Qualitative Risk Assessment: What is the risk of food or food contact materials and surfaces being a source or transmission route of SARS-CoV-2 for UK consumers?

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Quality Assurance log

Reviewer type	Name of reviewer/ SAC	Date distributed	Date comments addressed
Internal			
Internal expert peer reviewer	**Paul Cook**	**2020-05-11**	**2020-05-13**
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Scientific Advisory Committee	**ACMSF Incidents subgroup**	**2020-05-18**	**2020-06-09**

Change log

Minor updates included updating figures on the total number of confirmed infections and deaths and adding additional evidence to the section on the probability of livestock being susceptible to SARS-CoV-2.

Significant additions and revisions since v2.1:

New sections

- The probability of cross-contamination of food in the retail environment, particularly food sold loose (section 8).

Significant revision

- The sections describing virus survival on surfaces (section 4) and heat inactivation (section 5) were revised to reflect new data, and the way these data are presented has been changed to assist interpretation.

*based on scientific evidence available up to and including this date.

Contents

Acknowledgements

This risk assessment was reviewed by the incidents subgroup of Advisory Committee on the Microbiological Safety of Food (ACMSF), prior to publication.

Risk question

What is the risk of food or food contact materials and surfaces being a source or transmission route of SARS-CoV-2 for UK consumers?

Summary

Overall risk estimate

We consider that the probability that UK consumers will receive potentially infectious exposures of SARS-CoV-2 via the consumption of food or the handling of food contact materials or packaging is Negligible as assessed by pathway A (food of animal origin) and Very Low ("very rare but cannot be excluded") as assessed by pathway B (contamination of food), with an overall risk of **Very Low**. The uncertainty associated with this estimate is **High**, partly as there are significant data gaps relating specifically to SARS-CoV-2; a number of assumptions in this document are therefore based on data relating to other coronaviruses (SARS-CoV and MERS-CoV). Although an overall probability has been provided, decisions should also be informed by the individual probabilities assigned to each section (Appendix 2) as necessary.

The worldwide case fatality rate for the disease COVID-19 appears to be around 7% based on current reports (29th April 2020), meaning the severity of detriment is considered **High** (Severe illness: causing life-threatening or substantial sequelae or illness of long duration); high-risk groups include people with weakened immune systems, older people, and those with certain long-term conditions like diabetes, cancer, chronic lung disease and cardiovascular disease.

Uncertainty relating to severity of detriment is considered **Low**; significant volumes of data are now available although current case fatality estimates may be biased as a result of incomplete outcomes and the potential overrepresentation of severe cases, due to early testing strategies only testing cases severe enough to result in hospitalisation.

We note that the genome of SARS-CoV-2 suggests that it is most closely related to SARS-CoV, for which foodborne transmission has not been implicated in any cases of infection. This assessment represents a conservative estimate of risk whilst acknowledging and reflecting current knowledge gaps.

Limitations of this assessment

This risk assessment does **not** currently consider:

- The risk associated with illegal importation activities. This is due to the lack of data on volumes of product illegally entering the UK as well as their processing and transportation;
- The occupational risk to food preparers or those frequently exposed to products of animal origin, for example slaughterhouse workers;
- Implications for integrity of the food chain, including reduced availability of food handlers, packers or distributors if they themselves become ill or there is reduced availability of approved disinfectants etc for cleaning of food manufacturing equipment and food preparation areas due to shortages;
- The impacts of altered behavioural choices, for example changes in consumer preference, repackaging of bulk foodstuffs for domestic usage, home delivery;
- Potential for transmission via human breast milk;
- Potential for transmission via water.

Key uncertainties

Potential future developments which could significantly alter this assessment include:

- Evidence indicating that transmission via food is occurring, either from experimental or observational studies;
- Improved data on the incidence of infection in the UK, particularly of the proportion of infections which are subclinical;
- Evidence that food animals could become or have become infected;
- New data significantly changing our assessment of the effects of storage or processing on the activity of virus in food, or survival of SARS-CoV-2 on surfaces and in the general environment;
- Evidence of transmission of infectious SARS-CoV-2 virus via the faecal-oral route;
- Changes in production procedures due to social distancing requirements or altered PPE usage.

Interpretation of categories used in this risk assessment

Tables from ACMSF (ACM/1065) adapted from EFSA 2016 modified from OIE 2004.

Table 1: definition of qualitative categories for probability of occurrence

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 2: definitions of qualitative categories for severity of consequence

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 (e.g. transient diarrhoea)
Medium	Moderate illness: incapacitating but not usually life-threatening, sequelae rare, moderate duration (e.g. diarrhoea requiring hospitalisation)
High	Severe illness: causing life-threatening or substantial sequelae or illness of long duration (e.g. chronic hepatitis)

Table 3: definitions of qualitative categories for expressing uncertainty

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

Background

On 31 December 2019, the National Health Commission of the People's Republic of China notified the World Health Organization (WHO) of a cluster of cases of pneumonia of unknown cause in Wuhan City, Hubei Province, China. Most early cases were associated with visiting Wuhan South China Seafood City market, which reportedly sold meat, poultry, seafood and live animals. On the 11th and 12th of January the WHO received further evidence from the National Health Commission identifying the cause of these infections as a novel coronavirus first isolated on the 7th of January. The novel coronavirus has been named SARS-CoV-2 and the disease caused by it has been named COVID-19.

Hazard Identification

The hazard is identified as SARS-CoV-2.

SARS-CoV-2 is located in the subgenus *Sarbecovirus*, genus *Betacoronavirus*, family *Coronaviridae* and it is closely related to the only other virus in this subgenus, Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV). Beta-coronaviruses are enveloped viruses with a large (27-32kb), positive-sense single-strand RNA genome. Phylogenetic comparisons of a number of SARS-CoV-2 genomes suggests that they share a most recent common ancestor dated to late November or early December 2019, the time of the earliest retrospectively confirmed human cases (Anderson et al. 2020).

Based on cases reported by national authorities to WHO at 10:00 CEST 28th April, there are currently 2 954 222 cases globally, with 84347 cases confirmed in China (resulting in 4643 deaths). There are 2,869,875 confirmed cases outside China, in 209 other countries and territories, with 197,954 deaths. The vast majority of cases outside China are no longer linked to travel to Wuhan, Hubei Province. Cases were originally linked to travel from China but the majority are now local transmission. In Europe there are a reported 1,097 667 cases, with 199,414 cases and 26,977 deaths in Italy. As of the 29th April 2020, there are 165,225 confirmed cases in the UK and there have been 26,097deaths.

Exposure assessment

There are two overarching pathways for potential foodborne exposure to SARS-CoV-2, which are:

A. via the consumption of foodstuffs of animal origin (primarily meat, eggs, milk, dairy and blood products) from infected animals, or

B. via the consumption of foodstuffs cross-contaminated by one or more of the following: contaminated products of animal origin, foods of non-animal origin, food contact materials, preparation surfaces, or infected individuals involved in food preparation.

Each of these pathways could theoretically apply to food produced and prepared overseas and then imported into the UK, to food produced overseas and prepared in the UK, or to food both produced and prepared in the UK

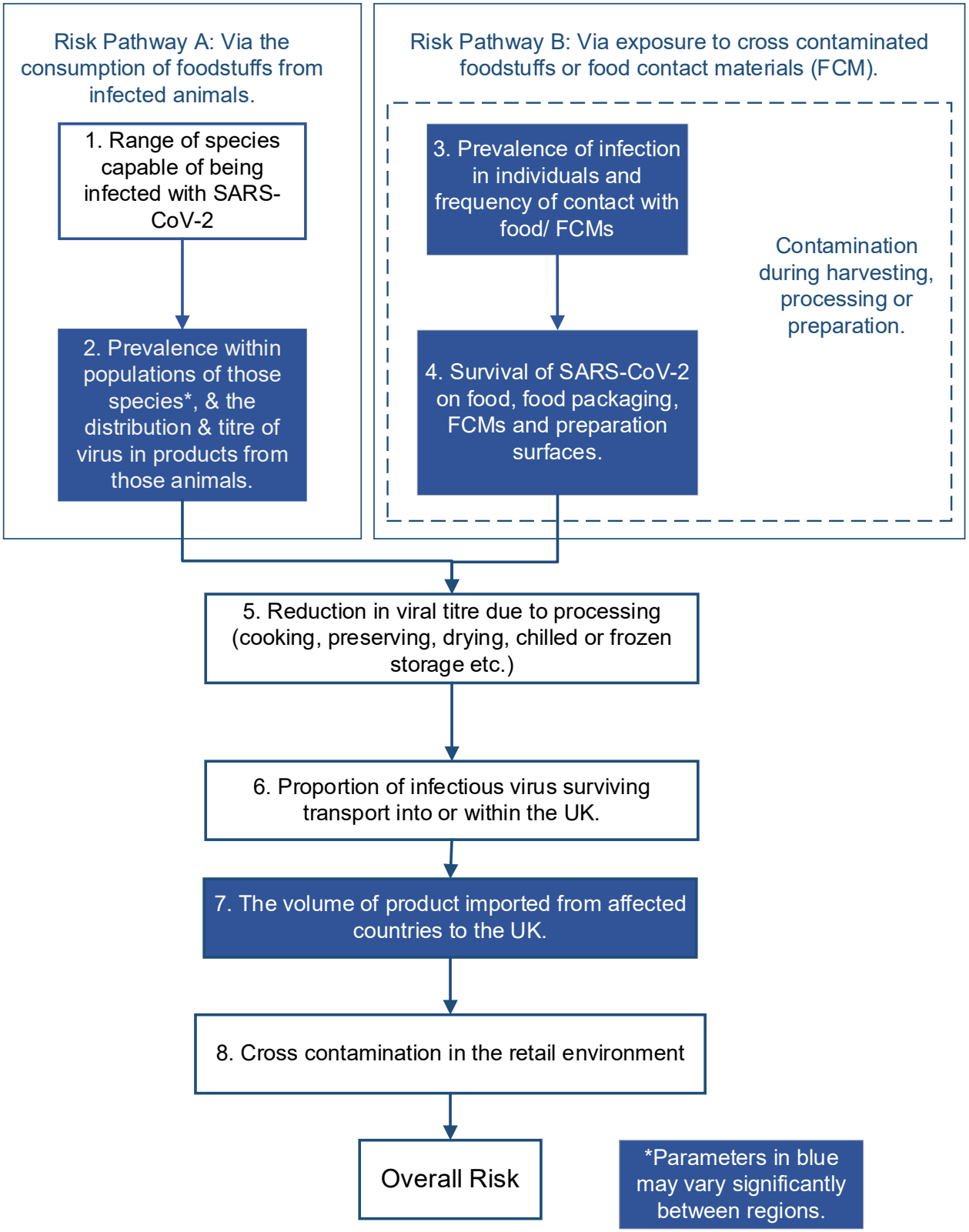
The seven key steps affecting the risk presented by foodstuffs consumed by UK consumers, and how they depend on the type of foodstuff and its origin, are illustrated in Figure 1 and then discussed in turn in the following sections. Some sections of the risk assessment are applicable to more than one stage of the food production chain, a more detailed diagram of where each risk question may be applicable can be found in Appendix 2.

In arriving at an overall probability for a pathway, individual step probabilities were first combined using a matrix rule; a probability of “Low” lowered the overall qualitative probability by one category; “very low” by two categories, and “negligible” by three categories; “Medium” resulted in no change and “high” increased the probability category by one. An independent assessment was then made of the resulting overall risk level, following independent internal review, in view of the sum total of evidence to ensure it was within the definitions considered. This helps to ensure transparency in approach while addressing acknowledged inaccuracies that can result in some cases from unsupervised matrix combinations of qualitative probabilities, for example when combining high and low qualitative probabilities (WHO/FAO 2008).

For this assessment, both the matrix rule approach and independent final risk estimate arrived at the same qualitative measure of risk for both pathways (A and B).

To combine estimates for the two pathways (Pathway A and Pathway B) and arrive at an overall estimate, the higher of the two categories was taken.

Figure 1: Key steps in the two pathways considered for potential foodborne and food contact materials exposure



Probability of susceptible animals being infected with SARS-CoV-2

The species responsible for the original human infections has not yet been identified, and the range of species capable of being infected with SARS-CoV-2 is not yet known (**uncertainty**). Betacoronaviruses mainly infect bats (Anthony et al. 2017), but also infect other species, including rodents and lagomorphs (hares and rabbits). Experiments in which various species were deliberately exposed to SARS-CoV-2 found no evidence that pigs, chickens or ducks could become infected, but did find evidence of efficient replication in ferrets and cats (Shi et al., 2020), and a small number of animals have tested positive for SARS-CoV-2 including tigers (USDA-APHIS 2020), a domestic cat (International Society for Infectious Diseases, 2020a), a dog in Hong Kong (International Society for Infectious Dieaseses 2020b) and mink at a farm in the Netherlands .The first known cases of SARS-CoV-2 were a cluster associated with the Wuhan South China Seafood City market, a "wet market" which sold meat, poultry, seafood and a large range of live animals. This market was closed on January 1st 2020. The animal species for the original zoonotic transmission to humans is unknown (**uncertainty**).

SARS-CoV-2 is a mammalian coronavirus. Viruses in the family *Coronaviridae* exhibit frequent host-switching (Bolles et al. 2011) and some infect mammalian livestock species (such as bovine coronavirus (BCoV) in cattle and porcine epidemic diarrhoea virus in pigs). SARS-CoV was capable of infecting palm civets, and MERS-CoV was capable of infecting dromedary camels (WHO 2019). A single study has reported the isolation of SARS-CoV from naturally-exposed pigs (Chen et al. 2005) and one experimental challenge study with SARS-CoV (using high doses and multiple exposure types) has suggested that pigs were susceptible to asymptomatic infection with SARS-CoV, but did not develop high enough levels of virus to transmit the virus (Weingartl et al., 2004). However, as stated above, an experimental infection study using SARS-CoV-2 found no viral RNA or serconversion in intranasally-challenged pigs, chickens and ducks or in animals housed with the intranasally-challenged animals (Shi et al. 2020).

Previous attempts using SARS-CoV to experimentally infect poultry (chickens, turkeys, geese, ducks, and quail) have been unsuccessful (Swayne et al. 2004). We consider that the probability of consumer exposure via food products such as eggs and meat from infected avian hosts is therefore **Negligible** and not further considered.

Expert opinion received from CEFAS via Defra[1] suggests that fish and seafood animals are not susceptible to infection by the SARS-CoV-2 virus and therefore represent a **Negligible** probability as they are not potential host organisms for known species of *Coronaviridae*. They are not further considered in risk pathway A in this risk assessment.

However, the risk of exposure via seafood particularly shellfish through accumulation and carriage of infectious virus is specifically assessed in a separate risk assessment. This assesses the risk to UK consumers of exposure to infectious SARS-CoV-2 via the consumption of farmed produce that have become contaminated via exposure to infectious virus via wastewater systems, specifically, bivalve molluscs originating in UK waters.

For other groups of mammals (either livestock or those traditionally viewed as wildlife

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[1] "Aquatic *Nidovirales* briefing note: (with respect to *Coronavirus*)" authored by R. Paley, 18th Feb 2020

species), in the absence of specific challenge information and ambiguity about the potential host range of the virus, the likelihood is considered to be "**Very low**".

As SARS-CoV-2 is a mammalian coronavirus the risk of exposure via consumption of infected amphibians and insects is **Negligible**, although such foods could still become contaminated via the processes described in Pathway B.

This is summarised in Table 4 below.

Table 4: Probability of certain animals being susceptible to infection with the virus

Category	Probability
Fish and seafood species	Negligible
Other species (including mammals)	Very Low
Avian species (e.g. poultry)	Negligible
Amphibians and insects	Negligible

Prevalence of virus within populations of susceptible animals, and the distribution and titre of the virus in edible products obtained from those infected

Although SARS-CoV-2 was identified based on a cluster of cases apparently originating at a market selling food in Wuhan, no specific evidence implicating foodborne transmission of SARS-CoV-2 has been found. However, foodborne infection through poor hygiene and potentially involving contact with contaminated surfaces or water cannot be completely discounted. Infected animals bought live for consumption may provide a source of infection, particularly if poor hygiene practices are followed during slaughter, preparation and cooking. We were unable to find any reports of the detection of SARS-CoV-2 from any livestock animals during the current outbreak. WHO currently recommends that veterinarians should maintain a high level of vigilance and to report any unusual presentations seen in any animal species present in markets to veterinary authorities, and all companies producing food within the UK and those exporting to the UK should be implementing food standards and hygiene protocols which include not permitting visibly sick animals to enter the food chain. Therefore, if disease is present in an animal population and results in clinical disease in that species, it would need to be at a sufficiently low level to escape detection or be inapparent during the incubation period. Therefore, if SARS-CoV-2 does generally result in clinical disease in nonhuman hosts it is assumed that if animal populations are infected the prevalence would be at a low level, reducing the probability that food products would be produced from an infected animal, although there is no active testing or surveillance to verify this. As the host range of the virus is currently not known, there is also currently no data on the proportion of infected animals likely to display clinical disease, or on the likely relationship between the development of clinical disease and infectiousness in infected animals, adding uncertainty to this assumption (**uncertainty**).

The distribution and titre of virus in the tissues of infected wild animals or livestock, is currently not known (**uncertainty**). The potential for the virus to remain infectious in the tissues of infected slaughtered animals is not known (**uncertainty**). For SARS, a disease caused by the closely-related SARS-CoV, research suggests that transmission was likely only for individuals sat close to or involved in the slaughter of infected animals rather than those consuming their meat (Wang et al. 2005), and meat is not known to be a route for the

transmission of other coronaviruses. Earlier in the outbreak WHO promoted precautionary generic recommendations to avoid the consumption of raw or undercooked animal products, as undercooking carries a high risk of infection from a variety of other pathogens which may cause disease in humans. However, this was not coronavirus-specific advice and has now been removed from WHO guidance.

The shedding of coronaviruses in the milk of infected wild animals and certain farmed or working animals is poorly understood (**uncertainty**). MERS-CoV RNA and antibodies to MERS-CoV are detectable in dromedary camel milk, although in quantities too low for virus isolation to be attempted (Reusken et al. 2014), and *E. coli* was not present at detectable levels, suggesting that faecal contamination was unlikely to be the source in this study. MERS-CoV persisted with a decreased viral titre in experimentally-spiked milk for several days at +4°C (van Doremalen et al. 2014). Current WHO recommendations are that pasteurisation is likely to inactivate MERS-CoV and it has been shown that heat treatment (30 minutes at 63°C) of camel milk containing MERS-CoV reduced levels of infectious virus below the threshold of detection (van Doremalen et al. 2014), although no data could be found on significantly higher temperatures but of shorter duration more closely emulating processes such as HTST pasteurisation (**uncertainty**).

The host organism(s) for SARS-CoV-2 has not yet been identified, however, there was some evidence of a potential association between the consumption of unpasteurized dromedary milk and cases of the related MERS-CoV. Therefore, with no further information at this time, the probability of food products being produced from an infected animal is **Very Low**, and the probability that there are sufficient infectious viral titres present in the edible fraction of derived meat and dairy products to infect a consumer is considered **Very Low**.

Probability of cross-contamination (UK or in importing countries)

The probability of cross-contamination from infected human handlers to food will be dependent on the frequency of contact that is sufficient to transfer a significant amount of virus, the degree to which hygiene measures mitigate the transmission, and the subsequent survival of the virus on that food, food contact materials, or packaging.

Frequency of contact from infected food handlers and the degree to which hygienic food preparation methods mitigate this exposure

For certain commodities, multiple people can be involved in the food chain from farm to fork during cultivation, harvesting, manufacturing, processing, packaging, preparation and serving which may result in cross- contamination to food if the human handlers are infected.

Coronaviruses are mainly transmitted by large respiratory droplets and direct or indirect contact with contaminated secretions. SARS-CoV-2 RNA has been detected in saliva, blood, faeces, gastric duodenal and rectal epithelia and in urine (Xiao et al. 2020, Zhang et al. 2020), A study of SARS-CoV-2 showed that faecal samples from 41 (55%) of 74 confirmed COVID-19 patients were positive for SARS-CoV-2 RNA (Wu et al., 2020). ECDC reports that 30% of cases have stool samples which test positive for SARS-CoV-2 from day 5 of symptom onset (ECDC, 2020).The rate of shedding of intact virus in secretions and which secretions this may occur in is not yet known (**uncertainty**), the rate of shedding if any or viable virus before developing visible symptoms is unknow (**uncertainty**). Human-human transmission of SARS-CoV-2 has been confirmed as the main source of

transmission, however the risk of infection via the faecal-oral route cannot be excluded. To date there are no further studies on viral shedding via other body fluids such as sweat (**uncertainty**).

WHO advice to the public to reduce exposure to SARS-CoV-2, and a number of other pathogens, includes frequently cleaning hands using alcohol-based hand rub containing 60% or higher concentration of alcohol, or soap and water, avoid touching eyes, nose and mouth without rigorous and regular hand washing. As an enveloped virus, SARS-CoV-2 is relatively fragile. Good food hygiene practices should still be followed, such as avoiding cross contamination of foods with body fluids from infected animals or humans, including foods potentially contaminated with animal saliva. Raw meat, blood products, milk or animal organs should be handled with care to avoid cross-contamination. Unprocessed fruit and vegetables should be handled hygienically, well washed and/or peeled before consumption or preparation.

The average incubation period (time from exposure to the onset of symptoms) for COVID-19 is 5.1 days, and 97.5% of those who develop symptoms will do so within 11.5 days (Lauer et al 2020), a study by the CDC showed that individuals may test positive for the presence of SARS-CoV-2 7days prior to symptom onset. Arons et al (2020) found that 56% of individuals in their study tested positive for SARS-CoV-2 but were asymptomatic, of which 89% later developed symptoms, viable virus was isolated from 70% of the asymptomatic individuals. However there are a number of cases where asymptomatic individuals have tested positive for the presence of SARS-CoV-2 but not go on to develop symptoms (Pan et al. 2020) Transmission dynamics of SARS-CoV-2 are not fully understood (**uncertainty**) and the precise time during which workers may be asymptomatic but still shedding SARS-CoV-2 is variable dependant on the individual. Workers who have visited high risk countries or have been in contact with COVID-19 cases are advised to self-isolate at home for 14 days. Based on current government advice, workers at UK food businesses presenting with clinical signs such as a raised temperature and a new continuous cough should be considered unfit to work. However, people may become infectious prior to the development of clinical signs, although the extent of this is not known (**uncertainty**).

In areas outside the UK, EU or EU certified areas, the likelihood that individuals infected with SARS-CoV-2 are involved specifically in food production for export is difficult to estimate **(uncertainty)** but is likely to be **Low**. A recent paper suggested that the rate of low or asymptomatic transmission in China was 86% (Ruiyun et al., 2020) including potential false negatives. However, the estimated prevalence does not reflect the imposition of strict quarantine and self-isolation measures which would reduce the prevalence in the working population even further. The number of detected cases in the UK coupled with the surveillance and current government advice means that the likelihood of a food handler or others involved in the manufacture of food being infectious can currently be considered to be **Low**.

However, if good food hygiene practices, HACCP and self-isolation policies are followed by all workers (**uncertainty**), it is our opinion that the probability of cross-contamination resulting in food products, food contact materials or packaging in the UK being contaminated with infectious virus during food production is **Very Low.** The associated uncertainty is **Medium** and this opinion may be reviewed as further information becomes available.

The survival of the virus on food packaging, food contact materials or food preparation surfaces

The main transmission route of SARS-CoV-2 in the UK is assumed to be direct human-human transmission via infectious droplets. A study on the survival of SARS-CoV-2 in aerosols found that SARS-CoV-2 remained viable throughout the 3 hour experiment, with a reduction of $10^{1.2}$ median tissue culture infectious dose ($TCID_{50}$) per litre of air in 3 hours at room temperature (21-23°C) and 65% relative humidity (Van Doremalen et al. 2020). However, aerosolised particles behave differently to the larger droplets produced for example from coughing, which would fall more rapidly onto a surface. The main route of SARS-CoV-2 transfer to food packaging, food contact materials and food preparation surfaces is assumed to be via cross contamination from infected individuals. A table summarising the survival times of SARS-CoV-2 and other coronaviruses on surfaces can be found in Appendix 1. A review of the survival of SARS-CoV can be found in Kampf et al. (2020) and Otter et al. (2016). SARS-COV-2, SARS-CoV and MERS-CoV all survive better than influenza virus on surfaces, SARS-CoV and SARS-CoV-2 have similar survival times on most surfaces, with the exception of cardboard where SARS-CoV-2 appears to be inactivated more slowly on cardboard than SARS-CoV (Van Doremalen et al. 2020). The studies that measure viability of SARS-CoV-2 or any coronavirus often start with an initial viral titre significantly higher than would be expected to be present through 'natural' cross contamination. The experiments also measure samples dried onto surfaces in tissue culture medium which may not have the same properties or rate of drying as virus transferred to a surface in respiratory droplets or as a result of coughing (**uncertainty**).

Survival on paper and cardboard

Cardboard: SARS-CoV-2 inoculated onto cardboard at a concentration of $10^{3.7}TCID_{50}$ per ml dropped below the detectable limit of $10^{0.6}TCID_{50}$ in 24 hours at 21-23°C and 40% relative humidity (Van Doremalen et al. 2020) .

Paper: No infectious SARS-CoV-2 could be recovered from inoculated paper or tissue paper after 3 hours at 22°C and 65% relative humidity, representing a reduction of $10^{7.8}$ $TCID_{50}$ to 10^2 $TCID_{50}$ per ml (Chin et al. 2020). The time for which SARS-CoV dried onto paper could be recovered was found to vary between five minutes (at 10^4 $TCID_{50}$/ml) and 24 hours (10^6 $TCID_{50}$/ml) at room temperature, depending on the starting titre of SARS-CoV virus inoculated (Lai et al. 2005).

Survival on plastic

Van Doremalen et al. (2020) observed a reduction from $10^{3.7}$ $TCID_{50}$ to $10^{0.6}$ $TCID_{50}$ per mm^2 in 72 hours, giving a half-life of SARS-CoV-2 on polypropylene of 6.8 hours (at 21-23°C and 40% relative humidity), while Chin et al. (2020) reported the detection of viable SARS-CoV-2 above the detectable limit of 10^2 $TCID_{50}$ per ml for up to 7 days after inoculation of $10^{7.8}TCID_{50}$ per ml onto (unspecified) plastic, at 22°C and 65% relative humidity.

One study found that infectious SARS-CoV with an initial starting concentration of 10^7 $TCID_{50}$ per mL could be recovered after 20 days dried onto the surface of 24-well plastic plates (plastic type not specified), in media at 40% relative humidity (Chan et al. 2011) whereas a second study found that the quantity of infectious SARS-CoV dried onto

polystyrene Petri dishes declined from roughly 10^7 $TCID_{50}$ to roughly 10^2 $TCID_{50}$ over six days, but could still be recovered (at close to the detection limit) after six days (Rabenau et al. 2005). Human coronavirus 229E was found to decline to an undetectable level from an initial concentration of 10^3 PFU over 4-5 days on PVC and PTFE (Warnes et al. 2015).

A number of different plastics are used in the food chain including plastic films which may contain creases where the virus may become trapped, in addition to novel packaging materials such as compostable plastic equivalents. The survival time of SARS-CoV-2 on most specific types of plastic and alternative materials used in the food chain is unknown (**uncertainty**).

Survival on other surfaces

Survival of SARS-CoV-2 was tested on a number of other surfaces. No viable virus could be detected after 2 days on wood or cloth or 4 days on glass or banknotes. Results were reported for all three surfaces as the time taken to reduce the titre from $10^{7.8}$ $TCID_{50}$ to 10^2 $TCID_{50}$ per ml, tested at 22˚C and 65% relative humidity (Chin et al. 2020). SARS-CoV at an initial concentration of 10^6 TCID per ml was tested on wood board, glass, cloth and metal and viable virus was detected for up to 5 days (Duan et al. 2003).

A study on survival of SARS-CoV-2 on stainless steel found a reduction from $10^{3.7}$ $TCID_{50}$ to $10^{0.6}$ $TCID_{50}$ after 48 hours, giving a half-life of 5.6 hours on stainless steel at 21-23°C and 40% relative humidity (Van Doremalen et al. 2020), whereas a second study found SARS-CoV-2 could be detected for up to 7 days on stainless steel (reduction of $10^{7.8}$ $TCID_{50}$ to10^2 $TCID_{50}$ per ml) at 22°C and 65% relative humidity (Chin et al. 2020).

Infectious Human coronavirus 229E (HuCoV229E) could be recovered from ceramic surfaces for 4-5 days from an initial concentration of 10^3 PFU (Warnes et al. 2015).

No viable SARS-CoV-2 could be detected on copper after 4 hours (a reduction of $10^{3.7}$ $TCID_{50}$ to $10^{1.5}$ $TCID_{50}$ (Van Doremalen et al. 2020) whereas HuCoV229E survived for up to 40 minutes on copper and copper alloys, but these alloys are not widely used in the food industry at the present time (Warnes et al. 2015).

Survival on the surface of foods

A small number of studies have looked at the persistence of coronaviruses on fresh produce. HCoV 229E inoculated onto iceberg lettuce could no longer be detected after 4 days at 4ºC (representing a reduction of >1.31 log_{10}) and could not be recovered from inoculated strawberries (Yepiz-Gomez et al. 2013). Another study using BCoV as a surrogate for SARS-CoV found that BCoV inoculated onto lettuce leaves could remain viable for up to 14 days under refrigeration conditions, and that washing did not completely remove all viable virus (Mullis et al. 2011). However these experiments inoculated large titres of virus in growth media onto the lettuce (~5.0 ×10^4 $TCID_{50}$). Mullis et al. (2011) also showed that if bovine coronavirus was inoculated onto the lettuce in faecal matter the survival time was significantly shorter. Outside the laboratory the virus would potentially be present on surfaces associated with organic matter, which may affect the survival time (**uncertainty**) and at lower doses than in most of these experiments.

Disinfectants

Unlike bacteria, viruses are unable to replicate outside of the host cells. Therefore, if SARS-CoV-2 was present on a food preparation surface, food contact material or food packaging the virus could not replicate. Even under optimal conditions the viral titre would not increase.

Chin et al. (2020) studied the ability of a number of disinfectants to inactivate SARS-CoV-2 at an initial concentration of $10^{6.8}$ $TCID_{50}$/ml. The threshold of detection varied depending on the cytotoxicity of the disinfectant:; for hand soap and chloroxylenol it was 10^3 TCID50/ml; for povidone-iodine, chlorhexidine, and benzalkonium chloride it was 10^4 $TCID_{50}$/ml, and for other disinfectants it was 10^2 TCID50/ml. Household bleach (diluted 1:49 and 1:99), 70% ethanol, 7.5% povidone iodine, 0.05% chloroxylenol, 0.05% chlorohexidine, and 0.1% benzalkonium chloride all achieved a reduction to below the threshold of detection within five minutes; hand soap achieved a reduction to $10^{3.6}$ $TCID_{50}$/ml after five minutes and to below the threshold of detection before the next observation point (15 minutes).

Rabenau et al. (2005) tested the ability of a range of disinfectants to inactivate SARS-CoV. Their efficiency ranged from a reduction factor (RF value) of >3.25 to a maximum reduction factor of >6.13 (). A paper summarising the survival of coronaviruses and the effectiveness of disinfectants can be found at (Kampf et al. 2020); the most effective disinfectant in reducing the viral titre of SARS-CoV in the papers summarised was either 85% or 95% ethanol.

In cases where viral contamination occurs with organic matter, organic matter generally protects the virus and reduces the effectiveness of the disinfectants (similar to the presence of protein affecting the effectiveness of heat in destroying SARS-CoV observed by Rabenau et al. 2005). For example, in influenza studies from Thomas et al. (2008), influenza survival times on bank notes was increased significantly by the presence of mucus, precise increases varied depending on strain and initial viral titre.

Reduction in viral titre due to processing

A review of the available literature has found a number of publications that have investigated the impact of processing on the related SARS-CoV and other members of the *Coronaviridae* family.

No processing: viability studies on SARS-CoV show that from an initial concentration of 10^6 $TCID_{50}$ viable virus could be detected for up to 96 hours in sputum and faeces, and 72 hours in urine with low level infectivity (exact rate of reduction unknown (**uncertainty**)). Viral activity remained stable at 4°C, 20°C and 37°C for at least two hours (Duan et al. 2003).

Chilling: The viability of SARS-CoV-2 was recorded at 4°C in liquid culture. There was only a 0·7-log reduction over the whole 14 day period, suggesting that SARS-CoV-2 is relatively stable at chilled temperatures (Chin et al. 2020). Other species of *Coronaviridae* have also been found to survive for periods of over two weeks in liquids at 4°C with little inactivation

of the virus (loss of ~0.5 log_{10} pfu; Lamarre and Talbot 1989), although this is likely to depend on the matrix of the sample.

Freezing: No significant reduction in titre was seen in *Coronaviridae* samples frozen to -70°C and thawed for 25 cycles (Lamarre and Talbot 1989).

Preserving: SARS-CoV-2 was tested to measure the effect of a range of pH values between 3 and 10 on viability. Little reduction in viability was seen by incubating SARS-CoV-2 at any pH value in this range for 60 minutes (Chin et al. 2020). However longer time frames such as those used in pickling have not been tested (**uncertainty**). Some preservatives such as vinegar have been shown to reduce viral activity in *Coronaviridae* species (Rabenau et al. 2005). Similarly, the $F_0$3 canning process (heating to 121°C for at least 3mins) should destroy the virus based on heating experiments (see below). However, without knowing the exact preservatives, processing steps and pH of each food in this group it is not possible to identify whether all preserving would reduce viral activity (**uncertainty**).

Drying: desiccation reduces the viral activity of *Coronaviridae* species, with the rate of inactivation differing between species. SARS-CoV, which as stated above is the most closely related virus known to SARS CoV-2, is among the more resistant of the coronaviruses tested; infectious virus could still be recovered from samples initially containing 10^6-10^7 $TCID_{50}$ of SARS-CoV after nine days of drying at room temperature (21-25°C; Rabenau et al. 2005). As we do not know how long the food products will have been dried for, the amount of water left in the products, the product pH, or the timeframe from start of desiccation to the product being consumed it is not possible to accurately say whether the virus would be inactivated (uncertainty).

Heating: A study by Chin et al (2020) measured the effects of heat on SARS-CoV-2. The results of these experiments are detailed below in Table 5.

Table 5: Reduction in viral titre of SARS-CoV-2 at five temperatures adapted from Chin et al 2020, the maximum number of days required to inactivate SARS-CoV-2 in virus transport medium from an initial titre of $10^{6.8}$TCID50/ mL to below the detection limit of 10^2 TCID50/mL.

Temperature	Inactivation time
4°C	>14days
22°C	<12days
37°C	<2days
56°C	<30mins
70°C	<5mins

The most effective temperature to reduce viability of SARS-CoV-2 (in liquid culture) was 70°C where the reduction to below detectable level (2 Log $TCID^{50}$) occurs in under 5 minutes, 56°C achieves the same reduction in viral titre in up to 30 minutes, whereas at 37°C the same reduction takes up to two days and 12 days at 22°C. SARS-CoV-2 is

relatively stable at 4°C and little change in viral titre was detected across the 14 day experiment (Chin et al. 2020).

It is not known how protein content of the substrate affects the heat stability of SARS-CoV-2. However, the reduction in titre of SARS-CoV due to heat is dependent on the level of protein present. In the absence of protein, heating at 56˚C for 30 minutes reduces viral titre by at least 5-6 $\log_{10}$ $TCID_{50}$/ml (i.e. to below the threshold of detection in the study), but the reduction was only ~2 $\log_{10}$ when protein (20% FCS) was present (Rabenau et al. 2005). Another paper found that heating to 56°C for 90 minutes, 67°C for 60 minutes and 75°C for 30 minutes in a variety of substrates reduced the infectivity of SARS-CoV by at least 6 $\log_{10}$ (initial dose 10^6 $TCID_{50}$, no detectable cytopathic effect after treatment) (Duan et al. 2003). A further study on SARS-CoV found a 4 $\log_{10}$ $TCID_{50}$ at 65ºC for 4 minutes or more, although some infectious virus remained (Darnell et al. 2004). This paper also found that SARS-CoV was inactivated (>3$\log_{10}$ $TCID_{50}$) by ultraviolet C light (UVC) at 254 nm for <5 mins (Darnell et al. 2004).

Because these studies were not specifically intended to inform food safety risk assessments, the heating regimes were not designed to represent typical cooking profiles. However, it is assumed that any virus present would be via cross-contamination and therefore only likely to be present on the surface of foods. SARS-CoV-2 exposed to 70ºC lost infectivity after 5 minutes (Chin et al. 2020). Assuming SARS-CoV-2 is only present on the surface of the food heating to ensure the middle of the food is 70ºC for 2 minutes should sufficiently heat the outside of the food to inactivate any virus present. The viral titre used as the starting concentration for laboratory-based viability studies such as these are often significantly higher than the viral titre that could be present via cross contamination.

Many foods are composite foods and therefore SARS-CoV-2 may be present throughout these foods. Heating to 72ºC for 2 minutes may not sufficiently heat the inside of the food product to destroy any virus present (**uncertainty**), however for foods to be cooked, cooking instructions should provide guidance to thoroughly heat the product if followed (**uncertainty**).

A large proportion of ready to eat (RTE) products will undergo no further inactivation step. It is also not possible to define the protein content of products which may undergo further cooking. It is therefore not possible to reduce the probability of exposure to product groups as a consequence of post-production processing with confidence (**uncertainty**), although RTE foods produced in accordance with good hygienic practice are unlikely to have been contaminated before consumption if sealed in packaging.

Proportion of infectious virus surviving transport into or within the UK

The proportion of infectious virus on imported food, food packaging and FCM surviving transport and or storage is dependent on the product origin, method of transport, product type and packaging material. As described in section 5, different processing methods such as desiccation may reduce any potential viral load. However, this may also be dependent on shipping time, for example dried products shipped over a number of weeks would have time for any virus present to desiccate fully whereas fresh produce arriving by air would not. Dried or preserved products are also more likely to spend time in warehouses, storage facilities or distribution centres which would give a longer period between production and consumption and give further time for inactivation. However, a higher proportion of virus is likely to remain infectious in products that are shipped and stored frozen or chilled.

Total food import data collected by HMRC does not contain information on which products are ready to eat (and therefore would have no further inactivation step other than consumer/caterer storage and handling) or to be further processed or cooked. It is therefore not possible to reduce the likelihood of exposure by product type as a consequence of anticipated post-import processing with confidence (**uncertainty**). It is also not possible to estimate the time between production and consumption for UK based products as some may be used more quickly than others (such as fresh produce) but exact storage and distribution times will be supply chain dependent (**uncertainty**).

Volume of product imported from affected countries to the UK

As there are coronavirus cases in 213 countries and territories to date it is not possible to collectively assess the food import from all affected countries. Taking into account the considerations listed above in sections 4,5 and 6 it may be possible to individually assess imports of interest from a particular country if the need arises.

Particular uncertainties which may require reassessment include countries or regions with a high concentration of cases, if an animal host species is identified, or occurrences of reverse zoonosis are identified. The previous version of this risk assessment focussed on imports from China (as the country of origin for SARS-CoV-2) but this is no longer relevant given the wider distribution of COVID-19 cases to date.

Contamination in a retail environment

The prevalence and survival of SARS-CoV-2 in a retail environment is unknown (**uncertainty**). Within this section of the risk assessment we specifically consider the probability of contamination of prepacked food and food sold loose, and not of food prepackaged for direct sale or food sold hot for immediate consumption. Some food deliveries such as veg boxes and supermarket deliveries may present similar exposure (such as products collected from retail shelves and packed for delivery) however, this is dependent on the processes of each retailer. For the specified categories of food, SARS-CoV-2 contamination may originate with shop employees or customers.

The food products considered broadly fit into three groups: 1) prepacked food, 2) Loose foods that will be cooked, 3) Loose foods which undergo no further processing (foods that will be washed or peeled may fit into groups 2 or 3). Either the external packaging of packed food, or the surface of food sold loose, may become contaminated by routes such as workers or customers in shops coughing, exhaling, or transferring contamination on their hands from other sources to items while picking them up. If consumers pick up food items and then return them to the shelf, there may be multiple opportunities for contamination to occur. The rate of inactivation of SARS-CoV-2 is dependent on temperature (as described in section 5), and will therefore differ for virus contaminating food maintained at ambient, chilled or freezing temperatures (where the latter is rarely sold loose). The persistence of a small number of other coronaviruses on the surface of fresh produce has been investigated, as described in section 4; however there have as yet been no studies of SARS-CoV-2 specifically (**uncertainty**).

Group 1: packaged foods. Foods in this section if sealed in packaging are less likely to be contaminated at retail as they have been sealed since the production stage (the potential

for contamination during production is assessed in section 3). Any cross contamination occurring at the retail stage would be on the outside of the packaging. Food business employees are expected to follow good hygiene practice, including regular handwashing, and consumers are advised to wash their hands before and after preparing food. Additional controls have also been introduced by many food business operators. RTE foods produced in accordance with good hygienic practice are unlikely to have been contaminated before consumption if sealed in packaging (any contamination occurring due to handling prior to packaging is considered in section 3) and any contamination of the hands during handling is likely to be mitigated by current handwashing recommendations.

Group 2: Loose foods that will be cooked. Foods in this group will mostly consist of vegetables. Cross contamination in a retail environment would be surface contamination. Preparation such as washing, and peeling may reduce any possible SARS-CoV-2 present. As described in section 5, SARS-CoV-2 is sensitive to higher temperatures and thorough cooking should eliminate any SARS-CoV-2.

Group 3: Loose foods which undergo no further processing. A large fraction of food consumed in this category is likely to consist of fruit, some vegetables, and baked goods produced on-site, where these facilities remain open. Little is known about the survival of coronaviruses on food and there are no specific studies on SARS-CoV-2 survival on foods (**uncertainty**). The ready to eat produce in group 3 may fit into smaller subcategories of foods that can be washed or peeled before consumption, foods stored at refrigerated temperatures and foods ready to eat off the shelf. As SARS-CoV-2 would only be present through cross contamination, the virus would only be present on the surface of the item therefore washing under a running tap or peeling should significantly reduce the amount of virus present. Handwashing would also reduce cross-contamination of the food product. As SARS-CoV-2 is stable at 4^{o}C (section 5) refrigeration would not reduce the titre of any potentially infectious virus. As for packaged food, consumers are advised to wash their hands before and after preparing food.

Cross contamination in a retail environment such as a supermarket could be due to cross contamination from other customers particularly people with COVID-19 that are presymptomatic or asymptomatic, as the prevalence in the general population is unknown (**uncertainty**). We have no data to estimate the number of consumers handling a product in a retail setting prior to purchase (**uncertainty**); reasons for handling a product and then returning it to a shelf may include to check best before or use by dates, to check allergy information, visually inspect the condition of fresh fruit and vegetables, selection in error, or a change of mind. Packaged goods may be cross contaminated in the same way as unpackaged or loose foods.

Assuming all customers and retail staff follow government guidance on self-isolation at the onset of symptoms consistent with COVID-19, good practice when coughing or sneezing, and good hand hygiene both when visiting shops and during food preparation, and given the relatively low proportion of infectious presymptomatic or asymptomatic individuals in the non-isolating population at any one time, we consider that **the potential for further cross contamination of food products at retail is Very Low**. This estimate is associated with **High uncertainty** due to the lack of data on the prevalence of SARS-CoV-2 in retail environments, data on the behaviours of shoppers in a retail, and data on the proportion of infections that are asymptomatic and the relative infectivity of presymptomatic and asymptomatic individuals.

Risk pathway A: The estimated risk from infected animals

This pathway consists of steps 1, 2, and 5 above, as well as 6 and 7 for imported products, (Table 6). To summarise:

Step 1: the risk from infected eggs, poultry meat and fish and seafood is assumed to be **Negligible**; the likelihood that meat and blood products, milk and dairy products from other species (including mammals) may be susceptible to the virus is considered to be **Very Low**.

Step 2: the probability that products consumed in the UK would be derived from infected animals with sufficient viral titres in edible fractions is considered to be **Negligible**.

Step 5: Some food processing methods would be expected to reduce the viral titre; however, due to the diverse range of products available both through international imports and domestic production, it is not possible to provide a generalised probability covering all products. Heating to 56^{o}C for 30 minutes is likely to inactivate the virus if present in food. Heating to temperatures above 72^{o}C for shorter periods has been shown to significantly reduce the infectivity of any virus present.

Step 6 (imported route only): survival of virus present in products stored or transported under chilled or frozen conditions is likely to be variable but in some cases the virus may survive for a period of weeks.

Step 7 (imported route only): low volumes of meat and other food products of animal origin are imported from China (see Appendix 1); data for other affected areas is currently being incorporated. Data using historical trade volumes may not be representative of current trade patterns which vary between years or the full extent of imported foods (e.g. composite foods).

Overall, the combined likelihood of human exposure to the virus from infected animals (livestock or wildlife) from which meat or products of animal origin are derived is considered to be **Negligible**, with **High** uncertainty.

Risk pathway B: Cross-contaminated foodstuffs

Summarised in Table 6.

Large quantities of food including fruit and vegetables are imported to the UK from locations worldwide and in many cases with minimal processing. This risk pathway B estimates the probability of consumption of cross-contaminated foods and therefore must consider both food products of animal origin (POAO) and foods not of animal origin (FNAO).

This pathway consists of steps 3,4,5,8 for domestic food production and steps 3,4,5,6,7,8 for imported foods.

Step 3: The prevalence of infection in people involved in food cultivation, harvesting, preparation and processing in the UK is currently considered to be **Low**; the prevalence of infection in those people involved in food production in other areas of the world is currently considered to be **Low**.

On the assumption that good food hygiene practices are adhered to, the probability of contamination in either domestic or international production is **Very Low**.

Step 4: The survival of SARS-CoV-2 on different surface materials that may be found in food packaging, FCM or food preparation areas varies depending on surface type, temperature, humidity and initial viral titre (dose) or SARS-CoV-2. However, a range of disinfectants are effective at removing the virus. Given the number of uncertainties we are unable to reduce the risk level as a result of this step (no change).

Step 5: Some food processing methods would reduce the viral titre; however, due to large range of products available both through international import and domestic production, it is not possible to state a generalised probability for all products. Some food processing methods would be expected to reduce the viral titre; however, due to the diverse range of products available both through international imports and domestic production, it is not possible to provide a generalised probability covering all products. Heating to 56^{o}C for 30 minutes is likely to inactivate the virus if present in food. Heating to temperatures above 72^{o}C for shorter periods has been shown to significantly reduce the infectivity of any virus present.

Step 6 (imported or UK produced): Virus present in products stored or transported under chilled or frozen conditions may survive for a period of weeks, and this was therefore considered unlikely to significantly alter the likelihood of exposure via such products.

Step 7 (imported only): the overall volume of food and FCM and other food packaging imported into the UK is high, but will vary significantly by region of origin.

Step 8: The probability of SARS-CoV-2 on food products via cross contamination from consumers in a retail environment particularly ready to eat products sold loose is **Very Low** as this probability is dependent on the product, and the amount of potential touches or contact with consumers as well as the prevalence of infection in the specific area.

Overall the likelihood of exposure to SARS-CoV-2 via contamination from food products produced both domestically and internationally (imports) is **Very Low**. Although the likelihood in some steps with pathway B is considered Negligible, due to the high volumes of food and FCM and food packaging produced both domestically and internationally a conservative estimate of **Very Low** is assigned. Imports defined in section B exclude illegal imports.

Hazard Characterisation

Illness caused by coronavirus species vary and range from cold like symptoms to more severe illness in humans including gastroenteritis and respiratory tract diseases. SARS-CoV-2 has been associated with cases of viral pneumonia and respiratory tract disease (WHO 2020, Gov.uk 10th January 2020).

An analysis of the clinical presentation of 41 patients (median age of 49) with lab-confirmed COVID-19 in China published online on 24th January 2020 (Huang et al. 2020) suggests that common symptoms at onset of illness are fever (98%), cough (76%) and myalgia/fatigue (44%); less common were sputum production (28%), headache (8%), coughing blood (5%), and diarrhoea (3%). Laboured breathing developed in 55% of patients after a median time from onset of 8 days. 63% of patients had lymphopenia and all patients had pneumonia with ground glass opacity. More severe cases progress to acute respiratory distress syndrome (ARDS), acute cardiac injury, acute kidney injury, and shock. (Jiang et al. 2020).

Current evidence suggests that a high proportion of patients developing severe clinical disease had pre-existing health conditions, and this group is likely to represent most of the individuals at risk of severe disease.

Potential for infection via ingesting virus

Food has not currently been identified as a source of infection with SARS-CoV-2 and the genome of SARS-CoV-2 suggests that it is most closely related to SARS-CoV, for which foodborne transmission was also not implicated in any cases of infection. However, this route cannot be ruled out and was also not investigated directly. We therefore make the conservative assumption that such transmission is possible (**uncertainty**). The infectious dose of SARS-CoV-2 via the oral route is unknown (**uncertainty**). SARS-CoV-2 requires the presence of the Angiotensin-converting enzyme 2 (ACE2) receptor to infect a cell (Letko et al. 2020; Walls et al. 2020), which is present in various human tissues including oral and nasal mucosa, nasopharynx, stomach, small intestine, and colon (Hamming et al. 2004;). One study showed gastrointestinal infection caused by SARS-CoV-2 (Xiao et al. 2020). The pH of human stomach acid is between 1.5 and 3.5 (Beasley et al. 2015), the survival of SARS-CoV-2 is unknown below pH 3, and the survival of SARS-CoV-2 was only tested at pH's above 3 for 60 minutes (**Uncertainty**), the matrix of the food eaten may also offer some protection against stomach acid (**Uncertainty**). However, studies on SARS-CoV suggest that the virus is likely to be inactivated by the pH's 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.

Risk Characterisation

Table 6: Summary of risk steps and probabilities.

Section	Description of step	Probability
1	Consumer exposure via food products such as eggs and meat from infected avian hosts	**Negligible**
	Consumer exposure via fish and seafood	**Negligible**
	Consumer exposure via other species (including mammals)	**Very Low**
2	Consumer exposure via the prevalence of virus within populations of susceptible animals, and the distribution and titre of the virus in edible products obtained from those infected	**Very Low**
3	Consumer exposure via the prevalence of infection in human handlers producing commercial food (UK or in importing countries)	**Low**
	Consumer exposure via the frequency of close contact of infected food handlers and the degree to which hygienic food preparation methods mitigate this exposure	**Very Low**
4	Survival of SARS-CoV-2 on surfaces	Variable depending on surface and conditions*
5	Reduction in viral titre due to processing	Variable based on specific processing *
6	Probability that infectious virus on food survives transport into or within the UK (imported foods only)	Variable based on specific product*
7	Volume of product imported from affected countries to the UK	Not assessed*
8	Cross contamination of food products in a retail environment	**Very Low**
Overall probability	Pathway A (1,2,5,6,7)	**Negligible**
	Pathway B (3,4,5,6,7,8)	**Very Low**

*assumed not to reduce the risk as a worst-case assumption

Our risk assessment is formatted according to the extended two-dimensional representation of risk recommended by ACMSF in 2019. It includes probability statements for individual steps within each pathway as well as overall probabilities for pathways A and B and for both pathways combined according to the process defined in the Exposure Assessment section above.

We consider that the probability of exposure of UK consumers to SARS-CoV-2 via food produced in the UK is Negligible via pathway A (food of animal origin) and Very Low via pathway B (cross contamination of food), with the overall probability of exposure via both pathways considered to be **Very Low**. The uncertainty associated with these estimates is **High** as there are still limited data relating specifically to SARS-CoV-2.

The worldwide case fatality rate for COVID-19 appears to be around 7% based on current reports, meaning the severity of detriment is considered **High** (Severe illness: causing life-threatening or substantial sequelae or illness of long duration), although as noted above severe disease has so far mostly occurred in individuals with pre-existing health conditions. Uncertainty relating to severity of detriment is **Low** as a large amount of data is now available.

We note that the genome of SARS-CoV-2 suggests that it is most closely related to SARS-CoV, for which foodborne transmission was not strongly associated in any cases of infection.

Key uncertainties

This is a rapidly moving outbreak and important uncertainties remain, specifically:

- The potential for SARS-CoV-2 to infect via ingestion, and the dose-response relationship;
- The prevalence of the SARS-CoV-2 virus in humans.
- Which animal species are capable of being infected with SARS-CoV-2;
- The proportion of any susceptible animals that are infected;
- The titre and survival of any SARS-CoV-2 in edible fractions of products from infected animals;
- Whether food products (meat and blood products, milk and eggs) of infected animals are being illegally imported into the UK, and relevant volumes;
- The role of workers in the food industry particularly infected food handlers including asymptomatic ones in any transmission of SARS-CoV-2;
- Further evidence to support precise heat inactivation times and temperatures to inactivate SARS-CoV-2 in foodstuffs;
- The survival of SARS-CoV-2 on the surfaces of RTE food sold loose (e.g. fruit, vegetables and baked goods) and the reduction in viral titre caused by washing and peeling.

Limitations of this assessment

This risk assessment does **not** consider:

- The risk associated with illegal importation activities. This is due to the lack of data on volumes of product illegally entering the UK as well as their processing and transportation.
- The occupational risk to food preparers or those frequently exposed to products of animal origin, for example slaughterhouse workers.
- Implications for integrity of the food chain, including reduced availability of food handlers, packers or distributors if they themselves become ill or reduced availability of approved disinfectants etc for cleaning of food manufacturing equipment and food preparation areas due to shortages.
- The impacts of altered behavioural choices for example, change in choice of products, catering supply to domestic supply, internet shopping.
- Faecal-oral transmission.
- Human breast milk.
- Water

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Appendix 1

Table 7: Summary of published studies on coronavirus survival on surfaces, times given are time points after which no viable virus was detected.

Surface	Virus	Time	Initial viral titre	Conditions	Reference
PVC	HCoV 229E	5 days	10^3 PFU	21°C 30-40% Relative Humidity	Warnes et al 2015
PTFE (Teflon)		5 days			
Ceramic		5 days			
Glass		5 days			
Rubber (silicon)		3 days			
Stainless steel		5 days			
Brass>70%Copper		<40mins			
Nickel		<120mins			
Plastic plate	SARS-CoV	5 days	10^5TCID$_{50}$ /mL	22-25°C 40-50% Relative Humidity	Chan et al 2011
Polystyrene plate	SARS-CoV	6 days (without FCS)	10^7TCID$_{50}$ /mL	21-25°C	Rabenau et al 2005
Paper	SARS-CoV	24 hours*	10^6TCID$_{50}$ /mL	Room Temperature	Lai et al 2005
Plastic gown		2 days*			
Cotton gown		24 hours*			
Metal	SARS-CoV	5 days	10^6TCID$_{50}$ /mL	Room Temperature	Duan et al 2003
Wood		4 days			
Paper		4-5 days			
Glass		4 days			
Copper	SARS-CoV-2	4 hours	10^6TCID$_{50}$ /mL	21-23°C 40% Relative Humidity	Van Doremalen et al 2020
Cardboard		24 hours			
Stainless steel		48 hours			
Plastic		72 hours			
Paper	SARS-CoV-2	3 hours#	$10^{7.8}$TCID$_{50}$ /mL	22°C 65% Relative Humidity	Chin et al 2020
Tissue Paper		3 hours#			
Wood		2 days#			
Cloth		2 days#			
Glass		4 days#			
Bank Note		4 days#			
Stainless Steel		7 days#			
Plastic		7 days#			

*Times varied by viral titre, these are the maximum survival times based on the highest initial viral titre.

[#]Time was defined as the first time point at which no virus was detected.

Survival time is defined as the time after which the viral titre dropped below the detectable level (detectable level was variable depending on the experiment). For less precise end times this was due to the viral titre reaching the required log fold reduction before that time point was measured.

Appendix 2

Flow diagram of steps in food production chain where each section may be relevant.

At each stage of the food production chain one or more sections of the risk assessment are relevant. The numbers in circles correspond to the relevant section of the risk assessment (summarised in table 8 below). The precise number of steps from raw product to home consumption varies depending on the product.

Figure 2: illustrative diagram of risk pathways A and B showing key component steps.

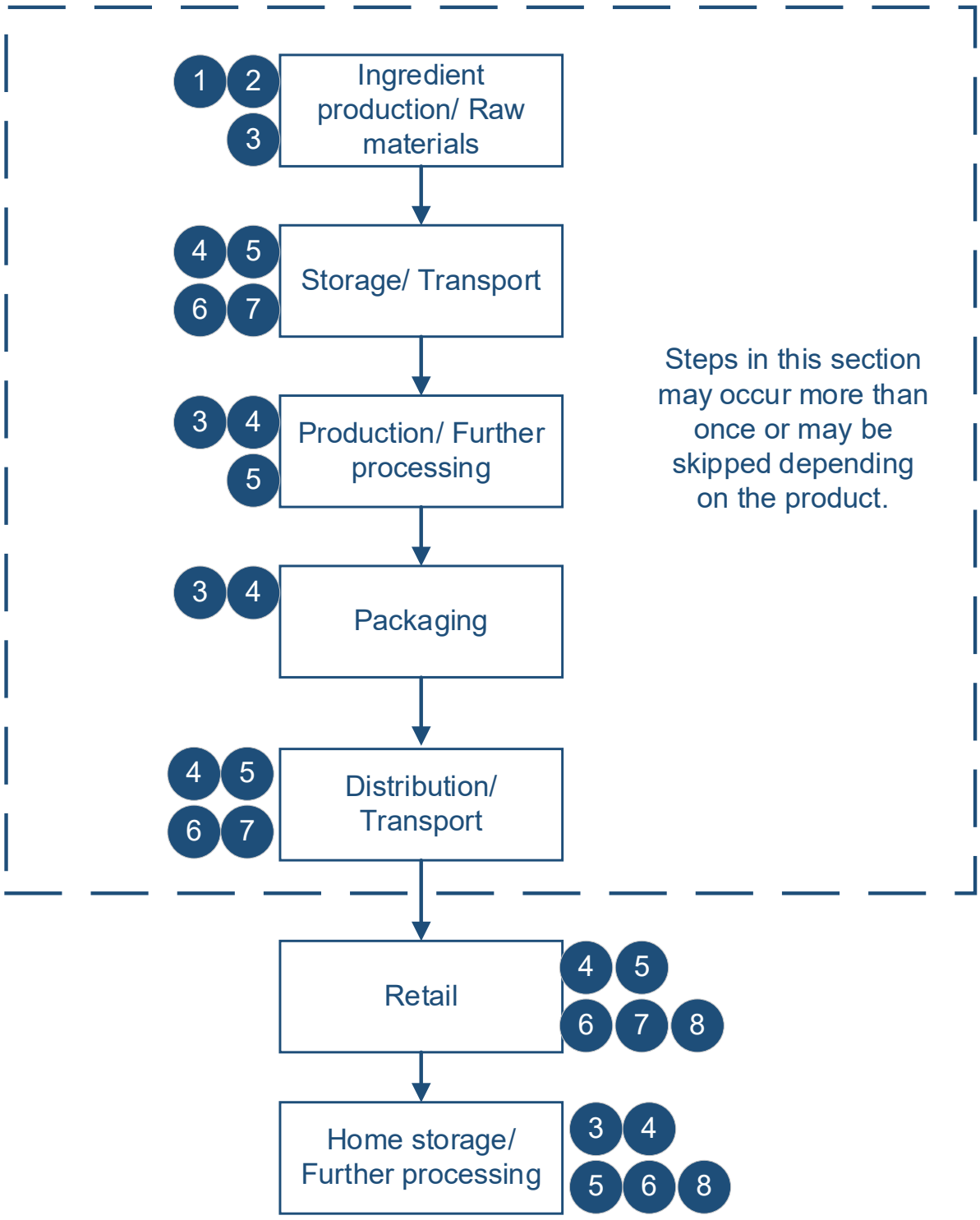

Table 8: summary of risk steps within both pathways.

Risk pathway	Number	Step
A	**1**	Range of species capable of being infected with SARS-CoV-2
A	**2**	Prevalence within the populations of those species, & the distribution &titre of virus in products from those animals
B	**3**	Prevalence of infection in individuals and frequency of contact with food/ FCMs
B	**4**	Survival of SARS-CoV-2 on food, food packaging, FCMs and preparation surfaces
A/B	**5**	Reduction in viral titre due to processing (cooking, preserving, drying, chilled or frozen storage etc.)
A/B	**6**	Proportion of infectious virus surviving transport into or within the UK
A/B	**7**	The volume of product imported form affected countries to the UK
B	**8**	Cross contamination in the retail environment