Information related to meat fermentations at temperatures of 115°F or higher

Normally, there is a concern about pathogen growth and toxin production by *Staphylococcus aureus* during fermentations that are too slow. To avoid this problem, processors normally use the "degree-hour" values as Critical Limits. These values indicate how quickly the product pH must reach 5.3 or lower at various fermentation temperatures. However, there are no degree-hour values provided for fermentation temperatures of 115°F or higher.

The attached textbook information shows that growth of *Salmonella* and *Escherichia coli* O157:H7, and toxin production by *Staphylococcus aureus* are not reasonably likely to occur at 115°F or warmer. As a result, no time Critical Limit is necessary for a fermentation step done at 115°F or warmer.

The maximum temperature for *Salmonella* growth is 46.2°C, which 115.2°F (page 225 of the section from *Microorganisms in Foods*).

The maximum temperature for *E. coli* O157:H7 growth is 45°C, which is 113°F (page 129 of the section from *Microorganisms in Foods*).

The maximum temperature toxin production by *Staphylococcus aureus* is 46°C, which is 114.8°F (page 548 in the section from *Modern Food Microbiology*).

MICRO-ORGANISMS IN FOODS

5

CHARACTERISTICS OF MICROBIAL PATHOGENS

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The publisher would like to make clear that Microorganisms in Foods 5 carried an incorrect subtitle when first printed. The correct subtitle is Characteristics of Microbial Pathogens. We would like to apologise to the ICMSF for any inconvenience this error may have caused.

The Commission wish the book to be referenced as ICMSF (1996) *Microorganisms in Foods 5. Characteristics of Microbial Pathogens*, Blackie Academic & Professional, London (ISBN 0412 47350 X)

While storage at low temperatures may permit survival, the public health impact can be reduced by minimizing the number of salmonellae.

Control procedures must also recognize that salmonellae can become established and multiply in the food-processing environment, where they become a source of contamination. This problem is best controlled by a correct facility programme. These factors have been discussed previously (ICMSF, 1988).

Various procedures have been developed to destroy salmonellae in foods, including the use of heat, irradiation, acidification and combinations of factors. Many of the procedures reflect the information contained in the tabular section of this chapter. The ICMSF has discussed several of the common procedures used to destroy salmonellae in ready-to-eat foods. Procedures have been described for different classes of product, e.g. cooked turkey, dried milk, desiccated coconut, milk chocolate, peanut butter, dried infant formula, pasta, fermented sausage, mayonnaise and salad dressings (Simonsen *et al.*, 1987).

Table A Limits for growth of salmonellae when other conditions (e.g. temperature, pH, a_w) are near optimum

Conditions	Minimum	Optimum	Maximum
Temperature (°C)	5.2*	35–43	46.2
pH	3.8	7–7.5	9.5
a_w	0.94	0.99	>0.99

* Most serotypes fail to grow at <7°C

require special reagents and expertise and are time-consuming. Because of their limited usefulness in routine testing and their lengthy and sophisticated methodologies, these procedures will not be described here. Interested readers should refer to recent review articles (Doyle and Padhye, 1989; Doyle, 1991; Meng *et al.*, 1994).

Distribution in nature and importance in foods

At present, it is difficult to assess the extent to which these organisms are involved in foodborne illness throughout the world. Their involvement is probably understated, mainly because the procedures for isolation and characterization of EPEC, ETEC and EIEC are not suited to routine testing of foods and few laboratories are sufficiently equipped to identify these pathogens. Well-documented food-associated outbreaks due to EIEC (Doyle and Padhye, 1989), ETEC (Doyle and Padhye, 1989) and *E. coli* O157:H7 (Doyle, 1991; Griffin and Tauxe, 1991) have been described. Outbreaks caused by EPEC, EIEC or ETEC occur very infrequently in developed countries. In contrast, many food-related outbreaks of *E. coli* O157:H7 infection have been reported in the US, Canada and the UK during the past decade (Doyle, 1991). Most of these outbreaks have been associated with eating undercooked ground beef or, to a lesser extent, drinking raw milk. Few data are available on the prevalence of EPEC, ETEC or EIEC in foods, largely because of the absence of easily performed laboratory assays. A few surveys of ETEC in foods have been reported (Doyle and Padhye, 1989); however, isolates from these studies were not characterized as human pathogens. Hence, the significance of these results relative to food-borne disease is unknown. Certain foods in developing countries have been identified as vehicles of ETEC infections. A prospective study of traveller's diarrhoea in physicians attending a conference in Mexico City revealed that ETEC accounted for about 45% of cases of diarrhoea and that illness was associated with the consumption of salads containing raw vegetables (Merson *et al.*, 1976). Water has also been identified as an ETEC vehicle in several outbreaks as well as in surveys done in developing countries (Doyle and Padhye, 1989). Surveys of foods for *E. coli* O157:H7 in Wisconsin revealed that up to 3% of retail ground beef and 1–2% of pork and poultry were contaminated with the organism (Doyle and Schoeni, 1987; Padhye and Doyle, 1991).

Growth and survival characteristics

In several instances, data for non-pathogenic *E. coli* were included in the tables because data for the pathogenic types of *E. coli* were largely lacking. In addition, many of the studies done to determine the influence of environmental conditions on the survival and growth of pathogenic *E. coli* have been done with mixtures of EPEC, ETEC and EIEC. In such instances it is therefore not possible to distinguish the effects of various parameters on specific types of pathogenic *E. coli*.

Some strains of pathogenic *E. coli* can grow at temperatures as low as 7°C and as high as 46°C, the optimum range being 35–40°C. However, *E. coli* O157:H7 is slightly more limited in its growth range, with a minimum temperature for growth of 8°C, a maximum of about 44–45°C and an optimum of 37°C. Pathogenic *E. coli* generally survives well in foods at refrigeration temperature (3–7°C), with $\times 10^{0.5}$ to $\times 10^{1.5}$ reduction over 1–5 weeks storage; little or no change is observed in *E. coli* O157:H7 populations in ground beef over 9 months at −20°C while populations of non-pathogenic *E. coli* are reduced 10-fold over 38 weeks at -25.5°C.

Thermal inactivation studies have revealed that *E. coli* O157:H7 is more sensitive to heat than typical *Salmonella* spp. Hence, heat treatments that are sufficient to kill *Salmonella* should also kill *E. coli* O157:H7. Similarly, irradiation studies have revealed that non-pathogenic *E. coli* has no unique resistance to gamma irradiation and should be killed by treatments sufficient to eliminate *Salmonella*.

The effect of pH on growth is dependent on the type of acid present. *E. coli* O157:H7 can grow at pH 4.5 in a medium adjusted with HCl but not in a medium adjusted with lactic acid. Pathogenic *E. coli* will not grow in fermented cheeses at pH ≤ 5.4.

There have been few reports on the effect of preservatives and disinfectants on pathogenic *E. coli*. However, it has been determined that these bacteria can grow in 6% NaCl and are more tolerant to sodium chloride and sodium nitrite than typical strains of *Salmonella* spp. *E. coli* O157:H7 can grow, albeit slowly, in broth containing 6.5% NaCl but not 8.5% NaCl. Pathogenic *E. coli* has no unique resistance to chlorine and should be killed by treatments sufficient to destroy *Salmonella*.

There is increasing evidence that *E. coli* O157:H7 may survive, and even grow, on salad vegetables. When stored at 5°C, populations declined on shredded lettuce, diced cucumber and

Modern Food Microbiology

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INCIDENCE IN FOODS

In general, staphylococci may be expected to exist, at least in low numbers, in any or all food products that are of animal origin or in those that are handled directly by humans, unless heat-processing steps are applied to effect their destruction. They have been found in a large number of commercial foods by many investigators (see Chapters 4, 5, and 9; Tables 4–3, 4–14, 5–6, and 9–1).

NUTRITIONAL REQUIREMENTS FOR GROWTH

Staphylococci are typical of other Gram-positive bacteria in having a requirement for certain organic compounds in their nutrition. Amino acids are required as nitrogen sources, and thiamine and nicotinic acid are required among the B vitamins. When grown anaerobically, they appear to require uracil. In one minimal medium for aerobic growth and enterotoxin production, monosodium glutamate serves as C, N, and energy sources. This medium contains only three amino acids (arginine, cystine, and phenylalanine) and four vitamins (pantothenate, biotin, niacin, and thiamine), in addition to inorganic salts[73] Arginine appears to be essential for enterotoxin B production.[116]

TEMPERATURE GROWTH RANGE

Although it is a mesophile, some strains of *S. aureus* can grow as low as 6.7°C.[5] The latter investigators found three food-poisoning strains that grew in custard at 114°F (45.6°C) but decreased at 116–120°F (46.7–48.9°C), with time of incubation. They grew in chicken à la king at 112°F (44.4°C) but failed to grow in ham salad at the same temperature. In general, growth occurs over the range 7–47.8°C, and enterotoxins are produced between 10°C and 46°C, with the optimum between 40°C and 45°C.[98] These minimum and maximum temperatures of growth and toxin production assume optimal conditions relative to the other parameters, and the ways in which they interact to raise minimum growth or lower maximum growth temperatures are noted below.

EFFECT OF SALTS AND OTHER CHEMICALS

Although *S. aureus* grows well in culture media without NaCl, it can grow well in 7–10% concentrations, and some strains can grow in 20%. The maximum concentrations that permit growth depend on other parameters such as temperature, pH, water activity (a_w), and oxidation–reduction potential (Eh) (see below).

S. aureus has a high degree of tolerance to compounds such as tellurite, mercuric chloride, neomycin, polymyxin, and sodium azide, all of which have been used as selective agents in culture media. *S. aureus* can be differentiated from other staphylococcal species by its greater resistance to acriflavine. In the case of borate, *S. aureus* is sensitive, whereas *S. epidermidis* is resistant.[59] With novobiocin, *S. saprophyticus* is resistant, whereas *S. aureus* and *S. epidermidis* are not. The capacity to tolerate high levels of NaCl and certain other compounds is shared by *Micrococcus* and *Kocuria*, which are widely distributed in nature and occur in foods generally in greater numbers than staphylococci, thus making the recovery of the latter more difficult. The effect of other chemicals on *S. aureus* is presented in Chapter 13.