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Safety and storage stability of horse meat for human consumption

C.O. Gill *

Agriculture and Agri-Food, Lacombe Research Centre, 6000 C&E Trail, Lacombe, Alberta, Canada T4L 1W1

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Abstract

Most horse meat is consumed by humans and/or animals in the region where it is produced. However, horse meat for human consumption is exported in large quantities from the Americas and in lesser quantities from Eastern Europe, to Western Europe and Japan where it is often eaten raw. Horse meat prepared to a good hygienic condition should not be prone to early microbial spoilage, but contamination of the meat with *Salmonella* and *Yersinia enterocolitica* may be relatively common, and infection of the meat with *Trichinella* may occur occasionally. Those organisms from horse meat could cause disease when the raw meat is eaten. Moreover, accumulation of cadmium in horse liver and kidney may render those tissues unsafe for human consumption.

Keywords: Horse meat; Microbial spoilage; *Salmonella*; *Yersina enterocolitica*; *Trichinella*; Cadmium

1. Introduction

Ancestral horses were evidently hunted to provide meat for humans in pre-historic times (Clutton-Brock, 1981). The horse was possibly first domesticated primarily as a meat animal. Even so, domestication probably involved some riding of the animals, because it seems unlikely that men on foot could have maintained control over herds of horses (Azzaroli, 1985). In historic times, the consumption of horse meat by people has varied widely with differences in the economies and cultures of human societies (Zeuner, 1963). Thus, milk and meat from the herds of horses essential for transport have been and still are important parts of the diets of the nomadic peoples of the Eurasian steppe (Conrad, 1978); but the consumption of horse meat in Western Europe was for long restricted, in part because eating it was associated with some pagan rites or festivals (Ciampi, 1961; Hertrampf, 2003). However, even in societies where horse meat is not regarded as a suitable food for humans, people may consume the meat in considerable quantities, knowingly or not (Cutrufelli, Mageau, & Schwab, 1991; Janssen, Hägele, Buntjer, & Lenstra, 1998). Unintended consumption of horse meat by people may be frequent when working horses are numerous and regulatory control of the meat supply is weak (Walley, 1896).

Readily available meat industry statistics apparently do not distinguish between horse meat intended for consumption by humans or by animals (MRH Viandes, 2004). For regions where there is essentially no market for horse meat as a human food, such as Australasia and North America, any product that was not exported could be regarded as animal food, while it seems likely that most imported horse meat are intended for human consumption (Table 1). Otherwise, the fraction of meat from horses that is used for human food is uncertain. For example, in Mexico it is apparently believed that "horse meat is seldom used for human consumption" (Perez Chabela, Rodriguesz Serrano, Lara Calderon, & Guerrero, 1999), yet the country produces some 70,000

* Tel.: +1 403 782 8113; fax: +1 403 782 6120.
E-mail address: gillc@agr.gc.ca.

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Table 1
Amounts of horse meat produced within the regions of the world, and amounts exported or imported by countries within each region during 2001

Region	Horse meat (thousands of tonnes)		
	Produced	Exported	Imported
Asia	281	–	10
Eastern Europe	12	10	8
Western Europe	64	42	113
North America	39	25	–
Central America	79	2	3
South America	84	54	–
Australasia	21	4	–
Not identified	114	15	6
World total	*694*	*152*	140

Data from MRH Viandes (2004).

Table 2
Amounts of horse meat produced within, exported from or imported to countries that were major importers of horse meat during 2001

Country	Horse meat (thousands of tonnes)		
	Produced	Exported	Imported
Italy	51	–	23
Belgium	–	29	37
France	13	6	30
The Netherlands	–	5	13
Japan	–	–	10

Data from MRH Viandes (2004).

tonnes of that meat per year and exports little (MRH Viandes, 2004). Whatever the quantities of the available horse meat that are eaten by humans or animals, the statistics show that most such meat is consumed in the country where it is produced. The main exporters of horse meat are countries in South and North America and Western Europe. The meat exported from the Americas is mostly shipped to other regions, but the meat exported from Western European countries is traded mainly to other countries within the region. As working horses are not common in Western Europe, many of the horses slaughtered there are imported from countries in Eastern Europe (Ancelle, 1998).

Horse meat is exported from other regions mainly to Western Europe. Only four Western European countries and Japan commonly import more than ten thousand tonnes of this meat each year (Table 2). Horse meat is regarded as a human food in all those countries, and it appears that most of the imported horse meat is intended for human consumption.

Horse meat may provide a relatively cheap source of animal protein in countries where horses are extensively used as draft animals and for human transport. However, in industrialized countries, the numbers of horses are relatively small. Consequently, in such countries the meat may become something of a luxury item. It might then be expected that horse meat imported into industrialized countries would be mainly in the forms of boxed, vacuum packaged or frozen product, to extend the storage life and minimize transportation costs, as with beef. Considerable quantities of frozen meat are indeed traded, and Japan imports substantial quantities of vacuum packaged product. Even so, much horse meat is imported into Europe in carcass form. The value of the product in Western Europe is sufficient to allow the regular air freighting of chilled carcass quarters to Europe from the Americas (Gill & Landers, 2004).

Horses slaughtered for human consumption have been mainly working animals, supplement by the feral animals that are found in some places. Where working horses are few, many of the animals available for slaughter are horses that were reared for recreational riding or racing. The slaughter for human consumption of such companion animals and wild horses is not considered acceptable by some. Thus, the slaughter of horses for human consumption has been severely curtailed in the USA and may ultimately be made illegal there (Castaldo, 2002). The possibility of other industrialized countries following such a lead cannot be wholly discounted. Alternatively it is possible that horses may be raised specifically for meat, as seems to be occurring in some Eastern European counties for supply of the Western European market (Murrell et al., 2004).

In some countries where horse meat is sold, such as France, Italy and Mexico, it has traditionally been retailed by butchers who deal in only that meat (Chemorin, 2002; Pennazio, Cantoni, & Julini, 1988; Perez Chabela et al., 1999). However, in European countries at least, horse as well as other meats are apparently being sold increasingly by supermarkets (Laurichesse et al., 1997).

Butchering of horse meat can include the removal of tendons or thin slicing to obtain a tender product (Chemorin, 2002). The meat is apparently thoroughly cooked in various dishes in all countries where horse meat is eaten, and is prepared in various preserved forms (Paleari, Soncini, Beretta, & Rossi, 1992). However, in some countries, notably France, Italy and Japan, it is commonly eaten raw or after only minimal cooking, as many consumers of horse meat in those countries apparently believe that diseases are less likely to be acquired from horse than from other meats (Magras, Fédérighi, & Soulé, 1997). The consumer preference for raw horse meat must be taken into account when assessing the risks associated with its consumption.

2. Storage quality

There appears to have been little study of the storage qualities of horse meat. However, the storage stability of the meat can be deduced by consideration of the general behaviour of meat spoilage flora, the composition of the meat, and its microbiological condition at packing plants.

Meat stored in air is usually spoiled by the activities of the strictly aerobic pseudomonads which impart putrid odours and flavours to the meat when glucose is exhausted or unavailable and amino acids are consumed instead (Dainty, Edwards, & Hibbard, 1985). When glucose is present in tissues at concentrations about or above 0.1 mg/g, spoilage is delayed until the numbers of the spoilage flora are about 10^8 cfu/cm^2. If little or no glucose is present in the tissues, spoilage occurs when bacterial numbers are about 10^6 cfu/cm^2 (Gill, 1996).

Under anaerobic conditions, as in vacuum packs, the aerobic flora is suppressed and one dominated by lactic acid bacteria will develop. If the meat pH is <5.8, acid and dairy spoilage odours and flavours will develop only after the flora has attained maximum numbers of about 10^8 cfu/cm^2. However, if the pH is >5.8, more potent spoilage organisms can grow to cause early spoilage of the meat (Stanbridge & Davies, 1998).

As little glucose is present at fat tissue surfaces, and the tissue pH is > 6.0 fat can spoil before muscle tissue, if the fat tissue remains moist without being bathed in exudate from the muscle (Gill & Newton, 1980). Drying of fat surfaces on carcasses and spreading of exudate over the surfaces of vacuum packaged cuts generally preclude the early spoilage of fat tissue, which has not been reported for horse meat.

During the development of rigor in muscle tissue, much of the glycogen in the tissue is converted to lactic acid; and relatively small amounts of glucose are formed from glycogen as a result of alpha-amylase activity (Bendall, 1973). When muscle tissue is initially rich in glycogen, some will still be present in the tissues when rigor is complete. The tissue pH will then be about 5.5, and lactic acid and glucose will be present at concentrations of about 9 and $\geqslant$0.1 mg/g, respectively (Nychas, Dillon, & Board, 1988). If the muscle tissue is deficient in glycogen, glucose will be wholly depleted while the pH is still high, and the tissue will contain little or no glucose. Meat in that condition can have a dark, firm and dry (DFD) appearance, and will spoil relatively rapidly under either aerobic or anaerobic conditions (Gill, 1986).

Although published data on the composition of horse muscle are limited, it appears that the tissue is generally relatively rich in glycogen. Initial glycogen concentrations of up to 22 mg/g have been reported for horse muscle, while the glycogen content of beef muscle is generally $\leqslant$10 mg/g (Lawrie, 1998). Consequently, after the completion of rigor, horse muscle could be expected to have a low pH and relatively high concentrations of residual glycogen and glucose. Indeed, the ultimate pH of horse muscle has been reported to be generally <6.0, with the pH of the *Longissimus dorsi* usually being $\leqslant$5.8 (Ley, 1996); and the concentrations of glycogen and reducing sugars, which would include glucose, in the *L. dorsi* muscle post rigor have been reported as >5 and >0.5 mg/g, respectively (Ulyanov & Tuleuov, 1976). DFD horse meat has not been reported; and horse meat of a pale, soft, exudative (PSE) or watery condition also has apparently not been observed. The PSE condition in pork and the watery condition in beef arise when the pH of muscle tissue falls rapidly to attain low values while the tissue is still warm (Borchert & Briskey, 1964; Fischer & Hamm, 1980). If DFD and PSE quality defects are indeed absent from horse meat, that may be a result of horses being bred for work rather than for meat production.

In view of the findings that indicate a generally low pH and high glucose content for horse muscle, the storage quality of the meat should be generally good, provided that microbiological contamination is well controlled during its preparation. The microbiological condition of horse meat prepared in Mexico and Tunisia may be poorer than that of the other meats prepared in those countries (Fliss, Simard, & Ettriki, 1991; Perez Chabela et al., 1999). Those findings probably reflect poor conditions and/or practices at facilities for slaughtering horses and butchering the meat, as the microbiological conditions of horse carcasses in France and North America are reported to be similar to those of dressed beef carcasses produced in those countries (Gill & Landers, 2004; Hubard, Dorey, & Collobert, 1996). Moreover, the microbiological conditions of horse meat and beef produced in at least some areas of South America may be similar, in view of the similar microbiological conditions found for South American, vacuum packaged horse meat and beef available commercially in Europe (Paleari, Bersani, Vittorio, & Beretta, 2002). However, it must be noted that the microbiological conditions of horse and beef carcasses at the end of processing at North American slaughtering plants are likely to differ, because beef carcasses at most North American plants are now subjected to decontaminating treatments, such as pasteurizing, while horse carcasses are not (Gill & Landers, 2003). Consequently, in North America, the final microbiological condition of beef carcasses can be considerably better than that of horse carcasses.

Despite the similar microbiological conditions of horse and beef carcasses in some regions, there appears to be a common belief that horse meat spoils more rapidly than beef. That has been attributed to enhanced microbial growth in the former meat as a consequence of its high glycogen content (Rossier & Berger, 1988). As the presence of glycogen in the meat could not accelerate the growth of the spoilage flora, that explanation can be dismissed. Indeed it appears that horse meat in carcass or vacuum packaged forms may show marked microbiological stability, because of the drying of carcass surfaces or because the pH of and initial microbial loads on cuts are both usually low (Becherel, 1991). Perceptions of early spoilage probably arise from the relatively rapid and obvious discoloration of horse meat in air, which is related to the high levels of myoglobin in the muscle (Becherel, 1991).

3. Enteric pathogens

The carriage of *Salmonella* by horses is well established. *Salmonella* were recovered from the faeces of only 3% of horses entering a veterinary hospital in the US (Smith, Reina-Guerra, & Hardy, 1978), but from 13% of horses with colic but not diarrhea admitted to a second US hospital (Palmer, Benson, & Whitlock, 1985). Such findings would suggest that *Salmonella* is relatively infrequent in healthy horses. However, *Salmonella* were recovered from 15% of caecal samples and from 27% of faecal samples from horses slaughtered at plants in the US and Argentina, respectively (Anderson & Lee, 1976; Quevedo, Dobosch, & Gonzáles, 1973). The incidence of *Salmonella* in samples of meat from horse carcasses at the US plant was 27% (Anderson & Lee, 1976). High incidences of *Salmonella* in tissue from horse carcasses have also been found elsewhere, with 18 % of mesenteric lymph nodes from horses slaughtered at a Brazilian plant, and 47% of lymphatic and muscle tissue samples from horse carcasses at an Argentinean plant being positive for *Salmonella* (Giorgi, 1973; Monteverde, Simeone, Morán, Hermida, & Colombino, 1969).

In contrast, only about 4% of samples of muscle tissues from the carcasses of horses and donkeys slaughtered at a Brazilian plant were positive for *Salmonella* (Hofer et al., 2000). Similarly, only about 2% of samples of liver and mesenteric lymph nodes from horses slaughtered at an Italian plant were *Salmonella* positive (Mann, Cavrini, & Pieracci, 1964); and no *Salmonella* were recovered from samples of surface tissue from the carcasses of horses slaughtered at a French plant (Collobert, Guyon, Dieuleveux, & Dorey, 2001). The horses slaughtered at the Italian plant included animals from not only Italy but also from several other countries in both Western and Eastern Europe. The same would probably be true of the horses slaughtered at the French plant, given the limited number of French horses available for slaughter in recent years.

The samples from horses slaughtered at the French plant were examined for *Campylobacter* and *Escherichia coli* O157:H7 also. No sample yielded *Campylobacter* and *E. coli* O157:H7 was recovered from only one of the 320 carcasses (Collobert et al., 2001). Verotoxigenic *E. coli* (VTEC) were not recovered from any of a few swab samples from horse carcasses or of horse meat, which were included in large numbers of samples of both those types from various species (Piérard, Van Damme, Moriau, Stevens, & Lauwers, 1997); and *E. coli* O157:H7 was not detected in 50 samples of ground horse meat from Northern Italy (Bacci et al., 2002). In a German study, VTEC were isolated from only about 1% of the faecal samples from some 400 horses; and from only one of 43 samples of ground horse meat (Pichner, Sander, & Gareis, 2001).

Those findings suggest that *Campylobacter* and VTEC may be uncommon on horse meat. However, contamination of horse carcasses with *Yersinia enterolitica* may be relatively frequent, as that organism was recovered from 28% of caecal content samples from some 200 horses slaughtered at an Italian plant (Cattabiani, Ossiprandi, & Freschi, 1995). Examination of faecal samples from animals not presented for slaughter also indicated that *Yersina enterocolitica* may commonly be carried by horses, in which it can cause disease (Bottarelli, Ossiprandi, Freschi, & Cattabiani, 1997; Vaissaire, Moret, & Gueraud, 1994). Thus, the findings for horses and carcasses suggest that horse meat on retail sale may be frequently or infrequently contaminated with *Salmonella*, depending on the source of the meat; while *Y. enterocolitica* too may be relatively common, and *Campylobacter* and VTEC may be infrequent contaminants of horse meat.

High incidences of *Salmonella* in samples of frozen meat from Argentina, Brazil and Uruguay have indeed been reported (van Schothorst & Kampelmacher, 1967), while *Salmonella* was recovered from 10% of samples from horse meat imported into France (Dorey & Collobert, 1999). However, in a recent study no *Salmonella* were recovered from frozen horse meat in Brazil (de Assis, Destro, Franco, & Landgraf, 2000). Moreover, *Salmonella* were recovered from none and 2% of chilled horse meat from animals slaughtered within Italy and France, respectively; (Dorey & Collobert, 1999; Pollastri, Magri, Colantoni, & Fagan, 1994). *Y. enterocolitica* were recovered from 3% of Italian ground horse meat (Pollastri et al., 1994), but *Campylobacter* was recovered from neither domestic nor imported horse meat on retail sale in France (Dorey & Collobert, 1999). There appears to be no report on the presence of VTEC in horse meat offered for retail sale.

The limited information available therefore indicates that *Salmonella* must and *Y. enterocolitica* might be expected on horse meat, although the incidences of both may well be low when the meat is prepared under good hygienic conditions. *Campylobacter* and VTEC may be rare on horse meat, but whether that is so must be uncertain while relevant data are few or entirely lacking.

In addition to the four pathogens that have been discussed, horse meat offered for retail sale has been examined for the presence of *Listeria monocytogenes*. The incidence of *L. monocytogenes* in frozen horse meat from Brazil and ground horse meat in Morocco have both been reported to be about 7% (de Assis et al., 2000; Kriem, el Marrakchi, & Hamama, 1998); while the incidence of *L. monocytogenes* in raw cured meat in Belgium was found to be 6% (Uyttendaele, De Troy, & Debevere, 1999). The *L. monocytogenes* found on horse meat may

Table 3
Outbreaks of trichinellosis in Western Europe linked to consumption of horse meat, 1975–1998

Country	Date (month/year)	Number of cases	Origin of the infected horse or meat	Product imported	Species of *Trichinella*
France	12/75	125	Eastern Europe	Horse	N.D.[b]
	8/85	431	USA	Carcass	*T. murelli*
	10/85	642	West German (Poland?)[a]	Carcass	*T. spiralis*
	2/91	21	USA	Carcass	N.D.
	12/93	538	Canada	NS[c]	*T. spiralis*
	9/94	7	Mexico	NS	*T. spiralis*
	3/98	128	Serbia	Horse	*T. spiralis*
	–/98	407	Serbia	Horse	*T. spiralis*
Italy	10/75	89	Yugoslavia or Poland	Carcass	*T. britovi*
	–/84	13	Yugoslavia	Carcass	N.D.
	–/86	>300	Yugoslavia or Poland	Carcass	*T. britovi*
	–/90	>500	N.D.	Carcass	*T. spiralis*
	2/98	92	Poland (Serbia?)[a]	Horse	*T. spiralis*

Data from Ancelle (1998) and Boireau et al. (2000).
[a] The carcass or horse was imported from the named country, but the animal may have originated from the country in parenthesis.
[b] Not determined.
[c] Not stated.

have originated from flora persisting in packing and processing plants rather than, or as well as from organisms derived directly from the hide or gut contents of animals during carcass dressing (Gobat & Jemmi, 1991). Whatever the source or sources of the organism it appears the *L. monocytogenes* must be expected on horse meats offered for retail sale.

4. Parasites

Outbreaks of trichinellosis associated with the consumption of horse meat have occurred in France and Italy, where it is commonly consumed raw, and Mexico (Pozio, 2001). Animals as well as humans acquire trichinellosis by consumption of muscle tissue that harbours larvae of *Trichinella* spp. (Murrell, Fayer, & Dubey, 1986). Thus the presence of *Trichinella* in the muscle tissue of the herbivorous horse requires some explanation.

The incidence of *Trichinella* in slaughtered horses is very low (de Borchgrave, Geerts, Buyse, & vanKnapen, 1991). The species mostly responsible for outbreaks of trichinellosis associated with the consumption of horse meat is *Trichinella spiralis* which is the species involved in the classic domestic cycle of human infection. The domestic cycle results from the consumption of inadequately cooked, infected pork, with infection of domesticated pigs by feeding them waste containing infected pork (Campbell, 1988). However, outbreaks of horse meat associated trichinellosis involving *Trichinella britovi* and *Trichinella murelli*, which are species found in wild, carnivorous animals such a foxes, bears and racoons, have been reported (Dick, de Vos, & Dupouy-Camet, 1990; Pozio, Cappelli, Marchesi, Valeri, & Rossi, 1988). *T. britovi* and *T. murelli* occur, respectively, in temperate regions of Eurasia and North America (Pozio, 2001).

Outbreaks of trichinellosis resulting from the consumption of horse meat have occurred in Western Europe after as well as before the implementation in 1985 of an international requirement that samples of muscle tissue from all horses slaughtered for human consumption be examined microscopically for the presence of *Trichinella* (Ancelle et al., 1998). The 13 documented outbreaks during the years between 1975 and 1998, inclusive, have involved reported cases that ranged from <10 to >600 (Table 3). However, the numbers of outbreaks and cases may be underestimated, because mild infections with *Trichinella* may cause only influenza-like symptoms that are likely to be attributed to the common, viral disease rather than to a relatively rare, parasitic infection (Ancelle, 1998). Apart from human error and the low incidence of infection, factors contributing to failures to identify infected carcasses may include small numbers of *Trichinella* larvae in the meat, and examination of tissue from the diaphragm when larvae may be more numerous in tongue and head muscles (Boireau et al., 2000; Gamble, Gajadhar, & Solomon, 1996).

Reported outbreaks of trichinellosis associated with the consumption of horse meat have mostly involved meat from horses that originated from countries in Eastern Europe where trichinellosis in pigs has become prevalent in recent years (Boireau et al., 2000). Apparently, some 30% of horses in that region will readily consume both raw and cooked meats (Murrell et al., 2004). Presumably, meat would also be consumed by a substantial fraction of horses elsewhere. It has therefore been suggested that trichinellosis in horses may be largely due to the intentional feeding of horses destined for slaughter with mashes that have been prepared with the inclusion of waste meats, food scraps, and/or the carcasses of animals reared or captured for their skins (Murrell et al., 2004; Pozio, 2001). Such mashes are fed to improve the condition of, and thus increase the price obtained for horses that are to be sold for slaughter. Even so, the acquisition of *Trichinella* from the carcasses of infected rodents present in feeds or on pastures by chance cannot be wholly discounted (Pozio, 2001).

Whatever the source of the *Trichinella*, it appears that some infection of horses must be expected while they are mostly reared and managed for purposes other than the provision of meat. The risk of humans acquiring *Trichinella* from horse meat seems to be disappearingly small when the usual preparation of the meat involves it being thoroughly cooked (Boireau et al., 2000). However, occasional outbreaks of human trichinellosis may be inevitable in regions where horse meat is preferably eaten rare or raw, at least until the absence from the meat of *Trichinella* larvae can be assured by some more efficient and certain method than the microscopic examination of muscle tissue samples (van Knapen, 2000).

It has been reported that horse meat is free of the coccidian parasites *Toxoplasma gondii*, which is pathogenic for humans, and *Neospora canium*, which is associated with animal but not human disease, although both were detected in cattle (Wyss et al., 2000). There appears to be no reports of horse meat being examined for other parasites.

5. Cadmium

Cadmium is a highly toxic element that can accumulate in animal tissues, particularly kidney and liver (Fasset, 1975). The trace quantities naturally present in the environment can be greatly augmented by industrial activities with consequent increase in the amounts of cadmium in the tissues of grazing animals (Kottferová & Korénéková, 1995). Horses apparently have a greater propensity to accumulate cadmium than do other grazing animals (Salisbury, Chan, & Saschenbrecker, 1991). Moreover, at the time of slaughter, horses are often >5 years old whereas other meat animals are generally aged <2 years and the cadmium content of animal tissues tends to increase with age (Antoniou, Tsoukali-Papadopoulou, Epivatianos, & Nathanael, 1989). Consequently, levels of cadmium in the tissues of horses slaughtered for human food are often much higher than the levels in tissues of other food animals.

A tolerable weekly intake of cadmium of no more than 0.007 mg/kg of body weight has been suggested (Beldoménico et al., 2001). Such an intake might sometimes be exceeded during a single meal as a result of the consumption of horse meat, as levels of cadmium in horse muscle tissue up to about 1.5 mg/kg have been reported, although mean levels were generally <0.2 mg/kg (Decastelli, Galeno, & Giaccone, 1991). However, the suggested maximum weekly intake would likely be consumed at a single meal if horse liver were eaten, as mean and maximum levels of cadmium of 3 and 17 mg/kg, respectively, have been reported from horse liver (Salmi & Hirn, 1981). With consumption of horse kidney, exceeding the suggested maximum weekly intake during a single meal would be almost certain, as mean and maximum levels of cadmium in that tissue have been reported to be >20 and >350 mg/kg, respectively (Decastelli et al., 1991). Thus, unless horses are young and known to be little exposed to cadmium horse liver and kidney would seem to be unsuitable for human consumption, although horse liver is consumed in Japan and possibly elsewhere.

6. Concluding remarks

Published information on the microbiological and other qualities of horse meat is limited. However, the available information indicates that the intrinsic qualities of horse muscle will generally preclude its early microbial spoilage, either aerobically or anaerobically when the numbers of spoilage bacteria initially present on the meat are relatively low. The microbiological contamination of horse carcasses during carcass dressing can apparently be controlled by attention to the details of skinning and eviscerating operations, as with the carcasses of cattle. However, the implicit assumption among consumers of raw horse meat that meat from carefully dressed carcasses will be largely free of pathogenic bacteria is unwarranted, as some contamination of the meat with at least *Salmonella* and *Y. enterocolitica* must be expected.

Decontamination of horse carcasses as is practiced with beef carcasses in North America is not permitted for meat produced in or imported by the EU, and would probably be unwelcome in a trade that still involves much meat in carcass form, because of the discolouration of carcasses that occurs when decontamination treatments are effective (Bolton, Doherty, & Sheridan, 2001). Carcass decontamination would anyway not ensure against the recontamination of meat during carcass breaking (Gill, 2000), or do anything to resolve the problem of occasional infection of horse meat with *Trichinella*. Thus, health risks from horse meat are likely to persist in regions where the traditional consumption of the raw meat continues.

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