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Gastrointestinal outbreaks associated with fermented meats

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Abstract

Fermented meats, including salami, various types of fermented sauages and snack sticks have seen a revival in their popularity in recent years. The production of such foodstuffs generally lies in traditional techniques, however, both the quality and in particular the safety of such products intrinsically rests with the microbiology of the fermentation processes. Simultaneously, there has been increased concern over the safety of such products following the increased incidence of outbreaks of *Salmonella* and verocytotoxigenic *Escherichia coli* food-poisoning related to these products. This update reviews the prevalence of fermented meat associated food-poisoning outbreaks ($n = 13$) and the proposed microbiological specifications used to assess the safety of such foodstuffs.

Keywords: Fermented meat; Food poisoning

The modern food processor is under increasing demands to produce ''natural'', ''wholesome'' products, in order to appease today's health-conscious public and thus gain consumer acceptance. In a society where ''additive-free'' products are in vogue, food scientists are beginning to explore alternative methods of preservation, in order to meet current consumer demands. The employment of a natural fermentation procedure offers such an alternative and is beginning to gain popularity.

The production of fermented meat products began as one of humans' earliest attempts at preservation, possibly as far back as 1500 BC, when people learned that the addition of salt and sugar to ground meat, followed by a holding period was beneficial in the preservation of the meat and resulted in a product acceptable to the palate. As time passed, various geographical areas developed unique varieties of preserved meat products that varied in size, shape, texture and flavour. However, it was not until the time of Pasteur that it was realized that microorganisms caused this fermentation of carbohydrate to lactic acid. Today the production of fermented meat products relies largely on the employment of commercially available lyophilized single and mixed strain bacterial starter cultures to aid with a controlled fermentation.

The origins of human illness associated with the ingestion of fermented meats has been related to zoonotic contamination and subsequent survival of viable food-poisoning pathogens in processed products. The largest bacterial load in such products is that of the lactic acid starter cultures or the endogenous lactic acid flora in the fermentation mix or back-slop. Lactic acid bacteria are not commonly observed as invasive organisms in human clinical specimens, although they may be present in large numbers on the skin or in faeces. Therefore, as they are not frequently isolated from invasive sites, i.e., blood and cerebral spinal fluid, they are not generally considered to have a major pathogenic role in human disease. Previous studies in Southern Finland over the period 1989–1992 demonstrated lactobacilli to be of low pathogenic potential with only eight strains being isolated from a total of 3317 blood cultures (Saxelin et al., 1996). In 2000, only three patients produced a positive blood culture yielding an isolate of *Lactobacillus* spp., which was reported to the Northern Ireland Public Health Laboratory. However, there have been several historical reports of *Lactobacillus plantarum* being the causal agent of endocarditis (Bar, Euteneuer, & Schuster, 1987; Shinar, Leitersdorf, & Yevin, 1984).

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Frequently manufacturers add or encourage mould growth on the outer layers of the product to give the meat additional sensory characteristics, including taste, smell and appearance. However, it is important that fungal strains employed, either mould starter culture or traditional wild-type isolates do not produce aflatoxin or any other mycotoxins, as secondary metabolites. There have been several reports in the literature detailing the production of such compounds in fermented meats (Ciegler, Mintzlaff, Weisleder, & Leistner, 1972; Ostry & Polster, 1989).

More importantly, there have been several recent reports which highlight the significance of fermented meats being a source of food-poisoning organisms, resulting in outbreaks (Table 1). However, it should be remembered that outbreak cases represent the minority of all laboratory-confirmed cases of gastrointestinal infection and compared to other meat products, the number of outbreaks due to fermented is relatively small. Of concern has been the appearance of outbreaks of verocytotoxigenic *Escherichia coli* associated with fermented meats. However, it is difficult to estimate the true incidence of outbreaks and indeed sporadic cases of gastrointestinal infection associated with fermented meats, as reliance on the peer-reviewed literature alone might underestimate the true position since by definition, data published in the literature should be original and may not accurately reflect all actual outbreaks.

The production of fermented meats gives rise to several possible hazards, including mainly: (a) employment of contaminated raw meat with food-poisoning organisms, especially the verocytotoxigenic *E. coli* and (b) slow and inefficient fermentation processes, i.e., failure to lower pH significantly and quickly, anti-lactic acid bacterial bacteriophage activity.

The employment of the total viable count (TVC) is of limited value when examining these products using quantitative techniques. This is due to the endogenous lactic acid organisms giving rise to high counts, which cannot be correlated with the microbiological quality of the products. To overcome this, certain workers have added hydrogen peroxide to TVC plates and have subsequently enumerated only catalase-positive colonies, as the lactic acid flora do not produce catalase. However, finished product should conform to the microbiological guidelines, as previously described by Gilbert et al. (2000), with particular emphasis on faecal indicator organisms and pathogens, as detailed (Table 2). In addition, US guidelines have also recommended the detection of thermonuclease and enterotoxin, as *Staphylococcus aureus* may initially be present and produce toxin, but is gradually killed off during the fermentation process (Johnston & Tompkin, 1995).

Several reports have attempted to model the survival of gastrointestinal bacterial pathogens in fermented meats. In most of the outbreaks described in Table 1, the minimum infectious dose (MID) was not stated, with the exception of the outbreak of food-poisoning in the Netherlands in 1985, where the incriminated Bologna sausage was demonstrated to have 10^6 colony forming units (CFU) of *Salmonella typhimurium* per gram of sausage, in addition to 10^3 and 10^4 CFU/g of *S. aureus* and *Clostridium perfringens*, respectively (van Netten et al., 1986). Furthermore, Tilden et al. (1996) estimated that the MID in the outbreak of *E. coli* O157 in dry fermented salami was smaller than 50 *E. coli* O157:H7

Table 1
Food-poisoning outbreaks and foodborne illness associated with the consumption of fermented meats

Organism	Food type involved	Number of people affected	Country	Reference
(i) Confirmed outbreaks				
E. coli O157:H7	Genoa salami	39	Ontario, Canada	Williams et al. (2000)
E. coli O157:H7	Dry cured salami	23	Washington state and Northern California	Alexander et al. (1995) and Tilden et al. (1996)
E. coli O111:H-	Mettwurst	21	Adelaide, S. Australia	Paton et al. (1996)
S. typhimurium DT124	Salami sticks	101	England	Cowden et al. (1989)
S. typhimurium	Fermented pork, Bologna-style sausage	17	The Netherlands	van Netten, Leenaerts, Heikant, and Mossel (1986)
S. typhimurium PT193	Salami	83	Italy	Pontello et al. (1998)
C. botulinum	Fermented beaver tail and paw	14	Southwest Alaska, USA	Anon. (2001)
	Fermented trout	2	Hedmark, Norway	Schjonsby (2002)
	Fermented meats		Canada	Hauschild and Gauvreau (1985)
(ii) Epidemiological association				
Toxoplasma gondii	Salami	–	Poland	Paul (1998)
Salmonella and staphylococcal food-poisoning	Dry fermented sausage		The Netherlands	Hartog, de Boer, Lenssinck, and de Wilde (1987)
L. monocytogenes	Salami	–	Philadelphia, USA	Schwartz et al. (1989)

Table 2
Guidelines for the microbiological quality of fermented meats (Gilbert et al., 2000)

Criterion	Microbiological quality (CFU/g unless stated)			
	Satisfactory	Acceptable	Unsatisfactory	Unacceptable/potentially hazardous
(i) Indicator organisms				
Enterobacteriaceae	<100	100 to $<10^4$	$\geqslant 10^4$	N/A
E. coli (total)	<20	20 to <100	$\geqslant 100$	N/A
Listeria spp. (total)	<20	20 to <100	$\geqslant 100$	N/A
(ii) Pathogens				
Salmonella spp.	Not detected in 25 g			Detected in 25 g
Campylobacter spp.	Not detected in 25 g			Detected in 25 g
E. coli O157 and other VTEC	Not detected in 25 g			Detected in 25 g
L. monocytogenes	<20	20 to <100	N/A	$\geqslant 100$
S. aureus	<20	20 to <100	100 to $<10^4$	$\geqslant 10^4$
C. perfringens	<20	20 to <100	100 to $<10^4$	$\geqslant 10^4$
Bacillus cereus and other pathogenic *Bacillus* spp.	$<10^3$	10^3 to $<10^4$	10^4 to $<10^5$	$\geqslant 10^5$

bacteria. However, in most other cases, it was estimated that the MID was very small. Table 3 lists the MID of several bacterial and single-celled gastrointestinal pathogens, which demonstrates that with certain of these pathogens, for example, verocytotoxigenic *E. coli* O157:H7 and *Campylobacter jejuni*, the MID is extremely small (i.e., between 10 and 500 cells). Hence, this significantly reduces the margin for error for fermented meat manufacturers, whereby the HACCP control is to effectively completely eliminate all such pathogens from final product. In an attempt to do so, various predictive models have been developed. Pond, Wood, Memin, Barbut, and Griffiths (2001) examined three model systems to examine the survival of *E. coli* O157:H7 in uncooked, semidry fermented sausage. Three models were developed that included different variables to best describe *E. coli* O157:H7 reduction. Model A included the variables, water activity, pH, time and quadratic variables pH and time, whereas Model B separated the processing stages into fermentation and drying. The fermentation included the variables pH and temperature $\times$ time and interaction between the two variables. The drying stage was modeled using the variables time and water activity and interaction between the two. Finally, Model C looked at the variables, water activity and time at pH 5.3 to achieve a 2-D log reduction of *E. coli* O157:H7 and the interaction between the variables (Pond et al., 2001). Pond et al. concluded that modeling can be a useful tool in assessing manufacturing practices for uncooked fermented salami processes. Tilden et al. (1996) suggested that even with good manufacturing practices in place, *E. coli* O157:H7 may survive currently accepted processing methods. Heuvelink, Zwartkruis-Nahuis, Beumer, and de Boer (1999) demonstrated that *E. coli* O157 was present in a small number of fermented ready-to-eat meats (1/328) [0.3%] samples examined in the Netherlands and showed that this pathogen could remain viable at 7 or 15 °C in raw minced beef, even to which acetic acid was added, thus lowering the pH to 4.0. Whereas Levine, Rox, Green, Ransom, and Hill (2001) reported cumulative three year *Salmonella* and *Listeria monocytogenes* positive rates for dry and semidry fermented sausages to be 1.43% and 3.25%, respectively.

Table 3
Minimum infective dose of foodborne pathogens in human volunteers (Kothary & Babu, 2001)

Organism	Minimal infective dose
Bacteria	
C. jejuni	500
E. coli	
Enteropathogenic *E. coli* (EPEC)	10^6
Enterotoxigenic *E. coli* (ETEC)	10^7
Enteroaggregative *E. coli* (EaggEC)	10^8
Verocytotoxigenic *E. coli* (VTEC)	10
Salmonella anatum	5.9×10^5
Salmonella bareilly	1.3×10^5
Salmonella derby	1.5×10^7
Salmonella meleagridis	7.6×10^6
Shigella dysenteriae	10
Shigella flexneri	100
Shigella sonnei	500
Vibrio cholerae (classical)	10^4
V. cholerae (El Tor)	10^3
V. cholerae (O139)	10^4
V. cholerae (Non-01)	10^6
Vibrio parahaemolyticus	3×10^7
Single-celled organisms	
Cryptosporidium parvum	10
Entamoeba coli	1

The commercial production of fermented meats has potentially several inherent microbiological hazards within processing and therefore processors should

review their manufacturing procedures in terms of carrying out a comprehensive HACCP analysis. Consequently all raw meat should be considered to be contaminated with foodborne pathogens for the purposes of any risk assessment and controls put in place to eliminate these hazards to food safety. Even well-organized traditional operations which have historically produced safe quality products should review their operations in accordance with HACCP principles to maintain product safety.

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