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Detection of *Listeria monocytogenes* by Using the Polymerase Chain Reaction  

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A method was developed for detection of *Listeria monocytogenes* by polymerase chain reaction amplification followed by agarose gel electrophoresis or dot blot analysis with a 32P-labeled internal probe. The technique identified 95 of 95 *L. monocytogenes* strains, 0 of 12 *Listeria* strains of other species, and 0 of 12 non-*Listeria* strains.

*Listeria monocytogenes* has long been acknowledged as a cause of sporadic human infection in immunocompromised patients, newborns, and pregnant women (4). However, in recent years, outbreaks of listeriosis which have been associated with the consumption of contaminated food have been recognized (2, 6, 13). It has therefore become increasingly important to identify contamination of food with *L. monocytogenes* to prevent new outbreaks. Isolation and identification of the organism by standard microbiological techniques are slow and laborious (4). Thus, we have sought to develop a method for the rapid detection of the organism using genetic techniques.

All pathogenic strains of *L. monocytogenes* are known to be hemolytic, with two hemolysins identified (11). Transposon mutagenesis studies have indicated that the sulfhydryl-activated hemolysin, listeriolysin O, is an important virulence factor for the organism (3, 8). The gene for this protein has been identified and sequenced from a serotype 1/2a *L. monocytogenes* strain by Mengaud and colleagues (9). We have used a portion of this gene sequence to develop a polymerase chain reaction (PCR) assay for detection of *L. monocytogenes* (12).

Initial studies were performed with the Maritime *L. monocytogenes* strain (13). Chromosomal DNA was purified by standard techniques (7), and PCR amplification was performed by the methods of Saiki et al. (12) with a pair of 24-mer oligonucleotide primers that define a 606-base-pair segment of the listeriolysin gene (9). Thirty amplification cycles were performed, each consisting of denaturation at 94°C for 2 min, primer annealing at 51°C for 2 min, and extension at 74°C for 2.5 min. The reaction products were analyzed by agarose gel electrophoresis followed by ethidium bromide staining. When 10-fold dilutions of the purified chromosomal DNA were tested, the predicted 606-bp segment was successfully amplified in samples containing 18 ng to 1.8 μg of chromosomal DNA (Fig. 1A). Studies performed with purified chromosomal DNA from *Listeria ivanovii* ATCC 19119 and *Listeria seeligeri* SLCC 3954 at concentrations of 10 ng and 1 μg resulted in no detectable amplified DNA, as expected. To confirm the identity of the 606-bp amplification product from the *L. monocytogenes* DNA, slot blot hybridization was performed with a 32P-labeled 24-mer oligonucleotide probe that is internal to the primer pairs on the listeriolysin O gene. The probe hybridized with the PCR products of samples containing as little as 5 ng of template *L. monocytogenes* DNA (Fig. 1B), but no hybridization signal was observed with the primers or unamplified *L. monocytogenes* DNA (data not shown).

We next determined whether the PCR technique could be used with crude bacterial cell lysates. *L. monocytogenes* cells were suspended in sterile distilled water, and lysis was attempted with sonication for 60 s, boiling for 2 min, or treatment with 1% sodium dodecyl sulfate and 1 mg of lysozyme per ml. By using hybridization with the 32P-labeled oligomeric probe described above, it was possible to detect amplification products ranging from approximately 4 to 400 boiled *L. monocytogenes* CFU (Fig. 2A); results were less favorable with the other lysis techniques. Using agarose gel electrophoresis (without a probe) to detect the amplification product, we were able to consistently identify as few as 104 *L. monocytogenes* CFU suspended in water (Fig. 2B).

To define the sensitivity and specificity of the assay, the PCR technique was applied to other bacterial strains by using crude cell lysates of 108 CFU as the template and agarose gel electrophoresis for product detection. A 606-bp PCR product was obtained from 95 of 95 human, food, environmental, animal, and research laboratory *L. monocytogenes* isolates (Table 1). Some strain-to-strain variability in the relative efficiency of the cell lysis by sonication or boiling was observed (data not shown). In contrast, with the same cell concentration and lysis techniques, a PCR product was not obtained from 12 strains representing non-*L. monocytogenes* *Listeria* species and 12 strains of other genera (Table 1). Each of these strains was tested at least in duplicate, by both the boiling and sonication cell lysis methods.

The utility of the PCR assay for detection of *L. monocytogenes* in commercial whole homogenized milk or human cerebrospinal fluid (CSF) was then studied. Fluid samples were inoculated with the Maritime strain, and the cells were pelleted by centrifugation at 5,000 × g, washed in saline and then in water, and then lysed by microwaving. Successful amplification of listerial DNA occurred in each fluid at cell concentrations of 105 CFU/ml (Fig. 3).
The results of this study demonstrate that PCR amplification of the listeriolsin O gene may provide a rapid alternative to standard techniques for the detection of L. monocytogenes in biological fluids and food products. All L. monocytogenes strains tested to date have been successfully detected by this assay regardless of isolate source, serotype, or electrophoretic type. This compares favorably with a recently reported probe which detects all serotypes except 4a by conventional nucleic acid hybridization (10).

Recent studies using DNA hybridization techniques and affinity-purified antibodies have suggested that L. ivanovii ATCC 19119 and L. seeligeri SLCC 3954 contain a gene homologous to the L. monocytogenes listeriolsin gene and produce a protein recognized by antiserum to the L. monocytogenes protein (5). We did not detect a PCR amplification product from whole-cell lysates or purified DNA from these strains. This discordance is likely due to the high degree of stringency of the PCR procedure which we employed.

This assay may prove to be useful for rapid detection of L. monocytogenes in CSF and blood samples in the clinical laboratory. In the food industry, where contamination of surfaces, equipment, and food with nonpathogenic Listeria spp. is common, the ability to rapidly detect pathogenic Listeria strains without cross-reaction with nonpathogenic strains can potentially improve upon current approaches. However, because the concentration of bacteria in contaminated foods is frequently less than $10^3$ cells per ml (1), the sensitivity of the assay must be improved before it can be used directly on clinical or food samples.
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LITERATURE CITED

FIG. 3. Agarose gel electrophoresis (1.2% agarose gel with 0.125 μg of ethidium bromide per ml) of products of PCR amplification of L. monocytogenes cells in milk or CSF. Lane 1, 10⁷ CFU in saline; lane 2, 1-kilobase ladder; lane 3, 10⁴ CFU in milk; lane 4, 10⁶ CFU in milk; lane 5, 10⁵ CFU in milk; lane 6, 10⁴ CFU in milk; lane 7, 10⁵ CFU in CSF; lane 8, 10⁴ CFU in CSF; lane 9, 10⁵ CFU in CSF. The amplified segments all appeared at a size of approximately 606 bp.