

# Prevalence and Level of *Listeria monocytogenes* and Other *Listeria* Species in Selected Retail Ready-to-Eat Foods in the United Kingdom

C. L. LITTLE,<sup>1\*</sup> S. K. SAGOO,<sup>1</sup> I. A. GILLESPIE,<sup>1</sup> K. GRANT,<sup>1</sup> AND J. McLAUHLIN<sup>2</sup>

<sup>1</sup>Department of Gastrointestinal, Emerging, and Zoonotic Infections, Health Protection Agency Centre for Infections, 61 Colindale Avenue, London NW9 5EQ, UK; and <sup>2</sup>Health Protection Agency Regional Microbiology Network, London WC1V 7PP, UK

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## ABSTRACT

Although listeriosis is a rare cause of human disease in the United Kingdom, an increase in the number of cases has been observed since 2001, almost exclusively in persons older than 60 years. This increase prompted this study on the microbiological safety of ready-to-eat (RTE) foods, which included those types potentially linked to cases of listeriosis. Between May 2006 and April 2007, 6,984 RTE foods were sampled (2,168 sliced meats, 1,242 hard cheese, 1,088 sandwiches, 878 butter, 725 spreadable cheese, 515 confectionery products containing cream, and 368 probiotic drinks). The food types with the highest prevalence of *Listeria monocytogenes* were sandwiches (7.0%) and sliced meats (3.7% within shelf life, 4.2% end of shelf life). *L. monocytogenes* at >100 CFU/g (exceeding the European Commission's food safety criteria limit) only occurred in sandwiches (0.4%) and sliced meats (0.7% within shelf life, 1.0% end of shelf life). Contamination with *L. monocytogenes* at >100 CFU/g was more frequent in meats that were prepacked and/or of pack size  $\geq 300$  g and in sandwiches that were supplied prepacked that contained salad vegetables as an ingredient. Satisfactory microbiological quality was associated with premises on which the management was trained in food hygiene and those that complied with hazard analysis and critical control point principles. This study provides important information about the microbiological safety of RTE foods and demonstrates that the control of *L. monocytogenes* in such foods, and in particular sandwiches and sliced meats, is essential in order to minimize the risk of this bacterium being present at levels hazardous to health at the point of consumption.

Human listeriosis is a rare but serious foodborne disease, with high morbidity and mortality in vulnerable populations (e.g., pregnant women and the unborn, newborns, the elderly, and the immunocompromised) (19). It is among the most frequent causes of death from foodborne infections in industrialized countries (12). The disease is predominantly caused by the consumption of contaminated ready-to-eat (RTE) foods (12, 19). Since 2001, an increase in the number of listeriosis cases in humans has been observed in several European Union (EU) countries, including England and Wales, predominantly in persons older than 60 years (5, 12, 19, 20).

*Listeria monocytogenes* is widely distributed in the environment and is, therefore, present in a variety of raw food materials. The organism can grow at refrigeration temperatures and survive in food for prolonged periods under adverse conditions (2). A European Commission regulation provides limits for the levels of this bacterium in RTE foods (9, 10). The limit varies according to the type of consumer, characteristics of the food, and information available on the food. Absence of *L. monocytogenes* in 25 g is required in some foods, e.g., RTE foods intended for infants and those for special medical purposes. While for others, such as those that do not support growth of the

organism, or for which shelf life assessment as been carried out, the higher limit is 100 CFU/g (10). Levels of  $\leq 100$  CFU/g are considered to be of low risk for human disease in the normal population; however, the risk is likely to increase for vulnerable populations (12). In 2008, the European Food Safety Authority recommended that efforts to reduce risks to human health should focus on practices both during the production process of RTE foods and in the consumer's home. The European Food Safety Authority further recommended the generation and analysis of data for RTE foods where *L. monocytogenes* is most commonly found to better assess the risk of foods associated with listeriosis (12).

In an attempt to better understand the increase of listeriosis in the elderly population, this study focused on the prevalence of *L. monocytogenes* in selected RTE foods. The food types in the 1-year study included those that were potentially linked to cases ( $\geq 60$  years old) through public health investigations of *L. monocytogenes* in the United Kingdom (i.e., sliced meat, sandwiches, cheese, butter) (18, 19). In order to reflect the potential for deterioration in microbiological quality during shelf life, prepackaged sliced meats were tested both immediately after collection and at the end of shelf life. Additional information on food labeling instructions relating to storage and use was assessed for all food products.

\* Author for correspondence. Tel: +44 20 8327 7931; Fax: +44 20 8327 7112; E-mail: christine.little@hpa.org.uk.

## MATERIALS AND METHODS

**Sample collection.** National surveillance of human *L. monocytogenes* infections in England and Wales is coordinated by the Health Protection Agency Center for Infections. Exposure questionnaires from patients with listeriosis were reviewed, and food types commonly reported by patients were chosen for inclusion in the study.

A total of 6,984 food samples collected from retail premises were examined by 31 official control laboratories in the United Kingdom between 1 May 2006 and 30 April 2007. These samples comprised 2,168 sliced meats, 1,088 sandwiches, 1,242 hard cheese, 725 spreadable cheese, 878 butter, 368 probiotic drinks, and 515 confectionery products containing fresh, or synthetic or imitation cream. Retail premises were selected at random from the local authority environmental health department's database of food businesses via a random number generator. All samples ( $\geq 100$  g) were collected and transported to laboratories by sampling officers from 296 environmental health departments in accordance with the Food Standards Agency Food Law Code of Practice (14). Information about samples was recorded on a standard questionnaire. Sampling officers also provided information on the premises and compliance with food hygiene legislation, based on risk assessment criteria detailed in the Food Hygiene Inspection Rating Scheme (Annex 5 of the Food Standards Agency Food Law Code of Practice (14)).

**Sample examination.** Of 684 duplicate prepacked sliced meat samples collected, one sample was tested on collection and the second tested at the end of its shelf life (i.e., "use-by" date) after storage in a monitored laboratory refrigerator at  $6 \pm 2^\circ\text{C}$ . The presence and levels of *L. monocytogenes* and other *Listeria* spp. were sought in accordance with Health Protection Agency standard microbiological methods (22). Microbiological results were compared with Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs (as amended) (10), and "Guidelines for the Microbiological Quality of Some Ready-to-Eat Foods Sampled at the Point of Sale" (Table 1) (17). Isolates of *L. monocytogenes* were sent to the Laboratory of Gastrointestinal Pathogens, Health Protection Agency Center for Infections, for molecular serotyping and amplified fragment length polymorphism (AFLP) as described previously by Doumith et al. (6) and Guerra et al. (21).

**Statistical analysis.** Descriptive and statistical analysis of the data was undertaken by using Microsoft Excel and Epi Info version 6.04d. Relative proportions were compared by using the chi-squared test ( $\chi^2$ ) and Fisher's exact test. A probability value of less than 5% was defined as significant.

## RESULTS

**Listeria monocytogenes contamination of selected RTE foods.** A greater proportion of sandwiches were contaminated with *L. monocytogenes* (7.0%) compared with sliced meats within shelf life (3.7%,  $P = 0.0003$ ) or at end of shelf life (4.2%,  $P = 0.0174$ ), confectionery products (0.8%,  $P < 0.0001$ ), and hard cheese (0.2%,  $P < 0.0001$ ) (Table 1). However, more sliced meats contained *L. monocytogenes* at  $>100$  CFU/g (0.7% within shelf life, 1.0% at end of shelf life) compared with sandwiches (0.4%), hard cheese (0%), and confectionery products (0%). *L. monocytogenes* was not detected in any samples of spreadable cheese, butter, or probiotic drinks (Table 1).

Of the 166 *L. monocytogenes* isolates, 147 (88.6%) were sent for subtyping: 62.6% were serogroup 1/2a, 21.1% were 4b, 14.3% were 1/2b, and 2.0% were 1/2c (Table 2). Overall, 16 different *L. monocytogenes* subtypes were isolated; all 16 subtypes were obtained from sandwiches, 9 from sliced meats, 2 from hard cheese, and 2 from confectionery products. The subtypes 1/2a IX, 1/2a VII, 1/2b II, 4b I, and 4b IV subtypes predominated (Table 2).

**Sliced meats in relation to the presence of Listeria spp. and L. monocytogenes.** Both *Listeria* spp. and *L. monocytogenes* were detected in fewer sliced chicken samples (2.7 and 1.3%, respectively) compared with other meat types (6.6 to 9.2% *Listeria* spp. [ $P = 0.0058$ ], 3.7 to 4.4% *L. monocytogenes* [ $P = 0.0357$ ]) (Table 1). Most (82%) sliced meats collected were prepacked (Table 3). More samples that were sliced to order contained *Listeria* spp. and *L. monocytogenes* (10.8 and 3.0%, respectively) compared with those that were prepacked (5.8% [ $P = 0.0043$ ] and 3.8%, respectively). *Listeria* spp. and *L. monocytogenes* at  $>100$  CFU/g were, however, more prevalent in prepacked sliced meats than in those sliced to order (Table 3).

Of prepacked sliced meat samples, most (67.4%) were modified atmosphere packed (Table 3). A higher proportion of normal atmosphere-packed (air) samples contained *Listeria* spp. and *L. monocytogenes* (11.8 and 8.9%, respectively) compared with those that were either modified atmosphere packed (4.8 and 3.3%, respectively [ $P = 0.0086$ ]) or vacuum packed (7.0 and 4.0%, respectively [ $P > 0.05$ ]). In contrast, *Listeria* spp. and *L. monocytogenes* at  $>100$  CFU/g were more prevalent in vacuum-packed meats (Table 3).

Two-thirds of sliced meats sampled had a pack size of 100 to  $<200$  g (Table 3). A higher proportion of samples of pack size  $\geq 300$  g contained *Listeria* spp. and *L. monocytogenes* (14.1 and 11.5%, respectively) compared with those of smaller pack sizes (3.9 to 7.9% *Listeria* spp. [ $P = 0.0154$ ], 2.4 to 4.8% *L. monocytogenes* [ $P = 0.0022$ ]). Furthermore, the proportion of samples with *Listeria* spp. decreased as the pack size decreased ( $\geq 300$  g, 14.1%; 200 to  $<300$  g, 7.9%; 100 to  $<200$  g, 6.5%;  $<100$  g, 3.9% [ $\chi^2$  for trend  $P = 0.0026$ ]). Fifty-three percent (41 of 78) of sliced meats of pack size  $\geq 300$  g were modified atmosphere packed. Of these, 17.1 and 14.6% contained *Listeria* spp. and *L. monocytogenes*, respectively, with 4.9% at  $>100$  CFU/g.

Storage temperatures for cooked meats should be  $\leq 5^\circ\text{C}$ , although storage up to  $\leq 8^\circ\text{C}$  may be used with an appropriate shelf life (4, 28). At the time of sampling, most samples were stored or displayed at  $\leq 5^\circ\text{C}$  (46.1%) or between  $>5$  and  $\leq 8^\circ\text{C}$  (45.8%) (Table 3). More samples displayed or stored at  $\leq 5^\circ\text{C}$  contained *Listeria* spp. and *L. monocytogenes* (9.2 and 4.6%, respectively) compared with those at  $>5^\circ\text{C}$  to  $\leq 8^\circ\text{C}$  (3.6 and 2.5%, respectively [ $P < 0.0001$ ]) but not those at  $>8^\circ\text{C}$  (12.3 and 7.7%, respectively [ $P > 0.05$ ]) (Table 3).

It is illegal to sell food beyond its use-by date. This date was recorded on the packaging for 94.2% (1,146 of 1,216) of prepacked sliced meats. Based on the use-by date, most samples had remaining shelf lives ranging between 6 to 10 days (35.2%) and 11 days and more (46.7%). *L.*

TABLE 1. *Listeria* spp. and *Listeria monocytogenes* contamination of selected retail RTE foods

RTE food	No. (%) of samples	<i>Listeria</i> spp., no. (%)				<i>Listeria monocytogenes</i> , no. (%)			
		ND in 25 g <sup>a</sup>	D in 25 g and <10 CFU/g <sup>b</sup>	10–≤100 CFU/g	>100 CFU/g <sup>c</sup>	ND in 25 g	D in 25 g and <10 CFU/g	10–≤100 CFU/g	>100 CFU/g <sup>d</sup>
Sliced meats									
within shelf									
life	1,484 (21.2)	1,385 (93.3)	80 (5.4)	6 (0.4)	13 (0.9) <sup>e</sup>	1,429 (96.3)	42 (2.8)	3 (0.2)	10 (0.7) <sup>f</sup>
Beef	218 (14.7)	198 (90.8)	15 (6.9)	2 (0.9)	3 (1.4)	210 (96.3)	5 (2.3)	1 (0.5)	2 (0.9)
Chicken	226 (15.2)	220 (97.3)	5 (2.2)	0	1 (0.5)	223 (98.7)	2 (0.9)	0	1 (0.4)
Ham	949 (63.9)	882 (93.0)	55 (5.8)	4 (0.4)	8 (0.8)	909 (95.8)	31 (3.3)	2 (0.2)	7 (0.7)
Tongue	91 (6.1)	85 (93.4)	5 (5.5)	0	1 (1.1)	87 (95.6)	4 (4.4)	0	0
Sliced meats at									
end of shelf									
life	684 (9.8)	636 (92.9)	28 (4.1)	10 (1.5)	10 (1.5) <sup>g</sup>	655 (95.8)	18 (2.6)	4 (0.6)	7 (1.0) <sup>h</sup>
Beef	88 (12.9)	81 (92.1)	5 (5.7)	1 (1.1)	1 (1.1)	84 (95.5)	3 (3.4)	0	1 (1.1)
Chicken	121 (17.7)	118 (97.6)	0	1 (0.8)	2 (1.6)	119 (98.3)	0	0	2 (1.7)
Ham	455 (66.5)	417 (91.6)	23 (5.1)	8 (1.8)	7 (1.5)	432 (94.9)	15 (3.3)	4 (0.9)	4 (0.9)
Tongue	20 (2.9)	20 (100.0)	0	0	0	20 (100.0)	0	0	0
Sandwiches									
Ham	1,088 (15.6)	949 (87.2)	116 (10.7)	13 (1.2)	10 (0.9) <sup>i</sup>	1,012 (93.0)	63 (5.8)	9 (0.8)	4 (0.4) <sup>i,j</sup>
Cheese	285 (26.2)	243 (85.2)	37 (13.0)	3 (1.1)	2 (0.7)	265 (93.0)	17 (5.9)	2 (0.7)	1 (0.4)
Tuna	204 (18.8)	184 (90.2)	16 (7.8)	2 (1.0)	2 (1.0)	194 (95.1)	8 (3.9)	2 (1.0)	0
Egg	252 (23.2)	219 (86.9)	27 (10.7)	3 (1.2)	3 (1.2)	227 (90.1)	20 (7.9)	2 (0.8)	3 (1.2)
mayonnaise	347 (31.8)	303 (87.4)	36 (10.3)	5 (1.4)	3 (0.9)	326 (94.0)	18 (5.2)	3 (0.8)	0
Hard cheese									
Cheddar	1,242 (17.7)	1,208 (97.3)	34 (2.7)	0	0	1,240 (99.8)	2 (0.2)	0	0
Gloucester	802 (64.6)	780 (97.3)	22 (2.7)	0	0	801 (99.8)	1 (0.2)	0	0
Lancashire	108 (8.7)	105 (97.2)	3 (2.8)	0	0	107 (99.1)	1 (0.9)	0	0
Leicester	78 (6.3)	72 (92.3)	6 (7.7)	0	0	78 (100.0)	0	0	0
Leicester	254 (20.4)	248 (97.6)	6 (2.4)	0	0	254 (100.0)	0	0	0
Confectionery									
products									
with:	515 (7.4)	501 (97.3)	13 (2.5)	0	1 (0.2) <sup>k</sup>	511 (99.2)	4 (0.8)	0	0
Fresh cream	392 (76.1)	379 (96.6)	12 (3.1)	0	1 (0.3)	388 (99.0)	4 (1.0)	0	0
Synthetic cream	123 (23.9)	122 (99.1)	1 (0.9)	0	0	123 (100.0)	0	0	0
Butter	878 (12.6)	875 (99.6)	3 (0.4)	0	0	878 (100.0)	0	0	0
Spreadable									
cheese	725 (10.4)	722 (99.6)	3 (0.4)	0	0	725 (100.0)	0	0	0
Probiotic drinks	368 (5.3)	364 (98.9)	4 (1.1)	0	0	368 (100.0)	0	0	0
Total	6,984	6,640 (95.1)	281 (4.0)	29 (0.4)	34 (0.5)	6,818 (97.6)	129 (1.8)	16 (0.2)	21 (0.3)

<sup>a</sup> ND, not detected.<sup>b</sup> D, detected.<sup>c</sup> A *Listeria* count of >100 CFU/g is of unsatisfactory microbiological quality according to United Kingdom guidelines for the microbiological quality of various RTE foods (17).<sup>d</sup> A *Listeria monocytogenes* count of >100 CFU/g exceeds food safety criteria for an RTE food placed on the market during its shelf life and is thus deemed to be legally unsatisfactory (Regulation [EC] No. 2073/2005, as amended) (10).<sup>e</sup> *Listeria innocua* and *Listeria welshimeri*: range of  $3.3 \times 10^2$  to  $1.8 \times 10^3$  CFU/g.<sup>f</sup> *L. monocytogenes*: range of  $1.2 \times 10^2$  to  $8.0 \times 10^5$  CFU/g.<sup>g</sup> *L. innocua* and *L. welshimeri*: range of  $1.4 \times 10^2$  to  $1.8 \times 10^4$  CFU/g.<sup>h</sup> *L. monocytogenes*: range of  $4.6 \times 10^2$  to  $3.3 \times 10^4$  CFU/g.<sup>i</sup> *L. innocua* and *L. welshimeri*: range of  $1.8 \times 10^2$  to  $2.6 \times 10^4$  CFU/g.<sup>j</sup> *L. monocytogenes*: range of  $2.2 \times 10^2$ – $1.2 \times 10^3$  CFU/g.<sup>k</sup> *L. innocua*:  $1.7 \times 10^3$  CFU/g.

TABLE 2. Subtypes of *Listeria monocytogenes* isolated from sliced meats, sandwiches, hard cheese, and confectionery products

Typing character (serotype, AFLP)	No. (%) of samples	Sliced meats (no. of samples)	Sandwiches (no. of samples)	Hard cheese (no. of samples)	Confectionery products (no. of samples)
1/2a II	2 (1.4)		Ham (2)		
1/2a III	7 (4.7)	Ham (5)	Egg mayonnaise (1), ham (1)		
1/2a VI	2 (1.4)		Tuna (2)		
1/2a VII	19 (12.9)	Ham (9), beef (1)	Egg mayonnaise (4), ham (3), cheese (1), tuna (1)		
1/2a IX	54 (36.7)	Ham (21), beef (2), chicken (1), tongue (1)	Tuna (13), egg mayonnaise (9), ham (3), cheese (3)	Cheddar (1)	
1/2a XI	2 (1.4)		Egg mayonnaise (2)		
1/2a XIV	5 (3.4)	Ham (2), beef (1)	Ham (2)		
1/2a XVIII	1 (0.7)		Ham (1)		
1/2b II	16 (10.9)	Ham (4), chicken (3), beef (2)	Tuna (2), egg mayonnaise (1), ham (1)		Dairy cream cake (1), chocolate éclair (1), vanilla slice (1)
1/2b IV	5 (3.4)	Ham (3)	Cheese salad (1)	Gloucester (1)	
1/2c VII	3 (2.0)	Ham (2)	Egg mayonnaise (1)		
4b I	11 (7.5)	Ham (4), tongue (2)	Cheese (2), egg mayonnaise (1), tuna (1)		Dairy cream cake (1)
4b IV	11 (7.5)	Ham (6), beef (2)	Ham (2), cheese (1)		
4b V	7 (4.7)		Ham (3), tuna (3), cheese (1)		
4b IX	2 (1.4)		Ham (2)		
Total	147	71	70	2	4

*monocytogenes* at >100 CFU/g was more likely to be found in sliced meats with a remaining shelf life of 0 to 5 days (1.5%) or 6 to 10 days (1.0%) than in meats with more than 10 days left (0.4%) (Table 3).

**Sandwiches in relation to the presence of *Listeria* spp. and *L. monocytogenes*.** Both *Listeria* spp. and *L. monocytogenes* were detected less frequently in cheese sandwiches (9.8 and 4.9%, respectively) compared with other filling types (12.7 to 14.7% *Listeria* spp., 6.1 to 9.9% *L. monocytogenes*). Seventy percent of the sandwiches contained salad ingredients (Table 3). More sandwiches with salad ingredients contained *Listeria* spp. (15.0%) and *L. monocytogenes* (8.9%) compared with those without (7.6% *Listeria* spp. [ $P = 0.0007$ ], 3.1% *L. monocytogenes* [ $P = 0.0006$ ]). *Listeria* spp. and *L. monocytogenes* at >100 CFU/g were also more prevalent in sandwiches that contained salad ingredients (Table 3).

Most (82%) sandwiches collected were prepacked. More prepacked sandwiches contained *Listeria* spp. and *L. monocytogenes* (14.4 and 8.1%, respectively) compared with those made to order (5.5 and 2.0%, respectively) ( $P = 0.0004$ ), and these were also more likely to contain these organisms at >100 CFU/g (Table 3). The British Sandwich Association recommends that manufactured sandwiches should be delivered and stored or retailed at 5°C and never higher than 8°C (3). At the time of sampling, 58.6% of prepacked sandwiches were displayed or stored at ≤5°C, and 31.4% at >5 to ≤8°C (Table 3). The display and storage temperature of the prepacked sandwiches had no significant effect on the proportion of sandwiches that contained *Listeria* spp. and *L. monocytogenes*.

The use-by date was recorded on the packaging for 83.0% of prepacked sandwiches. Based on the use-by date, 92.4% samples collected had remaining shelf lives ranging from 0 to 2 days (Table 3). *L. monocytogenes* was less likely to be found in sandwiches with a remaining shelf life of ≤2 days (7.5% [57 of 764]) than in sandwiches with more than 2 days left (16.7% [10 of 60,  $P = 0.0229$ ]). The four samples with *L. monocytogenes* at >100 CFU/g all had 2 days of shelf life remaining (Table 3).

**Hard cheese in relation to the presence of *Listeria* spp. and *L. monocytogenes*.** A higher proportion of Lancashire cheese samples contained *Listeria* spp. (7.7%) compared with other hard cheese varieties (1.2 to 2.8%) ( $P = 0.0143$ ). *L. monocytogenes* was recovered from 0.1% of cheddar and 0.9% of Gloucester cheese samples (Table 1). Sixty-one percent (758 of 1,242) of hard cheese samples were made with pasteurized milk, 1.4% (17) from unpasteurized milk, and for 37.6% (467) of samples, this information was not known (i.e., not specified on the label or packaging). More unpasteurized milk cheese samples contained *Listeria* spp. (5.9%) compared with pasteurized milk cheeses (2.4%). *L. monocytogenes* was only detected in pasteurized milk cheeses (0.3%).

Ninety-one percent (1,125 of 1,242) of hard cheeses collected were prepacked and 9.0% (117) were cut to order. *Listeria* spp. and *L. monocytogenes* were only detected in prepacked cheeses (3.0 and 0.2%, respectively). Eighty-nine percent (1,100 of 1,242) of cheese samples were stored or displayed at ≤8°C, 7.4% (92) at >8°C, and for 4.0% (50) of samples, this information was not recorded. Of cheese samples that were stored >8°C, 3.3% contained *Listeria* spp. and 1.1%

TABLE 3. Sliced meat and sandwiches details in relation to presence of *Listeria* spp. and *Listeria monocytogenes* at >100 CFU/g

Sample type	No. (%) of samples	No. (%) of samples with <i>Listeria</i> >100 CFU/g (n = 13)	No. (%) of samples with <i>L. monocytogenes</i> >100 CFU/g (n = 10)
Sliced meats (n = 1,484)			
Packaging			
Prepacked	1,216 (81.9)	12 (1.0)	9 (0.7)
Sliced to order	268 (18.1)	1 (0.4)	1 (0.4)
Prepacked product (n = 1,216)			
Vacuum packed	200 (16.5)	5 (2.5)	3 (1.5)
Modified atmosphere packed	820 (67.4)	8 (1.0)	6 (0.7)
Normal atmosphere packed	101 (8.3)	0	0
Not recorded	95 (7.8)	0	0
Pack size			
<100 g	206 (13.9)	2 (1.0)	2 (1.0)
100–200 g	991 (66.8)	9 (0.9)	6 (0.6)
200–300 g	126 (8.5)	0	0
≥300 g	78 (5.3)	2 (2.5)	2 (2.5)
Not recorded	83 (5.5)	0	0
Temp stored or displayed			
≤5°C	684 (46.1)	10 (1.5)	7 (1.0)
>5 to ≤8°C	680 (45.8)	3 (0.4)	3 (0.4)
>8°C (range: 9–20°C)	65 (4.4)	0	0
Not recorded	55 (3.7)	0	0
Remaining shelf life (days) (n = 1,146)			
<0 <sup>a</sup>	5 (0.4)	0	0
0–5	200 (17.4)	3 (1.5)	3 (1.5)
6–10	404 (35.2)	7 (1.7)	4 (1.0)
>11	537 (46.7)	2 (0.4)	2 (0.4)
Sandwiches (n = 1,088)			
Salad ingredients present:			
Yes	760 (69.9)	8 (1.1)	4 (0.5)
No	328 (30.1)	2 (0.6)	0
Packaging			
Prepacked	888 (81.6)	10 (1.1)	4 (0.5)
Made to order	200 (18.4)	0	0
Prepacked sandwiches, stored or displayed (n = 888)			
≤5°C	520 (58.6)	5 (1.0)	3 (0.6)
>5 to ≤8°C	279 (31.4)	5 (1.8)	1 (0.4)
>8°C (range: 9–24°C)	58 (6.5)	0	0
Not recorded	31 (3.5)	0	0
Prepacked sandwiches, remaining shelf life (days) (n = 826)			
<0 <sup>a</sup>	2 (0.3)	0	0
0–2	764 (92.4)	9 (1.2)	4 (0.5)
3–4	60 (7.3)	1 (1.7)	0

<sup>a</sup> Expired past use-by date; not in compliance with United Kingdom food labeling regulations of 1996.

*L. monocytogenes*, which was slightly higher than those stored at ≤8°C (2.5% *Listeria* spp., 0.1% *L. monocytogenes*).

**Confectionery products in relation to the presence of *Listeria* spp. and *L. monocytogenes*.** More confectionery product samples with fresh cream contained *Listeria* spp. (3.3%) than did product samples with synthetic cream (0.8%). *L. monocytogenes* was only recovered from products with fresh cream (1.0%). Seventy-two percent

(373) of the confectionery products were stored or displayed at ≤8°C, 20.2% (104) at >8°C, and for 7.4% of samples, this information was not recorded. More samples that were displayed or stored at ≤8°C contained *Listeria* spp. and *L. monocytogenes* (3.2 and 1.1%, respectively) compared with those at >8°C (1.0 and 0%, respectively).

**Butter in relation to the presence of *Listeria* spp. and *L. monocytogenes*.** Eighty percent (703 of 878) of butter

samples collected were salted (1 to 2% salt), 10.2% (89) were lightly salted (<1% salt), and 7.4% (65) were unsalted; for 2.4% (21) of samples, this information was not known. Ninety-seven percent (853 of 878) of butter samples were made from pasteurized milk, 0.8% (7) from unpasteurized milk, and for 2.1% (18) of samples, this information was not known. Ninety percent (789 of 878) of samples were stored or displayed at  $\leq 8^{\circ}\text{C}$ , 5.9% (52) at  $> 8^{\circ}\text{C}$ , and for 4.2% (37) of samples, this information was not recorded.

*L. monocytogenes* was not detected in any of the butter samples. Only samples of unsalted butter contained *Listeria* spp. (4.6% [3 of 65],  $P = 0.0004$ ). *Listeria* spp. were detected in 0.4% (3 of 853) of butter made from pasteurized milk and only found in butter stored or displayed at  $\leq 8^{\circ}\text{C}$  (0.4% [3 of 789]).

**Spreadable cheese in relation to the presence of *Listeria* spp. and *L. monocytogenes*.** Of prepacked spreadable cheeses sampled, 74.8% were classified as cheese spread and 25.2% as cream cheese. Ninety-one percent (662 of 725) of samples were unflavored, and 9% (63) were flavored (chives, garlic, herbs, or pepper). Ninety percent (650 of 725) were stored or displayed at  $\leq 8^{\circ}\text{C}$ , 4.5% (33) at  $> 8^{\circ}\text{C}$ , and for 5.5% (42) of samples, this information was not recorded. *Listeria* spp. were recovered from 0.4% (2 of 542) of cheese spreads and 0.6% (1 of 183) of cream cheeses, all of which were unflavored types. *L. monocytogenes* was not detected in these cheeses.

**Probiotic drinks in relation to the presence of *Listeria* spp. and *L. monocytogenes*.** Of probiotic drinks sampled, 47.8% were unflavored and 52.2% were flavored (strawberry, raspberry, orange, or mixed fruit). Ninety percent (332 of 368) were stored or displayed at  $\leq 8^{\circ}\text{C}$ , 2.2% (8) at  $> 8^{\circ}\text{C}$ , and for 7.8% (28) of samples, this information was not recorded. *Listeria* spp. was recovered from 1.7% (3 of 176) and 0.5% (1 of 192) of unflavored and flavored drinks, respectively. *L. monocytogenes* was not detected in probiotic drinks.

**Selected RTE foods in relation to product labeling, storage information, shelf life, and durability dates.** Among the 5,558 prepacked foods sampled, 43.4% had no instructions on the packaging or label relating to shelf life after opening (e.g., “consume within 3 days”), while 39.8% did. This information was not recorded for 16.8% of samples. Eighty-seven percent of the foods sampled had storage temperature information present on the packaging or label, and of these, 64.8% advised to keep the product refrigerated, with 22.2% specifying a refrigeration temperature (Table 4). The storage, shelf life information, and durability dates were easily visible and clearly legible as judged by the sampling officer for 92.1% of the samples collected (Table 4). For 62.1% of samples, the storage, shelf life information, and durability dates were printed or written in black type on a white background, with 44.4% having a 10-point font size (Table 4). In 2.6% of the packages, this information was printed in yellow and white, and in 2.9% by using 6-point font size.

TABLE 4. Details of product labeling (storage information, shelf life, and durability dates) on prepacked foods

Product labeling	No. (%) of samples ( $n = 5,558$ )
Storage temp information on packaging/label	
“Keep refrigerated”	3,603 (64.8)
Particular temp given	1,234 (22.2)
0 to $\leq 5^{\circ}\text{C}$	975 (79.0)
$> 5$ to $\leq 8^{\circ}\text{C}$	259 (30.0)
No temp indicated	519 (9.3)
Not recorded	202 (3.7)
Storage, shelf life, durability date details	
Easily visible and clearly legible	
Yes	5,120 (92.1)
No	278 (5.0)
Not recorded	160 (2.9)
In black type on white background	
Yes	3,450 (62.1)
No	1,708 (30.7)
Not recorded	400 (7.2)
Font size of type/print	
10 point	2,468 (44.4)
8 point	1,033 (18.6)
6 point	161 (2.9)
Other (12, 14, 16, 18 point)	1,295 (23.3)
Not recorded	601 (10.8)

**Retail premises and compliance with food hygiene legislation.** Food businesses were categorized from A to E in accordance with risk assessment criteria of the Food Hygiene Inspection Rating Scheme. Premises in category A are higher-risk businesses (Table 5) (14). More samples containing *Listeria* spp. and *L. monocytogenes* were from category A premises (17.3 and 8.7%, respectively) than from premises in other categories (4.2 to 6.6% *Listeria* spp. [ $P < 0.0001$ ], 2.0 to 2.6% *L. monocytogenes* [ $P = 0.0183$ ]) (Table 5).

As part of the Food Hygiene Inspection Rating Scheme, businesses receive a “Consumer-at-Risk” score based on the number of consumers likely to be at risk if there is a failure of food hygiene and procedures (14). This score ranges from 0 to 15, with a score of 0 indicating very few consumers at risk (Table 5). A higher proportion of samples containing *Listeria* spp. and *L. monocytogenes* were recovered from premises with Consumer-at-Risk scores of 0 to 5 (5.2 and 2.7%, respectively) compared with those with scores of 10 to 15 (3.4 and 1.2%, respectively [ $P < 0.0024$ ]) (Table 5). Furthermore, the proportion of samples with *Listeria* spp. decreased as the Consumer-at-Risk score increased (0, 5.6%; 5, 5.2%; 10, 3.2%; and 15, 2.4%) ( $\chi^2$  for trend  $P = 0.0046$ ) (Table 5).

In accordance with the Food Hygiene Inspection Rating Scheme, businesses were allocated a score of 0 to 30 based on Confidence in Management and Control Systems, with a score of 0 indicating a high level of high confidence (Table 5) (14). A higher proportion of samples from premises where there was no, little, or some confidence in management contained *Listeria* spp. and *L. monocytogenes*

TABLE 5. Microbiological quality of selected foods collected from retail premises

Premises details	No. (%) of samples (n = 6,299)	No. (%) of samples with all <i>Listeria</i> spp. (n = 296)	No. (%) of samples with <i>L. monocytogenes</i> (n = 137)
<b>Inspection rating category</b>			
Category, minimum frequency of inspection			
A, at least every 6 mo	23 (0.4)	4 (17.3)	2 (8.7)
B, at least every 12 mo	499 (7.9)	33 (6.6)	13 (2.6)
C, at least every 18 mo	3,403 (54.0)	152 (4.5)	69 (2.0)
D, at least every 2 y	1,141 (18.1)	61 (5.4)	29 (2.5)
E, alternative enforcement strategy	707 (11.2)	30 (4.2)	17 (2.4)
Not recorded	526 (8.4)	16 (3.0)	7 (1.3)
<b>Consumers-at-Risk score</b>			
0 (very few)	121 (1.9)	7 (5.6)	5 (4.1)
5 (few)	4,368 (69.3)	227 (5.2)	110 (2.5)
10 (intermediate)	1,099 (17.5)	35 (3.2)	12 (1.1)
15 (substantial)	41 (0.7)	1 (2.4)	1 (2.4)
Not recorded	670 (10.6)	26 (3.9)	9 (1.3)
<b>Confidence-in-Management score</b>			
0 (high)	443 (7.0)	15 (3.3)	8 (1.8)
5 (moderate)	2,173 (34.5)	78 (3.6)	23 (1.1)
10 (some)	2,398 (38.1)	132 (5.5)	68 (2.8)
20 (little)	549 (8.7)	42 (7.6)	27 (4.9)
30 (none)	30 (0.5)	3 (10.0)	2 (6.7)
Not recorded	706 (11.2)	26 (3.7)	9 (1.3)
<b>Compliant with principles of HACCP (EC No. 852/2004, Article 5)</b>			
Yes	4,434 (70.4)	189 (4.3)	40 (0.9)
No	926 (14.7)	61 (6.6)	74 (7.9)
Not recorded	939 (14.9)	46 (4.9)	23 (2.4)
<b>Manager food hygiene training</b>			
Received training and attended:			
Foundation	4,735 (75.1)	204 (4.3)	89 (1.9)
Intermediate	3,031 (64.0)	147 (4.9)	72 (2.4)
Advanced	882 (18.6)	29 (3.3)	11 (1.3)
Other course (company training, MLC HACCP, C&G) <sup>a</sup>	195 (4.1)	10 (5.1)	1 (0.5)
Not recorded	333 (7.0)	12 (3.6)	3 (0.9)
No training	294 (6.3)	6 (2.0)	2 (0.7)
Not recorded	697 (11.1)	51 (7.3)	33 (4.7)
Not recorded	867 (13.8)	41 (4.7)	15 (1.7)

<sup>a</sup> MLC, Meat and Livestock Commission; C&G, City and Guilds.

(5.8 and 3.3%, respectively) compared with premises where there was moderate or high confidence in management (3.6 and 1.1%, respectively [ $P < 0.0001$ ]) (Table 5). Furthermore, the proportion of samples with *Listeria* spp. decreased as confidence in management increased (0 [high], 3.3%; 5 [moderate], 3.6%; 10 [some], 5.5%; 20 [little], 7.6%; 30 [none], 10.0% [ $\chi^2$  for trend  $P < 0.0001$ ]) (Table 5).

Seventy percent of samples collected were from premises that complied with hazard analysis and critical control points (HACCP) requirements (8) (Table 5). A higher proportion of samples collected from premises that did not comply with HACCP requirements contained *Listeria* spp. and *L. monocytogenes* (6.6 and 4.3%, respectively) compared with those that did (4.3 and 1.7%, respectively [ $P = 0.0035$ ]) (Table 5). Seventy-five percent of samples were collected from premises whose managers

had received food hygiene training (Table 5). More samples collected from premises with managers that had not received food hygiene training contained *Listeria* spp. and *L. monocytogenes* (7.3 and 4.7%, respectively) than those with managers with training in food hygiene (4.3 and 1.9%, respectively [ $P = 0.0010$ ]) (Table 5).

## DISCUSSION

This study has shown that in 99.7% of selected retail RTE foods the food safety criteria limit (>100 CFU/g) in Regulation (EC) No. 2073/2005 (as amended) (10) for *L. monocytogenes* was not exceeded. This limit was exceeded in 0.4% of prepacked sandwiches and in 0.7 and 1.0% of sliced meats within and at end of shelf life, respectively. Full investigations of these incidents were undertaken by the appropriate food authorities, manufacturers, and the United

Kingdom Food Standards Agency. Overall, the prevalence of *L. monocytogenes* observed in sandwiches (7.0%) and sliced meats (3.7% within shelf life, 4.2% end of shelf life) was also higher than that found in all other RTE food types examined (0 to 0.8%).

Although *Listeria* spp. other than *L. monocytogenes* are rarely implicated in disease, they are indicators of the likely presence of *L. monocytogenes*. Significant risk factors identified with the presence of *Listeria* spp. and *L. monocytogenes* at >100 CFU/g in sandwiches sampled in the present study were if prepacked and/or contained salad ingredients. Previous studies of retail sandwiches in Wales (2005 to 2006) and Ireland (2002) reported a similar prevalence of *L. monocytogenes* (5.2 to 11.0%) and at >100 CFU/g (0.3%) (13, 27). Similarly, sandwiches supplied to hospitals in the United Kingdom (2005 to 2006) had a comparable prevalence of *L. monocytogenes* (7.5%) (24). A range of food types have been associated with transmission of listeriosis, and prepacked sandwiches were the most commonly detected food type associated with transmission in England and Wales (18, 19). The microbiological quality of ingredients incorporated into sandwiches is of importance. The British Sandwich Association recommends a target level of <10 CFU/g of *L. monocytogenes* in sandwiches at production, and that the presence of any *Listeria* spp. in a product must be investigated, as it could indicate a failure in procurement, preparation, and/or storage of food materials (3).

There are numerous reports on the incidence of *L. monocytogenes* in retail RTE meats, ranging from 0.9 to 21.0% (23). The prevalence of *L. monocytogenes* in sliced meats in the present study (3.7%) was higher than that reported previously in the United Kingdom in 2002 (2.0%) (7). *L. monocytogenes* at >100 CFU/g at the end of shelf life of prepacked sliced meats in the current study (1.0%) was the same as that found in the United Kingdom during 2003 (0.9%) (29). Sliced meats were more frequently contaminated with both *Listeria* spp. and *L. monocytogenes* at >100 CFU/g when they were prepacked and/or sold in large pack sizes. Continuous efforts should be made to improve food safety of sliced meats and prevent growth of *L. monocytogenes* by adequate cooking, appropriate hygienic measures to avoid contamination, assessing the influence of packaging type on shelf life, and by shelf life control.

Management food hygiene training and the presence of hazard analysis systems in food premises has been shown to make a significant contribution to an improvement in the microbiological safety of RTE foods (25). This is further corroborated by the results from this study. The implementation of a hazard analysis system or similar food safety management plans in food premises provides a framework for good hygiene practice. Compliance with the principles of HACCP, and associated relevant supervision and instruction and/or food hygiene training for all employees is a legal requirement (8). Evidence from this study highlights smaller retail premises (as indicated by Consumer-at-Risk scores), and premises with poor Confidence-in-Management scores, as an area for concern with regard to

presence of *L. monocytogenes* and other *Listeria* spp. in RTE foods and food safety risks.

The *L. monocytogenes* serogroups most often causing human infection in the United Kingdom are 4b and 1/2a, with the subtype 4b AFLP I being most common in England and Wales (18, 26). A preliminary case-case study of human *L. monocytogenes* subtypes in relation to food exposure history from 2005 to 2007 in England and Wales showed associations between exposures of subtypes to pork or dairy products (4b I), fish and dairy products (1/2a IX), and sliced meats (ham, chicken, turkey), cheese, and sandwiches (1/2a VII) (18). The predominant serogroup of *L. monocytogenes* recovered in this study from sliced meats and sandwiches was serotype 1/2a (63%), with AFLP subtypes IX and VII most common. However, 21% of meat and sandwich food isolates were serotype 4b, with AFLP subtypes I and IV most common.

Consumers are believed to benefit from clear recommendations on good food hygiene practice (i.e., at what temperature to keep food chilled at all times), and from being encouraged to take careful note of the shelf life of food in their refrigerators (12). Packaging and labeling safety-based guidance on the proper storage and handling of refrigerated RTE foods should therefore help to reduce the risk of listeriosis. A small proportion of RTE foods in this study had this information present in a format that many consumers would have difficulty in reading, and thus should be avoided, i.e., using 6-point font size. Labeling design should continue to make every effort on legibility and clarity, particularly as there is a growing elderly population where there will be more people with suboptimal vision (15). This is being currently considered as part of an EU food labeling review (11). Dietary recommendations about when to avoid certain foods and educational messages about food preparation are also important. Advice from the United Kingdom Food Standards Agency to pregnant women warns against consumption of pâté, soft mold-ripened cheeses, and blue-veined cheeses, and recommends cooking raw meat thoroughly (16). The United Kingdom Advisory Committee on the Microbiological Safety of Food recommended in 2008 that dietary advice on the avoidance of high-risk foods be amended and also be provided routinely to other susceptible groups, such as the elderly population, as well as to those who prepare their food and those who provide medical advice about the risks of listeriosis to these groups (1).

Significant progress has been made in recognizing foods that present a risk of *L. monocytogenes* infection, and in developing strategies and processes that can minimize this risk. This study highlights that further emphasis must be given to the reduction of *L. monocytogenes* in high-risk foods, such as prepacked sliced meats and sandwiches, which are consumed without any further treatment.

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