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Controversial Commentary

# In-flight transmission of foodborne disease: How can airlines improve?

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ABSTRACT

Food contamination during air travel presents unique risks to those affected. Foodborne pathogens can cause serious illness among all on board, and potentially jeopardize flight safety. These risks are likely to increase with current trends of "densification" and a predicted massive expansion of air travel. While aircraft are being equipped with ever newer designs with a focus on efficiency and comfort, regulations remained largely unmodified in terms of basic hygiene requirements. Strict guidelines for food hygiene exist for on-ground food settings and catering kitchens. There is uncertainty about hygiene standards on board commercial aircraft, and little regulatory oversight of what happens to food in-flight. In two hypothetical scenarios we indicate the potential risks associated with poor food handling practice onboard aircraft, with the ultimate aim of bringing aviation food safety in line with on-ground regulations. Changes in cabin design alongside adequate training in safe food handling have the potential to increase public health protection. We urge a review of existing in-flight hygiene protocols to better direct the development of regulation, prevention, and intervention measures for aviation food safety.

## 1. Introduction

Food handling practices on board commercial aircraft are often under-regulated and there are real barriers that hinder adherence to hygiene measures. Airlines serve hundreds of millions of meals to passengers each year [1]. With the increase in global air transport, ever more people are potentially exposed to the risk of poor food hygiene in aviation settings. Due to fierce competition between airlines, there has been a growing trend of "densification", i.e. designing aircraft to maximise seat numbers, cutting space in aircraft toilets and galleys. There are more flights, carrying more passengers, to more remote destinations and with longer flight times than ever before.

Recorded cases of food-borne disease account for only a small fraction of actual disease events [2]. The WHO estimates that each year as many as 600 million people worldwide fall ill from contaminated food, 420 000 of whom die [3]. The application of hygiene protocols is an effective measure to prevent the spread of disease [4]. Most countries have established complex, enforceable food hygiene regulations for on-ground food settings, such as ensuring that food handlers have easy access to toilets and handwashing basins. However, these regulations do not generally apply to food handling in flight and adapting standards to aircraft cabins presents a challenge: there are operational constraints, such as limited space for sanitary facilities, and also time constraints, such as having to comply with protocols and internal rules. Despite the difference with routines and rituals in on-ground food settings, food safety is governed by the same fundamental principles of hygiene, food science and public health. These disciplines have well-established theoretical foundations and robust methodologies. However, they are under-represented in the aviation environment and industry practices and are often not underpinned by enforceable legislation or lack a solid epidemiological evidence base [5].

Although aircraft are recognised as important vehicles for outbreaks and the rapid spread of foodborne diseases [6], only few reports of foodborne illness exist that are associated with aircraft [7]. This may be due to the strict food controls in airline catering stations, but many in-flight illness events go unrecognised, and may only be investigated if they have a major public health or economic impact [3]. In most instances, identification of epidemiological links between cases is extremely challenging. Illness often occurs after passengers and crew have dispersed to different public health jurisdictions [8]. Potential in-flight contamination and resulting outbreaks are difficult to differentiate from disease cases attributable to pre-flight exposure. Outbreak investigation is further limited by ill people not seeking health care, delayed reporting, limited testing of specimens, or lack of cooperation between airlines and health authorities regarding passenger data. Even in the event of disease tracing, investigation efforts often only go back to the

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**Box 1**
Reports of outbreaks of foodborne illness associated with commercial air transport, including suspected outbreaks of Norovirus gastroenteritis from other inflight contamination sources during 1947–2011.

| Year | Agent | Vehicle/contamination source | Origin | No. cases | Reference |
|---|---|---|---|---|---|
| 1947 | *Salmonella typhi* | Sandwiches | Anchorage, USA | 4 | [10] |
| 1961 | *Staphylococcus aureus* | Chicken | Vancouver, Canada | 13 | [11] |
| 1965 | *Staphylococcus aureus* | Roast turkey | Adelaide | 4 | [12] |
| 1966 | *Salmonella, staphylococcus* | Roast chicken | Adelaide | 3 | [12] |
| 1966 | *Staphylococcus aureus* | Trifle desert | New Delhi | 15 | [12] |
| 1967 | *Escherichia coli (E. coli)* | Oysters | London | 23 | [13] |
| 1967 | *Salmonella enteritidis* | Mayonnaise | Vienna | 380 | [12] |
| 1969 | Multiple | Unknown | Hong Kong | 21 | [14] |
| 1969 | Multiple | Unknown | Hong Kong | 24 | [15] |
| 1970 | *Clostridium perfringens* | Turkey | Atlanta, USA | 25 | [16] |
| 1971 | Unknown | Shrimp and crab salad | Bangkok | 23 | [17] |
| 1971 | *Shigella sonnei* | Unknown | Gran Canaria | 219 | [18] |
| 1971 | *Shigella sonnei* | Seafood cocktail | Bermuda | 78 | [19] |
| 1972 | *Vibrio parahaemolyticus* | Seafood appetizer | Bangkok | 15 | [20] |
| 1972 | *Vibrio cholerae* | Appetizer | Bahrain | 47 | [21] |
| 1973 | *Vibrio cholerae* | Cold asparagus & egg salad | Bahrain | 66 | [22] |
| 1973 | *Salmonella Thompson* | Breakfast | Denver, USA | 17 (at least) | [14] |
| 1975 | *Staphylococcus aureus* | Ham | Anchorage, USA | 197 | [23] |
| 1975 | *Salmonella oranienburg* | Unknown | Rome | 23 | [12] |
| 1976 | *Salmonella typhimurium* | Cold salads | Las Palmas, Spain | 550 | [24,25] |
| 1976 | *Salmonella brandenburg* | Multiple items | Paris | 232 | [26,27] |
| 1976 | *Staphylococcus aureus* | Cream cakes | Rio de Janeiro | 28 | [28] |
| 1976 | *Vibrio parahaemolyticus* | Unknown | Bombay | 28 | [29] |
| 1978 | *Vibrio cholerae non-01* | Sandwiches | Dubai | 61 | [29] |
| 1982 | *Staphylococcus aureus* | Custard | Lisbon | 6 | [14,25] |
| 1983 | *Salmonella enteriditis* | Swiss steak | New York, USA | 12 | [14,25] |
| 1983 | *Shigella* sp. | Unknown | Acapulco | 42 | [14,25] |
| 1984 | *Salmonella enteritidis* | Aspic glaze | London | 866 | [30] |
| 1985 | *Salmonella enteritidis* | Mousse with cream | Faro | 30 | [31] |
| 1986 | *Salmonella infantis* | Multiple items | Vantaa | 226 | [32] |
| 1988 | *Shigella* sp. | Cold food items | Minnesota, USA | 240 | [33] |
| 1989 | *Salmonella enteritidis* | Multiple items | Spain/Finland | 71 | [34] |
| 1991 | *Salmonella* sp. | Unknown | Greek Island | 415 | [35] |
| 1991 | *Staphylococcus aureus* | Chocolate cake | Illinois, USA | 26 | [36] |
| 1991 | *Norovirus* | Orange juice | Melbourne | 3053 | [37] |
| 1992 | *Vibrio cholerae* | Seafood salad | Lima | 80 | [38] |
| 1992 | *Vibrio cholerae* | Seafood salad | Buenos Aires | 75 | [38] |
| 1993 | *Enterotoxigenic E. coli* | Unknown | Charlotte, USA | 56 | [39] |
| 1997 | *Salmonella enteritidis* | Chocolate éclair | Canary island | 455 | [40] |
| 2002 | *Norovirus** | Contaminated surface (vomitus) | London | 5 | [41] |
| 2008 | *Norovirus** | Contaminated surface (vomitus, faeces) | Boston, USA | 22 | [42] |
| 2009 | *Norovirus** | Contaminated surface (vomitus) | Unknown | 27 | [43,44] |
| 2009 | *Norovirus** | Contaminated surface (vomitus) | Los Angeles, USA | 63 | [45] |
| 2009 | *Shigella sonnei* | Raw carrot | Hawaii | 47 (at least) | [46] |
| 2011 | *Salmonella heidelberg* | Milk or eggs | Tanzania | 25 | [47] |

*These cases were not traced to a specific food source but were likely related to other sources of contamination from inflight vomiting events. Contaminated surfaces or food preparation areas are a key transmission source for norovirus, particularly in confined spaces [48].

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catering station [9]. See Box 1 for reports of outbreaks of foodborne illness associated with commercial air transport.

International air travel harbours a range of food safety hazards that emerge from the nature of aircraft cabin environments. Features of the aircraft cabin that predispose to pathogen transmission are large numbers of individuals in a confined space, and shared sanitary facilities [49]. Although the risk of in-flight food poisoning also depends on the types of foods delivered, the characteristics of people consuming the food, and the source of airline catering, contamination usually arises from unhygienic practices in food handling, inadequate food storage, and poorly enforced standards [14]. Evidence suggests that pathogens can survive for hours to months on various surfaces and spread to other individuals via direct or indirect contact. This persistence has been identified in aircraft cabins on tray tables, worktops, sink faucets and washroom door handles [50]. Larger aircraft built for longer distance and increased passenger capacity will present even greater challenges to food hygiene.

An incidence of food poisoning among crew can directly affect flight safety. For example, pilot incapacitation can have a direct impact on flight performance, and a common cause of pilot incapacitation is gastrointestinal illness [51]. Even subtle incapacitation of a pilot at a critical phase of the flight may jeopardize flight safety, such as symptoms occurring in the onset-stage of food poisoning. Regulatory and monitoring systems appear to be non-existent for in-flight food safety [52]. Few clear standards exist for hygiene requirements in aircraft cabins, and airlines generally establish their own set of cleaning standards [53]. While poor hand hygiene is often at the root of major food poisoning outbreaks, there are no requirements for a minimum number of washrooms, such as a toilet/passenger ratio, similar to an emergency door/flight attendant/passenger ratio [53], and no requirements for designated crew toilets or handwashing sinks in galleys. There is also little oversight of in-flight food handling processes, such as audits or compliance controls [52]. While aircraft are being equipped with ever newer designs with a focus on efficiency and comfort, regulations remained largely unmodified in terms of basic hygiene requirements.

In this Commentary, we discuss three dimensions of food hygiene in-flight: onboard contamination sources, personal hygiene, and barriers to safe food handling. Two hypothetical infection scenarios illustrate the potential for in-flight contamination, aimed to highlight the divide between on-ground and in-flight food safety regulation.

### 1.1. Contamination sources

Evidence suggests that about one in every five cases of food-borne illness is caused by contaminated food handlers' hands [54]. When applied to the confines of aircraft cabins, not only may contaminated hands play a key role in the occurrence of foodborne illness, but the nature of the galley design also impacts on safe food-handling practices [55]. Outbreaks of gastrointestinal illness on aircraft have been traced to in-flight incidents of vomiting in the cabin and lavatories [45]. Washroom use played a role in infection transmission when 41 travellers contracted gastrointestinal illness from one traveller's vomit [4]. The lack of recognition of vomiting events by cabin crew can lead to failure in informing destination health authorities, thereby impeding disease tracing and follow-up efforts. As passengers and crew share toilet facilities, there is a greater risk for increasing the spread of infection.

The potential for disease transmission by cabin crew is illustrated through their work in the cabin, where transmission can recur from the same source over multiple flight sectors [43]. Outbreaks resulting from indirect transmission through exposure to contaminated surfaces occurring days after the contamination incident have been reported in other contexts [56]. The type and sequence of work activity also determines the risk of contamination. For example, failing to wash hands after touching soiled workplace surfaces is likely to be riskier than failing to wash hands after touching one's uniform. Failure to wash hands after using the toilet is likely to be riskier if the next activity is preparing a bread basket than refurbishing toiletries.

Although food handlers are typically discouraged from handling food or beverages if they have symptoms of illness that could be contagious, cabin crew were found to often fly when feeling unwell or sick [57]. Infected crewmembers may thus also act as a reservoir for disease transmission in-flight [41,58].

### 1.2. Personal hygiene and barriers to safe food handling

According to the WHO, handwashing with soap and water is the most important hygiene measure to prevent the spread of infection. There may be debate about handwashing in terms of detergents used and length of the washing process, but the benefits of handwashing in preventing foodborne illness are well documented [59]. The WHO, the International Flight Services Agency (IFSA), and the International Air Transport Association (IATA) all provide guidance on best practices on in-flight food safety and hygiene practices [1,60,61]. IFSA's guidance is based on the HAACP (Hazard Analysis and Critical Control Point) system, which is widely used in the food industry and which involves identification or specific hazards and measures for their control. Although the IATA notes that cabin crew should follow the same code of practice as on-ground food handlers [60], there are real barriers for crewmembers to adhere to the same stringent hand hygiene practices required for most on-ground food settings. For cabin crew to be able to apply good handwashing practice in-flight depends on (1) the number of facilities available, (2) whether handwashing facilities are in close proximity to work stations [62] and (3) whether washrooms are vacant or galley sinks are suitable for handwashing.

Food preparation often correlates with high use of toilets by passengers (e.g. just after take-off), providing limited opportunity for crewmembers to wash their hands prior to beverage and meal service. Moreover, the combination of time pressure and lack of adequate facilities is a barrier for compliance with handwashing [63]. Cabin crew may get caught in role conflicts between safety and service tasks, which can lead to unsafe behaviour due to time constraints [64]. Similar to the way that constricted space for food handlers in small restaurants impedes adherence to good hygiene practice [65], the constraints of the aircraft galley, too, increase the risk of food safety lapses. In addition, most sinks in aircraft galleys are not designed for handwashing, as the faucet design requires one hand to operate the faucet handle [33].

There is much debate about the use of hand sanitizer products in food handling settings, with arguments such as: handwashing with soap and water is more effective for pathogen removal from hands [66,67]; hand sanitizers should ideally be used after handwashing, but not as a substitute [68]; and hand sanitizers have no impact on hand hygiene compliance [69]. In particular, hand sanitizers are ineffective on viruses such as norovirus. Vinyl gloves can provide some protection from contamination, but they can also create a false sense of security and encourage high-risk behaviours when people are not adequately trained. Improper glove use was reported by Gaynor et al. [46] where flight catering employees touched door handles and carts with gloved hands before handling raw vegetables with gloved hands. Moreover, whether gloves can be used during service is dependent on airline-specific policy [70].

### 1.3. Scenarios

The following hypothetical scenarios illustrate the implications of in-flight food safety lapses, such as direct contamination by food handler hands, and opportunistic pathogen transmission through secondary sources. While these circumstances are conjectural, they represent plausible real-life events in the context of confined space conditions, limited handwashing opportunities, multitasking, role conflicts, as well as shared facilities among staff and customers. Similar to in-flight airborne disease transmission described by Han et al. [71] we assume that the movement and contact activities of cabin crew, passengers, and potentially the index case can significantly increase their personal infection risks, as well as the risk for disease transmission.

### 1.4. Scenario 1: norovirus

Noroviruses are highly infectious and easily transmitted by multiple routes in confined settings, resistant to most disinfectants, and thus hard to contain using conventional sanitary measures [43]. Although typically self-limiting, severe disease cases occur in young children, the elderly, and the immunocompromised. Outbreaks of norovirus have been traced to in-flight incidents of vomiting in the cabin and lavatories [45]. On a full flight carrying 467 passengers, and a scheduled flight time of 13 h 40 m, a crewmember prepared four sandwich trays for premium class when she was intermittently called to the cabin for rubbish collection. Unable to wash her hands as all lavatories were occupied, she turned back to service preparations. The sandwiches were later displayed in the aircraft kitchen for self-service. Two vomiting events outside of a washroom were reported during the flight, but no disinfection of specific areas occurred. Eighteen business class passengers were part of a soccer team who resided in the same hotel as the crew during the three-day layover at the destination. Two days after arrival, vomiting and diarrhea occurred among two crewmembers and seven soccer players. Norovirus was confirmed as causative agent in all cases. In-flight food items were no longer available for disease tracing. Laboratory testing of retained meals at the catering kitchen showed no signs of contamination.

This scenario demonstrates the ease with which viruses can transfer between a contamination source and food items, and the potential to spread infections among people. Dissemination of norovirus is facilitated by substandard sanitary conditions and vomiting events [42], with lavatory use being a significant risk factor [59]. The pattern of norovirus outbreaks highlights the potential of aerosol transmission as well as surface contamination in confined settings [72]. Ho et al. [73] note how during a cruise ship outbreak a link could not be established to food consumption. However, the risk of gastroenteritis among passengers using shared toilet facilities was twice that of passengers who had a private facility. Consequently, the number of passengers sharing toilets was related to the rate of illness. Because 18 passengers and the crew stayed at the same location post-flight, investigative efforts were able to determine the causative agent, and to establish a likely linkage to a common contamination source. This is not usually the case. Passengers typically disperse in different directions before falling ill. Data on suspected norovirus transmission in-flight support the view that contaminated areas are rarely successfully identified and adequately treated [42,59]. Contamination from initial vomiting events can cause infections for several days, even after routine cleaning [43,56]. Post-flight measures dictate notification to ground staff of areas contaminated with vomit [74]. This was omitted in the scenario, implying a lack of recognition of the severity of vomiting events among crew. Only few reports of norovirus-related transmission risk exist that are associated with aircraft [45,59,72].

### 1.5. Scenario 2: salmonella

Salmonella are resilient bacteria that can survive several weeks in dry environments and several months in water. The illness salmonellosis causes acute onset of abdominal pain, diarrhea, fever, and nausea. Children and the immunocompromised are more likely to develop severe disease. Burslem et al. [30] reported salmonella outbreaks that affected nearly 1000 passengers, aircrew and ground staff. A full flight with 352 passengers departed late. Scheduled flight time was 14 h 20 m. Crewmembers prepared bread baskets for premium class and stored eight hot pork dishes in the oven for sleeping passengers. Two crewmembers had been suffering from diarrhea following a previous trip but reported for work despite feeling unwell. Approximately 10 h after the first meal was served, 12 premium class passengers, six economy class passengers, and one pilot developed symptoms of abdominal cramps and diarrhea. Five passengers and the pilot were admitted to hospital after landing. Salmonella enterotoxin was detected in all stool samples.

The source of contamination in this scenario could have been contaminated hands handling bread rolls, or inadequate storage of heated meals where bacteria multiply. In an assessment of the hygienic quality of airline meals, the most prominent contributing factors for salmonella outbreaks were found to be infected food handlers and inadequate refrigeration [75]. Salmonella bacteria have been repeatedly found in meat products [14,76]. While bread is seen as an unusual outbreak vehicle for salmonella [77], poor personal hygiene could have contributed to the contamination. Temperatures achieved during the baking process would typically destroy any pathogen in bread, but in this scenario the bread rolls were handled after heating the bread. Delays extend the time lag between food production and consumption and increase opportunities for pathogen growth. While poor practices can involve inadequate storage at inappropriate temperatures, cabin crew may also be asymptomatic carriers of food poisoning pathogens [78]. Travel to worldwide locations over the course of just one month puts crewmembers at heightened risk of eating or drinking contaminated food or water [52].

## 2. Discussion

Illness may not develop for days or weeks after exposure to contaminants, rendering outbreak investigation in aircraft settings extremely difficult. Passengers and crews disperse quickly, and food samples are unlikely to be available as leftover food is thrown away after a flight. Determining the real number of food poisoning incidences and contamination events on aircraft is further hampered by limited access to customer complaints and food safety-related records [52,79].

Multi-tasking with limited access to handwashing facilities was problematic in both scenarios. Cabin crew had to smooth out service disruptions at the expense of safe handling practices. As airlines increasingly reduce space for lavatories in favour of revenue-generating seats, aircraft cabins largely remain unmodified in terms of basic hand hygiene requirements. Quantity and design of aircraft galleys and washrooms is not down to aircraft type, but to airline choice [80]. The limited space for sanitary facilities may lead to splash exposure from small wash basins, and also increase the risk of coming into contact with soiled surfaces. The scenarios underscore the importance of preventive measures such as appropriate handwashing, and proper handling and storage of food.

There is a serious lack of data regarding crew hand hygiene, or of the merits of using gloves or hand sanitisers. This presents a significant barrier to identifying the true incidence of inflight food contamination and the urgent need to evaluate the usage of provided measures such as hand sanitizers, and to adequately train crewmembers in safe food handling. While improved hygiene may not be sufficient to break the chain of person-to-person transmission, enhanced hygiene measures are likely to reduce the transmission of norovirus during an outbreak [81]. Commercial pressures to maximise passenger numbers should not be at the expense of allowing space for adequate hygiene measures. Profits must not undermine safety. The incorporation of the internationally recognised HACCP system should become standard. Trials in the airline catering industry have been found to be cost-effective [82] and it could prove highly beneficial for onboard food safety.

## 3. Conclusion and recommendations

Food handling processes are governed by the same universal rules, whether they take place in on-ground settings or onboard aircraft. Yet attempts to contain the spread of foodborne disease via aircraft are constrained by a lack of basic hygiene infrastructure and concepts of profit over health and safety. Trends of densification mean fewer and more compact washrooms and galleys, alongside increasing passenger loads. The operation of ultra long-haul flights means increased handling of food over an extended period of time, bringing more opportunity for food safety lapses. Extended flight times also increase the risk of disease transmission and pilot incapacitation, because there is an increased risk for the sudden collapse of a crewmember resulting from food poisoning with a short incubation period.

Ensuring better adherence to in-flight food hygiene rules requires assessment of the cabin layout. Mirroring the stringent hygiene standards of on-ground food settings, there needs to be identification of those elements of the cabin layout which pose a risk to food safety and hinder personal hygiene measures. Researchers could help develop new sanitary techniques by studying what factors most influence handwashing onboard, and also look at the effectiveness of hand sanitizer gels in the cabin workspace, as well as the acceptance of hand sanitizers by cabin crew as a substitute for handwashing. Better insight can then identify areas of weakness to design operationally feasible approaches. Airline training on hand hygiene should focus on understanding when hand hygiene is most critical, and which sanitary options are most beneficial and conducive to compliance. Developing aircraft-specific food safety plans could further serve as guidance for crew, and also raise awareness of their role as food handlers, and their importance in outbreak investigations.

Achieving onboard food safety will require a multi-pronged approach involving increased research, improved cabin design, improvements in aircrew training and behaviours, and harmonised governance [See Box 2]. The latter would require collaborative efforts of bodies such as the ICAO, IATA, IFSA and WHO. Future efforts should focus on quantifying the relative importance of in-flight disease transmission to public health. But most importantly, aircraft design should be bound to regulations that determine health and safety priorities. Just as

**Box 2**

Suggestions to improve on-board food safety.

Research.

- More data are required on disease transmission, including modelling and full disease tracing.
- Hazard Analysis and Critical Control Point (HACCP) Analysis.

Design.

- Adequate sanitary facilities, e.g. sufficient toilets and wash basins.
- Adequate space for good hygiene practice.
- Ergonomic design, e.g. taps.

Behaviours/training.

- Handwashing, including use of hand sanitisers.
- Food handling practice.
- Management of conflicting requirements of food preparation and service provision.

Governance.

Collaboration between regulatory bodies to develop harmonised governance, e.g:

- Aircraft food safety plans.
- Harmonised cleaning standards and policies.
- Regulatory and monitoring systems.

ergonomics in galley design play an important role in preventing fatigue and injury, design should also ensure adequate handwashing opportunities. Such seemingly basic initiatives can provide a powerful means to improved food safety in aviation. Only by improving the current facilities, regulations and inspections, and by performing the rituals of hygiene practices, can the airline industry gain the status of a 'safe' food handler.

## Author contributions statement

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