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Stylized map of Botswana incorporating national flag elements. Image generated using OpenAI (DALL·E) and modified by the corresponding author.

Microbiological Safety Status of Foods of Animal Origin in Botswana: A Primer for Risk-Based Food Safety Decision Making

ABSTRACT

This study reviews the microbiological safety and regulatory framework of foods of animal origin in Botswana as a primer for identifying and implementing risk-based mitigation strategies in the country. Primary literature was retrieved from Google Scholar, PubMed, SciELO, Scopus, and Web of Science. The results revealed varying prevalence rates of key pathogens in foods: *Bacillus cereus* (2.8%), *Escherichia coli* spp. (2.3–100%), *Listeria monocytogenes* (1.1–2.8%), *Salmonella* spp. (4.2–40%), *Staphylococcus aureus* (16–20%), including methicillin-resistant strains (MRSA), and *Vibrio* cholera (1%). Multiple antimicrobial-resistance patterns were also reported across pathogens.

Cysticercus bovis was observed in cattle from non-export slaughter facilities, with prevalence rates ranging from 6.2 to 29.2% across districts. Risk factors for pathogen spreading include cross-contamination during processing, lack of temperature control, limited use of antimicrobial treatments in local slaughter facilities, and inadequate food safety knowledge among handlers. This review underscores the urgent need for robust food safety systems, targeted interventions, enforcement of current regulations, and capacity-building efforts to mitigate risks and safeguard public health. The findings provide a basis for regulatory authorities to strengthen oversight and adopt the hazard analysis and critical control points (HACCP) system to enhance food safety in Botswana.

OVERVIEW

The annual global burden of foodborne diseases is estimated to exceed 600 million cases and 420,000 deaths *(44)*. Additionally, these illnesses account for 33 million disability-adjusted life years (DALYs), with 40% of the burden affecting children under the age of five *(44)*. Foods of animal origin are a significant component of diets worldwide, providing essential nutrients that also support the growth of various microorganisms. Consequently, these foods serve as a primary vehicle for the transmission of key foodborne pathogens such as *Campylobacter* spp., *Clostridium* spp., *Escherichia coli* (various pathotypes), *Listeria monocytogenes*, *Salmonella enterica*, and *Vibrio* spp., responsible for over 90% of global foodborne illness cases *(11)*.

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Gastrointestinal illness is a common issue in Africa, with several documented instances across the continent that highlight the persistent threat of foodborne illnesses in the region, underscoring the need for improved food safety measures. A study in southern Africa revealed that 42% of 778 individuals tested had bloody diarrhea caused by *E. coli* O157 linked to the consumption of beef and untreated water *(8)*. Similarly, 143 residents in western Uganda experienced acute gastroenteritis approximately 72 hours after consuming meat from a cow suspected of dying from anthrax septicemia *(31)*. In Ethiopia, an investigation involving 1,225 pediatric patients treated at clinics found the prevalence of gastrointestinal illnesses to be 5.3% for *Salmonella* and 4.9% for *Shigella (4)*, although the exposure routes were not described.

Urio et al. *(43)* reported that diarrheal diseases are the second leading cause of mortality among children under five years in Botswana, following only acute respiratory infections. Kasule et al. *(14)* identified rotavirus in 43 out of 249 (17.3%) stool samples collected from children with diarrhea. Similarly, *Salmonella* and *Shigella* were frequently isolated from stool samples of patients with diarrhea in the country *(34)*. Pernica et al. *(32)* detected *Campylobacter* spp. in 14% of stool samples from children suffering from acute gastroenteritis at two referral hospitals in Botswana. Furthermore, 37 cases of human brucellosis were reported in Botswana between 1974 and 1993, with nearly half (17 cases) occurring in children under 14 years old *(3)*. The ingestion of raw milk was identified as the primary vehicle of infection *(39)*. Additionally, consuming buffalo bush meat and living in close proximity to wildlife, which may harbor *Brucella* spp., pose potential risk factors for brucellosis.

Botswana is a landlocked developing country in sub-Saharan Africa with a population of approximately 2.5 million. Nearly 43% of the population resides in rural areas, while Gaborone, the capital city, has a population of 246,327 *(41)*. In 2023, Botswana's gross domestic product (GDP) per capita was estimated at $7,820, compared to $82,769 in the United States *(46)*. Like many other developing African nations, Botswana faces a high unemployment rate of 23.6%, particularly among the youth, who make about 30% of the total population. The country also faces significant public health challenges, most notably a high incidence of the human immunodeficiency virus (HIV), which affects 20.8% of the population *(41)*. HIV is the leading cause of mortality in Botswana, which has the third-highest HIV prevalence globally, surpassed only by Eswatini (26.8%) and Lesotho (21.1%) *(45)*. As of 2019, the average life expectancy in Botswana was 62.2 years, compared to the global average of 73.3 years. Despite agriculture contributing less than 2% to Botswana's GDP, livestock production, particularly cattle, accounts for 80% of the agricultural GDP, primarily through beef exports. According to a 2015 agricultural survey, Botswana's livestock population included 1,744,166 cattle, 1,205,238 goats, 242,432 sheep, 760,370 chickens, and 4,398 pigs *(40)*.

Developing countries often face significant challenges due to limited resources and infrastructure, which hinder efforts to improve public health. Common issues include inadequate roads, unreliable electricity, lack of access to potable water, insufficient health facilities, shortages of healthcare personnel, and limited medical supplies. While foodborne diseases are a global concern, their impact is disproportionately higher in developing nations. In highly industrialized countries, it is estimated that less than 10% of foodborne illness cases are reported. In contrast, less than 1% of cases are reported in developing countries *(37)*, likely due to a lack of resources for accurate epidemiological investigations and limited public awareness of food safety practices. To mitigate the risks posed by microbial foodborne pathogens, food safety management systems such as the Hazard Analysis and Critical Control Points (HACCP) system, have been developed. These systems facilitate the identification and control of hazards throughout the food production chain. While Botswana regulates the meat and poultry industries, enforcement of food safety regulations is inconsistent, particularly in local slaughter operations compared to export facilities. This study aims to critically review the microbiological safety and regulatory framework for foods of animal origin in Botswana. The findings will help identify challenges and opportunities for adopting HACCP as a standardized food safety system in the country.

REVIEW METHODOLOGY

A systematized search was conducted on Google Scholar, PubMed, SciELO, Scopus, and Web of Science. A combination of relevant key words including "Botswana" and "Foodborne" OR "food safety" OR "foodborne illness" was used to search for the relevant primary data. For specific foodborne pathogens, key words such as "Botswana" AND "*Salmonella*" OR "*E. coli*" OR "*Campylobacter*" OR "*Shigella*" OR "*Listeria*" OR "*Staphylococcus*" OR "*Vibrio*" were used. Studies providing information on the incidence, occurrence, prevalence, or presence of foodborne pathogens in foods of animal origin in Botswana were included. Additionally, research on foodborne parasitic zoonoses was considered. Only articles written in English, regardless of publication year, were included. Studies focusing on produce and other foods of non-animal origin were excluded. Relevant food-related acts and regulations were also reviewed, sourced online and from government websites, including the Ministry of Health and Wellness.

PRODUCTION AND CONSUMPTION OF ANIMAL PRODUCTS IN BOTSWANA

Most of the beef from cattle sold to the Botswana Meat Commission (BMC) is exported to the European Union (EU) and to regional markets, such as South Africa, whereas meat from cattle harvested in local slaughter facilities is consumed locally. In 2015, an estimated 60,093 and 35,171

head of cattle were sold to the BMC and to the butchers, respectively *(40)*. The country's exports of fresh and chilled beef products declined from $62 to $29 million in 2019 *(2)*. In 2015, home slaughter of goats, sheep, and beef cattle accounted for 3.9% (47,530/1,205,238), 3.5% (8,589/242,432), and 1.3% (22,260/1,744,166) of the total meat production, respectively *(40)*. Home harvesting of livestock continues to be a common practice, primarily for family consumption and for public gatherings, such as funerals, weddings, parties, and other ceremonies. Therefore, such animals and meat are exempt from inspection by the competent authority *(17)*. These animals are often kept at rural cattle posts, and slaughter sites can be up to 20 km away from the point of consumption. Therefore, meat is frequently transported in open-back vehicles with little to no refrigeration, resulting in temperature abuse before further handling or preparation.

Meat sold in supermarkets and butcheries is primarily sourced from livestock harvested at local slaughter facilities. At butcheries, carcasses are fabricated into cuts or further processed into products like boerewors (sausage) and biltong (dried meat). Boerewors is typically displayed in refrigerated cases, while biltong may be stored at room temperature or prepackaged. Excess meat is kept in freezers. Boerewors, a type of sausage originating from South Africa, consists of 90% meat (30% fat) and 10% non-meat ingredients such as rusk, spices, Worcestershire sauce, and vinegar, mixed with ice water and briefly hydrated before sale *(5)*. Biltong is traditionally made by slicing raw meat into thin strips, seasoning it with salt and spices, and air-drying it without refrigeration, increasing the risk of cross contamination from the processing environment.

During the 2008–2009 period, an estimated 70,000 tons of poultry meat, including 2,960 tons of further processed chicken, were consumed in Botswana *(25)*. According to the Food and Agriculture Organization's (FAO) food balance sheet, the estimated per capita annual supply (kg/capita/year) in Botswana for various food products was as follows: bovine meat (7.85), mutton and goat meat (3.76), pig meat (0.74), poultry meat (5.33), other meats (11.26), edible offal (3.77), eggs (1.95 dozen), and milk excluding butter (117.74 liters) *(9)*. These figures show food available at the point of sale, not actual consumption rates. Due to high unemployment rates, many individuals have turned to backyard farming, particularly broiler production, to sustain themselves. However, uninspected chicken meat is often sold to individual consumers and street vendors, with limited sales to supermarkets or government institutions *(26)*. Backyard poultry farming has long been overlooked by authorities until recently, when media reports highlighted its illegality due to air pollution concerns *(16)*, but no mention was made regarding the public sale of home-slaughtered chickens.

Despite an annual production of 10,157,608 dozen eggs and a per capita consumption of 62 eggs *(36)*, epidemiological data on eggs remains lacking. These figures exclude family consumption from undocumented poultry *(15)*. Although Botswana is nearly self-sufficient in egg production *(26)*, the absence of data highlights a gap in food safety monitoring. This review indicates that the public in Botswana consumes significant quantities of protein from various animal species, which may serve as a route of exposure to various foodborne pathogens.

MICROBIOLOGICAL SAFETY STATUS OF FOODS OF ANIMAL ORIGIN

Meat and poultry

Four common foodborne pathogens – *B. cereus*, *E. coli*, *Staphylococcus aureus* (including methicillin-resistant, MRSA), and *Salmonella* spp. have been isolated from various meat and poultry products in Botswana *(Table 1)*. Numerous studies have documented the presence of *Salmonella* spp. in various meat and poultry products. For instance, a 35.1% prevalence (40/114) of *S.* Typhimurium *(13)* and a 10.9% prevalence of *Salmonella* spp. (5/46) *(12)* were estimated in chicken and beef livers, respectively, while *Salmonella* spp. was isolated in 20 out of 72 (27.8%) chicken sausage samples 361) in Gaborone. Moreover, Gashe and Mpuchane *(12)* isolated *Salmonella* spp. from various beef products, including minced meat – 11 out of 55 (20%), tripe (ruminant stomach) – 6 out of 40 (15%), boerewors – 5 out of 55 (9%), steak – 3 out of 52 (5.8%), kidney – 3 out of 58 (5.2%), and stew – 2 out of 48 (4.2%) samples. Likewise, the prevalence of *Salmonella* spp. in various types of meat sausages sold in Gaborone was 25.3% (20/79) for beef, 17.9% (14/78) for pork, and 15.5% (11/ 71) for mutton *(36)*. In a similar research study, *Salmonella* prevalences recorded in various raw beef products were 26% (31/120) in sausages, 20% (24/122) in minced meat, and 7% (4/58) in burger patties, respectively *(29)*. The prevalence of *E. coli* O157 in various beef products in butcheries and grocery stores in Gaborone was 5.22 (7/134), 3.76 (5/133) and 2.26% (3/133) in beef cubes, minced meat, and fresh sausages, respectively *(20)*. Gashe and Mpuchane *(12)* isolated *E. coli* in 100% of both beef livers and tripe, 60% in each of the minced meat and stew meat and 75% of the boerewors. Shiga toxin-producing *E. coli* (STEC) is a common pathogen associated with beef products. In Botswana, antimicrobial washes are not mandatory in slaughter operations, except at export facilities, where chlorinated and hot water treatments may be used. Substandard sanitary practices coupled with a lack of physical or chemical antimicrobial interventions may contribute to the high detection rates of various pathogens in products that do not come from export facilities.

The prevalence of *B. cereus* in beef biltong sold in local supermarkets in Gaborone was 2.8% (4/145) *(22)*. Also, Murindamombe et al. *(30)* isolated *B. cereus* from 96 of 148 (65%) of ready-to-eat composite foods sold by vendors in Gaborone. These foods were served with a choice of

either beef or chicken, in addition to various starches and vegetables, making it difficult to implicate a single food item. Likewise, there is limited epidemiological data regarding the prevalence of *S. aureus* in Botswana. The presence of *S. aureus* in foods may suggest mishandling of foods by food handlers during posing a risk of foodborne intoxication. For instance, the majority, 57.5% (115/200) of the food handlers in Gaborone tested positive for *S. aureus (19)*. Loeto et al. *(18)* isolated *S. aureus* in 15/49 (30.6%) of isolates from cooked meat samples in three vending sites in Gaborone, the results of which the authors attributed to a lack of safe food-handling skills and food safety knowledge among vendors. A recent study showed that 16 out of 25 (64%) cooked meat samples (beef and chicken) sold by street vendors in Gaborone tested positive for MRSA *(38)*.

As indicated above, backyard farming is a common practice in the country. Backyard producers often lack basic skills for safe food handling, as well as access to proper sanitary facilities. In most cases, chicken slaughter happens in open spaces under unsanitary conditions, which compromises food safety. Moreki *(26)* observed that over 70% of backyard chicken producers harvested their chickens in open spaces, despite most of them, 90%, indicating that they understood hygiene requirements. Although the poultry industry is regulated in Botswana, backyard broiler production is overlooked, so products are commonly sold to the public. Consequently, the microbiological quality of these products is unknown. Importantly, many of these operations occur in major villages with a high proportion of older adults, a population more vulnerable to infection and its complications from foodborne infections.

Fish and fishery products

Salmonella spp. have been isolated from different types of fish sold by street vendors in Gaborone. Of 47 whole tilapia samples, 19 (40%) were positive, while 13/42 (31%) of catfish samples were positive compared to 22/101 (22%) of gutted tilapia samples *(24)*. Likewise, the prevalence rate of *V. cholera* in fish and tilapia (gutted) sold in Gaborone was 1 out of 101 samples (1%) *(24)*. Also, the prevalence rate of *Citrobacter braakii* in frozen tilapia, gutted tilapia, catfish, and whole tilapia was 27 out of 50 (54%), 49 out of 101 (48.5%), 14 out of 42 (33.3%), and 15 out 47 (31.9%), respectively *(24)*. These authors also isolated *Klebsiella pneumoniae* and *Enterobacter* (now *Cronobacter*) *sakazakii*, which may reflect poor sanitary practices during handling. Considering that a high proportion of the Botswanan adult population is HIV-positive, the presence of potential opportunistic pathogens in the food supply is a public health concern.

Milk and dairy products

The Department of Animal Production annual report of 2011–2012 indicates that 3.1 million liters of fresh milk were produced locally, compared to an estimated 62 million imported, implying that about 65 million liters was consumed in 2011. This resulted in a consumption rate of about 32.5 liters per person during the same period *(27)*. However, there is limited data on the microbiological safety of milk and dairy products in Botswana *(Table 1)*. The prevalence rate of *S. aureus* and *Salmonella* spp. in raw camel milk was 20% (2/10) and 20% (2/10), respectively *(21)*. The researchers suggested the lack of sanitary handling of milk such as dirty udder and teats and unclean worker hands as the main source of milk contamination. Moreover, *Staphylococcus* spp. was isolated in 23% of commercially pasteurized cow's milk, while 23% of raw milk samples tested positive for *E. coli (1)*. Furthermore, an opportunistic pathogen, *Pseudomonas aeruginosa*, was isolated in 23% of raw cow's milk *(1)*. Under traditional settings, dairy cattle are hand-milked, and milk is commonly contaminated with cattle dung, hair and other contaminants such as flies. Morobe et al. *(28)* detected *L. monocytogenes* in cheese, 2.8% (7 out of 250–300) and raw milk, 1.1% (3 out of 250–300) samples. The presence of *L. monocytogenes* in ready-to-eat foods is hazardous to public health considering the high stress tolerance and virulence of this organism, particularly for the immuno-compromised population. In Botswana, it is not uncommon to see vendors selling raw milk and sour milk in recyclable containers of unknown cleanliness serving as a source of cross-contamination enhanced by a lack of cold chain maintenance by the roadsides.

Prevalence of foodborne parasites

Very few studies have evaluated the prevalence of foodborne parasitic zoonoses in the country *(Table 2)*. The overall prevalence of *Cysticercus bovis*, the etiological agent of bovine cysticercosis, in the southeastern district was 6.1% *(23)*, while prevalence at administrative districts was 7.3, 6.0, 5.5 and 4.5% for South, Southeast, Kweneng, and Kgatleng, respectively *(23)*. In addition, Uchendu et al. *(42)* recorded average prevalence rates of 29.2, 18.9, 13.5 and 12.8% in Kgalagadi, Northeast, Ghanzi and Central districts, respectively. The Livestock and Meat Industries Act *(17)* states that any organ of the carcass that has 10 or more bladder worm cysts must be condemned as unfit for human consumption. Similarly, the presence of one to nine cysts in the carcass musculature and viscera surfaces warrants condemnation as unfit for human consumption, unless subjected to cold storage at -10°C for 14 consecutive days, or subjected to frozen storage, in such a manner that the temperature at the thermal center of the carcass or viscera is reduced to not more than -15°C within 24 hours of the commencement of the blast freezing and that immediately thereafter the carcass and viscera are retained in cold storage at a temperature of not more than -10°C for a continuous period of not less than 72 hours, among other control measures.

Prevalence of antibiotic resistance in Botswana

Botswana, like many other countries, is facing challenges of antimicrobial-resistant pathogens in the food supply and in human and veterinary clinical medicine. Indiscriminate use of antibiotics in food animals threatens public health and the economy in several ways, including cost implications in medical expenses. Antimicrobial-resistant foodborne pathogens have been recovered from foods of animal origin in Botswana *(Table 1)*. Antimicrobial susceptibility tested on different serotypes of *Salmonella* isolated from beef, chicken, mutton, and pork sausage samples showed a common resistance pattern comprised of amikacin, cefuroxime, gentamicin, and tobramycin *(36)*. Overall, three resistance patterns observed were in beef, eight in chicken, four in mutton and four in pork sausages *(36)*. In one study, the antimicrobial resistance of *Salmonella* serogroups B, C, E and G isolated from various beef products *(Table 1)* was high to tetracycline (33.3%) and low to chloramphenicol (5%) *(12)*. Although all *Salmonella* serotypes (serogroups B, C, D, E/G and Poly O-A-S) isolated from minced meat, fresh sausages and burger patties were resistant to sulfafurazole (100%), four were resistant to at least two antibiotics tested *(29)*.

Seetswane et al. *(38)* recovered MRSA from cooked meat, salads and cereals sold by food vendors in Gaborone. This pathogen was resistant (100%) to oxacillin, penicillin G, and vancomycin, as well as various other antibiotics tested. However, these authors did not specify the food type. In another study, 15 isolates of *E. coli* O157:H7 were recovered from 400 samples (134 meat cubes, 133 minced meat and 133 sausages). Although all isolates were susceptible to ampicillin, gentamycin and cotrimoxazole, only one isolate was susceptible to all antibiotics, while varying resistance patterns were observed in only five isolates (*Table 1*; *20*). A penicillin G – tetracycline pattern, 33.3% and 14.3% was common to both isolates of *L. monocytogenes* on raw milk and cheese, respectively. In addition, two more patterns, comprised of chloramphenicol, penicillin G, novobiocin, sulfamethaxozole and chloramphenicol, penicillin G, novobiocin, streptomycin and tetracycline of 143% each, were observed in cheese isolates *(28)*.

Studies reporting the presence of antimicrobial-resistance bacteria and gene determinants in foods are valuable for establishing baseline prevalence, informing risk assessments, and guiding surveillance strategies in primary agricultural production, but more research is needed to understand their direct impact on human health.

STATUS OF FOOD SAFETY REGULATIONS IN BOTSWANA

Currently, three food-related acts are used in the country *(Table 3)*. First, the Food Control Act, passed by the National Assembly in August 1993 aims to ensure the production and supply of clean, safe, and wholesome food commodities to consumers *(10)*. The act authorizes officers to access and inspect any premises that prepare and/or process food commodities intended to be sold to the public. It further empowers officers to take legal action against non-conforming food businesses which contravene the provisions of the act and where there is evidence that food safety is being compromised. Only individuals involved in the processing of foods intended for consumption within the household are exempted from compliance with the Food Control Act. These regulations have been updated frequently, the latest being the Food Control (Inspections and Investigations of Food at Food Premises) Regulations of 2023. The regulations enable authorized officers to examine any food found on the business premises and to take appropriate action to ensure a safe food supply such as sampling food commodities for analysis to ensure its safety especially where there is suspicion of adulteration.

The Livestock and Meat Industries Act (Chapter 36:03), passed in 2007, guides the competent authority and the food business operators about the requirements of operating an abattoir *(17)*. Two Livestock and Meat Industries Act Regulations – Poultry Abattoir and Meat Inspection and Control of Red Meat Abattoir of 2007, are in effect. The act requires that all animals presented for harvest at slaughter facilities be subjected to compulsory ante-and post-mortem health inspections by competent persons such as the meat inspector or official veterinarian. Competent people have the authority to pass, detain for further examination or reject any product, carcass or part thereof or any animal they deem unfit for human consumption. The act also prohibits the sale of fresh meat and meat products from uninspected livestock to the consumers and outlines penalties for anyone who contravenes any provision of these regulations. More recently, a new act, the Botswana Meat Industry Regulatory Authority Act of 2023, has been passed and will soon replace the Livestock and Meat Industry Act of 2007. In theory, this act could be amended to include the provisions to regulate home slaughter including backyard chicken, further protecting food safety.

The Public Health Act (Chapter 63:01) of 1971 prohibits anyone from processing, preparing, or transporting any food intended for human consumption intended for sale unless such food is hygienic, healthy, free from disease, infection or contamination and unless suitable arrangements have been made to prevent infection or contamination of the food *(34)*. The Public Health Act mandates that meat sold or showcased in butcheries be protected against any form of contamination, including contamination from the public. In addition, it stipulates that carcasses and edible offal intended for transportation by vehicles exceeding 16 km must be chilled immediately post inspection and that the temperature of the deepest part of the carcass or parts thereof may not exceed 7°C, while that of the offal may not exceed 3°C at any time during transportation.

TABLE 1. Prevalence of foodborne pathogens in meat, poultry, fish, milk and dairy products in Botswana

Organism	Product	Prevalence (%)	Number of samples	Location	Drug-resistance patterns	Detection method	Reference
Salmonella spp.	Kidney (beef)	5.2	58	Gaborone	Serogroup B: T (16.7%) Serogroup C: T (33.7%), GM (16.7%) Serogroup E or G: GM (5%), CFX (15%), T (10%), C (5%)	Culture-based	*12*
	Liver (beef)	10.9	46	Gaborone			
	Minced meat (beef)	20.0	55	Gaborone			
	Steak (beef)	5.8	52	Gaborone			
	Stew (beef)	4.2	48	Gaborone			
	Tripe (beef)	15.0	40	Gaborone			
	Wors (raw sausage, beef)	9.0	55	Gaborone			
	Minced meat (beef)	20.0	122	Gaborone	See section 4.5	Culture, biochemical and serological confirmation	*29*
	Beef sausage	26.0	120	Gaborone			
	Beef burger patties	7.0	58	Gaborone			
	Chicken livers	35.1	114	Gaborone	NR	Culture, biochemical and serological confirmation	*13*
	Catfish	31.0	42	Gaborone	NR	Culture-based	*24*
	Tilapia (Whole)	40.0	47	Gaborone	NR	Culture-based	
	Tilapia (Gutted)	22.0	101	Gaborone	NR	Culture-based	
	Beef sausage	25.3	79	Gaborone	See section 4.5	Culture, biochemical and serological confirmation	*36*
	Mutton sausage	15.5	71	Gaborone			
	Chicken sausage	27.8	72	Gaborone			
	Pork sausage	17.9	78	Gaborone			
	Raw camel milk	20.0	10	Tsabong	NR	Culture-based	*21*
E. coli	Liver (beef)	100	NR	Gaborone	NR	Culture-based	*12*
	Minced meat (beef)	60.0		Gaborone			
	Stew (beef)	60.0		Gaborone			
	Tripe (beef)	100		Gaborone			
	Wors (raw sausage) (beef)	75.0		Gaborone			

Continued on the next page.

TABLE 1. Prevalence of foodborne pathogens in meat, poultry, fish, milk and dairy products in Botswana (cont.)

Organism	Product	Prevalence (%)	Number of samples	Location	Drug-resistance patterns	Detection method	Reference
E. coli O157	Meat cubes (beef)	5.2	134	Gaborone	KF (53%), ST (33%), CO (26%), T (26%), S (0.7%)	Culture, biochemical and serological confirmation	*20*
	Minced meat (beef)	3.8	133	Gaborone			
	Fresh sausages (beef)	2.3	133	Gaborone			
L. monocytogenes	Cheese	2.8	250–300	Gaborone	See section 4.5 in the text.	Culture and catalase test	*28*
	Raw milk	1.1	250–300		PG, T (33.33%)		
V. cholera	Tilapia (Gutted)	1.0	101	Gaborone	NR	Culture-based	*24*
B. cereus	Beef biltong	2.8	62	Gaborone	NR	Culture-based	*22*
S. aureus	Raw camel milk	20.0	10	Tsabong	NR	Culture-based	*21*
Methicillin-resistant *S. aureus*	Meat (beef and chicken) (cooked)	16.0	25	Gaborone	OC (100%), VM (100%) PG (100)	Culture, biochemical and PCR	*38*

NR: Not reported. Antibiotics: AM, Ampicillin; KF, Cephalothin; CO, Colistin Sulphate; GM, Gentamicin; S, Streptomycin; ST, Sulphatriad; T, Tetracycline; TS, Cotrimoxazole; CFX, Cephalothin; C, Chloramphenicol; AN, Amikacin; CXM, Cefuroxime; TM, Tombramycin; FT, Nitrofurantoin; SXT, Trimethoprim-sulfamethoxazole; AMC, Amoxicillin-clavulanic acid; FOX, cefoxitin; OC, Oxacillin; VM, Vancomycin; PG, Penicillin G; E, Erythromycin; FA, Fusidic Acid; NB, Novobiocin

TABLE 2. Prevalence of *Cysticercus bovis* in beef products in Botswana

Prevalence (%)	Number of samples	Location/district	Detection method	Source of data	Reference
13.24	N/A	Central and Kweneng	Postmortem examination	Abattoir records	*42*
18.96	N/A	Northeast	Postmortem examination		
29.15	N/A	Kgalagadi	Postmortem examination		
12.77	N/A	Ghanzi	Postmortem examination		
6.2	26,827a	Southeastern	Postmortem examination		*23*

[a] Total number of cattle slaughtered and inspected in local facilities in the study area.

TABLE 3. Summary of food-related acts and regulations used in Botswana

Acts	Regulations	Reference
Public Health Act (Chapter 63:01), 1971	Chapter 63:01 - Public Health: Index to subsidiary legislation, 1983	https://faolex.fao.org/docs/pdf/bot91836.pdf
Diseases of Animals Act (Chapter 37:01), 1977	Diseases of Stock (Poultry) Regulations, 1941	https://www.faao.org/faolex/results/details//en/c/LEX-FAOC006487
	Diseases of Animals (BSE Control (Removal of Specified Risk Material)) Regulations, 2004	https://faolex.fao.org/docs/pdf/bot65990.pdf
Food Control Act (Chapter 65:05), 1993	Labelling of Prepackaged Foods Regulations, 2003	https://faolex.fao.org/docs/pdf/bot66062.pdf
	Labelling of Food Additives Regulations, 2003	https://faolex.fao.org/docs/pdf/bot66061.pdf
	Marketing of Foods for Infants and Young Children Regulations, 2005	https://faolex.fao.org/docs/pdf/bot66216.pdf
	Food Grade Salt Regulations, 2010	https://faolex.fao.org/docs/pdf/bot196943.pdf
	Food Control (Maximum Levels of Melamine in Food) Regulations, 2010	https://faolex.fao.org/docs/pdf/bot204493.pdf
	Food Control (Maximum Levels of Aflatoxins in Foods) Regulations, 2011	https://faolex.fao.org/docs/pdf/BOT196888.pdf
	Food Control (Food Safety Alerts and Recall Procedures) Regulations, 2018	https://faolex.fao.org/docs/pdf/bot204440.pdf
	Food Control (Tolerance of Poisonous Noxious Seeds in Grain Cereals, Legumes and Oilseeds Intended for Human Consumption) Regulations, 2019	https://faolex.fao.org/docs/pdf/BOT196862.pdf
	Food Control (Inspections and Investigations of Food at Food Premises) Regulations, 2023	Botswana Government Gazette, May 26, 2023
Livestock and Meat Industries Act (Chapter 36:03), 2007	Livestock and Meat Industries (Poultry Abattoir) Regulations, 2007	https://faolex.fao.org/docs/pdf/bot91431.pdf
	Livestock and Meat Industries (Meat Inspection and Control of Red Meat Abattoir), 2007	https://faolex.fao.org/docs/pdf/bot91430.pdf

The Diseases of Animals Act (Chapter 37:01) of 1977 was enacted to, among others, prevent and control diseases of animals, regulate the import, export and movement of animals, as well as to provide for the quarantine of animals in certain circumstances (7). Of the many regulations available, only two are relevant to food safety. First, The Diseases of Stock (Poultry) Regulations prohibit anyone from introducing any poultry into Botswana except from the Republic of South Africa and unless that species has been examined and is free from salmonellosis, tuberculosis, and Newcastle disease, psittacosis and equine encephalomyelitis. Second, the Bovine Spongiform Encephalopathy (BSE) control (removal of specified risk material (SRM)) regulations of 2004 require that SRM of every cattle slaughtered at an abattoir or export slaughterhouse be removed immediately post slaughter and disposed accordingly.

CONCLUSIONS

This review highlights the critical challenges in the microbiological safety of foods of animal origin in Botswana. Key findings indicate widespread contamination with foodborne pathogens, including *B. cereus*, *E. coli* O157:H7, *L. monocytogenes*, *Salmonella*, *S. aureus*, and *Vibrio* spp., several of which display various patterns of antibiotic resistance. Inconsistent food safety practices and limited enforcement of existing regulations, especially in local slaughter facilities, seem to be leading contributing factors for contamination. Furthermore, inadequate training of food handlers, lack of temperature control, and the absence of antimicrobial interventions exacerbate risks. The findings emphasize the urgent need to strengthen epidemiological and microbiological capacity in the country with the goal of assessing the risk of foodborne illness for a variety of pathogen/food combinations. Targeted interventions, including adopting standardized food safety systems, particularly the hazard analysis and critical control points (HACCP) system, may help mitigate contamination. The implications of this work are constrained by the limited access to government data that could contribute valuable information to develop and implement food safety interventions as well as the scarcity of primary literature addressing microbial contamination in Botswana. Little available data has been collected in or around the capital city, indicating that epidemiological data is even more lacking in rural areas. Addressing these gaps is essential to protect public health and strengthen Botswana's food safety framework.

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