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Assessment of the Microbiological Quality of Meat Pies from Retail Sale in England 2013

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ABSTRACT

Outbreaks of foodborne illness caused by *Bacillus cereus* and *Listeria monocytogenes* in England associated with meat pie consumption were detected in 2012. To obtain baseline data for pies unrelated to outbreaks, 862 samples of ready-to-eat meat pies were collected at retail or from catering facilities in England in 2013 and examined to enumerate food-poisoning bacteria and indicator organisms using Organization for Standardization (ISO) methods for *Listeria* spp. including *L. monocytogenes* (ISO 11290), *Clostridium perfringens* (ISO 21528), coagulase-positive staphylococci including *Staphylococcus aureus* (ISO 6888), *Bacillus* spp. including *B. cereus* (ISO 1737), *Escherichia coli* (ISO 16649), *Enterobacteriaceae* (ISO 21528), and aerobic colony counts (ACCs; ISO 4833). Microbiological quality was satisfactory in 94% of samples, borderline in 5%, and unsatisfactory in 1%. The proportion of pies from markets that were borderline or unsatisfactory significantly increased, and the proportion of borderline or unsatisfactory pies from supermarkets significantly decreased. Among the refrigerated (0 to 15°C) pies, microbiological quality significantly decreased in pies stored at >8°C and further significantly decreased at in pies stored at ambient temperature (>15 to 25°C). Samples collected at 25 to 40°C had the highest proportion of borderline or unsatisfactory results, but results improved in pies stored at >40°C. The most common cause for borderline or unsatisfactory results was elevated ACCs (5% of all samples). Within the individual microbiological parameters, borderline or unsatisfactory results resulted from elevated *Enterobacteriaceae* or *Bacillus* levels (10 samples for each), *C. perfringens* levels (2 samples), and *S. aureus* or *E. coli* levels (1 sample each). *L. monocytogenes* was recovered from one pie at <10 CFU/g. A literature review revealed a range of microbiological hazards responsible for food poisoning and meat pie consumption, and surveillance data from 1992 to 2012 from England indicated that *C. perfringens* was the most commonly reported cause of outbreaks of foodborne illness.

Key words: Food poisoning; Food poisoning bacteria; Indicator organisms; Meat pies; Microbiological quality

Meat pies are a type of ready-to-eat food comprising a pastry case enclosing various cooked or raw meats with salts, spices, vegetables, stocks, and sometimes other animal products such as boiled eggs. The ingredients are usually baked after assembly; however, other cooking methods such as steaming or frying also are used. After baking, additional spices or glazes can be added to the surface, and jellified fillings can be added. Ready-to-eat pies are supplied by a wide range of retailers and sold refrigerated, sometimes for reheating by the consumer, and in heated cabinets for immediate consumption. Meat pies also are sometimes stored at ambient temperatures before sale. The whole of the pastry case and the interior meat filling are intended for consumption.

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In 2012, two unrelated food poisoning incidents were associated with consumption of meat pies. In June, a local authority environmental health department received a report of three people vomiting approximately 2 h after consuming two different meat and potato pies from the same batch that had been purchased from a market stall where they had been stored at ambient temperature. *Bacillus cereus* at 1.5×10^6 CFU/g was detected in remnants of the partially eaten pie. Six pies subsequently collected from the manufacturer during June were all microbiologically satisfactory. Approximately 1 month later, two cases of illness were reported from two members of the same family who had consumed pies from the same manufacturer. Four pies were collected from a small retailer (stored at 10°C at the end of a 9-day shelf life), and *B. cereus* was detected in all pies at 10^8 CFU/g. The manufacturing process was reviewed, and additional controls were implemented *(26)*.

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

Target	Level (CFU/g)			
	Satisfactory	Borderline	Unsatisfactory	Unsatisfactory, potentially injurious to health
Bacillus spp. (including *B. cereus*)	$<10^3$	$\geq10^3$–$<10^5$	NA[b]	$\geq10^5$
Clostridium perfringens	<10	≥10–10^4	NA	$\geq10^4$
Listeria monocytogenes	<10	≥10–<100	NA	≥100
Listeria sp. (other than *L. monocytogenes*)	<10	≥10–<100	≥100	NA
Staphylococcus aureus and other coagulase-positive staphylococci	<20	≥20–$<10^4$	NA	$\geq10^4$
Escherichia coli	<20	≥20–$<10^2$	$\geq10^2$	NA
Enterobacteriaceae	$<10^2$	$\geq10^2$–10^4	$\geq10^4$	NA
Aerobic colony counts				
Pies collected from hot cabinets (category 2[a])	$<10^3$	$\geq10^3$–$<10^5$	$\geq10^5$	NA
Pies collected from frozen, refrigerated, or ambient temp environments (category 3[a])	$<10^4$	$\geq10^4$–$<10^7$	$\geq10^7$	NA

[a] From the Health Protection Agency *(15)*.
[b] NA, not applicable.

The second incident involved an outbreak of listeriosis. In July 2012, an individual developed meningitis, and *Listeria monocytogenes* was subsequently recovered from the patient's cerebrospinal fluid *(1)*. The patient identified a pork pie purchased from a market and consumed 2 days later as a potential food vehicle. Remnants from this pie were not available for testing; however, a friend of the patient purchased a pork pie from the same market and sent this unrefrigerated pie to the patient's home. Microbiological tests revealed *L. monocytogenes* at 10^4CFU/g, *Listeria seeligeri*, and *Enterobacteriaceae* at 10^6CFU/g in this pie. Molecular typing (including whole genome sequencing) of the *L. monocytogenes* cultures from both the patient and the pork pie revealed the same strain. Further analysis identified a total of 14 listeriosis cases in this outbreak between 2010 and 2012, all associated with pies from the same manufacturer. The same strain of *L. monocytogenes* was recovered from six of seven pies on retail sale in 2012 (all at <20 CFU/g) from this manufacturer. The outbreak strain was also recovered directly from the manufacturing site, i.e., from one pie after cooking and from environmental sites including a table where a gelatin glaze was added to the pies after cooking. Following improvements regarding the disinfection of the jelly tank and pump and the provision of separate dedicated foot baths for cleaning boots in both the high- and low-risk areas of the production environment, no further *L. monocytogenes* contamination was detected in pies. The market trader who sold the pork pie to the index case had no hand washing facilities in the storage depot and no refrigeration facilities in the van used to transport the product to the market stall. The market trader voluntarily agreed to stop selling meat products. The *L. monocytogenes* outbreak strain has not been recovered from any subsequent cases of human listeriosis in the United Kingdom and not been found among any isolates from food (approximately 7,000 cultures tested between 2010 and 2015) *(1)*.

A review of literature indicated limited information on the microbiological quality of ready-to-eat meat pies on retail sale in England. The purpose of this study was to provide baseline data for pies unrelated to outbreaks and to compare these data with information obtained during investigations of food poisoning incidents.

MATERIALS AND METHODS

Sample collection. Samples of ready-to-eat pies with meat as a major ingredient were collected at retail and from catering outlets during January to March 2013 by sampling officers from environmental health departments in England. At least 100 g was collected and transported in accordance with the Food Standards Agency Food Law Code of Practice *(12)*. All food samples were examined by one of the five Health Protection Agency (HPA) Official Control Laboratories in England (Food, Water, and Environmental Microbiology Laboratories located at Birmingham, London, Preston, Porton, and York). Information on retailer, vendor, caterer, sample type, and storage at the point of sale was collected by the sampling officer using a standardized questionnaire.

Microbiological examination. Samples were examined using internationally recognized standard methods for the presence and level of *Listeria* spp. (including *Listeria monocytogenes*) *(16, 17), Clostridium perfringens (20),* coagulase-positive staphylococci (including *Staphylococcus aureus*) *(18), Bacillus* spp. (including *B. cereus*) *(21), Escherichia coli* (based on BS ISO 16649-2:2001 but using a surface spread rather than pour plate technique) *(3), Enterobacteriaceae (19),* and aerobic bacteria (aerobic colony counts; ACCs) *(4)*. Isolates of *Bacillus* spp., *C. perfringens, L. monocytogenes,* and *S. aureus* were identified in each of the individual laboratories as outlined by the standard methods. Cultures of *C. perfringens* and *L. monocytogenes* were sent to the HPA Gastrointestinal Bacteria Reference Unit for confirmation and further characterization.

Microbiological results were interpreted according to the HPA guidelines for assessing the microbiological safety of ready-to-eat foods placed on the market *(15)* (Table 1) and, where relevant, using European Commission Regulation 2073/2005 on microbiological criteria for foodstuffs *(10)*.

TABLE 2. *Microbiological quality of 862 ready-to-eat meat pies collected at the point of sale*

Sample type	No. (%) of samples			
	Total	Satisfactory	Borderline	Unsatisfactory
All samples	862	808 (94)	45 (5)	9 (1)
Type of storage				
Frozen	7	7 (100)	0	0
Refrigerated	563	535 (95)	24 (4)	4 (1)
Ambient temp	100	93 (93)	6 (6)	1 (1)
Hot	115	100 (87)	11 (10)	4 (3)
Unknown	77	73 (95)	4 (5)	0
Type of retailer				
Bakery	64	60 (94)	3 (5)	1 (2)
Butcher shop	100	91 (91)	7 (7)	2 (2)
Market	22	17 (77)	5 (23)	0
General retail	402	377 (94)	21 (5)	4 (1)
Supermarket	183	181 (99)	1 (0.5)	1 (0.5)
Catering[a]	88	79 (90)	8 (9)	1 (1)
Other, unknown	3	3 (100)	0	0
Major meat constituent				
Beef	448	424 (95)	19 (4)	5 (1)
Poultry	130	124 (95)	3 (2.5)	3 (2.5)
Lamb	18	15 (83)	3 (17)	0
Pork	190	176 (93)	14 (7)	0
Meat (not specified)	45	39 (87)	5 (11)	1 (2)
Other	12	12 (100)	0	0
Unknown	19	18 (95)	1 (5)	0
Microbiological parameters				
Bacillus spp. (including *B. cereus*)	862	852 (99)	9 (1)	1
C. perfringens	862	860 (100)	1	1
L. monocytogenes	862	862 (100)[b]	0	0
Listeria sp. (other than *L. monocytogenes*)	862	862 (100)[c]	0	0
S. aureus	862	861 (100)	1	0
E. coli	862	861 (100)	1	0
Enterobacteriaceae	862	852 (99)	7 (1)	3
Aerobic colony counts	862	818 (95)	36 (4)	8 (1)

[a] Cafés, restaurants, fish and chip shops, public houses, take-out establishments, or other catering facilities.
[b] *L. monocytogenes* detected by enrichment in only one sample.
[c] *L. innocua* (three samples) and *L. welshimeri* (one sample) detected by enrichment only.

Confirmation of identity and typing of *C. perfringens* and *L. monocytogenes*. *C. perfringens* isolates were identified and characterized by the detection of the *C. perfringens* alpha toxin and enterotoxin genes with a real-time duplex PCR assay *(14)*.

L. monocytogenes isolates were identified using a duplex real-time PCR assay to simultaneously amplify specific fragments of the *L. monocytogenes* hemolysin gene *(24)* and phospholipase gene *(32)*. *L. monocytogenes* isolates were classified into molecular serogroups using the multiplex gel-based PCR assay previously described *(8)* and into molecular subtypes based on fluorescent amplified fragment length polymorphism (fAFLP) profiles *(27)*.

Statistical analysis. Contingency tables were used to provide descriptive analysis, and statistical analysis of the data to establish associations between variables was conducted using chi-square tests of association. When the outcome was significant, an ordered logistic regression was used (Stata version 13, Timberlake Consultants Ltd., London). Results were considered significant when the probability value was less than 5%.

RESULTS

A total of 862 samples of ready-to-eat meat pies were collected from January to March 2013. The major meat constituent, type of retailer, and storage conditions are shown in Table 2. Information on temperature of storage at the point of sale was available for 91% of the samples. At the time of collection, 1% of the pies were frozen, 72% were refrigerated (0 to 15°C), 13% were at ambient temperatures (>15 to 25°C), and 15% were in heated displays (>25 to 94°C). Sixty-eight percent of the samples were collected from general shops or supermarkets; the remainder were obtained from other retailers, i.e., bakeries, butcher shops, markets, or catering facilities (e.g., cafés, restaurants, public houses, and fish and chip shops).

Based on the HPA guidelines for assessing the microbiological safety of ready-to-eat foods placed on the market *(15)*, 94% of the samples were of satisfactory microbiological quality, 5% were borderline, and 1% were

TABLE 3. *Method of storage at display used by different types of retailers for 779 ready-to-eat meat pies*

Type of retailer	No. (%) of samples				
	Total	Frozen	Refrigerated	Ambient temp	Hot
Bakery	62	0	23 (37)	28 (45)	11 (18)
Butcher shop	90	1 (1)	82 (91)	5 (6)	2 (2)
Market	17	0	9 (53)	7 (41)	1 (6)
General shop	350	1	255 (73)	40 (11)	54 (15)
Supermarket	177	0	159 (90)	11 (6)	7 (4)
Catering[a]	83	5 (6)	35 (42)	9 (11)	34 (41)

[a] Cafés, restaurants, fish and chip shops, public houses, take-out establishments, or other catering facilities.

unsatisfactory (Table 2). The only criterion within Regulation (EC) No. 2073 *(10)* applicable to this product is that for *L. monocytogenes,* and all samples complied with the regulation limit of 100 CFU/g for products placed on the market.

A significant association was found between the type of storage and the microbiological quality of the pies; as storage temperature increased, the proportion of pies considered borderline or unsatisfactory significantly increased (Spearman's rank correlation, $P = 0.002$; log odds ratio likelihood ratio test, $P = 0.002$). A strong association also was found between the type of retailer and the microbiological quality of the pies (Table 2). For pies obtained from markets, a significantly higher proportion had borderline results. For pies obtained from supermarkets, significantly fewer had borderline results (generalized ordered logistic model likelihood ratio = 25.50, df = 10, $P = 0.0045$). The most common major meat constituent was beef (52%), followed by pork (22%), poultry (15%), and other meat types (11%) (Table 2). A weak association was found between microbiological quality and the major meat constituent of the pies; lamb and unspecified meat pies tended to be of lower microbiological quality, although this finding was not significant using a standard logistic regression model.

Results for the individual microbiological parameters are shown in Table 2. The most common cause for borderline or unsatisfactory results was elevated ACCs, which were detected in 44 (5%) of the samples. Within the individual microbiological parameters, the most common causes for borderline or unsatisfactory results were elevated *Enterobacteriaceae* or *Bacillus* levels (10 samples for each, 1% of the total), followed by *C. perfringens* (2 samples) and *S. aureus* or *E. coli* (1 sample each). Further characterization of the *C. perfringens* isolate (2.1×10^6 CFU/g) from a single sample of a steak and mushroom pie with an unsatisfactory classification revealed that this isolate did not contain the enterotoxin gene and therefore was not capable of causing diarrheal disease. The *C. perfringens* isolate from the single borderline sample was not further characterized.

No sample yielded *Listeria* sp. at >10 CFU/g. *L. monocytogenes* was recovered from one pie (a minced beef pie collected from a refrigerated display of a delicatessen) by enrichment culture only (<10 CFU/g); this isolate was characterized as serotype 1/2c, fAFLP type VIIc.86. Other *Listeria* species were recovered from four samples, all stored in refrigerated displays and all by enrichment culture only (<10 CFU/g). *Listeria innocua* was recovered from three samples (steak and kidney pie, steak pie, and pork pie) obtained from a café, butcher, and supermarket. *Listeria welshimeri* was isolated from a chicken pie, but no information on the type of retailer from which this sample was collected was available.

Information on the storage method used for display at the point of sale and by different types of retailers was available for 779 ready-to-eat meat pies (Table 3). A significant association was found between the retailer type and the storage type ($\chi^2 = 168.64$, df = 10, $P < 0.0001$); bakeries and markets had a significantly higher proportion of pies stored at ambient temperature and a consequently lower proportion of frozen or refrigerated pies. Catering outlets had a significantly higher proportion of hot pies followed (less commonly) by bakeries and general shops. Supermarkets had significantly fewer hot pies than did other types of retailers and (like butcher shops) were more likely to sell pies at refrigerated temperatures. Fewer frozen and refrigerated pies were found in bakeries, where the most common storage practice was ambient display.

Among the 778 refrigerated, ambient temperature, and hot displayed samples, temperature at the point of sale was collected for 524 (67%) of the samples (Table 4). Among the refrigerated samples, a significant decrease in the microbiological quality was found for products stored above 8°C, and quality was further significantly decreased in those pies sold at ambient temperatures. Although relatively small numbers of samples were collected between 25 and 40°C, a higher proportion of borderline or unsatisfactory results were obtained among these samples, although the difference was not significant with an ordered logistic regression model. Hot pies stored at above 40°C were of higher quality than those stored at ambient temperatures or at >25 to 40°C. Borderline or unsatisfactory levels of *Bacillus* spp. were the most common contributory factors to poor quality for the hot pies.

Data on the remaining shelf life at the time of sampling was available for 153 (18%) of the samples collected, ranging from 0 to 13 days. Among the 153 samples, 101 (66%) had a remaining shelf life of less than 5 days, and of the 25 samples sold on the final day of the shelf life, 20 samples were recorded as sold on the day of production.

Details of the pies, types of retailers, and microbiological parameters for samples classified as unsatisfactory or borderline are shown in Tables 5, 6, and 7 for the refrigerated, ambient temperature, and hot stored products,

TABLE 4. *Temperature at the point of sale for refrigerated, ambient temperature, and hot stored ready-to-eat meat pies samples collected at the point of sale*

Temp regime	No. (%) of samples			
	Total	Satisfactory	Borderline	Unsatisfactory
All samples with a specific temperature	524	495 (95)	24 (4)	5 (1)
Refrigerated ($n = 442$)				
0–8°C	400	383 (96)	15 (4)	2
>8 to 15°C	42	39 (93)	3 (7)	0
Ambient temp ($n = 20$)				
>15 to 25°C	20	18 (90)	2 (10)	0
Hot ($n = 62$)				
>25 to 40°C	8	6 (75)	1 (12)	1 (12)
>40 to 55°C	8	8 (100)	0	0
>55 to 70°C	28	25 (89)	2 (7)	1 (4)
>70 to 94°C	18	16 (89)	1 (6)	1 (6)

respectively. Among the 27 products sold in refrigerated displays, the unsatisfactory or borderline samples were categorized as such predominantly because of high ACCs (17 samples) or high *Enterobacteriaceae* counts. *L. welshimeri was* detected in one sample with a high ACC and *Enterobacteriaceae* count (Table 5). Within these poor quality refrigerated products, four samples had high counts of bacterial spore formers: two with *C. perfringens* and two with *Bacillus* species (Table 5). Among the eight ambient temperature stored products of borderline or unsatisfactory quality (Table 6), six had high *Enterobacteriaceae* counts (one had a high *E. coli* count) and six also had high ACCs. Elevated levels of *B. cereus* also were detected in two samples from these products stored at ambient temperature (Table 6). In contrast to the refrigerated or ambient temperature products, none of the 15 borderline or unsatisfactory pies sold from hot displays (Table 7) had elevated *Enterobacteriaceae* or *E. coli* counts, but 12 had high ACCs, and elevated levels of *Bacillus* were detected in 7. One sample of hot displayed pie contained *S. aureus* at 10^2 CFU/g, but the exact temperature that this product was stored at was not recorded.

DISCUSSION

In England during 2012, food poisoning incidents were associated with consumption of meat pies contaminated by either *B. cereus* or *L. monocytogenes (1),* which indicates the microbiological risks associated with the consumption of this product *(26).* A search of the international peer-reviewed literature revealed that meat pie consumption has been associated with outbreaks of infection with *Clostridium botulinum (6), C. perfringens (29), Salmonella (5, 25),* and

TABLE 5. *Details of 27 ready-to-eat meat pie samples classified as borderline or unsatisfactory and stored refrigerated at the point of sale*

Microbiological quality	Type of pie	Type of retailer	Unsatisfactory or borderline parameters (CFU/g)[a]
Unsatisfactory	Steak and mushroom	Butcher shop	*C. perfringens,*[b] 2.1×10^6; ACC, 10^2
Unsatisfactory	Steak and ale	Public house	*Enterobacteriaceae,* $>1.5 \times 10^5$; *Bacillus* spp., 4.8×10^3; ACC, 2.8×10^7
Unsatisfactory	Creamy chicken short crust	Supermarket	*E. coli,* 3.5×10^4; *Enterobacteriaceae,* 4.9×10^4; ACC, 5×10^7
Unsatisfactory	Chicken	Butcher shop	ACC, 1.8×10^7; *Enterobacteriaceae,* 3×10^2; *L. welshimeri* detected (enrichment only)
Borderline	Steak and onion	Butcher shop	*C. perfringens,* 1.0×10^2
Borderline	Meat	General shop	*Enterobacteriaceae,* 6.2×10^2; ACC, 9.4×10^6
Borderline	Pork	Garage shop	*Enterobacteriaceae,* 1.2×10^2
Borderline	Pork	Take out	*Enterobacteriaceae,* 1.5×10^2; ACC, 9×10^3
Borderline	Beef	Delicatessen	*Bacillus* spp., 4×10^3
Borderline	Pork	Farm shop	*Enterobacteriaceae,* 1×10^3; ACC, 9.2×10^6
Borderline	8 pork 2 steak and onion 7 other[c]	6 general shops 5 butcher shops 6 other retailers[d]	ACC, 10^4–1.7×10^7

[a] ACC, aerobic colony count.
[b] *C. perfringens* enterotoxin gene not detected.
[c] Beef and onion pie, lamb and mint pie, meat and potato pie, minced beef pie, steak pie, lamb samosa, chicken balti pie.
[d] Two bakeries, two supermarkets, one farm shop, and one café.

TABLE 6. *Details of eight ready-to-eat meat pie samples classified as borderline or unsatisfactory and stored at ambient temperature at the point of sale*

Microbiological quality	Type of pie	Type of retailer	Unsatisfactory or borderline parameters (CFU/g)[a]
Unsatisfactory	Beef	Market stall	*E. coli,* 1.3×10^4; *Enterobacteriaceae,* 1.8×10^4; ACC, 1.5×10^5
Unsatisfactory	Cottage	Bakery	*Enterobacteriaceae,* 1.9×10^5
Borderline	Beef and onion	Bakery	*Bacillus* spp., 1.4×10^4; *B. cereus,* 9.8×10^3; ACC, 2.7×10^4
Borderline	Cornish pasty	General shop	*Enterobacteriaceae,* 2×10^2; ACC, 2×10^2
Borderline	Pork	Not stated	*Enterobacteriaceae,* 10^3; ACC, 9×10^5
Borderline	Meat	Café	*B. cereus,* 2×10^3
Borderline	Pork	Market stall	*Enterobacteriaceae,* 1.9×10^2; ACC, 2.5×10^4
Borderline	Pork	Market stall	*Enterobacteriaceae,* 9.5×10^2; ACC, 2.7×10^4

[a] ACC, aerobic colony count.

S. aureus (2). A recent case control study identified consumption of pork pies as a risk factor for patients infected with hepatitis E virus *(28).* A review of the Public Health England (PHE) electronic Foodborne and non-Foodborne Gastrointestinal Outbreak Surveillance System (e-FOSS) outbreak database for England (1992 to 2012) revealed 24 food poisoning outbreaks (384 cases) linked to meat pie consumption. In addition to the listeriosis outbreak in 2012, 17 outbreaks were due to *C. perfringens* infection, 3 to *Salmonella* infection, 1 to norovirus, and 2 outbreaks were of unknown etiology *(26).*

Results from the survey described here, which was performed in early 2013 in England, revealed that 94% of 862 ready-to-eat meat pies sampled at the point of sale (and not known to be associated with food poisoning outbreaks) were of satisfactory microbiological quality; only 1% of these pies were unsatisfactory. This finding is in marked contrast to those for samples tested as part of the two incidents investigated in 2012 and associated with either *B. cereus* or *L. monocytogenes* infections. The five samples collected as part of the incident associated with *B. cereus* all had unsatisfactory levels of *Bacillus,* but this level of contamination was detected in only 1 (0.1%) of the 862 samples tested in the present survey. In the investigation of the listeriosis outbreak, six of seven pork pies from the implicated manufacturer that were on retail sale were contaminated with *L. monocytogenes*. The single *L. monocytogenes* isolate recovered from a pie in the present survey (0.1% of the 862 pies sampled) had a unique type that had not been previously associated with human infection *(26).*

Limited comparative data on the microbiological quality of meat pies on retail sale are available, and we were able to locate only two other similar studies. A survey of 775 ready-to-eat cooked pies, pasties, and other similar savory products from mobile food vendors in the United Kingdom was carried out in 1993 *(7),* and a survey of 754 ready-to-eat savory pastries on retail sale was reported from Australia in 2009 *(23).* The prevalence of *L. monocytogenes* in the United Kingdom study (0.4% contamination rate, all at levels <20 CFU/g) was similar to that in the present study, but *L. monocytogenes* was not investigated in the Australian study. In common with the present study, *Bacillus* species (including *B. cereus*) were the most common microbiological hazard detected in both of the previous studies; *Bacillus* species (including *B. cereus*) were detected in 6% of samples in the United Kingdom study at $>10^3$CFU/g *(7)* and in 0.6% of samples in the Australian study (one sample at 300 CFU/g) *(23).* Results of testing for *C. perfringens* (the most common agent associated with outbreaks reported in England) were also similar among the three studies: 0.2% of samples in the present survey, 0.9% in the previous United Kingdom survey *(7),* and 0% in Australia *(23).*

TABLE 7. *Details of 15 ready-to-eat meat pie samples classified as borderline or unsatisfactory and stored hot at the point of sale*

Microbiological quality	Type of pie	Type of retailer	Unsatisfactory or borderline parameters (CFU/g)[a]
Unsatisfactory	Chicken and mushroom	General shop	*Bacillus* spp., 5.6×10^6; ACC, 5.7×10^6
Unsatisfactory	Steak and kidney	Fish and chip shop	ACC, 1.4×10^5; *Bacillus* spp., 2.4×10^3
Unsatisfactory	Steak and kidney	General shop	ACC, 6.9×10^5
Unsatisfactory	Steak	General shop	ACC, 2.6×10^7
Borderline	Steak and kidney	General shop	*Bacillus* spp., 3.8×10^3; ACC, 3.4×10^3
Borderline	Chicken and mushroom	Fish and chip shop	*Bacillus* spp., 2.6×10^3; ACC, 2.6×10^3
Borderline	Meat and potato	Market stall	*Bacillus* spp., 9.8×10^3; ACC, 2.0×10^4
Borderline	Meat and potato	General shop	*Bacillus* spp., 3.7×10^3; ACC, 6.0×10^3
Borderline	Chunky steak	General shop	*S. aureus,* 1.0×10^2
Borderline	Steak and kidney	Take out	*Bacillus* spp., 1.9×10^4; ACC, 2.4×10^4
Borderline	1 meat, 1 steak and kidney, 1 chicken curry, 1 steak slice, 1 Cornish pasty	3 bakeries, 2 general shops	ACC, $2.3–7.8 \times 10^3$

[a] ACC, aerobic colony count.

Both of the English food poisoning incidents in 2012 involved meat pies sold at markets. In the survey described here, samples collected from markets generated the highest proportion of results of borderline or unsatisfactory microbiological quality (23%); these results were significantly different from those obtained for samples from other settings, in which only an estimated 6% of samples had reduced microbiological quality. This finding is similar to that from the 1993 United Kingdom survey, in which products from market stalls were of significantly poorer microbiological quality than those from mobile vendors or other settings *(7)*.

The designation "meat pies" covers a variety of products with various constituents. Some pies are prepared on a relatively small scale and sold where they are cooked (e.g., a bakery) usually with a short shelf life. The products sold at the end of the shelf life in this study were, at the time of sampling, labeled to be consumed on the day of baking. However, meat pies may be produced on larger scales with refrigerated shelf lives of several weeks, and preservatives such as nitrite are used in some of these products, which are more likely to be sold at supermarkets or general retailers.

In this survey, markets and bakeries had significantly higher proportions of products that were sold at ambient temperatures (41 and 45%, respectively), which may be a contributory factor to the poorer microbiological quality of these products. Overall, the highest proportion of products of borderline and unsatisfactory microbiological quality were sold at either ambient temperature or the lower end of the "hot-hold" temperature range of 15 to 40°C (10 and 11%, respectively). This temperature range is most likely to support bacterial growth. No specific information on the growth of pathogens in meat pies is available; however, growth of *L. monocytogenes* has been found in vitro in cooked pork products *(22, 30),* including those with a gelatin glaze *(14)*. *Bacillus* spp. were the predominant group of spoilage organisms in cooked potato-topped pies stored at 37°C for 3 days *(31)*. This observation indicates that raw materials may contain *Bacillus* endospores that can survive the cooking process and subsequently grow in the finished product; this scenario also is likely to apply to *C. perfringens*.

Temperature control of foods is important to prevent the reproduction of pathogenic microorganisms and the formation of toxins. European Commission Regulation 852/2004 *(9)* requires suitable temperature-controlled handling and storage conditions of sufficient capacity for maintaining foodstuffs at appropriate temperatures. However, this regulation states that "limited periods outside temperature control are permitted, to accommodate the practicalities of handling during preparation, transport, storage, display and service of food, provided that it does not result in a risk to health." The *Guidance on Temperature Control Legislation in the United Kingdom (11)* allows the sale of foods that are normally sold to consumers with a short shelf life that "for the duration of its shelf life, may be kept at ambient temperatures with no risk to health." These foods include "cooked pies and pasties that are completely encased in pastry to which nothing has been added after baking . . . even though they are not ambient shelf stable." Not all meat pies will be included in this category because some have ingredients added after baking such as gelatin glazes, herbs, or spices. It was not possible to apply this categorization to the pies examined in the present survey. However, adequate storage should be applied to all meat pies, including temperature control, which was likely to have been a contributory factor in the listeriosis outbreak *(1),* in *Bacillus* food poisoning outbreaks in 2012, and in *C. perfringens* infection outbreaks, which have been reported as the most common cause of illness associated with this food type in England and Wales through the PHE e-FOSS.

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