was temperature abused, the normal aerobic spoilage microflora could be suppressed, but pathogenic facultative anaerobes would grow unabated (Genigeorgis, 1985; Hintlian and Hotchkiss, 1986; Gill and DeLacy, 1991). At present, there is little epidemiological or other data available indicating that there are any problems with VP/MAP of raw beef. However, the potential must be considered when evaluating the hazards associated with beef.

B. Potential for Foodborne Pathogens

Low levels of pathogenic bacteria can be isolated from a varying percentage of raw beef products. A number of studies have examined raw beef products for *L. monocytogenes* worldwide, with reported incidence rates ranging from 0 to >50% (Ryser and Marth, 1991). The incidence rates for *Salmonella* on raw beef are generally low (<5%); however, higher rates have been reported (Felsenfeld, et al., 1950; Weissman and Carpenter, 1969; Goo, et al., 1973; Nazer and Osborne, 1976; Stolle, 1981). The incidence of *E. coli* 0157:H7 in raw beef appears to be low, and associated with dairy cattle (Doyle and Schoeni, 1987; Belongia, et al., 1991; Wells, et al., 1991).

The sources of pathogenic microorganisms vary. For example, *S. aureus* is generally associated with food handlers or mastitic cows. *Salmonella, E. coli*, and other enteric pathogens are typically associated with fecal material and can be commonly isolated from the hooves and hides of cattle (Stolle, 1981). There appear to be several means by which enteric pathogens become attached to raw beef, though there does appear to be a preferential binding to connective tissue (Benedict, et al., 1991). Recent research has indicated that the preferential binding of *Salmonella* to connective tissue involves a genetically encoded cell surface binding site (Sanderson, et al., 1991). *L. monocytogenes* can be endemic in cattle; however, recent European studies (Ryser and Marth, 1991) suggest that the food processing environment can be an important source of this pathogen. The presence of low levels of pathogenic bacteria on beef may be unavoidable; however, care must be exercised to ensure that this level is minimal. Further, beef products should be handled in a manner that assures that pathogens of significance have little or no opportunity to proliferate (Gill and DeLacy, 1991).

A variety of mesophilic foodborne pathogens are potentially capable of growing in the microbiological environment associated with both the surface or the interior if the meat is held above 8–10°C (Mackey, et al., 1980; Grau, 1981; Gibson and Roberts, 1986; Smith, 1987). The microflora of raw beef may contain members that competitively inhibit the growth of enteric pathogens such as *Salmonella* under certain conditions (Gilliland and Speck, 1977; Gill and Newton, 1980). However, a number of studies have concluded that the microflora of raw beef cannot be relied on to prevent the growth of mesophilic pathogens in temperature-abused beef (Mackey, et al., 1980; Smith, 1985, 1987; Mackey and Kerridge, 1988). Further, vacuum and modified atmosphere packaged raw beef that is temperature abused at ≥12°C and ≥15°C may support significant growth of *Salmonella* before overt spoilage is detected (Gill and DeLacy, 1991). Initial studies on the growth characteristics of *E. coli* 0157:H7 (Buchanan and Klawitter, 1992c; Glass, et al., 1992) indicate that it is likely to behave in a manner similar to other serotypes of *E. coli* and *Salmonella* (Smith, 1985, 1987; Hughes and McDermott, 1989).

Psychrotrophic pathogenic species, including *L. monocytogenes*, *Yersinia enterocolitica*, *Aeromonas hydrophila*, and some strains of *Bacillus cereus*, represent a special concern because they are capable of growth at refrigeration temperatures. While both *Y. enterocolitica* and *B. cereus* have been epidemiologically linked to products of animal origin, typically they are not associated with raw beef products. *Aeromonas hydrophila* can be frequently isolated from refrigerated raw beef; however, the role of this organism in disease outbreaks involving non-immunocompromised individuals is still poorly understood (Palumbo, et al., 1991).

While there have been no outbreaks of listeriosis attributed to raw beef products, *L. monocytogenes*' growth characteristics, increased thermal resistance compared to enteric pathogens, and incidence in raw and cooked meat products (Ryser and Marth, 1991) has prompted investigations of its behavior in raw beef. *Listeria monocytogenes* is capable of growth in temperature-abused raw beef (Buchanan and Klawitter, 1992a); however, there are conflicting reports concerning the ability of the organism to grow in raw beef at ≥5°C (Kahn, et al., 1972; 1973: Johnson, et al., 1988a, b; Grau and Vanderlinde, 1988; Buchanan, et al., 1989; Gill and Reichel, 1989; Glass and Doyle, 1989; Shelef, 1989; Dickson, 1990; Buchanan and Klawitter, 1991; Kaya and Schmidt, 1989, 1991). The observed differences may be attributable to either the pH (Gill and Reichel, 1989; Kaya and Schmidt, 1991) or the physical form (cuts versus ground) (Buchanan and Klawitter, 1991) of the meat. The effects of individual microorganisms of meat microflora on the growth of *L. monocytogenes* include none, inhibitory, and even stimulatory, depending on the specific species or strain (Ingram, et al., 1990; Tran, et al., 1990; Mattila-Sandholm and Skytta, 1991). A number of raw meat isolates of lactic acid bacteria, particularly *Carnobacterium* and *Lactobacillus* species, have been reported to produce bacteriocins against *L. monocytogenes* (Schillinger and Lucke, 1989; Ahn and Stiles, 1990a, b; Mortvedt and Nes, 1990; Lewus, et al., 1991; Buchanan and Klawitter, 1992a, b). While there are potential applications for controlling foodborne pathogens through the use of a competitive microflora (Buchanan and Klawitter, 1992b), the current state of knowledge does not allow this to be relied on as a primary means of control. The primary means for controlling psychrotrophic pathogen growth remains the maintenance of storage temperatures as low as possible (≤2°C) and a normal low pH (<5.8).

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