

1 **Comparison of the biotypes of *Yersinia enterocolitica* isolated from pigs, cattle**  
2 **and sheep at slaughter and from humans with yersiniosis in Great Britain during**  
3 **1999-2000.**

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11 **Running Title:** *Y. enterocolitica* in humans and livestock

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1 **ABSTRACT**

2 A. McNally, T. Cheasty, C. Fearnley, R. W. Dalziel, G. A. Paiba, G. Manning, D. G.  
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4 **Aims:** To investigate the relationship between livestock carriage of *Y. enterocolitica*  
5 and human disease. The biotypes/serotypes of strains recovered from the faeces of  
6 pigs, cattle and sheep at slaughter during a national survey in Great Britain in 1999-  
7 2000, were compared to those of strains isolated from human cases of yersiniosis  
8 during the same period.

9 **Methods and results:** The faecal carriage of *Y. enterocolitica* by cattle, sheep and  
10 pigs at slaughter was 6.3%, 10.7% and 26.1% respectively. *Y. enterocolitica* biotype  
11 (BT) 1a was the most frequently isolated biotype from livestock (58%) and was the  
12 predominant biotype (53%) isolated from human cases over the same period. The  
13 main recognised pathogenic *Y. enterocolitica* biotype isolated from livestock was BT3  
14 (O:5,27) (35% of sheep, 22% of pigs and 4% of cattle) but this biotype was not  
15 detected in any of the human isolates investigated. The major pathogenic biotypes of  
16 strains isolated from humans were BT3 (O:9) (24%) and BT4 (O:3) (19%) whereas of  
17 the veterinary isolates investigated, only pigs (11%) carried BT3 (O:9) strains.

18 **Significance and impact of study:** Because of significant overlaps in phenotypes of  
19 the veterinary and human strains it is not possible to comment on the correlation  
20 between host and pathogenicity, especially of biotype 1a. The data suggest that further  
21 investigations using methods with greater discriminatory power are required.  
22 However the data also suggests that pigs may be the primary reservoir for human  
23 pathogenic *Y. enterocolitica* infection.

24 **Keywords:** *Y. enterocolitica*, prevalence, pigs, cattle, sheep, humans, biotype.

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## 1 INTRODUCTION

2 *Yersinia enterocolitica* is a Gram negative member of the *Enterobacteriaceae* family.  
3 Infection with this organism in humans can lead to a range of diseases from mild  
4 diarrhoea to the more severe complication of mesenteric lymphadenitis (Bottone  
5 1999). Although severe disease is rare, septicaemia and death may occur in infected  
6 immunocompromised patients and patients transfused with contaminated blood  
7 (Bottone 1999). Other post-infection sequelae such as arthropathies are common  
8 amongst some patient groups (Bottone 1999). Approximately 300 cases of yersiniosis  
9 are reported per annum in England and Wales by the Communicable Disease  
10 Surveillance Centre (CDSC), however diarrhoeic stool samples are rarely cultured for  
11 presence of *Yersinia* spp. *Y. enterocolitica* is also difficult to isolate from such  
12 specimens as it is overgrown by other enteric organisms. Therefore it is likely that the  
13 reported incidence is underestimated. In continental Europe, the incidence and  
14 importance of yersiniosis as a cause of enteric disease is considerably higher.  
15 Belgium, Holland, and Germany report enteropathogenic *Yersinia* as rivalling  
16 *Salmonella* spp. as a cause of gastro-enteritis (Doyle 1985; Bottone 1997).

17 *Y. enterocolitica* strains are classified on the basis of biochemical  
18 characteristics (biotype), and may then be further differentiated by serotype. Biotype  
19 1b strains are presumed to be highly pathogenic due to their lethality in a mouse  
20 infection model, while biotypes 2 - 5 are generally considered as having a relatively  
21 lower pathogenicity in the same model. Using the same criteria biotype 1a strains are  
22 classified as non-pathogenic. Previous surveys of human cases in the UK have  
23 implicated strains of biotype 3 (serotype O:9 and O:5,27), biotype 2 (serotype O:9),  
24 and biotype 4 (serotype O:3) as major causative agents of yersiniosis (Prentice *et al.*  
25 1991). However, the predominant biotypes may vary with geographical region, with

1 strains of biotype 1b and biotype 4 (serotype O:3) predominantly isolated in the  
2 United States (Bottone 1997).

3 The primary route of human infection is proposed to be foodborne.  
4 Transmission of enteropathogenic *Yersinia* spp. by food, particularly dairy and meat  
5 products, is well documented and increasingly prevalent world-wide (Fredriksson-  
6 Ahomaa *et al.* 2000; Fredriksson-Ahomaa *et al.* 2001; Falcao *et al.* 2003; Fredriksson-  
7 Ahomaa and Korkeala 2003; Fredriksson-Ahomaa and Korkeala 2003; Jones 2003).  
8 In particular, porcine products are implicated as the major source of human *Y.*  
9 *enterocolitica* infection, with numerous epidemiological studies linking consumption  
10 of uncooked or undercooked porcine reticuloendothelial tissues with yersiniosis  
11 (Prentice *et al.* 1991; Bottone 1999; Gourdon *et al.* 1999; Fredriksson-Ahomaa *et al.*  
12 2001; Falcao *et al.* 2003; Fredriksson-Ahomaa and Korkeala 2003; Fredriksson-  
13 Ahomaa and Korkeala 2003; Jones 2003). The high prevalence of *Y. enterocolitica* in  
14 pigs has also been reported, as well as presence in other livestock, cats and dogs and  
15 many wild animals (Skjerve *et al.* 1998; Fredriksson-Ahomaa *et al.* 1999; Floccari *et*  
16 *al.* 2000; Fredriksson-Ahomaa *et al.* 2000; Atanassova *et al.* 2003; Bonardi *et al.*  
17 2003; Watabe *et al.* 2003). As yet, no national structured survey of faecal carriage by  
18 livestock has been undertaken in Great Britain.

19 Although the ubiquitous nature of *Yersinia* spp in livestock is well recognised  
20 the relationship between veterinary isolates and human disease remains unclear. The  
21 comparative investigation of veterinary and human strains, geographically and  
22 temporally related, is therefore required to determine whether all *Y. enterocolitica*  
23 strains present in the environment possess the ability to cause disease in humans, or if  
24 only a subset of strains are likely to lead to human infection, as is the case with other  
25 enteric pathogens (Kim *et al.* 1999; McNally *et al.* 2001).

1           The faecal carriage of *Y. enterocolitica* in cattle, sheep and pigs at slaughter in  
2 Great Britain was last determined in a structured national survey performed in 1999-  
3 2000. All *Y. enterocolitica* isolates were then biotyped and serotyped, and the  
4 phenotypes compared to strains isolated from human cases of yersiniosis by the  
5 Health Protection Agency (HPA) over the same period.

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## 7 **MATERIALS AND METHODS**

### 8 **Abattoir survey and livestock sampling**

9 Cattle, sheep, and pigs were sampled for carriage of *Y. enterocolitica* as part of the  
10 first randomised national survey to determine the prevalence of foodborne pathogens  
11 in livestock at slaughter in Scotland, England and Wales. The survey was undertaken  
12 between March 1999 and February 2000. Ligated caeca were collected from 2509  
13 pigs sampled at 34 abattoirs. Ligated rectal samples were collected from 891 cattle  
14 and 973 sheep that were sampled at 118 abattoirs. All ligated samples were  
15 transported to VLA testing laboratories for processing within 24 hours of collection.  
16 Upon receipt at the testing laboratories, the samples were allocated a sample number,  
17 conferring anonymity to the abattoirs and herds from which samples were taken.  
18 Sampling was arranged to ensure even seasonal distribution throughout the 12-month  
19 period and ensure sample collection was proportionate to the throughput of each of  
20 the participating abattoirs. Samples were also taken to ensure an even spread of  
21 sampling throughout Great Britain (28.4% Midlands region, 32.8% North and  
22 Scotland, 38.8% South). A maximum of 5 samples was collected on any one occasion  
23 to prevent the clustering of sampling from the same herds.

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1 **Isolation and phenotyping of *Y. enterocolitica* isolates**

2 All samples were processed within 3 days of collection. On receipt at the laboratory  
3 the caecal/rectal contents were removed aseptically from the ligated viscera. *Y.*  
4 *enterocolitica* isolation was performed as described according to the method of  
5 Schiemann (Schiemann 1979). Briefly, caecal/rectal material (2ml containing  
6 approximately 2g) were emulsified in 20ml of 0.066M phosphate buffered saline  
7 (PBS - pH 7.3) and refrigerated at 2 - 8°C for 14 days. The broth was sub-cultured  
8 onto selective CIN (Cephsulodin-Irgasin-Novobiocin) agar and incubated at 31°C for  
9 18-24 hours. Suspect *Yersinia* colonies were sub-cultured on to 10% sheep's blood  
10 agar and MacConkey agar and incubated at 37°C for 18-24 hours. Identification of *Y.*  
11 *enterocolitica* was confirmed by colony morphology, urease test and API 20E  
12 biochemical typing strip. All confirmed *Y. enterocolitica* isolates were sub-cultured  
13 onto Dorset slopes and despatched to the Laboratory of Enteric Pathogens (LEP),  
14 Health Protection Agency (HPA), Colindale for phenotyping. Isolates were biotyped  
15 and serotyped according the modified scheme of Wauters (Bottone 1999).

16 **Isolation of human *Y. enterocolitica* isolates**

17 During the corresponding time to the National Abattoir Survey (March 1999 –  
18 February 2000), 164 *Y. enterocolitica* strains isolated from patients presenting to their  
19 GP with diarrhoea, were confirmed by the LEP. All strains were isolated from patients  
20 in England and Wales, and were biotyped and serotyped at the LEP using identical  
21 methodology as that employed in the abattoir survey.

22 **Veterinary and human strain comparison**

23 The 814 *Y. enterocolitica* strains isolated from the abattoir survey study were grouped  
24 according to source, and then further grouped according to biotype and serotype. The  
25 pathotypes of these veterinary strains were then compared to the pathotypes of the 164

1 *Y. enterocolitica* isolates sent to LEP from laboratories throughout England and Wales  
2 during the same period of 1999/2000. This allowed a temporal comparison of *Y.*  
3 *enterocolitica* isolated in Great Britain during 1999 – 2000.

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## 5 **RESULTS**

### 6 **Prevalence and biotypes of *Y. enterocolitica* in pigs in Great Britain**

7 From a total of 2509 pigs sampled, 742 (29.6%) of the samples tested were positive  
8 for *Yersinia* spp. Of the 742 isolates, 654 (26.1% of samples, 88% of total *Yersinia*  
9 spp.) were *Y. enterocolitica*. Other species isolated from pigs were *Y. intermediae*, *Y.*  
10 *rhodei*, and *Y. frederksenii*, the latter being the most common (1.6%, 1.1%, and 8% of  
11 *Yersinia* spp. isolates respectively). There was no statistical bias of isolation with  
12 respect to geographical region of the UK, though carriage rates were highest during  
13 December and January, with carriage rates significantly decreasing during the summer  
14 months ( $p=0.00001$ ,  $\chi^2$ -test). Of the pig *Y. enterocolitica* isolates, the most common  
15 (53.4%) strain type was biotype 1a (Table 1). In addition, 22% were biotype 3 (O:5,  
16 27), 11% biotype 3 (O:9) and 5% biotype 4 (O:3).

### 17 **Prevalence of *Y. enterocolitica* in sheep and cattle in Great Britain**

18 Only 56 of the 891 cattle sampled in the survey (6.3%) yielded *Y. enterocolitica* by  
19 culture. Of these 56 isolates only 2 were recognised pathogenic biotypes, both being  
20 biotype 3 (O:5, 27) (Table 2) whilst the remainder were biotype 1a.

21 Of the 973 sheep sampled in the survey, 104 (10.7%) were positive for  
22 *Y. enterocolitica*. Sixty two percent of isolates were biotype 1a but most of the  
23 remainder were biotype 3 (O:5, 27) (Table 3).

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## 1 **Characterisation of *Y. enterocolitica* strains from human cases of yersiniosis**

2 During the same period of 1999/2000 that the national abattoir survey was conducted,  
3 164 *Y. enterocolitica* strains were received by the LEP. The majority (53%) were  
4 biotype 1a, 24% were biotype 3 (O:9) and 19% biotype 4 (O:3) (Table 4). Only 1.2%  
5 were biotype 3 (O:5, 27).

6

## 7 **DISCUSSION**

8 In this study, the caecal/faecal carriage of *Y. enterocolitica* in livestock (pigs, cattle  
9 and sheep) at slaughter in Great Britain has been defined using a structured national  
10 abattoir survey. Over 25% of pigs, 10% of sheep, and 6% of cattle carried *Y.*  
11 *enterocolitica*. Such a high prevalence in pigs is well documented (Skjerve *et al.*  
12 1998; Fredriksson-Ahomaa *et al.* 1999; Fredriksson-Ahomaa *et al.* 2000; Atanassova  
13 *et al.* 2003; Bonardi *et al.* 2003; Watabe *et al.* 2003). Although at a lower prevalence,  
14 the carriage of *Y. enterocolitica* by sheep, cattle and other domestic animals is also  
15 well recognised (Fantasia *et al.* 1985; Floccari *et al.* 2000; Falcao *et al.* 2003). More  
16 importantly, the role of such veterinary strains in human intestinal infectious disease  
17 is unknown. Comparison of strain phenotypes in the various host populations is the  
18 classical approach to such a question. However, for *Y. enterocolitica* the population  
19 structure, even in humans, appears to be geographically variable. For example,  
20 biotype 1B strains are commonly reported in the USA but are almost unreported in  
21 Europe, and there is biotype diversity even among studies across Europe (Bottone  
22 1999). Because all *Y. enterocolitica* isolates from human cases from England and  
23 Wales are sent to the HPA for characterisation, this national abattoir survey provided  
24 a unique opportunity to compare directly, using classical biotyping and serotyping  
25 approaches, veterinary and human strains, which are temporally related.



1           In all three livestock species investigated *Y. enterocolitica* biotype 1a was the  
2 major strain type recovered. This biotype is assumed to be non-pathogenic in humans,  
3 due to the absence of known virulence factors including the lack of the yersinia  
4 virulence plasmid (pYV) (Grant *et al.* 1999). It was interesting that 1a was also the  
5 predominant (53%) biotype identified in cases of human yersiniosis. Whether such  
6 human isolates were causative of disease or merely secondary colonisers is unclear. In  
7 a recent national intestinal infectious disease (IID) study (Food Standards Agency  
8 2000), 85% of *Y. enterocolitica* isolates from patients presented to a General  
9 Practitioner (GP), compared with 93% of isolates from matched healthy controls,  
10 were biotype 1a, suggesting no association with disease. This was supported by data  
11 for community cases and controls (73% and 90% respectively) in the same study.  
12 Nevertheless, recent research, based on *in vitro* and *in vivo* models provides support  
13 that biotype 1a strains are capable of causing disease in humans (Tennant *et al.* 2003;  
14 Tennant *et al.* 2003). One explanation for this anomaly may be that there is a range of  
15 virulence potential in biotype 1a strains. This hypothesis is supported by experimental  
16 evidence indicating that biotype 1a strains from human disease cases are generally  
17 more invasive for, and escape at higher numbers from, eukaryotic cells *in vitro*  
18 compared to biotype 1a strains isolated from the environment (Grant *et al.* 1999).  
19 From the data presented here and in the IID study (Food Standards Agency 2000)  
20 biotyping and serotyping appear to contribute little to this debate. Typing techniques  
21 with greater discriminatory power, and preferably linked to pathogenicity markers, are  
22 required to address this question. Preliminary evidence suggests that molecular  
23 typing techniques such as amplified fragment length polymorphism (AFLP) may be a  
24 useful tool in the future (unpublished data).

1 Previous studies have demonstrated that *Y. enterocolitica* biotype 3 (O:9 and  
2 O:5,27), biotype 2 (O:9), and biotype 4 (O:3) are the most common strains of the  
3 presumed pathogenic group isolated from humans in the UK (Prentice *et al.* 1991;  
4 Bottone 1999). However, during the survey period (1999-2000) the predominant  
5 strains received by the LEP were of biotype 3 (O:9) (24% of all isolates) and biotype  
6 4 (O:3) (19% of all isolates), with no biotype 2 observed. Biotype 2 and Biotype 3  
7 strains can often be confused due to the difficulty in interpreting the Indole test, which  
8 differentiates the two. All isolates were typed by dedicated staff at the HPA using  
9 identical reagents which had successfully identified both BT2 and BT3 strains,  
10 suggesting this is a real observation. This is consistent with the IID study (Food  
11 Standards Agency 2000) where the only potentially pathogenic strains isolated from  
12 human cases were biotype 3 (O:9) (12.7% of all isolates), and biotype 4 (O:3) (2% of  
13 all isolates). Evidence for the potential pathogenicity of these biotypes is much  
14 stronger as no biotype 4 (O:3) strains and only 1 (2%) biotype 3 (O:9) strain was  
15 isolated from healthy humans during this study. In contrast, the prevalence of biotype  
16 4 (O:3) strains in livestock for 1999-2000 was considerably lower than in strains  
17 typed by the LEP during the same period. In the abattoir survey prevalence of biotype  
18 4 (O:3) was 5% in pigs, 1% in sheep and none in cattle. Thus, other potential  
19 reservoirs of this pathogenic biotype need to be considered, though the possibility  
20 may exist that BT4 (O:3) isolates are present in too few numbers to be isolated using  
21 these techniques. For example, very low numbers of BT4 (O:3) isolates may be  
22 present in faecal contents but may proliferate on refrigerated meat products. Also  
23 *Y. enterocolitica* is more prevalent on the tonsils of pigs than in the intestinal contents,  
24 leading to the possibility that only heavily colonised animals are detected in this  
25 survey (Fredriksson-Ahomaa and Korkeala, 2003). Outside Great Britain, surveys

1 have shown that other domestic animals, particularly dogs are recognised carriers of  
2 biotype 4 (O:3) (Fantasia *et al* 1985; Fenwick *et al* 1994; Fukushima *et al* 1984).  
3 Thus, dogs, and potentially other domesticated wildlife, could also be a significant  
4 source of infections with this biotype in the UK.

5         Biotype 3 (O:5,27) was by far the predominant pathogenic biotype carried by  
6 sheep and pigs, and was the only one recovered from cattle. As only 1% of human  
7 strains during 1999-2000 were biotype 3 (O:5,27), and none from the IID study, it  
8 seems likely that this biotype is either poorly transmissible or relatively non-  
9 pathogenic to man. In contrast, biotypes 3 (O:9) and 4 (O:3) were not uncommon in  
10 pigs (27% and 5 % respectively) and were also recovered from sheep. It seems likely  
11 therefore that livestock, and in particular, pigs are potential sources of human  
12 infection with these strains. Moreover, strain-specific differences in prevalence among  
13 humans and animals suggest some host-associated differences in colonisation  
14 potential that warrant further investigation.

15         Overall it seems from this first national abattoir survey of cattle, sheep and  
16 pigs, that *Y. enterocolitica* is a relatively ubiquitous organism in livestock in Great  
17 Britain. Unfortunately the relationship between these veterinary strains and human  
18 yersiniosis remains unclear as, using biotyping and serotyping as discriminatory tools,  
19 there is little correlation between the prevalence of strain carriage in livestock and  
20 disease in humans. This is further complicated by the high proportion of strains that  
21 belong to the putatively non-pathogenic, 1a, group in both humans and livestock.  
22 Clearly further research is required to elucidate the pathogenicity of biotype 1a strains  
23 and to determine their role in human infection. Because the only putatively pathogenic  
24 biotypes isolated from cattle and sheep were BT3 (O:5,27) strains, which were  
25 uncommon in humans, these food producing animals seem unlikely sources of human

1 infection, however, pigs appear to be the reservoir of human cases caused by biotype  
2 3 (O:9) and possibly biotype 4 (O:3). The use of molecular epidemiological tools,  
3 with higher discriminatory power, will be required to further understand these  
4 relationships.

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1   **REFERENCES**

2

3   Atanassova, V., Hugenberg, J. and Ring, C. (2003). Detection of *Yersinia*  
4       *enterocolitica* in slaughter pigs. *Genus Yersinia: Entering the Functional*  
5       *Genomic Era*. **529**: 325-327.

6   Bonardi, S., Brindani, F., Pizzin, G., Lucidi, L., D'Incau, M., Liebana, E., and  
7       Morabito, S. (2003). Detection of *Salmonella* spp., *Yersinia enterocolitica* and  
8       verocytotoxin-producing *Escherichia coli* O157 in pigs at slaughter in Italy.  
9       *International Journal of Food Microbiology* **85**(1-2): 101-110.

10   Bottone, E. J. (1997). *Yersinia enterocolitica*: the charisma continues. *Clinical*  
11       *Microbiology Reviews* **10**(2): 257-276.

12   Bottone, E. J. (1999). *Yersinia enterocolitica*: overview and epidemiologic correlates.  
13       *Microbes and Infection* **1**(4): 323-333.

14   Doyle, M. P. (1985). Food-borne pathogens of recent concern. *Annual Reviews in*  
15       *Nutrition* **5**: 25-41.

16   Falcao, J. P., Falcao, D. P., Correa E. F., and Brocchi, M. (2003). A virulence study of  
17       *Yersinia enterocolitica* O : 3 isolated from sick humans and animals in Brazil  
18       using PCR and phenotypic tests. *Genus Yersinia: Entering the Functional*  
19       *Genomic Era*. **529**: 317-319.

20   Fantasia, M., Mingrone, M. G., Crotti, D., and Boscato, C. (1985). Isolation of  
21       *Yersinia enterocolitica* biotype 4 serotype O:3 from canine sources in Italy.  
22       *Journal of Clinical Microbiology* **22**(2): 314-315

23

- 1 Fenwick, S. G., Madie, P., Wilks, C. R. (1994). Duration of carriage and  
2 transmission of *Yersinia enterocolitica* biotype 4, serotype O:3 in dogs.  
3 *Epidemiology and Infection* **113**(3): 471-477.
- 4 Floccari, M. E., Carranza, M. M., and Parada, J. L. (2000). *Yersinia enterocolitica*  
5 biogroup 1A, serotype O : 5 in chicken carcasses. *Journal of Food Protection*  
6 **63**(11): 1591-1593.
- 7 Food Standards Agency (2000). A report of the study of infectious intestinal Disease  
8 in England. The Stationary Office. London.
- 9 Fredriksson-Ahomaa, M., Bjorkroth, J., Hielm, S., and Korkeala, H. (2000).  
10 Prevalence and characterization of pathogenic *Yersinia enterocolitica* in pig  
11 tonsils from different slaughterhouses. *Food Microbiology* **17**(1): 93-101.
- 12 Fredriksson-Ahomaa, M., Hallanvuori, S., Korte, T., Siitonen, A., and Korkeala, H.  
13 (2001). Correspondence of genotypes of sporadic *Yersinia enterocolitica*  
14 bioserotype 4/O : 3 strains from human and porcine sources. *Epidemiology*  
15 *and Infection* **127**(1): 37-47.
- 16 Fredriksson-Ahomaa, M., Hielm, S., and Korkeala, H. (1999). High prevalence of  
17 yadA-positive *Yersinia enterocolitica* in pig tongues and minced meat at the  
18 retail level in Finland. *Journal of Food Protection* **62**(2): 123-127.
- 19 Fredriksson-Ahomaa, M. and Korkeala, H. (2003). Low occurrence of pathogenic  
20 *Yersinia enterocolitica* in clinical, food, and environmental samples: a  
21 methodological problem. *Clinical Microbiology Reviews* **16**(2): 220-229.
- 22 Fredriksson-Ahomaa, M. and Korkeala, H. (2003). Molecular epidemiology of  
23 *Yersinia enterocolitica* 4/O : 3. *Genus Yersinia: Entering the Functional*  
24 *Genomic Era.* **529**: 295-302.

- 1 Fukushima, H., Nakamura, R., Iitsuka, S., Tsubokura, M., Otsuki, K., Kawaoka, Y.  
2 (1984). Prospective systematic study of *Yersinia spp.* in dogs. *Journal of*  
3 *Clinical Microbiology*. **19**(5):, 616-622.
- 4 Gourdon, F., Beytout, J., Reynaud, A., Romaszko, J. P., Perre, D., Theodore, P.,  
5 Soubelet, H., and Sirot, J. (1999). Human and animal epidemic of *Yersinia*  
6 *enterocolitica* O : 9, 1989-1997, Auvergne, France. *Emerging Infectious*  
7 *Diseases* **5**(5): 719-721.
- 8 Grant, T., Bennett-Wood, V. and Robins-Browne, R. M. (1999). Characterization of  
9 the interaction between *Yersinia enterocolitica* biotype 1A and phagocytes and  
10 epithelial cells in vitro. *Infection and Immunity* **67**(9): 4367-4375.
- 11 Jones, T. F. (2003). From pig to pacifier: chitterling-associated yersiniosis outbreak  
12 among black infants. *Emerging Infectious Diseases* **9**: 1007-1009.
- 13 Kim, J., Nietfeldt, J., and Benson, A. K (1999). Octamer-based genome scanning  
14 distinguishes a unique subpopulation of *Escherichia coli* O157:H7 strains in  
15 cattle. *Proceedings of the National Academy of Sciences of the United States*  
16 *of America* **96**: 13288-13293.
- 17 McNally, A., Roe, A. J., Simpson, S., Thomson-Carter, F. M., Hoey, D. E. E., Currie,  
18 C., Chakraborty, T., Smith, D. G. E., and Gally, D. L. (2001). Differences in  
19 levels of secreted locus of enterocyte effacement proteins between human  
20 disease associated and bovine *Escherichia coli* O157. *Infection and Immunity*  
21 **69**: 5107-5114.
- 22 Prentice, M., Cope, D., and Swann, R. A. (1991). The epidemiology of *Yersinia*  
23 *enterocolitica* infection in the British isles 1983-1988. *Contributions to*  
24 *Microbiology and Immunology* **12**: 17-25.

- 1 Schiemann, D. A. (1979). Synthesis of a selective agar medium for *Yersinia*  
2 *enterocolitica*. *Canadian Journal of Microbiology* **25**(11): 1298-1304.
- 3 Skjerve, E., Lium, B., Nielsen, B., and Nesbakken, T. (1998). Control of *Yersinia*  
4 *enterocolitica* in pigs at herd level. *International Journal of Food*  
5 *Microbiology* **45**(3): 195-203.
- 6 Tennant, S. M., Grant, T. H., and Robins-Browne, R. M. (2003). Pathogenicity of  
7 *Yersinia enterocolitica* biotype 1A. *FEMS Immunology and Medical*  
8 *Microbiology* **38**: 127 - 137.
- 9 Tennant, S. M., Skinner, N. A., Joe, A. and Robins-Browne, R. M. (2003). *Yersinia*  
10 *enterocolitica* biotype 1A: Not as harmless as you think. *Genus Yersinia:*  
11 *Entering the Functional Genomic Era.* **529**: 125-128.
- 12 Watabe, M., Rao, J. R., Stewart, T. A., Xu, J., Millar, B. C., Xiao, L., Lowery, C. J.,  
13 Dooley, J. S. G., and Moore, J. E. (2003). Prevalence of bacterial faecal  
14 pathogens in separated and unseparated stored pig slurry. *Letters in Applied*  
15 *Microbiology* **36**(4): 208-212.

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1 Table 1. Prevalence of biotypes/serotypes of *Y.enterocolitica* isolates from pigs,  
 2 sampled at abattoirs in Great Britain during 1999-2000.

Biotype	Serotype	No. Isolates	Percentage
1A	06,30	77	11.79
	0,? <sup>*</sup>	82	12.56
	019,8	46	7.04
	05	42	6.43
	O10, K1	18	2.76
	O41,43	17	2.6
	O7	16	2.45
	O4,32	12	1.84
	O8	12	1.84
	O13,7	7	1.07
	Others <sup>†</sup>	20	3.05
BT 3	05,27	142	21.75
	0,9	71	10.87
	O,? <sup>*</sup>	26	3.98
	Others	10	1.52
BT4	03	33	5.05
	Others	5	0.77
BT2	Various <sup>‡</sup>	3	0.46
BT6	Various	2	0.3

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4 <sup>\*</sup>O? indicates the strain was non-typeable.

5 <sup>†</sup>Others refers to uncommon serotypes of which only one strain was identified.

6 <sup>‡</sup>Various refers to the presence of more than one serotype within this biotype group.

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1 Table 2. Prevalence of biotypes/serotypes of *Y.enterocolitica* isolates from cattle  
 2 sampled at abattoirs in great Britain during 1999-2000.

Biotype	Serotype	Number	Percentage
BT1a	O:?*	14	30.44
	O:6, 30	10	21.74
	O:5, 27	4	8.7
	O:19, 8	4	8.7
	O:6, 31	3	6.52
	O:4, 32	2	4.35
	O:47	1	2.17
	O:41, 43	1	2.17
	O:4, 33	1	2.17
	O:37	1	2.17
	O:7	1	2.17
	O:21	1	2.17
	O:14	1	2.17
BT3	O:5, 27	2	4.35

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4 \*O? indicates the strain was non-typeable.

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1 Table 3. Prevalence of biotypes/serotypes of *Y.enterocolitica* isolates from sheep  
 2 sampled at abattoirs in great Britain during 1999-2000.

Biotype	Serotype	Number	Percentage
BT1a	O:6, 30	13	14.94
	O:? *	11	12.64
	O:19, 8	6	6.9
	O:5, 27	6	6.9
	O:4, 32	4	4.6
	O:6, 31	3	3.45
	O:5	2	2.3
	O:47	2	2.3
	O:41, 42	2	2.3
	O:41, 43	1	1.15
	O:7	1	1.15
	O:36	1	1.15
	O:13, 7	1	1.15
	O:10, K1	1	1.15
BT3	O:5, 27	30	34.5
BT4	O:3	1	1.15
BT2	O:9	1	1.15
	O:5, 27	1	1.15

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4 \*O? indicates the strain was non-typeable.

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- 1 Table 4. Prevalence of biotypes/serotypes of human *Y.enterocolitica* isolates received
- 2 by LEP, HPA during 1999-2000.

Biotype	Serotype	No Isolates	Percentage
1A	O,?*	28	17.1
	05	13	7.93
	O6,30	11	6.71
	O19,8	6	3.66
	O41,43	6	3.66
	O8	5	3.05
	O6,31	4	2.44
	O4,32	3	1.83
	010,K1	2	1.22
	O36	2	1.22
	013,7	1	0.61
	03	1	0.61
	046	1	0.61
	048	1	0.61
	05,27	1	0.61
	07	1	0.61
O rough	1	0.61	
3	O9	39	23.8
	O?	2	1.22
	O5	2	1.22
	O5,27	2	1.22
4	O3	32	19.5

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- 4 \*O? indicates the strain was non-typeable.