing plants that contribute to persistent contamination.

Here, we report the results of a study of three meat processing plants and one poultry processing plant. The plants were sampled for *L. monocytogenes* over a period of several years, and the *L. monocytogenes* isolates were characterized by a molecular typing method. The aims of the study were to investigate contamination routes and sites of persistent and nonpersistent strains in food processing plants and to recognize factors in the processing line that predispose the line to persistent contamination. Increased knowledge of the behavior of persistent and nonpersistent *L. monocytogenes* strains is essential for the planning of preventive measures in meat and poultry processing plants.

MATERIALS AND METHODS

***L. monocytogenes* isolates.** A total of 596 *L. monocytogenes* isolates were recovered at the food processing plants as a part of quality control programs during a period of several years. Samples were collected from the processing environment (walls, floors, and drains), equipment, products, and raw materials. Swabs or sponges were used to sample the processing environment and equipment. Isolation was performed according to the Nordic Committee on Food Analysis *(2)* or the International organization for Standardization standards *(3)*. Both standards include a two-step selective enrichment process followed by plating on selective media. Identification was based on hemolytic activity, Gram staining, catalase reaction, motility at 25°C, and further identification by the API *Listeria* kit (BioMérieux SA, Marcy l'Etoile, France). One isolate

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TABLE 1. *Food processing plants and investigated processing lines and products*

Food plant	Processing line[a]	Product
A	I. Cooking, chilling, slicing, and packing	RTE[b] meat product
	II. Cooking, chilling, slicing, and packing	RTE meat product
	III. Cooking, chilling, peeling, and packing	RTE meat product
	IV. Chilling, slicing, and packing	Fermented RTE meat product
B	I. Chilling, slicing, and packing	RTE meat product
	II. Chilling, weighing, and packing	RTE meat product
	III. Slicing and packing	Fermented RTE meat product
	IV. Slicing and packing	Cold-smoked raw meat product[c]
	V. Cooling and packing	Raw meat product[c]
C	I. Cooking, chilling, slicing, and packing	RTE meat product
	II. Cooking, chilling, peeling, dicing, and packing	RTE meat product
	III. Cooking, chilling, weighing, and packing	RTE meat product
	IV. Cooking, freezing, and packing	Meat product (with uncooked nonmeat ingredients)[c]
	V. Cooking, cooling, and packing	RTE meat product
	VI. Cooking, cooling, and packing	RTE meat product
	VII. Cooking, cooling, and packing	RTE meat product
D	I. Cooking, chilling, weighing, and packing	RTE poultry product
	II. Freezing and packing	Raw poultry product[c]
	III. Marinating, cooling, and packing	Raw meat product[c]

[a] Process(es) describing the nature of the processing line are mentioned. The pre–heat treatment processing steps (preparation and formation of the raw mass) are not mentioned.
[b] RTE, ready-to-eat.
[c] Cooking required before eating.

per sample was further characterized. The isolates were stored at −70°C.

Food processing plants. Plants A, B, and C produced mainly ready-to-eat pork and beef products, and plant D produced poultry products. A total of 18 *L. monocytogenes* isolates (processing environment 2, equipment 9, product 7) were collected from plant A, 92 isolates (processing environment 24, equipment 49, product 18, raw material 1) from plant B, 307 isolates (processing environment 43, equipment 199, product 63, raw material 2) from plant C, and 179 isolates (processing environment 38, equipment 104, product 37) from plant D. The processing lines investigated are presented in Table 1.

DNA isolation and pulsed-field gel electrophoresis (PFGE) typing. Pure *L. monocytogenes* cultures were grown on blood agar for 24 h at 37°C, after which a single colony was transferred into brain heart infusion broth (Difco, Detroit, Mich.). Cells were harvested from 2 ml of brain heart infusion broth after overnight incubation at 37°C. DNA was isolated as described by Björkroth et al. *(6),* with modifications described by Autio et al. *(4).* Briefly, plugs were lysed for 3 h and a 1-h wash with ESP at 50°C was performed once. Two rare-cutting restriction enzymes, *Asc*I (New England Biolabs, Beverly, Mass.) and *Apa*I (Boehringer Mannheim, Mannheim, Germany) were used for restriction endonuclease digestion. The samples were electrophoresed through 1.0% (wt/vol) agarose gel (Seakem Gold; FMC Bioproducts, Rockland, Maine) in 0.5× TBE (45 mM Tris, 4.5 mM boric acid [pH 8.3], and 1 mM sodium EDTA) at 200 V and 14°C in a Gene Navigator system with a hexagonal electrode (Pharmacia, Uppsala, Sweden). Pulse times ramped from 1 to 35 s for *Asc*I and *Apa*I for 18 h. The gels were stained with ethidium bromide and visualized and digitally photographed with an Alpha Imager 2000 documentation system (Alpha Innotech, San Leandro, Calif.). Fragment size was determined with a low-range PFG marker (New England Biolabs).

PFGE pattern analysis. The PFGE type was obtained by combining both restriction enzyme profiles into one unique profile. A PFGE pattern was considered unique if one or more bands differed from other PFGE patterns.

Serotyping. One randomly selected *L. monocytogenes* strain of each PFGE type was selected for serotyping. Serotyping was performed with commercial *Listeria* antisera (Denka Seiken, Tokyo, Japan) as described by the manufacturer.

Persistence of a strain. *L. monocytogenes* strains that were found repeatedly (five times or more) over a period of time (≥3 months) were considered to be persistent. Strains found sporadically (fewer than five times) or within a limited time period (<3 months) were considered to be nonpersistent.

RESULTS

Distribution of persistent and nonpersistent *L. monocytogenes* PFGE types. A total of 596 *L. monocytogenes* isolates were divided into 47 PFGE types by combining the macrorestriction patterns (MRP) of *Asc*I (42 MRP) and *Apa*I (38 MRP) and into five serotypes (1/2a, 1/2b, 1/2c, 3a, and 4b) (Table 2). All plants were contaminated with one or several persistent strains and several nonpersistent strains. The percentage of the persistent PFGE types of the total number of PFGE types ranged from 17% in plant A to 41% in plant C (Table 3). Thirty-five *L. monocytogenes* PFGE types were plant specific, seven PFGE types were common for two plants, and five PFGE types were common for three plants (Table 2). Identical PFGE types were found

TABLE 2. Listeria monocytogenes *pulsed-field gel electrophoresis (PFGE) and serotypes, persistence, and contamination status in food processing plants A, B, C, and D*

PFGE type	MRP[a]		Serotype	Food plant	P or N[b]	No. of contaminated lines	Site of contamination	No. of isolates
	*Asc*I	*Apa*I						
1	1	2	1/2c	D	N	1	Equipment	4
2	2	2	1/2c	D	N	1	Equipment	2
3	3	30	1/2a	B	N	1	Equipment	3
4	4	9	1/2c	D	N	1	Environment, equipment	3
5	5	11	1/2c	B	N	1	Product	1
6	6	22	1/2a	B	P	1	Environment, equipment	9
				C	N	1	Product	1
				D	N	1	Environment	3
7	6	8	1/2c	D	N	1	Equipment	2
8	7	6	1/2c	C	N	1	Equipment	1
				D	P	1	Environment, equipment, product	72
9	7	5	1/2c	D	N	1	Environment, equipment	3
10	8	5	1/2c	D	N	1	Environment	1
11	9	3	1/2c	A	N	1	Product	1
				B	N	1	Equipment, product (raw mass)	2
				C	P	2	Environment, equipment	32
12	10	6	1/2c	D	N	1	Equipment, product	4
13	11	1	1/2c	B	N	1	Environment	1
				D	P	1	Environment, equipment, product	28
14	11	7	1/2a	D	N	1	Equipment	1
15	12	15	1/2a	A	N	1	Environment, equipment, product	3
				B	P	2	Environment, equipment, product	50
				C	N	2	Environment, equipment	3
16	13	15	1/2a	A	N	1	Product	1
				C	N	2	Environment	2
17	14	16	1/2a	C	P	4	Environment, equipment	31
18	15	20	1/2a	C	P	2	Equipment, product	6
19	16	21	1/2a	B	N	1	Environment, product	3
				C	P	3	Environment, equipment, product	31
				D	N	1	Equipment	1
20	17	26	1/2a	B	N	1	Equipment	1
21	18	19	1/2a	B	N	1	Equipment	3
22	19	10	1/2a	C	P	2	Equipment, product	11
23	20	23	1/2a	D	N	1	Environment	2
24	21	29	1/2a	C	P	1	Environment, equipment, product	45
25	22	24	1/2a	C	N	1	Environment	2
				D	N	1	Environment	3
26	23	24	1/2a	C	N	1	Equipment	2
27	24	17	3a	D	P	2	Environment, equipment, product	14
28	25	25	1/2a	B	P	2	Equipment, product	8
29	26	4	1/2a	C	N	1	Equipment, product	3
30	27	19	1/2a	B	N	1	Product	1
31	28	27	1/2a	D	P	1	Equipment, product	12
32	29	28	1/2a	A	P	1	Equipment, product	11
33	30	27	1/2a	C	N	1	Equipment, product	4
34	31	18	1/2a	C	N	1	Equipment, product	3
35	32	18	1/2a	C	N	1	Equipment, product	3
36	33	12	1/2a	A	N	1	Equipment, product	1
				B	P	1	Equipment, product	5
				D	N	1	Equipment, product	1
37	34	14	1/2a	C	P	2	Equipment, product	96
				D	N	1	Equipment, product	2
38	34	13	1/2a	B	N	1	Equipment, product	4
39	35	37	4b	D	N	1	Equipment, product	2
40	36	38	4b	C	N	1	Equipment, product	1

TABLE 2. *Continued*

PFGE type	MRP[a]		Serotype	Food plant	P or N[b]	No. of contaminated lines	Site of contamination	No. of isolates
	*Asc*I	*Apa*I						
41	37	33	4b	C	P	2	Equipment, product	13
42	38	33	4b	C	N	2	Equipment, product	2
43	39	31	4b	C	N	1	Equipment, product	1
44	39	32	4b	C	N	1	Equipment, product	1
45	40	36	1/2b	B	N	1	Equipment, product	1
				D	P	1	Equipment, product	8
46	41	35	1/2b	A	N	1	Equipment, product	1
47	42	34	4b	C	P	1	Equipment, product	13
				D	P	1	Equipment, product	11

[a] MRP, macrorestriction patterns.
[b] Persistent (P) or nonpersistent (N) PFGE type.

both in meat and in poultry processing plants. In all, 19 PFGE types were found to be persistent and 28 PFGE types to be nonpersistent. Nine persistent PFGE types were found to be nonpersistent in another plant (Table 2).

Ten persistent PFGE types and three nonpersistent PFGE types contaminated two or more processing lines in a plant (Table 2). The processing lines contaminated with identical PFGE types were either located in the same compartment, such as processing lines V to VII in plant C, or in different compartments, such as processing lines I and II in plant B.

Differences in the location of persistent and nonpersistent PFGE types were observed (Table 4). All persistent PFGE types, except one, were found at least at two sampling sites, of which one was the equipment. Almost half of the persistent PFGE types were found at all three sampling sites (i.e., in the processing environment, equipment, and products). Two-thirds of the nonpersistent PFGE types were found at only one sampling site. The proportion of persistent and nonpersistent PFGE types differed in raw and cooked products, the proportion of the persistent PFGE types being eight times higher in the cooked product (Table 5). The majority of the persistent PFGE types (13 of 15) were found more than once in the final product, whereas the majority of the nonpersistent PFGE types (11 of 15) were found only once in the final product.

Contamination of process surfaces and products. Processing machines such as slicing machines, spiral freezers, packing machines, and conveyors were frequently contaminated with *L. monocytogenes*. Surfaces of the processing machines in direct contact with the product were contaminated, with the exception of peeling machines, which were only contaminated on surfaces having indirect contact with the product. The contamination sites in the processing machines are presented in Table 6.

The same persistent PFGE types were, in several cases, found in a processing line, both from the processing machines and from the products manipulated by the machines. This was observed, e.g., in the slicing and dicing lines in

TABLE 3. *Persistent and nonpersistent* Listeria monocytogenes *pulsed-field gel electrophoresis (PFGE) types found in food processing plants A, B, C, and D*

Food plant	PFGE type	P or N[a]	No. of PFGE types (%)
A	32	P	1 (17)[b]
	11, 15, 16, 36, 46	N	5 (83)[c]
B	6, 15, 28, 36	P	4 (29)[b]
	3, 5, 11, 13, 19–21, 30, 38, 45	N	10 (71)[c]
C	11, 17–19, 22, 24, 37, 41, 47	P	9 (41)[b]
	6, 8, 15, 16, 25, 26, 29, 33–35, 40, 42, 44	N	13 (59)[c]
D	8, 13, 27, 31, 45, 47	P	6 (29)[b]
	1, 2, 4, 6, 7, 9, 10, 12, 14, 19, 23, 25, 36, 37, 39	N	15 (71)[c]

[a] Persistent (P) or nonpersistent (N) PFGE type.
[b] Percent persistent PFGE type(s) of total number of PFGE types in the plant.
[c] Percent nonpersistent PFGE type(s) of total number of PFGE types in the plant.

TABLE 4. *Location of persistent and nonpersistent* Listeria monocytogenes *pulsed-field gel electrophoresis (PFGE) types in plants A, B, C, and D*

Sampling site	P or N[a]	No. of PFGE types
Processing environment	P	0
	N	9
Equipment	P	0
	N	16
Product	P	1
	N	9
Processing environment and product	P	0
	N	1
Equipment and product	P	6
	N	4
Processing environment and equipment	P	5
	N	4
Processing environment, equipment, and product	P	8
	N	1

[a] Persistent (P) or nonpersistent (N) PFGE type.

TABLE 5. *Number of persistent and nonpersistent* Listeria monocytogenes *pulsed-field gel electrophoresis (PFGE) types in heat-treated and non–heat-treated products (includes raw materials)*

Heat treatment of product	P or N[a]	No. of PFGE types (%)
Yes	P	12 (71)
	N	5 (29)
No	P	3 (23)
	N	10 (77)

[a] Persistent (P) or nonpersistent (N) PFGE type.

plants A (processing lines I and II), B (processing lines I and IV), and C (processing lines I and II) where the slicing machines were contaminated, as well as in the end products. This was also observed in processing line IV of plant C and line I of plant D, where post–heat treatment processing machines—such as the spiral freezers, conveyors leading from the freezer to the packing machine, weighing system in processing line I in plant D, packing machines, and final end products—were contaminated with persistent PFGE types. The PFGE types found in the raw materials or raw products were not established in the post–heat treatment processing machines.

Processing lines IV and V in plant B and II and III in plant D produced raw products and were persistently contaminated, whereas the fermented, uncooked ready-to-eat meat products in plants A (processing line IV) and B (processing line III) were not persistently contaminated.

Effect of compartmentalization on *L. monocytogenes* contamination. Two processing lines (I and II) with differing degrees of compartmentalization in plant B exhibited different contamination levels. The line that was less compartmentalized was found to be more extensively contaminated with *L. monocytogenes* and for longer periods of time. Both processing lines produced a cooked pork and beef product independently of each other; one line cooled, sliced, and packaged the product and the other line chilled the product in a spiral freezer and packaged the product. Schematic layouts of the processing lines, including compartmentalization and contamination status, are presented in Figure 1.

The dicing line (II) and the slicing line (I) in plant C were located next to each other and compartmentalized in a similar manner, but to a lesser degree than processing lines I and II in plant B. Both processing lines were heavily contaminated with several PFGE types. The dicing line was contaminated throughout with PFGE type 37, and the slicing line harbored the processing line–specific PFGE type 11. The slicing line was also contaminated with PFGE type 37, but to a much lesser extent than the dicing line. The processing environment in the area between the ovens and coolers, which was common to both lines, was contaminated with several PFGE types. Schematic layouts of the processing lines, including compartmentalization and contamination status, are presented in Figure 1. A similar effect of compartmentalization on the contamination status that was observed in plant C (processing lines I and II) was also observed in a processing line (I) in plant D.

TABLE 6. Listeria monocytogenes *contamination sites of processing machines*

Processing machine	Contamination site	Direct/indirect surface contact with product
Freezer	Spiral conveyor	Yes/—
	Supporting structures	No/likely
	Surfaces[a]	UN[b]
Slicing machine	Blades	Yes/—
	Blade cover	Yes/—
	Control panel	No/likely
	Motor	No/unlikely
	Lubricant	No/unlikely
	Ball-race screw	No/unlikely
	Surfaces[a]	UN[b]
Dicing machine	Blade	Yes/—
	Blade cover	Yes/—
	Surface under blade	No/likely
	Product-remains collector	No/unlikely
Peeling machine	Control panel	No/likely
	Surface under the peeler	No/unlikely
	Surfaces[a]	UN[b]
Weigher (with head system)	Funnel	Yes/—
	Surfaces[a]	UN[b]
Packing machine	Chamber	Yes/—
	Surfaces[a]	UN[b]
Conveyor	Belt	Yes/—
	Supporting structures	No/likely

[a] Specific site not known.
[b] UN, unknown.

DISCUSSION

The processing machines were persistently contaminated in all plants. It is of concern that the surfaces of the processing machines having direct contact with products were contaminated. Several heat-treated products were contaminated with the same PFGE type found in the processing machines, emphasizing the role of the processing machines in the contamination process of the final products. It also suggests that the processing machines (e.g., slicers, dicers, freezers, and conveyors) were poorly sanitized. Part of the difficulty in sanitizing processing machines is attributable to their complex structure, which prevents sufficient disassembly for cleaning. However, the peeling machines were not found contaminated on surfaces in direct contact with products, which might have been a result of the hot steam applied in the peeling process.

The persistent PFGE types were often widely spread in the processing plants, contaminating several sampling sites and more than one processing line. The persistent PFGE type might have been introduced into different processing lines independently, or the contamination has been transferred from one line to another with the personnel or equipment, splashes from inadequate washing procedures, or air. However, Autio et al. *(4)* could not show the spread

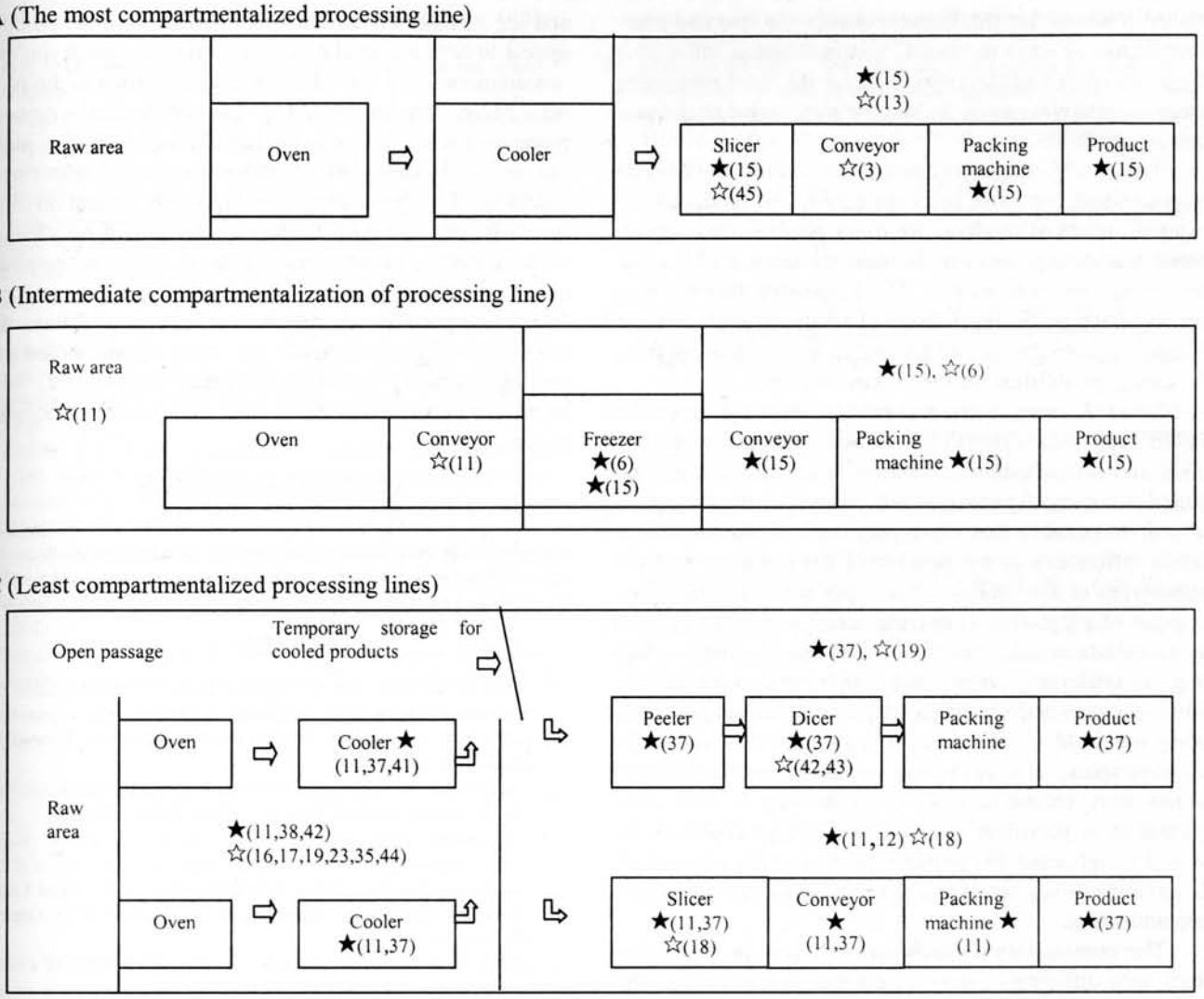

FIGURE 1. *Four processing lines, including the effect of compartmentalization on* Listeria monocytogenes *contamination status, are presented. Each line processed a heat-treated meat product that was further handled in the processing machines. (A) Plant B, processing line I. The raw and post–heat treatment areas are separated, and the processing line is compartmentalized. (B) Plant B, processing line II. The raw and post–heat treatment areas are not separated. The oven opens to the raw area, but the conveyor between the oven and freezer is sheltered. (C) Plant C, processing lines I and II. The raw and post–heat treatment areas are not separated. Symbols: arrows show the flow of the product, stars indicate findings positive for* L. monocytogenes*, and the number following the star indicates the PFGE type (black star, persistent PFGE-type contamination of the processing line; white star, nonpersistent PFGE-type contamination of the processing line).*

of *L. monocytogenes* by air in a heavily contaminated food processing plant. In contrast, relocation of processing machines has transferred *L. monocytogenes* contamination from one site to another *(16)*.

The higher proportion of persistent PFGE types in heat-treated than in raw products emphasizes the importance of the persistent PFGE types as contaminants of final heat-treated products. In fact, the PFGE types found in raw materials or raw products were not able to establish themselves in the post–heat treatment lines. These findings suggest that the persistence of a strain in a food plant is not a result of continuous flow of the strain via raw materials, which is supported by several studies showing that persistent strains are usually not found in the raw materials *(4, 21, 23)*. In contrast, strain-specific properties apparently influence the survival and colonization of the organism in food processing facilities. Enhanced adherence of persistent *L. monocytogenes* strains *(18)* and differences in disinfectant susceptibility *(1, 17)* and cadmium resistance *(10)* have been proposed as having an influence on the survival of persistent and nonpersistent *L. monocytogenes* strains. However, raw materials are often known to be contaminated with *L. monocytogenes (12, 14, 24)* and, therefore, to pose a heavy contamination pressure in the raw area. In fact, Berrang et al. *(5)* found indistinguishable *L. monocytogenes* strains from the drains on the raw side and the heat-treated products in one out of two poultry processing lines. These findings justify the presumption that the persistent strains are introduced into the food processing plants via the raw materials at some point.

The percent persistent PFGE types of the total number of PFGE types in plant C was higher than in the other

plants. It seems that the barrier between the raw and post–heat treatment areas in plant C was inadequate, allowing a large number of PFGE types to enter the food processing areas and enabling some to become established in the processing machines.

The raw product processing lines were persistently contaminated, but those processing lines that produced fermented uncooked products were not persistently contaminated. Competing flora can decrease the amount of *L. monocytogenes* on surfaces *(13, 15),* suggesting that the processing lines producing fermented products might contain competing flora that would prevent *L. monocytogenes* from becoming established on the process surfaces.

Some *L. monocytogenes* strains showing a similar PFGE type were categorized as persistent strains in one plant and nonpersistent in another plant, emphasizing the complex nature of persistent and nonpersistent contamination. It is possible that the typing method was unable to detect differences in the genome of the strains or that the phenotypes of the similar PFGE types were different (e.g., because of adaptation to environmental stress factors such as disinfectants). *L. monocytogenes* strains might adapt (e.g., to quaternary ammonium compounds), with the difference in resistance between adapted and nonadapted cells being multifold *(1, 17).* Also, it is possible that with additional samples, some of the nonpersistent *L. monocytogenes* strains were recovered more often, leading to their categorization as persistent strains. The serotype could not be shown to influence the persistence of a strain because all *L. monocytogenes* serotypes were able to cause persistent contamination.

The contamination status was different in processing lines with differing degrees of compartmentalization. The processing line in plant B that was less compartmentalized was observed to be more frequently contaminated and for longer periods of time than the processing line with well-separated operations in the same plant. The slicing and the dicing lines in plant C were poorly compartmentalized, and the raw area was not separated from the post–heat treatment area. The processing lines were contaminated throughout with persistent *L. monocytogenes* PFGE types, especially the dicer, slicer, conveyor, and packing machine, which were difficult to sanitize. These observations indicate that compartmentalization and separation of different operations, especially the separation of the raw area from the post–heat treatment area, is important in the *L. monocytogenes* contamination status of a processing line. Poor or no separation of the raw and post–heat treatment areas makes prevention of personnel or equipment movement between different processing steps difficult. Proper compartmentalization (i.e., fixed walls) prevents undesired traffic between the raw and post–heat treatment areas.

Persistent contamination of meat and poultry processing plants is a result of many interacting factors. The properties of the *L. monocytogenes* strain appears to play an important role, as suggested in earlier studies *(1, 19),* but the design of the processing line, including the processing machines and the degree of compartmentalization, also influences the contamination status. The processing machines and the surfaces that are in direct contact with the products appear to have a central role in sustaining *L. monocytogenes* contamination and spreading the contamination to the products. More attention should be focused on the hygiene of processing machines, not only in the food processing plants but also at the design stage of the machines. Compartmentalization of the processing line, especially separation of the raw from the post–heat treatment area should be adequate because poor compartmentalization can lead to extensive contamination of the post–heat treatment processing machines. Properly compartmentalized processing lines and the design of more hygienic and easily disassembled processing machines should enable better control of *L. monocytogenes* contamination in meat and poultry processing plants.

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