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Susceptible-infected diffusion of food safety opinion dissemination: Infrastructure-driven spread and behavior-embedded substance

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A R T I C L E I N F O

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A B S T R A C T

This study examines how food safety information disseminates across three structurally distinct Chinese social media platforms, Weibo, TikTok, and Xiaohongshu (XHS), during crisis events. Rather than serving as neutral transmission channels, these platforms are conceptualized as dynamic Information Service Systems (ISS), in which algorithmic infrastructures and content substances co-produce public meaning, emotional salience, and trust dynamics. Drawing on the Substance–Infrastructure (S-I) model, specifically Type II logic, where infrastructure drives substance, we theorize that technical mechanisms such as feed algorithms, trending systems, and visibility logics interact with semantic features like emotional tone, media modality, and narrative framing to shape the velocity, reach, and epistemic reliability of crisis communication. Employing a mixed-methods design that combines temporal Exponential Random Graph Models (ERGM), Susceptible-Infected (SI) diffusion simulations, and BERT-based sentiment analysis, we identify how different network structures, decentralized, centralized, and hybrid, interact with conformity, homophily, and neophilia to produce platform-specific information ecologies. TikTok's architecture enables high-speed virality with minimal deliberative anchoring, limiting the platform's ability to support trust repair; XHS facilitates high-affinity trust ecosystems led by key opinion leaders, but is vulnerable to echo chambers and insular misinformation; Weibo, with its hybrid infrastructure, supports rapid escalation and multi-directional discourse, but suffers from volatility in trust due to inconsistent epistemic control. These distinct affordances explain the asymmetric amplification of food safety narratives and the divergent trajectories of public trust, consolidation, polarization, or collapse, across platforms. As a contribution, the study introduces the Integrated Design and Operation Management (IDOM) framework, which positions platforms as reflexive control systems that must adapt to real-time signals of uncertainty and trust decay. It further underscores the need for resilient public governance that aligns institutional interventions with platform-specific logics and user cognitive baselines, advocating for a coordinated socio-technical ecosystem capable of sustaining trustworthy, inclusive, and responsive food safety communication in the digital era.

1. Introduction

Food safety incidents, ranging from contamination threats to large-scale product recalls, can rapidly erode public trust, significantly altering consumer behavior and destabilizing markets when public health is compromised. In these high-stakes scenarios, social media platforms offer decentralized and rapid channels for sharing critical information, providing real-time updates, and enabling dynamic engagement between regulatory authorities, companies, and the general public (Ivanov et al., 2023). In regions with extensive social media use, such as China, platforms like Weibo, TikTok, and Xiaohongshu (XHS) are essential for rapidly disseminating information and shaping public responses during food safety crises (Shu et al., 2024). These platforms accelerate the flow of critical updates while significantly influencing public sentiment and actions in real time (Liao et al., 2023).

On the 'bright' side, social and digital media have bridged physical

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distances, enabling the rapid dissemination of critical insights and providing farmers, regulators, and consumers with real-time updates, access to innovative agricultural practices, and a wealth of shared expertise (Venkatesh et al., 2024). Customers, as a key recipient of information, social media acts as a vital resource by offering transparency and direct access to information about food safety, production methods, and product recalls (Li et al., 2023). This connectivity empowers consumers to make informed choices, strengthens trust in the agri-food system, and supports public health by disseminating accurate information about food quality and safety standards (Zhao et al., 2024). However, the 'bright' or ideal side of social media is countered by a potent 'dark' side. The very qualities that make these platforms essential for rapid information dissemination, openness, reach, and immediacy, also make them susceptible to misinformation, disinformation, and malinformation (Sarraf et al., 2024). This "information disorder" can exacerbate confusion and mistrust during crises, as unverified or deliberately false information often circulates as swiftly as legitimate updates. In contexts like food safety and public health, the spread of misleading information can undermine public confidence, distort perceptions of risk, and even influence behaviors in ways that amplify harm, as seen during the COVID-19 pandemic (Chaudhuri et al., 2024). Reports of false claims about health protocols and food safety have shown how information disorder can erode trust, leading to poor decision-making and weakened community resilience (Kumar et al., 2024).

Specifically, the risks associated with information disorder during food safety crises can be better understood through a dual-layered system model, adapted from the substance-infrastructure (S-I) framework developed in enterprise system design (Zhang et al., 2019). In this framework, a platform operates as a mini socio-technical system, where infrastructure serves as the technical carrier that enables information flow, while substance constitutes the semantic and emotional content that circulates within it. Consistent with the Type II S-I system logic, where infrastructure drives substance, the architecture of a social media platform determines how information is generated, prioritized, filtered, and delivered to users over time. The infrastructure layer thus refers to the algorithmic and structural mechanisms, such as feed design, trending topic systems, and recommendation algorithms, that shape what content is visible, when it appears, and to whom. These mechanisms condition the velocity, reach, and amplification of information, forming the operational logic of the digital environment. The substance layer, in contrast, refers to the form and meaning of content itself: the emotional tone, visual format, and interactional style that characterize user-generated posts. As Zhang et al. (2005) note, changes in one system component (e.g., visibility) are often dependent on changes in another (e.g., emotional framing), and their relational pattern, though possibly hidden, can be captured using data-driven methods such as machine learning. To empirically examine these dynamics, this study draws on data from three widely used yet structurally diverse platforms in China: Weibo, TikTok, and XHS. Each represents a distinct model of infrastructure, substance interaction. Weibo, resembling Twitter, relies on a trend- and hashtag-based infrastructure that promotes real-time topic convergence and centralized information visibility, often shaped by repost counts and verified accounts. TikTok, by contrast, follows a highly personalized algorithmic infrastructure that pushes emotionally compelling short videos to users based on behavioral data, enabling viral diffusion even from previously unknown accounts. XHS, structurally akin to Instagram in its focus on visual content and lifestyle themes, functions as a hybrid of community curation and interest-based discovery. Its feed logic incorporates lifestyle tagging and social clustering, resulting in clustered and context-specific content dissemination. These infrastructural differences shape the types of content (substance) that dominate: while TikTok and XHS amplify emotionally expressive, visually rich, and highly affective storytelling, Weibo tends to foreground text-based public commentary, official narratives, and celebrity discourse. Crucially, as in other dynamic systems, these two layers are not independent but mutually reinforcing (Zhang and Wang, 2016). The platform infrastructure governs which types of content gain exposure, while the content's emotional valence and format directly shape user interaction patterns, engagement, sharing, and trust formation, that recursively influence future algorithmic behavior. During food safety emergencies, this dynamic coupling becomes especially consequential, as emotionally charged narratives may gain rapid visibility on certain platforms, while others act as centralized hubs for authoritative messaging. Thus, understanding the interaction between infrastructure and substance is key to explaining divergent information flows and public responses across platforms.

While existing research has offered valuable insights into social media engagement during crises (Ivanov et al., 2023, Das et al., 2023), significant theoretical and empirical gaps remain in understanding how platform-specific structures influence the dynamics of food safety information dissemination. Most prior studies emphasize short-term surges in user activity during the initial outbreak of a crisis, often overlooking the temporal evolution of information visibility, user interaction, and trust dynamics in the later stages (Al Aziz et al., 2024). Moreover, the combined effects of platform infrastructures, such as feed architecture, algorithmic curation, and trending mechanisms, and the substance of content, such as emotional tone, media format, and community behavior, have rarely been examined in an integrated manner. To address these gaps, this study asks: (1) How do platform-specific infrastructures and content substances jointly influence the speed, reach, and engagement of food safety information dissemination during crises? (2) How do the structures of user interaction and information visibility evolve across different platforms as a food safety crisis progresses? (3) What platform-specific strategies can be recommended to individual disseminators, platform operators, and public agencies to improve the resilience and trustworthiness of food safety communication beyond the initial crisis phase?

This study employs an integrated approach to analyzing the dissemination of food safety information across social media platforms, grounded in a dual-layered framework where infrastructure functions as the technical carrier of information and substance represents its communicative core. To examine the infrastructure layer, which refers to the structural pathways through which information flows, we apply Temporal Exponential Random Graph Models (ERGM) to capture how network structures adapt and evolve during different stages of a crisis, revealing shifts in user interaction patterns (Chen et al., 2024). In parallel, the Susceptible-Infected (SI) model is used to simulate the diffusion process, modeling how specific pieces of information spread across the network and identifying key users who act as super-spreaders (Brusset et al., 2023). To analyze the substance layer, which encompasses the emotional tone and semantic framing of content, we utilize Bidirectional Encoder Representations from Transformers (BERT) for sentiment analysis. This model enables the extraction of contextually rich insights into public sentiment, allowing us to track changes in emotional valence, positive, negative, or neutral, throughout the progression of food safety crises (Vairetti et al., 2024). Together, these models provide a comprehensive view of how technical structures and content dynamics jointly shape information dissemination in digital public health contexts.

This study contributes a comprehensive framework for understanding digital information dissemination during food safety crises by extending the SI model to the context of social media platforms. Conceptualized as dynamic socio-technical systems, platforms are analyzed through the interaction between algorithmic infrastructure, such as feed architecture, recommendation systems, and trending mechanisms, and content substance, including emotional tone, media format, and user engagement. Methodologically, the study integrates temporal ERGM to analyze evolving network topologies, a SI model to simulate content diffusion and identify influential actors, and BERT-based sentiment analysis to trace shifts in public affect and trust. This multi-method design captures the temporal and structural complexity of crisis communication and maps the feedback loop between user response and algorithmic adjustment. On a practical level, the study frames social media as an information service system and demonstrates how different platform architectures either facilitate or constrain the circulation of both factual and misleading content during emergencies. It further identifies design-sensitive intervention points, such as rumor correction strategies, visibility modulation, and verified source amplification, that can strengthen system-level resilience.

2. Literature Review

The digital dissemination of food safety information in times of crisis has evolved into a complex socio-technical process shaped by the content of messages and by the architecture of the platforms that carry them. Contemporary scholarship increasingly departs from the traditional assumption of digital platforms as neutral channels, instead conceptualizing them as actor-networks (Latour, 1999), whose infrastructural features, network topology, algorithmic visibility rules, and information flow constraints, actively co-construct the reach, interpretation, and credibility of crisis communication. Within this framing, the S-I framework provides a robust theoretical apparatus to untangle the dual mechanisms at play (Wang et al., 2019). “Infrastructure” captures the operational and algorithmic scaffolding of platforms (Wang et al., 2016), while “substance” denotes the semantic, emotional, and epistemic content that flows through these structures (Zhang and Van Luttervelt, 2011). Crucially, substance is not transmitted passively; it is recursively shaped, amplified, or suppressed by infrastructural affordances. In this sense, the digital platform does not merely carry messages, it transforms them (Wang et al., 2013).

This entanglement resonates with the Data–Information–Knowledge–Wisdom (DIKW) hierarchy, which conceptualizes cognition as a progressive transformation from raw data into actionable wisdom (Rowley, 2007). In theory, well-structured platforms should facilitate this upward conversion: converting alerts (data) into verified warnings (information), enabling collective interpretation (knowledge), and guiding effective public behavior (wisdom) (Baskarada and Koronios, 2013). However, in the digital environment, this transformation is often non-linear and fragile. Infrastructure distorts or accelerates transitions along the DIKW path (Guerrero-Prado et al., 2021). Consider, for example, a foodborne illness alert issued by a national health agency. When disseminated through a government-backed emergency app with push notifications, where institutional authority and interface design reinforce urgency, it may trigger immediate behavioral compliance, such as food avoidance or medical consultation. However, the same alert circulated on a commercial microblogging platform like Twitter or X may be reframed, diluted, or even contested as users remix the message with personal anecdotes, conspiracy theories, or satirical commentary. Here, the alert’s epistemic trajectory is determined by the platform’s interactional dynamics and engagement incentives (Avalle et al., 2024). Thus, epistemic elevation is contingent on content integrity and on infrastructural affordances and the emotional and relational signals embedded in platform design (Sullivan et al., 2020).

The architecture of digital networks, whether centralized, decentralized, or hybrid, critically influences how food safety messages propagate. In centralized networks, high-centrality nodes such as government accounts or institutional Key Opinion Leaders (KOLs) act as initial signal broadcasters due to their privileged visibility (Bento et al., 2024). While this structure enables rapid reach, it also concentrates epistemic risk: misinformation issued from a central node can spread quickly and resist correction (Hossain et al., 2023). Decentralized platforms, by contrast, are slower but more fault-tolerant. Hybrid designs that embed authoritative voices within distributed communities strike a balance between speed and resilience, reducing amplification errors while supporting redundancy-based verification (Yue and Shyu, 2024). These network configurations are epistemic infrastructures that shape whether public discourse leads to action or confusion.

Equally significant is the temporal evolution of discourse. Early crisis phases are often dominated by immediate and concrete content: contamination alerts, recall notices, or exposure warnings (Zhou et al., 2024). Over time, public interest shifts toward latent themes such as accountability, regulatory gaps, and structural reform (Santoro et al., 2023). However, the fluidity of topic transition depends on network clustering and homophily. Highly clustered sub-networks may trap discourse in echo chambers, reinforcing a single narrative and resisting updates (Tan et al., 2024). Heterophilic and loosely connected networks, though slower initially, enable cognitive diversification and facilitate broader thematic transitions (Arazzi et al., 2023). In this sense, topic evolution is not a semantic process alone, it is structurally mediated and governed by how networks route attention and emotional investment. Another pivotal dimension concerns the construction and circulation of authority. In high-uncertainty contexts, individuals rely heavily on heuristic cues-verification badges, follower counts, or professional titles to evaluate credibility (Pang and Pavlou, 2023). As predicted by the Elaboration Likelihood Model (Petty & Cacioppo, 1986), these peripheral routes to persuasion dominate under cognitive load. Platforms reinforce these heuristics by prioritizing visibility for accounts with high reputational capital (Khern-am-nuai et al., 2023), creating a double-edged dynamic: while it accelerates information uptake, it also introduces risk when visibility is uncoupled from epistemic reliability. When influential but non-expert figures disseminate misinformation, the architecture itself amplifies the damage (Chaudhuri et al., 2024). Therefore, platform design must integrate multi-source verification and cross-platform trust signaling to avoid over-reliance on single points of failure.

Perhaps most insidiously, emotion operates as a structural vector in its own right (Dangi et al., 2023). Emotionally salient content, especially that evoking fear, anger, or injustice, disproportionately attracts attention and encourages recirculation (Lagrange, 2025). In food safety contexts, moral intuitions about bodily purity, risk aversion, and institutional betrayal are readily activated. Engagement-driven algorithms respond to these signals by further elevating such content, creating recursive loops that entrench emotionally charged narratives. Even when corrections are issued, the original narrative often dominates cognitive memory, a phenomenon known as the continued influence effect. Emotion, therefore, is a variable in the infrastructure of visibility. Sentiment analysis must be mapped alongside algorithmic engagement pathways to fully account for the co-production of belief and behavior (Amangeldi et al., 2024). These dynamics converge in what may be termed a structural dual-impact mechanism, an interactive system in which platform-level rules and user-level behaviors continuously shape one another. On the one hand, infrastructural factors like repost friction, feed ranking, and content moderation govern how information is routed and persisted (Plantin and Punathambekar, 2019). On the other hand, user actions, how people interpret, reframe, and selectively amplify messages, feed back into the system, recalibrating what gets seen and believed (Lee and Hancock, 2024). This recursive relationship generates diverse information ecologies: one message may be immediately debunked in a network favoring redundancy and deliberation (Pal et al., 2019), while gaining long-term traction in a platform architecture that prioritizes emotional salience and low-friction sharing (Tomalin, 2023). In such systems, the same informational substance yields radically different social outcomes, depending on the interplay of structure and affect.

Taken together, these structural and semantic dynamics demand an integrated and anticipatory approach to platform governance. The Integrated Design and Operation Management (IDOM) framework conceptualizes information systems as adaptive socio-technical assemblages (Paraschos et al., 2022). Unlike traditional crisis communication models that treat message design and dissemination as separate phases, IDOM posits that design decisions (e.g., information architecture, interface nudging, visibility settings) and operational decisions (e.g., moderation response, debunking strategies, timing of official statements) must be co-optimized in real time (Zhang et al., 2019). In practical terms, this requires platforms to develop systems that can dynamically adjust trust signals, spotlight topic shifts, and reroute visibility pathways based on emerging patterns in user interaction and public sentiment. The implication is clear: effective communication during food safety crises is not achieved solely through better messaging but through better design of the digital environment in which those messages are embedded. A resilient platform is one that can manage both structure and substance concurrently anticipating failure points, correcting biases, and aligning platform dynamics with evolving public health goals.

3. Methodology

3.1. Data collection

Data were systematically gathered from three major social media platforms: TikTok, Weibo, and XHS. These platforms were selected for their significant user bases and their influential roles in shaping public discourse on food safety incidents (Liu et al., 2023; Shu et al., 2024; Sun et al., 2024). Key food safety incidents were ranked based on combined user interaction metrics from all three platforms, including post volume, number of commentators, and overall engagement. Events with the highest interaction across these platforms were prioritized for analysis, focusing on those with the greatest impact on public opinion. As shown in Table 1, the selected events (all without verification from official sources) included the "Adulterated Lamb Incident", "Aspartame Carcinogens Issue", "Haitian Soy Sauce Event", "Pre-packaged Food Discussion", and the "Rat Head Incident". For each identified event, data were extracted using platform-specific APIs and web scraping tools. The extracted data comprised the number of posts related to the event, the number of commentators and publishers, anonymized user information, and timestamps. The data collection covered a specific time period, starting from the initial report of the incident and extending for several months to years after the event, ensuring comprehensive temporal coverage. Additionally, specific metrics such as commentCount, shareCount, diggCount, and IP addresses were also collected (Please refer to dataset).

Table 2 highlights key differences in social network structures across TikTok, XHS, and Weibo for various food safety incidents. While the average degree remains consistent around 2.0 on all platforms, significant variation exists in centralization and diameter. TikTok networks are relatively decentralized (centralization scores of 0.045 to 0.13) and have larger diameters (up to 18), indicating fragmented discussions and longer paths for information spread. In contrast, XHS networks are highly centralized (scores between 0.814 and 1.0) with smaller diameters (3 to 4), signifying quicker, more focused dissemination around a few key users. Weibo shows mixed patterns, with centralization and diameters varying across incidents, reflecting both centralized and decentralized structures depending on the context.

3.2. Data preprocessing

The data preprocessing phase involved several key steps to ensure the accuracy and consistency of the dataset across multiple platforms. First, data cleaning was performed to remove duplicate entries, irrelevant posts, and spam, ensuring that only high-quality data remained for analysis. This was followed by normalization, where timestamps and user identifiers from different platforms were standardized using a function $T_{standard} = f(T_{original})$, ensuring uniformity in time format across all sources. Next, filtering was applied to isolate interactions directly related to the food safety incidents of interest by using event-specific keywords. The filtering process, represented as $X_{filtered}{=}X_{raw} \cap K_{incident-related}$, ensured that the data focused only on relevant discussions, reducing noise. Subsequently, opinion analysis was performed using the BERT natural language processing model, which extracted and quantified user sentiment from comment content (Joloudari et al., 2023). The BERT model processed the text by generating context-aware embeddings w_i and encoded sequences z_i, leading to the sentiment classification $S_i = BERT(z_i, w_i)$. This allowed the extraction of user opinions and reactions regarding the events. Finally, a directed graph was constructed to model the network of user interactions, where nodes represented users and edges symbolized interactions such as comments or shares. The edges were defined as $E_{ij} = \{(u_i, u_j) | u_i \, interacts \, with \, u_j\}$, which allowed for further analysis of the social network, including identifying influential users and tracking information spread.

3.3. Model implementation

ERGM explains *who* plays key roles in the network (through structural features like centrality) (Leifeld and Cranmer, 2019), while SI explains *how* these roles influence the spread of information (Doostmohammadian et al., 2020), making them essential for a comprehensive analysis of both network structure and information diffusion.

ERGM captures the evolution of network structures over time, accounting for changes in relationships (edges) between users. Given a social network modeled as a graph $G(V, E)$, the probability of observing the relationships y of G is expressed as:

$$P(Y = y|\theta) = \frac{\exp(\theta' g(y))}{k(\theta)}$$

Table 1
General information about the datasets collected from three different social media platforms, namely Weibo, XHS, and TikTok (The dates in the 'Event' column indicate the time and date when the events first occurred or were reported).

Event	Source	#Posts	#Commentators	#Publishers	Timespan
Adulterated Lamb	TikTok	89,547	71,747	151	2019–09-01: 2024–02-11
(09/2019)	XHS	14,720	13,870	169	2019–12-14: 2024–02-12
	Weibo	785	757	27	2020–06-14: 2024–02-07
Aspartame Carcinogens	TikTok	104,225	88,881	165	2023–05-08: 2024–02-10
(05/2023)	XHS	23,058	21,237	98	2023–05-01: 2024–02-11
	Weibo	6,506	6,078	189	2023–06-29: 2024–02-04
	Weibo	1,640	1,592	75	2022–03-23: 2023–10-01
Haitian Soy Sauce	TikTok	67,706	56,266	152	2022–10-01: 2024–02-06
(10/2022)	XHS	5,452	4,923	118	2022–10-01: 2024–02-04
	Weibo	3,169	3,038	103	2022–10-01: 2024–02-03
Pre-packaged Food	TikTok	152,138	131,013	159	2022–01-22: 2024–01-24
(01/2022)	XHS	32,839	30,414	194	2022–01-03: 2024–02-06
	Weibo	17,841	14,902	424	2023–09-23: 2024–01-16
Rat Head Incident	TikTok	197,789	120,200	136	2023–06-04: 2024–02-08
(06/2023)	XHS	20,206	17,892	133	2023–06-01: 2024–02-06
	Weibo	13,075	12,147	244	2023–06-06: 2024–02-07

Table 2
Descriptive statistics about the social networks.

Event	Network	Average Degree	Diameter	Centralization	Density
Adulterated Lamb	TikTok	2.002	12	0.13	0.0
	XHS	1.999	4	0.814	0.001
	Weibo	1.985	2	1.0	0.015
Aspartame Carcinogens	TikTok	2.005	14	0.058	0.0
	XHS	2.0	4	1.0	0.0
	Weibo	2.0	8	0.366	0.002
Haitian Soy Sauce	TikTok	2.01	16	0.045	0.0
	XHS	2.0	3	1.0	0.0
	Weibo	1.994	2	1.0	0.006
Pre-packaged Food	TikTok	2.006	18	0.083	0.0
	XHS	2.0	4	1.0	0.0
	Weibo	2.004	12	0.319	0.002
Rat Head Incident	TikTok	2.014	12	0.128	0.0
	XHS	2.0	4	1.0	0.0
	Weibo	2.005	8	0.272	0.001

where θ contains model parameters, $g(y)$ is a vector of network statistics, and $k(\theta)$ is a normalization constant defined as $k(\theta) = \sum_y \exp(\sum_H \theta_H g_H(y))$. The log-odds of a tie forming y_{ij} over time is conditional on the rest of the graph

y^c_{ij}, i.e.,$logit\left(P\left(Y_{ij,t}=1|y^c_{ij,t-1}\right)\right)$.

On the other hand, the SI model focuses on the dynamics of information spread through networks. It models how susceptible nodes (users) become infected (i.e., receive and spread information) through interactions with already infected nodes. The SI model tracks this spread using the following differential equation:

$$\frac{dI(t)}{dt} = \beta S(t) \bullet I(t),$$

where β is the infection rate, $S(t)$ is the number of susceptible nodes, and $I(t)$ is the number of infected nodes at time t. This model identifies superspreaders and the rate at which information spreads, providing insights into the intensity and reach of information dissemination.

3.4. *Substance × Infrastructure= conditional diffusion readiness*

To move beyond network topology and capture the interactional logic between platform architecture and message design, we define the probability of a dyadic information transfer $P(y_{ij})$ as governed not only by Network Structure (captured via ERGM) and Infection Proximity (captured via SI), by the jointed influence of:

- I_p: Infrastructure-level variables, e.g., algorithmic recommendation intensity, interface push or pull logic, sharing friction, exposure depth.
- S_C: Substance-level variables, e.g., emotional salience, epistemic quality, credibility cues, and content modality.

Thus, we conceptualize a conditional diffusion readiness score R_{ij}, embedded at the dyadic level:

$$R_{ij} = a \bullet I_P(i,j) + \beta \bullet S_c(i\rightarrow j) + \gamma \bullet [I_P(i,j) \bullet S_c(i\rightarrow j)]$$

Where:

$I_P(i,j)$: describes the infrastructural pathway between node i and j (e.g., platform affinity strength, feed visibility probability),

$S_c(i\rightarrow j)$: describes the content characteristics shared by i and received by j,

γ: represents the interaction coefficient reflecting contextual modulation, e.g., emotional content may be more potent in algorithmic amplification environments.

This score R_{ij} acts as a modulatory weight that adjusts: Tie formation probability in ERGM: ties between users are more likely when R_{ij} is high, i.e., infrastructure and substance are aligned to promote interaction; Transmission rate β in SI model: content spreads more rapidly when R_{ij} is elevated.

For ERGM: We modify the ERGM tie formation probability to incorporate R_{ij} as an exogenous covariate:

$$P(Y = y|\theta, R) = \frac{exp(\theta' g(y) + \lambda \sum_{i,j} R_{ij} \bullet y_{ij})}{k(\theta, R)}$$

Here, λ captures the influence of IS alignment on the formation of edges. A high R_{ij} boosts the log-odds of a tie forming between i and j, conditional on the network structure.

For SI: We allow the transmission rate β_{ij} between any two nodes to vary by R_{ij}, yielding a heterogeneous SI model:

$$\frac{dI(t)}{dt} = \sum_{i,j} \beta_{ij}(t) \bullet S_i(t) \bullet I_j(t), where \beta_{ij}(t) = \beta_0 \bullet \int (R_{ij})$$

This formulation allows more accurate modeling of selective contagion, messages spread faster and further when both infrastructure and message salience are conducive to engagement.

4. Results

4.1. *Network structures and information dissemination patterns across platforms*

The Cumulative Distribution Functions (CDFs) for the component sizes across TikTok, XHS, and Weibo offer key insights into the distribution of discussion group sizes for various food safety incidents. On TikTok, the CDFs reveal a rapid rise, which indicates that most discussion groups or components are relatively small, typically consisting of a few thousand commentators (Fig. 1). This suggests that TikTok's network structure is largely decentralized, with numerous small clusters engaging independently on specific incidents. Such a structure implies that TikTok users are less dependent on key influencers, as many conversations unfold simultaneously across the platform. Consequently, information spreads in a more dispersed manner, without a few dominant figures controlling the flow of discourse.

In contrast, XHS displays a significantly different network structure, characterized by larger and more centralized clusters. The CDFs for XHS exhibit a slower rise, indicating that component sizes vary more broadly, with some clusters being significantly larger than those observed on TikTok (Fig. 2). This pattern suggests that discussions on XHS are more dependent on central influencers, such as KOLs, who attract large numbers of users and facilitate concentrated discussions. These highly connected groups lead to more centralized discussions, where information dissemination is largely driven by a few dominant nodes. This

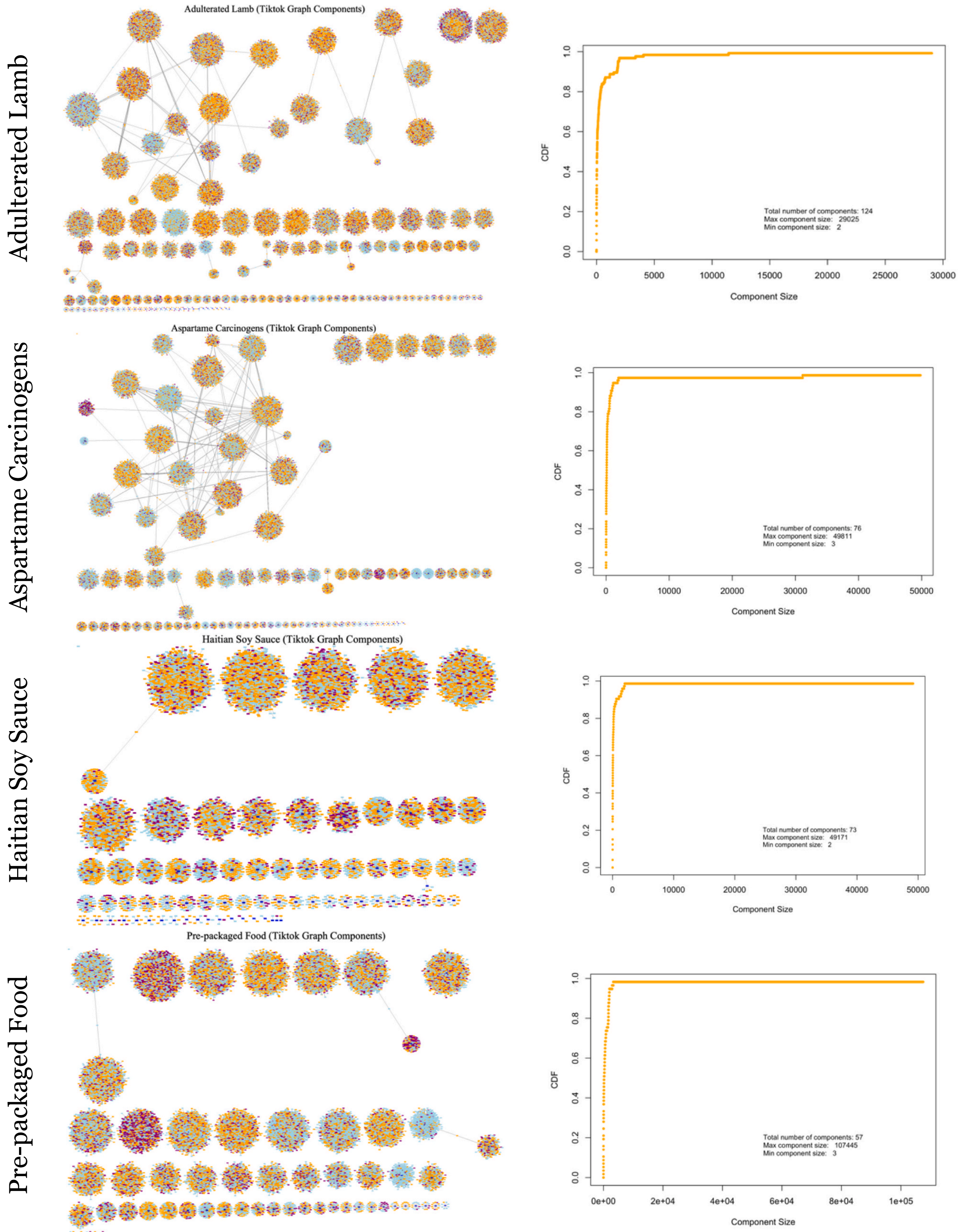

Fig. 1. TikTok Network components and components statistics.

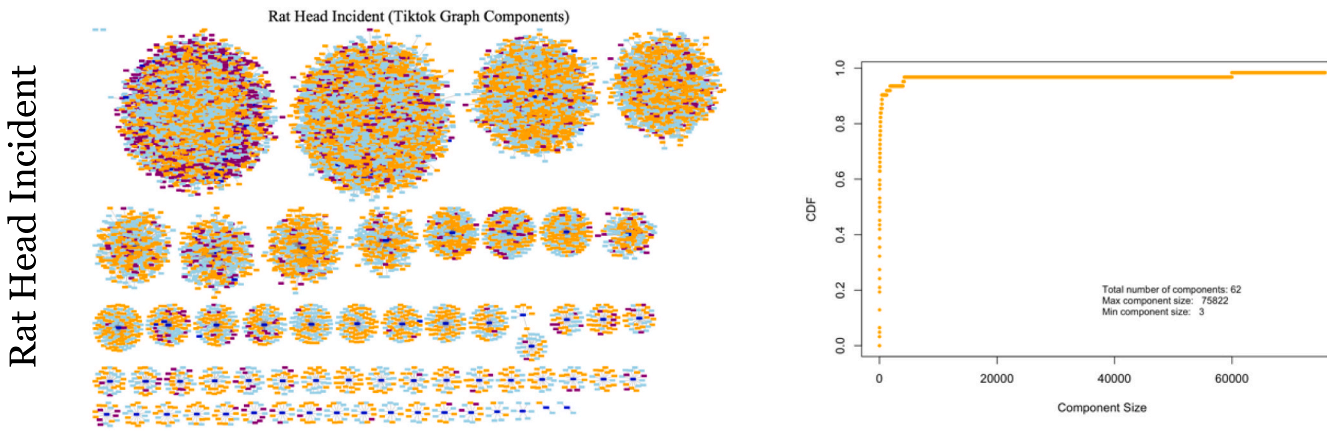

Fig. 1. (*continued*).

centralized structure contrasts with the more fragmented nature of TikTok's networks, highlighting how XHS fosters deeper, more concentrated community engagement around key figures.

Weibo, however, shows greater variability in its network structures (Fig. 3). Some incidents, such as "Pre-packaged Food" and "Aspartame Carcinogens", reveal a more decentralized network, resembling TikTok, with smaller clusters and more distributed conversations. In other cases, like the "Rat Head Incident" and "Haitian Soy Sauce", the network exhibits greater centralization, similar to XHS, where a few large clusters dominate the discussion. The mixed pattern of Weibo's network, as shown by its CDFs, reflects the flexibility in supporting both centralized and decentralized information flow. Depending on the nature of the event, discussions can either fragment into smaller, independent groups or converge around key influencers, making Weibo a hybrid platform for social interactions.

4.2. Publisher and commentator distribution

The analysis across TikTok, XHS, and Weibo reveals a consistent imbalance between publishers and commenters, where the majority of users are primarily engaged in commenting, while only a small fraction act as publishers. This results in a low average degree close to 2 and a sparse network structure (Fig. 4). Most users are peripheral, engaging with content from a small number of publishers without much interaction among commenters, indicating limited horizontal interaction. The low density of network further confirms that only a small portion of possible connections between users is realized. Despite some variability in cluster sizes across platforms, all three-foster a hierarchical communication structure where publishers dominate content creation and dissemination, leading to strong vertical relationships between content creators and consumers. The dominance of commenters highlights the critical role of publishers in maintaining engagement, as they shape the information flow to a larger audience with minimal reciprocal interaction or peer-to-peer exchanges among commenters.

4.3. Geographical distribution of commentators

The analysis shows that provinces such as Zhejiang, Jiangsu, Guangdong, Shandong, and Sichuan consistently lead discussions on food safety incidents across platforms (Fig. 5). These regions demonstrate higher engagement levels, suggesting that users in these areas are more active in contributing to online conversations. This trend can be explained by several factors, including greater media coverage, higher public awareness, and more developed digital infrastructures, which facilitate higher social media interaction. Despite differences in how discussions are structured, TikTok showing more decentralized engagement across various regions, while XHS tends to be centralized around a few key areas, the commonality across platforms is that these economically advanced regions consistently dominate the discourse. This indicates that regions with higher socioeconomic status and better access to information are more likely to participate in discussions on critical topics such as food safety. The higher discussion intensity in these regions also underscores their influential role in shaping public opinion and driving conversations across different social media platforms, compared to less active or smaller provinces.

4.4. Opinion dynamics

Fig. 6 visualizes the dynamics of user opinions over time for several high-profile food safety incidents, revealing key trends in how public sentiment evolves. Across all incidents, negative and neutral opinions consistently outnumber positive ones, reflecting a generally cautious or critical stance from commentators when discussing these events. As time progresses, opinions tend to converge towards neutrality and indicates a potential stabilization of public sentiment. This shift towards neutrality can be explained by factors such as newly arriving commentators who, after reviewing previous discussions, may form more measured perspectives, or the possibility of external factors, such as hired "spammers", attempting to mitigate the perceived severity of the incidents.

The data also highlight interesting patterns in how public interest fluctuates over time. Events like the Aspartame Carcinogens, Haitian Soy Sauce, and Rat Head Incident initially receive significant public attention, leading to heightened engagement and a surge in both negative and neutral comments. However, over time, the intensity of discussion around these events gradually diminishes, reflecting a cooling-off period as the incidents fade from the immediate concern of public. On the other hand, certain events, like the Pre-packaged Food Discussion, show an opposite trend. These events might not attract much attention initially, but public interest builds gradually, with increasing numbers of commentators contributing to the discussion, driving the event into prominence over time. This evolving dynamic, where certain incidents experience a sharp initial spike in engagement followed by a gradual decline, while others grow in prominence more slowly, suggests that different events resonate with the public in distinct ways. The cooling-off of initially prominent incidents could be due to a saturation of information or a lack of new developments, whereas the rising interest in other incidents might be driven by delayed media coverage or new revelations that reignite public discourse. The trend of opinions becoming more neutral over time further supports the idea that, as more users engage and the conversation matures, extreme opinions (both positive and negative) are replaced by more balanced and informed viewpoints.

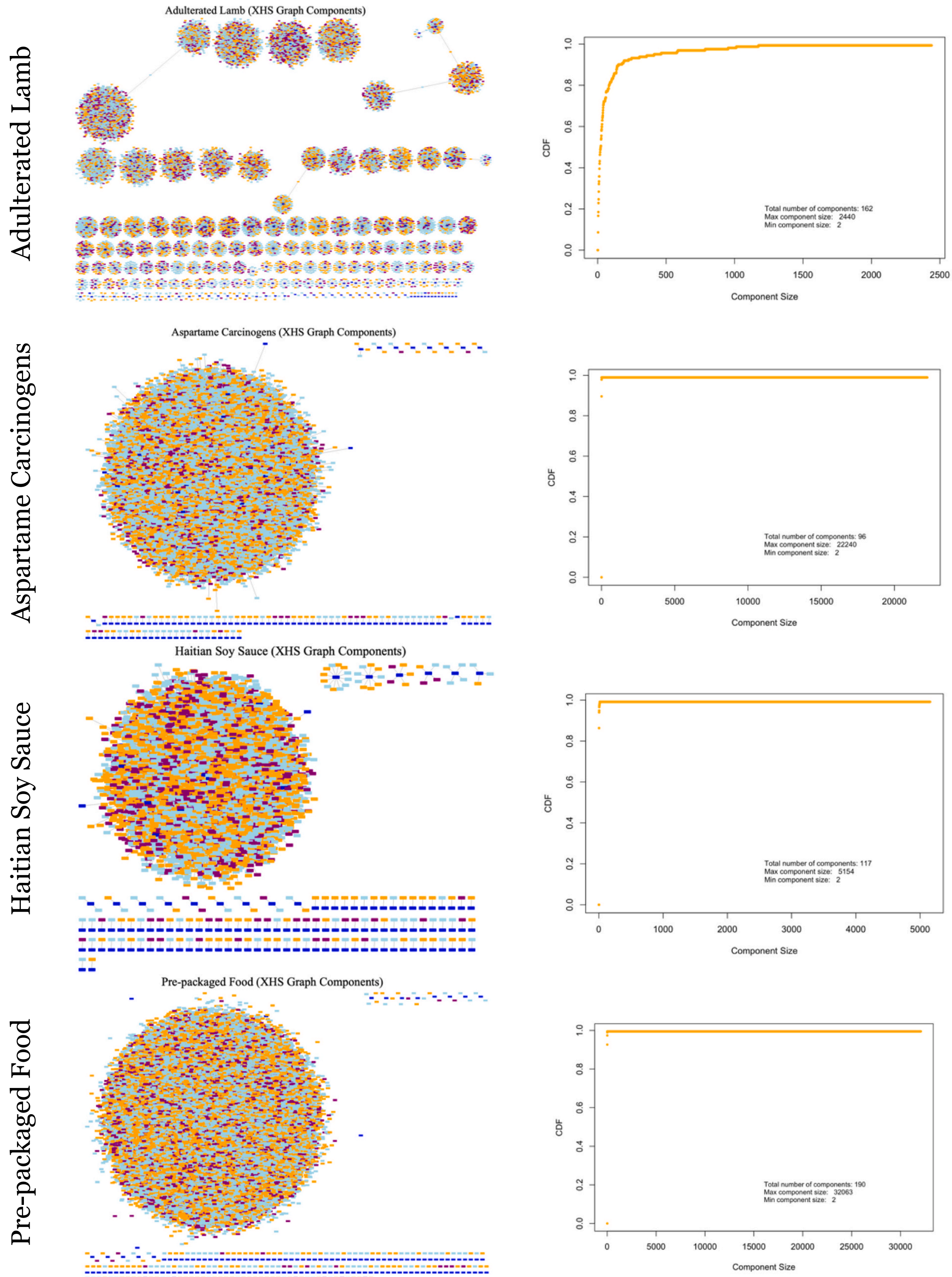

Fig. 2. XHS Network components and components statistics.

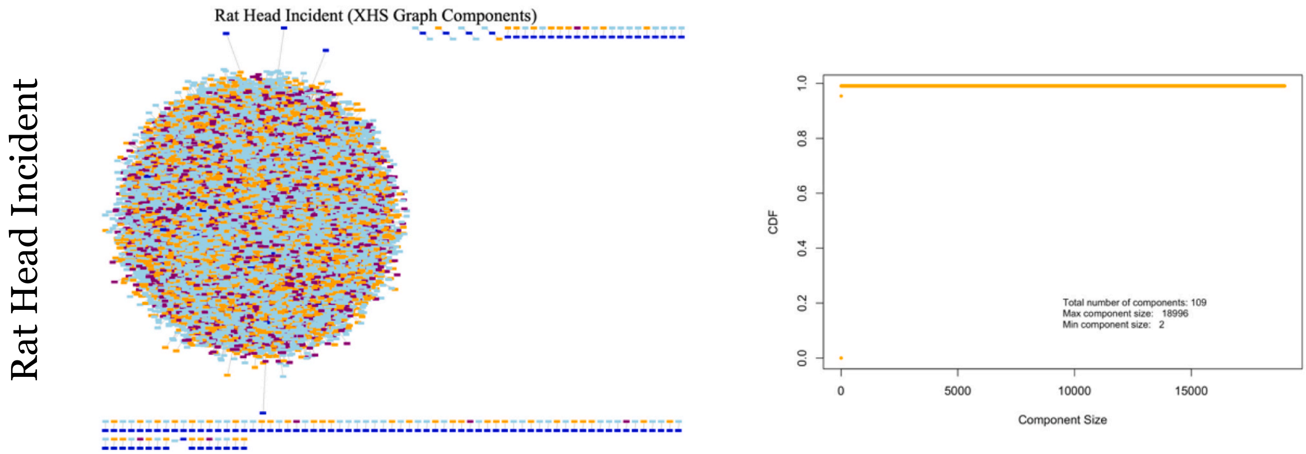

Fig. 2. (*continued*).

4.5. Edge formation dynamics over time

Fig. 7 shifts the focus towards the structural growth of interactions within the network by showing the edge formation rate over time. In the case of incidents like Aspartame Carcinogens, Haitian Soy Sauce, and the Rat Head Incident, we see a rapid surge in edge formation within the initial stages (1 to 2 months), indicating heightened public involvement during the early phases of the event. However, this engagement fades over time as fewer new connections form, signaling a cooling-off period. This decrease in interaction intensity aligns with the earlier observation of sentiment stabilization in Fig. 6, where the initial emotional reactions, whether negative or neutral, gradually level off as the topic exits the immediate interest. Conversely, events like the Adulterated Lamb and Pre-packaged Food incidents experience renewed spikes in edge formation after a considerable delay, roughly 2 to 4 years later. This pattern suggests that renewed media coverage or related incidents might have triggered these resurgences in public attention. The delayed edge formation indicates that certain topics can regain relevance in the public discourse when external factors, such as new revelations or related issues, reignite interest, leading to a secondary wave of engagement. The presence of these delayed surges of interaction reinforces the idea that some incidents are subject to longer cycles of public engagement, contrasting with those that fade more rapidly after their initial peak.

4.6. Joint distributions of infectiousness and susceptibility

Analyzing the joint distributions of infectiousness and susceptibility across different social media platforms provides crucial insights into the dynamics of information dissemination and audience influence. Fig. 8 consists of plots where each row represents the same event across three platforms, TikTok, XHS, and Weibo, allowing us to compare how information spreads and how the vulnerability of users to influence differs by platform and topic. The x-axis in each plot denotes infectiousness, representing the likelihood of users spreading information, while the y-axis represents susceptibility, indicating the likelihood of users for being influenced by others. The color gradients within the contour plots show data density, with lighter colors representing higher densities. These lighter regions indicate the overlap where infectiousness and susceptibility are the greatest.

A consistent trend observed across all events is that TikTok exhibits the lowest levels of infectiousness and susceptibility, indicating minimal engagement among its user bases. Most data points are concentrated in the lower spectrum of both axes, suggesting limited information propagation. This pattern indicates that users on TikTok are neither highly influential nor highly susceptible, resulting in discussions that are largely contained without significant reach or virality. This trend persists across all events analyzed, highlighting TikTok's general limitation in terms of effective information spread compared to XHS and Weibo. On XHS, the distributions show that while susceptibility is generally higher, infectiousness remains moderate to low across events. Specifically, the density tends to concentrate in the susceptibility range of 0.4 to 0.7, suggesting that XHS users are relatively receptive to information but not actively sharing it. This pattern of moderate susceptibility combined with limited infectiousness implies that users are interested in the topics being discussed but do not engage in spreading the information further. Consequently, the overall information dissemination on XHS is slower and less widespread compared to platforms like Weibo. Weibo, however, consistently demonstrates higher infectiousness across the majority of events, suggesting the presence of highly influential users who significantly contribute to spreading the discussions. The data density often falls within the 0.5 to 0.8 range for infectiousness, coupled with moderate susceptibility levels. This implies that while there are influential nodes actively disseminating information, the broader community susceptibility to being influenced varies. These platform-specific dynamics indicate that Weibo has a greater potential for rapid information dissemination, driven by influential users capable of sparking information cascades.

4.7. Adopters and cumulative adaptors

After analyzing infectiousness and susceptibility, understanding how information spreads, and identifying which factors contribute to rapid versus gradual adoption become essential. Examining adopters and cumulative adopters provides crucial insights into the dynamics of information diffusion, helping to determine how and why users engage with certain topics or events at different rates. Each row in the Fig. 9 represents a different event, allowing for a comparative analysis of how information diffuses through the platforms over time. The y-axis represents the number of adopters or cumulative adopters, while the x-axis shows the timeline of adoption. The red line represents cumulative adoption over time, while the black line represents new adopters within specific intervals. By analyzing these plots, we can observe distinct trends and behaviors related to how users across different platforms adopt and disseminate information about these events.

The first key observation is the variation in adoption speed and intensity across platforms. For TikTok, adoption tends to increase gradually, with a long initial period of low adoption rates before eventually showing a sharp increase near the later stages. This suggests that the content on TikTok tends to gain momentum more slowly, relying on accumulating enough social influence before the adoption rate spikes. In contrast, XHS shows an early rise in adoption followed by a steady, incremental increase. This pattern indicates that information on XHS gains

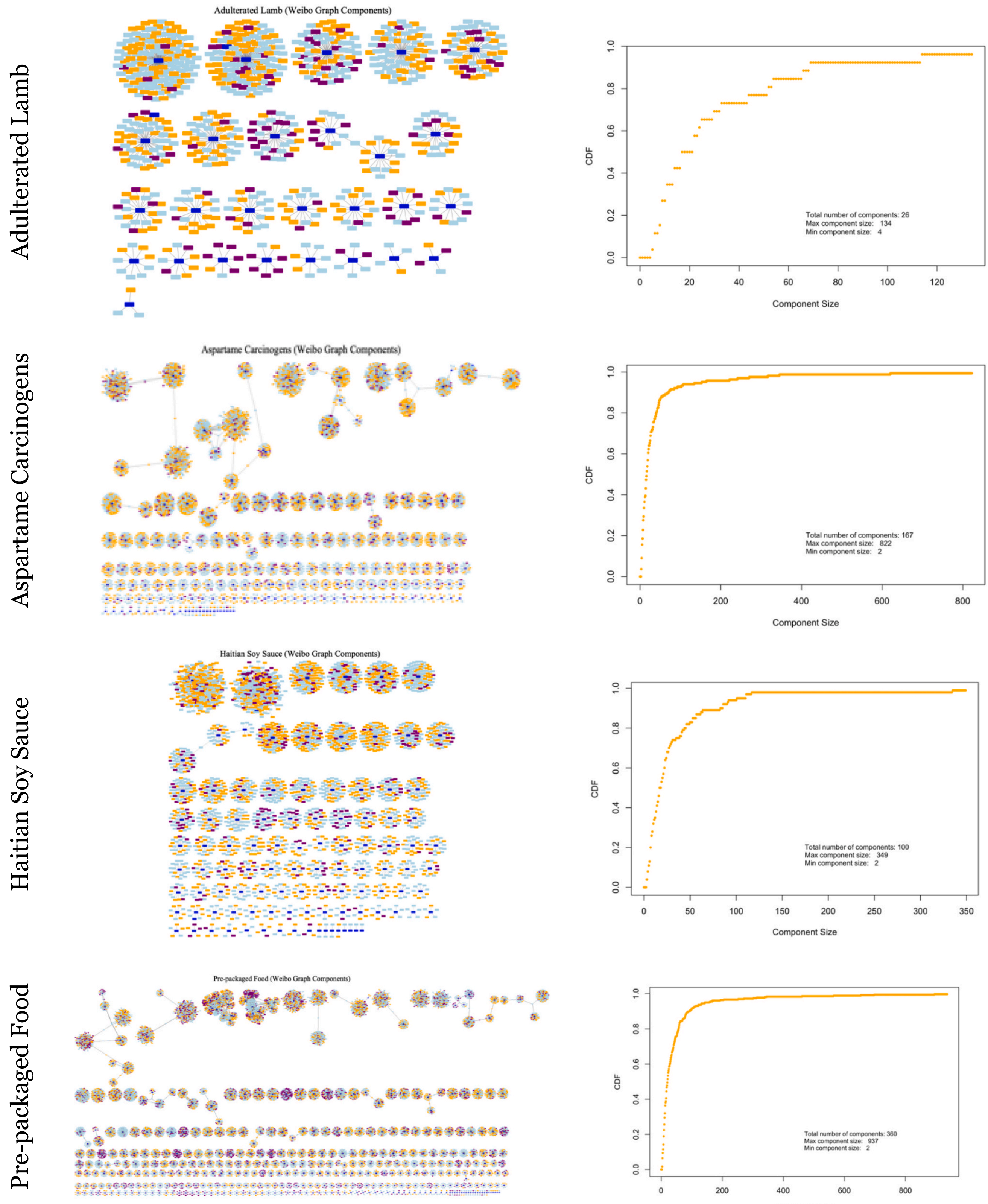

Fig. 3. Weibo Network components and components statistics.

initial traction relatively quickly but then maintains a consistent adoption pace without significant surges. Weibo, on the other hand, often exhibits a steep adoption curve at the beginning, followed by a plateau, highlighting the presence of early adopters and influential nodes driving rapid initial dissemination, which eventually levels out as the remaining users take more time to adopt.

Another notable insight from the figure is the difference in the cumulative adoption between platforms. For some events, such as the

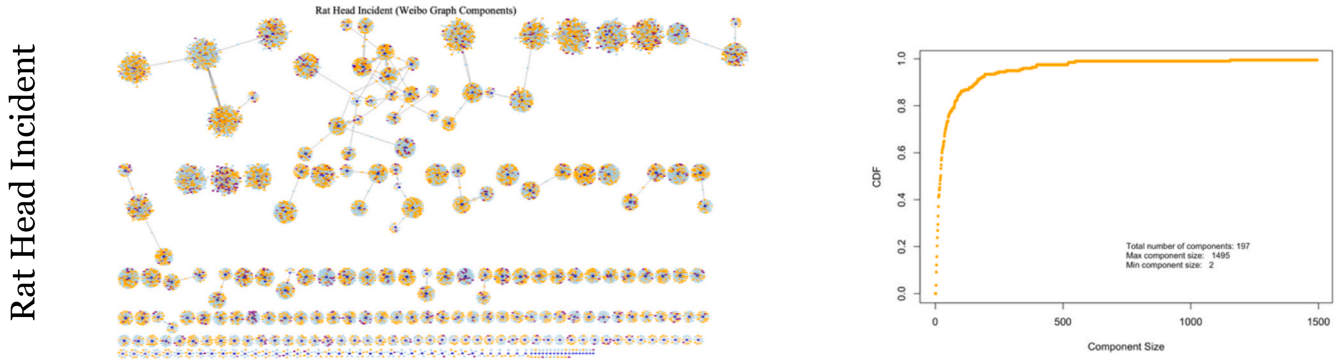

Fig. 3. (*continued*).

"Haitian Soy Sauce Event" or "Aspartame Carcinogens Issue", Weibo demonstrates a significantly higher cumulative adoption rate compared to TikTok and XHS. This suggests that Weibo, with its influential users and rapid information cascades, is more effective at reaching a large portion of the community quickly, whereas TikTok and XHS struggle to match this level of penetration. TikTok's slower cumulative growth implies a need for sustained engagement over time to achieve a similar level of dissemination. The contrasting behavior of XHS highlights its role as a platform with steady, ongoing adoption but lacking the rapid, viral spread typically seen on Weibo. The figure also reveals differences in adoption spikes among platforms for each event, which can be indicative of social triggers or external influences driving sudden adoption. For instance, on Weibo, there are distinct jumps in adoption, suggesting that certain external events or campaigns triggered bursts of user interest, rapidly increasing the number of adopters. In comparison, TikTok and XHS show smoother adoption trends with fewer spikes, implying a more organic and consistent spread of information without sudden changes in user behavior. The presence of these adoption spikes on Weibo highlights the platform's susceptibility to external influences, which can quickly mobilize a large number of users, thereby facilitating rapid spread through influential nodes. This suggests that while TikTok and XHS users are more likely to adopt information at a steady pace, Weibo is highly reactive, capable of rapidly amplifying events given the right triggers.

4.8. *Platform mechanisms of food safety information diffusion*

TikTok's communication space is shaped by an infrastructure designed for velocity over coherence,an environment optimized for rapid content turnover and high-frequency algorithmic exposure. Information is diffused widely but absorbed shallowly. This structural signature is reflected in the empirical data: a prevalence of small, weakly connected clusters, low levels of infectiousness and susceptibility, and delayed engagement peaks. The joint distribution of infectiousness and susceptibility further reinforces this dynamic: most users on TikTok neither influence others nor are meaningfully influenced themselves, resulting in a flattened diffusion structure where information tends to circulate within short-lived, low-interaction bursts. Consequently, cumulative adoption curves for food safety incidents on the platform often remain stagnant during the early phase, only rising sharply at later stages,if at all, suggesting that it takes substantial external attention or algorithmic momentum before an issue enters collective awareness. Such dynamics point to an infrastructural logic where visibility is algorithmically driven and temporally short-lived, rather than reinforced through relational embedding or cumulative trust. Within the S-I model, this reveals a decoupling between infrastructure and substance, the technical layer pushes content in rapid pulses, but the interaction layer lacks anchoring mechanisms to consolidate attention, dialogue, or community formation. From an IDOM perspective, TikTok exemplifies a loosely coupled, high-throughput service configuration, where performance is measured by impression metrics rather than informational stability. It prioritizes delivery over deliberation, and novelty over narrative accumulation. As a result, information flows through the system in parallel bursts, efficient in reach, but fragile in retention and self-correction. The absence of relational density or feedback consolidation means that once misinformation begins to circulate, the system offers little endogenous resistance, memory, or repair capability. In the context of food safety incidents, often marked by ambiguity, emotion, and the absence of authoritative verification, this makes TikTok a particularly brittle environment. Risk signals may spread rapidly but shallowly, triggering alarm without the narrative infrastructure required for either trust building or clarification. In such cases, public concern may spike briefly, then evaporate, leaving little space for follow-up correction, institutional engagement, or informed risk appraisal.

XHS, by contrast, exhibits a structurally tighter coupling between technological infrastructure and content dynamics. Its centralized cluster structures, vertically tiered publisher, audience relations, and slow but stable adoption trajectories suggest that exposure is mediated less by algorithmic breadth and more by social endorsement. Infectiousness remains relatively low, but susceptibility is concentrated in the 0.4–0.7 range, indicating that users are receptive to content but seldom act as secondary disseminators. This leads to a layered but narrow dissemination logic: information is internalized, discussed, and occasionally recirculated, but rarely achieves rapid systemic reach. Adoption data further confirms this tendency: cumulative adoption curves on XHS rise early but incrementally, without the sharp accelerations characteristic of viral contagion. For food safety issues, this creates a paradox. On the one hand, the platform nurtures attentive and engaged discussions within high-affinity communities, allowing for in-depth concern and sustained moral engagement. On the other hand, it generates insular opinion clusters that may reinforce misinformation if not adequately addressed from within. From the S-I perspective, this is a tightly coupled architecture, where infrastructure and substance are aligned to foster internal consistency at the cost of systemic permeability. Under the IDOM framework, this structure ensures communication fidelity but reduces adaptability. If a false narrative, say, about chemical additives or contamination, gains traction in a trusted KOL's network, the very mechanisms that ensure coherence may suppress correction, allowing the story to persist well beyond its factual expiry date.

Weibo presents a more fluid and adaptive configuration. Its ability to shift between decentralized and centralized structures, depending on the event's content and social temperature, reveals a modular infrastructure attuned to both trending amplification and influencer broadcasting. This dual modality supports rapid escalation of topics, as seen in the platform's high infectiousness scores and steep early adoption spikes. Users demonstrate considerable capacity to both influence and be influenced, forming the conditions for large-scale information cascades. Content moves swiftly between trending algorithms and relational relays, enabling real-time synchronization of user attention. Cumulative

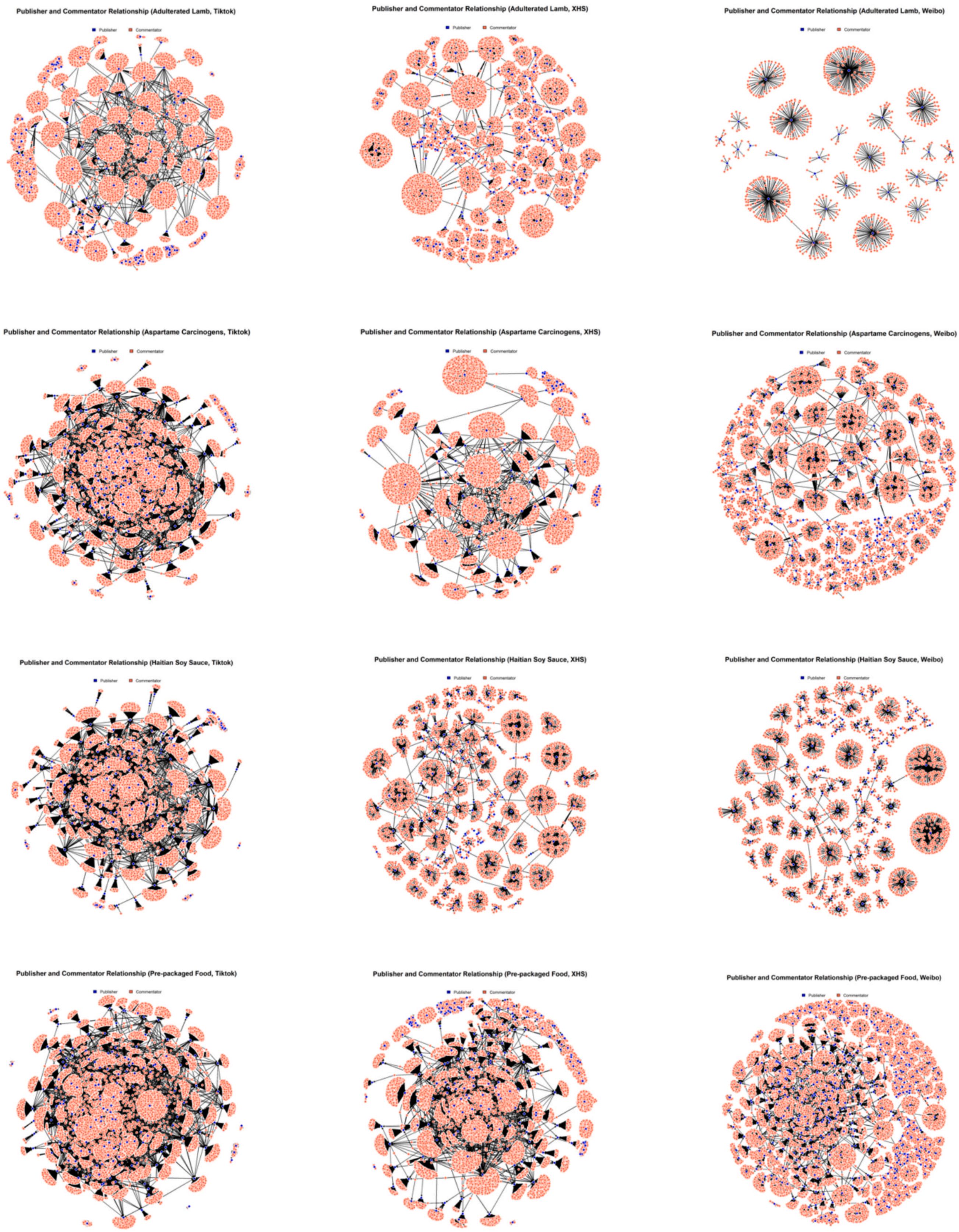

Fig. 4. Publisher and commentator distribution in the Weibo, XHS and TikTok networks.

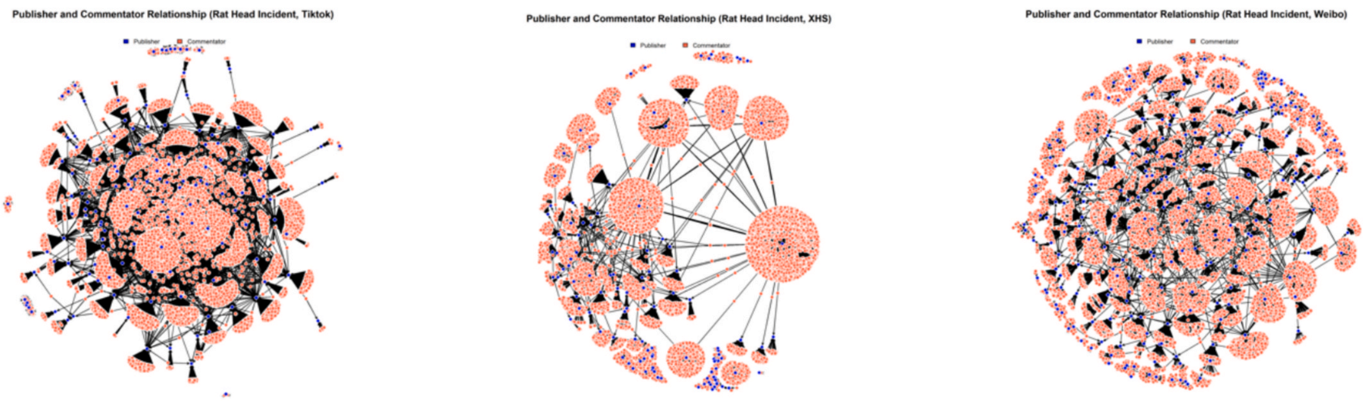

Fig. 4. (*continued*).

adoption curves on Weibo tend to rise sharply in the early phase, then plateau, suggesting that the platform excels at initial mobilization but may exhaust audience attention quickly. In the S-I framework, Weibo demonstrates high vertical and horizontal transmission elasticity, the infrastructure can amplify content across system layers, while the substance layer quickly adapts to contextual stimuli. From an IDOM perspective, Weibo functions as a semi-open system with short, recursive feedback loops. It allows external shock, news cycles, policy interventions, or user mobilization, to reconfigure discourse almost instantaneously. This agility enables the platform to mobilize public attention at scale, which is particularly powerful in the context of public health emergencies. However, it also means that emotionally charged or misleading content can cascade before validation mechanisms activate. Without embedded structural dampeners or deliberative buffers, the system may overreact to weak signals, producing amplification without verification and attention without retention. In the domain of food safety, this responsiveness allows risk signals to circulate quickly, opens the system to volatility, overreaction, or premature blame attribution, particularly when scientific evidence lags behind public interpretation.

These divergent platform logics reveal that S-I alignment is a foundational determinant of how food safety information spreads, stabilizes, or self-disrupts. TikTok's system favors ephemerality over resilience: it broadcasts without binding. XHS privileges coherence over reach: it cultivates depth at the expense of adaptability. Weibo enables responsiveness without restraint: it circulates fast, but with volatile control. These are not stylistic distinctions, but embedded operational models, distinct ways in which platforms configure attention, influence, and error tolerance. Together, these perspectives offer a powerful explanatory lens: why some platforms amplify food-related rumors explosively, others contain them quietly, and why public trust can either consolidate, polarize, or collapse depending on how the environment scaffolds interaction.

5. Discussion

The asymmetric amplification of food-related rumors across digital platforms, where some narratives ignite viral cascades while others dissipate quietly, necessitates a shift in analytical lens. Rather than viewing social media as linear pipelines of content transmission, this study reconceptualizes platforms such as TikTok, Weibo, and XHS as Information Service Systems (ISS): open, adaptive, and cybernetic environments in which heterogeneous agents, users, algorithms, institutions, co-produce public knowledge through recursive feedback loops (Beer, 2022).

Drawing on Service System Theory (Bardhan et al., 2010) and systems engineering (Böhmann et al., 2014), we define the ISS boundary to encompass both technical infrastructure (e.g., recommendation algorithms, trending logic, content visibility mechanisms) and socio-cultural architectures (e.g., community norms, emotional triggers, historical trust trajectories). These platforms are epistemic ecosystems that dynamically regulate what is seen, believed, and acted upon (Fig. 10). Every informational pulse, be it a food safety alert, rumor, or correction, is filtered through interactions among information generators (e.g., users, KOLs, institutional actors), dissemination architectures (e.g., topic hubs, For-You pages), and interpretive agents (e.g., user clusters with varying cognitive styles and norms).

Each subsystem performs a regulatory function: users provide behavioral data (e.g., sharing, commenting, flagging), communities encode and reinforce normative cues, algorithms translate engagement into visibility, and institutions inject validation or correction signals (Hao et al., 2025b). These semi-autonomous modules together form a distributed control structure, in which governance is emergent rather than centrally dictated. Critically, this governance is nonlinear and path-dependent, platform responses evolve in reaction to informational shocks, structural biases, and user cognition, rather than according to deterministic rules (Thietart and Malaurent, 2024). On platforms such as TikTok, information flow is organized through weak-tie architectures that permit the lateral diffusion of content across minimally connected micro-clusters. These configurations encourage interpretive pluralism but undermine coordinated response, allowing contradictory narratives, correct and false, to co-exist in self-contained feedback loops (Chan and Fu, 2017). Granovetter's weak-tie theory, when transposed onto a digital topology governed by engagement-maximizing algorithms, reveals a trade-off between deliberative capacity and temporal synchrony (Granovetter, 1983). Misinformation becomes locally validated within micro-publics, where emotional salience outpaces factual accuracy. This creates "informational eddies", in which corrective interventions may arrive yet fail to circulate systemically (Ecker et al., 2022). Such systems exhibit high resilience to single-point failure but suffer from latency and fragmentation during crisis events requiring unified action, such as product recalls or contamination outbreaks. Compounding this issue is the platform's inherent temporal structure: a logic of "nowcasting" that prioritizes real-time performance over slow epistemic repair (Torres et al., 2018). Misinformation thrives in this gap because it is emotionally resonant and temporally optimized, moving faster than correction, feeding off ambiguity, and diffusing before institutional knowledge has even been stabilized (Nanath et al., 2022). The role of algorithmic infrastructure in this dynamic cannot be overemphasized. These algorithms function as endogenous controllers, they enforce system goals through embedded reward functions (Yeung, 2018). The predominant optimization criterion, engagement, serves as a surrogate for relevance but introduces epistemic distortion (Hao and Demir, 2025). In food safety scenarios, emotionally charged misinformation (e.g., graphic contamination visuals) is algorithmically privileged, due to its virality. As such, algorithms create reinforcement loops, where initial misinformation is amplified, re-validated, and insulated against correction.

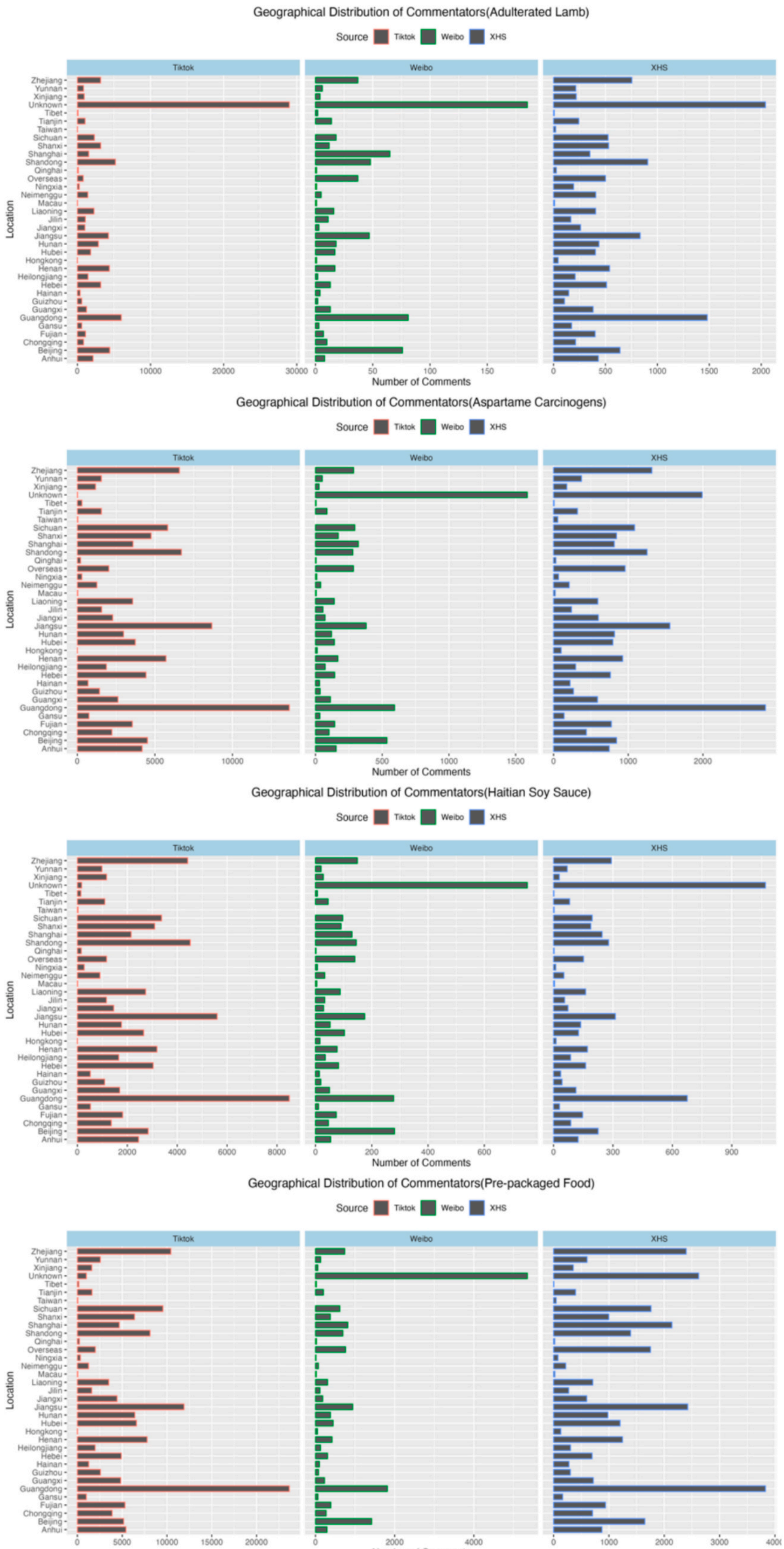

Fig. 5. Geographical distribution of commentators.

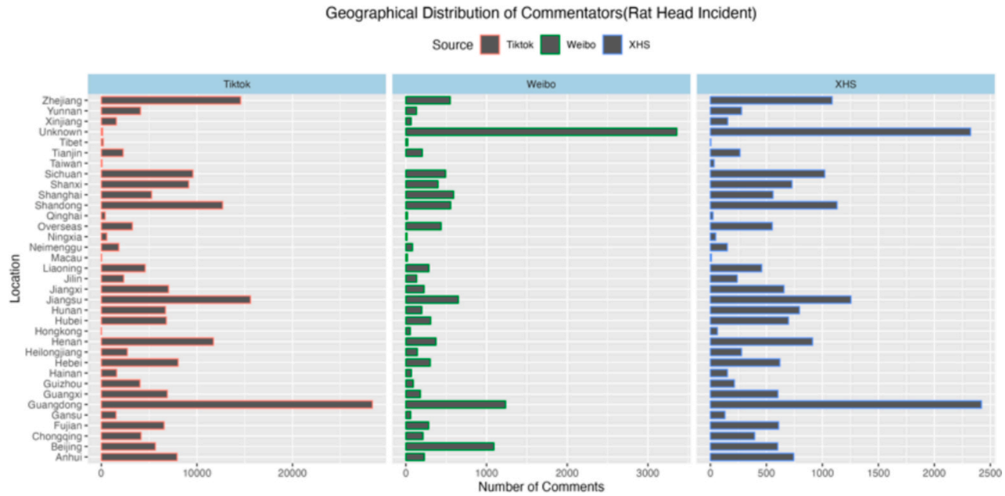

Fig. 5. (*continued*).

Drawing on control theory, this feedback resembles a miscalibrated autopilot: sensor input (user behavior) triggers an overcorrection (algorithmic amplification), which destabilizes the informational equilibrium rather than restoring it (Wan et al., 2022). Moreover, these control loops rarely incorporate a mechanism for epistemic accountability. There is no memory of prior mistakes encoded into future recommendations, no system-wide feedback for trust decay or narrative volatility. Instead, the system is geared toward short-term optimization, producing a structurally myopic model of public knowledge (Liu et al., 2023).

By contrast, XHS's architecture is vertically structured, heavily reliant on KOLs who function as epistemic relays between institutional knowledge and lay publics. The platform embeds a modernized two-step flow model, wherein KOLs serve dual roles as gatekeepers and narrative framers, selectively curating information that fits their personal branding or perceived credibility. This design ensures rapid top-down dissemination during emergencies, streamlining the delivery of verified food safety messages. The efficiency of this system was particularly evident during the COVID-19 pandemic, where corrective narratives from regulatory bodies were swiftly channeled through influencer networks, maintaining public compliance and trust (Chiang et al., 2024). However, the structural advantage of speed entails a fragility: when a high-trust node disseminates misinformation, the damage is amplified with equal velocity and authority (Luo et al., 2023). The rat head incident illustrates this vividly, a single authoritative post, later debunked, had already reconfigured public perception across millions of nodes. In this context, platform structure becomes a vector of epistemic risk: speed accelerates both trust propagation and breakdown. More importantly, the concentration of narrative control in KOLs creates a singular failure mode: once corrupted or co-opted, these actors collapse the distinction between individual expression and systemic authority, leaving users with no epistemic recourse but distrust (Sun et al., 2024). Weibo, occupying a hybrid position, illustrates architectural adaptability as a trust-regulatory mechanism. In times of low salience, the platform accommodates decentralized interpretive processes, allowing user communities to debate, contest, and refine narratives around food sustainability, ethical sourcing, and consumer rights. In contrast, during acute crises, Weibo reverts to a centralized control mode, algorithmically boosting state-sanctioned information while suppressing conflicting content. This oscillation reflects what Woods conceptualized as "graceful extensibility", the capacity of complex systems to modulate control intensity in response to perturbation without collapsing. Such capacity is critical to managing uncertainty without overfitting the system to a singular logic (Fadlullah et al., 2017). The resilience of Weibo thus resides in its capacity for mode-shifting, enabling pluralism under normal conditions and cohesion under threat. However, this adaptivity can obscure responsibility: as control shifts back and forth between state and crowd, it becomes unclear who is answerable when misinformation persists or when suppression causes overcorrection (Lewandowsky et al., 2012). Without stable accountability circuits, the system becomes elastic but morally opaque.

In this system model, government interventions are operationalized as control signals aimed at modulating the system's informational state toward stability (Zhang et al., 2020). These include real-time announcements, policy clarifications, and debunking campaigns (Fig. 10). However, for control to be effective, signals must align with the platform's internal state variables, namely, algorithmic affordances and user-level trust baselines (Chaudhuri et al., 2024). When these signals are out of sync, due to poor timing, lack of cultural congruence, or historical distrust, they produce feedback misalignment, a condition in which corrective signals are either ignored, filtered, or inverted. This leads to what we term epistemic fracture, wherein institutional credibility collapses and counter-narratives (often conspiratorial or emotionally resonant) gain discursive dominance. Crucially, this misalignment is a control systems failure: the intended regulatory intervention fails to reach, resonate with, or recalibrate its target substructure. The resulting information disorder is systemic dysfunction, a breakdown of signal-response coherence between controller and system (Desouza et al., 2020).

To repair this dysfunction, platforms must be designed as reflexive control systems capable of self-diagnosing, adapting, and restoring epistemic order (Aïmeur et al., 2023). This calls for a transition from conventional "robustness" to adaptive coherence, a dynamic equilibrium wherein the system continuously adjusts feedback strength and structure based on environmental perturbations. Within this model, three layers of restitution are required: (1) factual recalibration, ensuring content accuracy through cross-source verification (Moravec et al., 2022); (2) narrative recontextualization, explaining the provenance and rationale of corrections (Spitzberg, 2021); and (3) trust rescaffolding, offering interface-level cues and interaction models that rebuild user belief in the information ecosystem (Maddah and Esmaeilzadeh, 2023). Control mechanisms such as delay-before-share features, dynamic warning labels, and uncertainty visualizations must be tuned to the system's local dynamics, including user emotional states, cultural epistemologies, and historical memory. Importantly, these mechanisms cannot be universal or static, they must be modular, interpretable, and feedback-responsive, evolving in tandem with the system they regulate (Zhou et al., 2025).

Operationalizing such a reflexive system requires diagnostic modeling and continuous monitoring, where key metrics are used to

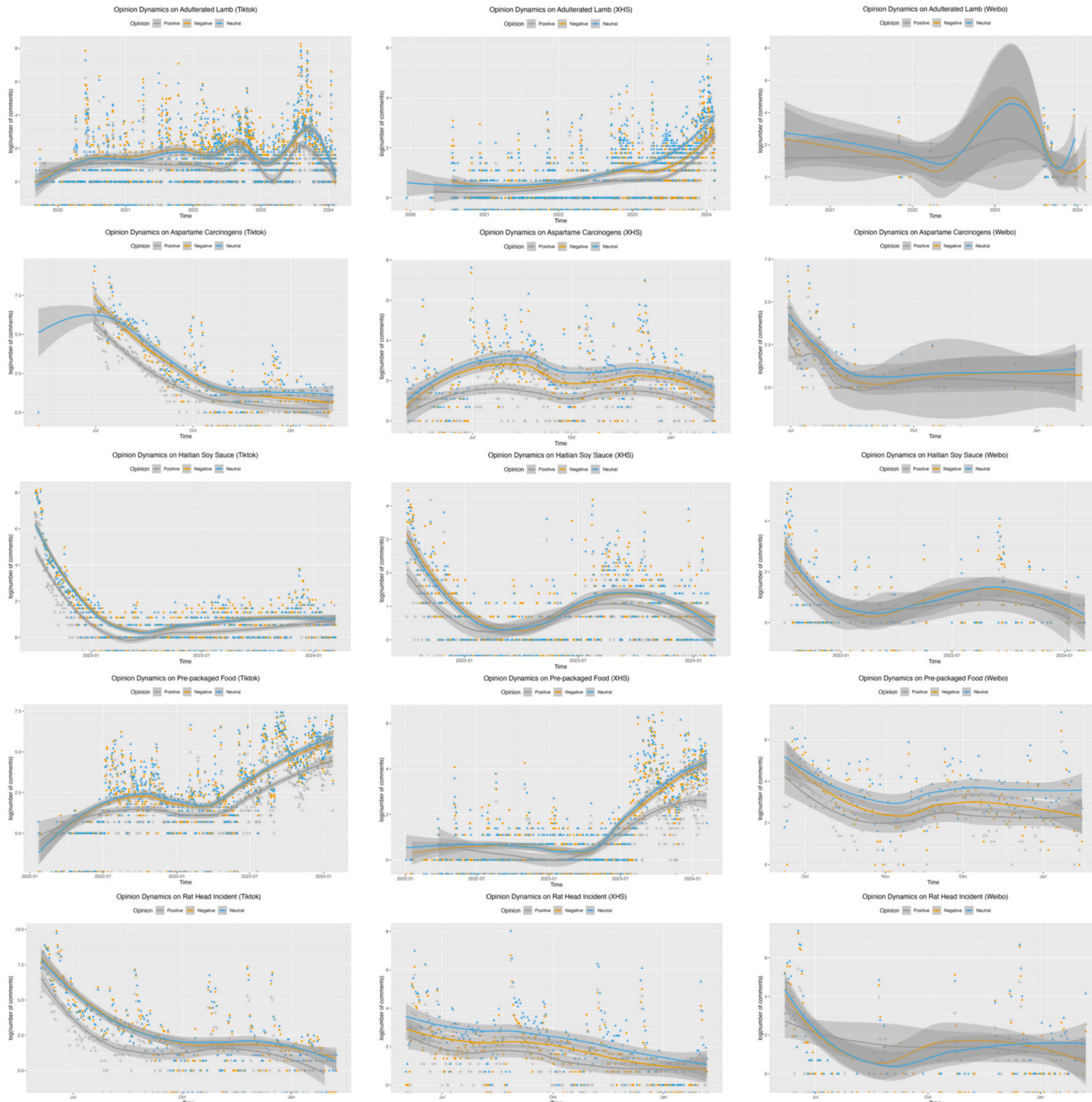

Fig. 6. Opinion dynamics over time (The x-axis counts for the number of commentators who held Positive, Negative, or Neutral opinions on a per day basis).

track system health and guide intervention. These include: misinformation half-life, correction latency, trust trajectory curvature, and user-algorithm-controller synchronization indices. Together, these metrics form the foundation for a predictive control layer, enabling early detection of system drift and timely coordination across institutional actors. However, measurement without governance alignment remains inert. Thus, governments, platforms, and civil society actors must establish a shared protocol layer, a governance interface, that allows for real-time alignment of signals, thresholds, and responses (Zhang and Hao, 2024). This is particularly vital for "epistemic cold zones", rural, linguistically marginalized, or algorithmically underexposed user populations. In such segments, informational failure is not due to systemic exclusion from the feedback loop. Ensuring resilient ISS design thus demands a commitment to epistemic inclusion, where platform governance mechanisms are culturally adaptable, technologically accessible, and cognitively empowering. Ultimately, trust in food safety information cannot be sustained through content policing alone; it must emerge from system architectures that anticipate turbulence, distribute accountability, and learn from breakdown, transforming fragility into resilience through principled, real-time coordination (Zhang and Wang, 2024).

In the domain of food safety, where informational failure can trigger behavioral errors with immediate public health consequences, this systemic model has practical urgency (Liu et al., 2024). Platforms must evolve into reflexive control systems, capable of sensing misalignment, adjusting feedback gain, and learning from historical failures.

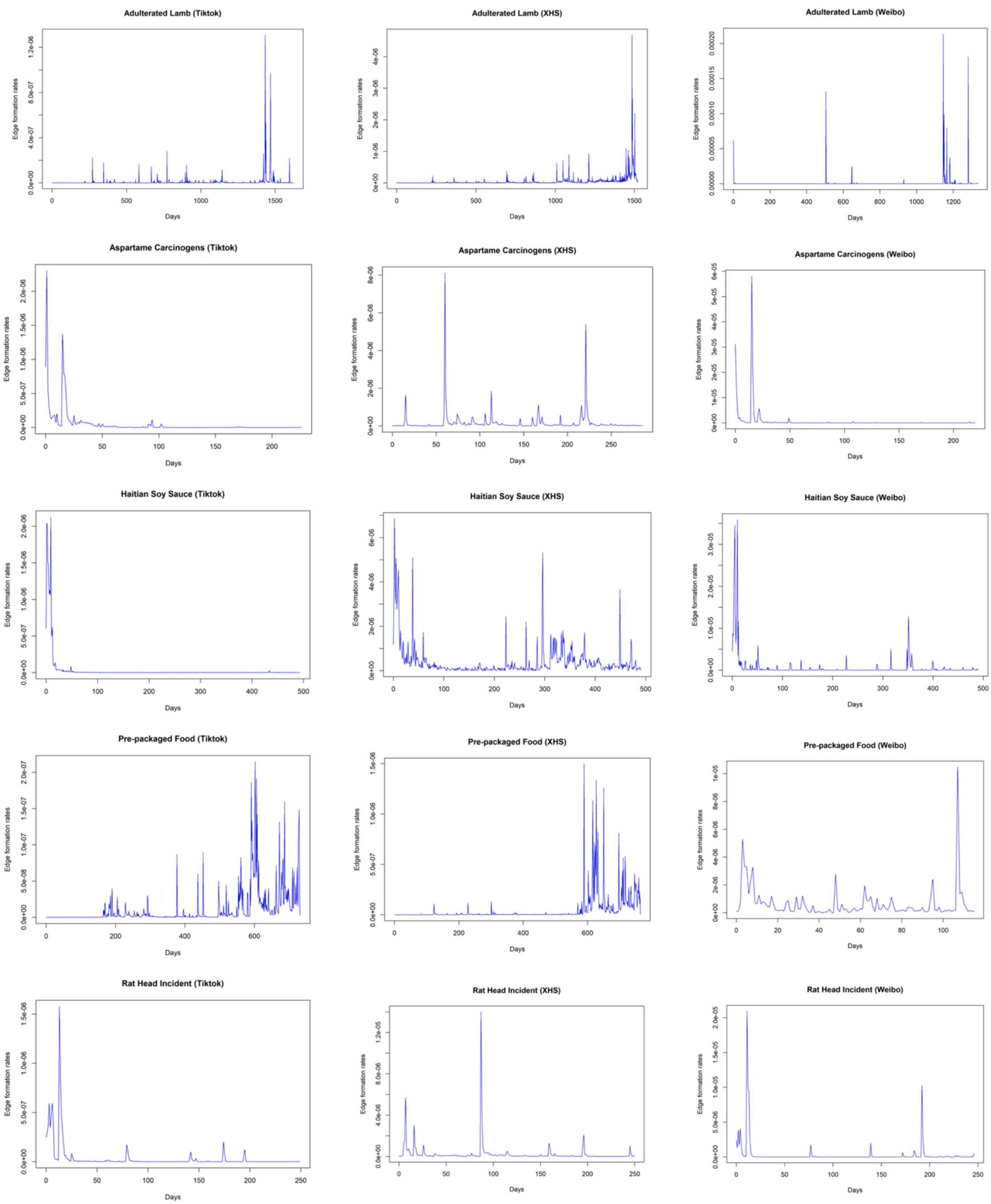

Fig. 7. Edge formation rate.

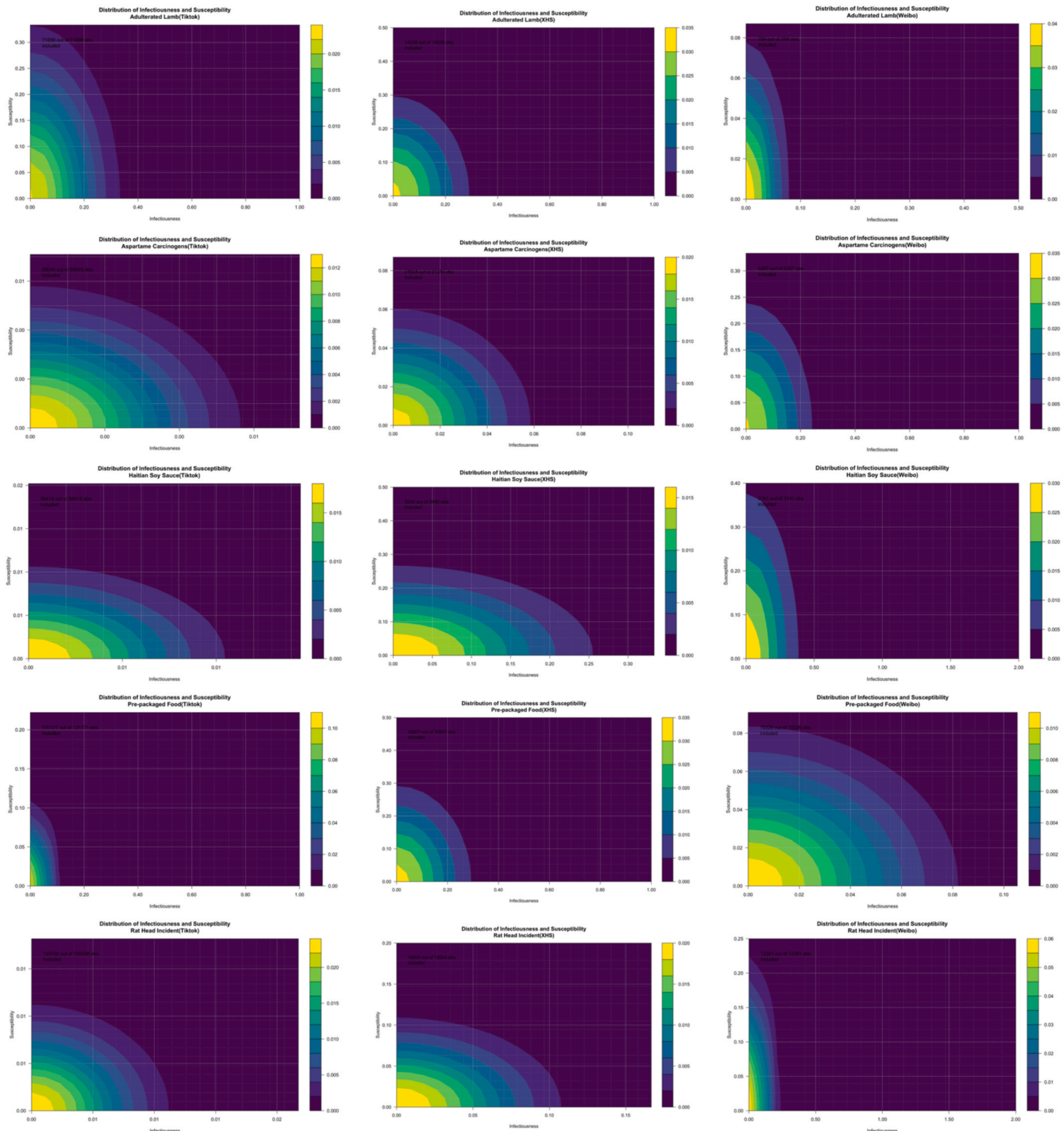

Fig. 8. Joint distributions of infectiousness and susceptibility in the social networks.

Institutions must reorient themselves as co-architects of trust infrastructure, embedding flexible governance logic into the operational of platforms (Hao et al., 2025b). Users must be empowered through education, interface transparency, and participatory verification mechanisms, transforming from passive recipients into active epistemic agents capable of co-regulating informational stability (Gao et al., 2023). Trust, once broken, must be understood not as a commodity to be regained but as a relationship to be continuously maintained, situated at the interface between memory, design, and action. To govern food safety knowledge in a digitally saturated world is to engage in real-time socio-technical orchestration, balancing speed, accuracy, authority, and inclusivity (Hao et al., 2025a). Platform upgrades are insufficient if they do not address the foundational design principles that govern how information is sensed, filtered, and enacted (Warnke et al., 2024). A truly resilient information ecosystem must learn to anticipate turbulence, absorb disruption, and self-correct before systemic coherence is lost. Only through this paradigm can platforms do more than inform; they must become infrastructures of collective trust, epistemic repair, and public health resilience, capable not only of stopping the next misinformation wave but of learning from it, metabolizing its failures, and emerging

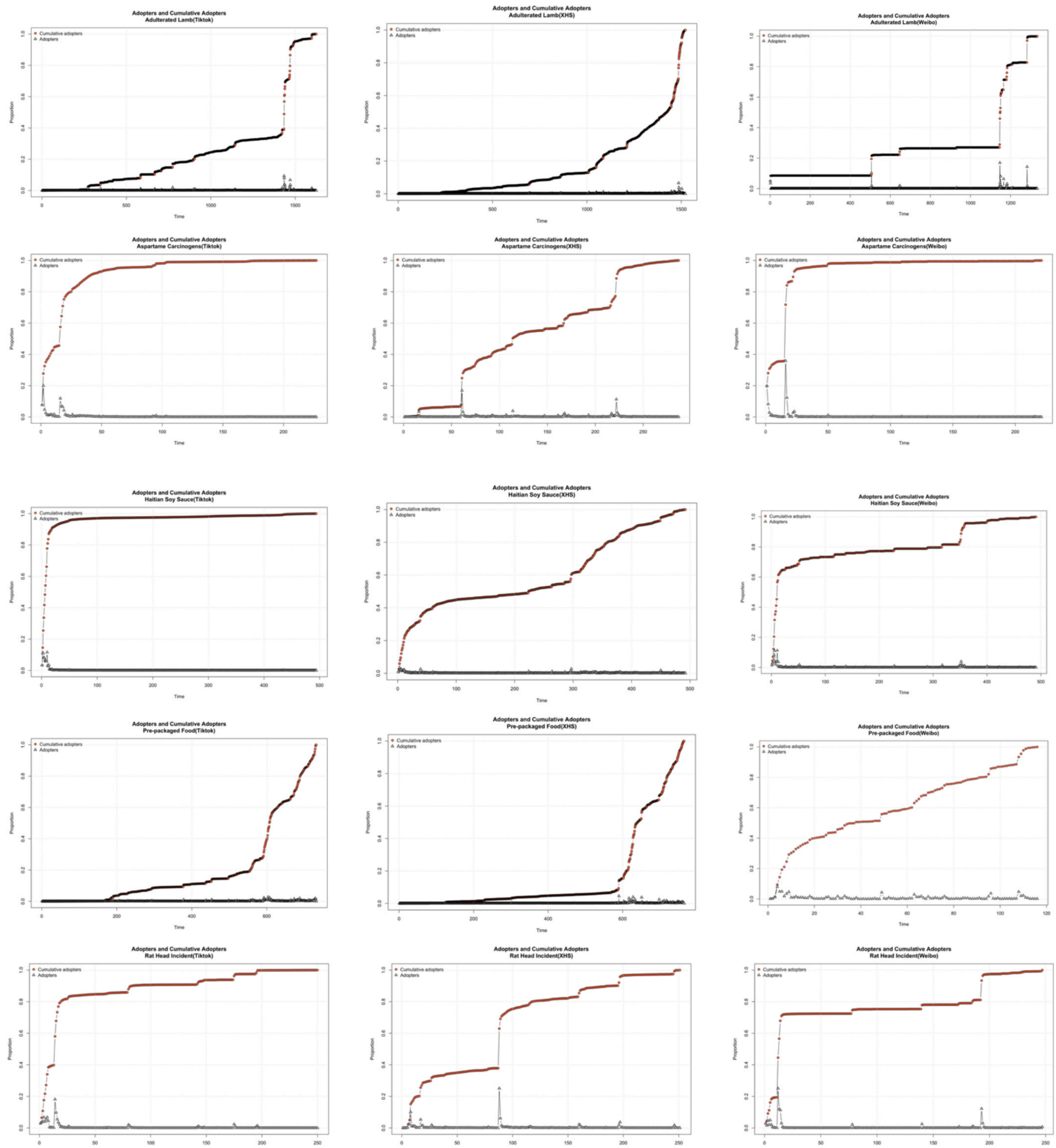

Fig. 9. Adopters and cumulative adaptors.

with stronger institutional memory and shared epistemic ground.

6. Conclusions

This study redefines the dissemination of food safety information not as a matter of message accuracy or user rationality alone, but as a function of platform-specific systemic behavior under crisis. By framing social media platforms as ISS, recursive, cybernetic ecologies composed of human cognition, algorithmic governance, and institutional modulation, we shift the analytical focus from isolated content to the structural and dynamic conditions under which public understanding emerges, decays, and recovers. In doing so, we directly address the three foundational research questions: (1) how infrastructures and content substances jointly shape the dissemination process, (2) how user interaction and visibility evolve over time, and (3) what interventions can build trustworthy, resilient diffusion pathways in the aftermath of disruption. Our findings reveal that the spread and interpretation of food safety information are neither platform-neutral nor content-

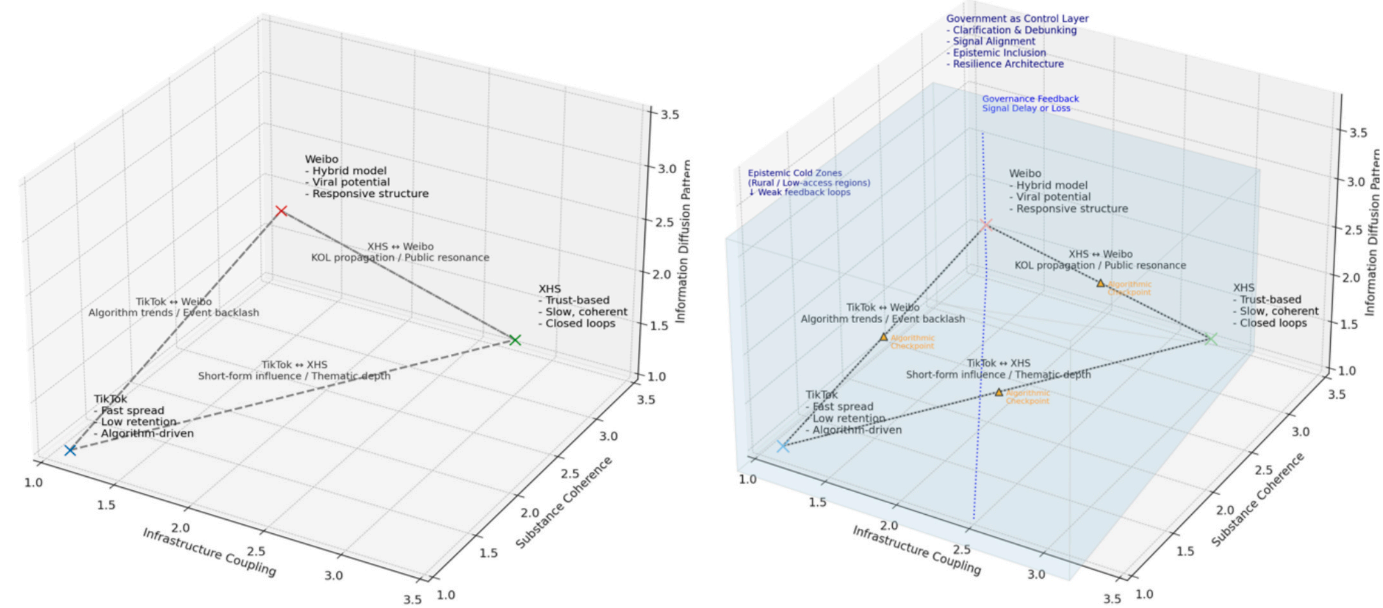

Fig. 10. S-I Alignment and Government Interventions in Food Safety Information Diffusion.

deterministic. Rather, they emerge from the nonlinear interaction between algorithmic infrastructures and the semantic-affective properties of information, situated within evolving socio-technical feedback loops. TikTok, with its fragmented weak-tie topology and engagement-maximizing algorithm, enables expressive pluralism yet impairs epistemic consolidation. Its architecture rewards volatility, rapid bursts of attention and emotionally resonant formatswhile providing little scaffolding for deliberative correction or long-term memory. Misinformation, once seeded, travels through loosely coupled clusters with minimal resistance, and truth, even when introduced, often fails to achieve coherence or salience.

In contrast, XHS exhibits a centralized and authority-oriented architecture, wherein content credibility is tightly linked to a handful of KOLs. This configuration allows for rapid dissemination of curated narratives and enables fast shifts in public sentiment, but also embeds risk: once high-trust nodes propagate flawed messages, misinformation gains stability within insulated epistemic loops. XHS thus presents a paradox of speed versus resilience, its strengths in narrative amplification become weaknesses when trust is misallocated or manipulated. Meanwhile, Weibo's hybrid architecture, alternating between decentralized user interactions and centralized topic guidance, exhibits greater epistemic elasticity, enabling adaptive modulation in response to crises. Its dual-mode structure supports both rapid crisis escalation management and sustained deliberation, offering a rare balance between immediacy and reflection.

These platform divergences underscore a central insight: crisis communication effectiveness is not merely an outcome of message quality, but of how well platform architectures synchronize with evolving user cognition under conditions of uncertainty. In ISS terms, each platform forms a distinct epistemic ecology, a configuration of infrastructural affordances, feedback timing, and trust pathways, that governs how publics know, act, and respond. Importantly, these ecologies are not static; they shift as crises unfold. Early-stage volatility, mid-stage polarization, and late-stage fatigue follow different trajectories across platforms, shaped by network topologies, information pacing mechanisms, and the location of epistemic anchors. Understanding these temporal dynamics is essential for designing interventions that preempt epistemic drift and rebuild coherence in real time. From a systems engineering perspective, the resilience of food safety communication lies not in eliminating noise, but in the system's capacity to maintain interpretive stability under informational shock. We propose a three-layer trust repair model, factual recalibration (injecting timely corrections), narrative recontextualization (embedding truth within resonant frames), and interactional re-scaffolding (designing interfaces that support reflection and memory). Without alignment across these layers, even accurate signals risk being rejected, delayed, or cognitively bypassed. Epistemic fracture, where the controller's intent fails to register within the system, emerges not from ignorance, but from feedback misalignment between platform rhythms, user sensemaking, and institutional signaling. Critically, our study moves beyond the binary of misinformation versus correction, and toward a reflexive governance model. Here, platforms are cybernetic regulators, capable of detecting weak signals, adjusting amplification thresholds, and coordinating with institutional actors in real time. For example, TikTok requires early-stage seeding of verified content into weak-tie networks and the integration of credibility-aware algorithms that privilege coherence over virality. XHS must implement pre-dissemination verification pipelines for KOLs and introduce multi-source visibility tools that disrupt epistemic insulation. Weibo, with its hybrid affordances, is well-suited for adaptive feedback loops, such as real-time trust dashboards or friction-based sharing controls that activate during high-risk episodes. Across all platforms, the interface layer must evolve to support cognitive traceability, through citation overlays, version histories, and uncertainty tags, thereby equipping users not just with facts, but with the epistemic tools to reason through them.

Policy Proposition for Governmental Intervention in Digital Food Safety Communication

To enhance the stability and credibility of food safety information in digital ecosystems, governments must evolve from reactive broadcasters to embedded regulatory agents within the informational feedback loops of social media systems. In these algorithmically driven environments, public trust is not established through factual accuracy alone, but through the alignment of corrective signals with the cognitive timing, emotional cadence, and interface structure of user engagement. Government interventions must be calibrated to the platform's epistemic architecture: rather than issuing static announcements, regulators should seed verified signals early via diverse, trusted community nodes, enabling resilient diffusion before misinformation solidifies. Simultaneously, real-time verification protocols and credibility indicators should be embedded at the content level to scaffold user interpretation. In moments of high volatility, friction-based interventions,such as delay mechanisms, automated source triangulation, and semantic conflict detection, can slow virality while preserving deliberative capacity. Most critically, a centralized Digital Resilience Dashboard is needed to monitor epistemic stress in real time, enabling precision-guided, context-sensitive governance. In this systems approach, informational stability is not enforced from above, but co-produced through recursive, adaptive feedback between institutional controllers, platform infrastructures, and user cognition.

Designing Epistemic Infrastructures: A Governance Agenda for Platform Operators.

For platform operators, the central task is no longer reactive moderation, but the proactive design of epistemically stable information architectures. Relying solely on engagement metrics to prioritize content is insufficient in the context of public risk communication. Algorithms must evolve to integrate epistemic weighting, which accounts for semantic consistency, provenance transparency, and inter-network coherence. This demands a fundamental reconfiguration of diffusion logics, moving from models that optimize for click-through and retention to those that simulate the long-term effects of content on interpretive clarity and public reasoning. Furthermore, algorithmic governance must be modular and responsive: instead of applying static rules across contexts, platforms should dynamically activate content friction, visibility dampening, or cross-signal triangulation based on real-time indicators of volatility. Ultimately, a platform's credibility will rest not just on its ability to suppress misinformation, but on its capacity to restore epistemic symmetry, aligning what is known, what is visible, and what is collectively trusted.

Fostering Epistemic Agency: Civic Literacy and Collective Verification in the Digital Age.

At the individual and civil society level, fostering epistemic agency becomes equally critical. Users are not passive consumers of content; they are interpretive agents and decentralized moderators within the platform's information service system. Digital literacy must expand to include platform literacy,an understanding of how algorithmic cues, feedback loops, and emotional salience shape information flows and cognitive outcomes. To build this capability, simulation-based training programs that immerse users in ambiguity-rich crisis scenarios, where competing partial truths circulate, can improve resistance to interpretive overload and impulsive sharing. Civil society organizations, in turn, can support this ecosystem by cultivating peer-based verification networks, small, distributed communities that engage in deliberative filtering of high-risk content. These microstructures strengthen bottom-up trust and create buffers against systemic drift, anchoring the public epistemic space from below.

This research advances a systems-oriented rethinking of food safety communication but leaves several important frontiers open for empirical and computational inquiry. First, we call for agent-based modeling of platform-specific crisis trajectories, incorporating user belief models, content credibility weights, and algorithmic routing. These simulations can vary crisis onset speed, rumor virality thresholds, and control signal timing to map critical transition points where misinformation either dissipates or entrenches. Comparing outcomes across synthetic models of TikTok, XHS, and Weibo can identify the topological features and feedback configurations most conducive to epistemic recovery. Second, cross-cultural studies are necessary to assess the transferability of intervention strategies across national contexts. For instance, how does rumor suppression differ between authoritarian and participatory media environments? How does trust in institutions affect user sensitivity to risk cues or correction signals? These inquiries will reveal whether epistemic fragility is structurally embedded in the platform or shaped by local political culture and literacy patterns. Additionally, longitudinal tracking of food safety crises across platforms could identify markers of systemic exhaustion, moments when public engagement collapses despite informational clarity, revealing limits of communicative resilience. Finally, an exciting frontier lies in adaptive, AI-augmented governance. Reinforcement learning agents could be trained to optimize control feedback timing, source elevation, and content pacing across evolving information environments. By learning from real-time user responses and system dynamics, platforms could continuously adjust governance parameters to reduce epistemic volatility. Such systems, if designed with transparency and auditability, could shift us toward platforms that govern themselves in alignment with public reasoning, through anticipatory sensemaking infrastructure. In summary, this study lays the foundation for a paradigm shift: from viewing food safety communication as reactive public messaging, to seeing it as a challenge of designing resilient, reflexive, and governable epistemic ecologies. The core insight is that trust and truth are emergent properties of the systems that carry it.

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Xinyue Hao: Conceptualization, Methodology, Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Dapeng Dong:** Data curation, Visualization. **Chang Liu:** Data curation, Visualization. **Emrah Demir:** Conceptualization, Writing – original draft, Supervision. **Samuel Fosso Wamba:** Supervision, Writing – review & editing.

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Data availability

Data will be made available on request.

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