



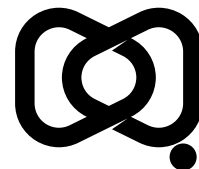
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A large foodborne outbreak of *Salmonella* Typhimurium linked to bánh mì, Western Australia, 2024

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Abstract

In March 2024, the Department of Health in Western Australia investigated an outbreak of *Salmonella* linked to a food venue serving bánh mì (Vietnamese sandwiches). Outbreak cases were notified via laboratories, health services, local government, and cases referring sick co-exposed individuals. Structured interviews were conducted to determine demographic, illness and food exposure histories, and descriptive analyses were performed. The investigation identified 146 outbreak cases linked to the food venue. All outbreak cases had symptoms of salmonellosis, and 34 cases (24%) were hospitalised. Descriptive analysis found a strong association between illness and the consumption of bánh mì (139 cases) or tofu salad (three cases) from the food venue. This finding was supported by environmental and laboratory evidence, with *Salmonella* Typhimurium multilocus variable-number tandem repeat analysis linking 112 cases (77%) to samples from the food venue's benchtop blender and tofu mix. The contaminated blender had been used to make three products: chicken and pork liver pâté, raw-egg mayonnaise, and a crispy rice tofu. The liver was undercooked before blending and was suspected to be the most likely source of the outbreak. To control the outbreak, the venue stopped using the blender and switched to using commercial mayonnaise, and staff were trained on safer cooking and hygiene processes. The outbreak highlights the critical importance of application of food safety standards in commercial kitchens, especially in relation to commonly used appliances, and to raw liver and mayonnaise products. Furthermore, it demonstrated that open and timely communication between food businesses, local government, laboratories and health agencies are key to the rapid identification of, and response to, foodborne outbreaks.

Keywords: Salmonella; outbreak; liver pâté; bánh mì; eggs; mayonnaise; epidemiology

Introduction

Salmonella is a cause of gastroenteritis predominantly acquired through ingestion of contaminated food. It has a median incubation period of 6–72 hours.¹ The majority of foodborne outbreaks reported in Australia are caused by *Salmonella*, with *Salmonella* Typhimurium (STM) the most commonly identified serotype, and eggs and poultry the most frequently implicated food items.²

On 20 March 2024, the Communicable Disease Control Directorate at the Western Australia (WA) Department of Health received a laboratory notification of 15 *Salmonella*-positive patients who had attended the same metropolitan hospital and had been diagnosed in the preceding 5 days.

On the same day, the local government authority Environmental Health Officer (EHO) received notification from a food venue that several patrons had fallen ill after dining at their venue. The venue's social media had also received several contemporary and uncharacteristic 'negative' reviews from customers reporting gastrointestinal illness.

This report outlines the investigation into the point source outbreak at the sandwich venue. The investigation involved epidemiological, environmental and laboratory analyses to characterise cases; to determine the primary source of the outbreak; and to implement control measures to prevent further illness.

Methods

Epidemiological investigation

All individuals notified to the WA Department of Health by the laboratory on 20 March 2024 with a confirmed *Salmonella* infection in the preceding five days were investigated. Additional people were included for investigation if they had dined at the venue of interest, had developed diarrhoea or vomiting since 1 March 2024, and were referred to the WA Department of Health by local government or their family or friends. On 25 March 2024, the laboratory characterised isolates from the first 15 *Salmonella* cases as *S. Typhimurium* (STM) multi locus variable-number tandem repeat analysis (MLVA) 03-14-06-12-523. Subsequently, all individuals in WA who were diagnosed with this MLVA, or with a closely related strain, were included for investigation.

Individuals were interviewed via telephone using the OzFoodNet *Salmonella* priority trawler questionnaire.³ This included questions about food exposures in the seven days preceding illness; demographics; travel history; and symptoms. Data were recorded and analysed in Microsoft Excel.

A confirmed outbreak case was anyone who had diarrhoea or vomiting that developed on or after 1 March 2024, had eaten food from the venue, and was diagnosed with STM MLVA 03-14-06-12-523 or with a closely related strain. The epidemiological component of the confirmed case definition was later updated to include MLVA 03-14-06-12-523 STM infections among household members of a case who had eaten at the venue.

A probable outbreak case was someone with diarrhoea or vomiting that developed on or after 1 March 2024 and had consumed food from the venue, but did not have a specimen taken for microbiological diagnosis.

All confirmed and probable cases were included in the descriptive analysis, and summary statistics were calculated for demographics, symptom profile, severity of illness, and details of exposure to the venue, including date of visit and menu item(s) consumed.

Environmental investigation

EHOs visited the food venue of interest on 21 March 2024 and implemented initial control measures, one day after initial notification to the WA Department of Health. Further visits were conducted on 26 March 2024, 9 April 2024 and 19 April 2024.

EHOs visibly reviewed the cleanliness of the venue's surfaces and appliances and reviewed their food preparation practices. Raw and ready-to-eat food products, and surfaces of the preparation bench, sink, cutting board and food blender were sampled. Data was collated on the number and type of menu items sold daily via sales reports.

The Environmental Health Directorate at the WA Department of Health traced the venue's egg supplier to the egg farm. Farming practices were investigated, and environmental samples (boot swabs and faeces) were collected from all five production sheds and a single growing shed. The butcher and abattoirs supplying the pork mince and pork and chicken liver were respectively traced; and, given the strain of *Salmonella*, efforts were made to identify the primary farm supplier of chicken liver.

Laboratory investigation

Faecal samples sent to laboratories were first tested for enteric pathogens including *Salmonella*, *Shigella*, *Campylobacter*, and Shiga toxin-producing *Escherichia coli* using multiplex polymerase chain reaction (PCR) testing, with reflex culture occurring for all *Salmonella* PCR-positive samples. All diagnoses of *Salmonella* were notified to the WA Department of Health, with cultured *Salmonella* isolates referred to PathWest Laboratory Medicine WA for serotyping, MLVA typing, and whole genome sequencing as appropriate.

Food specimens and swabs from the environmental investigation, including egg farm samples, were processed for *Salmonella* at PathWest; *Salmonella* isolates from the environmental investigation underwent the same typing as clinical isolates.

Ethics approval was not required for this investigation, as it was conducted as part of the public health response to a notifiable infectious disease and food-borne outbreak under the *Public Health Act 2016 (WA)*.⁴

Results

Epidemiological results

There were 183 cases identified for investigation, of whom 170 were contactable for interview. Of these, there were 146 outbreak cases (86%), with 112 confirmed and 34 probable cases. The remaining 24 investigated cases (14%) were positive for STM MLVA 03-14-06-12-523 or a closely related strain, but were not defined as outbreak cases as they did not report exposure to the venue.

Table 1 shows the demographic characteristics and food exposures of the 146 outbreak cases. Over half were male (56%); outbreak cases had a median age of 37 years (range 1–80 years). Almost half of the cases (49%) were unwell for more than a week, and 23% were hospitalised.

Nearly all outbreak cases had dined at the venue (97%), consuming either bánh mì (95%) or tofu salad (2%). Four cases (3%) did not dine at the venue but had an epidemiological link as household contacts of an outbreak case.

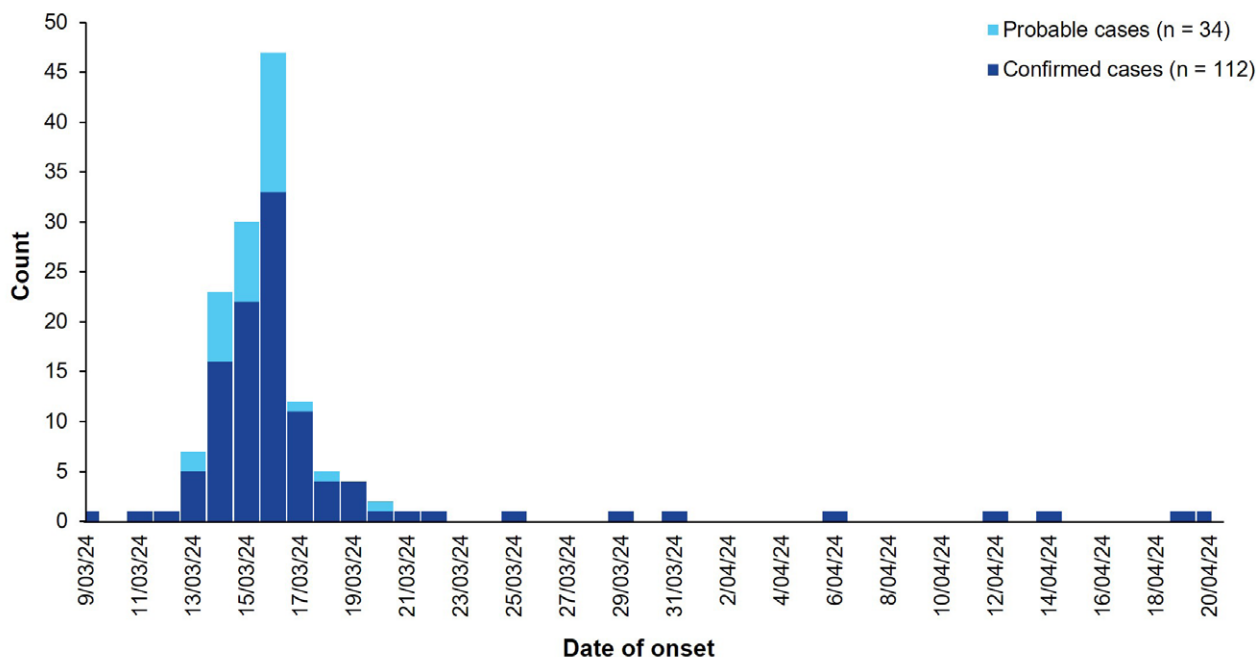
Of the 142 outbreak cases who had dined at the venue, 137 cases attended between 29 February 2024 and 21 March 2024, with the highest attendance of 46 cases on 15 March 2024. Only five cases attended the venue between 28 March 2024 and 16 April 2024, and all had consumed tofu products in either a bánh mì or salad. One of these cases consumed their tofu bánh mì at the venue's second retail outlet.

Table 1: Demographic characteristics and symptomatology of *Salmonella* Typhimurium outbreak cases, Western Australia, 9 March – 20 April 2024

Characteristic	Category	Number	Percentage
Case type	Confirmed case	112	77
	Probable case	34	23
Sex	Male	82	56
	Female	64	44
Age in years	Median	37	—
	Range	1–80	—
Symptoms ^a	Diarrhoea	145	99
	Lethargy	134	92
	Abdominal pain	129	88
	Fever	127	87
	Vomiting	66	45
	Bloody diarrhoea	36	25
Illness severity ^a	Diarrhoea for seven or more days	72	49
	Emergency department presentation	47	32
	Hospitalised	34	23
Exposure to food venue of interest	Yes, ate a bánh mì	139	95
	Yes, ate a tofu salad bowl	3	2
	No, household contact was exposed	4	3
Total cases	—	146	100

a Percentage totals sum to more than 100%, as some cases reported multiple symptoms and/or severity of illness.

Figure 1: Epidemiological curve of the *Salmonella* Typhimurium outbreak by date of onset and case type, Western Australia, 9 March – 20 April 2024



The epidemiological curve of the outbreak, with onset dates during 9 March – 20 April 2024, is shown in Figure 1. Of the 146 confirmed and probable outbreak cases, there were 128 (88%) with disease onset between 13 March 2024 and 19 March 2024.

One case had STM first identified in their stool in August 2024, more than four months after exposure to the venue, and more than three months after the outbreak was considered to have ended. This case consumed a bánh mì from the venue in March 2024, several days before the onset of a diarrhoeal illness. Their symptoms persisted for several months prior to testing.

The 24 cases with STM MLVA 03-14-06-12-523 who were investigated, but not epidemiologically linked to the venue, had a median age of 38 years, and 79% were male. Similar to the epidemiological curve of the outbreak, the date of illness onset for these cases also peaked on 17 March 2024.

Environmental results

On 21 March 2024, EHOs observed that the premises were clean, well maintained, and organised, complying with most aspects of the Food Standards Code. However, food handlers at the venue had yet to complete mandatory food handler training, and knowledge gaps about the correct procedures for cleaning and sanitation of food processing equipment were identified.

No staff at the venue reported any illness or overseas travel in the 14 days prior to the outbreak.

The venue sold a range of food items including bánh mì, salad bowls, spring rolls and dumplings. Bánh mì was their most popular menu item, with 400 to 600 sold daily during the outbreak period. Bánh mì contained a choice of protein (roast pork, chicken, meatballs, crispy tofu, or egg with bacon) with salad, herbs, chilli, and mayonnaise common ingredients to all. All meat-based bánh mì included liver pâté.

To make pâté, different sized pieces of chicken and pork liver were placed on a tray and baked for eight minutes at 160 °C before being charred on a grill. The livers were then fried in a wok with pork mince, seasoning and egg whites. This mix was processed in the blender, removed, spread onto trays, steamed, and baked for a further 85 minutes, before being stored for future use.

On examining this recipe, EHOs measured that the internal temperature of the largest liver piece was less than 60 °C after the wok frying step. This indicated that the livers were not consistently reaching the thermal threshold required for *Salmonella* inactivation before being placed in the blender.

Mayonnaise was made by blending raw eggs and oil in the same blender. The pH of the mayonnaise was 6.1, indicating insufficient acidification to retard pathogen growth (target pH: 4.2 or below).⁵ Additionally, each batch of mayonnaise was stored and reused for up to three days, after being stored in the refrigerator overnight.

The crispy coating for tofu was made by processing roasted rice in the blender, before using it to coat precooked shredded tofu. The product was batched and frozen for up to 1 month before being used without further cooking.

The blender's rubber seals were visibly contaminated with food residue. These seals were not separated from the lid during cleaning. Instead, the entire lid was hand washed, sprayed with a household cleaning product, and wiped down.

The venue's management was cooperative throughout the investigation, providing timely and accurate information and access to EHOs as required.

Environmental health investigation of the egg farm noted that only two of the recommended three doses of *Salmonella* vaccine were being administered to the flocks.⁶ Despite the variation from standard practice, no STM was detected in any environmental samples collected from either the production or growing sheds. No biosecurity breaches or primary production issues were identified, and the egg producer confirmed receiving no complaints of illness associated with their product.

The butcher and abattoir supplying the venue's mince and livers were identified in the traceback investigation. However, the abattoir where the chicken livers were processed was supplied by multiple chicken meat farms each day, with the livers from the production day consolidated before being supplied on to multiple distributors and retailers. Traceback of chicken livers to the farm was not possible due to this consolidation, time lag, insufficient documentation, and unavailability of samples from the same batch of livers implicated in the outbreak.

Laboratory results

The STM MLVA types 03-14-06-12-523 (n = 109), 03-14-06-11-523 (n = 1), 03-14-07-12-523 (n = 1) and 03-14-06-13-523 (n = 1) were identified in stool samples of 112 outbreak cases (77%). These MLVA types had not previously been identified in WA.

On 25 March 2024, *Salmonella* spp. was detected on a swab of the venue's blender taken on 21 March 2024; on 2 April 2024, MLVA typing confirmed that the isolate matched the outbreak strain. Samples of defrosted crispy tofu taken on 19 April 2024 were also confirmed to be contaminated with *Salmonella*. The remaining samples from surfaces and food at the venue were negative for *Salmonella*.

No STM was found on testing of samples from the egg farm.

Whole genome sequencing was conducted on 15 clinical samples with illness onset dates ranging between 11 March 2024 and 19 April 2024. Results confirmed that all cases were genomically clustered to one another and to the blender sample, all within two single nucleotide polymorphisms (SNPs).

Whole genome sequencing was conducted on twelve of the 24 cases with STM MLVA types 03-14-06-12-523 who were not outbreak cases as they had not been exposed to the venue. These cases were also genomically clustered to the outbreak strain.

Public health action and control measures

On 21 March 2024, one day after becoming aware of the outbreak, EHOs instructed the venue to replace their in-house mayonnaise with a commercial product and provided information on cleaning and sanitation of food processing equipment. When the swab for the blender confirmed the detection of *Salmonella* spp. on 25 March 2024, the venue was also instructed to cease using the appliance until it was correctly cleaned, resampled, and microbiologically cleared by laboratory testing.

The venue's pâté recipe was also revised: the baking time for the livers was prolonged, and more oil and wine added to the mix to increase the maximum temperature during frying. Staff were trained to use a thermometer probe to ensure that the internal temperature of liver pieces reached 75 °C (undergoing a kill step) before being placed into the blender. Samples of pâté made using this revised recipe tested negative for any pathogen contamination.

EHOs provided food hygiene and safety training to the venue's staff. This included education on safe temperature zones for food, how to conduct temperature checks, and the requirements for handling high-risk ingredients. Staff were given practical demonstration and written guidance on dismantling, cleaning and sanitising the blender. All staff signed to confirm their understanding and acknowledgement of updated cleaning procedures.

Despite implementation of these control measures, two further outbreak cases were identified on 19 April 2024. Both cases reported consuming crispy tofu (in a salad and bánh mì) from the venue between 28 March 2024 and 4 April 2024. EHOs made a further visit to the venue on the afternoon of 19 April 2024 and identified the use of defrosted crispy tofu batches that had been produced prior to decontamination of the blender. Samples of this tofu also tested positive for STM 03-14-06-12-523. Remaining contaminated batches of crispy tofu mix were discarded.

No further cases of illness among patrons of the venue were reported after implementation of this final control measure. The venue committed to using only commercially produced mayonnaise and ensuring all staff were appropriately trained in food safety processes. In response to the outbreak, the WA Department of Health published guidelines on *Cleaning and sanitising of blenders and mixers*.⁷

Discussion

The most likely source of this STM outbreak was undercooked chicken liver that contaminated a food blender. The STM in the liver likely contaminated the blender, before being amplified in its unclean seals, leading to persistent cross-contamination of mayonnaise and crispy tofu used in bánh mì and salads.

Salmonella was only isolated from two environmental sources, the tofu and blender, at the venue. The chicken livers could not be microbiologically confirmed as the primary source of the outbreak. However, they were determined to be the most likely cause through observation of large, undercooked pieces being placed in the blender, and the lack of contamination of raw eggs or other raw ingredients. Furthermore, *Salmonella* is known to penetrate raw chicken livers,⁸⁻¹⁰ with pâté and liver products responsible for previous salmonellosis outbreaks.¹¹⁻¹³

Salmonella was likely transmitted to patrons by two food types: crispy tofu and mayonnaise. *Salmonella* was detected in the tofu, but this product was only consumed by a few cases. Conversely, while no *Salmonella* was isolated from the mayonnaise, the product had been used across all types of bánh mì, and consumed by nearly all outbreak cases. Furthermore, the mayonnaise had been prepared in the contaminated blender, did not undergo a kill step, and is a known hazard for *Salmonella* transmission.^{2,5} Mayonnaise sampled during the investigation was likely not part of a contaminated batch due to the delay between exposure to the ingredient and notification of the outbreak.

The 24 cases diagnosed with the STM MLVA of interest that were not linked to the outbreak had similar demographics to the outbreak cases. This suggests that their source of illness was due to the same primary food source as the outbreak cases, or that there was secondary transmission from outbreak cases within the community.

Bánh mì have been implicated in 44 foodborne outbreaks between 2013 and 2022 in Australia, with an associated 876 cases of illness.ⁱ *Salmonella* Typhimurium was confirmed to be responsible for over three quarters of these outbreaks. Bánh mì contain the high-risk ingredients of mayonnaise ('raw egg butter') and liver pâté. Food Standards

i Outbreak Register data were provided by the Health Protection and Surveillance Division, Interim Australian Centre for Disease Control, Australian Government Department of Health and Aged Care, on behalf of OzFoodNet.

Australia New Zealand (FSANZ)¹⁴ provides guidance on the requirements for safe production of these two ingredients in commercial kitchens.⁵

The risk of blender contamination in commercial kitchens has also been identified by FSANZ⁵ and in previous foodborne outbreaks. Insufficient cleaning under the seals of a blender can lead to a build-up of food residue, which, combined with a moist and warm environment, can lead to the development of a bio-film and proliferation of microorganisms that can contaminate other food products processed in the blender.⁷

In 2015, a *Salmonella* outbreak affecting 250 people was linked to the Brisbane Convention and Exhibition Centre.¹⁵ For this outbreak, inadequate cooking temperatures of raw products placed in the blender, combined with improper cleaning and sanitising processes, also contributed to the outbreak.

Based on the FSANZ Foodborne Disease Costing Model, the estimated economic cost of this WA outbreak linked to bánh mì was \$AUD 1,860,000 (90% uncertainty interval: 1,060,000–3,300,000).¹⁶

The outbreak was successfully contained after a coordinated and thorough investigation by local EHOs, the WA Department of Health and PathWest. The food venue's co-operation and frequent interagency communication assisted in prompt outbreak source identification and rapid effective public health risk reduction.

Limitations

This investigation had several limitations.

Firstly, the primary origin of the STM was not microbiologically confirmed. Liver samples were taken from the food venue several days after the exposure period. This delay meant that they were not of the same batch that was used during the exposure period. No further liver samples were taken from the supplier on traceback investigation, and the primary source could not be identified.

The true number of outbreak cases was likely underestimated due to ascertainment bias. Laboratory-confirmed salmonellosis notifications are known to only represent a small proportion of true incident cases.¹⁷

An analytical study could have provided stronger evidence for the implicated food items. However, it was considered to not be required as there was sufficient evidence from the epidemiological, environmental and laboratory investigations to identify the most likely source of the outbreak, and control measures were effective.

Conclusion

This *Salmonella* outbreak associated with bánh mì was the largest reported foodborne outbreak linked to a single food venue in Western Australia since the commencement of OzFoodNet records in 2001.

This outbreak caused significant morbidity, highlighting the importance of application of the FSANZ Food Standards Code in commercial kitchens, including the direction that food equipment surfaces in contact with food must be 'clean and sanitary' where they 'do not permit the transmission of infectious diseases'. The FSANZ *Safe Food Australia* guidebook also advises that special care must be taken with egg and liver products due to their pathogenic potential. Finally, business owners must ensure that all food handlers are appropriately trained and skilled in safe food preparation and hygiene processes. More stringent enforcement of the code could be considered to reduce the risk of foodborne outbreaks in Australia.

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Conflicts of interest

None to declare.

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