Food Contaminants — Viruses

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ABSTRACT

Viruses have been detected in a limited number of foods. Although methods used to examine these foods were usually restricted to detection of human enteroviruses, animal viruses were found in some meats, milk, and eggs: limitations in methodology may have caused other viruses present to go undetected. As the sensitivity of methods increases, studies are being undertaken to detect a greater variety of human intestinal viruses. Data from these investigations should provide the information needed to determine the incidence and public health significance of food contamination by viruses. In areas where virus-contaminated foods may be expected, washing and heating foods to 70°C should provide reasonable protection against the inadvertent consumption of viruses.

For more than 100 years viruses have been known to be the causative agents of disease in humans and animals, but until the advent of cell culture techniques, it was impossible or extremely difficult to study viruses in the laboratory. Clinical virology laboratories were established, and viruses were implicated as causative agents of numerous diseases. Secretions from infected individuals or animals were found to contain viruses that were usually mixed with other types of microorganisms. Use of antibiotics to eliminate contaminating bacteria allowed secretions to be processed in cell culture for propagation of pure cultures. In some instances, dilution techniques were sufficient to eliminate contaminants because viruses were present in higher concentrations than other organisms.

Early studies attempting to detect viruses in foods were unsuccessful because virus contaminants were present at lower levels than had been observed in the infected human or animal. In addition, natural food poisons and other microbial contaminants frequently destroyed the cell cultures. This necessitated development of methods of greater sensitivity that would also eliminate toxicity and contamination problems. Since 1960 a limited number of laboratories have reported detection of viruses in foods. Methods have improved, and at the present time virus concentrations of less than one particle/gram of food may be detected. Studies on increasing the effectiveness of methodology are continuing, and as refinements are made, more information will become available. Such data should provide health officials with the information necessary to determine the extent and public health significance of virus food contamination.

VIRUS ISOLATION FROM FOODS

A limited number of foods have been examined for the presence of human virus contaminants. Foods of special interest to the investigators were those that were consumed raw or had minimum heat treatment. Polioviruses, coxsackieviruses and echoviruses were isolated from a variety of raw vegetables and cherries (3.4.9). Some samples of milk from cattle, goats, and sheep were found to contain poliovirus, and a number of animal viruses (23,26,34,35,40,49,61,63,74,81,98,101,112); and cytomegaloviruses and the Herpes simplex virus were detected periodically in human milk (22,39). A small percentage of market samples of beef, fish, pork and beef loaf, and bologna contained polioviruses and echovirus 6 (10,11,79,95,102). In addition, samples of oysters, clams and mussels collected from markets and approved and nonapproved waters have been shown to be contaminated with polioviruses, coxsackieviruses and echoviruses (6,7,19,20,27,28,30,58,66,69,71,109).

In cooperation with the Food and Drug Administration, State health agencies maintain continuous surveillance of shellfish-harvesting waters. These preventive public health practices do not exist in many parts of the world. For example, the incidence of contaminating viruses in market samples of shellfish examined in France ranged from 10 to 20% of the samples examined (20). In the United States, less than 1% of shellfish samples was found to contain viruses (26). However, the true level of shellfish contamination is not known because of the limited number of samples that have been examined. Shellfish have been shown to be capable of bioaccumulating viruses from sea water, and they may retain viruses for several days, even when transferred to clean waters (38,41,42,59,60,67,68,70,75,82). Potentially, any viruses present in water, especially those that are particulate-associated, could be bioaccumulated by shellfish.

Animal viruses, e.g., parainfluenza, syncytial, Japanese encephalitis, foot-and-mouth disease, leukosis, Newcastle disease, infectious bronchitis, and papilloma viruses, have been recovered from milk, butter, beef, pork, lamb and eggs (15,18,65,76,87,88,93,100,113). In addition, known human viruses, e.g., polioviruses, echoviruses, coxsackieviruses, reoviruses, influenza viruses and adenoviruses, have occasionally been shown to infect cattle, goats, pigs, sheep, buffalo, and yak (13,31,32,33,90). Most of these animals lived in close
association with humans, sometimes being stabled in the same building as their owners.

**SOURCES OF VIRUS CONTAMINATION OF FOOD**

Viruses gain entrance into the food supply in a manner similar to that of bacterial pathogens. The potential pathways for transmission are shown in Fig. 1. The sources of greatest disease potential are human secretions or excretions. Periodically, foods contaminated with excretions containing hepatitis A virus have been responsible for outbreaks of disease. When shellfish have been contaminated, hundreds of cases of clinical disease have been reported (2,86,89).

![Potential Pathways for Virus Contamination of Foods](image)

**Potential Pathways for Virus Contamination of Foods**

Figure 1. Potential pathways for virus contamination of foods.

Recently, a number of communities changed their methods of sewage disposal to use land as a filter for sludges and effluents of sewage treatment plants. This change in methodology should reduce the numbers of viruses present in the waters of the United States and reduce the potential for contamination of shellfish. Disposal of human wastes on land, however, could result in contamination of food crops and animals unless proper precautions are taken to minimize this potential hazard (57). The volume of sewage produced by some of our larger cities is so great that land application is impossible, and much of this waste will continue to be discharged into the oceans.

**The infected human**

Humans are the greatest polluters of their environment, and viruses discharged by them are highly infectious. Viruses are probably present in the urine of individuals infected with any viral disease that has an infectious blood phase, and viruses that infect the respiratory tract are present in secretions swallowed by the infected person and are passed in the feces. A number of viruses will infect the intestinal tract and are periodically present in the fecal discharges. Therefore, wastes from the infected human are of public health significance when discharged into the environment, and any direct or indirect contact with food may result in contamination.

**The infected food animal**

A common opinion is that diseases in animals are not associated with diseases in humans and that organisms producing disease in humans are probably not infectious for animals. In recent years, studies have shown that when humans and animals live in close association with one another, viruses may be transmitted between species. In the U.S., most food animals are not in close contact with humans, but it is possible that infections could occur when human refuse or sewage is disposed on the land or in the waters consumed by such animals. Some viruses, such as influenza, may be transmitted directly from humans to animals by the respiratory route (13,53). The extent of human viral infections of animals in the U.S. is not known since few animals are investigated for the presence of human viruses.

Animals suffer from a variety of viral diseases, which sometimes occur in epidemic proportions; some of these diseases can be transmitted to humans (1,5,11,14,21,43,47,72,73,97,99,106). In some instances, the disease produced may be lethal in the animal while producing only minimal infection in the human, e.g., Newcastle disease (77). Other diseases, such as tickborne encephalitis virus infections that produce minimal disease in animals, may produce serious infections in humans (36).

The frequency with which viruses are present in animals at the time of slaughter is unknown, but viruses such as foot-and-mouth disease and tickborne encephalitis have been shown to be present in the fluids and organs of infected animals (16,83). The persistence of these viruses in the carcasses of slaughtered animals is variable. It has been shown that as tissues break down by autolysis, the pH drops and an acid environment antagonistic to the foot-and-mouth disease virus is produced. Under these conditions, the virus is rapidly destroyed. However, if the carcass is frozen shortly after slaughter, the viruses will persist for undeterminate periods (16,17).

**Rodents and insects**

Humans have attempted to protect their food supply from damage caused by insects, rodents and other animals. Historically, they were concerned with protecting the volume of harvested materials and maintaining protected stores for use in periods of short food supply. Only recently has it been understood that the visible destruction wrought by rodents and insects was not the only reason to protect foods during storage, since disease organisms may also be transmitted by the adulterated...
foods. Viruses may be excreted in urine or feces from rodents during the time of feeding on the stored food supplies (12,24,37,44,54,62,78,91,92,96,108). In addition, organisms are present on hair, footpads and underbellies of rodents and may be mechanically transmitted as the animals move and feed on foods. Little information is available concerning the infectivity of rodent viruses for humans, but lymphocyte choriomeningitis virus can infect personnel in animal care facilities and poultry workers (77,110,111). The virus causing epidemic diarrhea in infant mice serologically cross-reacts with a similar agent causing infectious diarrhea in humans (45).

Insects, such as flies, have been responsible for transmitting microbial pathogens into the food supply (64). Disease organisms may be transmitted in the feces of insects and by mechanical action as the insect moves across the foods. It is difficult to determine epidemiologically the association of insects and rodents with the food supply and virus disease in the consumer. However, exclusion of insects and rodents from food should reduce the potential for viral infection in humans.

**Consumption of virus-contaminated food: potential for infection**

The types and numbers of viruses present in a food sample are directly related to the disease potential of the food. Only limited data are available to indicate the minimal infectious dose of viruses for humans via the oral route. The data shown in Table 1 pertaining to the infectious dose of poliomyelitis virus were obtained from studies of humans fed attenuated strains of poliovirus as immunizing agents. Such viruses are believed to be less infectious than the wild strains of viruses. Analyses of the data indicate that only a few viruses were required for infection (48,50,51,52,85,94). Other viruses, such as hepatitis A and tickborne encephalitis, can be infectious to humans when consumed in a food product (36,86,89). The minimal dose required for infection by these two viruses is unknown.

Studies have been made, using other routes of infection, to determine the minimum infectious dose of viruses. Two excellent review articles have been published on this subject, and the data indicated that 1 to 10 viruses were sufficient to produce disease in the susceptible human or animal (84,111). Therefore, small numbers of viruses present in a food supply may be sufficient to infect a susceptible human. Such infected persons may be foci for infection of others via the contact route.

Most viruses isolated from foods have been members of the enterovirus group. These viruses, which are common contaminants of the environment, consistently produce clinical or subclinical disease in children. They may also produce disease in susceptible adults who have had little or no previous contact with the organisms. Although many infections caused by enteroviruses produce few if any symptoms, clinical syndromes may be noted. The enteroviruses most commonly known to the consumer are those of the poliovirus group. Before immunization programs were initiated in the U.S., serious syndromes were produced by polioviruses in infected children and adults. In some instances, death resulted. However, most humans that were infected showed few symptoms, but the subclinical infection was sufficient to produce immunity.

Recently, rotaviruses, parvoviruses, papovaviruses and enterovirus-like particles have been detected in feces during intestinal outbreaks and in urine (8,25,29,45,46,80,105). Many of these viruses did not replicate in cell culture systems, even when recovered from the intestine in high concentrations. Potentially, such viruses are of public health significance, and when suitable culture techniques are developed, they may be found to be a more common contaminant of foods than are enteroviruses. Human intestinal viruses having a high potential as food contaminants are shown in Table 2.

**Precautions that may be taken to prevent infections**

In environmentally advanced countries, fruits and vegetables should be well rinsed, and the bruised and damaged areas removed. In geographic areas where contaminated food crops might be found, contaminated drinking water should be expected. In such locations, all foods should be heated to a minimum processing temperature to destroy viruses.

**TABLE 1. Oral route infectivity of attenuated poliovirus for humans.**

<table>
<thead>
<tr>
<th>Virus</th>
<th>Subject</th>
<th>Dose</th>
<th>Antibody response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poliovirus 1 (SM)</td>
<td>Adults</td>
<td>200 PFUa</td>
<td>4/4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 PFU</td>
<td>4/4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 PFU</td>
<td>2/3</td>
</tr>
<tr>
<td>Poliovirus 2 (P712)</td>
<td>Adults</td>
<td>100 TCD/50b</td>
<td>Infected</td>
</tr>
<tr>
<td>Poliovirus 3 (Fox)</td>
<td>Infants</td>
<td>100-1000 PFUa</td>
<td>4/4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300-1000</td>
<td>7/9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 PFU</td>
<td>2/3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 PFU</td>
<td>3/10</td>
</tr>
</tbody>
</table>

aPFU = plaque forming units.

bTCD/50 = 50% tissue culture dose.

**TABLE 2. Human intestinal viruses with high potential as food contaminants.**

<table>
<thead>
<tr>
<th>1. Picornaviruses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polioviruses 1-3</td>
</tr>
<tr>
<td>Coxsackievirus A 1-24</td>
</tr>
<tr>
<td>Coxsackievirus B 1-6</td>
</tr>
<tr>
<td>Echovirus 1-34</td>
</tr>
<tr>
<td>Enterovirus 68-71</td>
</tr>
<tr>
<td>Probably hepatitis A</td>
</tr>
<tr>
<td>2. Reoviruses</td>
</tr>
<tr>
<td>Reovirus 1-3</td>
</tr>
<tr>
<td>Rotaviruses</td>
</tr>
<tr>
<td>3. Paroviruses</td>
</tr>
<tr>
<td>Human gastrointestine viruses</td>
</tr>
<tr>
<td>4. Papovaviruses</td>
</tr>
<tr>
<td>Human BK and JC viruses</td>
</tr>
<tr>
<td>5. Adenoviruses</td>
</tr>
<tr>
<td>Human adenoviruses types 1-33</td>
</tr>
</tbody>
</table>
temperature of 70 °C (≈ 160 °F) ([55,104]). Enteroviruses inoculated into ground beef were inactivated at this temperature. Red meats heated to 70 °C turn brown, thus providing a visual indicator that the virus inactivating temperature has been achieved ([103]). When eating outside the home, only hot foods should be consumed for thermal processing of foods provides protection against viruses, parasites and bacterial pathogens.

If consumption of raw fruits and vegetables is desired, they should be rinsed and submerged for at least 2 min in water maintained at about 80 °C (about 176 °F) ([56,107]). This temperature should ensure that all surfaces of the food will be exposed to a temperature of 70 °C. The temperature loss of the heated water in the container will depend on the volume of water in the vessel and the amount of food being decontaminated. Therefore, care should be taken to monitor the water temperature. If a safe water supply is available, the fruits or vegetables could be cooled quickly in cold water. Appearance and taste of most fruits and vegetables processed by this temperature loss of the heated water in the container will provide a visual indicator that the virus inactivating amount of food being decontaminated. Therefore, food after processing. Cross-contamination frequently decontaminated foods. Foods that are consumed without cooking are subsequently used to process cooked or inactivated food products.

Care should be taken that recontamination of food does not occur. This may be prevented by careful handwashing and proper placement of the heat-treated food after processing. Cross-contamination frequently occurs in the home and in food establishments when hands, utensils and surfaces used to prepare raw foods are subsequently used to process cooked or decontaminated foods. Foods that are consumed without cooking should be processed separately and knives, cutting boards and utensils should be clean and not previously used in preparing meats and other potentially contaminated food products.

REFERENCES

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