An assessment of the risk of companion animals acquiring Salmonella, Escherichia coli spp., Campylobacter spp. and MRSA from contaminated raw pet food, and associated risks to pet owners from the use of these product in the home.

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Summary

Raw pet food (RPF) has become more popular in recent years among pet owners in developed countries. RPF products are made from Category 3 Animal-By-Products (ABP) that have been passed fit for human consumption in a slaughterhouse but are surplus to human consumption needs. As RPF products do not undergo cooking or heat treatment there is no formal ‘kill step’ in the production process, resulting in an end product that can be contaminated with a range of pathogens.
This assessment considers the risk of dogs and cats acquiring *Salmonella* spp., beta-glucuronidase-positive *Escherichia coli* (*E. coli*), Shiga toxin-producing *Escherichia coli* (STEC), Campylobacter spp. and methicillin-resistant *Staphylococcus aureus* (MRSA) infection from contaminated RPF products. The risk of infection to pet owners through handling these products in the home or via transmission from an infected pet is also considered.

A survey recently undertaken by the Food Standards Agency to sample and test raw dog and cat food products on retail sale in the UK from March 2023 to February 2024 has detected a high prevalence of these pathogens in RPF products, which is reflected in the literature in similar surveys done in other parts of the world. These pathogens are potentially harmful to dogs and cats when consumed in RPF and to owners via cross contamination.

This risk assessment was produced using a multidimensional model of risk. The risk levels and severity of detriment are summarised in the tables below and are discussed in further detail in the risk assessment.

Table 1: Risk levels for companion animals

Pathogen	Risk level to dog	Uncertainty around risk level to dog	Risk level to cat	Uncertainty around risk level to cat
***Salmonella* spp.**	Medium	Medium	Medium	Medium
***Campylobacter* spp.**	Low	Medium	Low	Medium
MRSA	Very Low	High		
STEC	Low	Medium	Very Low	High
Non-Pathogenic *E. coli*	Negligible	Medium	Negligible	Medium

Table 2: Risk Levels for Pet Owners

Pathogen	Risk level to pet owner through handling contaminated RPF	Uncertainty around risk level to pet owner (handling RPF)	Risk level to pet owner through contact with infected pet	Uncertainty around risk level to pet owner (transmission through infected pet)
***Salmonella* spp.**	Low	Medium	Very Low	High
***Campylobacter* spp.**	Low	Medium	Very Low	High
MRSA	Very Low	High	Very Low	High
STEC	Low	Medium	Very Low	High
Non-pathogenic *E. coli*	Negligible	Medium	Negligible	Medium

Table 3: Severity of Detriment for infections in companion animals

Pathogen	Severity of Detriment in dogs	Uncertainty around Severity of Detriment in dogs	Severity of Detriment in cats	Uncertainty around Severity of Detriment in cats
***Salmonella* spp.**	Medium	Medium	Medium	Medium
***Campylobacter* spp.**	Low	Medium	Low	Medium
MRSA	Low	Medium	Low	Medium
STEC	Low	Medium	Low	Medium
Non-pathogenic *E. coli*	Negligible	Medium	Negligible	Medium

Table 4: Severity of Detriment for infections in pet owners

Pathogen	Severity of Detriment in pet owners	Uncertainty around Severity of Detriment in pet owners
***Salmonella* spp.**	High	Low
***Campylobacter* spp.**	Medium	Low
MRSA	Low	High
STEC	High	Low
Non-pathogenic *E. coli*	Negligible	Low

Several key uncertainties remain after reviewing the available evidence. In particular the uncertainty around prevalence and symptoms of clinical infection in companion animals as there is less research published on animal health compared to human disease. Due to a lack of data on MRSA infection in cats we were unable to provide a risk level. There is also uncertainty around how RPF is handled in the home by pet owners, for example, how they are stored or prepared.

Risk Question

What is the risk to companion animals (dogs and cats) from the consumption of raw pet food (RPF) contaminated with *Salmonella* spp., beta-glucuronidase-positive *Escherichia coli* (*E. coli*), Shiga toxin-producing *Escherichia coli* (STEC), *Campylobacter* spp. and methicillin-resistant *Staphylococcus aureus* (MRSA) and what is the risk to pet owners from feeding these to their pets?

In scope

- The foodborne risk to dogs and cats through the consumption of contaminated products
- The cross-contamination risk to pet owners through handling of contaminated products in the home (e.g. storage and preparation).
- The risk to the pet owner through transmission of pathogens from pets, infected by consumption of contaminated products (e.g. shedding in faces).
- All strains of the pathogens listed in the risk question.

Out of scope

- Risk of infections routes other than foodborne (in particular wound and skin infection caused by MRSA)
- Pathogens not listed in the risk question.

Hazard identification

Background

RPF has become increasingly popular in recent years among pet owners in many developed countries, driven by non-specialist publications from the 2000's which promoted the use of RPF as a more 'natural' diet for dogs and cats (Freeman and Michel, 2001; Towell, 2008). Figures collated by the UK pet food association indicate that the size of the UK RPF market has grown significantly over recent years and is now estimated to be worth more than £130 million, within a total UK pet food market of £3.8 billion in 2023 UK Pet Industry Statistics | UK Pet Food.

RPF is made up of Category 3 Animal-By-Products (ABP) that have been passed fit for human consumption in a slaughterhouse but are either surplus to human consumption needs or are not normally consumed by people in the UK, e.g., offal or tripe. RPFs contain certain Category 3 ABP which have not undergone any preserving process other than chilling or freezing, as defined in retained Commission Regulation (EU) No. 142/2011.

As RPF does not undergo any heat/cooking treatment (e.g., no formal 'kill step' in the production process), the final retail product can be contaminated with microorganisms including pathogens and Antimicrobial Resistant (AMR) bacteria. Two studies carried out by the U.S. Food and Drug Administration (FDA) and Utrecht University in the Netherlands have shown that raw dog and cat food can be contaminated with commensal and pathogenic bacteria such as *Salmonella* spp. and STEC (van Bree et al., 2018a; Medicine, 2020).

A survey has recently been undertaken by the Food Standards Agency to sample and test raw dog and cat food products on retail sale in the UK from March 2023 to February 2024 for a range of microbiological contaminants and AMR pathogens. Furthermore, the packaging for a subset of products has also been tested for the same contaminants prior to opening.

Although testing is not yet complete (306 out of 380 samples currently tested), the results so far have identified 20% of samples positive for Salmonella spp., 11% of samples positive for *Campylobacter* spp., 9% of samples positive for MRSA, 11% of samples positive for STEC and 99% of samples positive for beta-glucuronidase-positive *E. coli* [results not yet published] Furthermore, swabbing of the outer packaging of a subset of the samples tested (155 outer packages) identified, 0.6 % of packaging samples positive for *Salmonella* spp., 0.6 % of packaging samples positive for *Campylobacter* spp. and 10.3% of packaging samples positive for *E. coli* [results not yet published].

As with any raw meat, these pathogens are potentially harmful to dogs and cats when consumed in RPF and to owners via cross contamination. Vulnerable populations such as young children, the elderly and immunocompromised are particularly at risk. This also includes puppies, kittens and dogs and cats with pre-existing disease.

Pathogens in scope of risk assessment

Salmonella spp. is a gastrointestinal zoonotic pathogen. Transmission of *Salmonella* spp. occurs via the faecal-oral route. The primary vehicles for *Salmonella* spp. infections are therefore animal products such as meat and dairy products due to under-processing or cross-contamination. Cases have also been linked to environmental source. Process failures commonly associated with Salmonella spp. contamination include temperature abuse, inadequate heat treatment and unhygienic handling.

Campylobacter spp. are Gram-negative bacteria. There are more than 20 species of *Campylobacter*, but the most common pathogenic species involved in gastroenteritis are *C. jejuni* and *C. coli*. The main reservoir of *Campylobacter* is poultry and it can also live in the gastrointestinal tract of mammals including livestock and pets, such as cats and dogs (Nadeem et al., 2015).

S. aureus is a common Gram-positive bacterium which normally acts as a commensal. It is estimated that 20-30% of healthy people have the bacterium present on their skin or mucous membranes (EFSA, 2009). Most of the time it is harmless but can result in opportunistic infection in humans, most associated with skin or wound infections, although can also cause foodborne infection. It can also result in more serious systemic infections. MRSA are strains of *S. aureus* which are resistant to beta-lactam antibiotics. This is problematic as beta-lactam antibiotics such as penicillin are commonly used to treat a range of infections.

E. coli are Gram-negative, bacteria mainly found in the gut of warm-blooded animals (commensal bacteria). *E. coli* is a highly successful competitor representing the most abundant facultative anaerobe of the human intestinal microflora (Kaper et al., 2004). Typically, 90-95% of *E. coli* strains possess the ?-glucuronidase gene (G et al., 2017). The vast majority of ?-glucuronidase-positive *E. coli* are non-pathogenic (Nagano et al., 2004). *E. coli* are usually harmless, but some strains which produce toxins, such as STEC might cause severe foodborne diseases, and in some cases mortality (“WHO,” 2022).

STEC are a group of pathogenic organisms characterised by their ability to produce Shiga toxins. All STEC strains may have the potential to cause diarrhoea with bacterial and host factors playing a key role. It may be associated with severe illness, e.g. haemolytic uremic syndrome (HUS), bloody diarrhoea (BD) and/or hospitalisations with an estimated mortality rate of 3-5 % (WHO, 2022). There are multiple serogroups of STEC, however the most common in the UK is O157.

Exposure assessment

General

There are a wide range of RPF products available on the market, typically comprising meat (and small fragments of bone in some instances) as found in processed pet food (e.g., chicken, lamb, beef, etc.), or marketed for their offal content such as duck hearts or tripe. RPFs may contain secondary ingredients including fruit, vegetables, grains, oils and other nutrients (e.g., vitamins, minerals, etc.). Meat products, not typically popular at retail, are often marketed as 'premium' RPF (e.g., hare, kangaroo, wild boar or venison etc.). Although some RPF is sold freeze dried, the vast majority of products are sold frozen in pouches, vacuum-packs or sausage-shaped tubes (chubs) and can vary in size from single meals (typically 500g) to bulk packs weighing several kilograms. Studies have shown that vacuum and modified atmosphere packaging can inhibit growth of *Salmonella* spp., *Campylobacter* spp., *E. coli* and MRSA on meat products, however, inhibition depends on the specific packaging and atmospheric conditions (Balamurugan et al., 2011; Kudra et al., 2011; Djordjevi? et al., 2018) of which the specific processing methods are unknown but appear to vary for packaging sampled as part of the FSA surveillance project [results not yet published].

Frozen pet food products typically have a durability date (best before) in excess of one year and are often stored in domestic environments alongside frozen food intended for human consumption.

The pH and water activity (aw) of individual RPF products are unknown (uncertainty). Iulietto et al., (2015) reported the aw of unprocessed fresh meat to be <0.99 (0.98-0.99) with a typical pH range between 5.5 to 6.2. Another study by Presume et al., (2022) reported RPF products containing beef liver and beef heart had a pH range of 6.29-6.33 which is permissible for bacterial growth.

No further processing is carried out on RPF products to alter the water activity or pH and there is no heat treatment or 'kill step' to reduce any possible microbiological contamination. When frozen RPF is defrosted prior to consumption there may be an opportunity for pathogen growth depending on the conditions used, particularly if the product is left to defrost at room temperature for a prolonged period (**uncertainty**). Labelling requirements under both the Animal By-products and Marketing and Use Regulations do not specifically require safe handling instructions, so it is unclear how these products are being defrosted or stored after defrosting (**uncertainty**).

Salmonella spp.

Salmonella spp. can grow between 5°C and 47°C with an optimum growth temperature of 37°C. *Salmonella* spp. are destroyed by pasteurisation temperatures and the standard 70°C for two minutes (or equivalent) cooking advice is normally sufficient to kill any *Salmonella* spp. present in food. *Salmonella* spp. numbers may decline slightly upon freezing but cells largely remain viable (Dominguez and Schaffner, 2009). The minimum water activity that permits growth of *Salmonella* spp. is 0.94 however cells are able to survive in dried foods for extended periods of time. The optimum pH for the growth of *Salmonella* spp. is 6.5-7.5, however, growth has been reported at pH values as low as 4.0 (Chung and Goepfert, 1970). Without processing, such as cooking to provide a 'kill step', *Salmonella* spp. present in RPF will be maintained and possibly grow during or after defrosting, given the typical physicochemical properties of the product.

In the FSA survey of RPF products sold at retail, 20% of product samples and 1% of outer packaging swabs were positive for *Salmonella* spp. spp. [results not yet published], which is consistent with similar studies carried out on raw pet food in other countries (Weese, Rousseau and Arroyo, 2005; Finley et al., 2008; van Bree et al., 2018a). The prevalence of *Salmonella* spp. in raw pet food is much higher than reported in similar studies looking at retail meat intended for human consumption. For example, the prevalence has been reported at 2% in chicken and <1%

in turkey meat (FSA, 2023), 3.9% in pork (Little et al., 2008), 2.0% in lamb (Little et al., 2008) and between 0.3-1.3% for beef (Little et al., 2008; Bishop, 2019).

MRSA

Methicillin-resistant *Staphylococcus aureus* (MRSA) are strains of *Staphylococcus aureus* that have developed resistance to methicillin and other common antibiotics.

MRSA is usually associated with healthcare-acquired infections such as skin and wound infection, which is not in scope of this risk assessment (Sergelidis and A. S. Angelidis, 2017). The ability for *Staphylococcus aureus* to also cause a food-borne illness is due to its ability to produce staphylococcal enterotoxins (SEs) in food. Any MRSA strain carrying genes conferring SE production may have the potential to act as a foodborne pathogen (Sergelidis and A. s. Angelidis, 2017).

S. aureus grows over a wide range of temperatures and pH and may grow in a wide assortment of foods, including raw meat. Therefore, food that is contaminated with SE producing strains, if left at temperatures that allow growth of the bacteria (i.e., inadequate refrigeration) can be a source of SE-outbreaks (Pinchuk, Beswick and Reyes, 2010).

Table 5: Adapted from (Tatini, 1973) table on growth and toxin production ranges and optimum of *S. aureus*

Factor	Optimum for growth	Range for growth	Optimum for Staphylococcal enterotoxin production	Range for Staphylococcal enterotoxin production
Temperature	37	7 - 48	37 - 45	10 - 45
pH	6 -7	4 - 10	7 - 8	4 - 9.6
Water activity (aw)	0.98	0.83 - 0.99	0.98	0.85 - 0.99

S. aureus are resistant to drying and may grow and produce SEs in foods with aw as low as 0.85. The organism is killed at cooking and pasteurisation temperatures; however, heat resistance is increased in dry, high-fat and high-salt foods. Optimum pH for SE production is 5.3-7.0 and the optimum for SE production is ?0.90 aw. SEs are resistant to heat. Both the *S. aureus* bacterium and SEs survive frozen temperature (El-Banna and Hurst, 1983).
A study from the Netherlands found that MRSA strains were isolated from 264 (11.9%) of 2217 samples of raw beef, pork, veal, lamb/mutton, chicken, turkey, fowl and game from retail products (de Boer et al., 2009). In the FSA survey of RPF products sold at retail, 9% of product samples tested have found to be positive for MRSA [results not yet published].

Despite the frequency with which MRSA has been detected in raw meat and its ability to produce SEs, there is a lack of conclusive evidence as to its role in foodborne disease or its transmission routes on relation to meat and other foods (Boer 2009, Waters, 2011). A 2009 EFSA report on the public health significance of MRSA in animals and foods reported that a specific MRSA strain,

CC398, has been reported in food-producing animals (eg pigs, veal, calves and chickens) and companion animals. However, it has not been commonly associated with foodborne infections. The conclusion of the EFSA report was that “there is currently no evidence that MRSA can be transmitted to humans through the consumption or handling of contaminated food.” (EFSA evaluates factors contributing to MRSA in pigs | EFSA, 2010)

Campylobacter spp.

Campylobacter spp. are thermotolerant organisms, with a temperature growth range between 30°C and 45°C (optimum 37°C – 42°C). Pasteurisation effectively kills *Campylobacter* spp. and it is readily destroyed by cooking temperatures. Studies have shown that at 57ºC *Campylobacter* spp. have a D-value (min) of 0.79 – 0.98 FSAI, 2011). Therefore, a cooking temperature of 70°C for 2 minutes (or equivalent) in the thickest part of the product would be sufficient to inactivated *Campylobacter* spp.

Campylobacter spp. can grow in a pH range between 4.9 to 9.0 (optimal 6.5-7.5). It has a narrow tolerance in terms of aW with growth between 0.987 and 0.997 (NZ data sheet, no date). Therefore, raw fresh meat provides optimal survival and growing conditions for *Campylobacter* spp. under suitable temperature conditions.

Campylobacter spp. can be spread by improper handling and cross contamination events in the home. It is thought that the majority of sporadic cases of campylobacteriosis are associated with food prepared and consumed less than thoroughly cooked in the home (Goddard et al., 2022).

The prevalence of *Campylobacter* spp. on raw retail meat, particularly poultry, has been well documented. An FSA survey of raw chicken and turkey at retail found that the contamination with *Campylobacter* spp. was estimated to be 47.5% of 305 samples with the levels of *Campylobacter* spp. reported to range from below the limit of detection to 27500 cfu/g (FS430917, 2023) A recent Scottish study reported that 0.1% of 1000 beef mince samples tested at retail were positive for *Campylobacter* spp. (FSS, 2019) but no recent evidence of levels on lamb meat at retail could be identified (**uncertainty**).

Campylobacter spp. has been detected in RPF in several studies. In the FSA survey of RPF products sold at retail, 11% of product samples and 1% of outer packaging swabs were found to be positive for *Campylobacter* spp. spp. [results not yet published]. A New Zealand based study found that *Campylobacter* spp. spp. were found in 28% of RPFs sampled, the majority of which were poultry based (Bojani? et al., 2017).
Campylobacter spp. is highly sensitive to drying and freezing (‘ACMSF’, 2019) meaning that its apparent absence from some surveyed RPF, is not surprising. Several surveys in the USA and Canada did not isolate *Campylobacter* spp. from over 300 samples taken from RPF products containing predominately poultry but also beef, lamb, ostrich, rabbit and salmon (Weese, Rousseau and Arroyo, 2005) (25 samples), (Strohmeyer et al., 2006)(240 samples),(Lenz et al., 2009) (42 samples). The study by Weese, Rousseau and Arroyo, (2005) included frozen and freeze dried preparations and the work by Strohmeyer et al., (2006) used frozen samples. It is unknown if the RPF sampled in the remaining studies was frozen, chilled or vacuum packed (**uncertainty**).

E. coli, including STEC

E. coli, including STEC growth has been observed in the range of 7-50°C (optimal temperature 37°C), although growth has been reported in some strains at 4°C. It can also survive freezing for extended periods (e.g. survived in sun-dried algal mats stored in plastic bags at 4°C over a period of 6 months; survived freezing temperatures in the pucks of manure) (Jang et al., 2017). If RPF is stored refrigerated or frozen there is still potential for *E. coli*, including STEC survival and cross-

contamination (Gao, Smith and Li, 2006).

STEC has been documented to have a D-value (minute) of 1.1-1.3 at 55-70°C in meat ('Standardising D and Z values for cooking raw meat', no date) therefore if the product were cooked, (2 min at 70°C or equivalent), exposure to pathogenic organisms could be reduced as this will destroy most pathogens. Good kitchen hygiene will help to reduce cross contamination.

Optimal pH for *E. coli*, including STEC growth is near-neutral (pH 7) but growth has been reported in some cases as low as 3.6. Minimum aw for growth is >0.95. According to Presume et al., 2022, the pH range of RPF products (mentioned above) is capable of supporting the growth of *E. coli*, including STEC in these products (**uncertainty**).

Several studies, summarised in Table 6, have shown that *E. coli*, including STEC are present in commercially available RPFs.

Table 6: Studies of commercial RPF and presence of *E. coli* including STEC

Authors	Bacteria / strain	Result
Treier *et al*., (2021)	STEC (stx1 and stx2 genes)	35/59 (59%)
van Bree *et al*., (2018b)	STEC O157:H7	8/35 (23%)
Weese, Rousseau and Arroyo, (2005)	*E. coli*	15/25 (64%)

In the FSA survey of RPF products sold at retail, 48% of product samples were found to be presumptive positive for STEC by PCR, of which 9% of samples were confirmed by culture isolation [results not yet published]. Whilst 100% of product samples and 15% of outer packaging swabs were found to be positive for *E. coli*, 15% of product samples had levels <5000 cfu/g.

Cross contamination to pet owners.

Current FSA guidance on handling of RPF includes recommending good hygiene practices such as washing hands after handling, storing RPF products away from human food and cleaning all surfaces in contact with the product. It is also recommended that designated utensils and containers are used to store, defrost and prepare the RPF and that uneaten pet food is thrown away as soon as reasonably practical RPF | Food Standards Agency. The FSA RPF retail survey found that product packaging advice varied greatly between manufacturers [results not yet published]. Some product labels contained instructions such as to wash hands after handling and to store away from human food. However, other product labels included no handling instructions. It is unclear how many pet owners are likely to follow available guidelines (**uncertainty**). Poor handling and hygiene practices will likely lead to cross contamination and possible human infection. Furthermore, contamination from the pet, if infected by consumption of the RPF, is also possible as dogs and cats are known to carry and shed these pathogens in the faeces. The rate of transmission via this route is unknown (**uncertainty**).

Hazard characterisation

Salmonella spp. in humans

In humans, symptoms of *Salmonella* spp. infection can range from asymptomatic carriage to severe diarrhoea. This is usually self-limiting; however, it can be more severe in vulnerable groups, including the elderly, pregnant women, the young, and the immunocompromised, leading to systemic infection and death. The incubation period of *Salmonella* spp. is usually between 12-72 hours; however, this may be longer (CDC, 2013; UKHSA, 2014). The infectious dose is generally high at around 106 infectious particles; however, this varies between host susceptibility, serovars and food vehicles. After symptoms have subsided, carriage and shedding of the organism can occur for a few weeks, up to months (Gal-Mor, 2019).

Salmonella spp. in dogs and cats

Although infection is most frequently subclinical in healthy adult dogs and cats, *Salmonella* spp. can cause gastroenteritis and even septicaemic disease in these animals. A number of cases have been reported such as fatal septicaemic salmonellosis in cats from consumption of RPF (Stiver, 2003), gastroenteritis in greyhound (Morley et al., 2006) and diarrhoea in puppies (van Bree et al., 2018a).

The clinical signs in animals are highly variable, depending on the strain, host type, age and health status. Acute episodes typically occur 3–5 days after exposure, but clinical signs have been reported 12 hours post exposure. The infectious dose of *Salmonella* spp. in dogs or cats could not be determined by literature search, however, in mice it has been shown to be highly variable (from 102 to 108 organisms) depending on strain (uncertainty) (Marks et al., 2011).

The most common clinical signs include fever, malaise, vomiting, anorexia, abdominal pain, and diarrhoea (Marks et al., 2011). Conjunctivitis is sometimes seen in affected cats and when enteritis becomes chronic, abortion may occur in pregnant dogs. Clinical signs are most common in puppies and kittens or in older animals with concurrent disease (Salmonellosis in Animals - Digestive System - MSD Veterinary Manual).

The 2023 report on '*Salmonella* in animals and feed in Great Britain: 2022' from APHA reported 857 *Salmonella* spp. isolations from dogs in 2022 from clinical investigations, an increase of 17.2% compared to 2021 and more than a 13-fold increase compared to 2020. The most commonly reported serovars from dogs in 2022 were *S. Typhimurium* and *S. Infantis*, which along with *S. Enteritidis* are also the most prevalent causes of human disease (APHA, 2023). As the numbers of cases are from clinical investigations, and adult cats and dogs are often asymptomatic carriers of these bacteria, it is likely that the prevalence of infection in companion animals is greater than prevalence captured in the report.

Even in healthy animals, *Salmonella* spp. may colonize the gut and pass to human owners resulting in gastroenteritis (Finley, Reid-Smith and Weese, 2006) if hygiene practices are poor. While faecal shedding of *Salmonella* spp. is generally thought to last up to one week if contaminated RPF is consumed once, shedding may last for up to eight months if animals are fed contaminated RPF over a longer period (van Bree et al., 2018a). A systematic review of case–control studies has shown that direct contact with pets plays a major role in human salmonellosis (Pires et al., 2014). Direct transmission of *Salmonella* spp. between pets and owners is estimated to account for between 3-6% of human salmonellosis cases a year (Stehr-Green and Schantz, 1987; Lowden, 2015).

Campylobacter spp. in humans

Campylobacter spp. is the most common cause of food borne disease in the UK and is thought to cause in excess of 600,000 human cases per year, with around 300,000 cases estimated to be acquired from food (FS101013, 2021).

Campylobacteriosis in humans is generally attributed to poultry products, but has also been associated with the consumption of other meats such as beef, pork and lamb (FS101013, 2021).

The infectious dose of *Campylobacter* spp. in humans is low. Black et al., (1988) suggested an infectious dose of 800 cfu which was derived from a feeding study. Very few data are available from outbreaks, and studies to determine the exact number of cells that will cause human infection have proved inconclusive, although examination of a bottle of bird-pecked milk, which was part of a batch implicated in an outbreak at a nursery, revealed contamination levels of less than 10 cells of *C. jejuni* per 100 ml (Riordan, Humphrey and Fowles, 1993).

The incubation period for *Campylobacter* spp. is usually 2 to 5 days but can range from 1 to 11 days. The most common symptoms of *Campylobacter* spp. infections are diarrhoea (frequently bloody), abdominal pain, fever, headache, nausea and/or vomiting. These symptoms typically last 3 to 6 days. Whilst diarrhoea is self-limiting, excretion of *Campylobacter* spp. can continue for two to three weeks.

Those particularly at risk of *Campylobacter* spp. infection are; the elderly (>65 years old), anyone who is immunocompromised, or those taking antacid treatment (CDC, 2023).

Campylobacter spp. infection can lead to long term complications such as reactive arthritis (9 in every 1,000 cases), Guillain-Barré syndrome (1 in every 1,000 cases) and other rare late consequences, such as Miller Fisher syndrome, haemolytic uremic syndrome, inflammatory bowel disease and functional gastrointestinal disorders - Third Report on Campylobacter spp. ACMSF 2019.

Campylobacter spp. in dogs and cats

Campylobacter spp. can cause clinical infection in dogs and cats with *C. jejuni* most likely to cause acute clinical signs. *C. coli*, *C. upsaliensis*. *C. helveticus* and *C. lari* (all potentially pathogenic to humans) have also been associated with intestinal disease in companion animals (Acke, 2018).

As in humans, young dogs and cats are more likely to acquire clinical Campylobacteriosis than adults, whilst young animals are more likely to shed the organism post infection (Hald and Madsen, 1997). *Campylobacter* spp. has been isolated from both healthy and sick dogs (Marks et al., 2011) with healthy dogs under 1 year shedding *Campylobacter* spp. even with no clinical signs (Burnens, Angéloz-Wick and Nicolet, 1992)(Hald et al., 2004) suggesting asymptomatic carriage.

Dogs become infected with *Campylobacter* spp. by ingesting infected faeces or contaminated food. Puppies under 6 months of age are most likely to become infected with *Campylobacter* spp. and present with self-limiting diarrhoea lasting 5–15 days. Diarrhoea may be watery to bloody with mucous or stained with bile. Other symptoms include vomiting, fever and anorexia (Marks et al., 2011). Occasionally it becomes a chronic infection and may be accompanied by an increased white blood cell count (MSD Manual, 2023).

No studies have been identified that report the infectious dose of Campylobacter spp. in dogs (**uncertainty**).

Between 2016 and 2020 there was a widespread outbreak of *C. jejuni* linked to puppies from a pet store in the USA. The outbreak affected 168 people in 18 states with no deaths reported but notably the outbreak strains exhibited multidrug resistance which was linked back to puppy breeders liberally administering antibiotics (Montgomery, 2018).

Campylobacteriosis is not common in cats, but when it does occur, it is most likely to affect kittens younger than six months old (Enteric Campylobacteriosis in Animals - Digestive System, 2022). *Campylobacter* spp. manifests in felines as self-limiting diarrhoea (Cook, 2008), which may be bloody. Some infected cats show no clinical signs (Marks, 2011) and are asymptomatic carriers. Although several species of *Campylobacter* spp. have been identified in both asymptomatic and diarrhoeic cats, *C. jejuni* is the organism most often associated with clinical disease. The severity of diarrhoea in infected cats seems to be dependent on several factors, including the level of protective antibodies and the presence of other intestinal pathogens (Marks et al., 2011) (Sandberg et al., 2002). No studies have been identified reporting the infectious dose of *Campylobacter* spp. in cats (**uncertainty**).

The prevalence of *Campylobacter* spp. carriage by cats and dogs has been shown to be significant. Parsons et al., 2010 collected 249 faecal samples from asymptomatic dogs attending UK veterinary practices to determine the prevalence and species distribution for *Campylobacter* spp. The prevalence of *Campylobacter* spp. spp. was 38%, with *C. upsaliensis* accounting for 98% of the isolates and *C. jejuni* for the remainder. This study did not collect information on the diet fed to the dogs. In a Finnish study Fredriksson-Ahomaa et al., (2017) tested faecal samples from pets, using PCR, showing Campylobacter spp. detection in 16 of 29 (55%) samples from dogs fed raw meat and 7 of 21 (33%) samples from dogs fed dry pellets. This was not a statistically significant difference but illustrates the high carriage of *Campylobacter* spp. in dogs.

MRSA in humans

S. aureus has the ability to produce *Staphylococcal* enterotoxins (SEs) when growing in foods in high cell densities. In humans, *Staphylococcal* food poisoning (SFP) is a food-borne intoxication caused by the ingestion of foods containing preformed SEs. SFP can be caused by the ingestion of 20–100 ng of toxins. The severity of the illness depends on the amount of toxin ingested and the general health of the individual (Asao et al., 2003)(Schelin et al., 2011)(Sergelidis and A. s. Angelidis, 2017). However, as discussed in section 3.3, there is no clear evidence that MRSA, results in foodborne infection (El-Banna and Hurst, 1983, p. ; EFSA, 2009; EFSA evaluates factors contributing to MRSA in pigs | EFSA, 2010).

MRSA in dogs and cats

The most common clinical sign of SE poisoning in dogs is vomiting, which usually occurs within 2- or 3-hours following ingestion. Diarrhoea can often develop within 2–48 hours and can be severe and bloody. The combination of both vomiting and diarrhoea in the affected animals can quickly lead to profound fluid and electrolyte abnormalities.

A small percentage of healthy dogs and cats are carriers of MRSA. Most canine and feline population-based studies have reported rates of 0-4% (Weese, 2010). However, colonisation of dogs and cats appears to be transient, as most eliminate the pathogen naturally within a few weeks (Loeffler and Lloyd, 2010).

During the last decade, MRSA has spread among dogs and cats on a worldwide basis (Damborg et al., 2016). Zoonotic transmission from infected or colonised pets to people can occur by direct contact or indirectly, however, it is difficult to assess the likelihood of owners acquiring infection from pets colonised or infected with MRSA little data is available (**uncertainty**).

STEC in humans

STEC are a group of bacteria associated with human disease, defined by the presence of one or both Shiga toxin genes; *stx*1 and *stx*2 (EFSA BIOHAZ Panel et al., 2020). In humans, symptoms include diarrhoea, abdominal pain, bloody diarrhoea and also more serious complications like

haemolytic uremic syndrome (HUS) which can be fatal. The young and the elderly are more susceptible to further complications than the general population (UKHSA, 2014). The incubation period is, on average, 3-4 days but can be anywhere between 1-9 days. For most patients, infection is self-limiting, and recovery is seen within 10 days.

STEC are zoonotic pathogens, with the primary source of human infection being from healthy ruminants, especially sheep and cattle. Humans can become infected by eating or drinking contaminated food or water, coming into direct or indirect contact with sick animals or their surroundings, or spreading the infection from person to person. Each transmission has the potential to cause sporadic infections and potentially outbreaks (UKHSA, 2014, 2017).

All STEC strains are pathogenic to humans and all STEC subtypes have the potential to cause severe illness (e.g. HUS). According to the EFSA Biohazard Panel on the pathogenicity of STEC, stx2a had the highest rate of causing HUS and hospitalisation of the stx subtypes between 2012-2017, with all other stx subtypes also associated with at least one severe illness outcome (EFSA BIOHAZ Panel et al., 2020). HUS develops in approximately 10% of patients infected with STEC O157 and is the leading cause of acute renal failure in young children. In the over 60s age group, thrombocytopenia (TTP) (low blood platelets) can also occur.

The infectious dose for STEC in humans is low (<100 cells for STEC O157O157:H7) and although there is uncertainty for serovars other than O157:H7, it is thought that the probability of infection following exposure to other STEC strains may approach that of O157:H7. (see EFSA for this conclusion: it is unknown whether the dose-response relationship of STEC that use intimin (encoded by eae) for attachment varies between strains belonging to different O groups. An investigation of an STEC outbreak involving serotypes O145:H28 and O26:H11 in ice cream found concentrations of 2.4 MPN/g for O145 and 0.03 MPN/g for O26 (Buvens et al., 2011). In an outbreak of STEC O111:H- associated with fermented sausage, the estimated exposure dose was 1 cell per 10 g (Paton et al., 1996). This indicates that the probability of infection upon exposure to other STEC strains may approach that of O157:H7.In August 2017, a cluster of four persons infected with genetically related strains of STEC O157:H7 was identified. These strains possessed the Shiga toxin (stx) subtype stx2a, a toxin type known to be associated with severe clinical outcome. One person died after developing HUS. Interviews with cases revealed that three of the cases had been exposed to dogs fed on a raw meat-based diet (RMBD), specifically tripe. In two cases, the tripe had been purchased from the same supplier (Kaindama et al., 2021).

STEC in dogs and cats

STEC related illness appears to be low in companion animals (**uncertainty**). However, some studies suggest that STEC can be carried in the intestines of cats and dogs (Bentancor et al., 2007; Kim, Lee and Kim, 2020). It is possible that pets fed RPF products contaminated with STEC could act as asymptomatic carriers and shed STEC in their faeces (**uncertainty**) (Treier et al., 2021).

In dogs there is some evidence to suggest that STEC infection can potentially cause idiopathic cutaneous and renal glomerular vasculopathy (CRGV) (**uncertainty**). CRGV is characterized by symptoms such as thrombocytopenia, haemolytic anaemia, and acute renal failure. Animals with CRVG do not have diarrhoea, but their clinical presentation is like that of HUS (Do and Seo, 2024).

There is limited evidence to determine the infectious dose or dose response in companion animals (**uncertainty**).

There is limited evidence to suggest that younger companion animals could potentially be more susceptible to infection (**uncertainty**). Dogs appear to show a decrease in infection up to the age of 12 years, when the odds of illness increases again (Groat et al., 2022).

E. coli in humans

E. coli are mainly found in the gut of warm-blooded animals (commensal bacteria). *E. coli* is a highly successful competitor representing the most abundant facultative anaerobe of the human intestinal microbiota (Kaper, Nataro and Mobley, 2004).

The presence of *E. coli* in food in general is used as an indicator and does not necessarily indicate a direct risk to health but can be indicative of poor practice, including: poor quality of materials, undercooking, cross-contamination, poor cleaning, poor temperature / time control. However, indicators are used to identify conditions that may lead to an increase in the risk of contamination with human pathogens.

E. coli in dogs and cats

It is possible that pets fed RPF products contaminated with *E. coli* could act as asymptomatic carriers and shed *E. coli* in their faeces (**uncertainty**). (Runesvärd et al., 2020) identified E. coli in 13/25 (52%) faeces samples from dogs fed RPF. *E. coli* was recovered from a 6-week-old puppy that died of septic bacterial enterocolitis and had been fed raw beef cat food. It is unknown if the cat food was the source of infection (**uncertainty**) (Jones et al., 2019).

Many strains of *E. coli* have been isolated from dogs with and without diarrhoea associated with granulomatous colitis (GC), but the role of many of these strains in disease causation in dogs and cats is poorly defined (Marks et al., 2011). A study documented that over 50% of dogs with GC harboured mucosal E. coli that were resistant to 1 or more antimicrobials, and resistance to fluoroquinolones was observed in 43% (Craven et al., 2010).

There is no conclusive evidence that generic *E. coli* causes illness in pets, although this cannot be completely ruled out (**uncertainty**).

Risk characterisation

This risk assessment was produced using a multidimensional model of risk which includes the probability of an adverse effect occurring alongside the detriment (harm or damage) associated with the severity of the microbiological hazard. The uncertainties associated with these categories and additional uncertainties are also considered (see Annex 1).

Frequency of occurrence of illness to companion animals

Salmonella spp.

There is sufficient evidence in the literature to show that *Salmonella* spp. spp. infection can cause severe illness in both cats and dogs, such as gastroenteritis and even septicaemic disease. As the product does not undergo further processing to destroy these bacteria and freezing will not destroy all viable cells, the risk to **dogs and cats** from the consumption of *Salmonella* spp. contaminated RPF is considered **medium** (occurs regularly) with a **medium** level of uncertainty.

Campylobacter spp.

Campylobacter spp. can cause clinical infection, such as diarrhoea, in dogs and cats, particularly in puppies and kittens. The risk of pets consuming RPF contaminated with *Campylobacter* spp. is slightly reduced as these products are often sold frozen and *Campylobacter* spp. is highly sensitive to freezing, therefore reducing contamination levels. Some previous studies have also failed to isolate *Campylobacter* spp. in RPF. The risk to **dogs and cats** of consuming *Campylobacter* spp. contaminated RPF is therefore considered **low** (rare but does occur) with a **medium** level of uncertainty.

MRSA

MRSA is not common in companion animals and predominantly presents as skin infections, which is not in scope of the risk assessment. There is some evidence that MRSA infection can cause vomiting and/or diarrhoea, however, the route of transmission is unclear and RPF has not been directly implicated in the literature. The risk of **dogs** consuming RPF contaminated with MRSA is therefore considered to be **very low** (very rare but cannot be excluded) with a **high** level of uncertainty, due to a lack evidence in the literature.

We were unable to provide a risk level for cats as we could not obtain sufficient evidence of clinical infection through consumption of contaminated food.

STEC

STEC related illness appears to be low in companion animals but can cause gastrointestinal upset such as diarrhoea, and a condition called CRGV in dogs. The risk to **dogs** is therefore considered to be **low** (rare but does occur) with a **medium** level of uncertainty.

The risk to **cats** however is **very low** (very rare but cannot be excluded) due to a low rate to clinical illness reported in cats with a **high** level of uncertainty as there are less reports of studies carried out in cats.

***E. coli* (non-pathogenic)**

E. coli typically lives as a commensal enteric species in dogs and cats and although it may not cause illness, is an indicator of poor hygiene in the process of the products, such as cross-contamination, poor cleaning, poor temperature / time control. The risk to **dogs and cats** from RPF found to be contaminated with non-pathogenic *E. coli* is therefore considered to be **negligible** (so rare that it does not merit to be considered) with a **medium** level of uncertainty.

Frequency of occurrence of illness to humans

***Salmonella* spp., *Campylobacter* spp. and STEC**

Overall, the pathogenic potential of *Salmonella* spp., *Campylobacter* spp. and STEC to humans is high (as discussed in the previous sections). However, the likelihood of exposure of humans to the strain (assuming that consumption of the feed is improbable) would depend on the hygiene practices employed when handling the feed, as well as the level and prevalence of contamination within the RPF. The risk to **pet owners** of *Salmonella* spp., *Campylobacter* spp. and STEC infection from handling contaminated products in the home is considered **low** (rare but does occur) with a **medium** level of uncertainty.

Not all pets who consume contaminated RPF will become infected and transmit the pathogens, however it is possible for this to occur in pets with or without clinical symptoms. Again, the likelihood of exposure to humans will depend on hygiene practices, e.g. washing hands after

handling faeces. The risk to pet owners from *Salmonella* spp., *Campylobacter* spp., MRSA and STEC infection from contact with an infected pet, that contracted the infection from RPF, is considered to be **very low** (very rare but cannot be excluded) with a **high** level of uncertainty.

MRSA

The risk to **pet owners** from MRSA infection from handling contaminated products in the home, or contact with an infected pet, is considered **very low** (Very rare but cannot be excluded) with a **high** level of uncertainty. This is due to the fact that there is very little evidence of foodborne illness resulting from MRSA infection, however, as MRSA strains produce SE they have the potential to cause clinical infection.

E. coli

The risk to **pet owners** from *E. coli* infection from handling contaminated products in the home, or contact with an infected pet, is considered **negligible** (so rare that it does not merit to be considered) with a **medium** level of uncertainty.

Severity of detriment for infections in companion animals

As discussed in section 3 the pathogens covered in this risk assessment cause a range of symptoms in dogs and cats, as a result the severity of detriment varies.

- The severity of detriment from infection of *Salmonella* spp. in dogs and cats is **medium** (Moderate illness: incapacitating but not usually life-threatening, sequelae rare, moderate duration) with **medium** uncertainty as it can cause severe gastroenteritis and even septicaemic disease in these animals (Morley et al., 2006; van Bree et al., 2018b) .
- The severity of detriment from infection of *Campylobacter* spp., MRSA and STEC in dogs and cats is **low** (mild illness: not usually life-threatening, usually no sequelae, normally of short duration, symptoms are self-limiting) with **medium** uncertainty as severe illness related to these pathogens in cats and dogs is rare (Loeffler and Lloyd, 2010; Acke, 2018; Treier et al., 2021).
- The severity of detriment from infection of non-pathogenic *E. coli* in dogs and cats is **negligible** (no effects, or so mild they do not merit to be considered) with **medium** uncertainty.

Severity of detriment for infections in humans

- The severity of detriment from infection of *Salmonella* spp. and STEC in humans is **high** (severe illness: causing life-threatening or substantial sequelae or illness of long duration) with **low** uncertainty as although in most cases these infections are mild and self-limiting in severe cases they can result in systemic infection and death, or in the case of STEC result in haemolytic uremic syndrome (HUS) which can be fatal (EFSA BIOHAZ Panel et al., 2020).
- The severity of detriment from infection of *Campylobacter* spp. in humans is **medium** (Moderate illness: incapacitating but not usually life- threatening, sequelae rare, moderate duration) with **low** uncertainty as severe illness associated with these pathogens is rare, however, it can result in severe, bloody diarrhoea and can result in sequelae (Sergelidis and A. S. Angelidis, 2017) .
- The severity of detriment from infection of MRSA (as a foodborne pathogen) in humans is **low** (Mild illness: not usually life-threatening, usually no sequelae, normally of short duration, symptoms are self-limiting) with **high** uncertainty as foodborne illness caused by S. aureus is usually mild and there is very little is very little evidence of foodborne illness

resulting from MRSA infection.
- The severity of detriment from infection of non-pathogenic *E. coli* and MRSA (as a foodborne pathogen) in humans is **negligible** (no effects, or so mild they do not merit to be considered) with **low** uncertainty.

Key Uncertainties

Several factors contributed to the uncertainties associated with the different risk levels identified in this risk assessment. Key uncertainties associated with different steps of the risk pathway are outlined below.

Uncertainties related to frequency of illness in companion animals.

- Prevalence of STEC clinical infection in companion animals.
- Prevalence of MRSA clinical infection in companion animals, particularly cats
- Infectious dose of pathogens in companion animals
- Physiochemical properties of products (e.g., pH, water activity, fat content)
- Type or modified atmospheric packing used.

Uncertainties related to frequency of illness in humans.

- Hygiene practices of pet owners including handling of RPF products and pet faeces.
- Storage of the product in the home (e.g., near to human food in the fridge or freezer).
- Numbers of pet owners in vulnerable categories (e.g., children, elderly, immunocompromised) using RPF.
- Lack of data on frequency of MRSA as a foodborne pathogen.

Uncertainties related to severity of detriment of infections in companion animals.

- Variability of clinical signs in animals which often depend on the pathogen strain and host type, age, and health status.
- Limited evidence on susceptibility of vulnerable populations to infections e.g. younger or older companion animals or animals with underlying health complications.

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Annex 1

This risk characterisation section of this risk assessment followed guidelines produced by the Advisory Committee on the Microbiological Safety of Food (ACMSF, 2020), where the frequency of occurrence and the severity of detriment are considered separately. The tables demonstrating the different levels of risk and uncertainty considered when concluding the risk characterisation are included below.

Table A1.1- A qualitative scale for the frequency of occurrence of foodborne risks.

Frequency category	Interpretation
Negligible	So rare that it does not merit to be considered
Very Low	Very rare but cannot be excluded
Low	Rare but does occur
Medium	Occurs regularly
High	Occurs very often
Very High	Events occur almost certainly

Table A1.2 - A qualitative scale for the severity of detriment of foodborne risks.

Severity category	Interpretation
Negligible	No effects, or so mild they do not merit to be considered
Low	Mild illness: not usually life-threatening, usually no sequelae, normally of short duration, symptoms are self-limiting (for example transient diarrhoea)
Medium	Moderate illness: incapacitating but not usually life-threatening, sequelae rare, moderate duration (for example diarrhoea requiring hospitalisation)

Severity category	Interpretation
High	Severe illness: causing life-threatening or substantial sequelae or illness of long duration (for example chronic hepatitis)

Table A1.3 - A qualitative scale for the level of uncertainty in food risk assessment.

Uncertainty category	Interpretation
Low	There are solid and complete data available; strong evidence is provided in multiple references; authors report similar conclusions
Medium	There are some but no complete data available; evidence is provided in small number of references; authors report conclusions that vary from one another
High	There are scarce or no data; evidence is not provided in references but rather in unpublished reports or based on observations, or personal communication; authors report conclusions that vary considerably between them