Qualitative assessment of the risk of SARS-CoV-2 to human health through food exposures to deer in the UK: Exposure assessment

The primary risk pathway is outlined in the figure one.

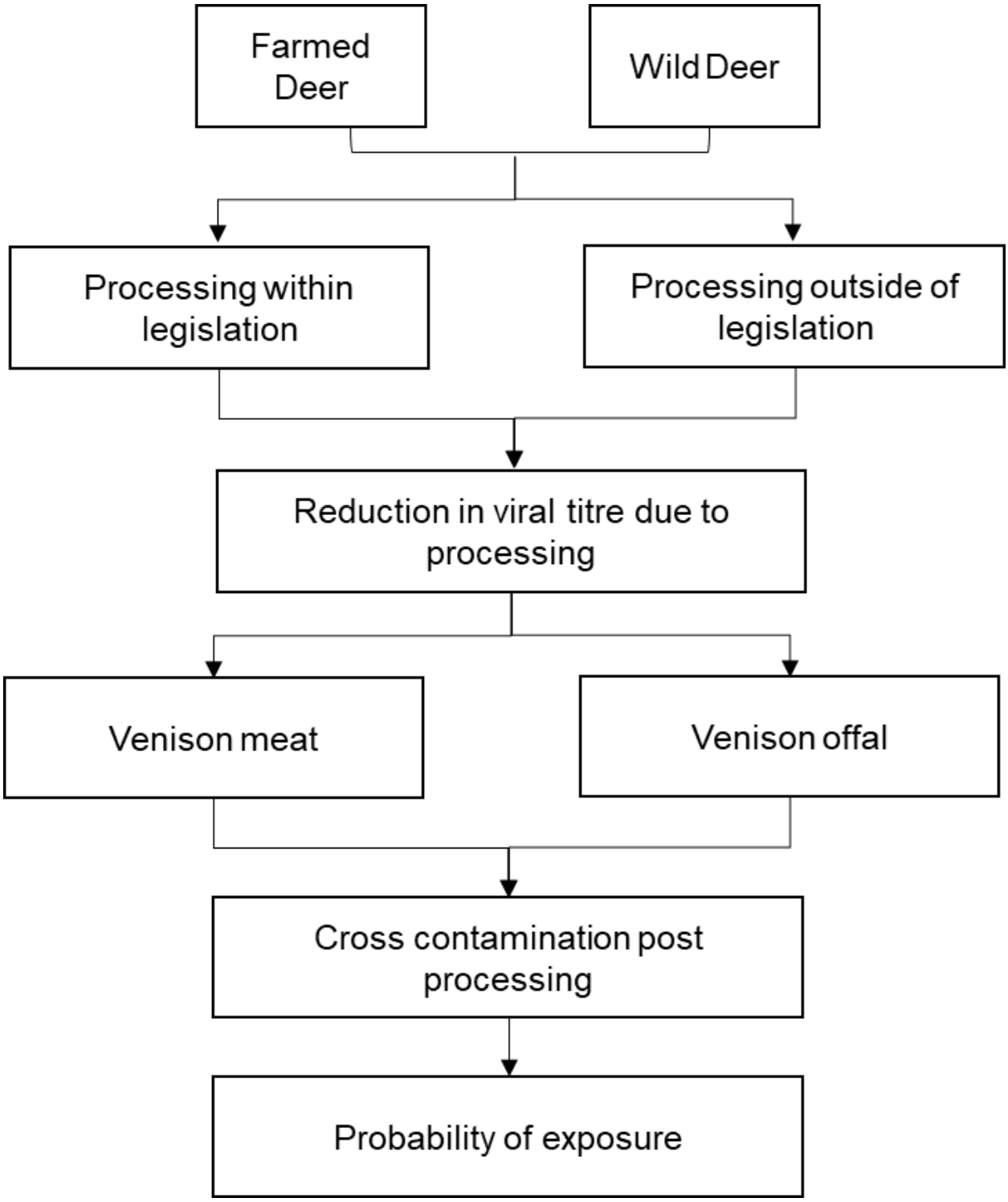

Figure one: Primary risk pathway (text version)

There are two separate pathways; one for wild deer and one for farmed deer.

Farmed Deer

1. Processing within legislation
2. Reduction in viral titre due to processing
3. Venison meat
4. Cross contamination post processing
5. Probability of exposure

Wild Deer:

1. Processing outside of legislation
2. Reduction in viral titre due to processing
3. Venison offal
4. Cross contamination post processing
5. Probability of exposure

Preparation and consumption of deer in the UK

All 6 deer species found in the UK can enter the UK foodchain, although the majority (67% based on 2001-2002 venison dealers records) comes from red deer (Gavin et al., 2019; Munro, 2002). Deer meat in the UK can come from farmed or wild deer. Enclosed deer herds in the UK are principally red deer bred on farms or fallow deer within parks, with an estimated 27,000 farmed deer and 40,000 park deer in the UK (DEFRA, 2021; Gavin et al., 2019).

Wild deer are shot by trained hunters and require a hunter's declaration. They are primarily processed in game handling establishments, which also process other wild game. Deer carcases will undergo visual inspection of the offal and meat during processing removing any deer with visible illness from the foodchain (The Deer Initiative 2009). It is unknown whether there will be visible signs of infection with SARS-CoV-2, for example lesions on the lungs (**uncertainty**), although this is unlikely and no testing for SARS-CoV-2 will be undertaken. A very small study of 4 white tailed deer reported no overt clinical disease following SARS-CoV-2 infection in any of the inoculated or contact animals during the 21-day experimental period (Palmer et al. 2021). During the evisceration process the green offal (organs associated with the digestive tract) is removed and discarded (often at the site of shooting), and the red offal and head removed and inspected by a trained hunter. The red offal may then enter the foodchain (The Deer Initiative 2009). Several websites provide recipes for offal from hunted deer, focusing mostly on deer heart, liver, tongue, kidney, and testicles ((Pendley, 2019, "Hunter, Angler, Gardener, Cook" 2008, "Field and Stream" 2019). In addition, a Scottish Market Insight report for venison states that 8% of people consuming venison at home have not bought it through retail establishments, and therefore may have hunted and butchered the animals themselves (Scottish Venison 2020), potentially bypassing some of these inspections.

Based on the number of deer slaughtered and processed, either by game handling establishments or slaughter lines, venison in Scotland and England is primarily from hunted wild deer, while venison in Wales and NI has a higher proportion of farmed deer to hunted wild deer (Upadhyay 2018). In the UK there was demand of 160,000 carcases per annum in 2015, with farmed deer making up approximately 3% of this (Gavin et al., 2019).

Based on 2016-2021 data from England, around 50-75,000 wild deer carcases are processed in game handling establishments each year under normal operating conditions (volumes were reduced during COVID measures but are recovering). The numbers of farmed deer processed in these establishments in England during the same time period ranged from 3,200 to 9,800 per year and accounted for between 5%-16% of total carcasses processed (Unpublished data; FSA).

In addition to legally sourced deer, a 2002 report by the British Deer Society (Munro 2002) stated that considerable numbers of deer are poached or illegally sourced (such as via road kill) and subsequently enter the foodchain. It has previously been estimated that hundreds/potentially thousands of animals enter the foodchain by this route (Munro 2002), although the true number is unknown (**uncertainty)**. Additionally, these animals may go into the same game handling establishments and therefore will undergo the same processing prior to consumption (**uncertainty**).

In 2019-2020, 1,221 tonnes of venison were sold (an increase of 20.1% from the previous year), with 4.7% of households having bought venison (Scottish Venison 2020). 12% of UK consumers reported eating venison at home within the past year while 10% reported eating it out of the home (Scottish Venison 2020). Food consumption data in the UK for venison showed a mean daily consumption of 19.22 g (for all individuals that consume venison). For high level consumers of venison (97.5th percentile), this increases to 187.7 g/day (Unpublished National Diet and Nutrition Survey data, Food Standards Agency). There are no data available on the quantity of deer offal consumed in the UK (uncertainty).

As a meat product, venison will be kept at refrigeration temperatures (? 5°C) and may be frozen (-18°C). It is unknown what proportion of venison is frozen prior to consumption, although there is no evidence that refrigeration or freezing will decrease the titres of SARS-CoV-2 on meat or meat products within the shelf-life of the product.

Venison can be consumed a number of ways. These can include:

1. Composite foods for example, pies, sausages, stews, etc. These usually require thorough / slow cooking of the meat prior to consumption which is highly likely to completely inactivate any virus present on or within the meat.
2. Joints or steaks. The outside surface will be thoroughly cooked, but the inside may still be consumed rare or less than thoroughly cooked.
3. There is some evidence that venison can also be prepared tartare (raw) ("Hunter-Eater", 2013; "Hunter, Angler, Gardener, Cook", 2013).

The proportion of venison sold in the UK that will be consumed less than thoroughly cooked or raw is unknown (**uncertainty**).

SARS-CoV-2 presence in muscle and organs

In one of the studies where deer were experimentally inoculated with SARS-CoV-2, the researchers investigated the presence of the virus in different tissues throughout the body (Palmer et al. 2021). No viral RNA was detected in sections of lung, kidney, brain, intestine, or mesenteric lymph nodes; muscles of the deer were not tested (Palmer et al. 2021). Whether muscle tissue (and therefore meat) can be infected with SARS-CoV-2 has not been well studied; similar coronaviruses have not been looked for in the muscles of mammals. SARS was not found within human muscles when it was found in other tissues (Ding et al. 2004), and more recent studies in humans determined ACE2 expression levels in muscle tissue were low (Li et al. 2020). From the very limited data on experimentally infected animals, it is thought to be unlikely that camel meat and internal organs will be infected by MERS?CoV, though further studies are needed to confirm this (Hemida et al. 2017).

Factors affecting SARS-CoV-2 survival

SARS-CoV-2 is no more resistant to heat than other viruses (WHO 2020). Research has shown SARS-CoV-2 (in liquid culture) is inactivated in under 5 minutes at 70°C and under 30 minutes at 56°C (Chin et al. 2020). This means that thorough cooking of venison meat would remove the risk of infection from meat. It is unclear whether less than thorough cooking of venison would completely inactivate infectious SARS-CoV-2 (**uncertainty**).

SARS-CoV-2 is susceptible to biocides used in the food production environment and consumer kitchens (Rowan, Meade, and Garvey 2021). Therefore, the likelihood of SARS-CoV-2 cross-contamination can be reduced using standard factory or household disinfectants and by following good hygiene practices.

Research has shown SARS-CoV-2 is relatively stable at chilled temperatures when in liquid broth (Chin et al. 2020). Similar results have been seen by (Fisher et al. 2021) who assessed the survival of SARS-CoV-2 on refrigerated and frozen chicken, salmon and pork pieces over 3 weeks. They found the titre and infectivity of SARS-CoV-2 remained stable at 4°C, –20°C and –80°C for the duration of the experiment. No studies have been published assessing the survival of SARS-CoV-2 on venison at chilled or frozen temperatures (**uncertainty**). Assuming it is similar to other meats, the cold chain of venison may allow the survival of SARS-CoV-2 in infected meat.

SARS-CoV-2 infection via handling of raw meat

If deer meat or offal is infected with SARS-CoV-2, then handling of the raw meat may allow for cross-contamination of surfaces; this may serve as a potential source of infection if people touch the contaminated surfaces and then touch a mucous membrane. As there currently is no evidence of SARS-CoV-2 presence in deer meat or offal, viral levels from such cross-contamination events and thus the potential dose encountered are not known (**uncertainty**). Two different risk assessments considering the risk of cross-contamination with food items infected with SARS-CoV-2 concluded the risk was negligible to very low (FSA 2020; Locas et al. 2022). Practicing good hygiene during food preparation will help reduce the potential risk of acquiring SARS-CoV-2 from contaminated meat/offal (FSA 2020; Locas et al. 2022; USDA Animal and Plant Health Inspection Service 2021).

SARS-CoV-2 infection from handling raw pet food

Outside personal consumption, another reason consumers may handle raw meat is as a food source for companion animals. Raw pet food containing deer meat and offal are available for purchase in the UK. It is not known what proportion of the raw pet food market may consist of deer meat and offal (**uncertainty**). The similarity between the deer population used to produce raw pet food and the population of deer that enters the food chain for human consumption is unknown. However, given that animal by-products used in the production of raw pet food are assumed fit for human consumption then deer entering both food chains are likely to be similar. Guidelines around storage and hygiene, related to handling raw pet food, recommend it be kept frozen until use and anything that comes into contact with the product (like hands, surfaces, utensils, etc), should be washed to prevent any cross-contamination (PHE and APHA 2018). As noted above, freezing is unlikely to reduce viral load. Raw pet food would not undergo any heat treatment that would reduce viral titres. Given the lack of evidence on whether SARS-CoV-2 infects muscle tissue and if ingesting the virus can lead to active infection, the risk from handling raw deer meat and offal produced as raw pet food is unlikely to serve as a source of human infection.

SARS-CoV-2 infection via food

SARS-CoV-2 requires the presence of the Angiotensin-converting enzyme 2 (ACE2) receptor to infect a cell ((Letko, Marzi, and Munster 2020); Walls et al., 2020)). This receptor is present in various human tissues – most importantly for infection through food are the oral mucosa, stomach, small intestine, and colon (Hamming et al. 2004). In addition, the pH of human stomach acid is between 1.5 and 3.5, and the survival of SARS-CoV-2 is unknown below pH 3 (**uncertainty**). However, studies on SARS-CoV-1 suggest that the virus is likely to be inactivated by the pHs found in large parts of the human digestive system (Darnell et al. 2004) and therefore infection via the oral mucosa may present the most credible route of infection during ingestion of contaminated foodstuffs. Certain medications may theoretically affect this potential for infection; for example, individuals undergoing treatment involving proton pump inhibitor medication are likely to have reduced stomach acidity with potential consequences for viral inactivation during digestion, although the effect of this on the likelihood of infection via the GI route has not been

proven (**uncertainty**).

There is little evidence that the oral / gastrointestinal route can lead to infection from SARS-CoV-2. One study has reported the detection of SARS-CoV-2 RNA in gastrointestinal tissues (Xiao et al. 2020), although there have been no studies that have proven oral transmission of SARS-CoV-2 (**uncertainty**). A previous FSA risk assessment on the risk of food or food contact materials and surfaces being a source or transmission route of SARS-CoV-2 for UK consumers concluded that the probability that UK consumers will receive potentially infectious exposures of SARS-CoV-2 via the consumption of food is Negligible (so rare that it does not merit to be considered) for foods of animal origin where the meat is contaminated due to infection of the animal, although the uncertainty was high due to the recent emergence of the virus (FSA 2020). This has been supported by several other risk assessments undertaken across the world ((CDC 2020), (US EPA 2020)). Additionally, a qualitative study showing the likelihood of exposure to SARS-CoV-2 via the food chain showed a negligible to very low risk throughout the food chain, but noted the lack of comprehensive evidence that ingestion of viral particles would be a route of infection for SARS-CoV-2 (Locas et al. 2022).