Journal of Food Protection, Vol. 79, No. 4, 2016, Pages 598–604
doi:10.4315/0362-028X.JFP-15-460

Assessment of the Microbiological Safety of Precut Fruit from Retail and Catering Premises in the United Kingdom

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MS 15-460: Received 8 October 2015/Accepted 10 December 2015

ABSTRACT

Fresh fruit has been associated with a number of foodborne outbreaks in recent years. In particular, a large outbreak of listeriosis in the United States in 2011 was associated with consumption of cantaloupe melon, and an outbreak of *Salmonella* Newport in the United Kingdom and Europe (also in 2011) was linked to watermelon consumption. A study of precut fruit products from catering and retail premises in the United Kingdom was, therefore, carried out to assess their microbiological safety. Between January and March 2012, samples (1,188) of ready-to-eat precut fruit were collected from retail and catering premises in the United Kingdom, and 99% were of satisfactory microbiological quality. However, four samples (0.3%) were of an unsatisfactory quality (one with 800 CFU/g *Listeria monocytogenes* and three with >100 CFU/g *Escherichia coli*), and five samples (0.4%) were of a borderline quality owing to the presence of *E. coli* (two samples with a level of 20 CFU/g), *Staphylococcus aureus* (two samples with levels of >50 CFU/g), or *L. monocytogenes* (one sample with a level of 80 CFU/g). *L. monocytogenes* or other *Listeria* species were detected in a further 54 samples (4.5%) at levels below the threshold considered to be borderline or unsatisfactory. A significantly larger proportion of samples from one national supermarket chain was contaminated with *L. monocytogenes* than other supermarkets, and two types were, in this study, unique to this supermarket. This study shows that overall, the microbiological quality of ready-to-eat precut fruit was good. However, the presence of *Listeria* species in 5% of samples highlights the need for good hygiene during preparation and satisfactory temperature and time control during storage of these food products.

Key words: Food safety; Fruit; *Listeria*; Survey

Fresh fruit is widely consumed and generally free from noxious substances, such as poisonous chemicals, toxins, and pathogenic organisms. It is promoted as a healthy snack, and packs of precut fruit are widely available in supermarkets and other retailers. However, this food commodity is often consumed as a highly perishable product receiving only minimal processing, and outbreaks of illness associated with the consumption of fruit have been reported. For example, outbreaks of norovirus associated with the consumption of imported, frozen raspberries affected more than 500 people in Denmark *(22),* while approximately 11,000 people became ill with norovirus in Germany following consumption of frozen strawberries *(25)*. A large outbreak of listeriosis that occurred in the United States in 2011, affecting 139 people across 28 states and causing 29 deaths, was associated with the consumption of cantaloupe melons, some of which were sold as a cut product *(26)*. Additionally, the Health Protection Agency (HPA; previously Public Health Laboratory Service) has previously published evidence to indicate that precut fruit collected from retail and production premises in 2002 had a high prevalence of *Listeria monocytogenes* (8%) compared with, for example, bagged leafy salad vegetables (retail) and open leafy vegetables (catering; approximately 4%) *(23)*. Of the precut fruit types, melons were found to have the highest rate of contamination by *L. monocytogenes* (18.5%). An HPA and local authority food study in North West England (September to December 2011) also revealed a relatively high rate of *L. monocytogenes* contamination in precut fruit (111 of 1,720, 6%) (A.F., personal communication, 2011), and one sample of precut watermelon was found to be contaminated with *Salmonella* Newport that was later shown to be part of an outbreak affecting six European countries *(3)*.

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TABLE 1. *Criteria for the interpretation of microbiology results*[a]

	Satisfactory	Borderline	Unsatisfactory	Unsatisfactory: potentially injurious to health
E. coli/g	<20	20–<100	>100	NA
S. aureus/g	<20	20–<10^4	NA	>10^4
L. monocytogenes/g	<10	10–<100	NA	>100
Listeria species/g (not *L. monocytogenes*)	<10	10–<100	>100	NA
Salmonella in 25 g	Not detected	NA	NA	Detected

[a] Adapted from Health Protection Agency *(15)*. NA, not applicable.

European Commission Regulation (EC) No 2073/2005 (as amended) *(11)* provides microbiological criteria for foodstuffs, including cut fruit and vegetables. A food safety criterion is specified, requiring the absence of *Salmonella* in 25 g for precut, ready-to-eat fruit and vegetables placed on the market during their shelf life. Because this product is a ready-to-eat food, there is also a requirement in this regulation for a limit for *L. monocytogenes* contamination of 100 CFU/g for products placed on the market during their shelf life. Moreover, a process hygiene criterion is included, specifying acceptable levels of *Escherichia coli* in these products at the end of the manufacturing process (i.e., of five samples taken from a batch, none should have an *E. coli* level of greater than 1,000 CFU/g, and no more than two should have a level greater than 100 CFU/g). However, despite public health incidents associated with outbreaks of infection following consumption of cut fruit, there is a lack of baseline data for the microbiological quality of this food commodity. The aim of this study was to provide data on the microbiological quality and safety of ready-to-eat precut fruit on retail sale in England and Northern Ireland during 2012.

MATERIALS AND METHODS

Sample collection. A total of 1,188 samples of ready-to-eat precut fruit (either packaged or in open containers at buffet bars or self-service counters) were collected from retail and catering premises by sampling officers from 167 environmental health departments in England and Northern Ireland between January and March 2012.

Samples (of at least 100 g) were collected and transported in accordance with the Food Standards Agency's "Food Law Code of Practice" *(13)* and were examined by official control laboratories in England (HPA Food, Water and Environmental Microbiology Laboratories at Birmingham, London, Preston, Porton, and York) and Northern Ireland (Public Health Laboratory, Belfast).

Information on samples and food businesses was obtained by local authority sampling officers' observation and inquiry, then recorded on a standard questionnaire. This included information on the type of food business, type of fruit collected, and storage conditions of the fruit prior to sampling.

Sample examination. A 10^{-1} homogenate of each food sample was prepared in maximum recovery diluent, according to International Organization for Standardization (ISO) 6887-1:1999 *(18),* and this was used to enumerate *E. coli* on tryptone bile X-glucuronide agar by using the spread-plate method *(30),* coagulase-positive staphylococci (according to ISO 6888-1:1999) *(19),* and *Listeria* species (including *L. monocytogenes,* based on ISO 11290-2:1998 and Amendment 1:2004, but with the variation that 0.5 ml of sample homogenate was inoculated onto a single agar plate) *(17)*. Samples were also examined for the presence of *Salmonella* species (according to ISO 6579:2002) *(20)* and *Listeria* species (ISO 11290-1:1996 and Amendment 1:2004) *(16)*.

All isolates of *L. monocytogenes* were sent to the Gastrointestinal Bacteria Reference Unit, HPA, for further characterization. Microbiological results were compared with the HPA guidelines for assessing the microbiological safety of ready-to-eat foods placed on the market *(15)* (Table 1).

Typing of *L. monocytogenes* isolates. *L. monocytogenes* was identified using a duplex real-time PCR amplifying simultaneously specific fragments of the *L. monocytogenes* hemolysin gene (*hlyA*) *(27)* and of the *L. monocytogenes* phospholipase *(14)*. Molecular serogrouping of *L. monocytogenes* isolates was performed by using the multiplex gel-based PCR assay previously described *(10)*.

Molecular subtyping was performed by fluorescent amplified fragment length polymorphism (fAFLP) with a modification of a protocol described previously for *Campylobacter* by Desai et al. *(8)*. Briefly, genomic DNA was digested with two restriction enzymes, *Hin*dIII and *Hha*I. Following restriction, digests were ligated to two sets of specifically designed double-stranded adapters. These adapters served as targets for FAM-labeled *Hind*-A and nonlabeled *Hha*-A selective primers for fragment amplification by PCR. Modifications to the original protocol included the introduction of a single double digestion and ligation step rather than three individual steps *(8)*. PCR products were separated on the 96-capillary ABi 3730XL DNA Analyzer (Applied Biosystems, Carlsbad, CA) alongside a GeneScan 600 LIZ Size Standard. Chromatographs were visualized on Peak Scanner version 1.0 (Applied Biosystems) software and exported as Excel (Microsoft Corporation, Redmond, WA) files into Bionumerics version 6.1 (Applied Maths, Austin, TX), where they were visualized as virtual electrophoresis gels and analyzed. The fAFLP types were identified by using in-house Bionumerics and Peak Scanner libraries and were designated a type based on a Roman numeral followed by a number.

Statistical analysis. Descriptive and statistical analyses of the data were undertaken by using Excel 2010 (Microsoft Corporation). Relative proportions were compared by using the Fisher's exact test (GraphPad Software, San Diego, CA). A probability value of less than 5% was defined as significant.

RESULTS

Sample numbers and overall microbiological quality. The types of fruits sampled are shown in Table 2. The majority of samples (856 of 1,188, 72%) contained more than one type of fruit, while 332 (28%) were single fruit types.

TABLE 2. *Precut fruit samples in relation to borderline and unsatisfactory results*

Fruit type	No. (%) of samples ($n = 1,188$)	No. (%) with borderline results	No. (%) with unsatisfactory results
Single fruit types	332 (27.9)	3 (0.9)	
Apple	5 (1.5)		
Blueberry	3 (0.9)		
Cherry	3 (0.9)		
Grape	8 (2.4)		
Mango	22 (6.6)		
Melon	240 (72.3)	3 (1.3)	
Pineapple	30 (9.0)		
Pomegranate	8 (2.4)		
Other[a]	13 (3.9)		
Mixed fruit types containing:	856 (72.1)	2 (0.2)	4[b] (0.5)
Apple	294 (34.3)		
Blackberry	12 (1.4)		
Blueberry	64 (7.5)		
Cherry	3 (0.4)		
Grape	550 (64.3)		
Kiwi	226 (26.4)		
Mango	178 (20.8)		
Melon	630 (73.6)		
Nectarine	4 (0.5)		
Orange	170 (19.9)		
Papaya	10 (1.2)		
Peach	12 (1.4)		
Pear	16 (1.9)		
Pineapple	407 (47.5)		
Pomegranate	17 (2.0)		
Raspberry	5 (0.6)		
Strawberry	139 (16.2)		
Other[c]	18 (2.1)		
Total	1,188	5 (0.4)	4 (0.3)

[a] Other includes blackberry, kiwi, peach, raspberry, jack fruit, mandarin, coconut, and sugar cane.

[b] Three owing to elevated levels of *E. coli* (fresh sliced apple mixed with fruit cocktail, collected from a restaurant buffet display; a mixture of apple, grape, melon, orange, pear, and strawberry, collected from a salad bar at a delicatessen; and a mixture of melon, orange, pineapple, and star fruit collected from a hotel self-service bar) and one owing to an elevated level of *L. monocytogenes* (a mixture of apple, grape, watermelon, pomegranate, and strawberry collected from a national supermarket).

[c] Other includes banana, grapefruit, lemon, lime, coconut, passion fruit, pawpaw, plum, satsuma, redcurrant, blackcurrant, star fruit, and tangerine.

Of the 1,188 samples, 1,179 (99.2%) were of satisfactory microbiological quality. Four samples (0.3%) were of an unsatisfactory or unsatisfactory and potentially hazardous quality: three owing to elevated levels of *E. coli* (these were fresh sliced apple mixed with fruit cocktail, collected from a restaurant buffet display, with a count of 840 CFU/g; a mixture of apple, grape, melon, orange, pear, and strawberry, collected from a salad bar at a delicatessen, with a count of 900 CFU/g; and a mixture of melon, orange, pineapple, and star fruit collected from a hotel self-service bar, with a count of 420 CFU/g); and one owing to an elevated level of *L. monocytogenes* (a mixture of apple, grape, watermelon, pomegranate, and strawberry collected from a supermarket, with a count of 800 CFU/g). A further five samples (0.4%) were of a borderline quality, owing to the presence of *E. coli* (two samples, both with a level of 20 CFU/g), *Staphylococcus aureus* (two samples, with levels of 50 and 80 CFU/g, respectively), or *L. monocytogenes* (one sample with a level of 80 CFU/g). *L. monocytogenes* was detected in 25 g, but with levels of <10 CFU/g, in 51 samples (4.3%), and other species of *Listeria* were detected in 25 g in five samples (0.4%), of which two also contained *L. monocytogenes*.

TABLE 3. *Precut fruit samples in relation to presence of* Listeria *species*

Fruit type	Total no. of samples containing fruit type	No. (%) of samples	
		L. monocytogenes detected in 25 g	*Listeria* species (not *monocytogenes*) detected in 25 g
Apple	299	6 (2.0)	2 (0.7)
Blackberry	13	1 (7.7)	
Blueberry	68	1 (1.5)	
Grape	558	22 (3.9)	2 (0.4)
Grapefruit	2	1 (50.0)	
Kiwi	228	7 (3.1)	1 (0.4)
Mango	200	5 (2.5)	
Melon	870	51 (5.9)	3 (0.3)
Orange	170	2 (1.2)	1 (0.6)
Pineapple	437	8 (1.8)	1 (0.2)
Pomegranate	25	1 (4.0)	
Star fruit	1	1 (100.0)	
Strawberry	139	3 (2.2)	1 (0.7)

Microbiology results for packaging and food business types from which samples were collected. Prepacked bags or boxes accounted for 1,011 (85.1%) of 1,188 of samples examined, while 136 (11.4%) samples were loose (i.e., not prepacked), and the type of packaging was not specified for 41 samples (3.5%). The proportion of loose samples giving borderline or unsatisfactory results (5 of 136, 3.7%) was significantly higher than that of prepacked samples (4 of 1,011, 0.4%; Fisher's exact test; $P = 0.0019$).

The majority of samples were collected from large national supermarket chains (835 of 1,188, 70.3%), while the remainder were from small local shops (197 of 1,188, 16.6%) and catering businesses (117 of 1,188, 9.8%), or the premise type was not specified (39 of 1,188, 3.3%). The proportion of samples collected from catering businesses giving borderline or unsatisfactory results (5 of 117, 4.3%) was significantly higher than that of samples from supermarkets and local shops (4 of 1,032, 0.4%; Fisher's exact test; $P = 0.0009$). In all five cases of unsatisfactory or borderline samples from catering businesses, these samples were collected from hotels and were loose rather than prepacked.

Detection of *Listeria* species in relation to fruit and food business types. Table 3 shows the number of samples of different fruit types from which *L. monocytogenes* and

TABLE 4. *Retailers and catering businesses in relation to presence of* Listeria *species in precut fruit samples*

Food business	Total no. of samples collected from business	No. (%) of samples	
		L. monocytogenes detected in 25 g	*Listeria* species (not *monocytogenes*) detected in 25 g
National supermarkets			
A	127	10 (7.9)	
B	184	2 (1.1)	
C	44	11 (25.0)	
D	160	9 (5.6)[a]	1 (0.6)[a]
E	77	1 (1.3)	1 (1.3)
F	169	10 (5.9)	
G	74	1 (1.4)	
Total	835	44 (5.3)	2 (0.2)
Independent retailers			
H	1	1	
I	9	1	1
J	1	1	
K	1		1
Others	185		
Total	197	3 (1.5)	2 (1.0)
Caterers			
L	12	1	
M	3	1[a]	1[a]
N	2	1	
O	2	1	
P	6	1	
Q	2	1	
Others	90		
Total	117	6 (5.1)	1 (0.8)
Not specified	39		
Total	1,188	53 (4.5)	5 (0.4)

[a] The same sample contained both *L. monocytogenes* and *L. innocua*.

other *Listeria* species were isolated. *L. monocytogenes* was isolated from a larger number of melon samples than other fruit types (51 of the samples from which *L. monocytogenes* was isolated contained melon, either as a single fruit type or combined with other fruit). However, when the number of samples containing each fruit type were taken into account, there was no statistically significant difference between the frequency of isolation of *L. monocytogenes* from melon compared with other fruits (Fisher's exact test; $P > 0.1$). *Listeria* species were detected in 45 (5.4%) of 835 of samples collected from supermarkets compared with 5 (2.5%) of 197 of samples from small retailers and 6 (5.1%) of 117 from catering businesses (see Table 4). These differences were not statistically significant (Fisher's exact test; $P > 0.09$).

Of the national supermarket chains, *L. monocytogenes* was isolated most commonly from samples collected from a supermarket identified as retailer C (11 of 44 samples from this retailer, 25%; Table 4). In comparison, rates of contamination with *L. monocytogenes* in samples taken from six other large, national supermarket chains represented in the study (retailers A, B, D, E, F, and G; Table 4) ranged from 1.1 to 7.9%. Thus, samples from retailer C were contaminated more frequently than from other retailers (Fisher's exact test; $P = 0.006$).

TABLE 5. *Typing results for* L. monocytogenes *strains isolated from precut fruit samples and the food businesses from which they were purchased*

Serotype	fAFLP type[a]	No. of samples	Food business (no. of samples)
1/2a	VI.23	1	F (1)
	VIIa.39	5	F (4); O (1)
	VIIa.39a	2	D (1); F (1)
	VIIa.45	2	D (1); L (1)
	VIIa.55	3	B (1); F (1); N (1)
	VIIa.90	3	A (3)
	VIIa.101	6	C (6)
	VIIa.103	8	A (4); D (3); F (1)
	VIIa.105	1	F (1)
	VIIa.109	2	I (1); J (1)
	IX.14	5	C (5)
	IX.18	1	H (1)
	XIV.7	1	A (1)
1/2b	II.22	6	A (1); D (4); P (1)
	II.27	1	Q (1)
	IVb.63	1	M (1)
1/2c	VIIc.43	1	E (1)
4	I.8b	1	B (1)
Not determined		3	

[a] fAFLP, fluorescent amplified fragment length polymorphism.

Characterization of *L. monocytogenes* isolates. While some fAFLP types were seen in only a single fruit sample, others were detected in more than one sample (Table 5). Moreover, some types appeared to be specifically associated with a single food business. For example, *L. monocytogenes* serotype 1/2a fAFLP types VIIa.101 and IX.14 were isolated from multiple samples collected from retailer C (six and five samples, respectively) but not from any other sources. These two types were isolated from samples tested at three separate laboratories in distinct geographical areas. In contrast, serotype 1/2a fAFLP types VIIa.103 and VIIa.55 and serotype 1/2b fAFLP type II.22 were each isolated from samples collected from three different food businesses.

Storage temperature of precut fruit samples. The majority of samples (746 of 1,188, 62.8%) were stored at a temperature of less than 8°C, according to sampling officers' response to the standard survey questionnaire. A storage temperature of equal to or greater than 8°C was reported for 102 samples (8.6%), while no temperature was recorded for the remaining 340 samples (28.6%). The proportion of samples of borderline or unsatisfactory quality and those containing low levels of *Listeria* species that were stored at a temperature of equal to or greater than 8°C (5 of 63, 7.9%) was not significantly different to the proportion of

satisfactory samples stored at these temperatures (96 of 1,125, 8.5%; Fisher's exact test; $P = 1.0$).

DISCUSSION

In this study, more than 99% of the precut fruit products sampled from retail or catering premises in England and Northern Ireland were of satisfactory microbiological quality, according to European Commission Regulation (EC) No 2073/2005 (as amended) *(11)* and the HPA guidelines for assessing the microbiological safety of ready-to-eat foods placed on the market *(15)*. These results reflect the generally high level of safety of these products. The results presented here are similar to those obtained in 2002 *(23)*: *Salmonella* was not detected in any of the 997 precut fruit samples examined. There was only one sample with *E. coli* at a level of greater than 20 CFU/g and two samples with *L. monocytogenes* at levels above 20 CFU/g. There were, however, 78 samples (8%) from which *L. monocytogenes* was detected, but at <10 CFU/g, compared with 4% in the current study. A study of fresh, minimally processed fruit and vegetables from retail establishments in Spain included 21 samples of ready-to-eat, fresh-cut fruit, of which *Salmonella, L. monocytogenes,* and *E. coli* were not detected in any sample *(1)*. A study of fresh produce in the United States included 90 samples of cantaloupe melon, of which *L. monocytogenes* and *E. coli* O157:H7 were not detected in any sample, but *Salmonella* Montevideo was detected in three melons (3.3%) *(21)*. In contrast, *Salmonella* was detected in 8.7% of 150 samples of precut fruit (pineapple, pawpaw, and watermelon) on retail sale in Nigeria *(5),* and in 9 (37.5%) of 24 fruit samples tested as part of a study in India *(32)*.

Intact fruits have dry waxy surfaces, a high water content (85 to 92%, depending on species), a high sugar content (1.7 to 15 g/100 g of fresh weight), and an internal pH range generally below 4.5 (e.g., orange 3.6 to 4.3; lime 1.8 to 2.0; grape 3.4 to 4.5; apple 2.9 to 3.3) *(4)*. Once cut, the low pH conditions (together with naturally occurring antimicrobial compounds) are not favorable for the growth of pathogens, such as *Salmonella* and *L. monocytogenes,* but may permit survival. The exception to this are melons and watermelons, which have a near neutral pH (6.2 to 6.7 for cantaloupe and honeydew melons and 5.8 to 6.0 for watermelons) and readily allow the growth of a range of bacterial foodborne pathogens, including *L. monocytogenes* and *Salmonella (24)*. Along with storage temperature, pH is considered to be the primary factor affecting bacterial growth on fresh fruit *(7)*.

In December 2011, an outbreak was recognized due to *Salmonella enterica* serovar Newport *(3)*. This was preceded by the isolation of the outbreak strain from cut watermelon collected at retail sale in November 2011 as part of a local survey of cut fruit in North West England. Eventually, 63 confirmed cases were recognized in England, Wales, Northern Ireland, Scotland, Ireland, and Germany with a strong epidemiological association with consumption of watermelon produced in Brazil. Outbreaks of infection due to melon consumption in the United States have recently been reviewed *(33)*. Among the 34 outbreaks detected (3,602 cases), *Salmonella* was the most common cause (56% of the outbreaks), followed by norovirus (15%), and the remainder owing to *Campylobacter jejuni,* Shiga toxin–producing *E. coli, L. monocytogenes,* and *Shigella sonnei*.

Risks posed by *Salmonella* in melons have recently been reviewed by the European Food Safety Authority *(12),* and many of these risk factors will be generic for a range of foodborne pathogens, including *L. monocytogenes*. The European Food Safety Authority report concluded that there are risks throughout the food chain for melons. Melons grow on or near to the surface of the soil and at primary production, environmental risk factors include proximity to animal-rearing operations, climatic conditions (e.g., heavy rainfall) that increase the transfer of pathogens from their reservoirs to the melon and watermelon plants, contact with animal reservoirs (domestic or wild life), use of untreated or insufficiently treated organic manures and other amendments, use of contaminated water either for irrigation or for application of agricultural chemicals, such as pesticides, and contamination or cross-contamination by harvesters, food handlers, and equipment at harvest or postharvest. Similar risk factors are likely to apply to other fruit crops, especially those that grow close to the ground.

Fruit damage during harvest, as well as cracking before or during harvest, are additional risk factors for pathogen contamination, particularly for melon and watermelon, which have a high internal pH and represent a good substrate for the growth of *Salmonella*. *E. coli* O157:H7 and *L. monocytogenes* have also been shown to grow on bruised apple tissue *(6, 9)*. Sharp-edged or poorly designed storage containers and liners are risk factors that may contribute to fruit damage. Although cooling fruits, such as apples, peaches, melons, and watermelons, with water during postharvest handling may reduce microbial loads on their outside surface, this process may also be a source of microbial cross-contamination *(24)*. During processing, cross-contamination via equipment, water, or food handlers is the main risk factor for contamination of melons and watermelons with *Salmonella (12)*.

Unrefrigerated storage of cut fruit is likely to be an important risk factor at retail and in catering establishments, as well as in domestic environments. Studies with melon, watermelon, and papaya pulp have demonstrated that both *Salmonella* Enteritidis and *L. monocytogenes* were able to grow at 10, 20, and 30°C, although growth was diminished at 10°C *(28, 29)*. Similarly, *Salmonella* species were able to grow at 12°C on both fresh-cut mangos and papayas, while *E. coli* O157:H7 grew only on papaya at this temperature; at 4°C, both organisms survived but did not demonstrate growth *(31)*. In this study, no significant difference was demonstrated in the proportion of samples stored above or below 8°C that gave satisfactory or unsatisfactory results, although the number of borderline and unsatisfactory samples was relatively small for statistical analysis. Note, however, that one of the five samples giving an unsatisfactory result (*E. coli* level of 840 CFU/g) was collected from a buffet display at ambient temperature (storage temperatures were not recorded for a further two of the unsatisfactory samples, and the remaining two were stored at temperatures of <8°C).

The contamination of 5% of the cut fruit examined in this study by *Listeria* species (albeit almost always at low contamination rates of <10 CFU/g) highlights the need for good shelf-life and temperature control to minimize the growth of this bacterium. Molecular characterization (fAFLP typing) of the *L. monocytogenes* isolates indicated that certain fAFLP types were associated with one supermarket chain, in particular. Because these isolates were detected in samples collected from different branches of the supermarket chain in three separate geographical regions of England, it seems likely that contamination with these strains occurred at the supplier premises (or earlier in the supply chain), rather than at the retail outlets themselves. Other fAFLP types were detected in samples from more than one food business. These types may be more ubiquitous in the environment, or alternatively, this may indicate a common supply chain for all of the affected businesses.

A comparison of the types of *L. monocytogenes* described here and recovered in this study of precut fruit was performed against cultures from all 75 human cases of listeriosis in the United Kingdom that had onsets of infection over the first 6 months of 2012 that were submitted to the Public Health England National Reference Laboratory. The onsets of infection coincided with the period of this food survey and allowed for a 3-month incubation period among human cases after the survey was completed. Among the 18 fAFLP types detected in isolates from cut fruit, 17 of these did not occur in any of the clinical cultures from humans. The only type that did occur in cut fruit and also occurred in human cases (serovar 1/2a fAFLP type IX.14) was recovered from two cases between January and June 2012, as well as other food types, and is relatively common among isolates from human cases during other periods. The analysis of these cultures by whole genome sequencing is justified in the future, as demonstrated in the investigation of isolates from listeriosis outbreaks and associated with other food types in the United Kingdom *(2)*.

While the majority of samples examined in this study were of satisfactory microbiological quality, results for a small proportion of samples indicated failures in hygiene procedures, particularly in catering premises. In general, prevention of microbial contamination of fresh fruit is preferable to control of growth once contamination has occurred, and this requires that good agricultural and management practices are applied at all stages of growth, harvest, packing, storage, distribution, and service of this food commodity.

ACKNOWLEDGMENTS

The authors thank the staff in environmental health departments throughout England and Northern Ireland and staff in the Public Health England Food, Water and Environmental Microbiology Laboratories, as well as the Public Health Laboratory, Belfast, for their contributions to this study. Thanks are also extended to the Gastrointestinal Bacteria Reference Unit, Public Health England, for typing of *L. monocytogenes* isolates.

REFERENCES

1. Abadias, M., J. Usall, M. Anguera, C. Solsona, and I. Vinas. 2008. Microbiological quality of fresh, minimally-processed fruit and vegetables, and sprouts from retail establishments. *Int. J. Food Microbiol.* 123:121–129.
2. Amar, C. F. L., T. Dallman, A. Underwood, and K. Grant. 2013. Whole genome sequencing for real time investigation of listeriosis outbreaks. Abstr. 18th Int. Symp. Probl. *Listeriosis*. Indian Council of Agricultural Research, Old Goa, India.
3. Byrne, L., I. Fisher, T. Peters, A. Mather, N. Thomson, B. Rosner, H. Bernard, P. McKeown, M. Cormican, J. Cowden, V. Aiyedun, C. Lane, and International Outbreak Control Team. 2014. A multi-country outbreak of *Salmonella* Newport gastroenteritis in Europe associated with watermelon from Brazil, confirmed by whole genome sequencing: October 2011 to January 2012. *Euro Surveill.* 19(31):pii=20866.
4. Carlin, F. 2007. Fruits and vegetables, p. 157–170. *In* M. P. Doyle and L. R. Beuchat (ed.), Food microbiology: fundamentals and frontiers. ASM Press, Washington, DC.
5. Chukwu, C. O. C., I. D. Chukwu, I. A. Onyimba, E. G. Umoh, F. Olarubofin, and A. O. Olabode. 2010. Microbiological quality of pre-cut fruits on sale in retail outlets in Nigeria. *Afr. J. Agric. Res.* 5:2272–2275.
6. Conway, W. S., B. Leverentz, and R. A. Saftner. 2000. Survival and growth of *Listeria monocytogenes* on fresh-cut apple slices and its interaction with *Glomerella cingulata* and *Penicillium expansum*. *Plant Dis.* 84:177–181.
7. de Roever, C. 1998. Microbiological safety evaluations and recommendations on fresh produce. *Food Control* 9:321–347.
8. Desai, M., J. M. J. Logan, J. A. Frost, and J. Stanley. 2001. Genome sequence-based fluorescent amplified fragment length polymorphism of *Campylobacter jejuni,* its relationship to serotyping, and its implications for epidemiological analysis. *J. Clin. Microbiol.* 39:3823–3829.
9. Dingman, D. W. 2000. Growth of *Escherichia coli* O157:H7 in bruised apple (*Malus domestica*) tissue as influenced by cultivar, date of harvest, and source. *Appl. Environ. Microbiol.* 66:1077–1083.
10. Doumith, M., C. Buchrieser, P. Glaser, C. Jacquet, and P. Martin. 2004. Differentiation of the major *Listeria monocytogenes* serovars by multiplex PCR. *J. Clin. Microbiol.* 42:3819–3822.
11. European Commission. 2005. Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. *Off. J. Eur. Union* L 338:1–26.
12. European Food Safety Authority. 2014. Scientific Opinion on the risk posed by pathogens in food of non-animal origin Part 2d *Salmonella* in melons. *EFSA J.* 12:3831. Available at: http://www.efsa.europa.eu/en/efsajournal/doc/3831.pdf. Accessed 17 September 2015.
13. Food Standards Agency (FSA). 2011. Food Law Code of Practice. FSA, London. Available at: http://www.food.gov.uk/enforcement/enforcework/food-law/. Accessed 17 September 2015
14. Hage, E., O. Mpamugo, C. Ohai, S. Sapkota, C. Swift, D. Wooldridge, and C. F. L. Amar. 2014. Identification of six *Listeria* species by real-time PCR assay. *Lett. Appl. Microbiol.* 58:535–540.
15. Health Protection Agency (HPA). 2009. Guidelines for assessing the microbiological safety of ready-to-eat foods placed on the market. HPA, London. Available at: https://www.gov.uk/government/publications/ready-to-eat-foods-microbiological-safety-assessment-guidelines. Accessed 17 September 2015.
16. International Organization for Standardization (ISO). 1996. ISO 11290-1:1996 including Amendment 1:2004. Microbiological examination of food and animal feedstuffs—horizontal method for detection and enumeration of *Listeria monocytogenes*—part 1: detection method. ISO, Geneva.
17. International Organization for Standardization (ISO). 1998. ISO 11290-2:1998 including Amendment 1:2004. Microbiological examination of food and animal feedstuffs—horizontal method for detection and enumeration of *Listeria monocytogenes*—part 2: enumeration method. ISO, Geneva.
18. International Organization for Standardization (ISO). 1999. ISO 6887–1:1999. Microbiology of food and animal feeding stuffs—Preparation of test samples, initial suspension and decimal dilutions for microbiological examination. Part 1: general rules for the preparation of the initial suspension and decimal dilutions. ISO, Geneva.

19. International Organization for Standardization (ISO). 1999. ISO 6888-1:1999, incorporating amendment no. A1 2003. Microbiology of food and animal feeding stuffs—horizontal method for the enumeration of coagulase-positive staphylococci (*Staphylococcus aureus* and other species)—part 1: technique using Baird-Parker agar medium. ISO, Geneva.
20. International Organization for Standardization (ISO). 2002. ISO 6579:2002. Microbiology of food and animal feeding stuffs—horizontal method for the detection of *Salmonella* spp. ISO, Geneva.
21. Johnston, L. M., L.-A. Jaykus, D. Moll, M. C. Martinez, J. Anciso, B. Mora, and C. L. Moe. 2005. A field study of the microbiological quality of fresh produce. *J. Food Prot.* 68:1840–1847.
22. Korsager, B., S. Hede, H. Bøggild, B. Böttiger, and K. Mølbak. 2005. Two outbreaks of norovirus infections associated with the consumption of imported frozen raspberries, Denmark, May–June 2005. *Euro Surveill.* 10(25):pii=2729.
23. Little, C. L., and R. T. Mitchell. 2004. Microbiological quality of precut fruit, sprouted seeds, and unpasteurised fruit and vegetable juices from retail and production premises in the UK, and the application of HAACP. *Commun. Dis. Public Health* 7:184–190.
24. Lund, B. M., and A. L. Snowdon. 2000. Fresh and processed fruits, p. 738–758. *In* B. M. Lund, T. C. Baird-Parker, and G. W. Gould. (ed.), The microbiological safety and quality of food, vol. 1. Aspen Publishers, Gaithersburg, MD.
25. Mäde, D., K. Trübner, E. Neubert, M. Höhne, and R. Johne. 2013. Detection and typing of norovirus from frozen strawberries involved in a large-scale gastroenteritis outbreak in Germany. *Food Environ. Virol.* 5:162–168.
26. McCollum, J. T., A. B. Cronquist, B. J. Silk, K. A. Jackson, K. A. O'Connor, S. Cosgrove, J. P. Gossack, S. S. Parachini, N. S. Jain, P. Ettestad, M. Ibraheem, V. Cantu, M. Joshi, T. DuVernoy, N. W. Fogg, Jr., J. R. Gorny, K. M. Mogen, C. Spires, P. Teitell, L. A. Joseph, C. L. Tarr, M. Imanishi, K. P. Neil, R. V. Tauxe, and B. E. Mahon. 2013. Multistate outbreak of listeriosis associated with cantaloupe. *N. Engl. J. Med.* 369:944–953.
27. Nogva, H. K., K. Rudi, K. Naterstad, A. Holck, and D. Lillehaug. 2000. Application of 5′-nuclease PCR for quantitative detection of *Listeria monocytogenes* in pure cultures, water, skim milk, and unpasteurized whole milk. *Appl. Environ. Microbiol.* 66:4266–4271.
28. Penteado, A. L., and M. F. F. Leitão. 2004. Growth of *Listeria monocytogenes* in melon, watermelon and papaya pulps. *Int. J. Food Microbiol.* 92:89–94.
29. Penteado, A. L., and M. F. F. Leitão. 2004. Growth of *Salmonella* Enteritidis in melon, watermelon and papaya pulp stored at different times and temperatures. *Food Control* 15:369–373.
30. Roberts, D., and M. Greenwood. 2003. Practical food microbiology, 3rd ed. Blackwell Publishing Ltd., Oxford.
31. Strawn, L. K., and M. D. Danyluk. 2010. Fate of *Escherichia coli* O157:H7 and *Salmonella* spp. on fresh and frozen cut mangoes and papayas. *Int. J. Food Microbiol.* 138:78–84.
32. Viswanathan, P., and R. Kaur. 2001. Prevalence and growth of pathogens on salad vegetables, fruits and sprouts. *Int. J. Hyg. Environ. Health* 203:205–213.
33. Walsh, K. A., S. D. Bennett, M. Mahovic, and L. H. Gould. 2014. Outbreaks associated with cantaloupe, watermelon, and honeydew in the United States, 1973–2011. *Foodborne Pathog. Dis.* 11:945–952.