

A REVIEW OF FOODBORNE OUTBREAKS IN PLANT-BASED MEAT SUBSTITUTES

BACKGROUND

Plant-based meat products are beneficial due to their inherently low water activity and the lower microbial load in raw ingredients from successful inactivation of bacterial endospores such as *Bacillus spp* and *Clostridium spp* during extrusion cooking. The challenge is the issue with the survival of gram-positive bacteria if inadequate post-processing treatments are applied. Gram negative bacteria are not found on the microbiota of the meat analogues. Despite this challenge, there was a lack of microbial activity demonstrated in the end-products, making these products typically safe. It is important to note that there is still a potential for a foodborne illness to exist under inadequate hygienic conditions in pre and post environments (Wild et al, 2014). For example, the ability for tempeh contamination occurs in either the bean preparation phase or the fermentation stage, therefore handling of soybeans and environmental controls during preparation is necessary in regulating spoilage organisms (Mulyowidarso, Fleet & Buckle, 1989). A study conducted by Ashenafi & Busse (1991) demonstrated that *Salmonella* and *E. Coli 0157:H7* multiply during fermentation. In this study, inoculation of *Lactobacillus plantarum* was used to lower the pH levels during the growth of *Rhizopus* mould and prevent spoilage organisms. Similarly, tofu contains a nutritious growth medium for micro-organisms. In particular, the most prevalent spoilage agents in tofu are *Enterobacteriaceae* organisms and *Pseudomonads* (Rossi et al, 2016).

PURPOSE

This study aims to evaluate foodborne illnesses caused by outbreaks, where the contribution of implicated sources come from meat substitutes and to use this understanding to illustrate the particular mechanisms that allow for the proliferation of pathogenic organisms. Drawing upon this evidence will highlight the significant role that plant-based meat substitutes play to the worldwide occurrence of foodborne illnesses, as well as illuminate whether it is an emerging threat to foodborne diseases.



METHODOLOGY

Articles used for this study were associated with outbreaks causing foodborne illnesses from meat substitutes between 1990-2018, where at least two cases were identified of which one must be laboratory confirmed. Articles included were only from published peer-reviewed journals scoped out from various databases such as Scopus, PubMed, Google Scholar, ProMed and Public Health Agency of Canada (PHAC) with no limitation on the geographic region.

RESULTS

Figure 1: Home-Fermentation Practices of Tofu

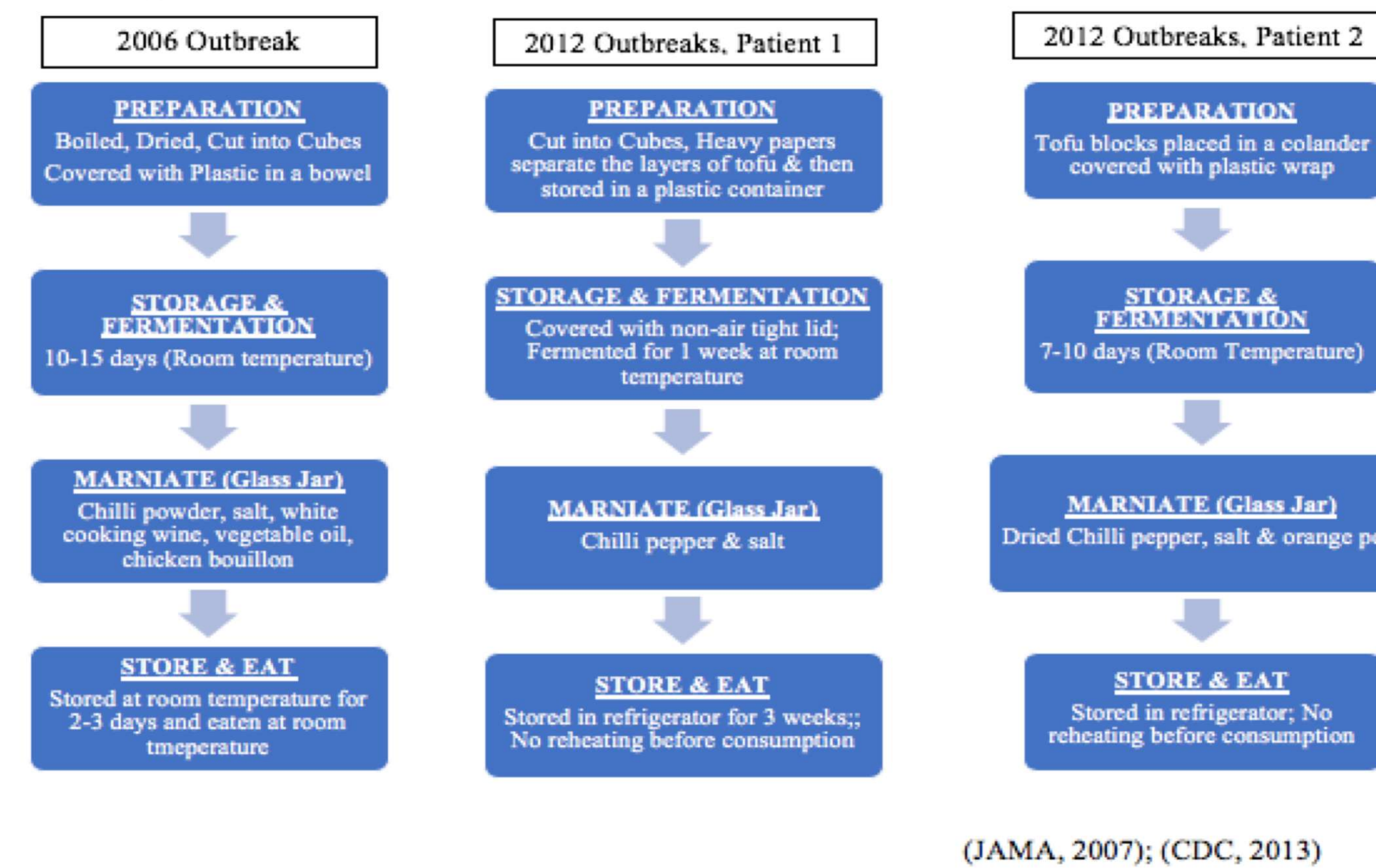


Table 2: Total Number of Outbreaks Per Year Per Meat Substitute

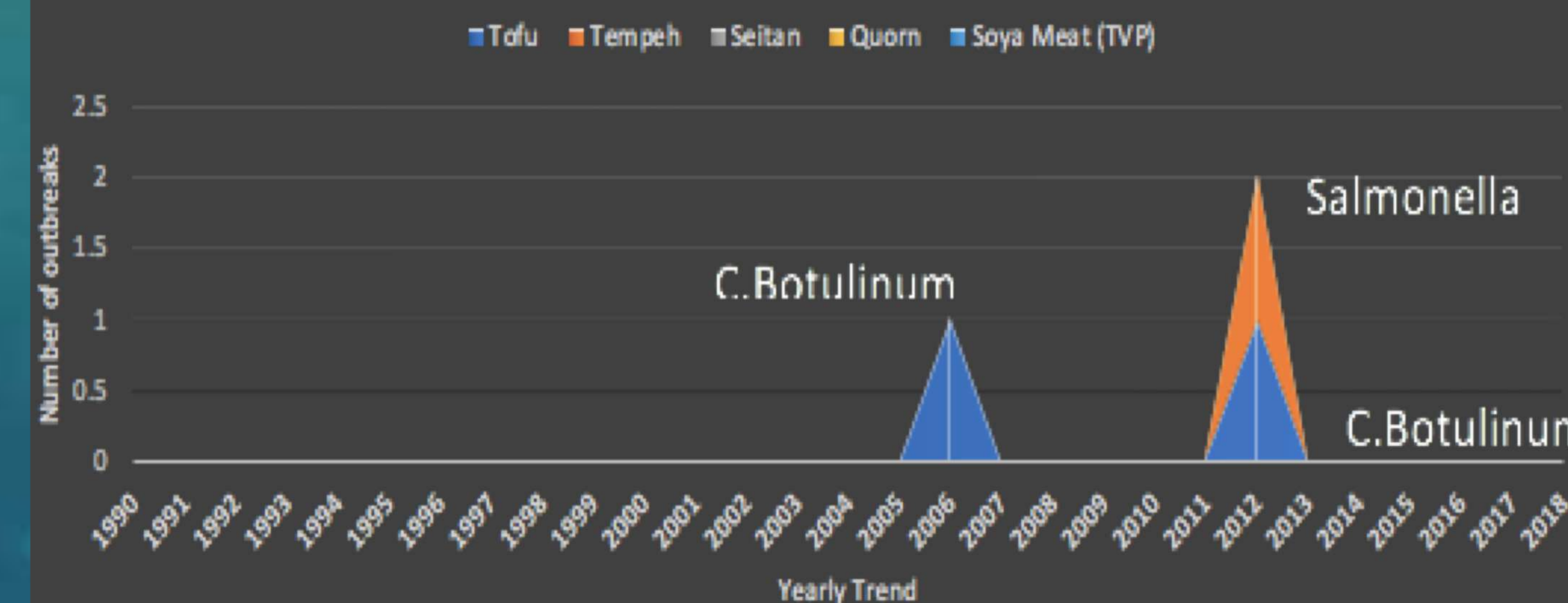


Table 1: Summary of Findings

Year of Outbreak	2006	2012	2012
Food Source	Home fermented tofu (Soybean Curd)	Home-fermented Tofu	Unpasteurized Tempeh
Pathogen	Clostridium Botulism Type A	Clostridium Botulism Type B	Salmonella Serotype Paratyphoid B
Category of Meat Substitute	Refrigerated	Refrigerated	Frozen
Cause of Outbreak	Fermentation Practices – Issues of Prolonged Storage at Room Temperature & Lack of Reheating	Storage Conditions, Time-Temperature Abuse Cross Contamination: Uncovered, Unrefrigerated Bins Fermentation Practices – Lack of Reheating	Contaminated Starter culture - Rhizopus Mould Cross Contamination with RTE foods Improper handwashing practices
Total Number of Suspected Cases	2	3; 1 asymptomatic	89
Total Number of Lab-Confirmed Cases	2	1	15
Geographic Region	California, USA	New York City, USA	North Carolina, USA
References	(JAMA, 2007)	(CDC, 2013)	(CDC, 2013)

DISCUSSION

TOFU 1. Potential Pathway between air drying after boiling of tofu in delaying fermentation

2. Negative Yeast Activity In Lactic Acid Fermentation

- Air exposure to a brining solution during storage retards lactic acid fermentation, allowing negative yeast activity to take over. The inability for the pH to drop to sufficient numbers with prolonged room temperature storage kept the *Enterobacteriaceae* population at high counts (Jablonska et al, 2019).
- Hazardous conditions arise as a consequence of post-process contamination, where the synergistic presence of aerobic bacteria in low-oxygen environments and *Clostridium Botulinum*, combined with prolonged storage in room temperature impacted acidity. This indicates that the production of toxins existed only with the presence of yeast, whereby the absence under adequate *Lactobacillus spp* did not produce any viable toxins (Odlough & Pflung, 1978).

3. Usage of Agroindustry Wastes (Orange Peel) in Honing the Characteristics of Gibberellic Acid (G3)

- In one study, carbon dioxide production from yeast fermentation lead to the net loss of dry matter (Jablonska et al, 2019).
- Differences between patient 1 and patient 2:** Orange peel acts as a solid substrate, producing a greater yield of citric acid, similar to *Gibberellic Acid* (Pal, Amirta, & Vivek, 2017).
- Thermodynamic fluctuations initiated prion-behaving yeast protein to activate the *Rho* genome found in *Clostridium Botulinum* (Ohashi et al, 2018). Under low salt and low acid conditions, studies show that *Enterobacteriaceae* like *E. Coli* have a competitive advantage, allowing them to survive longer due to this activated *Rho* gene (Yuan & Hochschild, 2017). Therefore, the absence of orange peel activating the *Rho* gene may have potentially lead to differences in toxin identification in the laboratory samples amongst the two cases.

TEMPEH: Quality of tempeh ultimately affected by inadequate hygiene practices in developing countries like Indonesia and implementation of one-step heating technique.

CONCLUSION

From 1990-2018, there were 3 foodborne illnesses reported from peer-reviewed journal articles, suggesting that the burden of illness of plant-based meat substitutes remain low. Our review indicates that home-fermented tofu caused the atypical formation of Clostridium Botulinum due to the changes in acidity from negative yeast activity, whereas Salmonella from tempeh was due to unhygienic processing conditions.

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