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PEER-REVIEWED ARTICLE

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Microbiological Food Safety and Regulatory Measures in Nepal: Status and Future Directions

ABSTRACT

Developing nations face higher incidences of foodborne diseases due to substandard food handling practices and inadequate regulatory measures. This publication reviews the prevalence of the most common foodborne pathogens associated with high-risk food commodities in Nepal. *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* were consistently reported. Despite inherent variations in prevalence, the occurrence of these pathogens was markedly high in meat, dairy, and street foods. The reported prevalence of *E. coli* ranged from 31.6 to 100% of meat samples and the prevalence of *S. aureus* ranged from 7.9% to 80% in various commodities. An alarming number of isolates were resistant to one or more clinically significant antibiotics. This review highlights the need for a multiprong approach to ensure food safety such as addressing water safety, improving the national epidemiological infrastructure and resources, promoting the prudent use of antibiotics, and providing food safety trainer to food workers. Additionally, implementing the Slaughterhouse & Meat Inspection Act of 1999 and the mandatory adoption of Good Manufacturing Practices and Hazard Analysis and Critical Control Points systems for high-risk commodity producers and processors would likely enhance food safety in Nepal.

OVERVIEW

Each year, an estimated 600 million people worldwide suffer from diarrheagenic foodborne disease (FBD), with 230,000 deaths associated with diarrheal illness *(50)*. *Campylobacter* spp., norovirus, pathogenic *Escherichia coli*, non-typhoidal *Salmonella*, *Shigella* spp., and *Vibrio* spp. are the leading etiological agents of morbidity, whereas non-typhoidal *Salmonella* spp., *Toxoplasma gondii*, *Listeria monocytogenes*, and norovirus are the leading causes of foodborne disease associated mortality *(37)*. Globally, children under five years of age account for 40% of FBD, with 125,000 annual deaths *(51)*. The World Health Organization (WHO) estimates that the annual worldwide loss of 33 million years of healthy lives can be attributed to the consumption of unsafe food *(50)*. Furthermore, up to 70% of diarrheal disease cases in developing nations can be attributed to poor food handling practices *(22)*.

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Nepal is a developing country in Southeast Asia with a total population of 30 million and an average annual per capita income of USD 1,362 *(11)*. Inadequate resources and insufficient infrastructure limit access to clean water, appropriate sanitation systems, and adequate refrigeration facilities. These factors contribute to the contamination and spoilage of food, increasing the risk of foodborne illnesses. In Nepal, diarrhea continues to be the leading cause of illness and death among children under five years of age *(45)*. A survey conducted in communities in Eastern, Central, and Western Nepal found that over half of diarrheal specimens from infants aged 6 weeks to 12 months were positive for diarrheagenic pathogens, particularly rotavirus (23.9%), *Salmonella* (12.4%), and *Campylobacter* (5.6%) *(10)*. Another study documented the prevalence of diarrheal disease in 43.8% of children under five years of age *(29)*. Although the study did not characterize the causative agents, it suggested that this population is particularly vulnerable to foodborne disease in Nepal.

As the country lacks organized epidemiological surveillance and systematic outbreak investigation, most of the foodborne disease outbreaks remain uninvestigated, and illness cases are vastly underestimated and/or underreported. Additionally, risky food handling practices, insufficient enforcement of food regulations, and limited public awareness increases the risk of foodborne illnesses among consumers *(3)*. To date, the body of research concerning high-risk food commodities remains constrained in its scope and volume. A notable gap exists in the comprehensive assessment of the microbial food safety landscape within the nation. In this review, we summarize the prevalence of major diarrheagenic foodborne agents associated with high-risk food commodities in Nepal and discuss future directions to safeguard consumer health through a more robust food safety regulatory system.

REVIEW METHODOLOGY

This manuscript is a narrative review informed by a systematized search strategy, conducted on Google Scholar, PubMed, and Scopus. The search queries included combinations of relevant keywords such as "Nepal" AND "foodborne" OR "food safety". Data on specific pathogens was searched using "Nepal" AND "*Campylobacter*" OR "*E. coli*" OR "*Listeria*" OR "*Salmonella*" OR "*Shigella*" OR "*Vibrio*" as well as "Nepal" AND "norovirus" OR "rotavirus" and "Nepal" AND "parasites". Out of 57 primary articles screened, studies involving clinical investigations, non-microbial food safety, and non-food sources were excluded. Only articles in English that provided information on the incidence, occurrence, presence, or prevalence of microbial pathogens in foods in Nepal were considered, regardless of publication year. Discrepancies regarding inclusion were resolved through discussion and consensus of two authors (RM and JD). Research papers published until December 2024 were included in the review. While a formal quality appraisal tool was not applied, each source was assessed by the authors for relevance and credibility based on study context, methodological transparency, and data quality. Data were extracted from 41 peer-reviewed journal articles. The information on foodborne outbreaks in the country was obtained from the national daily newspaper archive. In addition, data on food-related regulations, policies, and acts were obtained from the website of the Nepal Department of Food Technology and Quality Control (DFTQC). Lastly, information on the supply of high-risk food commodities was obtained from the website of the Nepal Ministry of Agriculture and Livestock Development (MoALD).

In total, 30 peer-reviewed journal articles with numerical data, 16 with qualitative data, 3 Nepali government publications, 2 statistical reports, 2 news articles, 1 conference paper, and 2 international reports were used. Some sources contributed both qualitative and quantitative data. Data extraction was manual and categorized by source type and data characteristics.

PREVALENCE OF PATHOGENS IN HIGH-RISK FOOD COMMODITIES

Meat and poultry

In Nepal, poultry is the primary animal protein source, followed by buffalos, goats, pigs, and others. The annual poultry production in the country is 227 million kilograms, and all other meats account for 294 million kilograms *(30)*. The data suggest a gradual increase in per capita meat consumption in the last few decades, and the consumption of poultry meat has sharply increased in recent years. However, the supply chain for meat and poultry lacks adequate sanitation and traceability practices. Local retailers commonly obtain animals from farms and vendors and conduct onsite slaughter for sale *(3, 49)*. Outdoor slaughtering is common, where large animals, including buffalos and pigs, are harvested and processed on the street sides, riversides, and open pasturelands *(1, 19)*. A study in the Rupandehi district documented the presence of flies, rodents, and other animals in 50% (95/190) of slaughter and meat processing facilities *(48)*. Additionally, personnel involved in meat processing were found to lack food safety knowledge. All these factors contribute to the risk of microbial contamination. In that regard, unhygienic slaughtering, evisceration, and processing practices are the primary reasons for microbial contamination of meat in the country *(15)*. In addition, using contaminated water during meat processing and unsafe transport of meat (lack of temperature control, exposure to open environments) further increase the risk of contamination *(15)*.

The most common pathogenic bacteria reported in meat in Nepal are *Campylobacter* spp., *E. coli* (various pathotypes), *Salmonella* spp., *Shigella* spp., *Staphylococcus aureus*, and *Vibrio* spp. *(Table 1)*. These bacteria can cause a range of symptoms,

from mild gastrointestinal discomfort to severe illness, and can pose a particular risk to vulnerable populations such as young children, pregnant women, and the elderly. Some of these pathogens are natural colonizers of the skin and gastrointestinal tract of meat animals and can contaminate meat during inefficient evisceration and other processing steps *(8)*. It is estimated that 95% (180/190) of the slaughterhouses in Nepal do not have appropriate evisceration facilities *(48)*, and antimicrobial washing of carcasses is not a common practice, thus increasing the risk of zoonotic disease from consuming contaminated animal products.

Recent studies in the country's major cities have reported high levels of *E. coli* contamination in poultry meat samples, ranging from 33% to 66.6% *(Table 1)*. A study in the Dharan district found 10 out of 15 samples were contaminated with *E. coli (4)*. A similar survey conducted in Biratnagar reported that 25 out of 40 poultry meat samples were contaminated with *E. coli (28)*. Similarly, 60% (24/40) of goat meat samples from Biratnagar were positive for *E. coli (28)*. Previously, a study in Kathmandu, which includes the capital city, reported that 100% (39/39) of pork, poultry, and buffalo meat samples were contaminated with *E. coli*, reflecting a more precarious situation *(12)*. Even though the *E. coli* pathotypes were not specified in these studies, such high level of contamination suggests an increased likelihood of the occurrence of human pathogenic *E. coli* strains and potentially other enteric pathogens.

A very high prevalence of *S. aureus* with 53.3% (8/15), 80% (8/10), 73.3% (11/15), and 70% (7/10) in poultry, buffalo, pork, and goat meat, respectively, was observed in samples from a local market in Dharan *(4)*. A similar study reported that 52.5% (21/40) of poultry samples from Biratnagar were contaminated with this pathogen *(28)*. As the skin and upper respiratory tract of humans and animals harbor this pathogen, such a high level of contamination could be due to inefficient sanitation of animal skin during slaughter and cross contamination from humans and other domestic animals.

Varying levels of *Salmonella* contamination in poultry meat are reported in the country, ranging from 14.5% to 60% *(Table 1)*. A study found an elevated prevalence of *Salmonella* in meat samples obtained from the Dharan district *(5)*. Specifically, the findings indicate that up to 35% (9/15) of meat samples, including poultry, beef, goat, and pork, were contaminated with *Salmonella*. A survey in Biratnagar found that 40% (16/40) of goat meat obtained from local markets was contaminated with *Salmonella (28)*. Meat processing surfaces, including cutting boards and knives, were contaminated with *Salmonella* in 40.2% (66/164) of meat stores in Kathmandu *(49)*. In contrast, a recent study reported *Salmonella* prevalence of 7.9% (6/70) in buffalo meat from the Bhaktapur District *(36)*.

Interestingly, between 33 to 46% of meat samples from Dharan harbored *Pseudomonas aeruginosa*, an opportunistic human pathogen posing threats to immunocompromised individuals *(4)*. *Campylobacter*, *Shigella*, and *Vibrio* are also prevalent in low to moderate frequencies in meat in Nepal *(Table 1)*. A study of slaughterhouses in Rupandhehi found that 12% (12/100) of water samples were contaminated with *Campylobacter* spp. suggesting a heightened likelihood of meat adulteration through contaminated water *(6)*. It is important to note that these studies were conducted in urban markets and that rural areas where hygiene practices are also lacking, are vastly unexplored. Additionally, there is a significant absence of available literature on the microbiological quality of buffalo, goat, and pork meat, which are in high demand in Nepal.

Eggs and egg products

The domestic egg production in Nepal stands at a substantial 1.5 billion units annually, encompassing both poultry and ducks, with consumption highly reliant on this domestic output *(30)*. On the farm, these eggs are collected, graded, and packed in paper crates inside cardboard boxes. In Nepal, eggs do not undergo washing after collection and are commonly stored at ambient temperature during distribution and marketing, a common practice in many places around the world. Cross-contamination in the crates may increase the likelihood of horizontal pathogen transfer to the consumer in the household. Recently, a study reported that 55% of poultry farm environmental samples in Chitwan harbored *Salmonella (38)*. This observation underscores the substantial risk of vertical pathogen transmission from the farms to the eggs. Still, comprehensive investigations of the microbial contamination of eggs in the country remain notably scarce, with a conspicuous absence of data concerning the health and economic ramifications linked to egg-related health issues.

Milk and dairy products

Dairy products are another high-risk commodity for pathogenic microbial contamination. Outbreaks of bacterial pathogens, including *C. jejuni*, *L. monocytogenes*, *Salmonella* spp., Shigatoxigenic *E. coli* (STEC), *S. aureus*, and other zoonotic diseases, have been traced to dairy products *(31)*. These pathogens may be introduced via the farm environment, during transportation, processing, and other stages of the supply chain. In Nepal, processed milk, yogurt, butter, paneer, ice creams, and skimmed milk are the major dairy products. The national annual milk production is 2.5 billion kilograms *(30)*. However, the dairy sector in the country exhibits a limited level of technological advancement. Animals are reared in small- to medium-sized farms, often hand-milked. The milk is then transported to dairy industries, and processed products are distributed locally. Dairy industries commercialize pasteurized milk and yogurt with a shelf life of less than a week. Additionally, for people in semi-urban and rural areas, animals raised on the

TABLE 1. Prevalence of foodborne bacterial pathogens in meat and meat processing surfaces in Nepal

Reported organism	Product	Prevalence (%)	Number of samples	Location	Drug-resistant isolates (%)	Detection method	Reference
E. coli	Meat (poultry & goat)	33.3	99	Chitwan	NA	Culture-based	*(33)*
	Meat (poultry, goat, pork & buffalo)	41.6	24	Dharan	AMX (100) CAZ (100) AMP (100) MDR (100)	Culture-based	*(18)*
	Poultry meat	33.3	180	Kathmandu, Lalitpur, Bhaktapur, Kaski	TE (68.3) SXT (65) CIP (43.3) GEN (33.3) COL (26.6)	Culture-based	*(20)*
	Poultry meat	33	70	Bhaktapur	AMX (69.6) TET (60.6) NAL (54.4)	Culture-based	*(36)*
	Buffalo meat	31.6	70	Bhaktapur	TET (41.6) AMX (16.6) GEN (12.5)	Culture-based	
	Meat (poultry, goat, pork & buffalo)	53	83	Dharan	AMX (100) TET (93) NAL (25) CEF (19)	Culture-based	*(5)*
	Poultry meat	62.5	40	Biratnagar	NA	Culture-based	*(28)*
	Goat meat	60	40	Biratnagar	NA	Culture-based	
	Poultry meat	66.6	15	Dharan	NA	Culture-based	*(4)*
	Goat meat	46.7	15	Dharan	NA	Culture-based	
	Buffalo meat	40	10	Dharan	NA	Culture-based	
	Pork	60	15	Dharan	NA	Culture-based	
	Meat (poultry, pork & buffalo)	100	39	Kathmandu	AMP (34) MDR (8)	Culture-based	*(12)*
S. aureus	Poultry meat	9	70	Bhaktapur	TET (44.4) AMX (33.3) AZY (22.2)	Culture-based	*(36)*
	Poultry meat	52.5	40	Biratnagar	NA	Culture-based	*(28)*
	Goat meat	48.8	40	Biratnagar	NA	Culture-based	
	Buffalo meat	7.9	70	Bhaktapur	AMX (50) CXT (50)	Culture-based	*(36)*
	Meat (poultry, goat, pork & buffalo)	68	83	Dharan	AMX (100) TET (63) NAL (17) CEF (13)	Culture-based	*(5)*
	Poultry meat	53.3	15	Dharan	NA	Culture-based	*(4)*
	Buffalo meat	80	10	Dharan	NA	Culture-based	
	Pork	73.3	15	Dharan	NA	Culture-based	

TABLE 1. Prevalence of foodborne bacterial pathogens in meat and meat processing surfaces in Nepal *(cont.)*

Reported organism	Product	Prevalence (%)	Number of samples	Location	Drug-resistant isolates (%)	Detection method	Reference
Salmonella spp.	Poultry meat	42.5	40	Biratnagar	NA	Culture-based	*(28)*
	Goat meat	41.3	40	Biratnagar	NA	Culture-based	
	Buffalo meat	7.9	70	Bhaktapur	NA	Culture-based	*(36)*
	Poultry meat	40	30	Kathmandu	NAL (58.3) AMP (25)	Culture-based	*(43)*
	Meat (Poultry, goat, pork & buffalo)	35	83	Dharan	AMX (100) TET (24) NAL (11)	Culture-based	*(5)*
	Poultry meat	60	15	Dharan	NA	Culture-based	*(4)*
	Goat meat	41.3	15	Dharan	NA	Culture-based	
	Buffalo meat	20	10	Dharan	NA	Culture-based	
	Pork	10	15	Dharan	NA	Culture-based	
	Meat processing surfaces (Zone 1)	40.2	164	Kathmandu	NA	Biochemical test with serological confirmation	*(49)*
	Poultry meat	14.5	55	Kathmandu	NA	Culture-based	*(27)*
	Buffalo meat	13.5	37	Kathmandu	NA	Culture-based	
P. aeruginosa	Poultry meat	46.7	15	Dharan	NA	Culture-based	*(4)*
	Buffalo meat	40	10	Dharan	NA	Culture-based	
	Goat meat	33.3	15	Dharan	NA	Culture-based	
	Pork	40	15	Dharan	NA	Culture-based	
Vibrio spp.	Poultry meat	5	50	Biratnagar	NA	Culture-based	*(28)*
	Poultry meat	2	15	Dharan	NA	Culture-based	*(4)*
	Buffalo meat	2	10	Dharan	NA	Culture-based	
	Goat meat	2	15	Dharan	NA	Culture-based	
Shigella spp.	Poultry meat	4	15	Dharan	NA	Culture-based	*(4)*
	Buffalo meat	2	10	Dharan	NA	Culture-based	
Campylobacter spp.	Pork	38.8 (*C. coli* 76% and *C. jejuni* 24%)	139	Chitwan	COL (72.2) TET (61.1) NAL (44.4) STX (44.4) CPFX (31.5)	Culture-based	*(17)*

Abbreviations: AMP, Ampicillin; AMX, Amoxicillin; AZY, Azithromycin; CAZ, Ceftazidime; CEF, Cefotaxime; CFX, Cephalexin; CHL, Chloramphenicol; CIP, Ciprofloxacin; CLOX, Cloxacillin; CPFX, Ciprofloxacin doxycycline hydrochloride; COL, Colistin; GEN, Gentamicin; MDR, Multidrug resistant; NAL, Nalidixic acid; DOXY, Doxycycline hydrochloride; NIT, Nitrofurantoin; STX, Trimethoprim/Sulfamethoxazole; TET, Tetracycline; NA, Not available.

family farm also serve as the main source of dairy products where unpasteurized milk gets delivered to consumers. Recent studies revealed contamination of milk and yogurt with *E. coli* and *S. aureus (Table 2)*.

It is a very common practice in Nepal to prepare yogurt at home for domestic consumption and use within days. The use of unhygienic utensils and poor handling practices lead to the introduction of microbes in yogurt. A study on homemade yogurt found that 63% of 29 samples harbored *S. aureus (7)*. The close association between the residence, food sources, kitchen, the backyard cattle/buffalo shed, the manure disposal site, etc., poses a direct threat to environmental contamination of dairy products. In addition, the hand milking practice and contamination of unwashed or improperly washed udder and its vicinity with manure and soil in the milking parlor are other significant sources of pathogen introduction in milk. Surprisingly, 20% (6/20) of pasteurized milk samples from Dharan was contaminated with *S. aureus (25)*, potentially attributed to improper pasteurization. This reflects the potential high exposure of consumers to foodborne illness via the consumption of contaminated dairy products, including those that have been thermally treated. It is customary, however, that consumers boil milk from the market and local farms, helping to reduce the risk of disease. Still, consumption of unpasteurized processed products and cross-contamination in the kitchen may lead to illness.

Street food

Popular street food dishes in Nepal include Panipuri, Chatpat, Chat-Chutney, and Momo. The quality of water used in preparing such foods is critical. In Nepal, street vendors greatly lack access to clean water and appropriate hand-washing facilities. The ingredients used in street foods, such as meat, chopped vegetables, tamarind water, chutneys, and fillings, require proper storage and handling to prevent spoilage and cross-contamination. Street vendors in Nepal often do not have appropriate cold storage mechanisms in the trailers they carry around. In addition, street food vendors may use shared utensils and equipment without adequate sanitation, leading to cross-contamination between different ingredients, including raw and cooked. Notably, the lack of food safety knowledge among the vendors and the neglected hygiene practices greatly contribute to the microbial contamination of street food in Nepal *(2)*.

Chutney, made of vegetable and fruit pulps are major ingredients, is known to be a source of foodborne pathogens in Nepalese street foods *(2)*. The raw ingredients used to make Chutney do not undergo thermal processing before serving thus contributing to pathogen growth in conditions of temperature abuse. A street food surveillance study in Bharatpur examined 150 Chutney samples and found that 20.67% (31/150) and 27.3% (41/150) were contaminated with *Salmonella* and *E. coli*, respectively. More importantly, out of those *E. coli*, 17% (7/41) were O157:H7 thus posing an extremely high health risk to consumers *(2)*. Similarly, in an investigation of Panipuri, a spicy high-demand street food, 16.6% (50/300) of ready-to-serve ingredients were contaminated with *S. aureus* and 10% (30/300) were contaminated with *E. coli (23)*. In another survey of ready-to-eat (RTE) salads served in various restaurants in the Chitwan district, 35.2% (66/216) of the samples were contaminated with *Salmonella* and 13.4% (29/216) were positive for *E. coli*, of which three samples were positive for the O157:H7 serotype *(35)*. Although limited in number, these studies reveal the high likelihood of contamination by foodborne pathogens in Nepalese street food, thereby posing substantial risks to public health.

Fresh produce

In Nepal, the national demand for fresh produce is largely supplied by domestic production and imports from India. The production and supply chain of fresh produce in the country often demonstrates insufficient consideration for microbial contamination with suboptimal agricultural practices, inadequate post-harvest handling, poor sanitation, and the utilization of questionable water sources for irrigation and sanitation. The practice of using unsafe water from rivers, sewage, effluents from a wastewater treatment plant, and natural ponds for cleaning and irrigation is common in the Kathmandu Valley *(34, 42, 43)*. Additionally, approximately 75% of the wastewater generated within the Kathmandu Valley is discharged untreated or undergoes minimal treatment before being released into waterways, contributing significantly to the pollution of local water reservoirs *(32)*. A study on the microbial quality of water used for irrigation in Kathmandu Valley revealed alarming contamination levels during the rainy season with high total coliforms and the presence of *E. coli*, *Cryptosporidium*, and *Giardia*. A staggering 96% (23/24) of the water samples from irrigation sources exhibited contamination with *E. coli* and coliforms *(42)*. Recently, a study encompassing five major metropolitan cities in the country reported that 59% of the water used in the fresh production system was contaminated with *E. coli (24)*. A similar study found high levels of coliform contamination (3.02 log CFU/ml) in irrigation water used by vegetable growing in Manahara, Kathmandu. The same study indicated possible transfer of coliforms from irrigation water to fresh produce, since the total coliform concentration found in untreated salad vegetables ranged from 2.04 to 3.02 log CFU/ml *(40)*. While the analytical method was not specified, a rinsate method was likely used. A quantitative microbial risk assessment modeling study on pathogenic exposure of consumers via vegetables in the Kathmandu Valley estimated the enteropathogenic *E. coli* (EPEC) exposure to be greater than 4 log per individual per annum with the current practices of cleaning vegetables with unsafe water *(41)*. In another study, researchers reported that

TABLE 2. Prevalence of foodborne bacterial pathogens in dairy and ready-to-eat products in Nepal

Reported organism	Product	Prevalence (%)	Number of samples	Location	Drug-resistant isolates (%)	Detection method	Reference
S. aureus	Raw milk	6.3	460	Chitwan	AMP (100) TET (51.7) CFZ (24.1) MET (6.9) MDR (96.6)	Culture-based	*(39)*
	Pasteurized milk	20	20	Dharan	NA	Culture-based	*(25)*
	Panipuri ingredients	16.6	300	Chitwan	MDR (14.8)	Culture-based	*(23)*
	Homemade yogurt	63	39	Eastern Nepal	NA	Culture-based	*(7)*
E. coli	Chutney	27.3	150	Chitwan	AMP (100) AMX (100) MDR (65.9)	Culture and biochemical	*(2)*
	Vegetables	51	100	Kathmandu, Bhaktapur, and Lalitpur	GEN (2) AMX (94) CIP (8) TET (63) COT (53)	Culture-based	*(32)*
	Pasteurized milk	30	20	Dharan	NA	Culture-based	*(25)*
	Salad mix	13.4	216	Chitwan	MDR (13.4)	Culture-based	*(35)*
	Panipuri ingredients	10	300	Chitwan	MDR (36.7)	Culture-based	*(23)*
Salmonella spp.	Salad mix	35.2	216	Chitwan	MDR (35.2)	Culture-based	*(35)*
	Chutney	20.7	150	Chitwan	AMP (100) AMX (100) MDR (45.2)	Culture-based	*(2)*
	Vegetables	7	100	Kathmandu, Bhaktapur, and Lalitpur	AMX (33) CIP (17)	Culture-based	*(32)*
Shigella spp.	Panipuri ingredients	2.6	300	Chitwan	CIP (50) GEN (25)	Culture-based	*(23)*

Abbreviations: AMC, Ampicillin; AMX, Amoxicillin; CFZ, Cefazolin; CIP, Ciprofloxacin; COT, Cotrimoxazole; GEN, Gentamicin; MDR, Multidrug resistance, MET, Methicillin; TET, Tetracycline; NA, Not available.

100% (100/100) of vegetable samples from Kathmandu, Bhaktapur, and Lalitpur were contaminated with coliforms and *Giardia (16)*. These reports suggest a significant risk of pathogenic microbial exposure to consumers through fresh produce in this region. However, comprehensive investigations on microbial safety of fresh produce from other parts of the country is greatly lacking.

Wedding celebrations and social dining

Food poisoning remains a pressing concern among Nepalese partygoers, with social dining, catering, and ceremonies serving as potential focal points for these events. Numerous cases of mass outbreaks potentially related to foodborne pathogens have been reported from various parts of Nepal. In December 2022, more than 150 people experienced headaches, nausea, fever, gastric pain, and diarrhea, after attending a wedding celebration in Palpa *(46)*. Similarly, another wedding celebration in Chitwan resulted in around 200 people falling sick *(47)*. Although the etiological agent was not reported, it is presumed that these instances of potential foodborne illness outbreaks may be prevented with higher awareness, better food safety practices, and increased access to clean water for cleaning and food preparation.

Prevalence of antibiotic resistance in nepal

The spread of antibiotic resistant bacteria through the food supply is a global public health crisis *(9)*. Past studies have pointed to the considerable presence of antibiotic-resistant pathogens in the Nepalese food system *(Tables 1 and 2)*. Prevalence of 100% resistance against ampicillin was observed in *S. aureus* (29/29) isolated from raw milk *(39)*. A study in Dharan reported that 100% of isolates of *E. coli* from meat samples were resistant to three different antibiotics: ampicillin, amoxicillin, and ceftazidime *(18)*. Similarly, 36.7% (11/30) of *E. coli* isolated from Panipuri ingredients were resistant to multiple drugs, including nitrofurantoin, cotrimoxazole, gentamycin, and ciprofloxacin *(23)*. In the same study, 14.8% (4/27) of *S. aureus* isolates were resistant to multiple drugs, including azithromycin, cefoxitin, and ciprofloxacin. In most studies, amoxicillin and ampicillin remained the least effective or completely resisted antibiotics. A recent survey of Chutney found that 45.2% (14/31) of *Salmonella* and 65.9% (27/41) of *E. coli* isolates were multidrug resistant against different antibiotics *(2)*. These antibiotics are still widely used in treating veterinary and human infections in the country. The presence of antibiotic-resistant bacteria in human food is a cause for concern as it may soon lead to a loss of effectiveness of front-line antibiotics in human clinical settings. Therefore, urgent action is required to address this issue and prevent the further spread of antibiotic-resistant bacteria in the Nepalese food chain.

FOOD SAFETY REGULATORY FRAMEWORK IN NEPAL

Nepal promulgated its first food act in 1966, serving as the country's primary legislation governing food safety. The major objectives of this act were to maintain the quality of food supplies in the country and to prevent the transmission of health hazards to consumers via food products. The act included provisions banning the production, sale, and distribution of inferior, contaminated, or unsafe food items; detaining food products under suspicion; requiring licenses for food establishments; and imposing penalties to firms and corporate bodies if found responsible for producing, selling, and/or distributing unsafe food *(13)*. In 1970, the country endorsed a food regulation reinforcing the Food Act of 1966. The regulation redefined the role and responsibilities of the Department of Food Technology and Quality Control (DFTQC) as the supreme body for food quality control in the country. It also established a food standard fixation committee and further elaborated the food facility registration, labeling requirements, and use of food preservatives and synthetic colors in food production *(14)*. In 1999, the country passed the Slaughterhouse and Meat Inspection Act to supply safe meat products. The act has the provision of compulsory antemortem inspection of animals and inspection of carcasses after slaughter by a designated meat inspector. The act gave the inspector the right to condemn the product or perform necessary laboratory examinations. Furthermore, the Plant Protection Act of 1972 and the Animal Health and Livestock Service Act of 1998 also contain some food safety aspects.

To date, the government of Nepal has endorsed 122 generic food standards, including milk products, tea, coffee, grain products, luncheon meat, and several other commodities under the Food Act of 1966. Three additional standards have been recently published in the Nepal Gazette for melamine, preservatives, and heavy metals *(26)*. The acts and regulations have been amended multiple times to comply with international standards and guidelines *(21)*. However, several gaps exist in the legislative and enforcement part of food safety regulation in the country. The existing food regulations focus more on nutritional quality, while economic adulteration and food safety are largely overlooked. The application of Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) systems are still not mandatory for food producers, processors, and handlers in Nepal *(3)*. Similarly, the country failed to enforce the Slaughterhouse and Meat Inspection Act of 1999 for two decades. These circumstances may have contributed to an increased risk of foodborne illness for consumers and may have obstructed the international trade of food commodities.

FUTURE DIRECTIONS FOR MICROBIAL FOOD SAFETY IN NEPAL

The 2015 federal constitution of Nepal upholds the fundamental right of citizens to food sovereignty and food security, ensuring access to sufficient and safe food. However, the nation has primarily failed to ensure a safe food supply. A multi-pronged approach involving the government, food industry, and consumers is necessary to ensure food protection. There is an immediate need to improve the human and technological capacity of regulatory agencies to enhance their role in promoting microbial food safety in the country. The future of food safety in the country relies on legislative amendments to the Food Act and regulations, technical strengthening, practical implementation, effective monitoring, training of food workers, and improved awareness in the community. It includes enforcing laws, improving inspection systems, promoting food safety education, and encouraging industry self-regulation. As the national food legislation largely misses the safety component, formulating a food safety policy will be a fundamental step in microbial food safety in the country. The existing Food Act should also be amended with modern and comprehensive safety principles. Formulating additional standards and updating current rules and standards to comply with the WHO/FAO Codex Alimentarius may result in a safer food supply and facilitate international trade.

It is essential to implement a comprehensive inspection and monitoring system, which can detect and address potential sources of contamination before they reach consumers. Systematic epidemiological studies of foodborne illness, effective implementation of the Slaughterhouse and Meat Inspection Act of 1999, the execution of mandatory GMP for food handlers, and obligatory adoption of HACCP systems for high-risk commodity producers and processors is an immediate need in the country. Regulation of the use of antibiotics in human and veterinary health facilities and animal farming should be part of an integrated antibiotic stewardship campaign to help minimize drug-resistant bacteria in the food supply chain in Nepal.

CONCLUSIONS

Foodborne disease poses a significant public health risk in Nepal, particularly through the consumption of contaminated high-risk food commodities such as meat, dairy products, fresh produce, eggs, street foods, and foods served in restaurants. Poor sanitation and insufficient enforcement of food safety regulations, coupled with the high prevalence of antibiotic-resistant pathogens in the Nepalese food system, exacerbate the public health burden of foodborne illness in this country. This narrative review analyzed the existing literature on diarrheagenic microbial agents in high-risk food commodities and revealed the primary causes of microbial contamination in the country's food supply. Although Nepal has enacted food safety regulations and standards, several gaps and challenges remain in the legislative and enforcement aspects. To ensure food safety and reduce the risk of foodborne illness, a multi-faceted approach involving stakeholders from various segments of the food industry, government officials, epidemiologists, and food safety researchers is highly needed.

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