The evaluation of Avian Influenza and Coronavirus as Pathogenic Enveloped Viruses for Possible Health Risk in Seafood: A Review

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Abstract: Human pathogenic viruses in seafood are a significant and emerging problem for public health, food safety, and socio-economic implications worldwide. They may exist in any form of untreated water due to pollution induced by fecal content of human or animal origin, directly infected through interaction with body secretions and fluids containing contagious viral particles, or indirectly by aerosols or other polluted fomites. Thus, human pathogenic viruses can cause infection anytime by transmitting them from water and food environments to seafood and its products. Nowadays, people go through an unprecedented, huge challenge and global health disaster around the world because of the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) outbreak. Non-enveloped viruses are commonly known to have more stable and can survive much longer than viruses with an envelope tag. However, some studies show that some enveloped viruses such as avian influenza can be accumulated by seafood and can survive at low temperature for a long time. Low temperature preservation of seafood during processing, storage, transfer, distribution, and display in retail stores are common methods to prevent the loss of quality and survival of the SARS-CoV-2 may be enough time to have all transmission routes at these low temperatures like other viruses. However, there have been no cases of COVID-19 infection identified through either water-borne or food-borne transmission since the beginning of the pandemic (almost a year). It seems that the main way of virus transmission is mostly person to person through respiratory droplets. So, it is thought to be that the risk of getting COVID-19 from seafood is very low and it can safely consume with proper cooking and hygiene protocol.

Keywords: Avian influenza, coronavirus, health risk, seafood

Su Ürünlerinde Patojenik Zarflı Virüsler Olarak Avian Influenza ve Koronavirüsün Olası Sağlık Riski Bakımından Değerlendirilmesi: Derleme

Öz: Su ürünlerinde patojenik virüsler, dünyada gida güvenliği, halk sağlıklı ve sosyo-ekonomik etkiler bakımından önemli bir sorundur. Bu virüsler, insan veya hayvan kaynaklı dışkı içeren neden olduğu herhangi bir arıtılmamış su kaynağından, doğrudan buluşçu viral pariküller içeren vücut salgıları veya sıvılarla veya doalya olarak aerosoller veya diğer kirli materyallerle enfekte olan bulasma nedeniyle bulunanlardır. Bu nedenle insan patojenik virüsleri, her an ve su adultesinde su ürünlerini buluşturarak enfeksiyona neden olabilirler. Günlümzede insanlar, şiddetli akut solumun sendromu - koronavirüs-2 (SARS-CoV-2) salgın nedeniyle tüm dünyada benzeri görülmemiş, büyük bir zorluk ve felaket yaşamaktadır. Genellikle, zarflı virüslerin daha kararlı olduğu ve zarflı virüslerden çok daha uzun süre hâylattaki kalabilme eğilimleridir. Bununla birlikte, bazı çalışmalarla biraz gribi gibi zarflı virüslerin deniz mahsullerinde birey arıtılmadığı ve dışkı sıklığında daha stabil olduğu gösterilmiştir. Su ürünlerinin işlenmesi, depolanması, aktarılması, dağıtıldığı ve perakende mağazalardan sergilendikleri sırasında dışkı sıklığı korunması kalite kaybı önlemek için kullanlan yangın bir yöntemdir ve SARS-CoV-2 dışkı sıklığında tüm bulasma yolcularını hâylattaki kalabilme için yeterli zaman sahibi olabilir. Bununla birlikte, salgın başladığında beri (yaklaşık bir yıl), su da gida kaynakları bulası yolcuları geçirebilmek için ilgili virüsün bakımdan daha kalabalık eylemler yapması beklenmektedir. Bu nedenle, COVID-19 virüsünün bu durumda ulaşabileceği risklerin de dahil olabileceği bilim insanlarının dikkatli bir şekilde ikinci vaka tüketilebileceğini düşünlülmektedir.

Anahtar kelimeler: Koronavirüs, kus gribi, sağlık riski, su ürünleri.
INTRODUCTION

Seafood and water-related transmission may also be suspected of enhancing the spread and production of zoonotic respiratory viruses (e.g., influenza, severe acute respiratory syndrome-coronavirus (SARS-COV), severe acute respiratory syndrome-coronavirus-2 (SARS-COV-2), Middle East Respiratory Syndrome-Coronavirus (MERS) and Nipah virus), facilitating the occurrence of zoonotic events with bushmeat (Ebola virus) handling (Liya et al., 2020; Ohimain, 2016; Qu et al., 2020; Wolfe et al., 2005). Highly Pathogenic Avian Influenza (HPAI) virus (H5N1) and SARS-CoV have been identified in the WHO study as having the possibility for spread from animals (WHO 2008). Avian influenza and coronavirus (SARS-COV and SARS-COV-2) as enveloped viruses are cause a significant and emerging food safety and public health problem and threat.

Coronaviruses (CoVs) have a diameter of 120–160 nm, non-segmented RNA genome between 26.4 and 31.7 kilobases, enveloped viruses with single-stranded and as the name implies "corona" (means crown), when seen under electron microscopy it has crowned like projections (Siddell, 1995). Within the envelope, there is the helical capsid composed of the RNA and genome nucleoprotein (Kampf et al., 2020; La Rosa et al., 2020b). The nonenveloped waterborne viruses such as adenoviruses, enteroviruses, coliphage, more commonly known for persistence and disinfection in water and wastewater, is different from the coronaviruses concerning the presences of having a lipid membrane and comparatively large ssRNA genome (Silverman & Boehm, 2020). Coronavirinae family is separated into four genera named as alpha-, beta-, gamma-and delta-coronavirus. Only alpha (HCoV-229E and HCoV-NL63) and beta coronaviruses (HCoV-HKU1, HCoV-OC43, MERS-CoV and SARS-CoV) are recognized to infect humans and animals related to respiratory and gastro-intestinal infections (Cui et al., 2019; La Rosa et al., 2020c; Sharma et al., 2020). In late 2019, SARS-CoV-2 as beta-coronavirus has emerged and can lead to high mortality rates (Qu et al., 2020). This novel coronavirus (SARS-CoV-2) outbreak called as COVID-19 has been announced a global pandemic by the World Health Organization (WHO) on March 11, 2020 (Qu et al., 2020; Randazzo et al., 2020).

Influenza is an extremely infectious respiratory illness, with several years of local clusters, with rare epidemics or pandemics. In the "Spanish" influenza pandemic of 1918-1919, Influenza viruses killed an estimated 20 to 50 million people worldwide (Tumpey et al., 2005). For a variety of reasons, the worldwide effect may be much greater this time (Webster, 1994). The influenza virus is common and can be seen in animals such as birds, horses, and pigs and also in humans, as sometimes cetaceans, dogs and mustelids can be infected from it as well. Generally, the natural hosts of certain avian influenza viruses are reservoirs in wild aquatic birds of the orders Anseriformes (e.g. ducks, geese, swans) and Charadriiformes (e.g. seagulls, terns, waders) (Hussain et al., 2016). Extremely pathogenic avian influenza (H5N1) has resulted in serious poultry and human illnesses. The Office International des Epizooties (OIE) and WHO recorded over 15,000 outbreaks of domestic birds from 2005 to 2018 and 861 human cases from 2003 to 2019 worldwide, respectively (Roy Chowdhury et al., 2019). Epidemics of avian influenza viruses from 68 countries were identified as of May 2019 (OIE, 2019).

This work will focus on the evaluation of avian influenza and coronavirus as human pathogenic enveloped viruses for possible health risks.

POSSIBLE ROUTES OF TRANSMISSION

The routes of transmission of seafood associated human pathogenic enveloped viruses are shown in Figure 1.
Viruses are stable in the environment and can be spread through air, water, food or by direct or indirect contact with contaminated body fluids. Viruses can enter the body through numerous sites containing either the respiratory and enteric tracts by aerosolized droplets and droplet nuclei, or the fecal-oral (Yezli & Otter, 2011). Over 140 types of pathogenic viruses can be transmitted from the aquatic environment (WHO, 1995). In the marine environment, all known seafood-borne pathogenic viruses caused an important public health hazard are transmitted via primarily the fecal-oral route, which regularly discharged to marine and estuarine waters either treated or untreated sewage (Griffin et al., 2003; Kovač et al., 2009) and urine, and respiratory secretions from the infected host which enter into sewage water (Wang et al., 2018). Various events such as floods, purified and untreated contaminated waste discharges or sewage flow can raise microbial contaminants in shellfish habitats. The bivalves are filter massive quantities of seawater and concentrate human pathogens (Bosch et al., 2005). Many species of seafood such as shrimps (Botero et al., 1996) or crabs (Goyal & Nelson, 1984) can carry viruses in their shells, and infected bivalves can be feeding by carnivorous shellfish such as lobsters or crabs, or fish (Hejkal & Gerba, 1981). In 2003, the WHO reported that the effect of waterborne infection of pathogens has caused 3.4 million deaths worldwide, while the EU reported that 13,548 children who were less than 14 die per year from these waterborne pathogens; nevertheless, it is impossible to measure the actual influence of viruses on all pathogens (Gibson, 2014).

Viral transmission can also occur through polluted seafood, due to insufficient hygienic activities by infected food handlers (Bosch et al., 2016; Koopmans, 2005; Seymour & Appleton, 2001; Shao et al., 2011; Todd & Grieg 2015), the aerosolized virus caused by infected persons (Koopmans & Duizer, 2004; La Rosa et al., 2020b; Qu et al., 2020) and their contamination sites within the human body like nervous system (Enterovirus, Nipah virus, Poliovirus, Parechovirus), respiratory system (HPAI-H5N1, SARS-CoV, Liver HAV, HEV), neural tissue and, and intestinal system (NoV, HRV, Sapovirus, Astrovirus, Adenovirus, Aichi virus) (WHO, 2008). The very first foodborne infection is a way to spread among the human population, which can then change and spread itself through person-to-person infection. Contaminated raw materials or fresh products are available from remote locations and can be used as ingredients in many types of food, thus raising the possibility for the spread of infection and the effects in the food industry (Bosch et al., 2018). Various the reported cases of foodborne virus disease have been related to infection of convenience, ready-to-serve food by a contaminated food handler, according to WHO reports (WHO, 2008).

AVIAN INFLUENZA (A)

Influenza A viruses are members of the Orthomyxoviridae family of one-stranded, negative-sense enveloped RNA viruses (Figure 2). These are classified as 18 haemagglutinin and 11 subtypes of neuraminidase (NA) (Palese & Shaw, 2007). Electron microscopy of isolated influenza (H1N1) virus particles is shown in Figure 2.

Figure 2. Electron microscopy of isolated influenza (A/H1N1pdm) virus particles in the culture supernatant (a) and (b) in filamentous forms in the lung sections (Nakajima et al., 2010).

Human influenza viruses mainly reproduce in the respiratory tract, but avian variants predominantly exist in the bird gastrointestinal tract. This means that the viruses are excreted with a large number of feces in dense waterfowl populations. Consequently, water is considered to be an essential element in the natural transfer of avian influenza viruses among populations of wild birds through an indirect fecal-oral way involving fecal polluted water in shared aquatic habitats (Bosch, 2007; Brown et al., 2009; Grabow, 2007; Markwell, 1982; Nazir et al., 2011; Root, 2014; Sandu & Hinshaw, 1981). There are two major routes of AIV transmission: (i) a direct bird-to-bird transmission and (ii) a waterborne transmission. Researches have shown that waterborne transmission is an effective way of distributing and transmitting the avian influenza virus (Dovas et al., 2010; Roche et al., 2009; Thanapongtharm et al., 2013). This transfer process is highly effective since it persists in water for long periods within such temperature ranges (Brown et al., 2009; Domanska-Blicharz et al., 2010; Stallknecht et al., 1990; Webster et al., 1978). Studies have shown that the H5N1 and H9N2 viruses can live longer with appropriate water conditions, including pH, salinity, and cold, for up to several months (Brown et al., 2009; Liu et al., 2005; Zhang, 2014). Dublineau et al., (2011) observed that the pandemic influenza virus can survive infectious as a minimum of 200 days at 4°C in water.

The varied biotic water ecosystems, including fish and shellfish, are also susceptible to a variety of contaminants being discharged into the marine environments. Shellfish as filter feeders appear to
bioconcentrate the virus in the contaminated aquatic environments (Huyvaert et al., 2012) and serve as effective vessels for their spread (Lees, 2000; Skrabler et al., 2005). Firstly, Scholtissek and Naylor, (1988) illustrated the expected function of combined culture by fish and ducks as fertilizer for fish farming systems in influenza pandemic transmission. Pathak et al., (2018) demonstrated that under laboratory conditions, bamboo shrimps (Atyopsis moluccensis), which are essential members of aquatic fauna for the reason that large fish, birds and humans eat them (Chace, 1983), may absorb the virus and stay infectious throughout the shrimp body. Huyvaert et al., (2012) has also reported that freshwater clams (Corbicula fluminea) can accumulate avian influenza and an important resource for early detection of H1N1 viruses in the marine environment. Eissa et al., (2012) documented that several aquatic species have a vital role in providing an intermediate path for the transmission, distribution, and dissemination of influenza viruses to and from susceptible marine and poultry populations with a two-year analysis in maritime and freshwater regions in Egypt from the neighborhood of natural migratory bird stop stations. They also detected avian influenza (H5N1) in Red Swamp Crayfish (Procambarus clarkii), Catfish (Clarias gariepinus), Puffer Fish (Lagocephalus sceleratus) and Mediterranean Cone Shell (Conus mediterraneus) in Egypt from the neighborhood of natural stopping stations for migratory birds. Densmore et al., (2019) is the first to confirm influenza A virus infection from a natural water source in clam and mussel tissue. Likewise, Stumpf et al., (2010) found that influenza A viruses were collected by zebra mussels (D. polymorpha) from topsoil, and that such viruses persist in the mussels for prolonged periods.

CORONAVIRUSES

Severe acute respiratory syndrome (SARS-CoV): A serious acute respiratory syndrome (SARS-CoV), which occurred in 2781 cases with 111 deaths recorded on 10 April 2003 from 17 countries on 3 continents, is both an enteric and respiratory disorder (Nwachuku & Gerba, 2004). SARS-CoV was phylogenetically distinct from all human and animal coronaviruses previously recognized (Weber et al., 2016). Figure 3 shows the ultrastructural appearances of SARS-CoV developed in Vero e6 cells (Ksiazek et al., 2003).

Because the virus is excreted in respiratory secretions, the feces often excrete significant numbers; as many as 1,31107 viruses per gram of feces. Studies have demonstrated that SARS-CoV can survive in stool samples at room temperature for 4 days (Nwachuku & Gerba, 2004; Wang et al., 2005; Weber et al., 2016). Infected stools in wastewater may create additional spread routes by creating virus-laden aerosols throughout wastewater flushing (Isakbaeva et al., 2004; Qu et al., 2020). Peiris et al., (2003) reported that epidemiological investigations of 321 patients who were associated with coronavirus- SARS outbreak in a high-rise residential estate in Hong Kong (March 24 in 2003) could be related to a defective sewage system. Several reports have recorded that coronavirus stays transmissible in water and wastewater for days to weeks (Casanova et al., 2009; McKinney et al., 2006; Nwachuku & Gerba, 2004). Scientists recorded that it took many days to reduce virus infectivity by 99% at room temperature, in liquid water or pasteurized settled sewage. SARS-CoV was observed at 20 °C for 2 days in hospital sewage, domestic wastewater and tap water and at 4 °C for up to 14 days (Pinon & Viallette, 2018), at least 17 days in fecal or urine (Wang et al., 2005), thereby demonstrating a clear temperature effect on viral persistence (La Rosa et al., 2020a; Leung et al., 2003). Two surrogate coronaviruses were tested by Casanova et al., (2009) and they noticed that this transmissible gastroenteritis (TGEV) and mouse hepatitis (MHV) viruses in pasteurized settled sewage stayed contagious for days to weeks. At 25 °C, it took 22 days for TGEV to minimize reagent-grade water by 99% and 17 days for MHV. The period for a 99 percent drop of pasteurized settled waste was 7 days for MHV, and 9 days for TGEV.

In marine environments, the rate of virus decay can be significantly affected by the viral genome and envelope properties; thus, coronaviruses are believed to have characteristics of survival and disinfection that vary
from smaller and non-enveloped viruses (Silverman & Boehm, 2020; Wigginton et al., 2015). Enveloped viruses are usually deemed inconsistent in aquatic life and thus have not been stressed in studies, procedures, or regulations on waterborne viruses. The waterborne infection has never been seen in humans, but identification of human coronavirus (HCoV) and SARS-CoV in the feces of infected patients was documented (Drosten et al., 2003; Esper et al., 2010; Vabret et al., 2006), indicating that the fecal-oral way can cause HCoV (La Rosa et al., 2020b) and SARS-CoV transmission. Nevertheless, certain enveloped viruses may live in soil and surface waters such as influenza A for long times. For example, certain coronaviruses are comparatively stable in aquatic life and can even spread to humans and cause serious outbreaks. The virus is similar to coronaviruses, which are known as part of the intestinal viral flora of a lot of people and were identified in the feces of patients and wastewater and were found to survive for a long time at low temperature (Leung et al., 2003; Wang et al., 2005; Ye et al., 2016). It was thought necessary to link waterborne infection with influenza virus, all of which have a typical envelope (Gundy et al., 2009; Peiris et al., 2003; Wigginton et al., 2015). However, there is a deficiency in the studies about waterborne transmission as with the avian influenza viruses. Consequently, the increased possibility of respiratory virus infections such as influenza and SARS especially in aquatic environments can not be overlooked for filter filtering shellfish and fish farming/catching in uncontrolled sewage and wastewater regions to protect human health against coronavirus through water (Todd & Grieg, 2015).

SARS-CoV, as well as monkeypox (Rimoin et al., 2010) and Nipah virus (Luby et al., 2009), can be transmitted via food-related occurrences, either by zoonotic food consumption or during food handlers and food production if the personal hygiene quality is poor (Bell et al., 2004; Bosch et al., 2016; Leung et al., 2006; Koopmans, 2012; Qu et al., 2020; Shao et al., 2011; Todd & Grieg, 2015). Mullis et al., (2012) studied the stability of coronaviruses on the lettuce surface by using BCoV as a surrogate of the Genus Betacoronavirus, which contains SARS-CoV, under household refrigeration conditions. They observed that lettuce BCoV maintained infectivity at 4°C for at least 14 days, and higher infectious particle amounts. They also saw that the coronavirus remained stable throughout the shelf-life of the lettuce, and caused a washing process (elution) to no longer eliminate the residual viruses. UV lights, thermal exposure (≥65°C), acidic pH (<3), or alkaline pH (>12) milieu could inactivate SARS-CoV (Darnell et al., 2004). It is suggested that SARS-CoV, even though it is mainly spread through droplets and direct contacts, should not be ignored for potential environmental transmission via water, bioaerosols, and food (Annaloura et al., 2020).

**Severe acute respiratory syndrome coronavirus 2 (SARS CoV-2):** SARS-CoV-2 is an enveloped RNA virus single-stranded as a genetic material having the size of 29.9 kb with a particle size of 100-160 nm in diameter, the largest among all the RNA viruses (Zehra et al., 2020). It contains four structural proteins, titled the S (spike), E (envelope), M (membrane), and N (nucleocapsid) proteins and belongs to beta-coronavirus (Liya et al., 2020). Transmission electron microscopy images of SARS-CoV-2 grown in the Vero cell line are given in Figure 4 (Taştan et al., 2020).

![Figure 4. Transmission electron microscopy images of SARS-CoV-2 grown in Vero cell line (Taştan et al., 2020).](https://www.worldometers.info/coronavirus/)

SARS-CoV-2 is the main reason for the global pandemic of Severe Acute Respiratory Syndrome, resulting in infections and death of millions worldwide with high variability in cases and mortality. On 11 March 2020, the WHO stated that Covid-19 was a pandemic on the grounds of "threatening rates of spread and magnitude, and threatening rates of inaction" (Medema et al., 2020). As of that date, it has already spread to more than 219 countries in the world surpassing more than 2 million deaths and nearly 96 million reported active cases worldwide (https://www.worldometers.info/coronavirus/).

**Water-borne Transmission:** SARS-CoV-2 is spread mainly by respiratory droplets from an infected individual to a susceptible host (Walker et al., 2020; Lai et al., 2020). At the present, various researchers have reported the infectious SARS-CoV-2 in the feces and urine of infected patients (Chen et al., 2020a; Elsamadony et al., 2021; Xiao et al., 2020 a,b). It is also reported by Wu et al., (2020a) who suggest that fecal-oral transmission could occur after viral clearance in the respiratory tract. Zheng et al., (2020) evaluated SARS-CoV-2 dynamics in China's Zhejiang province and they found the longer mean duration of SARS-CoV-2 in the stool samples (22 days, H-spread 17–31 days) than those in respiratory airways (18 days) and serum (16 days) samples. Several experiments in marine and drainage ecosystems around the world have observed signs of SARS-CoV-2 RNA (Ahmed et al., 2020; D’Aoust et al., 2021; Eslami & Jalili 2020; Lodder & de Roda Husman, 2020; Orive et al., 2020; Peccia et al., 2020; Wu et al., 2020b; Wurtzer et al., 2020). Randazzo et al., (2020) detected SARS-CoV-2 RNA in six wastewater
treatment plants in the main metropolises within the Province of Murcia (Spain), the lowest COVID-19 prevalence in the Iberian Peninsula. For the first time, Guerrero-Latorre et al., (2020) identified significant viral loads of SARS-CoV-2 from rivers in 180 urban streams of Quito, where insufficiently handled sewage discharges on June 5 during a COVID-19 season. They also reported that the amount usually removed (6-7 Log_{10}) through the recycled water disinfection methods is much lower than viral particles shedding (up to 10 Log_{10}) by infected people through sewage and greywater. Many researchers have been thought that these results showed an increased potential of contamination through the fecal-oral infection route from the water environment (Bhattacharjee, 2020; Chen et al., 2020b; Holshue et al., 2020; Medema et al., 2020; Oliver et al., 2020; Qu et al., 2020; Xiao et al., 2020a,b).

Water-borne human pathogenic viruses related to seafood are primarily spread via fecal-oral way due to feeding habits and their pre-harvest growing area, particularly where may contaminate the virus concerning the inadequate or raw discharge of feces or sewage in water bodies (Bosch et al., 2005; Butt et al., 2004; Gerba 2007; Grabow, 2007; Li et al., 2021). Although enveloped viruses were found to be degrading in water compared to nonenveloped viruses (Gundy et al., 2009; Lebarbenchon et al., 2011), studies have shown that seafood can accumulate enveloped viruses such as avian influenza (Densmore et al., 2019; Eissa et al., 2012; Huyvaert et al., 2012; Pathak et al., 2018). The structure of avian influenza, as well as the other enveloped viruses such as H1N1 "Spanish flu," SARS-CoV, MERS-CoV found in the stools and urine of infected human samples are similar to coronaviruses (Wigginton et al., 2015). Annalaura et al., (2020) detected the longer survival of SARS-CoV-2 in vitro experiments at low temperatures and they recommend that SARS-CoV-2 excreted in feces may enter infectious wastewater treatment plants particularly in cool climates. Furthermore, the existence of fecally infected food is supposed to be a significant role in coronavirus transmission by scientists (Badushvili et al., 2020; El Baz &Imziln, 2020; Li et al., 2021; Mullis et al., 2012; Tian et al., 2020; Zhang et al., 2020). Although, these concerns, even if there are no cases of waterborne transmission via fecal-oral route, have thought to be the importance of the possible waterborne transmission via fecal-oral route for SARS-CoV-2 (Ghermaout &Ghermaout, 2020; Heller et al., 2020; Qu et al., 2020; Rizou et al., 2020; WHO, 2019; Yeo et al., 2020), the current existence of it in feces and urine of infected people and its accelerated dissemination requires new attention to detect it in aquatic environment wth respect to the existence of the virus and its possible infectivity. However, the current evidence shows that the possible water-borne transmission of SARS-CoV-2 may be very low.

**Food-borne Transmission:** SARS-CoV-2 can be transmitted as a widely agreed mode of transmission for respiratory diseases by either touching a polluted surface or object and consequently infecting itself through oral, nasal or optical routes eyes (BFR, 2020; Dawson, 2020; Lei et al., 2020; Pressman et al., 2020; Shabbaz et al., 2020) or intake of infected food (Dawson, 2020). According to WHO, SARS-CoV-2 can spread through hands, sneezing and coughing of infected workers responsible for the preparation and packaging of foods (WHO, 2020).

Previous studies have shown that coronavirus stability is mostly dependent on the ambient temperature (Ijaz et al., 1985; Mullis et al., 2012; Siddell et al., 1983; Tennant et al., 1994). In a study conducted as a surrogate of bovine coronavirus Genus Betacoronavirus, it was shown that it survived on lettuce for up to two days at environmental temperature and at least 14 days at 4°C (Mullis et al., 2012). Van Doremalen et al., (2014) found that MERS-CoV can live at various temperatures for long periods, when it is injected into dromedary camel milk, goat milk, and cow milk. Nipah virus has been experimentally transmitted by liquids, causing a respiratory tract infection rather than intestinal tract infection (de Wit et al., 2014).

A new study showed that SARS-CoV-2 could stay viable in the environment for up to 3 hours, on copper for up to 4 hours, on carton for up to 24 hours and on plastic and stainless steel for up to 72 hours (Van Doremalen et al., 2020). In fact, SARS-CoV-2 experiments have shown that the virus is extremely stable at 4°C and WHO (2020) suggests that it may stay infectious at -20°C for a long time (up to 2 years) The survival of SARS-CoV-2 in salmon meat at cold storage (+4°C) by using end-point titration assay on Vero E132 cells has been shown by Dai et al., (2020). They found that salmon-attached SARS-CoV-2 ability remained infectious for more 24 than one week at 4°C. According to their results, they suggested that because seafood should be transported for import and export with cold storage (e.g., 0 ~ 4°C), SARS-CoV-2 for international transmission can be easily carry-through contaminated seafood within one week. Pung et al., (2020) pointed out that a cluster of COVID-19 patients in Singapore shared food and social interaction in a conference was caused. Yekta et al., (2020) also reported that there is some evidence that the transmission of SARS-CoV-2 may be possible through meat products. Li et al. (2021) also suggest that CoVs as well as norovirus (NoVs) known to be the primary causative agent of seafood transmitted illness (Bachofen 2018; Li et al. 2014), may be transmitted especially at low temperatures due to having enough time for remaining infectious on foods and/or food packaging.
materials. Similar suggestions have also been made by other researchers (Rizou et al., 2020) for frozen or cold stored foods.

Although no research studies have been conducted to examine the stability of SARS-CoV-2 on packaging under real-world conditions and through the supply chain, the findings of this study pose concerns that packaging may play an important role in helping to spread the virus, particularly at low temperatures (Boucher, 2020; Li et al., 2021). Consequently, as recommended by the WHO and regional health authorities, the Food Packaging Forum suggests that consumers pay regard to either (i) washing all the packages right away with soap and water or cleaning them with disinfectant directly when it gets in the house with soap and water, (ii) alternatively, unpacking the packaged things and then transferring them to clean pots to store them, and then tossing the packaging out, or (iii) quarantining the household items for three days in before they are touched again. Such guidelines refer to products bought in shops and brought to households, such as mail order grocery stores or meal delivery, etc. (Boucher, 2020), Seymour et al., (2020) suggested that washing hands or using hand sanitizer and disinfecting products should be done before carrying or touching packages to reduce the risk of potentially being exposed to coronavirus. Moreover, proper sanitation measures, as well as washing and sanitizing the surfaces of the kitchens and restaurants, are preferable safeguards compared to environmental surveillance of SARS-CoV-2 (FDA, 2020).

Moreover, proper cooking of seafood seems to be enough for safe consumption of them. Chin et al., (2020) observed that SARS-CoV-2 was inactivated after 5 minutes of incubation at 70°C. Such results reinforce the value of cooking or preparing food at 70°C for at least 5 minutes to reduce the possibility of transmission of SARS-CoV-2 via a possibly infected food supply. Shahidi (2020) suggests that consumption of all cooked food should be safe because no viable viruses can be identified after heat treatment. Until now, there were no records of COVID-19 being spread by seafood as well as other foods.

CONCLUSION

Nowadays, people go through an unprecedented, huge challenge and disaster all over the world because of the SARS-CoV-2 outbreak. Many scientific evidences indicate that the aquatic environments may contain both RNA fragments and viable viruses. Moreover, in-vitro experiments have been shown that SARS-CoV-2 may survive at low temperatures and the potentials to stay infectious on foods and/or food packaging materials long enough to potentially cause transmission. Low temperature preservation of seafood during processing, storage, transfer, distribution and display in retail stores are common methods. With this perspective, it seems that SARS-CoV-2 can survive on seafood and their environmental surface and fomites. However, there is no scientific evidence on waterborne or foodborne transmission of SARS-CoV-2. So, the chance of either waterborne or foodborne transmission of it is considered low and SARS-CoV-2 appears to mainly be spread through the respiratory tract. Consequently, seafood can safely consume with proper cooking and hygiene protocol.

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