Mayonnaise-Related Salmonellosis: Outbreaks, Risks, and Research-Based Solutions for Food Safety

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Abstract

Salmonella outbreaks have been reported more recently, in several Indian states, including Kerala, primarily due to the consumption of raw-egg mayonnaise. This review combines information from outbreaks in Kerala and around the world, the behavior of *Salmonella* in mayonnaise matrices, and research-based interventions. The pH, type of acid, temperature, and storage conditions all affect how long the mayonnaise lasts. Experimental studies show that refrigeration may help cells that have been damaged by acid, while controlled acidification ($pH \leq 4.1–4.2$) may be more effective at killing cells. Commercial formulations and pasteurized egg products are safer options. High-pressure processing (HPP) and other advanced methods show promise for large-scale production. The role of whole genome sequencing (WGS) in surveillance is discussed, along with practical control measures such as validated pH monitoring, limits on batch size, and equipment cleaning. Kerala's recent policy changes demonstrate how to enhance vendor training and ensure compliance with regulations.

Keywords: *Salmonella enterica*; mayonnaise; raw egg; foodborne outbreak; pH; refrigeration; WGS; HACCP; pasteurized eggs; high-pressure processing.

Introduction

Raw egg mayonnaise and other mayonnaise-like emulsions have repeatedly spread *Salmonella* around the world and, more recently, in several Indian states. Kerala has experienced recurring food poisoning incidents in which shawarma accompaniments and other dishes were implicated, prompting a state prohibition on raw-egg mayonnaise. Similar actions have since been taken in Telangana and Tamil Nadu. International investigations using modern typing and whole-genome sequencing (WGS) have directly linked kitchen-made mayonnaise to outbreaks in catering and institutional settings. This review synthesizes the epidemiology of Kerala and the global context, the microbiological behavior of *Salmonella* in mayonnaise matrices, detection and WGS-based attribution, and research-validated interventions that are practical for vendors and industry (1,2,3).

Mayonnaise and related emulsified dressings occupy a paradoxical position in food safety. Commercial acidic dressings, which use pasteurized ingredients and validated formulations, have an outstanding record of safety. *Salmonella* and other pathogens are inactivated by acetic acid at pH values typical for these products. In contrast, artisanal and kitchen-made mayonnaise prepared with raw shell eggs and inconsistent acidification/time–temperature controls have been recurrently implicated in salmonellosis outbreaks. This dichotomy is evident in classic industrial reviews and in contemporary public health experiences spanning households, catering, street food, and institutional settings (4,5).

In Kerala, the Commissioner of Food Safety banned raw-egg mayonnaise because of problems with dishes that contained mayonnaise and were often not kept at the right temperature. Telangana and Tamil Nadu also put bans in place after similar spikes in food poisoning. They did this because raw-egg emulsions can contain *Salmonella* (1,6,7,8).

Review approach methodology

A narrative, PRISMA-aligned review of peer-reviewed studies and grey literature was done to characterize epidemiology, microbiology, detection/ typing, and interventions relevant to mayonnaise-associated salmonellosis. Sources included outbreak reports and WGS investigations, challenge studies on pH/temperature effects, and regulatory/commodity specifications for egg and mayonnaise safety. Extraction focused on outbreak attributes (setting, vehicle, serovars, evidence) and matrix parameters (pH, acid type, temperature, time,

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survival). We emphasize the comparison of the Kerala/India experience with international precedents to propose feasible controls for artisanal vendors and industry (9, 4,10).

The review gave priority to (i) outbreak investigations that linked mayonnaise to *Salmonella* with laboratory confirmation or strong epidemiologic evidence, (ii) experimental challenge studies on *Salmonella* survival or inactivation across pH and temperature combinations in mayonnaise, (iii) WGS-based outbreak investigations, and (iv) regulatory and commodity specifications for egg ingredients and mayonnaise. Data extraction included outbreak location, setting, vehicle, serovar, case counts, evidence strength, and response measures. For studies, we recorded the matrix formulation, pH, acid type, temperature, time, and survival metrics.

Epidemiology: Kerala, India and global

Kerala has reported multiple incidents in which shawarma accompaniments and similar dishes were implicated; a widely reported case described a 16-year-old's death associated with contaminated shawarma, where mayonnaise was suspected as a vehicle, and other reports noted hospitalization of dozens of school children. In another case, officials linked a woman's death to mayonnaise served with "kuzhimanthi," which led to immediate action at the restaurant in question. Even though laboratory confirmation of serovars is not always made public, investigators often point to mayonnaise as the likely source of salmonellosis in these cases (1, 2).

The government took action by banning the production, storage, and sale of mayonnaise made with raw eggs in Kerala. The order cites laboratory results identifying harmful bacteria in market samples and uses the Food Safety and Standards Act's risk- based authority. After reports of food poisoning cases going up and worries about *Salmonella* risks, Telangana and Tamil Nadu banned raw-egg mayonnaise for a year (6, 7, 8).

Internationally, outbreaks have repeatedly implicated mayonnaise in settings such as clubs, restaurants, and schools. A 1989 London-area outbreak (68 cases) identified a strong association with sandwiches containing mayonnaise; *S. typhimurium* DT4 was found in many stool samples, with implicated eggs from a supplier flock. In 2013, an outbreak of *S. typhimurium* DT8 in Jersey was linked to farm-produced, home-made mayonnaise supplied at

social events; WGS later demonstrated the clonal nature of outbreak isolates from cases and mayonnaise. In 2019, a large *S. enteritidis* outbreak in a Chinese nursery school was traced to kitchen-made mayonnaise in egg sandwiches; near real-time WGS tied patient, sandwich, and mixer-bowl isolates within ≤1 SNP, and genomic tracing mapped the egg supply chain across provinces. Public Health (11, 12, 13).

Table 1. Mayonnaise-related cases and response

Location/ Year	Setting	Vehicle	Evidence	Response
Kasaragod, Kerala (2012; 2022)	Street food (shawarma)	Shawarma with mayonnaise	Epidemiology; officials identified mayonnaise as frequent culprit	Emphasized hygiene and storage risks in homemade mayo (1)
Thrissur, Kerala (2024)	Restaurant	Mayonnaise with "kuzhimanthi"	Suspected vehicle; enforcement action	Eatery sealed; case fatality reported (2)
Kerala (2024)	Statewide policy	Raw-egg mayonnaise	Lab finding of harmful microbes in market mayo	Prohibition under FSS Act Section 30(2)(a) (6)
Telangana (2024)	Statewide policy	Egg-based mayonnaise	Multiple incidents; *Salmonella* detected in victims	One-year ban; FSS Act invoked (7)
Tamil Nadu (2025)	Statewide policy	Raw-egg mayonnaise	High-risk classification (*Salmonella*, others)	One-year ban; pasteurized/ veg mayo allowed (8)
Jersey (2013)	Farm-catered events	Home-made mayonnaise	Mayonnaise sample positive; WGS cluster	WGS confirmed clonal DT8 among cases and food (12)

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Dongguan, China (2019)	Nursery school	Kitchen-made mayonnaise in sandwiches	66 positives across patients, food, handlers, mixer; WGS ≤1 SNP cluster	Multi-jurisdictional response; genomic source tracing to egg producer (3)
London (1989)	Private club	Sandwiches with mayonnaise	68 cases; *S. typhimurium* DT4 in	Source traced to egg supplier flock (11)

Microbiology of *Salmonella* in mayonnaise

Commercial mayonnaise and dressings achieve safety through validated acidification with acetic acid and pasteurized egg inputs, with multiple pathogens dying upon inoculation; pH in the range used by industry is a principal determinant of inactivation. Artisanal mayonnaise, by contrast, often employs raw shell eggs, variable acid type (vinegar vs. citrus), and inconsistent pH/time–temperature control, conditions under which *Salmonella* can survive, particularly at refrigeration temperatures that protect acid-injured cells. pH, acid type, storage temperature, fat content, salt and water activity, and plant antimicrobials are the main factors that affect survival of bacteria in mayonnaise. Bacterial reactions, like acid tolerance, cross- protection, and pH homeostasis, make predictions even harder (4, 9).

Controlled studies elucidate the influence of combined pH-temperature regimes on survival. In raw-egg mayonnaise adjusted to pH 4.2–4.6, *S. typhimurium* survives longer at 4 °C, and even after 10 days at pH 4.6, it can be revived. However, at 37 °C, when pH is 4.2, it quickly loses its viability, and at room temperature (about 23 °C), it becomes inactive within 24 hours. When the pH is higher (like 5.7), growth happens quickly at warm temperatures. These results indicate that immediate refrigeration can paradoxically preserve acid-injured *Salmonella*, contingent upon the product having previously experienced adequate acid contact duration at an inactivating pH (9, 14).

Synthesis of multiple studies suggests conservative targets: pH ≤4.1–4.2 using acetic acid (vinegar) appears more reliably bactericidal, with some guidance recommending holding acidified raw-egg mayonnaise at 18–22 °C for circa 24 h prior to refrigeration to enhance kill, while noting that refrigeration (4 °C)

within pH 4.2–4.5 can stabilize *Salmonella* for weeks. Because of the trade-offs between food safety and operations, pasteurized eggs or commercial bases are better because they do not need to be kept at room temperature (14).

Table 2. The ability of *Salmonella typhimurium* to survive in mayonnaise at different temperatures and pH levels (9, 4)

pH	4 °C	23 °C	37 °C	Key note
4.2	Survival with resuscitation up to 10 days	No growth or resuscitation at 24 h	Rapid loss of viability; no resuscitation at 24 h	Ambient storage more bactericidal than 4°C at low pH
4.4	Prolonged survival	No growth or resuscitation at 24 h	No growth or resuscitation at 24 h	Borderline pH requires time at ambient for kill
4.6	Max survival; resuscitation at 10 days	Survival >24h; resuscitation at 48 h	Viability lost within 24 h	Refrigeration protects acid-injured cells
5.7	No growth at 4°C	Rapid growth	Rapid growth	Warm temps dangerous at high pH

Detection, confirmation, and WGS attribution

High-fat, acidic matrices require unique microbiological workflows for recovery of sub-lethally injured cells. Culture-based enrichment and selective plating continue as confirmatory thresholds, and molecular screens (qPCR/LAMP) help facilitate rapid detection; viable-but-non-culturable conditions can yet complicate interpretation. WGS now provides definitive attribution by resolving isolate relatedness among patients, foods, and environments. In the Jersey DT8 outbreak, WGS clustered case and mayonnaise isolates within a tight clade (≤3 SNPs), while the 2019 Chinese nursery school outbreak showed a ≤1 SNP cluster encompassing sandwiches, a mayonnaise mixer, and patient isolates, with genomic source tracing mapping an upstream egg distribution network (4, 12, 3).

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Research-driven and practice-ready Interventions

- **Replace raw shell eggs** with pasteurized eggs (shell, liquid, frozen, or powder) or commercial mayonnaise bases. The FDA notes that commercial mayonnaise contains pasteurized eggs and is safe to eat. Where egg ingredients are procured, specifications should require that *Salmonella* is not detected per 100g, with compliance to USDA inspection standards (5, 10).
- **Validate acidification:** For any on-premise mayonnaise, adjust the pH to ≤4.1–4.2 with acetic acid and verify each batch with a calibrated pH meter. Recognize that refrigeration can protect against *Salmonella* at borderline pH levels, while controlled ambient holding can enhance kill; these trade-offs argue strongly in favour of pasteurized eggs to avoid hazardous holding practices (9).
- **Time–temperature and batch discipline:** Prepare small batches. If using pasteurized eggs and a validated pH, refrigerate at a temperature of ≤5 °C and limit the shelf life. If any deviation occurs, discard promptly. For raw-egg products (where permitted), adhere to local prohibitions; in states with bans, substitute with pasteurized or vegetarian mayonnaise (6, 8).
- **Hygiene and equipment sanitation:** Disassemble and sanitize blenders, bowls, and dispensing bottles between batches to disrupt biofilms and prevent cross-contamination from raw meats and surfaces; document cleaning cycles in commissary or high-volume operations (4).
- **Industrial options:** High-pressure processing (HPP) can deliver multi-log pathogen reductions in susceptible RTE foods; though matrix-specific validation is required, HPP is judged almost certainly safe from microbial and chemical perspectives relative to conventional treatments, offering a nonthermal hurdle worthy of feasibility assessment for mayonnaise-like emulsions (15).
- **Surveillance and WGS integration:** Embed WGS in routine outbreak response to rapidly link cases, foods, and environments; standardize collection of formulation and holding-time metadata to improve attribution and prevention (13, 12).

Table 3. Practical box: Vendor-ready checklist

Factors	Recommendations	Reference
Ingredients	Use pasteurized eggs or commercial mayonnaise; avoid raw shell eggs.	(5)
pH	Acidify to ≤4.1–4.2 with vinegar; verify each batch using a calibrated pH meter; record batch pH.	(14)
Time–Temperature	Make small batches; refrigerate ≤5 °C; discard per strict time limits; do not hold borderline pH mayo cold without prior validated acid contact time; in practice, rely on pasteurized inputs to avoid hazardous holding.	(9)
Sanitation	Disassemble and sanitize blenders/dispensers between batches; segregate from raw meat prep areas.	(4)

Kerala case focus: from incidents to systems change

The order issued by the Commissioner of Food Safety, Kerala, under Section 30(2)(a) of the Food Safety and Standards Act, makes it illegal to make, store, and sell mayonnaise prepared from raw eggs, citing the laboratory detection of pathogenic bacteria from various mayonnaise samples. This order aligns with the precautionary principles in the Act and it explicitly mobilizes surveillance, public communication, and enforcement. Thus, this has created a clear policy base for shifting vendors to safer inputs and practices (6).

Practical road map for Kerala highlights: (i) shifting to pasteurized egg or veg mayonnaise in all food enterprises; (ii) batch-size pH validation where emulsions are made on site; (iii) small-scale production with stringent time–temperature and discard criteria; (iv) cleaning and sanitizing blending/dispensing equipment; (v) focused training and prominent task aids among street vendors and tiny restaurants; and (vi) Food inspections should be done at peak hours and during big events. Coordinated actions can lower risks in a region, especially when nearby states put in place similar restrictions (8, 7).

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Discussion

There have been clusters and at least one death in Kerala and other Indian states linked to dishes that contain mayonnaise. Under the Food Safety and Standards Act, regulators in Kerala (2024) banned the making, storing, and selling of mayonnaise made with raw eggs. This was followed by a ban on mayonnaise made with raw eggs in Telangana and Tamil Nadu.

Homemade mayonnaise has been linked to outbreaks in clubs, catering, and schools around the world. WGS has linked case isolates to mayonnaise and preparation equipment, with single-SNP distances in large clusters. Experimental evidence demonstrates that the survival of *Salmonella* in mayonnaise is affected by pH, temperature, and formulation. Refrigeration can help cells that have been hurt by acid, but lowering the pH to ≤4.1–4.2 and keeping them at room temperature can kill cells more effectively than putting them in the fridge right away. Pasteurized eggs and commercial mayonnaise (with verified acid hurdles) are always safer than dishes made with raw eggs (6, 7, 8, 12, 9, 14).

The evidentiary base shows that mayonnaise-associated salmonellosis clusters in settings where raw eggs, borderline or unverified acidification, and temperature abuse intersect. Kerala's experience reflects global trends seen in outbreaks such as in clubs, restaurants, and schools, where kitchen-made mayonnaise was confirmed as the root cause. Research findings elucidate the seeming contradiction of acidic, high-fat emulsions promoting *Salmonella* survival at low temperatures.

Refrigeration slows down growth but can keep cells that have been damaged by acid alive. On the other hand, proper acidification and controlled ambient storage speed up inactivation. This method is microbiologically sound, but it could be dangerous for small businesses, which is why it's so important to use pasteurized ingredients (1, 9, 14).

Policy actions banning raw-egg mayonnaise, while blunt, are proportionate in high-risk, resource-constrained ecosystems rich in street foods, particularly given the ready availability of pasteurized options. As bans expire, a durable solution will combine procurement shifts, vendor-friendly HACCP mini-plans centered on pH and time–temperature limits, and WGS-enabled surveillance. Industrial producers and commissaries can explore HPP and other hurdles with matrix-specific validation to add safety margins without compromising sensory quality (6, 15, 5).

Conclusion

Some practical, research-based controls are using pasteurized egg products instead of raw shell eggs, checking the acidification level to ≤4.1–4.2 with batch-level pH checks, using small batches with strict time–temperature limits, and making mixers and dispensers cleaner. When validated for the specific matrix, high-pressure processing (HPP) is a strong nonthermal option for producers who make a lot of products. For surveillance and control, WGS and standardized reporting of formulation/holding parameters can accelerate attribution and prevention. Kerala's policy actions provide a foundation to align vendor training, inspection, and procurement toward safer mayonnaise.

Mayonnaise can still cause salmonellosis if raw eggs, inadequate acidification, and lack of enough time–temperature control all come in tandem. Kerala's targeted regulatory measures, alongside evidence-based interventions—including pasteurized eggs or verified commercial bases, stringent pH targets with batch verifications, and stringent sanitation protocols—provide a replicable framework for analogous situations. WGS gives clear attribution that can change supply chains and how people cook. With standardized formulation metadata in outbreak reports and practical vendor training, jurisdictions can turn mayonnaise from a common cause of outbreaks into a safe condiment.

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