Rapid Risk Assessment: Risk to UK consumers from Highly Pathogenic Avian Influenza (HPAI) H5N1 B3.13 in US dairy products

Area of research interest: Foodborne pathogens
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Risk Question

What is the risk to UK consumers from HPAI H5N1 strain B3.13 in imported milk, dairy products, colostrum and colostrum-based products originating from US dairy cattle?

Summary

Overall risk estimate

The probability that UK consumers will receive potentially infectious exposures to influenza of avian origin via imported US dairy products is assessed to be **Very Low**, due to the low amount of dairy products consumed in the UK that are imported from the US, the high proportion of those imports undergoing processing which is considered highly likely to inactivate any infectious virus present, and the assumed low oral infectivity of influenza virus for humans. “Very Low” is defined as “Very rare but cannot be excluded”. The probability is not Negligible because although highly likely, it is not certain that dried milk powder imported from the US has undergone sufficient processing to eliminate any infectious virus present. Confirmation of this would reduce the probability to Negligible.

The uncertainty in this estimate is **Medium**, largely because of uncertainty around the proportion of imported powdered milk which is freeze-dried, and the effect of those freeze-drying methods on virus infectivity (and given that most milk imported to the UK is for powdered milk production). “Medium” is defined as “There are some but no complete data available; evidence is provided in small number of references; authors report conclusions that vary from one another”. Because the uncertainty is “Medium” and this is a rapidly evolving situation, any new evidence that may require this rapid risk assessment to be updated will be actively monitored for.

In the event of infection, the severity of detriment is assessed as **Low**. The single confirmed case of human infection so far reported eye redness (consistent with conjunctivitis) as their only symptom (CDC, 2024), but is not believed to have been exposed via the consumption of contaminated products. The individual was treated with antivirals as a precaution, so it is unclear whether this would have resolved or progressed. “Low” is defined as “Mild illness: not usually life-threatening, usually no sequelae, normally of short duration, symptoms are self-limiting (e.g. transient diarrhoea)”.

The uncertainty in this severity is **High** which reflects the recent emergence of this strain, the limited clinical data on infection with this strain so far, and the fact that reporting disincentives make it difficult to be certain that other human infections have not occurred. “High” uncertainty is defined as “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”. However, in the event that someone is severely affected by an influenza-like illness in the US they would normally report to medical professionals and be hospitalised and tested. There is therefore some level of confidence that this strain is not resulting in large numbers of severe infections.

This document specifically assesses the risk from the strain involved in the current spill over outbreak in US dairy cattle. Strains of influenza vary widely in their clinical presentation in infected humans. However, the majority of human cases of influenza of avian origin have been associated with Asian genotypes or clades. For influenza of avian origin as a whole (in this case, ingested via poultry products), the severity is considered to be **High** with **Medium** uncertainty (Kintz et al., 2023).

Limitations of this assessment

This assessment only considers the risk associated with current outbreak of B3.13 in the US. It does not consider:

1. Speculation on the likelihood, timescale, and potential future routes of introduction into the UK, including via wild bird migration routes;
2. Assessment of the ability of existing surveillance processes such as syndromic surveillance, pre- and post-mortem inspections at slaughter, etc, to detect the presence of this strain in UK cattle;
3. Occupational risk to those working with cattle or in food production;
4. Risks to the health of UK animals (e.g. livestock and companion animals);
5. Consumer risks from beef or any products of animal origin other than dairy;

Key uncertainties

There are two key areas in the risk assessment where additional information would reduce uncertainty levels assigned:

There is significant uncertainty around the amount of **colostrum** currently imported into the UK, its uses, and the processing it undergoes.

The vast majority of dairy imported into the UK is **dried milk powder**, and it is not clear whether this production method always involved pasteurisation or whether, if it does not, the drying process used will be effective at inactivating any infectious virus present. In particular, one method of producing powdered milk (freeze-drying) avoids the use of high temperatures. It is considered likely that milk is pasteurised before this process, the process itself would inactivate infectious virus present, or both, but verification of this assumption could reduce the estimated risk for UK consumers.

Interpretation of categories used in this risk assessment

Tables from ACMSF (ACM/1334) adapted from EFSA, (2006) modified from OIE 2004.

Definitions of qualitative categories for probability of occurrence

Probability 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

Definitions of qualitative categories for severity of consequence

Probability category	Interpretation
Negligible	No effects, or so mild they do not merit consideration
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)

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 a small number of references; authors report conclusions that vary from one another
High	There are scarce or no data available; 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

In early 2024, a number of dairy herds in the US - initially in Texas - began to show nonspecific illness including inappetence and milk drop. 10-15% of animals on affected farms showed illness, with minimal deaths. At the sites in Texas, deaths of wild birds (pigeons, blackbirds, and grackles) and domestic cats, fed on unpasteurised colostrum, were also reported. Introduction to other states appears to have occurred as a result of livestock movements (Burrough, et al., 2024).

Although regional diagnostic labs were initially unable to identify a cause, samples received at the Iowa State University Diagnostic Laboratory in Ames on 24 March 2024 (Texas) and 25 March 2024 (Kansas) were found to be positive for influenza A virus (IAV) by PCR. A press release was issued on 25 March 2024 (APHIS, 2024) and an early-access manuscript fully describing these results was published on 29 April 2024 (Burrough, et al., 2024).

The USDA Animal and Plant Health Inspection Service (APHIS) issued a Federal Order on 24 April 2024 to introduce restrictions on the inter-state movement of dairy cattle, effective from 29 April 2024 (Tomlinson, 2024). However, the Federal Order does not apply to within-state movements, which are governed at a state level. It is unclear how effective existing restrictions

and controls will be at limiting the spread of the virus.

On 25 April 2024, the FDA reported that initial results of PCR testing on samples from its nationally representative commercial milk sampling study found influenza RNA in around 20% of retail samples tested, although the number of samples tested was not given (FDA, 2024). However, on 26 April 2024 the FDA reported some preliminary results suggesting that pasteurization is effective at eliminated infectious HPAI from milk (FDA, 2024).

APHIS has also established a page linking to the latest updates on the situation at Highly Pathogenic Avian Influenza (HPAI) Detections in Livestock | Animal and Plant Health Inspection Service (usda.gov), which also includes a regularly updated map of states that have detected the current strain of influenza in livestock. Figure 1 shows the state of play as of 30 April 2024.

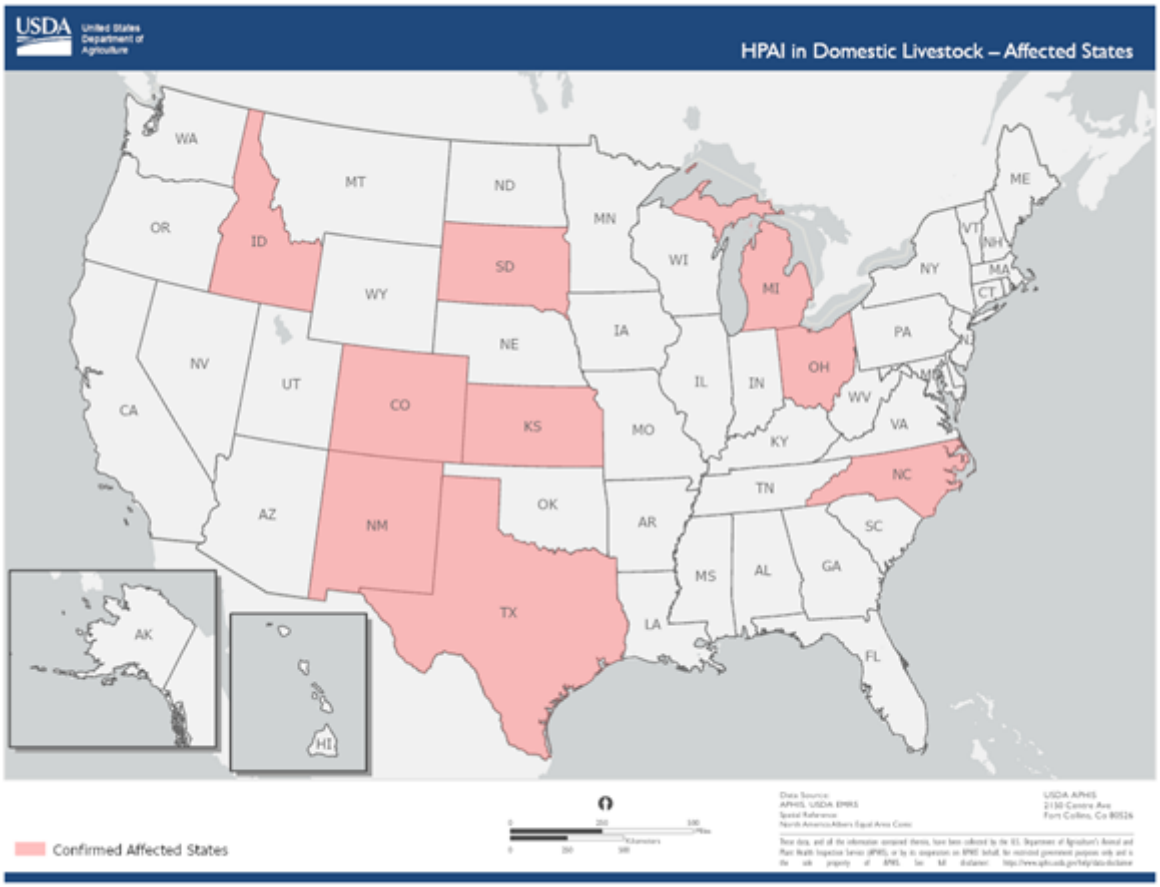


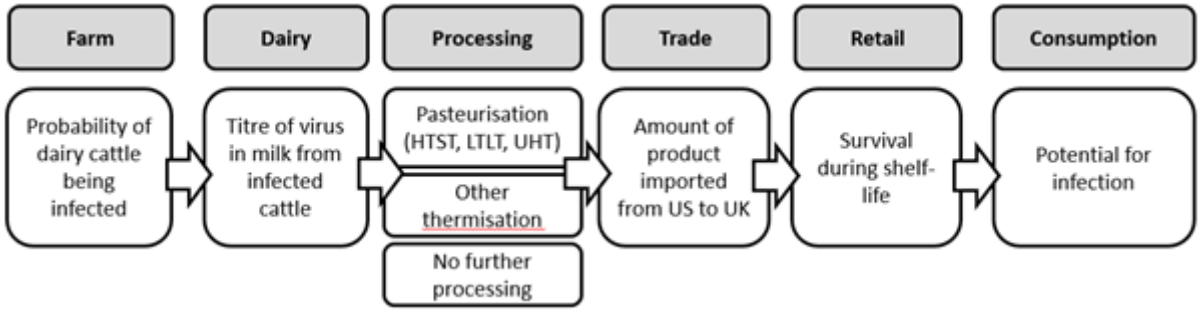
Figure 1: states with HPAI in livestock as of 30 April 2024

Hazard Identification

The hazard considered for this assessment is an influenza virus of avian origin classified as B3.13. Influenza viruses are negative-sense, single-stranded, enveloped RNA viruses classified in the family Orthomyxoviridae, 80-120nm in diameter. Analysis of available sequences supports the hypothesis of a single bird-cow crossover event followed by cow-cow spread (ASTHO, 2024).

Exposure Assessment

Risk pathway



Farm: probability of dairy cattle being infected with B3.13

As of 2 May 2024, influenza had been detected in 36 cattle herds across nine states in the US (USDA, 2024). This is likely to be an underestimate, especially given that FDA reported finding influenza virus RNA in around 20% of samples of retail milk tested. At peak incidence, 10-15% of animals on affected farms showed illness (Burrough, et al., 2024), but the total proportion infected at any one time is unknown.

On affected farms, incidence appeared to peak 4–6 days after the first animals were affected and then tapered off within 10–14 days; afterward, most animals were slowly returned to regular milking (Burrough, et al., 2024).

Dairy: titre of virus in milk from infected cattle

Unpasteurised milk shows high levels of viral nucleic acid (meaning a low Ct value). The lowest Ct value reported is 12.3 (Burrough, et al., 2024). The presence of viral nucleic acid alone does not necessarily reflect the presence of infectious virus, although the presence of some live virus in these raw milk samples has been confirmed. In a worst-case scenario, the quantity of viral RNA that would result in Ct value of 10 would be around $10^{8.5}\log_{10}$ infectious virus particles per ml of milk.

The milk from severely affected cattle is thicker and colostrum-like (USDA, 2004b). The FDA recommends producers discard milk from symptomatic cows (Zack, 2024). The FDA and USDA have indicated that they believe the US commercial milk supply to be safe both because of pasteurisation and because milk from sick cows is being diverted or destroyed (FDA, 2024b). However, there is still the potential for milk from sub-clinically infected cattle to enter the food chain.

On 25 April 2024, the FDA reported that initial results of PCR testing on samples from its nationally representative commercial milk sampling study found influenza RNA in around 20% of retail samples tested, although the number of samples tested was not given (FDA, 2024b). A research laboratory at Ohio State University reported finding PCR +ve results with 28% of samples of retail milk tested (Bovine Veterinarian, 2024).

Processing: effects on virus

Pasteurisation

99% of commercial milk supply in the US comes from farms that participate in the Grade “A” Milk Program and follow Pasteurized Milk Ordinance (PMO), which requires pasteurisation and the destruction of milk from sick cows (ASTHO, 2024).

Pasteurisation is a process that involves heating milk to a high temperature followed by rapid cooling before it is bottled or packaged, to ensure safety to the consumer by eliminating harmful

bacteria present in the milk as well as extend shelf life. Different temperature-time combinations are permitted, with the holding time being that required to achieve a specified reduction in the titre of the most heat resistant microorganism typically found in the foodstuff at the indicated temperature. For milk, this is a 12-log reduction in the numbers of *Coxiella burnetii* .

In the UK, milk is normally pasteurised using one of the following three methods:

High Temperature Short Time (HTST) is a continuous method in which milk is heated to 71.7°C for 15 seconds. It is used for large scale processing of liquid dairy products and is commonly used for drinking milk.

Low Temperature Long Time (LTLT) is a batch method in which milk is heated to 63°C for 30 minutes. It is commonly used for small batch pasteurisation, for example as part of the on-farm production of dairy products such as ice cream.

Ultra-High Temperature (UHT), which involves heating the milk to at least 138°C for at least 2 seconds.

In addition, US regulations permit three further temperature-time combinations: 89°C for a minimum of one second, 96°C for a minimum of 0.05 seconds, or 100°C for a minimum of 0.01 seconds.

Because the emergence of influenza of avian origin in cows was unexpected, there are limited data available on the effect of pasteurisation on milk containing B3.13 or any other influenza virus.

The FDA has indicated that it believes pasteurisation is likely to be completely effective at inactivating influenza virus in milk, based both on data from previous studies of the inactivation of heat-sensitive viruses by pasteurisation, and because inactivation of HPAI has been successful during the pasteurization process for eggs, which occurs at lower temperatures than what is used for fluid milk (FDA, 2024b).

The FDA has reported that finding influenza virus RNA in around 20% of samples of retail milk tested, although the number of samples tested was not given (FDA, 2024).

On 26 April 2024 the FDA reported some preliminary results suggesting that pasteurization is effective at eliminated infectious HPAI from milk (FDA, 2024).

Powdered milk products

There are three common methods for producing powdered milk (Miller, 2022). These consist of:

1. **Spray Drying** - milk is first flash-pasteurised to kill any bacteria. It’s then reduced to around 50% of its original mass by steaming, separating the vapour from the powder and condensing it to a liquid which is removed. The milk is then sprayed into a drying chamber, exposing it to hot air. The liquid milk droplets quickly evaporate, leaving behind a dry powder.
2. **Drum Drying** - a faster method that involves passing the milk over a thin film on a heated drum which steams the milk, leaving solids behind which are extracted and ground into a fine powder. Of the three methods listed here, drum drying is the least used as it can caramelise the milk.
3. **Freeze Drying** - freeze drying is complex and expensive and involves slowly freezing the milk at -50°C to -80°C. Milk is then subjected to low heat and low pressures in a partial vacuum, which helps a process called sublimation turning ice from solid state to gas. The gas is then condensed and collected, leaving behind a dry powder.

It is highly likely that the first two methods would inactivate any virus present in milk, although the effect of the final method is less certain.

On 26 April 2024 the FDA published a statement that PCR testing of “several” powdered infant and toddler formula samples came back negative (FDA, 2024). The statement does not specify the number of samples tested (although they were a subset of “an initial limited set of geographically targeted samples” collected as part of a national commercial milk sampling study in coordination with UDSA). The statement also does not state which of the aforementioned processing methods was used.

Cheese-making

The vast majority of US dairy products are pasteurised due to an FDA requirement that any dairy products that cross state lines must either be pasteurised or (in the case of cheese) aged for a minimum of 60 days. The amount of cheese in UK dairy imports from the US is extremely low, and much of this is for highly processed cheese which is highly likely to have undergone heat treatment sufficient to inactivate influenza virus during processing. However, production methods for individual cheese varieties are diverse and validation of the effectiveness of specific cheese production methods at inactivating virus is impractical.

Trade: amount of product imported from US to UK

So far in 2024 (1 January to 23 April) a total of **162,004kg** of milk and dairy product has been imported to the UK from the USA. 144,000kg (88.9%) of this was dried, and a further 15,967kg (10%) was for ice cream and other edible ice products, which in the expert opinion of the FSA will undergo pasteurisation if not already pasteurised. The remaining 2% has consisted of 5 consignments of “other” totalling 2036kg, and 1kg of whey (Pers. Comms. Imports Strategy Team (FSA), 2024).

In 2022-2023 the volumes were higher and included small amounts of (largest first) cheese and curd, whey, grated/powdered cheese, “other” cheese, butter, blue cheese, processed cheese, and milk/cream (Pers. Comms. Imports Strategy Team (FSA), 2024).

Several customs (CN) codes do not specify whether product is pasteurised or unpasteurised. Since 1987 the FDA has encouraged voluntary participation in the Grade “A” Program; nearly all (99%) of milk produced in the US comes from farms that participate in this programme and follow the Pasteurized Milk Ordinance (PMO), which requires the pasteurisation of milk and the prevention of milk from sick cattle from entering the food supply (ASTHO, 2024). In addition, since 1987 the FDA has required dairy products moving interstate to either be pasteurised or – in the case of cheese – aged for a minimum of 60 days, although export is not considered an interstate movement. It is therefore believed to be highly likely that all dairy originating from the US will have undergone pasteurisation, but this is not completely certain. In particular, under certain specific conditions virus can remain infectious during freeze-drying. Although it is highly unlikely that conditions during commercial dried milk powder freeze-drying would be suitable, validation of this assumption is recommended.

There is significant uncertainty around the amount of **colostrum** recently imported into the UK, its uses, and any processing undertaken. Defra colleagues located a single consignment of “colostrum” imported in December 2023 of size 2.2kg. Colostrum is consumed as a supplement by athletes and bodybuilders. It is not clear what processing this undergoes, and whether this would normally include pasteurisation, powder drying or other processing likely to damage virus infectivity.

Retail: survival during shelf life

Many dairy products are required to be stored at chilled or frozen temperatures which are likely to facilitate the persistence of any infectious virus remaining after production. Virus which survives freeze-drying may also persist well at ambient storage temperatures.

Consumption: potential for infection via ingesting virus

Although by far the most common transmission pathway for influenza virus to infect humans is via aerosol and droplet infections, there is anecdotal and experimental evidence that the consumption of the uncooked blood or meat of poultry, gamebirds or wild birds has transmitted the HPAI H5N1 virus to carnivorous animals, including tigers, leopards, domestic cats, domestic dogs, and a stone marten (Kaplan and Webby, 2013). However, reports of human infection via food are virtually unheard of.

Because of the limited data available, the infectious dose of AI for humans is unknown. However, several studies have investigated oral and intranasal inoculation of AI in animals (O'Brien et al., 2021). A study by Bertran and Swayne in 2014 in which ferrets were exposed to different HPAI viruses (H5 and H7 subtypes) through consumption of infected chicken meat, showed that the dose of virus needed to infect ferrets through consumption ($10^{8.9}$-$10^{9.2}EID_{50}$was much higher than via respiratory exposure ($10^{7}EID_{50}$) and varied with the virus strain (Bertran and Swayne, 2014).

A 2012 study by Reperant et al., showed that intragastric inoculation of domestic cats at a level of $10^{7.8}$ $TCID_{50}$ resulted in fatal systemic infection (Reperant et al., 2011). In 2011, Shinya et al showed that the inoculation of hamsters with H5N1 directly into the digestive tract at a level of $10^{7.1}$ -$10^{7.3}$ $TCID_{50}$ allowed the virus to enter the bloodstream through the digestive lymphatic system (Shinya et al., 2011).

Since there is a lack of data on AI prevalence and concentration in poultry products and the dose-response relationship in humans, assumptions are made during modelling when performing quantitative risk assessments (Bosch et al., 2018). To support the 2010 FDA/FSIS risk assessment, a dose response relationship was modelled using dose data (Bauer et al., 2010). Their results suggesting that the human EID50 for intranasal exposure could range from approximately $10^{7.8}$ - $10^{9.5}$ EID_{50} (Bauer et al., 2010).

Collectively, these results suggest that the orally infectious dose for humans is unlikely to be much lower than 10^{7} $TCID_{50}$.

Risk characterisation

Section	Probability
Presence of virus in product	
Milk	RNA in up to 28% of product, more likely to be around 20%. Virus levels in raw milk would be 108.5/ml in milk from infected herds (reasonably foreseeable worst-case scenario; assumes all animals contributing to bulk milk are shedding); likely to be significant dilution.
Colostrum	Assumed to be similar to milk above
Processing	
Pasteurisation	Assumed to eliminate infectious virus
Cheesemaking	Uncertain
Powdering (boiling)	Assumed to eliminate infectious virus
Powdering (freeze-drying)	Likely to eliminate infectious virus but uncertainty

The probability that UK consumers will receive potentially infectious exposures to influenza of avian origin via imported US dairy products is assessed to be **Very Low**, due to the low amount

of dairy products consumed in the UK that are imported from the US, the high proportion of those imports undergoing processing which is likely to inactivate any infectious virus present, and the apparently low oral infectivity of influenza virus in general for humans. “Very Low” is defined as “Very rare but cannot be excluded”. The probability is not Negligible because although highly likely, it is not certain that dried milk powder imported from the US has undergone processing that would eliminate any infectious virus present. Confirmation of this would reduce the probability to Negligible.

The uncertainty in this estimate is **Medium**, largely because of uncertainty around the proportion of powdered milk which is freeze-dried, and the effect of those freeze-drying methods on virus infectivity (and given that most milk imported to the UK is for powdered milk production). “Medium” is defined as “There are some but no complete data available; evidence is provided in small number of references; authors report conclusions that vary from one another”. Because the uncertainty is “Medium” and this is a rapidly evolving situation, any new evidence that may require this rapid risk assessment to be updated will be actively monitored for.

In the event of infection, the severity of detriment is assessed as **Low**. The single confirmed case of human infection so far reported eye redness (consistent with conjunctivitis) as their only symptom (CDC, 2024), but is not believed to have been exposed via the consumption of contaminated products. They were treated with antivirals as a precaution, so it is unclear whether this would have resolved or progressed. “Low” is defined as “Mild illness: not usually life-threatening, usually no sequelae, normally of short duration, symptoms are self-limiting (e.g. transient diarrhoea)”.

The uncertainty in this severity is **High** which reflects the recent emergence of this strain, the limited clinical data on infection with this strain so far, and the fact that reporting disincentives make it difficult to be certain that other human infections have not occurred. “High” uncertainty is defined as “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”. However, in the event that someone is severely affected by an influenza-like illness in the US they would normally report to medical professionals and be hospitalised and tested. There is therefore some level of confidence that this strain is not resulting in large numbers of severe infections.

This document specifically assesses the risk from the strain involved in the current outbreak in US dairy cattle. Strains of influenza vary widely in their clinical presentation in infected humans. However, the majority of human cases of influenza of avian origin have been associated with Asian genotypes or clades. For influenza of avian origin as a whole (in this case, ingested via poultry products), the severity is considered to be **High** with **Medium** uncertainty (Kintz et al., 2023).

Triggers for updating this assessment

This risk assessment is specific to UK consumers and the risk from influenza of avian origin via dairy products imported from the US and based on the evidence currently available. As such, changes in the epidemiological situation could require the risk assessment to be updated, such as:

1. Evidence that the virus is circulating in US beef cattle
2. Evidence that the virus is circulating in UK cattle (dairy or beef)
3. Confirmation of at least one case that can be confidently attributable to a foodborne transmission route
4. Confirmation that the virus has spread to other trading partners

Regarding the first point, the US government confirmed on 29 April 2024 plans to test ground beef samples for virus. Some dairy cows enter the food chain as meat when they grow old (Polansek and Polansek, 2024). Preliminary results released on 1 May 2024 reported that none of the first thirty samples tested were found to contain infectious virus (APHIS, 2024b).

In addition, further data on the effectiveness of pasteurisation or on the volume of dairy product imported from the US without completing pasteurisation would reduce uncertainties in this risk assessment, although evidence already available suggests that pasteurisation is effective at eliminating infectious virus.

Planned future research

The FDA is currently planning the following research studies, in partnership with the USDA (ASTHO, 2024):

1. Bench-top simulation of pasteurization studies using spiked milk and milk from affected cows, to confirm the effectiveness of HTST pasteurisation
2. Pasteurization validation studies using pilot scale continuous flow pasteurizer (spiked milk simulating real world levels of virus)
3. Study to determine viral load in raw milk presented to processors in affected states (taken from samples routinely collected as part of Grade “A” Program).
4. Survey of HPAI in milk and milk products at retail by qPCR and viral isolation via eggs (partial results released for milk)

Other NIH-funded research relevant to the scope of this risk assessment includes (ASTHO, 2024):

1. viral levels in fractionated milk
2. ingestion of raw milk from affected cows in rodents
3. pasteurisation validation

APHA (Defra) are also setting up bench-top simulation of pasteurization studies using spiked milk, although these results are likely to be available after the FDA research completes.

References

APHIS (2024) Federal and State Veterinary, Public Health Agencies Share Update on HPAI Detection in Kansas, Texas Dairy Herds | Animal and Plant Health Inspection Service. (Accessed: 2 May 2024).

APHIS (2024b) Updates on H5N1 Beef Safety Studies | Animal and Plant Health Inspection Service. (Accessed: 3 May 2024).

ASTHO (2024) Highly Pathogenic Avian Influenza Scientific Symposium. (Accessed: 2 May 2024).

Bauer, N. et al. (2010) Interagency Risk Assessment for the Public Health Impact of Highly Pathogenic Avian Influenza Virus in Poultry, Shell Eggs, and Egg Products (May 2010) | Food Safety and Inspection Service. (Accessed: 2 May 2024).

Bertran, K. and Swayne, D.E. (2014) High doses of highly pathogenic avian influenza virus in chicken meat are required to infect ferrets | Veterinary Research | Full Text. (Accessed: 2 May 2024).

Bosch, A. et al. (2018) ‘Foodborne viruses: Detection, risk assessment, and control options in food processing’, International Journal of Food Microbiology, 285, pp. 110–128.

Bovine Veterinarian (2024) USDA Now Requiring Mandatory Testing and Reporting of HPAI in Dairy Cattle as New Data Suggests Virus Outbreak is More Widespread | Bovine Veterinarian. (Accessed: 2 May 2024).

Burrough, et al. (2024) Early Release - Highly Pathogenic Avian Influenza A(H5N1) Clade 2.3.4.4b Virus Infection in Domestic Dairy Cattle and Cats, United States, 2024 - Volume 30, Number 7—July 2024 - Emerging Infectious Diseases journal - CDC. (Accessed: 2 May 2024).

CDC (2024) Highly Pathogenic Avian Influenza A (H5N1) Virus Infection Reported in a Person in the U.S, CDC. (Accessed: 25 April 2024).

EFSA (2006) ‘Opinion of the Scientific Panel Animal Health and Welfare (AHAW) related with the Migratory Birds and their Possible Role in the Spread of Highly Pathogenic Avian Influenza’, EFSA Journal, 4(5), p. 357.

FDA (2024b) ‘Questions and Answers Regarding Milk Safety During Highly Pathogenic Avian Influenza (HPAI) Outbreaks’, FDA [Preprint]. (Accessed: 2 May 2024).

FDA, C. for F.S. and A. (2024) ‘Updates on Highly Pathogenic Avian Influenza (HPAI)’, FDA [Preprint]. (Accessed: 25 April 2024).

Kaplan, B.S. and Webby, R.J. (2013) ‘The avian and mammalian host range of highly pathogenic avian H5N1 influenza’, Virus Research, 178(1), pp. 3–11.

Kintz, E. et al. (2023) ‘A Qualitative Assessment of the Risk of Acquiring Avian Influenza from Poultry Products’.

Miller, N. (2022) ‘How is Powdered Milk Made?’, Discovery UK, 20 September. (Accessed: 2 May 2024).

O’Brien, B. et al. (2021) ‘Exploring the potential of foodborne transmission of respiratory viruses’, Food Microbiology, 95, p. 103709.

Pers. Comms. Imports Strategy Team (FSA) (2024) ‘Milk and Dairy products from Canada, Mexico and USA from 2023 and 2024 V3 sent 01/05/2024’.

Polansek, T. and Polansek, T. (2024) ‘US to test ground beef in states with bird-flu outbreaks in dairy cows’, Reuters, 29 April. (Accessed: 2 May 2024).

Reperant, L.A. et al. (2011) ‘Highly pathogenic avian influenza virus H5N1 infection in a long-distance migrant shorebird under migratory and non-migratory states’, PLoS ONE, 6(11).

Shinya, K. et al. (2011) [PDF] Systemic Dissemination of H5N1 Influenza A Viruses in Ferrets and Hamsters after Direct Intragastric Inoculation | Semantic Scholar. (Accessed: 2 May 2024).

Tomlinson, S.-M.-A. (2024) ‘Federal Order Requiring Testing for and Reporting of Highly Pathogenic Avian Influenza (HPAI) in Livestock’.

USDA (2024) Highly Pathogenic Avian Influenza (HPAI) Detections in Livestock | Animal and Plant Health Inspection Service. (Accessed: 2 May 2024).

USDA (2004b) hpai-dairy-faqs.pdf.(Accessed: 3 May 2024).

Zack, J.-M.-A. (2024) ‘APHIS Requirements and Recommendations for Highly Pathogenic Avian Influenza (HPAI) H5N1 Virus in Livestock For State Animal Health Officials, Accredited Veterinarians and Producers’.

Annex 1: list of terms and definitions

Ribonucleic acid (RNA): the nucleic acid used instead of DNA by viruses such as influenza. Its presence – via a test such as PCR – does not show that infectious virus is present, although high concentrations of viral RNA are more likely to indicate the presence of infectious virus. For infectivity to be confirmed, RNA detection needs to be followed by a test such as virus isolation.

Polymerase Chain Reaction (PCR): a laboratory test for the presence of viral RNA. Typically quantitative PCR (qPCR), which gives an indication of the quantity of nucleic acid present in the form of a cycle threshold (Ct) value.

Cycle threshold (“Ct”) value: the output of a PCR test that indicates the concentration of the target nucleic acid sequence in a tested sample. The number of PCR cycles required until the target sequence exceeds a threshold; hence a low Ct value indicates a large initial concentration.

Virus isolation: a test for the presence of virus.

Viral infectivity assay: a test to quantify the amount of virus present. Normally involves serial dilution (i.e. looking for the point in a series of increasingly diluted samples at which virus is no longer detectable).

Viral titre: the number of virus particles per unit volume. Usually given as the result of an infectivity assay such as the 50% egg infectious dose (EID50) or 50% tissue culture infectious dose (TCID50).

“Spiked” samples: samples of a medium (e.g. milk) which have had virus artificially added to them in a laboratory (as opposed to samples taken from infected hosts).