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Transmission of common foodborne viruses by meat products

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Abstract

The most common foodborne viruses are single stranded RNA viruses which are adaptable and extremely resistant to environmental stress factors. Usual routes of food contamination are via stool material by persons shedding intestinal virus, or by saliva aerosols generated by shedding persons when coughing. Contamination of meat by animal viruses occurs when good hygienic and manufacturing practice fails. Once within food, viruses cannot replicate since they require living cells for this; hence food is not sensorily altered. Preventive measures in meat processing against pathogenic bacteria frequently have poor antiviral performance, while diagnostic techniques for viruses remain problematic.

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1. Introduction

Viruses are extremely small microorganisms, ranging in size from 20 to 400 nm. They have a simple structure made up of the viral RNA or DNA, surrounded by a protein coat and, in some viruses, a lipid envelope around the protein coat. Unlike bacteria, viruses are not free-living microorganisms and only replicate within the living cells of humans, animals, plants or bacteria. Viruses do not infect hosts at random; they rather have tropism towards specific

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group of cells and/or hosts. Once they invade cells, they take control over the cell metabolism and redirect it to synthesize more viral proteins and nucleic acids by utilizing cellular enzymes. Viral contamination of food occurs either as clinical contamination or as environmental contamination. In the case of clinical contamination, the virus replicates within an animal, products from which are then consumed without the virus being inactivated. This is fairly uncommon and there were just a few cases of viral infection of this type reported (tick-borne encephalitis in ruminant's milk)[1,2]. The most common route of viral food contamination is environmental contamination. This frequently involves direct contamination of food during handling by drops created when an infected person coughs or by contamination with stool material from a person infected with an intestinal virus. Environmental contamination occurs due to sewage coming in contact with water used for growing bivalve molluscs or in the production of fresh produce.

2. Characteristics of foodborne viral infection

Foodborne viral infection causes rather explosive outbreaks. Infective doses are extremely low i.e. only a few viral infectious particles (less than 100) are needed to cause infection and subsequent illness. Infected persons shed viral particles in stool and vomit, a peak level of 10^7-10^{10} viral copies per gram of feces. Although illness lasts only a day or two, shedding of virus can continue for up to 60 days[3]. Viruses do not replicate in food under any temperature and/or water activity since they require living cells to replicate. Hence they do not induce alterations of food ingredients and subsequently food smells, looks and tastes normal. However, due to lack of physiological activity they can persist for extended periods in conditions which can otherwise inactivate common foodborne pathogenic bacteria.

The most common foodborne viruses and their characteristics are presented in Table 1.

Table 1. Common foodborne viruses and their characteristics.

Virus/Family	Genome	Type of illness	Source	Transmission/ Food vehicle	Risk level
Norovirus/*Caliciviridae*	ss RNA	Gastroenteritis	Human stool, vomit	Fecal-oral/berry fruit, deli meat, shellfish	High
Hepatovirus A/*Picornaviridae*	ss RNA	Hepatitis A	Human stool	Fecal-oral and person-to-person/deli meat, raw beef, water, shellfish, fruit and vegetable	High
Orthohepevirus A/*Hepevirida*e	ss RNA	Hepatitis E	Pig liver	Environmental/Pork	Low to moderate

Except for Rotavirus, the likelihood of other human enteric viruses such as Adenovirus, Sapovirus, Aichivirus, Parvovirus and Poliovirus causing foodborne diseases is quite low due to their person-to-person transmission routes, so risk level should be considered low.

3. Virus transmission by meat

3.1. Raw meat

Retrospective studies on transmission routes by raw meat are sparse. To date, Orthohepevirus A (hepatitis E virus – HEV) genotypes 3 and 4 have been frequently found in intestinal tract of European pigs and boars (prevalence 6% to 85%)[4] and has been confirmed in raw pork. It is not known at what stage of slaughtering virus contaminates raw meat; however, being shed via animal feces and urine and not efficiently spread from human-to-human it has been assumed that poor evisceration practice (loosened, tied off rectum, cut bladder, punctured viscera) is the main causes of meat contamination. Food handlers should also bear in mind that pig liver is also main source of contamination due to HEV tropism toward hepatocytes.

Regarding Norovirus and Hepatitis A virus (HAV), epidemiological data demonstrated that infected handlers at slaughterhouses are repeatedly involved in transmission of these viruses, if they practice poor personal hygiene[5,6]. They may contaminate food directly or contaminate food contact surfaces with fecal material. In 2004 in Belgium, the number of cases of hepatitis A suddenly increased[7]. After an outbreak investigation, 269 cases of hepatitis A were identified. There were more men affected by the outbreak with a ratio of 1.4 to 1. The average age of the afflicted people was about 37 years old. The supposed cause of this sudden onset of illness was that the HAV virus was introduced into the food supply in the area from an infected employee. After thorough research, the source of infection was found to be a mid-30's male who contracted the disease and handled meat without wearing protective gloves in a common meat supplier before it went to the smaller butcheries.

Some effort to monitor foodborne viruses in the raw meat production chain has been made in Canada[8]. The study demonstrated one sample of raw pork out of 156 from retail had a human-like Norovirus strain GII.4. Although the pork could have been contaminated by an infected food handler, the detection of human-like Norovirus in pork suggests the possibility that meat could have been contaminated with noroviruses in animal feces during slaughter and processing.

3.2. Deli meat

Norovirus is the virus most commonly implicated in deli meat transmission. One of the large-scale outbreaks of acute gastroenteritis (AGE) occurred among rafters in the Grand Canyon, USA in September 2005[9]. Ninety-one rafting trips occurred during the study period. On 13 of these trips, three or more people developed AGE (137 ill rafters). Twelve such trips were examined further, and the only common factor was food provided by a single supplier. In a case-control study, 96% of rafters who became ill within 3 days after launch had consumed delicatessen meat from this supplier on day 1. All meat consumed by the ill rafters came from a single batch cut by an employee who had just recovered from a diarrheal illness and was not using gloves. Norovirus was detected in an unopened package from the batch associated with AGE and in two of four stool samples obtained from ill rafters. Interestingly, a stool sample from the employee tested negative. In October 2007, a Norovirus gastroenteritis outbreak occurred in Jönköping, Sweden, at a seminar for healthcare improvement, attended by 112 healthcare workers from different parts of Sweden[10]. The healthcare workers were asked to take part in this case-control study, and 83 persons, including 4 employees of the restaurant that provided food service, decided to participate. Thirty-three of these 83 persons acquired AGE during or shortly after the seminar. Epidemiologic investigations indicated that the lunch on the first day was contaminated with Norovirus and was subsequently the cause of the outbreak. The chef was ill 4 days before the outbreak started, and 3 days later other employees had also become ill.

According to data kindly provided by US Centre for Disease Control and Prevention, in 2013, the main food vehicles responsible for Norovirus infection in the USA were chicken sandwiches, buffalo sandwiches, and Italian sandwiches containing pepperoni salami and ham. Some authors conducted a study on modelling transmission of Norovirus during mechanical slicing of RTE meat products (Bologna type and lean meat)[11]. The data obtained indicated that in the worst case scenario, Norovirus (at infective level) can be mechanically transferred to more than 30 slices of Bologna type deli meat using single contaminated knife, while lean dried meat contained infective level of Norovirus in, at least, 7 consecutive slices.

4. Resistance of foodborne viruses and strategies for prevention

There is an interesting phenomenon that if a foodborne virus possesses more complex structure, it is less resistant to environmental factors. Clearly, Norovirus, HAV and HEV, being deprived of lipid envelope and possessing a protein coat only are unaffected by conventional measures taken to control foodborne bacteria, such as chilling and freezing. Packaging of meat in modified atmosphere also does not influence reduction of viral contamination. Viruses loose infectivity when dried on surfaces but persist for 30 days or more dried on paper, cloth, plastic, aluminum, and ceramics. Length of survival is linked to the type of surface, air humidity, and the presence/absence of organic material, as well as to the structure of the viral capsid proteins.Apart from ultrahigh temperature treatment, no methods would completely inactivate more than 3 log of foodborne virus, and if food becomes contaminated after processing, virus will remain active enough to cause infection. Common salt, for centuries used

to inhibit bacteria, does not induce antiviral effect. In contrast, it has been demonstrated that it protects Norovirus and HAV during high-pressure sterilization of meat[12]. UV light is an effective and clean tool for foodborne virus control but has limitations due to lack of meat matrix penetration. Ozone is highly effective against these three RNA viruses due to induction of protein peroxidation of capsid, and sometimes ozonized water is used to rinse raw meat; however, it alters taste and color of food[13]. Proper cooking of porcine liver does destroy infectivity of HEV. Boiling in water for 5 min and stir-frying for 5 min at 191°C to an internal temperature of 71°C inactivates this virus. However, incubation of infected liver for one hour at 56°C was not an effective heat treatment[14]. Since pork is usually cooked until well done it is not considered likely that hepatitis E is a common foodborne infection. However, it is possible that some sporadic infections result from consuming undercooked meat and from cross-contamination during food preparation.

Testing of antiviral effectiveness is cumbersome when it comes to human Norovirus. This virus is not cultivable so some surrogate cultivable strains (murine or canine Norovirus) are used to asses interventions. These frequently respond differently to stress caused by antiviral treatment when compared to human adapted strains. The only tool that remains for detection of Norovirus is real time reverse transcription PCR which is sensitive enough to detect as low as 10 viral copies per gram. However, completely inactivated viral particles that pose no threat to public health may still contain intact RNA, hence resulting in a positive virus assay. The RNA will eventually be degraded, but it is unknown how long this will take in different environments.

5. Challenges in diagnostics

Standardized protocols (ISO 15216:2013) for detecting foodborne viruses have been developed for soft fruit and bivalve shellfish. In addition, certified Norovirus and HAV reference materials for quality assurance purposes are now available commercially. Challenges in diagnostics include confirmation of positive PCR results, developing critical thresholds for virus genome copy levels in food products and interpreting positive PCR results alongside levels of fecal indicator organisms. Whether infectious or non-infectious, if Norovirus is detected in a meat product it indicates that a failure in deployment of GMP, GHP and HACCP has occurred at some point. Therefore, PCR-based analysis is very much a convenient tool in outbreak control.

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