RECORD OF RAPID RISK ASSESSMENT BY OF RISK ANALYST (BSRAG) 3RD APRIL 2014

The following is an extract of New Zealand's emerging risk assessment for PEDV that was written in April 2014. Please note that this is not a formal import risk analysis but an assessment that was written to try and capture emerging information as it became available. This assessment also does not include any information that has been made available since April and has not been subject to external review. During the conference further context will illustrate how this assessment sits alongside New Zealand's more usual risk-based approach.

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1. Justification

Porcine epidemic diarrhoea (PED) has spread to several new countries in the past year.

2. Is this something we have looked at before?

A previous emerging risk assessment was completed in June 2013 after PED was confirmed to have spread to the United States (see Appendix 1). PED has previously been formally assessed in risk analyses concerning the importation of pig semen and pig meat (MPI 1991; MPI 2012).

3. What has changed?

Since this previous emerging risk assessment, porcine epidemic diarrhoea virus (PEDV) has been identified in 27 States in the US (ProMed 16/03/2014), 4 Provinces in Canada (ProMed 25/02/2014), a previously uninfected Prefecture in Japan (Fukuoka), and is suspected to be present in Colombia (ProMed 19/03/2014).

4. Epidemiological background and relevant information

PEDV is a member of the family *Coronaviridae*, first described in 1971 when an outbreak occurred in England. The disease causing agent, however, was not identified until 1978 when swine from Belgium became infected. PED is also present in a number of other European and in Asia (Haung *et al.* 2013; Canadian Swine Health Board 2014). Outbreaks in Europe are now rare. There is no evidence to suggest the disease is present in Australia (Saif *et al.* 2012; Haung *et al.* 2013). PED is a highly contagious disease which only infects swine and is not zoonotic.

The most obvious clinical sign associated with PED is watery diarrhoea. Piglets up to one week of age may die from dehydration after 3-4 days of diarrhoea with mortality averaging 50% but can reach 100%. Older pigs typically recover after approximately 1 week. Morbidity can approach 100% (Saif *et al.* 2012).

PEDV replicates in the cytoplasm of enterocytes in the small intestine and in experimentally challenged piglets viral replication occurred 12-18 hours post-inoculation (P.I.) with clinical signs observed within 22-36 hours P.I. The virus is excreted for 7-9 days P.I. and long term carriers have not been reported (Saif *et al.* 2012).

Faecal-oral transmission is likely to be the main route of transmission. Acute outbreaks in farms often occur after infected pigs have been introduced to a naïve herd. The virus may also be transmitted by contaminated trucks, boots, or other fomites especially in cooler weather as this prolongs the survival of the virus in the environment (Saif *et al.* 2012).

Cell culture adapted PEDV has been found to lose infectivity when heated to ≥60°C for 30 minutes but is moderately stable at 50°C (Pensaert 1999). It has also been shown to be inactivated on metal surfaces when exposed to 71°C for 10 minutes or at 20°C for 7 seven days (Thomas *et al*. 2013). PEDV persists at a pH of 5-9 at 4°C and 6.5-7.5 at 37°C. It can also remain infective after freezing and thawing (Pensaert 1999).

Genetic analyses by Huang *et al*. (2013) looked at the time since genetic divergence had occurred between the United States-Chinese PEDV strains and the time since the strains within the United States had first diverged from each other. The time between these two events occurring would allow an estimate of when the virus was introduced to the United States. It was found that the last China-United States strain divergence occurred between 5 to 6 years ago and the first within United States strain divergence was approximately 1.5 years ago. The actual timeline of outbreaks falls within this range as China experienced an outbreak of PED in late 2010 and the United States first report of PED was in late spring 2013.

More recently, Iowa State University has sequenced PEDV from 15 cases and found that 5 isolates were closely related but were different to strains previously identified in North America. Further work is being undertaken to determine the exact relationship between these different strains (ProMed 2/02/2014).

If an outbreak of PED occurred in New Zealand it would have a significant economic impact on the pig industry. Initial losses would be expected to be high until immunity developed in herds. It has been estimated that PEDV may result in up to 5 million piglet deaths in the United States, equivalent to 4.5 per cent of all pigs sent to slaughter (ProMed 21/03/2014).

5. Pathways of introduction

There is no evidence to suggest that PEDV could be introduced into New Zealand by the importation of pig semen, pig meat, or pig sausage casings (MPI 1991; MPI 2012; MPI In press).

5.1. Importing Spray dried bovine and porcine blood products for further processing from the USA

In the North American outbreak it has been suggested that spray-dried porcine plasma (SDPP) used in pelleted pig feed may be responsible for the spread of PED. SDPP used in pelleted feed has tested positive for PEDV DNA. Despite this, the Canadian Food Inspection Agency (2014) has not been able to confirm a link between feed containing SDPP and PED cases in Canada. Further, this study and one by Rovira (2013) were unable to demonstrate disease in pigs fed contaminated feed. In a precautionary move, however, Grand Valley Fortifiers have issued a voluntary recall for certain pelleted feed containing SDPP in North America (ProMed 20/02/2014). The British pig industry are also identifying and isolating any feed containing SDPP. Red Tractor assurance, which regulates over 90 per cent of Britain's domestic pig supply already has a ban in place for SDPP containing feeds, although it may be an unknown ingredient in pig milk replacer and milk blend products (ProMed 21/03/2013).

How PED first entered the United States is still not known. It has been proposed that contaminated feed ingredients from China such as porcine plasma and rice hulls may be to blame, although, the importation of porcine plasma from Asia is illegal (Burch 2014; J. Zimmerman pers comm. with H. Pharo 24/03/2014).

Pig blood is sourced from animals that have passed ante-mortem inspection and is collected while the animal is whole to prevent cross contamination with internal organs or prohibited tissues (NASDBPP no date).

The manufacturing process for spray dried plasma involves introducing small droplets of plasma into a chamber at the same time as heated air (inlet temperature of air is approximately 221-248°C). The plasma then passes through an outlet that is set to a temperature of 80°C (range: 77-91°C). The holding time of the plasma within the drier is 30-90 seconds and is dependent on the machine's design and dimensions. The plasma is heated throughout to a temperature of 80°C (T. Faidley pers comm. with V. Melville 26th March 2014).

The North American Spray Dried Blood and Plasma Producers (NASDBPP) have released a report describing preliminary results of a series of experiments that have been undertaken to determine the safety of spray dried plasma with respect to PEDV transmission(NASDBPP 20/03/2014). The results present thus far conclude that:

- spray drying inactivates PEDV under simulated commercial manufacturing conditions (Inlet temperature of 200°C and outlet of 80°C) as it could not be detected post-processing;
- experimentally inoculated spray dried plasma loses infectivity by day 7 when stored at room temperature (20-22°C); and,
- commercially sourced spray dried plasma that tested PCR positive for PEDV genome did not transmit the virus to naïve pigs which were inoculated via the intra-gastric route.

These findings at this stage are preliminary and need to be treated with caution as they have not been subject to peer-review.

Swine vesicular disease virus, which is recognised to be a more thermally tolerant virus (see table 2 from NASDBPP 11/02/2014), has been shown to be inactivated when subjected to spray drying at a temperature of 80°C (Pujols *et al*. 2007). Similar results have also been obtained for Aujesky's disease virus and porcine reproductive respiratory syndrome virus, although the outlet temperature was higher (90°C; Polo *et al.* 2005).

New Zealand has an Import Health Standard (IHS) for the importation of spray dried porcine blood products for further processing into animal food from the United States of America (MPI 2004). Once SDPP is imported into New Zealand it may be added as an ingredient in pelleted pig feed. Pellets are produced by a moulding process which requires moisture, heat and pressure. Mash feed is subjected to liquid and steam within a conditioner at a temperature of 71 - 99°C, with a retention time of 30 – 60 seconds. Lower temperatures are used for nursery pig feed that contains milk and speciality feeds, and higher temperatures are used for diets that are higher in starch (e.g. corn, soybean based diets). Longer retention times can be achieved through the use of specialised conditioners (e.g. double pass conditioners) which can increase the retention time to 90 seconds or more. The conditioned mash feed then passes through the pelleting chamber where the temperature can increase by approximately 11°C due to the friction created when the feed passes through the die. It is uncertain if the whole pellet is exposed to this friction induced temperature increase as the centre of larger sized pellets may only experience a smaller rise in temperature (Nitikanchana 2014).

Nitikanchana (2014) has established a theoretical time/temperature model for the inactivation of PEDV ($Y= -13\ln(X) +187.31$) which is based on only three data points. The author readily acknowledges that due to the lack of data used to create the model any results derived from it needs to be interpreted with caution.

Using the above equation and the lowest time/temperature combinations that PEDV would be subjected to during the two separate heat treatments (SDPP- 80°C for 30 seconds; Pig pellets- 71°C for 30 seconds), the survival of PEDV can be investigated. At 80°C PEDV would be inactivated after an exposure of 2.3 minutes (138 seconds) and at 71°C the length of exposure would need to be 8.3 minutes (498 seconds). Although PEDV may not be inactivated after exposure to the two separate heat treatments, they would be expected to reduce the titre of virus in SDPP. Furthermore, an NASDBPP study has showed that PEDV is undetectable in experimentally inoculated SDPP held at room temperature after 7 days. This is significant as the time between the two heat treatments will exceed 7 days (i.e. SDPP processing occurs in North America, the product is shipped to New Zealand which takes approximately 18 days (New Zealand Shipping Timetable 2013), and then subsequently added to pelleted pig feed).

Under this IHS, 95,000 tonnes of SDPP have been imported in the last year from the United States (V. Melville pers. comm. 25/03/2014). Despite this, it has all been used as an ingredient in cat food which is subject to rendering (approx. heat treatment to 115-145°C for 40 to 90 minutes; Meeker and Hamilton 2006) which will inactivate PEDV. The likelihood of exposure to pigs is assessed as negligible.

Imported SDPP from the United States has not been added to pelleted pig feed in the last year, nonetheless it is permitted as a pig feed ingredient. Due to the evolving nature of this outbreak, the recent spread to new countries, and uncertainties around the role pelleted pig feed plays in the transmission of PED, MPI has adopted a precautionary approach to this disease outbreak and has suspended this IHS until further assurances can be provided regarding the safety of the product.

The theoretical time/temperature model predicts that the two heat treatments will not inactivate PEDV, although the empirical studies conducted thus far have shown that PEDV is not infectious after being spray dried. In addition, before SDPP is fed to pigs in New Zealand it will have been transported to New Zealand in a desiccated form which would be expected to inactivate any residual virus. Finally, it is then exposed to a second heat treatment when being added as an ingredient in pelleted feed. Only after PEDV has been exposed to all these processing steps will it be fed to pigs. Due to these reasons the likelihood of pigs being exposed to infectious PEDV in pelleted feed is assessed as negligible.

5.2. Pig by-products from Canada and/or the United States of America (meabyporic.nam)

Pig by-products include mechanically removed meat, offal, fat and blood (MPI 2011). As mentioned above meat is not associated with the spread of PEDV. This IHS has also been suspended as pig blood and offal may be able to transmit PEDV. There is no evidence of PEDV in pig fat and no suggestion that trade in lard has lead to the transboundary spread of this virus.

The only pig by-products that have been imported under this standard is pig lard intended for human consumption. The likelihood that PEDV will enter in this commodity is assessed as negligible.

Before this IHS was suspended pig by-products were permitted for importation after being subjected to one of a number of listed heat treatment (Table 1). The heat treatments were implemented to prevent the entry of porcine reproductive and respiratory syndrome virus (PRRSV; V. Melville pers comm. 24/03/2013). It has been asked if these heat treatments are also suitable for the inactivation of PEDV in blood and offal.

As explained previously there is limited data available concerning the inactivation of PEDV. It is also based on inactivation occurring on metal surfaces (71°C for 10 minute or 20°C for 7 seven days) and in culture-adapted PEDV (≥60°C for 30 minutes). There appears to be no information relating to the inactivation of PEDV in blood (other than spray dried plasma) and offal. The inactivation kinetics of viruses is influenced by the biological matrix it is associated with (i.e. faeces vs. blood), so the limited data on PEDV inactivation needs to be treated with caution when applied to blood and offal as no studies have been conducted looking specifically at viral inactivation in these two animal products.

Despite this, a closely related coronavirus (severe acute respiratory syndrome coronavirus; SARS-CoV) has had its stability assessed when held in various suspended fluids. Rabenau *et al*. (2005) held SARS-CoV in suspension (minimum essential medium) with and without a 20 per cent protein additive (fetal calf serum) at 56 and 60°C for 30 minutes. Results showed that complete inactivation was achieved when incubated at 60°C for 30 minutes irrespective of the protein additive. Darnell and Taylor (2006) assessed the inactivation rate of SARS-CoV in human serum and also confirmed complete inactivation when heated to 60°C for 30 minutes.

Importation of pig blood under this IHS could continue if it was heated to 60°C for longer than 30 minutes. This is under the assumption that the inactivation kinetics of SARS-CoV (a closely related virus) is similar to PEDV. If this assumption is correct then the risk of PEDV entering New Zealand in pig blood after being heated treated (60°C for longer than 30 minutes) is assessed as negligible. Additional time/temperature treatments will likely also inactivate PEDV, although these are yet to be investigated.

With regards to the safe importation of pig offal no data is available on PEDV survival in this commodity. Although applying the Nitikanchana (2014) model to the time/temperature treatments listed in this IHS will provide a limited inference on the suitability of these treatments for PEDV inactivation. Referring to Table 1 it appears that all time/temperature combinations except the first one (56°C for 60 minutes) will theoretically inactivate PEDV.

As there is a lack of empirical evidence describing the thermal tolerance of PEDV in offal, further studies are needed to investigate the survival of PEDV in heat treated intestines.

Further information that would further refine this analysis is:

- Temperature stability of PEDV in pig offal
- Oral infectious dose of PEDV required to cause disease; and.
- Manufacturing processes that offal containing pig feed is subjected to prior to consumption by pigs.

Table 1. Time/temperature processing requirements for the importation of pig by-products under the pig by-products from Canada and/or the United States of America IHS established for the prevention of PRRSV (MPI 2011).

Temperature (°C)	Time (minutes)	Temperature (°C) required to inactive PEDV according to Nitikanchana's (2014) equation (Y= -13ln(X) +187.31)	Theoretically capable of inactivating PEDV
56	60	57	No
57	55	57	Yes
58	50	58	Yes
59	45	59	Yes
60	40	60	Yes
61	35	61	Yes
62	30	62	Yes
63	25	63	Yes
64	22	64	Yes
65	20	65	Yes
66	17	66	Yes
67	15	67	Yes
68	13	68	Yes
69	12	68	Yes
70	11	69	Yes

5.3. Importing Animal by-products for pharmaceutical use, technical use or petfood from the European Community (inermlic.eec)

PED is present in Europe and although epidemics are now rare they still occur as the 2006 outbreak in Italy demonstrated (Saif *et al*. 2012). The decrease in outbreaks is likely due to the enzootic character of the virus and the presence of lactogenic immunity, which protects suckling pigs (Pospishil *et al*. 2002).

For pig by-products to be imported without a permit, they must be subjected to the same time/temperature requirements as described in table 1; or during processing have been subjected to a procedure which ensured the meat achieved a pH of 5 or below; or a pH of 7 or above (MPI 2004a).These requirements were implemented to prevent the entry of PRRSV.

Blood will present a negligible risk if heated to 60°C for longer than 30 minutes (see the above section for justification).

The alternative pH requirements that can be used instead of the time/temperature treatments will inactive PEDV in pig by-products when exposed to a pH of less than 5. At the higher pH range PEDV will survive up to a pH of 9. This means that the requirement of achieving a pH of greater than 7 in this IHS may not inactive the virus in blood and offal unless the pH is reached is above 9 (Pensaert 1999).

The rationale behind inactivating PEDV in offal is the same as for the section above (Pig by-products from North America) and the likelihood of entry is non-negligible.

This IHS is not currently suspended, although PED is present in the European Union and the IHS heat and pH treatments may not completely inactivate the virus (with the exception of blood; 60°C for longer than 30 minutes). The likelihood of entry is assessed as non-negligible.

Entry of PEDV via this pathway has not been observed and is likely due to a combination of reasons, including:

- Low prevalence of infection in pigs in Europe;

- Incidental heat treatment aimed at preventing the entry of PRRSV reducing the titre of PEDV in the commodity;
- Transportation time to New Zealand; and,
- Additional processing when made into pig feed.

5.4. Importing Dried Bovine/Porcine Blood for Human Consumption from Canada and the USA (edibloic.nam)

Under this IHS pig blood can be imported for human consumption and is not permitted for use in animal feed. The exposure risk is thus negligible.

Table 2: Managed pathways into New Zealand and the likelihood of entry (Red = non-negligible risk of entry via this pathway; Yellow = IHS currently suspended; Green = IHS or sections of the it present a negligible risk of entry)

Name of IHS	Year published	Likelihood of entry	IHS currently suspended	Rationale
Importing Spray dried cattle, deer, goat, pig, sheep blood products for further processing into animal food from Australia	2000	Negligible	No	PED not present in Australia
Importing Spray dried bovine and porcine blood products for further processing from the USA	2004	Negligible	Yes	This standard has been suspended, and will be amended to remove porcine blood.
Importing Animal repellent containing bovine/porcine blood from Sweden	2001	Negligible	No	No outbreaks to my knowledge identified from Sweden (Song and Park 2012), also likelihood of exposure is negligible due to blood products being associated with a animal repellent
Importing Animal by-products for pharmaceutical use, technical use or petfood from the European Community	2004	Non-negligible (pig offal)	No	Pig offal presents a non-negligible risk of entry Modified heat treatment for pig blood will result in a negligible risk of entry (60°C for at least 30 minutes). Pig fat presents a negligible risk of entry
Importing Porcine sausage casings from Canada and the USA	2004	Negligible	No	Infectious tissue not associated with casings
Import Health Standard for Natural Casings (Porcine/Ovine/Caprine) for Human Consumption from the European Union	2012	Negligible	No	Infectious tissue not associated with casings

Importing Pig Meat and Pig Meat Products for Human Consumption (various IHS's depending on country)	Various dates depending on country	Negligible	No	No evidence that PED is transmitted through the consumption of meat
Importing Pig By-Products from Canada and/or the United States of America	2011	Non-negligible (pig offal) Non- negligible blood treated for PRRS	Yes	IHS is currently suspended as a precautionary action until further assurances are provided. Pig offal presents a non-negligible risk of entry Modified heat treatment for pig blood will result in a negligible risk of entry (60°C for at least 30 minutes). Pig fat presents a negligible risk of entry
Importing shelf stable petfoods containing animal products from all countries	2007	Negligible	No	Food for livestock can not be imported under this standard
Importing pig semen from Approved Countries	2013	Negligible	No	No evidence of transmission of PEDV in semen
Importing porcine enzymes specified from Canada and the USA	1998	Negligible	No	No evidence of PEDV association with permitted enzymes

6. Conclusion

SDPP imports present a negligible likelihood of exposure to pigs, as it has only been used as an ingredient in cat food.

Pig blood imported to New Zealand may present a non-negligible likelihood of entry for PEDV when subjected to the various time/temperature treatments established to prevent PRRSV entry. Although, if heated to 60°C for at least 30 minutes the likelihood of entry is assessed as negligible.

Imports of pig by-products in the form of offal present a non-negligible likelihood of entry.

Also, as this disease situation is rapidly evolving it is important to actively monitor ProMed/IBIS for any further updates to ensure that the risk profile for New Zealand is re-assessed when needed.

7. Gaps in knowledge

- Definitive time/temp inactivation for PEDV in spray dried blood
- Time/temperature data for the inactivation of PEDV in blood and offal
- Whether pelleted pig feed is a vehicle for the spread of PED

8. ProMed timeline since the first outbreak in the United States (May 2013).

Date	Location	Summary	Archive number
19th May 2013	Iowa USA	First report of PED in the United States	20130519.1722634
4th June 2013	USA	Confirmed spread to 5 state: Colorado, Illinois, Indiana, Minnesota, Iowa	20130604.1753696
20th June 2013	USA	Mystery surrounding how PEDV entered the USA. Confirmed spread to 13 states: Arkansas, Kansas, and Pennsylvania. Previously, the virus had been found in barns in Colorado, Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Oklahoma, and South Dakota.	20130620.1782722
30th June 2013	USA	General information about disease and informs that USDA is investigating livestock transportation systems	20130630.1800448
5th July 2013	USA	Spread to two farms in North Carolina	20130705.1809157
2nd August 2013	USA	Research questioning hygiene practices in meat processing plants and transport systems aiding the spread of PED	20130802.1859532
5th August 2013	USA	Spread to four more states, they are not listed	20130805.1865372
30th August 2013	USA	Spread to the state of Wisconsin	20130830.1912388
2nd October 2013	USA	Contaminated feed appears to be the most probable source of PED outbreak as suggested by a veterinary consultant. Also, contaminated transport trucks, which are contaminated with materials and fomites and are transported by humans to uninfected farms, are likely to be spreading the disease. Recently with some of the outbreaks in the USA it has been shown that the virus might be transmissible by aerosol over long distances but this remains to be confirmed and assessed in a more scientific way. At this date PED has spread to 17 states	20131002.1979090
12th October 2013	USA	The total number of swine accessions and diagnostic case submissions testing positive for the porcine epidemic diarrhoea (PED) virus is now 724. From the week of 16 Jun to week of 29 Sep [2013], the total number of swine samples testing positive is 1919, up from 1750 the previous week (up 169). The most-affected states are: Oklahoma, 520; North Carolina, 456; Kansas, 433; Iowa, 180; Colorado, 79; Minnesota, 78; Ohio, 71; and Indiana, 26. Other states, where positive, reported 20 positives or fewer.	20131012.1997836
26th October 2013	USA	North Carolina spike in cases possibly due to cooler weather. About 250 infected farms with possibly up to 150 000 sows infected	20131026.2022621

27th October 2013	USA	Paper on the origin of PEDV outbreak in USA. Likely that virus has originated from China and has been separated from these strains for 2-3 years	20131027.2023953
12th January 2014	USA	Winter temperatures could aid the spread of PEDV	20140112.2168515
17th January 2014	USA	Canadian concerns about disease entering their country	20140117.2179182
27th January 2014	Canada	First report of disease in Ontario	20140127.2233682
1st February 2014	North America	Update: Total number of confirmed cases in the USA is 2692 in 23 states. Spread to a fourth farm in Ontario	20140201.2247583
2nd February 2014	North America	Canada: 5th case confirmed in Toronto. USA: disease spreading across the Midwest.	20140202.2250243
4th February 2014	USA	A new strain of PEDV has been isolated by Iowa vet laboratory. It is different to the strains investigated since the first outbreak last year and shows great similarity to strains isolated in China from 2004-2012	20140204.2253080
13th February 2014	Canada	Hog distribution hub identified in Ontario as receiving infected pigs. Distribution company employing biosecurity measures to prevent the spread of the disease.	20140213.2274651
19th February 2014	Canada	PED confirmed on a pig farm on Prince Edward Island	20140219.2286312
20th February 2014	North America	Pig feed products possibly linked to spread of PED. As a precaution a voluntary recall for pelleted feed products containing porcine plasma has been initiated, while further tests are being undertaken	20140220.2288707
25th February 2014	Canada	Quebec confirmed as the 4th province in Canada to be infected with PED	20140225.2298304
27th February 2014	North America	Idaho pig farm found to be infected with PED	20140227.2303137
7th March 2014	North America	Scientific testing by the Canadian Food Inspection Agency cannot confirm a link between feed containing blood plasma and PED cases in Canada.	20140307.2318706
16th March 2014	USA	PED spread to Arizona, 27 states now infected. Confirmed number of cases is now 4458.	20140316.2335756
19th March 2014	Colombia	A new porcine disease reported from Colombia, likely to be PED. Signs are the same as PED, awaiting confirmation. If confirmed it would be the first report of this disease in Colombia	20140319.2341300
19th March 2014	Japan	Likely first outbreak of PED in the Fukuoka Prefecture. First case of PED in Japan was in the 1980s, after an absence of about 7 years, PED reappeared in October 2013 in the Okinawa prefecture, followed by the prefectures of Kagoshima, Miyazaki, and Ibaraki.	20140319.2343107
21st March 2014	UK	UK pig industry focusing on identifying and isolating any pig feed containing spray-dried porcine plasma, until more is known about transmission route for PED	20140321.2346611

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10. APPENDIX 1 – Previous *Surveillance* PEDV article, December 2013

PORCINE EPIDEMIC DIARRHOEA: NORTH AMERICAN OUTBREAK 2013

New Zealand and overseas status

PEDV is an *Alphacoronavirus* in the *Coronaviridae* family, and is closely related to human coronavirus (HCoV). PED was probably first recognised in England in 1971, but the cause was not established until 1978 when outbreaks were reported in Belgium and the UK (Popischil *et al.*, 2002; de Groot *et al.*, 2012). Since then the disease has been described throughout much of the world but has not been identified in either Australia or New Zealand. Significant outbreaks of PED were described in Korea in the 1990s that subsequently spread across east and southeast Asia. New PED strains subsequently emerged in China and spread to Vietnam and Thailand. In late 2010, despite vaccination, more than a million piglets died in China following infection with PEDV; the mortality rate in infected piglets was reported to be 80–100 percent (Sun *et al.*, 2012; Williamson *et al.*, 2013).

In May 2013 a PED virus very similar to the highly virulent strains currently circulating in Asia was detected in the US. The virus is causing severe PED outbreaks in 15 states including pig-dense areas of Iowa, Colorado, Indiana, Illinois, North Carolina and Minnesota. Infection has been associated with significant losses in pre-weaning and growing pigs, with morbidity and mortality in affected herds ranging from 30 to 100 percent (USDA, 2013).

Transmission

PED is primarily thought to be transmitted through the faecal-oral route by contact with live infected pigs, pig faeces or manure and contaminated vehicles or fomites, including feed. However, the rapid long-distance spread of the virus between epidemiologically unrelated farms has created some concern that other modes of spread, including airborne transmission, may be important (Pensaert, 2006).

The source of PED introduction into the US is not yet known. It has been suggested that it entered through the movement of infected pigs from Canada, but no cases of PEDV have ever been confirmed in Canada. PEDV isolated in the US has been shown to be 99.4 percent similar to virus from severe Chinese outbreaks, and the outbreaks have been similar clinically to those seen across east Asia. This suggests the infection is most likely a result of introduction of the virus from that region. Some efforts have been made jointly between the pig industry and the US Department of Agriculture to investigate the possibility that contaminated feed from China has been a transmission pathway (Roberts & Middlemiss, 2013).

Porcine epidemic diarrhoea (PED) is a highly infectious coronavirus disease of pigs, caused by porcine epidemic diarrhoea virus (PEDV). Emerging strains associated with severe disease have been recognised in east and southeast Asia and have recently been identified in the US. PED causes profuse, watery diarrhoea in pigs of all ages. High mortality (up to 100 percent) may be seen in young pigs whereas the disease tends to be less severe in older animals, with a mortality rate of only 1–3 percent. Infection has been associated with significant losses in pre-weaning and growing pigs, with overall morbidity and mortality in affected herds ranging from 30 to 100 percent. If you suspect PED you should call the free exotic pest and disease hotline, 0800 80 99 66.

Pathogenesis

PEDV replicates in the cytoplasm of villous epithelial cells throughout the small intestine and colon, resulting in villous stunting in the small intestine similar to that described following infection with transmissible gastroenteritis virus (TGEV) (Popischil *et al.*, 2002). Studies to date have not shown viral replication in cells outside the intestinal tract (de Groot *et al.*, 2012).

Presentation

The main clinical sign associated with infection is profuse watery diarrhoea, which may affect all ages. Piglets less than two weeks old may die from dehydration after three to four days and an average mortality rate in this age group of 50 percent is described although it may be much higher, especially with emerging strains of PEDV that have been seen in Asia and North America. Abdominal pain may be seen in older pigs and although morbidity is likely to be high, a mortality rate of only 1–3 percent has been described (Roberts & Middlemass, 2013).

Infection with PEDV causes clinical signs comparable to TGEV (also a *Coronavirus*). Outbreaks of diarrhoea caused by infection with TGEV occur in pigs of all ages. Older animals generally recover within a week, while mortality in piglets less than seven days old is around

50 percent and may approach 100 percent. Morbidity may be close to 100 percent in naïve herds. Upon introduction to a farm TGEV spreads rapidly, often with nearly all pigs becoming infected in the first one to two weeks. The disease is more likely to become endemic on larger farms, on farms that have frequent or high numbers of incoming stock movements, or where ineffective control measures are implemented (The Pig Site 2013; Pensaert, 2013).

Diagnosis

PED diagnosis cannot be made on clinical signs alone. Direct immunofluorescence or immunohistochemical tests can detect viral antigen in sections of small intestine from acutely infected individuals, but loss of enterocytes limits the use of these tests in pigs that have died as a result of infection. Electron microscopy can be used to demonstrate the presence of PEDV particles in the faeces of infected pigs, but this will not distinguish PEDV from TGEV as both viruses have the same morphology (Popischil *et al.*, 2002). ELISA tests have been developed to detect PEDV antigens in faeces of infected individuals and also to detect specific antibodies in serum. Viral antigen can be detected in faeces 3–11 days after infection and serum antibodies appear seven days after infection. RT-PCR and *in situ* hybridisation tests have also been described (Pensaert, 2006).

Prevention and control

Most growing pigs recover from infection without treatment unless secondary infections occur. Infection in suckling pigs is almost always fatal unless the piglets are borne to immune dams that have survived prior PED infection and can supply ample protective antibodies through colostrum. Most control strategies take advantage of this by ensuring pregnant sows are rapidly infected (during the acute phase of an outbreak) before they farrow (Pensaert, 2006).

In the face of an outbreak of PED in an industry or area, high standards of biosecurity are required to prevent the introduction of infection onto susceptible farms. Once infected, a farm should be strictly quarantined and managed in such a way as to minimise the likelihood of further spreading the infection. On endemically infected farms, use of "all-in, all-out" practices is important to break the transmission cycle between actively infected pigs and younger, naïve animals (USDA, 2013).

Attenuated vaccines have been developed in South Korea, Japan and China but none are reliably efficacious in preventing infection or reducing the severity of clinical signs that result from infection with the prototype or newly emerged strains of PED. Similarly, vaccines against TGEV also have very limited efficacy.

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