

ORIGINAL ARTICLE

Prevalence and lineages of *Listeria monocytogenes* in Chinese food products

Xiaohui Zhou and Xinan Jiao

College of Bioscience and Biotechnology, Yangzhou University, Yangzhou, China

Keywordsfood products, lineage, *Listeria monocytogenes*, prevalence.**Correspondence**

X. Jiao, College of Bioscience and Biotechnology, Yangzhou University, Yangzhou 225009, China. E-mail: jiao@yzu.edu.cn

Present address

X. Zhou, Department of Veterinary Microbiology and Pathology, Washington State University, Pullman, WA 99163, USA.

2006/0248: received 22 February 2006, revised 22 May 2006 and accepted 25 May 2006

doi:10.1111/j.1472-765X.2006.01991.x

Abstract**Aims:** This study was undertaken to investigate the prevalence and lineages of *Listeria monocytogenes* in different kinds of food products in local Chinese markets.**Methods and Results:** A total of 2686 food samples and 645 water samples were collected and *L. monocytogenes* was isolated from 2.28% (76 of 3331) of all samples. The prevalence of *L. monocytogenes* (14 of 290, 4.83%) in raw meat products was significantly higher than that in other raw food products ($P < 0.05$). Among 844 ready-to-eat (RTE) food samples, 21 samples were positive for *L. monocytogenes*. RTE packaged food products from two supermarkets had a prevalence ranging from 0.00% to 25.00%. The prevalence of *L. monocytogenes* in meat products of freshly slaughtered hogs was 0.95% (four of 420), significantly lower than that in raw meat products in the retail markets ($P < 0.05$). Ten isolates were recovered from 645 water samples, which were collected after hands washing by shopkeepers or waiters. A total of 38 isolates were randomly selected for lineage classification based on the nucleotide variation of *actA* gene. Eighty percentage of isolates from RTE food products belonged to Lineage II while only 20% belonged to Lineage I.**Conclusions:** Food products in Chinese markets are contaminated with *L. monocytogenes*. Raw meat products have the highest contamination rates among all the raw food samples. RTE food products are more likely to be contaminated with Lineage II strains.**Significance and Impact of the Study:** The data presented here show the main contamination sources of *L. monocytogenes* in Chinese food products.**Introduction**

Listeria monocytogenes is a food-borne pathogen that can cause 2500 cases of meningitis encephalitis, sepsis, foetal death and abortions and 500 deaths in the United States annually (Mead *et al.* 1999). A variety of food products have been found to be contaminated with *L. monocytogenes* (Pini and Gilbert 1988; Harvey and Gilmour 1993; Fenlon *et al.* 1996; Jorgensen and Huss 1998). The incidence of *L. monocytogenes* in raw meats and cooked meats was about 35% and 18%, respectively, in Spain (Vitas and Garcia-Jalon 2004). In United States, around 45% of pork samples were found positive for *L. monocytogenes*

(Kanuganti *et al.* 2002) while <1% of cooked meats were contaminated with *L. monocytogenes* (Gombas *et al.* 2003). The occurrence of *L. monocytogenes* in retail raw pork and chicken was 20% and 37%, respectively, while *L. monocytogenes* was not recovered from vegetables in Japan (Inoue *et al.* 2000).

As listeriosis may occur through ingestion of food products contaminated with *L. monocytogenes*, prevalence data in different kinds of food products seem to be important in food safety assessment. Though many studies on the prevalence of *L. monocytogenes* have been conducted in different countries, limited data existed on the occurrence of *L. monocytogenes* in China. Therefore, it is

crucial to obtain information regarding the prevalence of *L. monocytogenes* in food products in Chinese markets.

Listeria monocytogenes strains can be divided into two or three distinct lineages based on different methods (Wiedmann *et al.* 1997; Call *et al.* 2003). Recently, we developed a simple subtyping method based on the nucleotide variation of *actA* gene and divided *L. monocytogenes* strains into two distinct lineages (Zhou *et al.* 2005). Compared with other DNA fragment size-based typing methods, DNA sequencing-based subtyping methods can generate unambiguous data that are portable through web-based databases and can be used for phylogenetic analyses. Our previous study also showed that strains of Lineage I were more virulent than those of Lineage II (Zhou *et al.* 2005). However, we do not know which lineage of *L. monocytogenes* is more commonly present in Chinese food products. This study was undertaken to investigate the prevalence and lineages of *L. monocytogenes* in different kinds of food products from four retail markets and two supermarkets in east coast China.

Materials and methods

Samples

From January 2003 to August 2003, a total of 2686 food samples and 645 water samples were randomly collected from four retail markets (markets A, B, C and D), two supermarkets (a and b) and one slaughterhouse in Yangzhou City, east coast of China. Markets A, B and C were located 1 mi apart. Market D was located approximately 3 mi from the other three markets. Supermarkets a and b were located 1 mi apart. The slaughterhouse was located in the suburb, around 5 mi from downtown. Samples of raw food products ($n = 1302$) were taken from meat (pork), fish, poultry, vegetables and bean curds in the four retail markets. During the same period, samples of ready-to-eat (RTE) food products ($n = 844$) were taken from pork, goose, chicken, liver, drumstick, pig tongue and beef. Six hundred and forty-five water samples, which were used, by shopkeepers and waiters to wash their hands were also collected. Water samples were collected after hands washing to detect *L. monocytogenes* on the hands of shopkeepers and waiters. Samples of packaged RTE food products ($n = 120$) from the supermarkets were taken from beef, goose, chicken, liver, drumstick and pork tongue. In order to know whether *L. monocytogenes* was introduced into meat products during transportation, we collected 420 meat samples of freshly slaughtered hogs, which were transported, directly to the four retail markets described above.

Water samples were transported in sterile tubes. All other samples were transported in sterile Stomacher 400

closure bags (Seward Ltd, London, UK). Samples were transported to the laboratory and held on ice. Sample analysis was initiated within 24 h of collection.

Bacteriological analysis

Twenty-five gram portions of all food sample, prepared using sterilized instruments, were homogenized in 225 ml of *Listeria* Enrichment Broth (LEB; Difco Laboratories, Detroit, MI, USA) using a Stomacher 400 laboratory blender (Seward Ltd). Water samples, in 25-ml volume, were inoculated into 225 ml of LEB. Following 24 h of incubation at 37°C, 0.2 ml of each enrichment culture was plated on Oxford medium containing the Oxford Antimicrobial Supplement (Difco Laboratories) and incubated at 37°C for 48 h. Esculin hydrolysis positive colonies with morphology typical for *Listeria* spp. were streaked for isolation on brain heart infusion (Difco Laboratories) agar and incubated at 37°C for 24 h. Pure culture isolates used for *hlyA* polymerase chain reaction (PCR) were grown in brain heart infusion broth at 37°C with shaking for 12–15 h.

Identification of *L. monocytogenes*

Four *Listeria*-like isolates obtained from each sample on Oxford plates were detected with a PCR assay targeting the listeriolysin O gene, *hlyA*, to identify *L. monocytogenes* isolates. Primers 1 (CCTAAGACGCCAATCGAAAAG AAA) and 2 (TAGTTCTACATCACCTGAGACAGA) amplify an 858-bp fragment of the *hlyA* gene (Bsat and Batt 1993). Amplifications were performed using GeneAmp PCR core reagents. Each reaction mixture (25 μ l) contained 1X PCR buffer, 1.5 mmol l⁻¹ MgCl₂, 125 μ mol l⁻¹ each dATP, dCTP, dGTP and dTTP, 0.5 μ mol l⁻¹ each primer, 1 U of *Taq* DNA polymerase and 2 μ l of a 1 : 10 dilution of a crude cell lysate prepared as described by Furrer *et al.* (1991). Amplification was performed in the thermocycler system (T-Gradient Thermoblock, Biometra, Göttingen, Germany). Thermocycling conditions included an initial hold of 2 min at 95°C, then a denaturation step at 94°C for 1 min, annealing at 60°C for 30 s, 30 s extension at 72°C for a total of 40 cycles. A final extension step of 72°C for 10 min was followed by a hold at 4°C. Amplified products were electrophoresed on 1.2% agarose gels at 120 V, stained with ethidium bromide (1 μ g ml⁻¹), and photographed with Tanon GIS1000 (Tanon, Shanghai, China). A positive result was indicated by the presence of an approximately 858-bp band. Other species (*L. innocua*, *L. grayi*, *L. seeligeri*, *L. welshimeri* and *L. ivanovii*) were used as our negative control and the EGD strain which is completely sequenced as our positive control.

Lineage classification

Lineage classification was performed for a total of randomly selected 38 *L. monocytogenes* isolates. The method for lineage classification was described in our previous report (Zhou *et al.* 2005). Briefly, 597 bp 3'-terminal region of the virulence gene *actA* was amplified and sequenced. Sequence data were used to classify these 38 Chinese *L. monocytogenes* isolates into phylogenetic lineages based on unrooted neighbour-joining tree.

Statistical analysis

The rates of recovery of *L. monocytogenes* among the four retail markets and among different food categories were compared using Pearson's chi-square test. Chi-square test was also performed to compare the prevalence of *L. monocytogenes* in meat samples of freshly slaughtered hogs and that of meat samples in the retail markets. *P*-values of ≤ 0.05 were considered significant.

Results

Prevalence of *L. monocytogenes* in raw food products from the retail markets

Data in Table 1 showed that the average prevalence of *L. monocytogenes* in the four retail markets was 2.11% (41 of 1947), ranging from 0.00% which were found in vegetables from markets A, B, bean curd from markets A, C and poultry from market C to 5.56% which were found in meat products from market A. The prevalence of *L. monocytogenes* in raw meat, fish, vegetables, bean curd and poultry products was 4.83%, 2.00%, 1.20%, 2.22%, 1.31% and 1.55% respectively. The prevalence of *L. monocytogenes* in raw meat (4.83%) was significantly higher than those of other food products ($P < 0.05$; Table 1). The average prevalence of *L. monocytogenes* in retail markets A, B, C and D was 2.57%, 2.09%, 1.62% and 2.04%

respectively. There was no significant difference in the average prevalence of *L. monocytogenes* among the four retail markets (Table 1).

Prevalence of *L. monocytogenes* in RTE food products from the retail markets

The average prevalence of *L. monocytogenes* in RTE food products from the four retail markets (A, B, C and D) was 2.49% ranging from 0.00% to 6.67% (Table 2). The highest prevalence level (6.67%) was found in the pork tongue from market A and the lowest prevalence (0.00%) was found in beef in markets C and D, goose from market C, chicken from market C, liver from markets A and D, drumstick from market B, pork tongue from markets B and C and pork from market B. The prevalence of *L. monocytogenes* in pork, goose, chicken, liver, chicken, pork tongue and beef was 2.26%, 2.14%, 2.46%, 2.21%, 3.82%, 2.06% and 2.35% respectively (Table 2). There was no significant difference in the average prevalence of *L. monocytogenes* among each kind of RTE food product. The average prevalence of *L. monocytogenes* in RTE food products from markets A, B, C and D was 3.20%, 1.89%, 2.09% and 2.70% respectively. There was no significant difference in the average prevalence of *L. monocytogenes* of RTE food samples among the four retail markets. A total of 10 *L. monocytogenes* isolates were recovered from 645 the water samples which were collected after hands washing by the shopkeepers and waiters in the retail markets.

Prevalence of *L. monocytogenes* in the packaged RTE food products from two supermarkets

Listeria monocytogenes was isolated from 13.33% (two of 15) of beef samples, 8.00% (two of 25) of goose samples, 4.00% (one of 25) of chicken samples, 6.67% (one of 15) of liver samples, 4.17% of drumstick samples and 18.75% of pork tongue samples. Prevalence of *L. monocytogenes*

Table 1 Prevalence of *Listeria monocytogenes* in raw food products from the four retail markets (A, B, C and D)

Product category	Number of positive samples/number of samples (%)				
	Market A	Market B	Market C	Market D	Total
Meat	5/90 (5.56)	3/65 (4.62)	3/80 (3.75)	3/55 (5.45)	14/290 (4.83) X
Fish	4/120 (3.33)	2/110 (1.82)	1/120 (0.83)	2/100 (2.00)	9/450 (2.00) Y
Vegetable	0/40 (0.00)	0/40 (0.00)	1/42 (2.38)	1/45 (2.22)	2/167 (1.20) Y
Bean curd	0/25 (0.00)	1/20 (5.00)	0/20 (0.00)	1/25 (4.00)	2/90 (2.22) Y
Poultry	2/120 (1.67)	1/80 (1.25)	0/45 (0.00)	1/60 (1.67)	4/305 (1.31) Y
Total	11/395 (2.78) Z	7/315 (2.22) Z	5/307 (1.63) Z	8/285 (2.81) Z	31/1302 (2.38)

Within the column of 'Total', values that are not followed by the same letter are significantly different ($P \leq 0.05$). Values that are followed same letters within the column and row of 'Total' are not significantly different ($P \geq 0.05$).

Table 2 Prevalence of *Listeria monocytogenes* in ready-to-eat (RTE) food products from the four retail markets (A, B, C and D)

Product category	Number of positive samples/number of samples (%)				
	Market A	Market B	Market C	Market D	Total
Pork	1/40 (2.50)	0/20 (0.00)	1/38 (2.63)	1/35 (2.86)	3/133 (2.26) X
Goose	1/38 (2.63)	1/35 (2.86)	0/25 (0.00)	1/42 (2.38)	3/140 (2.14) X
Chicken	1/36 (2.78)	1/32 (3.13)	0/26 (0.00)	1/28 (3.57)	3/122 (2.46) X
Liver	0/29 (0.00)	1/39 (2.56)	2/32 (6.25)	0/36 (0.00)	3/136 (2.21) X
Drumstick	2/41 (4.88)	0/35 (0.00)	1/23 (4.35)	2/32 (6.25)	5/131 (3.82) X
Pork tongue	1/15 (6.67)	0/26 (0.00)	0/27 (0.00)	1/29 (3.45)	2/97 (2.06) X
Beef	1/20 (5.00)	1/25 (4.00)	0/20 (0.00)	0/20 (0.00)	2/85 (2.35) X
Total	7/219 (3.20) Y	4/212 (1.89) Y	4/191 (2.09) Y	6/222 (2.70) Y	21/844 (2.49)

Values that are followed same letters within the column and row of 'Total' are not significantly different ($P \geq 0.05$).

Table 3 Prevalence of *Listeria monocytogenes* in ready-to-eat (RTE) packaged food products from the two supermarkets (a and b)

Product category	Number of positive samples/number of samples (%)		
	Supermarket a	Supermarket b	Total
Beef	1/5 (20.00)	1/10 (10.00)	2/15 (13.33)
Goose	0/10 (0.00)	2/15 (13.33)	2/25 (8.00)
Chicken	1/15 (6.67)	0/10 (0.00)	1/25 (4.00)
Liver	1/10 (10.00)	0/5 (0.00)	1/15 (6.67)
Drumstick	0/12 (0.00)	1/12 (8.33)	1/24 (4.17)
Pork tongue	1/8 (12.50)	2/8 (25.00)	3/16 (18.75)
Total	4/60 (6.67) X	6/60 (10.00) X	10/120 (8.33)

Values that are followed same letters within the row of 'Total' are not significantly different ($P \geq 0.05$).

in supermarkets a and b was 6.67% and 10.00% respectively. There was no significant difference between the prevalence in supermarkets a and b (Table 3). As the number of such samples was relatively small, statistic analysis was not conducted among the prevalence of *L. monocytogenes* in each kind of food product.

Prevalence of *L. monocytogenes* in the meat products from one slaughterhouse

The prevalence of *L. monocytogenes* in the meat products of freshly slaughtered hogs from one slaughterhouse was 0.95% with four positive samples in 420 collected samples. The prevalence of *L. monocytogenes* in meat products from slaughterhouse was significantly lower than that in meat products from retail markets ($P < 0.05$).

Lineage classification and distribution of *L. monocytogenes* in raw and RTE food products

A total of 38 isolates was randomly selected for lineage classification based on the nucleotide variation of *actA* gene and the isolates were divided into two genetic line-

ages. Thirteen of the 38 isolates belonged to Lineage I strains and 25 of the 38 isolates belonged to Lineage II strains. Eighty percentage (eight of 10) of the isolates from RTE food products belonged to Lineage II while only 20% (two of 10) belonged to Lineage I. Among the isolates recovered from raw product, 60.7% (17 of 28) belonged to Lineage II and 39.3% (11 of 28) belonged to Lineage I.

Discussion

Listeria spp. is a Gram-positive and intracellular bacterium of which *L. monocytogenes* is the most important pathogen to humans. Because *L. monocytogenes* can cause human severe infections and fatal consequences, the prevalence of *L. monocytogenes* in RTE food products became a major concern to researchers and policy-makers. The different virulence of Lineage I and Lineage II strains makes it important to know which lineage strains humans are more commonly exposed to. Though studies on the prevalence of *L. monocytogenes* were conducted in many countries (Uyttendaele *et al.* 1999; Inoue *et al.* 2000; Muraoka *et al.* 2003; Peccio *et al.* 2003; Holah *et al.* 2004), such studies are very limited in China. In addition, which lineage strains humans are more commonly exposed to has not been investigated. Thus, in this study we attempted to gain more information about the prevalence and lineage distribution of *L. monocytogenes* in different kinds of food products in China.

The results showed that the overall prevalence of *L. monocytogenes* in raw food products was 2.38% which is similar with that found in Chile in which prevalence of *L. monocytogenes* in raw food products ranged from 0.00% to 11.3% (Cordano and Rocourt 2001). However, the prevalence of *L. monocytogenes* in raw food products in China seems much lower than that found in Japan (25%; Inoue *et al.* 2000) and in Denmark (34%; Norrung *et al.* 1999). There was no significant difference between

the prevalence of *L. monocytogenes* in the four Chinese retail markets suggesting that within a relative small area the prevalence of *L. monocytogenes* may be similar. Raw food products are heated before consumption and this organism can be inactivated by a normal pasteurization process. If the cooking of raw food is adequate, one can assume that *L. monocytogenes* will be killed. However, the shopkeepers and waiters in the retail markets have a lot of chances to touch these contaminated raw food products. Therefore, it is not surprising that some water samples (1.55%, 10 of 645), which were collected after hands washing by the shopkeepers and waiters, were positive for *L. monocytogenes*. As raw food products and RTE food products were sold in the same retail markets, transmission of *L. monocytogenes* from raw food products to the RTE food products by the hands of shopkeepers and waiters may occur.

Our results also showed that the average prevalence of *L. monocytogenes* in raw meat products (4.83%) in the four markets was significantly higher than those in other kinds of food products. This was consistent with what was found by Gombas *et al.* (2003) who showed that the prevalence of *L. monocytogenes* in meat (1.17%) was higher than that in soft cheese. Another study by Iida *et al.* (1998) in Japan also showed that the *L. monocytogenes* contamination rates in retail fresh meat (36.4%) were significantly higher than those in other food products. A study conducted in China also showed that raw meat was found to be most heavily contaminated in seven kinds of food products (Wu *et al.* 2003). It is generally accepted that these food products are more easily to be contaminated due to the methods of slaughter, evisceration and sample preparation (minced, sliced, etc.), which allow ample opportunity for the cross-contamination to occur (Vitas and Garcia-Jalon 2004).

The average prevalence of *L. monocytogenes* in RTE food product was 2.49% much lower than what was found in Belgium (Uyttendaele *et al.* 1999). In RTE food products we did not find significant differences between the prevalence in pork and that in other kinds of food product. RTE food products were most likely contaminated after heating process because *L. monocytogenes* was not heat resistant. The source of *L. monocytogenes* in RTE food products may be contaminated from the raw food products in the same retail markets (Zhou and Jiao 2004).

It is generally considered that packaged RTE food products are rarely contaminated with pathogens in supermarkets in China. However, our results showed that the packaged RTE food products were also contaminated with *L. monocytogenes* and the prevalence ranged from 0.00% to 25.00%. The average prevalence of *L. monocytogenes* in the two supermarkets investigated in this study was 8.33% much lower than that found in Malaysia

supermarkets with an overall prevalence of 35% (Hassan *et al.* 2001). Contamination of *L. monocytogenes* in packaged RTE food products in supermarkets may come from food processing and packaging. A study conducted in the USA showed that *L. monocytogenes* was detected in 17.8% of 531 samples from food-processing environment and ribotyping data indicated that raw materials and the processing environment were the potential sources of finished product contamination (Norton *et al.* 2001).

In the present study, 420 fresh meat products in one slaughterhouse were collected for identification of *L. monocytogenes* and our results showed that *L. monocytogenes* was identified in 0.95% of all samples (four of 420). An interesting finding was that the prevalence of *L. monocytogenes* in fresh meat products in one slaughterhouse is significantly lower than those in retail markets ($P < 0.05$). Because meat products in the retail markets are produced in the slaughterhouse and transported directly to the retail markets for sale, the higher prevalence in meat products from the retail markets might be caused by the contamination during the meat transportation from slaughterhouse to the retail markets. Another possibility is that *L. monocytogenes* multiplies during storage and transportation.

Different genetic lineages of *L. monocytogenes* have different virulence potential and usually strains of Lineage I are more virulent than strains of Lineage II (Wiedmann *et al.* 1997; Borucki *et al.* 2004; Zhou *et al.* 2005). Therefore, it is important to know how humans are exposed to different lineages of *L. monocytogenes*. Our results showed that isolates from RTE food products to which humans are directly exposed mainly belong to Lineage II (80%). Lineage II strains are less virulent than Lineage I strains (Zhou *et al.* 2005) which suggest that humans are more likely exposed to less virulent strains. This result might partially explain why the prevalence of *L. monocytogenes* in RTE food product is high while incidence of listeriosis is low. More isolates from RTE food products are needed for the lineage classification to confirm our findings.

In conclusion, this study presented an overall prevalence of *L. monocytogenes* in different kinds of raw food products and RTE food products in four Chinese retail markets and fresh meat products in one slaughterhouse. Lineage distribution in RTE and raw food products was also presented. The data presented here showed the main contamination sources of *L. monocytogenes* in Chinese food products.

Acknowledgements

The authors thank Dr Martin Wiedmann for providing us with *Listeria media*. This study was supported by the National Natural Scientific Foundation of China

(30425031), the Teaching and Research Award Program for Outstanding Young Teachers in Higher Education Institutions of MOE, P.R.C. (TRAPOYT 175) and grants from Jiangsu Provincial Government (BE2003031, G2002-026).

References

- Borucki, M.K., Kim, S.H., Call, D.R., Smole, S.C. and Pagotto, F. (2004) Selective discrimination of *Listeria monocytogenes* epidemic strains by a mixed-genome DNA microarray compared to discrimination by pulsed-field gel electrophoresis, ribotyping, and multilocus sequence typing. *J Clin Microbiol* **42**, 5270–5276.
- Bsat, N. and Batt, C.A. (1993) A combined modified reverse dot-blot and nested PCR assay for the specific non-radioactive detection of *Listeria monocytogenes*. *Mol Cell Probes* **7**, 199–207.
- Call, D.R., Borucki, M.K. and Besser, T.E. (2003) Mixed-genome microarrays reveal multiple serotype and lineage-specific differences among strains of *Listeria monocytogenes*. *J Clin Microbiol* **41**, 632–639.
- Cordano, A.M. and Rocourt, J. (2001) Occurrence of *Listeria monocytogenes* in food in Chile. *Int J Food Microbiol* **70**, 175–178.
- Fenlon, D.R., Wilson, J. and Donachie, W. (1996) The incidence and level of *Listeria monocytogenes* contamination of food sources at primary production and initial processing. *J Appl Bacteriol* **81**, 641–650.
- Furrer, B., Candrian, U., Hoefelein, C. and Luethy, J. (1991) Detection and identification of *Listeria monocytogenes* in cooked sausage products and in milk by *in vitro* amplification of haemolysin gene fragments. *J Appl Bacteriol* **70**, 372–379.
- Gombas, D.E., Chen, Y., Clavero, R.S. and Scott, V.N. (2003) Survey of *Listeria monocytogenes* in ready-to-eat foods. *J Food Prot* **66**, 559–569.
- Harvey, J. and Gilmour, A. (1993) Occurrence and characteristics of *Listeria* in foods produced in Northern Ireland. *Int J Food Microbiol* **19**, 193–205.
- Hassan, Z., Purwati, E., Radu, S., Rahim, R.A. and Rusul, G. (2001) Prevalence of *Listeria* spp. and *Listeria monocytogenes* in meat and fermented fish in Malaysia. *Southeast Asian J Trop Med Public Health* **32**, 402–407.
- Holah, J.T., Bird, J. and Hall, K.E. (2004) The microbial ecology of high-risk, chilled food factories; evidence for persistent *Listeria* spp. and *Escherichia coli* strains. *J Appl Microbiol* **97**, 68–77.
- Iida, T., Kanzaki, M., Nakama, A., Kokubo, Y., Maruyama, T. and Kaneuchi, C. (1998) Detection of *Listeria monocytogenes* in humans, animals and foods. *J Vet Med Sci* **60**, 1341–1343.
- Inoue, S., Nakama, A., Arai, Y., Kokubo, Y., Maruyama, T., Saito, A., Yoshida, T., Terao, M. *et al.* (2000) Prevalence and contamination levels of *Listeria monocytogenes* in retail foods in Japan. *Int J Food Microbiol* **59**, 73–77.
- Jorgensen, L.V. and Huss, H.H. (1998) Prevalence and growth of *Listeria monocytogenes* in naturally contaminated seafood. *Int J Food Microbiol* **42**, 127–131.
- Kanuganti, S.R., Wesley, I.V., Reddy, P.G., McKean, J. and Hurd, H.S. (2002) Detection of *Listeria monocytogenes* in pigs and pork. *J Food Prot* **65**, 1470–1474.
- Mead, P.S., Slutsker, L., Dietz, V., McCaig, L.F., Bresee, J.S., Shapiro, C., Griffin, P.M. and Tauxe, R.V. (1999) Food-related illness and death in the United States. *Emerg Infect Dis* **5**, 607–625.
- Muraoka, W., Gay, C., Knowles, D. and Borucki, M. (2003) Prevalence of *Listeria monocytogenes* subtypes in bulk milk of the Pacific Northwest. *J Food Prot* **66**, 1413–1419.
- Norrung, B., Andersen, J.K. and Schlundt, J. (1999) Incidence and control of *Listeria monocytogenes* in foods in Denmark. *Int J Food Microbiol* **53**, 195–203.
- Norton, D.M., McCamey, M.A., Gall, K.L., Scarlett, J.M., Boor, K.J. and Wiedmann, M. (2001) Molecular studies on the ecology of *Listeria monocytogenes* in the smoked fish processing industry. *Appl Environ Microbiol* **67**, 198–205.
- Peccio, A., Autio, T., Korkeala, H., Rosmini, R. and Trevisani, M. (2003) *Listeria monocytogenes* occurrence and characterization in meat-producing plants. *Lett Appl Microbiol* **37**, 234–238.
- Pini, P.N. and Gilbert, R.J. (1988) The occurrence in the U.K. of *Listeria* species in raw chickens and soft cheeses. *Int J Food Microbiol* **6**, 317–326.
- Uyttendaele, M., De Troy, P. and Debevere, J. (1999) Incidence of *Listeria monocytogenes* in different types of meat products on the Belgian retail market. *Int J Food Microbiol* **53**, 75–80.
- Vitas, A.I. and Garcia-Jalon, V.A. (2004) Occurrence of *Listeria monocytogenes* in fresh and processed foods in Navarra (Spain). *Int J Food Microbiol* **90**, 349–356.
- Wiedmann, M., Bruce, J.L., Keating, C., Johnson, A.E., McDonough, P.L. and Batt, C.A. (1997) Ribotypes and virulence gene polymorphisms suggest three distinct *Listeria monocytogenes* lineages with differences in pathogenic potential. *Infect Immun* **65**, 2707–2716.
- Wu, S.Y., Li, Y.H., Ran, L., Fu, P., Li, Z.G. and Yao, J.H. (2003) Active surveillance on *Listeria monocytogenes* in seven kinds of food in 11 provinces of China in 2001. *Zhonghua Liu Xing Bing Xue Za Zhi* **24**, 657–660.
- Zhou, X. and Jiao, X. (2004) Investigation of *Listeria monocytogenes* contamination pattern in local Chinese food market and the tracing of two clinical isolates by RAPD analysis. *Food Microbiol* **21**, 695–702.
- Zhou, X., Jiao, X. and Wiedmann, M. (2005) *Listeria monocytogenes* in the Chinese food system: strain characterization through partial actA sequencing and tissue-culture pathogenicity assays. *J Med Microbiol* **54**, 217–224.