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Classical swine fever (CSF) is a highly contagious and economically significant viral disease of pigs. Although this disease was once widespread in pig-farming areas, it has been eradicated from many countries including the U.S. Reintroduction of the virus can be devastating. In 1997-1998, an outbreak in the Netherlands spread to involve more than 400 herds and cost approximately \$2 billion to eradicate.<sup>1,2</sup> Approximately 12 million pigs were killed, some in eradication efforts but most for welfare reasons associated with the epidemic.<sup>1,2</sup> The United Kingdom experienced an extensive CSF epizootic in 2000, and minor outbreaks were reported in Romania, Slovakia, Spain and Germany in 2001.<sup>3</sup> North America is also at risk for the introduction of this disease, which is still endemic in much of South and Central America.<sup>3</sup> Intensive swine production practices are used in the U.S. There may also be extensive movements of pigs at different phases of production, with the potential for direct or indirect contact between pigs from different sources. Both factors increase the risk of virus spread.<sup>3</sup> In addition, trade has become globalized, and international passenger travel and immigration have grown, increasing the risk of accidental introduction.<sup>3</sup>

Classical swine fever is caused by the classical swine fever virus (CSFV), a member of the genus Pestivirus and family Flaviviridae. This virus is transmitted between pigs by direct or indirect contact, often by the oronasal route.<sup>3,4,5</sup> Infected pigs are the only reservoir of virus. Blood, tissues, secretions and excretions contain infectious virus.<sup>3,5</sup> Outbreaks can originate from many sources, including contact with infected live pigs or fomites; however, the illegal feeding of pig swill (waste food from the human food chain) has been implicated in a number of cases.<sup>4,5</sup> The classical swine fever virus can be readily recovered from swine that die during the prodromal stage of the disease, as well as at later stages of disease.<sup>3-6</sup> The presence of CSFV in meat during the prodromal period suggests that asymptomatic infected pigs may, in some cases, enter the meat supply at abattoirs.<sup>6</sup> This meat could eventually be included in pig swill. Without measures to adequately inactivate the virus, this route of transmission could help disseminate classical swine fever. Pigs can probably become infected with

CSFV after ingesting only a few grams of infected meat.<sup>7</sup> In pigs inoculated with  $10^{6.5}$  TCID<sub>50</sub>\*/pig, virus titers of  $10^{3.4}$  TCID<sub>50</sub>/gram were recovered from muscle, and titers of  $10^{4.9}$  TCID<sub>50</sub>/gram from lymph nodes.<sup>7</sup>

In meat or meat products that are not heat-treated, virus inactivation occurs mainly as a result of acidification and proteolysis.<sup>8</sup> Proteolysis is caused by hydrolytic enzymes released from lysosomes during cell membrane breakdown after death, or by bacteria present in the meat.<sup>8</sup> These bacteria can include the normal flora, as well as starter cultures added to meat products such as sausages. Proteolysis is particularly active in unheated meat products that are minced and cured over a long period.<sup>8</sup> Acidification is primarily caused by lactic acid build-up after death, as glycogen stores are broken down. Porcine muscle tissues reach a pH of 5.3-5.8 at 4-12 hours after slaughter, if the meat is not frozen.<sup>8</sup> This pH drop occurs more slowly in other tissues including lymph nodes, fat and bone marrow.<sup>8</sup> The drop in pH stops if the meat is frozen.<sup>8</sup> Meat from stressed animals may have a higher pH.<sup>8</sup> In salami and similar products, pH is also influenced by the fermentation process.<sup>8</sup> CSFV is usually stable at a pH of 5-10.<sup>6</sup> It is quickly inactivated at very acid pH (pH 3 or less) or at a pH greater than 10.<sup>6</sup> Salting and smoking are not very effective in inactivating viruses.<sup>8</sup> In fact, some viruses are more resistant to inactivation by low pH when salt concentrations are high.<sup>8</sup> The rate at which CSFV is inactivated in pork products varies with the activity of natural processes such as proteolysis, as well as the specific techniques and conditions used during processing. A number of studies have examined the survival of CSFV in a variety of pork products.

## CSFV survival in pork meat and ham

CSFV can survive for variable periods in meat, with survival more likely at cold temperatures. This virus is most stable in frozen meat.<sup>6</sup> Viable CSFV has been recovered from frozen pork stored for more than four years.<sup>9</sup> (cited in 6) In chilled fresh pork, this virus has been shown to survive for up to 85 days.<sup>10-11, 12</sup> (cited in 6) Its survival time at room temperatures is not well established,<sup>6</sup> but in one study, no viable CSFV was recovered from artificially contaminated, factory-processed abattoir waste held at 20°C (68 °F) for four days or longer.<sup>13</sup> (cited in 6) Other sources suggest a survival time similar to that of rinderpest virus; in one review, CSFV is stated to remain viable for 33 days in skin and 73 days in muscle at room temperature.<sup>14</sup> (cited in 15)

\* TCID<sub>50</sub> = the quantity of a virus (or other agent) that will produce a cytopathic effect in 50% of the cultures inoculated.



In the proteinaceous environment of meat, CSFV does not appear to be inactivated by smoking or salt curing.<sup>6</sup> Reported virus survival times range from 17 to 188 days for different forms of smoking or salt curing.<sup>9, 11, 16-18, 19</sup> (cited in 6) The critical factor in virus survival in cured or smoked meat appears to be the storage temperature and time before the meat is marketed.<sup>6</sup> In cured, uncooked meat, CSFV remained infective for 34 to 85 days in one study.<sup>12</sup> (cited in 15) In a joint U.S. and Italian study, CSFV could not be cultured from Parma ham (salted hams produced using the 'Prosciutto de Parma' process) at 189 days in the Italian study, and 313 days in the U.S. study.<sup>19</sup> (cited in 15) These hams were not tested between 189 and 312 days. In another study, CSFV disappeared from Iberian hams by day 252, Iberian shoulder hams or white Serrano hams by day 140, and Iberian loins by day 126.<sup>20</sup> Curing times are 240-420 days for Iberian hams, 180-365 days for white Serrano hams, and 90-130 days for Iberian loins.<sup>15</sup> Traditional hams with long curing times are expected to be safe.<sup>6</sup> However, the protective efficacy of each individual curing process should be considered.<sup>20</sup>

## CSFV survival in sausages

Processing methods for sausages vary in different countries and regions.<sup>8</sup> Factors that may affect virus survival in sausage include the size of the meat particles, percentage of fat, type and quantity of sugars added, and starter cultures of micro-organisms, as well as the diameter of the sausage, the type of casing (intestinal or cellulose) and any additives.<sup>8</sup> For this reason, the inactivation rate for CSFV in sausages can depend on the processing method, and virus survival must be determined experimentally.<sup>8</sup> CSFV has been shown to survive for 147 days in intestinal casings processed in water at 42.2°C (107.9°F) for 30 minutes.<sup>21</sup> Sausage casings salted according to one commercial procedure, and held at 39°C (102.2°F), contained viable virus for up to 86 days.<sup>12</sup> (cited in 15) Sausage casings that had been salted according to another commercial procedure remained infective for 17 days.<sup>12</sup> (cited in 15)

After smoking, Italian salami and pepperoni are typically processed in drying rooms for at least 25 and 16 days, respectively.<sup>18</sup> In one U.S. study, viable virus was found for 15 days (after smoking) in pepperoni made from CSFV-contaminated meat.<sup>18</sup> Live CSFV was found in salami for 14 days after smoking.<sup>18</sup> After this time, samples of pepperoni and salami did not result in illness when inoculated into live pigs. However, other studies have suggested longer survival times. In one Italian study, CSFV was found

in salami for up to 75 days of curing.<sup>22</sup> In this study, viable virus was assessed by inoculation into piglets. CSFV was not found at 90 or 120 days. In another study, viable virus was found in Italian salami for up to 90 days, with no virus recovery at 100, 110 or 120 days.<sup>17</sup> (cited in 8) CSFV could also be inactivated in 29-31 mm Bratwurst by heating to 80-82°C (176-180°F) for 10 minutes; in 22-33 mm Vienna sausages by smoking at 80°C (176 °F) for 45 minutes and scalding at 80°C (176°F) for 8 minutes; and in 59-62mm Lyonerwurst by smoking at 82-85°C (180-185°F) for 50 minutes and scalding at 81-82°C (178-180°F) for 45 minutes.<sup>23</sup> in 15 The survival of CSFV in some types of sausage, such as Sibiu salami (produced in Romania) remains to be determined.<sup>8</sup>

## Destruction of CSFV by heat

Cooking destroys CSFV. Hams from infected pigs did not contain viable CSFV after being heated slowly to an internal temperature of 69°C (156°F) in a water bath.<sup>18</sup> CSFV in meat has also been inactivated by heating to 65.5°C (150°F) or greater for 30 minutes<sup>24</sup> or 71°C (160°F) for one minute.<sup>25</sup> (cited in 6) Temperature control is critical, as heating to 62.5°C (144.5°F) for 30 minutes does not inactivate the virus.<sup>24</sup> Virus survival in defibrinated pig blood is strongly influenced by temperature over a narrow temperature range: in defibrinated blood contaminated with 10<sup>5</sup> TCID<sub>50</sub>/ml, CSFV could not be recovered from blood held at 66°C (150°F) for 60 minutes, 68°C (154°F) for 45 minutes, or 69°C (156°F) for 30 minutes.<sup>26</sup> (cited in 6) In whole blood, the virus could be inactivated by preheating at 60°C (140°F) for 120 minutes before heating to 68°C (154°F) for 30 minutes, or preheating for 3 minutes then heating to 66°C (150°F) for 60 minutes.<sup>26</sup> (cited in 15)

## Conclusions

Classical swine fever virus has been shown to survive for long periods in uncooked pork meat, particularly when it is frozen.<sup>6</sup> This virus can also survive for extended periods in salted or cured meats, with the inactivation rate dependent on the processing method, as well as the storage time and temperature before marketing.<sup>6, 8</sup> Countries are at risk for the introduction of classical swine fever via pig swill contaminated with improperly processed or uncooked pork products.



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