CAMPYLOBACTER IN MEAT AND OFFAL

MICROBIOLOGICAL QUALITY OF BEEF, LAMB AND PORK MEAT CUTS AND OFFAL

NSW GOVERNMENT Food Authority

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Contents

Introduction

Campylobacter is found worldwide in poultry flocks at variable prevalence such as 64% in Ecuador (Vinueza-Burgos, Wautier, Martiny, Cisneros, & Van Damme, 2017), 52 to 62% in Thailand (Prachantasena et al, 2017), 89.1% in Israel (Wiseman et al, 2017), and 80.9% in Japan (Ishihara et al, 2017). The older the flock the higher the prevalence (Evans & Sayers, 2000, Zhang et al, 2016). Reported *Campylobacter* prevalence in poultry flocks is similar to reported prevalence for poultry meat.

It is also known that *Campylobacter* can be found in cattle, sheep and pigs at prevalence similar to those observed in chicken flocks. However, the prevalence reported for lamb, beef and pork meat are less than prevalence reported for poultry meats. The lower prevalence in red meat is attributed to the slower process of slaughter and the extended carcase chilling time prior to entry into the food chain. The extended chilling time dries the surface of the meat which results in a significant drop in numbers of *Campylobacter* (Humphrey, O'Brien, & Madsen, 2007).

Most campylobacteriosis cases are sporadic and therefore difficult to trace back to a single source. Outbreaks are usually associated with undercooked poultry and unpasteurised milk. Other foods that have been implicated in campylobacteriosis outbreaks include BBQ/grilled meat, undercooked meat, bottled and ground water (Humphrey, O'Brien, & Madsen, 2007).

Extensive work has been published around the world on the prevalence of *Campylobacter* in meat and offal at farm, abattoir, processor and retail level. Different studies have reported prevalence in beef varying from 5.3% for meat and 58.9% for offal at farm level. This variation continues at abattoir level, with levels of 0%, 31.7% and 47% being reported. Even wider variation has been reported at retail with some studies reporting 0% and others 12% up to 78%. Variable prevalence is also reported for lamb. At farm, reports of 10% and 44% have been published, while abattoirs prevalence of 0%, 18% and 75% have been found. Similarly, at retail, prevalence is highly variable with reports of 7%, 47% and 73%. Prevalence for pork is similar with 0% and 50% being reported at farm level, 0%, 17% and 36% at abattoir level and 0%, 22% and 79% at retail. A summary of some published works is in Appendix 1.

Aim

This survey was carried out to gather information on the prevalence and level of *Campylobacter* in beef, lamb and pork, for both cuts of meat and offal, at retail level in NSW. Other pathogens and microbiological indicator organisms were also tested.

Method

A total of 569 samples of raw meat and offal were purchased from supermarkets and butchers between March 2015 and December 2016. Samples were pre-packaged or unpackaged. Pre-packaged samples were generally bought from supermarkets and large wholesale butchers while unpackaged samples were bought from independent butchers. Samples were photographed, and all sample information was recorded. Samples were sent under temperature control to the laboratory for testing within 24 hours of purchase. Samples were tested for *Campylobacter* (presence/absence and enumeration), *Salmonella* (presence/absence), *E.coli* (enumeration). pH and water activity were measured and recorded.

Results

Overall, 59 samples (10.4%) were positive for *Campylobacter*.

Sausages

Seventy samples of raw sausages were tested for *E. coli* and *Campylobacter* (Table 1). Sausages included packaged and unpackaged; beef, lamb, pork and kangaroo; flavoured and unflavoured. *Campylobacter* was not detected in any sample and *E. coli* was detected at levels > 10 cfu/g in 12.9% of samples tested.

Table 1: Microbiological results of raw sausages

Category	***Campylobacter* detected**	***Campylobacter* >100 cfu/g**	***E. coli* > 10 cfu/g**
Sausages (n=70)	0/69 (0%)	0/67 (0%)	9/70 (12.9%)

Beef

A total of 139 beef meat and offal samples were tested for *E. coli*, *Campylobacter* and *Salmonella* (Table 2). *Campylobacter* and *E. coli* (detected at levels > 10 cfu/g) for all beef samples were 2.2% and 12.9% respectively. The two samples of beef whole cuts that were positive for *Campylobacter* were ox tails and the positive *Campylobacter* offal sample was a beef heart. *Salmonella* was not detected in any beef sample.

Campylobacter prevalence increased to 11% for beef offal only (n=9). Beef offal tested comprised of six heart and three liver samples. One heart sample was positive for *Campylobacter* and one liver sample was positive for *E. coli* at levels > 10 cfu/g.

Fifty-two percent of samples (n= 73) were pre-packaged, 46.0% (n=64) were unpackaged and 1.4% (n=2) were not recorded. The three samples positive for *Campylobacter* were all pre-packaged. Sixty-one percent of the samples (n=11) positive for *E. coli* at levels > 10 cfu/g in were unpackaged, 33.3% (n=6) were packaged and 5.6% (n=1) was not recorded.

Table 2: Microbiological results of beef meat and offal

	***Campylobacter* detected**	***Campylobacter* >100 cfu/g**	***E. coli* > 10 cfu/g**	***Salmonella* detected**
Whole cuts (n=46)	4.3% 2/46	0% 0/46	4.3% 2/46	0% 0/18
Diced (n=44)	0% 0/44	0% 0/43	9.1% 4/44	0% 0/15
Mince (n=40)	0% 0/40	0% 0/40	27.5% 11/40	0% 0/13
Total muscle meat (n=130)	**1.5%** **2/130**	**0%** **0/129**	**13.1%** **17/130**	**0%** **0/46**
Offal (n=9)	**11.0%** **1/9**	**0%** **0/9**	**11.0%** **1/9**	**0%** **0/9**
Total	**2.2%** **3/139**	**0%** **0/138**	**12.9%** **18/139**	**0%** **0/54**

Lamb

One hundred and eighty samples of lamb meat and offal were tested for *E. coli* and *Campylobacter*. Ninety-two of these were also tested for *Salmonella* (Table 3). *Campylobacter* prevalence and detection of *E. coli* at levels > 10 cfu/g for all lamb samples were 19.4% and 21.7% respectively. *Salmonella* was detected in one sample of lamb kidney.

Campylobacter prevalence for lamb offal was 55.9%. Offal samples included two brains, fourteen hearts, 27 kidneys, fifteen livers and one tongue sample. Twelve liver, fifteen kidney and six heart samples were positive for *Campylobacter.*

58.9% (n=106) samples were packaged, 39.4% (n=71) were unpackaged and packaging was not recorded for 1.7% (n=3) samples. Of the 35 samples positive for *Campylobacter*, 85.7% (n=30) were packaged and 14.3% (n=5) were unpackaged. Of the 39 samples positive for *E. coli* at levels > 10 cfu/g 35.9% (n=14) were packaged and 59.0% (n=23) were unpackaged (and 5.1% not recorded).

Table 3: Microbiological results of lamb meat and offal

	Campylobacter **detected**	***Campylobacter*** **>100 cfu/g**	***E. coli*** **> 10 cfu/g**	***Salmonella*** **detected**
Whole cuts (n=40)	2.5% 1/40	0% 0/39	1.0% 4/40	0.0% 0/13
Diced (n=42)	2.4% 1/42	0% 0/41	16.7% 7/42	0.0% 0/18
Mince (n=39)	0.0% 0/39	0% 0/38	33.3% 13/39	0.0% 0/17
Total muscle meat (n=121)	**1.7%** **2/121**	**0%** **0/118**	**19.8%** **24/121**	**0%** **0/48**
Offal (n=59)	**55.9%** **33/59**	**3.6%** **2/55**	**25.4%** **15/59**	**2.3%** **1/44**
Total (n=180)	**19.4%** **35/180**	**1.2%** **2/173**	**21.7%** **39/180**	**1.1%** **1/92**

Pork

A total of 179 samples of pork meat and offal were tested for *Campylobacter*, 178 were enumerated for *E. coli* and 107 were tested for *Salmonella* (Table 4). *Campylobacter* prevalence and *E. coli* detected at levels > 10 cfu/g for all pork samples were 11.7% and 28.6% respectively. *Salmonella* prevalence was 15.8%.

Campylobacter prevalence and *E. coli* detected at levels > 10 cfu/g increased to 26.8% and 57.1% for pork offal. Offal tested included four heart, twelve kidney, 31 liver, eight stomach and intestines and one uterus sample. Of these, four stomach and intestine, seven liver, three hearts and one kidney sample were positive for *Campylobacter*.

Table 4: Microbiological results of pork meat and offal

	Campylobacter **detected**	***Campylobacter*** **>100 cfu/g**	***E. coli*** **> 10 cfu/g**	***Salmonella*** **detected**
Whole cuts (n=47)	0% 0/47	0% 0/45	2.2% 1/46	0% 0/17
Diced (n=35)	8.6% 3/35	0% 0/33	14.3% 5/35	4.2% 1/24
Mince (n=41)	7.3% 3/41	0% 0/41	31.7% 13/41	0% 0/11
Total muscle meat (n=123)	**4.9%** **6/123**	**0%** **0/119**	**15.6%** **19/122**	**1.9%** **1/52**
Offal (n=56)	**26.8%** **15/56**	**2.8%** **1/36**	**57.1%** **32/56**	**28.6%** **16/56**
Total (n=179)	**11.7%** **21/179**	**0.6%** **1/155**	**28.6%** **51/178**	**15.9%** **17/107**

Discussion

The overall prevalence of *Campylobacter* in this survey ranged from 1.5% in beef meat to 55.9% in lamb offal. *Salmonella* prevalence ranged from 0% in beef and lamb meat to 28.6% in pork offal and *E. coli* detected at levels > 10 cfu/g ranged from 11% in beef offal to 57.1% in pork offal. In general, beef had the lowest prevalence across the three organisms, pork had the highest detections for *E. coli* and *Salmonella* and lamb had the highest prevalence for *Campylobacter*. These results are similar to a study reported by Little et al. (2008) which found lamb more likely to be contaminated with *Campylobacter* compared to pork and beef, and offal more likely to be contaminated with *Salmonella* or *Campylobacter* than muscle meat. Ghafir et al. (2006) also concluded that offal was more likely to be contaminated with *Campylobacter* than muscle meat.

Prevalence of *Campylobacter* in sausages was 0%. This may be influenced by the presence of preservative and salt in the sausages, however the preservative and salt levels were not measured. The prevalence of *Campylobacter* in sausages found in this survey is similar to those seen in Canada (Bohaychuk et al., 2006), Brazil (Ristori et al., 2017), Reunion Island (Trimoulinard et al., 2017) and Italy (Zanetti, Varoli, Stampi & De Luca, 1996) (Appendix 1).

Salmonella

The overall prevalence of *Salmonella* was very low in both beef and lamb at 0% and 1.1% respectively. *Salmonella* was not detected in any of the beef tested and only one sample of lamb (lamb kidney) was positive for *Salmonella*. *Salmonella* prevalence in pork muscle meat was also low at 1.9%, however for pork offal it was much higher at 28.6%. This higher prevalence of *Salmonella* in pork offal was similar to other published works from the United Kingdom (Little et al., 2008) and Korea (Im, Seo, Bae & Lee, 2016). Further work is required in this area.

E. coli

Detection of *E. coli* at levels > 10 cfu/g for meat and offal respectively were 13.1% and 11% for beef, 19.8% and 21.7% for lamb and 15.6% and 57.1% for pork samples.

Detection was similar for the three muscle meats but varied for the offal samples. Pork offal had higher detections: 57.1% compared to 21.7% for lamb and 11% for beef (noting that the number of samples tested for beef offal was much lower than lamb and pork).

Campylobacter

Prevalence of *Campylobacter* in this survey ranged from 1.5% for beef muscle meat to 55.9% for lamb offal.

Both lamb and pork offal had comparatively high prevalence for *Campylobacter*. Looking at the different organs analysed, twenty-seven lamb kidney samples were tested and 55% of these were positive for *Campylobacter*, fifteen lamb liver samples were tested and 80% of these were positive for *Campylobacter* and fourteen lamb hearts were tested and 42% were positive for *Campylobacter*. Lamb livers were twice as likely to be contaminated with *Campylobacter* than lamb hearts. The prevalence of *Campylobacter* seen in lamb offal was expected when looking at the range of reported prevalence mentioned in Appendix 1. Little et al. (2008) found *Campylobacter* prevalence of 36.6% in the lamb offal in the UK, Strachan et al. (2012) found prevalence of 78% in lamb liver in Scotland, Cornelius, Nicol & Hudson (2005) found prevalence of 66.2% in lamb liver in New Zealand and Scates, Moran & Madden (2003) found 80% prevalence in lamb liver in Northern Ireland.

Thirty-one pork livers were tested and 22% were positive for *Campylobacter*, twelve pork kidneys were tested and 8% were positive. The remaining three pork offal samples positive for *Campylobacter* were a heart, stomach and intestines. Detection of *Campylobacter* in pork offal was expected given published data where *Campylobacter* was detected at high prevalence in swabs and offal (Ghafir et al, 2006; Kramer et al, 2000; Little et al, 2008; Lynch et al, 2011; Mdegela et al, 2011; Nesbakken et al; Strachan et al, 2012; Von Altrock et al, 2013; Wong et al, 2006.)

More research with increased sample numbers is required to determine whether prevalence is lower at abattoir level compared to retail and whether one organ is more prone to *Campylobacter* contamination. This survey did not test to determine whether the bacteria were on the surface or internalised in the offal, but this survey can conclude that offal, in particular lamb offal, was a potential source of *Campylobacter*.

Conclusion

Lamb offal was more contaminated with *Campylobacter* than beef or pork offal. Beef also had a lower prevalence of the other organisms tested. This may be due to procedures at abattoir level, herd management and procedures unique to the beef industry.

Room for improvement in the microbiological quality of lamb and pork offal requires further investigation, particularly with regard to *Salmonella* and *Campylobacter*. Thorough cooking and safe handling of these foods is essential.

There appears to be little difference between unpackaged and packaged products and more work is required to determine prevalence at abattoir level and whether there is an increase in prevalence during processing and display.

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Appendix 1

Campylobacter prevalence in sausages

Table 5: Published prevalence of *Campylobacter* in raw sausages

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
United States (ns)	Ground pork/Pork sausages Ground pork/Pork sausages	Abattoir Retail	6.7 (8/120) 1.6 (3/192)	Cultural	Duffy et al, 2001
Italy (1994-95)	Pork sausages	Retail	2.4 (1/41)	Cultural	Zanetti, Varoli, Stampi & De Luca, 1996
Canada (2001)	Beef sausages	Retail	0 (0/100)	Cultural	Bohaychuk et al, 2006
Ireland (2007-2008)	Pork sausages	Retail	15 (35/229)	Cultural/PCR	Scanlon, et al. 2013
Reunion Island (2012)	Chicken and pork sausages	Retail	1.5 (3/203)	Cultural	Trimoulinard et al, 2017
Brazil (2017)	Pork sausages	Retail	0 (0/138)	Cultural	Ristori et al, 2017

Campylobacter prevalence in beef

Table 6: Published prevalence of *Campylobacter* in beef

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
USA (2002)	Faeces	Farm	51.2 (735/1435)	Cultural	Englen, Hill, Dargatz, Ladely, & Fedorka-Cray, 2006
England (2006-2008)	Faeces	Farm	58.9 (1944/3300)	Cultural/PCR	Duncan, Leatherbarrow, French, & Grove-white, 2014
Iran (2014-15)	Faeces	Farm	5.3 (8/150)	Cultural/PCR	Rahimi, Alipoor-Amroabadi & Khamesipour, 2016
Denmark (1995-96)	Faeces	Abattoir	47 (44/94)	Cultural	Nielsen, Engberg, & Madsen, 1997
Australia (1999)	Tripe, rumen pillars	Abattoir	0 (0/196) 1.8 (3/196)	Cultural	Bensink, Dobrenov, Mulenga, Bensink, & McKee, 2002
Belgium (1997-2003)	Carcases (1997)	Abattoir	3.3 (2/60)	Cultural	Ghafir, China, Dierick, Zutter, & Daube, 2006
	Cuts (1997)		5 (3/60)		
	Mince (1997)		0 (0/67)		
	Liver (1997)		31.7 (19/60)		
	Mince (2000-1)		0.6 (47/786)		
Japan (2002)	Liver (internal)	Abattoir	5 (6/108)	Cultural	Enokimoto, Kubo, Bozono, Mieno, & Misawa, 2007
Ghana (2013-14)	Faeces	Abattoir	13.2 (16/121)	Cultural/PCR	Kariakari, Obiri-Danso, Frimpong & Krogfelt, 2017

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
	Carcases		34.5 (38/110)		
UK (1998)	Liver	Retail	54.2 (52/96)	Cultural	Kramer, Frost, Bolton, & Wareing, 2000
Canada (1999-2001)	Mince Liver	Retail	0 (0/8) 12.5 (1/8)	Cultural	Medeiros, Sattar, Farber, & Carrillo, 2008
Canada (2001)	Mince	Retail	0 (0/100)	Cultural	Bohaychuk et al, 2006
Ireland (2001-2002)	Cuts	Retail	3.2 (7/221)	Cultural	Whyte et al., 2004
Australia (2002)	Cuts Mince	Retail	3 (1/36) 0 (0/36)	Cultural	Delroy, Combs, Kiermeier & Benovic, 2008
New Zealand (2003-4)	Minced or diced	Retail	3.5 (8/230)	Cultural	Wong et al., 2006
UK (2003-5)	Offal Cuts	Retail	12.2 (6/49) 4.7 (71/1514)	Cultural	Little, Richardson, Owen, de Pinna, & Threlfall, 2008
Canada (2004-2005)	Minced	Retail	0 (0/1200) (cultural) 46 (65/142) (PCR)	Cultural/PCR	Hannon et al., 2009
Scotland (2006-8)	Liver	Retail	69 (22/32)	Cultural	Strachan, McRae, Thomson, Rotariu, Ogden, & Forbes, 2012
USA (2010)	Liver cuts	Retail	78 (39/50) 0 (0/47)	PCR	Noormohamed & Fakhr, 2013
USA (2013)	Minced	Retail	30.5 (54/178)	PCR	Ortega et al., 2015

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
Poland (2011-2013)	Cuts	Retail	10.07 (15/149)	Cultural	Korsak, Mackiw, Rozynek, & Zylowska, 2015
Ireland (ns)	Mince	Retail	20 (4/20)	Cultural/PCR	Cloak, Duffy, Sheridan, Blair, & McDowell, 2001
Ireland (ns)	Mince	Retail	35 (66/186)	Cultural	Lynch, Cagney, McDowell, & Duffy, 2011
Japan (2013)	Liver	Unknown	21.6 (109/505)	PCR/Cultural	Mori et al., 2015

Campylobacter prevalence in lamb

Table 7: Published prevalence of *Campylobacter* in sheep flocks and meat

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
England (2006-2008)	Faeces	Farm	44.8 (430/960)	Cultural/PCR	Duncan, Leatherbarrow, French, & Grove-white, 2014
Iran (2014-15)	Faeces	Farm	10 (10/100)	Cultural/PCR	Rahimi, Alipoor-Amroabadi & Khamesipour, 2016
Australia (ns)	Faeces	Farm	13.3 (ns/3412)	PCR	Yang et al, 2014
Ghana (2013-14)	Faeces Carcases	Abattoir	18.6 (22/118) 35.9 (42/117)	Cultural/PCR	Kariakari, Obiri-Danso, Frimpong & Krogfelt, 2017
USA (ns)	Faeces	Abattoir	75.0 (72/96)	Cultural	Hanlon et al, 2018
Spain (ns)	Carcases	Abattoir	0 (0/30)	Cultural	Sierra, Gonzalez-Fandos, Garcia-Lopez, Fernandez, & Prieto, 1995
UK (1998)	Liver	Retail	72.9 (70/96)	Cultural	Kramer, Frost, Bolton, & Wareing, 2000
Ireland (2001-2002)	Meat	Retail	11.8 (31/262)	Cultural	Whyte et al., 2004
Australia (2002)	Cuts Mince Liver & kidneys	Retail	8 (3/36) 0 (0/36) 23 (8/35) 13 (5/40)	Cultural	Delroy, Combs, Kiermeier & Benovic, 2008

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
New Zealand (2003-2004)	Minced/Diced	Retail	6.9 (16/231)	Cultural	Wong et al., 2006
UK (2003-5)	Cuts Offal	Retail	7.4 (55/744) 36.6 (59/161)	Cultural	Little, Richardson, Owen, de Pinna, & Threlfall, 2008
Scotland (2006-2008)	Liver	Retail	78 (31/40)	Cultural	Strachan et al., 2012
Greece (2009)	Meat Liver (swab)	Retail	42.6 (20/47) 48.9 (23/47)	Cultural	Lazou, Dovas, Houf, Soultos, & Lossifidou, 2014
New Zealand (ns)	Liver	Retail	66.2 (180/272)	Cultural	Cornelius, Nicol, & Hudson, 2005
Northern Ireland (ns)	Liver	Retail	80 (24/30)	Various	Scates, Moran, & Madden, 2003

ns – not specified

Campylobacter prevalence in pork

Table 8: Published prevalence of *Campylobacter* in pork

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
Vietnam (2012)	Faeces	Farm	57.4 (35/61)	Cultural	Carrique-mas et al, 2014
Germany (2000-2004)	Brood sows	Farm (faecal samples)	50.8 (32/63)	Cultural	Alter et al., 2005
	Newborn piglets		0 (0/30)		
	Weaned piglets 1 week		32.8 (192/586)		
	Weaned piglets 3 weeks		41 (238/580)		
	Nursery unit 4 weeks		56.6 (320/565)		
	Fattening unit 12 weeks		60.4 (337/558)		
	Fattening unit 24 weeks		66.8 (394/590)		
Belgium (1997-2003)	Carcasses (swab 600cm2) (1997-1999)	Abattoir	17.0 (65/383)	Cultural	Ghafir, China, Dierick, Zutter, & Daube, 2006
	Meat (1997-1999)		10.0 (34/340)		
	Mince (1997-1999)		3.9 (14/355)		
	Mince (2000-2003)		2.5 (15/604)		

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
	Liver (1997-1999)		31.5 (64/203)		
Norway (1999-2001)	Carcass surface	Abattoir	36.5 (35/96)	Various	Nesbakken, Eckner, Hoidal, & Rotterud, 2003
Germany (2007-8)	Liver swabs	Abattoir	9.8 (147/1500)	Cultural/PCR	Von Altrock, Hamedy, Merle, & Waldmann, 2013
South Korea (2015)	Liver Hearts Kidney	Abattoir	0 (0/13) 10.5 (2/19) 0 (0/27)	Cultural/PCR	Chon et al., 2016
Northern Ireland (ns)	Liver (internal)	Abattoir	6 (24/400)	Cultural	Moore & Madden, 1997
Tanzania (ns)	Thigh swabs	Abattoir	10.6 (7/66)	Cultural	Mdegela, Laurence, Jacob & Nonga, 2011
	Rectum swabs		66.7 (44/66)		
UK (1998)	Liver	Retail	71.7 (71/99)	Cultural	Kramer, Frost, Bolton & Wareing, 2000
Canada (1999-2001)	Mince	Retail	0 (0/8)	Cultural	Medeiros, Sattar, Farber, & Carrillo, 2008
Canada (2001)	Chops	Retail	0 (0/98)	Cultural	Bohaychuk et al, 2006
Ireland (2001-2002)	Various	Retail	5.1 (10/197)	Cultural	Whyte et al., 2004
Australia (2002)	Cuts Mince	Retail	3 (1/40) 0 (0/39)	Cultural	Delroy, Combs, Kiermeier & Benovic, 2008

Country (year)	Sample	Point of sampling	Prevalence % (samples)	Method	Reference
New Zealand (2003-2004)	Minced or diced	Retail	9.1 (21/230)	Cultural	Wong et al., 2006
UK (2003-2005)	Cuts Offal	Retail	5.0 (66/1309) 18.3 (24/131)	Cultural	Little et al., 2008
Scotland (2006-2008)	Liver	Retail	79 (23/29)	Cultural	Strachan et al., 2012
USA (2010)	Cuts	Retail	2 (2/100)	PCR	Noormohamed & Fakhr, 2013
Poland (2011-2013)	Cuts	Retail	10.6 (16/151)	Cultural	Korsak, Mackiw, Rozynek, & Zylowska, 2015
Ireland (2007-2008)	Cuts Mince Diced	Retail	11 (10/87) 20 (13/64) 5 (1/19)	Cultural/PCR	Scanlon, et al. 2013
Ireland (ns)	Cuts & mince	Retail	22 (40/179)	Cultural	Lynch, Cagney, McDowell, & Duffy, 2011
Japan (2013)	Liver	Unknown	14.8 (74/500)	Cultural/PCR	Mori et al., 2015

ns – not specified

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