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Review

Microbiological Hazards and Food Safety Challenges in Street-Vended Foods in Mexico: A Narrative Review

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Abstract

Street food is a fundamental part of the diet for millions of people, especially in Mexico, standing out for its accessibility, cost, and connection to culinary culture. Street food represents a practical alternative for the population and economic benefits for those who sell it. However, its preparation and sale can involve microbiological health hazards if proper hygiene conditions and practices are not applied during the handling, storage, and sale of products. Studies in Mexico have shown the presence of pathogenic microorganisms in street food, including coliform bacteria, *Salmonella* sp., *Escherichia coli*, *Staphylococcus aureus*, and *Listeria monocytogenes*, among others, capable of causing foodborne illnesses. Therefore, this narrative review provides information available in various databases on street food, foodborne illnesses, causative agents, contaminants, and prevention measures. This study focuses on the Mexican context, including the socioeconomic relevance of these foods, microbiological contaminant hazards, prevention, and the regulatory framework. Although regulations and actions are in place for these foods, challenges remain related to food hygiene education for food handlers, microbiological surveillance of food, and the wide variety of products and sales outlets. Strengthening collaboration among authorities, academia, vendors, and consumers is essential to promote the availability of safe food and protect public health.

Keywords: foodborne pathogens; contamination; bacteria; gastroenteritis; street food; street food vending; microbiological quality; street food microbiology; Mexican street food; foodborne illnesses

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1. Introduction

Nutrition is a process in which food is supplied, providing essential nutrients for growth, repair, and maintenance, being a vital requirement for sustaining life [1]. Food intended for human consumption must possess four basic attributes, i.e., nutritional, sensory, commercial, and safety, constituting total quality. Food safety is a mandatory and non-negotiable attribute derived from the application of a set of necessary conditions and measures during the production, storage, distribution, and preparation phases to ensure that, once ingested, food does not cause harm or illness to the consumer [2,3].

Food throughout the food chain (primary production, processing, transportation, storage, distribution, preparation, and final consumption) can be contaminated by various physical, chemical, and biological agents originating from air, water, soil, animals, utensils, and humans, compromising its safety and posing a risk to consumer health [2,4,5].

Biological contaminants (viruses, bacteria, parasites, and fungi) in food can cause spoilage, reduce its shelf life, and turn it into a vehicle for disease-causing agents in consumers [2]. Foodborne illnesses are considered a major public health problem worldwide due to various factors, including their incidence, sequelae, and mortality, with a greater impact in developing countries like Mexico [2,6].

Access to food for a population can be through street vending [7–9], and it is considered an age-old phenomenon related to the development of various populations around the world, which makes it of interest from economic, sociocultural, and public health perspectives [8–10]. This is because food sold on the street is frequently prepared under highly unhygienic conditions; in addition, there is a lack of access to potable water and knowledge regarding food hygiene among food handlers. Together, this leads to a high risk of contamination and disease [7–9].

Global food consumption trends are geared towards a demand for products that meet safety standards [3]. Food safety is a fundamental public health issue worldwide and a priority for consumers, producers, and governments. Given that everyone has the right to access safe and nutritious food for a healthy and active life, it is essential that the various stages of the food chain—including production, handling, marketing, and consumption—be carried out under hygienic conditions. This ensures that the resulting products are safe, regardless of other quality attributes (nutritional or sensory), guaranteeing consumer health [11].

In Latin America, there is generally little funding for research on food safety in the formal and informal markets (street vending), and safety assessments are considered crucial for establishing food safety parameters in study areas [12]. Studies on the microbiological profile of food from street vendors in Latin American countries, such as Mexico, are scarce. Therefore, this review focuses on presenting a narrative literature review through the search, compilation, and analysis of information across various databases (Google Scholar, PubMed, Scopus, Redalyc, SciELO, etc.) that provides general information on foodborne illnesses, causative agents, street food, main microbiological contaminants in street food, and causes of contamination. It also focuses on Mexico, considering the types of street food offered, the microbiological evaluation of various foods in different locations, and the microbiological hazards present. Actions for the prevention and control of contamination are presented, including the regulatory framework for food safety in these types of foods. It provides an overview of the factors that influence safety during the preparation and marketing stages and the relevant information for taking actions to improve food safety and protect public health. The search and selection of information from various databases are described. The inclusion criteria were street food, microbiological indicators and pathogens detected, information availability, regulations, and location. Published articles and gray literature in English and Spanish were considered. No specific search and selection period

was defined. The information search was conducted using a Boolean method with search blocks such as foodborne illnesses, microbiological terms, geographic focus, control systems, and public health, as well as combinations of keywords and general or specific phrases such as "street food," or "food safety street vendors" or "street foodborne illnesses," or "microbiological risks of street food", or "microbiological evaluation of street food," or "microbiological analysis of street food," or "street food safety," or "food street vendors" or "microbiological evaluation of street food in Mexico," or "street food safety in Mexico," or "pathogens in street food at Mexico," or "street food hygiene," or "street food safety regulations in Mexico." In the selection and evaluation of the information, titles, abstracts, and fully available documents were reviewed. Information related to foodborne illnesses in Mexico and the causative agents of non-microbial origin was excluded.

2. Foodborne Illnesses

Food, in addition to being a source of nutrients, is also a vehicle for various agents harmful to consumer health, causing a variety of foodborne illnesses. These illnesses constitute a significant global public health problem due to their incidence, sequelae, mortality, new modes of transmission, vulnerable population groups, antimicrobial resistance of causative agents, and negative economic impact stemming from healthcare services, productivity, demand, and consumer confidence [13–17]. The World Health Organization (WHO) indicates that, each year, one in ten people becomes ill and 420,000 people, especially children under 5 years of age, die from these illnesses [18]. It is estimated that there are 1.5 billion cases of diarrhea annually, 70% of which originate from the consumption of food contaminated with microorganisms or toxins [15]. Factors such as environmental changes, antimicrobial resistance, the integration, concentration, and urbanization of populations, the emergence of vulnerable population groups, the rise in international food trade, technological advances in production, the increased use of additives, the increased consumption of manufactured products, and changes in lifestyle and eating habits, such as the consumption of packaged foods, fast food, and food eaten outside the home or on public streets, have contributed to the increase in foodborne illnesses [11,19].

Foodborne illnesses are considered syndromes resulting from the consumption of water or food contaminated with etiological agents in quantities that affect consumer health [20]. The populations most susceptible to these illnesses are the elderly, children, immunocompromised individuals, and those living in poverty and unsanitary conditions [14]. The highest-risk foods include meats, vegetables, grains, fish, eggs, milk, and dairy products [13,16]. Foodborne illnesses present a variety of symptoms such as nausea, vomiting, diarrhea, abdominal pain, and fever, as well as severe complications (sepsis, meningitis, miscarriages, Reiter's syndrome, Guillain–Barré syndrome) or, in extreme cases, death [20].

Approximately 250 types of causative agents of foodborne illnesses have been identified. These agents can be chemical (toxic inorganic compounds, antimicrobials, growth promoters, toxic food additives, lubricants and inks, natural toxins, disinfectants, heavy metals, pesticides, etc.), physical (fragments of glass, metal, wood, or other materials that can harm the consumer), or biological (bacteria, fungi, parasites, viruses, and prions) [14,19]. Most cases or global outbreaks of foodborne diseases are due to biological agents, particularly those of bacterial origin [13,14,21,22]. The most common bacteria in this regard include *Staphylococcus aureus*, *Salmonella* sp., *Bacillus cereus*, *Shigella* sp., *Campylobacter* sp., *Clostridium* sp., *Vibrio* sp., *Listeria monocytogenes*, and *Escherichia coli* [5,16,19,23].

Foodborne illnesses caused by biological agents are divided into two types: (1) Foodborne infections: In these infections, a pathogen is present in food and establishes itself and multiplies in the consumer. These infections are of two types: (a) Invasive infections: In these infections, microorganisms colonize tissues and organs. This is the case with bacteria

such as *Salmonella* sp., *Aeromonas* sp., *Campylobacter* sp., *Shigella* sp., *Vibrio parahaemolyticus*, *Yersinia* sp., and enteroinvasive *Escherichia coli*. (b) Toxicoinfections: In these infections, microorganisms colonize and multiply in the host's intestinal tract, excreting their toxins. This is the case with *Vibrio cholerae*, *Bacillus cereus* (enterotoxin-producing strains), *Clostridium botulinum*, *Clostridium perfringens*, and enteropathogenic variants of *E. coli* that produce enterotoxins, verotoxins, or both. (2) Food poisoning: It is caused by the toxins produced by bacteria that have grown to a certain concentration in food. Typical food poisoning-causing microorganisms include *Clostridium botulinum*, *Bacillus cereus* (producers of emetic toxin), and *Staphylococcus aureus* [5,6,14].

In the Americas, foodborne illnesses affect 77 million people annually, resulting in 9000 deaths. The main causative agents are bacteria and viruses, primarily through diarrheal disorders [12,24]. Common causative agents include norovirus, *Campylobacter* sp., *E. coli*, and *Salmonella* spp. [12]. In Mexico, gastrointestinal diseases are the leading cause of medical consultations and death, representing a significant public health issue that affects people of all ages and socioeconomic backgrounds, with children and the elderly being the most vulnerable groups [25]. Nationally, 7259 people died from intestinal infections between 2019 and 2020 [26]. Meanwhile, in 2023, epidemiological surveillance by the health sector reported 4,102,681 cases of intestinal infections and 25,509 cases of bacterial food poisoning in the national population [27]. Gastrointestinal diseases in Mexico are generally caused by various microorganisms present in contaminated water or food, including *E. coli*, *Shigella* sp., *Salmonella* spp., *Campylobacter* sp., *Yersinia enterocolitica*, *Vibrio cholerae*, *Aeromonas* spp., Rotavirus, *Giardia lamblia*, *Entamoeba histolytica*, *Ascaris* sp., and *Enterobius* sp. [25,27].

3. Street Food

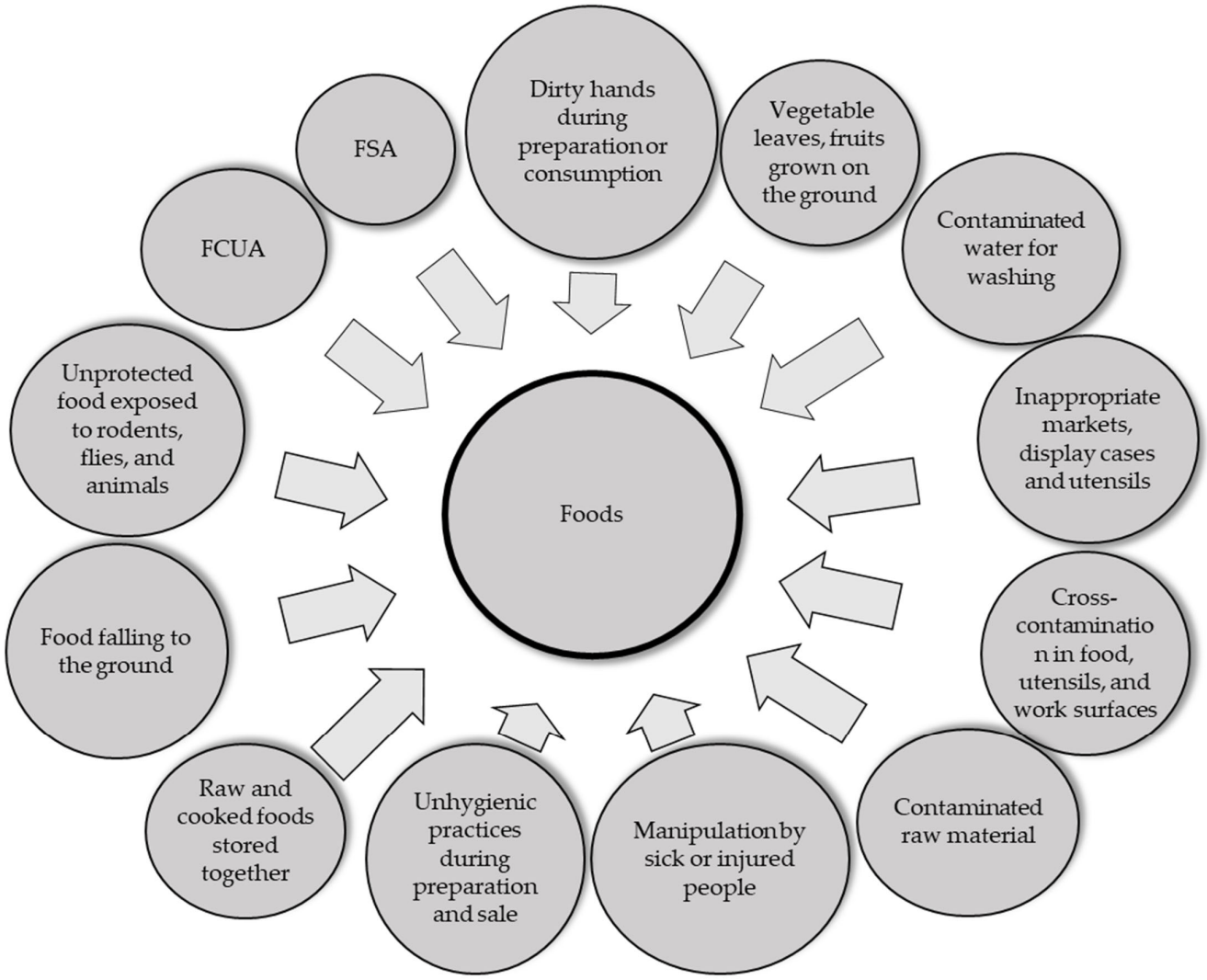
Street food is defined as ready-to-eat foods and beverages prepared and/or sold by fixed or mobile vendors, especially in streets and public places, for consumption on the spot or later, without any further preparation [10,28–30]. Street food is usually sold in areas with high foot traffic, such as near workplaces, schools, public transportation stops, and social and cultural events like sporting events, concerts, exhibitions, fairs, and festivals [31].

Street food vending contributes to access to affordable food for urban populations worldwide, improving diet, food security, nutrition, and flavor variety (experiences linked to local cultures or traditions), as well as providing quick service to all population groups (children, youth, and adults). It also improves the economic well-being of families, particularly in developing countries [7,8,29–32]. According to the estimates from the Food and Agriculture Organization of the United Nations (FAO), approximately 2.5 billion people purchase and consume street food every day [33]; therefore, street food is highly versatile across countries and cultures [28].

In Latin American countries, street food vending has shown an upward trend, driven by factors such as urban population growth, unemployment among street vendors, a lack of job opportunities in the formal sector, limited access to higher education, the rejection of women as productive units, age as a determinant of a person's capabilities, long commutes for workers, public demand for affordable and culturally appropriate food near workplaces, the scarcity or absence of regular and formal food establishments, and the need to work to survive and cover the individual's basic needs and their families [10,34].

It is estimated that, in developing countries, 20–25% of household spending is allocated to food products purchased outside the home, and some households depend entirely on food sold and supplied on the streets [8]. The most frequently sold foods on public roads in Latin America are hamburgers, French fries, juices, ceviche, empanadas, salads, hot dogs, etc. [35].

On the other hand, street food is generally considered a source of foodborne illnesses because these foods are often prepared under conditions with nonexistent or inadequate hygiene and are displayed openly, and they exhibit a high degree of contamination, which occurs either in their raw form or through cross-contamination [28,32]. This is frequently due to food handlers and preparers with no knowledge of hygiene, a lack of access to restrooms and potable water at points of sale, and hand and dish washing in containers or buckets, sometimes even without cleaning products (Figure 1). Therefore, although these foods are appreciated for their characteristics, such as their flavor and convenience, their safety is not guaranteed [7–9,28,32,36]. The pathogens commonly found in street food are diverse, including *Bacillus cereus*, *Clostridium botulinum*, *Clostridium perfringens*, *Staphylococcus* spp., *Salmonella* sp., *Shigella* sp., *Vibrio* spp., *Brucella* sp., *Campylobacter jejuni*, *Yersinia enterocolitica*, *E. coli*, *Listeria monocytogenes*, *Giardia lamblia*, and Hepatitis A virus [28,32,37–39].



FCUA: Food contaminated by unsupervised animals. FSA: Food from sick animals.

Figure 1. Factors associated with microbiological contamination of street food [37].

The safety and microbiological quality of prepared and sold foods have become an important public health issue. Since these foods can act as vehicles for disease transmission, the information gathered contributes to a greater understanding of the risks associated

with their consumption; however, microbiological studies of commercially available foods are scarce [8–10,23,28,31].

Several studies conducted worldwide indicate that street food can be contaminated with various microbiological hazards (Table 1), causing numerous outbreaks of foodborne illnesses. These studies point to several contributing factors, such as a lack of knowledge or insufficient understanding of hygiene practices of food handlers, including the cleaning of surfaces and utensils in contact with food; an inadequate supply and management of potable water; poor waste management; exposure to the environment; and the presence of insects, rodents, and birds that contribute to contamination [7–9,23,28,31]. The regular monitoring of street food and the implementation of food hygiene education are also recommended to prevent the incidence of foodborne illnesses [40].

Table 1. An assessment of the microbiological hazards of contaminants present in various types of street food around the world.

City/Country	Types of Street Food	Microbiological Hazards	Source
Chittagong/Bangladesh	Fuska; Sugar cane juice; Borhani.	Presence of between 60 and 77.5% of *Salmonella* sp. in the samples	[41]
Dinajpur/Bangladesh	Amra, Fuska, Chanachur, and Guava	Total viable count in different samples ranged from 8.0×10^5 CFU/g to 6.7×10^7 CFU/g. *E. coli* was present in 35% of the samples, *Staphylococcus* spp. in 30%, *Klebsiella* spp. in 25%, and *Salmonella* spp. and *Shigella* spp. in 5%.	[28]
Elementary School Street Food in Surabaya/Indonesia	Drinks	Presence of different enterobacteria in samples: *Shigella* spp. (4.1%), *Enterobacter agglomerans* (8.3%), *Edwardsiella tarda* (4.1%), *Yersinia intermedia* (12.5%), *Klebsiella oxytoca* (8.3%), *Klebsiella pneumoniae* (8.3%), and *Escherichia coli* (37.5%).	[39]
Dhaka/Bangladesh	Fried, salted, spicy, boiled, sweet, and sugared foods, fruits, juices, and rice crackers	High total viable count of bacteria (10^{11} CFU/g) and coliforms (10^8 CFU/g). Presence of *Escherichia coli* in 18%, *Staphylococcus aureus* in 42%, *Salmonella* spp. in 26%, *Vibrio* spp. in 11%, and *Campylobacter* spp. in 3% of the samples.	[38]
Maputo/Mozambique	Fruits, sandwiches, salads, full meals (hot food), and other typical Mozambican foods	Coagulase-positive staphylococci counts in samples ranging from 2.6 to 4.14 log CFU/g	[42]
Ouagadougou/Burkina Faso	Ready-to-eat beef sandwiches	Presence of *Salmonella* sp. in 100% of the samples	[43]
Mangaung/South Africa	Cooked meat	Total viable counts ranged from 50×10^5 to 33×10^5 CFU/g	[33]
Marrakech/Morocco	Cakes and pastry creams, prepared dishes (of animal and plant origin), vegetable and fresh produce, and dairy products	High levels of fecal coliforms and *E. coli* were found in 40% and 28% of the samples, respectively.	[44]

Table 1. *Cont.*

City/Country	Types of Street Food	Microbiological Hazards	Source
Quetta/Pakistan	Burgers, shawarma, pizza, and sandwiches	The aerobic plate count level in samples ranged from 6 $\log_{10}$ CFU/g to 9.8 $\log_{10}$ CFU/g. Overall, 40% of the samples were contaminated with pathogens such as *Salmonella* spp.	[45]
Gondar/Ethiopia	Sanbusa, Donat, Bombolino, and bread	A total of 61.1% samples were contaminated. The total mean aerobic bacterial count was 6.64×10^4 CFU/g. The total mean *Enterobacteriaceae* count was 5.55×10^4 CFU/g, and the total mean Staphylococcal count was 5.96×10^4 CFU/g.	[46]
Windhoek/Namibia	Ready-to-eat meats	Aerobic plate counts ranged from 0.89 to 5.54 $\log_{10}$ CFU/g. *Enterobacteriaceae* counts ranged from 0.89 to 5.54 $\log_{10}$ CFU/g. Overall, 42% of the samples contained *E. coli*, 10% were positive for Salmonella, and 6% were positive for *Shigella*. *L. monocytogenes* counts ranged from 0 to 1.94 $\log_{10}$ CFU/g. *S. aureus* counts ranged from 0.57 to 3.46 $\log_{10}$ CFU/g.	[47]
N'Djamena/Chad	Sandwiches	Thermotolerant coliforms and *E. coli* were detected in 100% of the samples; for total aerobic mesophilic bacteria, the average proportion in samples was 6.35×10^6 CFU/g, and for coagulase-positive staphylococci, it was 0.15×10^6 CFU/g.	[48]
Lome/Togo	Ready-to-eat salads	Total aerobic bacteria and total coliforms were detected in 100%, thermotolerant coliforms were detected in 37.6%, and *S. aureus* in 23.2% of the samples, with maximum proportions of 2600×10^5, 3000×10^3, 92×10^3, and 200 CFU/g, respectively.	[49]
Vitoria and Serra/Brazil	Coconut water, salty snacks, hot dogs, grilled meat skewer sandwiches, and boiled corn	*Staphylococcus aureus* and *E. coli* were present in all samples with counts of more than 3.51×10^6 CFU/g and 1.15×10^5 CFU/g. *Salmonella* spp. was detected in 6.3% of the samples.	[50]
Lisboa/Portugal	Ready-to-eat street food	Overall, 43.2% of the samples were classified as unsatisfactory, and 2.6% were found to be potentially hazardous due to the presence of *L. monocytogenes* > 10^2, *B. cereus* > 10^5, and/or coagulase-positive *S. aureus* > 10^4 CFU/g.	[31]
Bharatpur/Nepal	Masala and Pani Puri	A total of 10% of the samples presented *E. coli*, 16.6% *S. aureus*, 9.3% *Citrobacter* spp., 6% *S. typhi*, 5.3% *Pseudomonas* spp., 4.6% *B. cereus*, and 3.3% *S. paratyphi*.	[51]
Amravati/India	Pani Puri	A total of 93% of the samples show high proportions of pathogens such as *E. coli* (41%), *S. aureus* (31%), *Klebsiella* sp. (20%), *Pseudomonas* sp. (5%), and yeast (3%).	[40]

Table 1. *Cont.*

City/Country	Types of Street Food	Microbiological Hazards	Source
Pasaje/Ecuador	Fish ceviche	A total of 20% of the samples were positive for *E. coli* O157: H7.	[52]
Bogota/Colombia	Hot dogs, corn arepas, hamburgers, empanadas, raw and cooked sausages, fruit salad, orange juice, and pelanga	Overall, 25% of the samples were contaminated with *E. coli* and 11.8% with *Salmonella* sp.	[23]
San Jose/Costa Rica	Tilapia and shrimp ceviche	*Escherichia coli* was found in 15% of tilapia ceviche samples and in 4% of shrimp ceviche samples.	[53]

4. Street Food in Mexico

The Mexican community has access to a variety of street food establishments, making it an important element of many people's diets [10]. Street food establishments are a staple of the food environment and a source of cheap and nutritious food, and they provide employment for millions of low- and middle-income families [10,29,30].

It is estimated that there were 805,000 street food vendors in Mexico during the first three months of 2025, with an average age, education level, and salary of 44.4 years, 8.39 years, and 4500 Mexican pesos, respectively. The street food vendors worked approximately 34.5 h per week on average. The largest concentration of vendors was in the states of Puebla and Mexico, and in Mexico City [54].

Street food vendors in Mexico use various means to cook, display, store, and transport food, including mobile stalls such as bicycles and carts, semi-mobile stalls consisting of tables, chairs, and portable cooking utensils, and fixed stalls that can remain in one place overnight but can be easily moved to another [29]. Typical street food offerings are quite varied, with common items including tacos (a tortilla usually made of nixtamalized corn folded or rolled up that wraps various fillings, such as meats, stews, fish or vegetables), quesadillas (a corn or wheat flour tortilla folded in half, usually filled with cheese or various stews or ingredients), stews, dressings, fruit syrups, sopes (corn tortilla, fried and served with refried beans, cheese, cream, and sauce), corn on the cob and esquites (corn kernels), tortas (traditional and popular sandwich, prepared with white bread such as bolillo or telera, filled with various ingredients such as beans, meats, and vegetables), hot dogs, hamburgers, cakes, tamales (food made from nixtamalized corn dough, filled with a variety of ingredients (usually meat), cooked in vegetable leaves), sweets, snacks, atole (a hot corn-based drink), fruit cocktails (cut and peeled), paletas (popsicles), ice cream, fruit-flavored drinks, coffee, fermented beverages, fish, seafood, and seafood products [10,55].

5. Surveillance of the Safety of Street Food

The street food industry is generally unregulated and almost clandestine. Furthermore, food is commonly prepared and sold under conditions and practices exhibiting deficient or nonexistent hygiene, with limited access to potable water, sanitation facilities, and waste disposal, representing a significant health problem due to the risk of foodborne illnesses, proliferation of insects and rodents, and environmental contamination [7,8,34].

Several studies have reported the presence of pathogenic microorganisms in street food, which carries the risk of food poisoning and foodborne infections in the population. During 2000 to 2025, several studies related to the evaluation of the safety of products sold on public roads in Mexico have been carried out and reported (Table 2), generally

pointing out poor hygiene practices in the preparation, handling, storage, disposal, and sale of products with inherent risks to consumer health due to the presence of biological contaminants, mainly bacteria, and the need to carry out greater control and surveillance of the microbiological quality of street food by health authorities, as well as the promotion of food safety training for producers and handlers of these foods.

Table 2. Microbiological hazards present in street food sold in different locations in Mexico.

Location	Prepared and Marketed Foods	Microbiological Hazards	Source
Street vendors and fixed stalls, Obregon City, Sonora	Natural orange juice, fruit salad, prepared meats, natural fruit water, hamburger meats, and fish	Total and fecal coliforms in the range of <1 to 1100 MPN/g or mL, and presence of *Vibrio* sp. and *S. aureus*	[55]
Informal food vending. (Subway), Metro Collective Transportation System, Mexico City	Sauces	Presence of aerobic mesophiles, total coliforms, and fecal coliforms in 100%, 22%, and 5% of the samples, respectively; in the latter, *Escherichia coli* was identified.	[56]
Street stalls in the health jurisdictions, State of Tabasco	Tacos, stewed rice, fish, cabbage, cheeses, sauce, cabbage with coriander, horchata with milk, and meats	Presence of aerobic mesophiles, *Vibrio cholerae*, fecal coliforms, *S. aureus*, and *Salmonella* sp.	[57]
Street markets, South of Mexico City	Cheeses	Presence of *Salmonella* spp.	[58]
Street markets, Coyoacan, Mexico City	Vegetables, fried foods, meats, fish, and seafood	Fecal coliforms were present in 84.2% of the samples, 2% of the samples presented *S. aureus*, and 17% of fish and shellfish samples presented *Salmonella* sp.	[59]
Supermarkets and street vendors, Mexico City	Germinated and ready-to-eat salads	Aerobic mesophilic bacteria (AMB) were present in 100% of the salad samples, with 59% samples showing bacterial proportions of >5.17 log 10 CFU/g. Fecal coliforms (FCs) were present in 32% of the samples, and only 8% showed counts greater than 100 MPN/g. Regarding sprouts, 100% of the sprout samples were positive for AMB and total coliforms and 69% for FCs.	[60]
Stalls outside elementary schools, Guaymas, Sonora	Fried foods, fresh water, ice creams, cakes, whole corn on the cob prepared with cheese, mayonnaise and sauce, burritos, shredded meats, potatoes, beans, and chorizo	Total coliforms were detected in 66% of the samples, with the highest proportion being >1100 MPN/g or mL, and fecal coliforms were detected in 21% of the samples, with the highest proportion being >1100 MPN/g or mL.	[61]
Food stalls outside the university, Chiapas	Fresh water	Presence of total coliforms in all samples in the range of <3 to 240 MPN/mL and fungi and yeasts in the range of <10 to 130 CFU/mL	[62]

Table 2. *Cont.*

Location	Prepared and Marketed Foods	Microbiological Hazards	Source
Ice cream shops and supermarkets, Reynosa, Tamaulipas	Fresh fruit drinks and salads	Presence of aerobic mesophiles in 82.3% of the samples, fecal coliforms and *S. aureus* in 35.2%, and *Salmonella* spp. and *Shigella* spp. in 16.1% and 2.9%, respectively.	[63]
Restaurants and street vendors, Reynosa, Tamaulipas	Ceviche	Presence of *Aeromonas* sp. and *Pseudomonas* sp.	[64]
Supermarkets, street markets, and convenience stores, Chihuahua.	Cheeses	A total of 2.22% of the samples presented *L. monocytogenes*, and 8.88% of the samples were positive for *Salmonella* spp.	[65]
Street food stalls, Mexico City	Taco dressing	*E. coli* was present in 67% of the samples, and 7% of them were positive for diarrheagenic *E. coli* pathotypes.	[66]
Street vendors or food establishments located in public markets, Guadalajara	Orange juice	*Salmonella* spp. was detected in 9% of the samples and *Shigella* sp. in 5% of the samples.	[67]
Restaurants, Pachuca City	Fresh carrot juice	Overall, 100% of the samples presented coliforms, 96.8% fecal coliforms, 54.3% *E. coli*, 8.9% diarrheagenic *E. coli*, and 8.6% *Salmonella* spp.	[68]
Food services, mobile food carts, restaurants, vending machine operators, street food vendors, etc., 10 municipalities of Sinaloa	Prepared foods, meats, fruits, salads, beverages, dairy products, fish, and seafood	Fecal coliforms, *E. coli*, and diarrheagenic *E. coli* were detected in 13.4%, 7.92%, and 1.08% of the samples, respectively.	[69]
Street vendors, Mexico City	Freshly squeezed orange juice	All the samples were positive for aerobic mesophilic bacteria, with proportions ranging from 1.8 to 6.2 log CFU/mL, and 54%, 25%, and 13% of the samples were positive for total coliforms (TCs), fecal coliforms (FCs), and *E. coli*, respectively. TCs, FCs, and *E. coli* were present in proportions ranging from <3 to >1100 most probable number (MPN)/mL, <3 to 460 MPN/mL, and <3 to 11 MPN/mL, respectively.	[70]
Public market, Mexico City	Lamb meat tacos (barbecue)	Overall, 16.3% of the samples were positive for *C. perfringens*.	[71]
Vendors, shops, and markets, Chilpancingo City	Chicken meat, pork, beef, and cow's milk cheese	The main groups of microorganisms isolated from the cheese were *Enterobacteriaceae* (71%) and *Staphylococcus* sp. (29%). *Enterobacter* sp. (40%), *Klebsiella* sp. (26%), and *E. coli* (22%) were the most frequently isolated microorganisms, while *Salmonella* sp. represented only 4% of the isolated strains.	[72]

Table 2. *Cont.*

Location	Prepared and Marketed Foods	Microbiological Hazards	Source
Street vendors outside subway stations, Mexico City	Freshly squeezed orange juice	All samples tested positive for aerobic mesophilic bacteria, with limits ranging from 1 to 6.8 log CFU/mL, where 58.3%, 45%, and 8.3% of the samples tested positive for total coliforms, fecal coliforms, and *E. coli*, respectively, which were present in proportions ranging from <3 to >1100, <3 to >1100, and <3 to 53 MPN/mL, respectively.	[73]
Small retail markets, Sinaloa	Fresh cheese	*L. monocytogenes*, *E. coli*, and coliforms were detected in 9.3, 94, and 100% of the samples, respectively.	[21]
Street vendors, Colima	Cooked and precooked rice with vegetables	High counts of aerobic mesophilic bacteria ($> 10^5$ CFU/g) were obtained in 87.5% of the precooked rice samples and in 23.2% of the cooked rice samples. *B. cereus* was detected in 28.1% of the precooked rice samples and in 89% of the cooked rice samples.	[74]

MPN: most probable number. CFU: colony-forming units.

Microbiological analyses frequently performed on street food in Mexico involve the detection of indicator bacterial groups (coliforms, mesophilic bacteria, and fungi), which are used to identify inadequate hygiene practices in food preparation or the possible presence of associated pathogenic microorganisms. They also assess the presence of various pathogens of public health importance, such as *Salmonella* sp., *Listeria monocytogenes*, *E. coli*, *S. aureus*, and *Vibrio* sp., among others (Table 2). The food–pathogen combinations posing the greatest health risk were identified. It is shown that, in foods that contain meat as the main ingredient, *Enterobacter* sp., *Klebsiella* sp., *Salmonella* sp., *Escherichia coli*, *C. perfringens* and *Staphylococcus aureus* stand out; in dairy products, *Listeria monocytogenes*, *Salmonella* sp., *E. coli*, and *S. aureus*; in fruit and vegetable products, *Vibrio* sp., *S. aureus*, *E. coli*, *Shigella* sp., and *Salmonella* sp.; and in cereals, *B. cereus*. In sauces, *Escherichia coli* was found, while in fish and seafood preparations, *Vibrio* sp., *S. aureus*, *Salmonella* sp., and *Aeromonas* sp. were identified as relevant pathogens. The detection of indicator and pathogenic microorganisms suggests a high risk of disease associated with the consumption of street food, especially when proper hygiene conditions and practices are not followed during the preparation, storage, and sale phases.

Notably, the microbiological analysis of street food, both in the world (Table 1) and in Mexico (Table 2), presents a variety of scientific, technical, and/or social challenges that may lead to limitations or complications in comparing and interpreting data between regions. Among these challenges are the wide variety of street food due to cultural, economic, and geographic factors; variability in sales conditions (different levels of access to hygiene for vendors); difficulty in obtaining representative samples (collecting samples at different times and locations, which leads to high costs in terms of time and resources); a lack of uniformity in the microbiological analysis methods used; the technological and economic capabilities of analytical laboratories; and the informal nature of the food (which hinders inspection and data collection). This, coupled with the availability of or access to reports on the microbiological profile of these products, particularly in Mexico, is possibly due to factors such as passive surveillance, underreporting, and the lack of uniformity in sampling and analysis methods used. Therefore, to obtain more information, to improve the availabil-

ity and accessibility of microbiological analysis for assessing the microbiological quality of street food, and to identify health hazards globally and in Mexico, collaboration is required between government entities, academia, and international health and food organizations. Through actions such as increased sampling, expanded analysis coverage across a wider variety of foods, standardization of microbiological methods and criteria, expanded and continuous sanitary surveillance of informal food trade, creation of open and comparable databases, and accessible publications, it will be possible to obtain the comparable microbiological profiles of foods across different areas or regions, thus improving actions in the prevention of foodborne illnesses.

Upon evaluation, the presence of biological contamination, primarily bacterial (*Listeria monocytogenes*, *Salmonella* sp., *Aeromonas* sp., *Vibrio* sp., coliforms, and aerobic mesophilic bacteria), in a variety of street food sold in different parts of Mexico (Table 2) represents a potential health risk for consumers. This health risk can be intensified by inadequate hygiene during the preparation and storage of these foods. Some indicators for assessing the microbiological risk of street food include the hygienic conditions of the stall or vendor. High-risk conditions include the presence of flies or rodents, accumulated garbage (especially organic waste), food exposed to sunlight or stored without refrigeration, simultaneous handling of money and food, dirty food contact surfaces, a lack of handwashing, and the absence of a potable water source. Notably, hygiene education for street food vendors is a significant factor in managing microbiological risk. Thus, for the assessment of the health risk from street food, information is needed regarding microorganisms present, quality of water used, and hygienic handling and preservation conditions and practices, where failures in the latter increase the health risk, especially with highly perishable foods (meats, dairy, fish, seafood, etc.).

6. Prevention and Control of Foodborne Illnesses

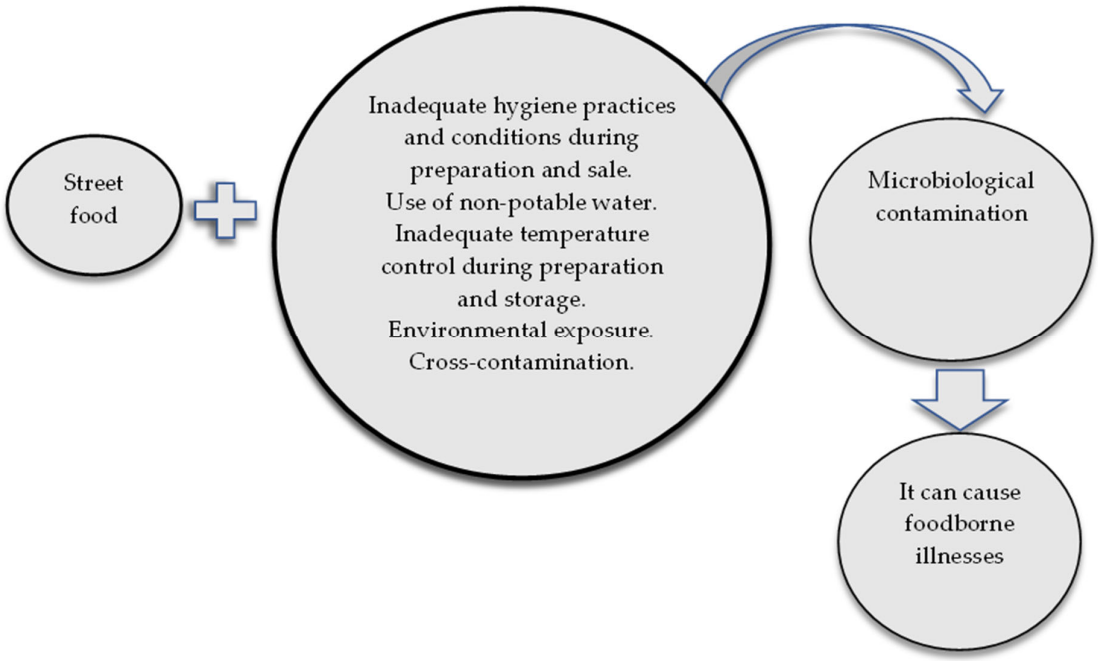
Microbiological contamination of street food has been noted previously [23,55]. The various factors that generally influence the occurrence of foodborne illnesses from consuming street food contaminated with microorganisms are inadequate refrigeration, food preparation well in advance of serving, improper cooking and reheating, excessive handling during preparation, inadequate hygiene and health status of food handlers, obtaining food or raw materials from contaminated sources, inadequate cleaning and disinfection of equipment and materials used in food preparation, and selling food in inappropriate locations, in addition to the presence of vectors such as insects (Figure 2) [5,19,23,75].

In the preparation, sale, and consumption of street food, the equipment used can vary, including mobile homes, food trucks, bicycles, food stalls among others [31] (Figure 3). This equipment varies in size, shape, construction materials, and available sanitary resources. It should be noted that the infrastructure requirements to ensure the microbiological quality of food change depending on the type of food being sold, i.e., whether (1) it has been previously prepared at home, (2) it is prepared at the stall, or (3) it is partially prepared at the sales stall [76].

Notably, in many of these food preparation and sales locations, key formal actions for food safety may be carried out inadequately or omitted, such as maintaining cleanliness, separating raw from cooked foods, thoroughly cooking food, maintaining food at safe temperatures, and using safe water and raw materials [19,31,77], resulting in food contamination and the appearance of cases of foodborne illnesses.

To ensure the safety of street food, the incorporation of the so-called "improved" technologies in food preparation and marketing has been proposed, which can address critical issues at street stalls, such as the supply of potable water, handwashing facilities, solid waste disposal containers, work surfaces or tables, display cases, dish drainers, and

space for food preservation (refrigeration and cooking). Adopting improved technologies involves the total or partial replacement of existing metal-based stalls and the use of stainless steel for work surfaces and polyvinyl or fiberglass for water tanks. This is subject to the vendor's economic means, as well as financing options and credit for street vendors to acquire these improved technologies [36,76].



Prepared by the authors.

Figure 2. Relationship between street food, contaminants and microbiological hazards, and foodborne illnesses.



Figure 3. Street food preparation and sales stalls in Mexico.

Foodborne illnesses caused by microorganisms can be prevented or controlled throughout the food chain by avoiding the consumption of raw foods; ensuring proper cooking, preparation, and storage procedures; and providing training in basic hygiene standards and procedures to those who prepare and handle food [5,19]. In the street food vending sector, in addition to implementing hygiene standards to ensure food safety, it is also necessary to strengthen government activity in urban planning, permit issuance, the enforcement and monitoring of standards on the microbiological safety of street food, and the provision of regular educational programs for vendors, consumers, and the general population, all in favor of public health [5,10,30,32].

The key factors influencing street food safety are as follows: the hygiene of the vendor or handler (the proper use of gloves, clean utensils, and separate surfaces, handwashing, the separate handling of money and food, and the use of potable water for cleaning), food storage temperature (refrigeration, freezing, or cooking), exposure time to the environment (short time after preparation), and type of food (food with high moisture and protein content, food cooked and cooled but not consumed for an extended period, and food excessively handled after cooking, which can be highly dangerous). Based on these factors, the recommendations for street food consumers to prevent foodborne illnesses caused by microorganisms are as follows: choose freshly prepared and heat-treated foods and beverages, as well as beverages made with purified water; avoid raw foods; avoid food and beverages if rodents or flies are present at the point of sale; and observe food rotation at the point of sale, as food that has been accumulated or reheated multiple times should be avoided.

Microbiological risk assessment is considered a fundamental tool of the Codex Alimentarius (CAC/GL 30-1999), encompassing hazard identification, hazard characterization, exposure assessment, and risk characterization. In the context of street food in Mexico, a general qualitative assessment of microbiological risk was developed, considering the available information on these foods. Finding that street food is an important food source for the Mexican population due to its accessibility, low cost, availability, and cultural relevance. However, inadequate hygiene practices, or absence thereof, during preparation, storage, transportation, and sale can promote microbiological contamination of food and increase the risk of foodborne illnesses.

The food that is commonly sold in street stalls and markets in Mexico presents a great diversity of both products and places of sale. Among the food items sold are tamales, tacos and prepared meats, fried foods, sauces, fruit salad, fresh fruit juices, vegetable salads, fish (ceviche), dairy products, and more.

The main microorganisms of public health importance associated with street food include: *Klebsiella* sp., *Salmonella* sp., *Shigella* sp., *Bacillus cereus*, *Escherichia coli*, *Clostridium perfringens*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Vibrio* sp., *Aeromonas* sp., and *Pseudomonas* sp. The presence of these microorganisms can originate from factors such as contaminated raw materials, use of non-potable water, improper handling, cross-contamination, storage at inappropriate temperatures, and prolonged exposure to the environment before consumption. Pathogens such as *Salmonella* sp., *Klebsiella* sp., *Shigella* sp., *Bacillus cereus*, *Escherichia coli*, *Clostridium perfringens*, *Listeria monocytogenes*, *Vibrio* sp., *Aeromonas* sp., and *Pseudomonas* sp. can cause infections, while *Staphylococcus aureus* can cause food poisoning, the common and widespread symptoms of which are nausea, vomiting, diarrhea, fever, and general malaise. *Listeria monocytogenes* poses a considerable risk to vulnerable populations such as pregnant women, older adults, and immunocompromised individuals.

Consumer exposure to pathogens in street food varies due to: 1. Food-related factors, such as the diversity of raw materials or ingredients used in its preparation, the type of

raw or pre-processed ingredients, and the type of food itself, as some require complex preparations or multiple handling stages, where the risk of contamination increases with more stages. 2. Factors related to the handler or vendor, such as: food hygiene training, access to handwashing facilities, availability of potable water and temperature control for ingredients and food, and simultaneous handling of money and food. 3. Environmental factors, including exposure to dust, insects or rodents, and high temperatures that promote microbial growth. 4. Consumer-related factors, including regular to high consumption of these foods, and their availability and accessibility to the general population, including vulnerable groups such as children, the elderly, and pregnant women.

The probability of exposure is moderate to high. Since street food is often sold in many places and is easily accessible, it is prepared and consumed under conditions that promote contamination or microbial growth when hygiene practices are lacking. The severity of the resulting illnesses can range from moderate to high, depending on the pathogen involved and the consumer's susceptibility. Consequences can vary from self-limiting infection and medical treatment to permanent health problems or death, especially in vulnerable groups.

The combination of frequent exposure, multiple opportunities for contamination, and the possible presence of pathogenic microorganisms of public health concern suggests a moderate to high microbiological risk for street food when adequate sanitary measures are not implemented.

The sale of food contaminated by various microbiological risks can lead to an increase in foodborne illnesses, affecting well-being and socioeconomic development. Among the preventive measures identified and recommended for food vendors is, primarily, regular training in food hygiene. For health authorities, the implementation of regular microbiological surveillance programs for marketed food is recommended, as well as health education and information programs for the general public, food handlers, and vendors. Meanwhile, recommendations or preventive measures for consumers include choosing establishments with adequate hygiene conditions and practices, opting for freshly prepared and heat-treated foods and beverages, and avoiding raw foods or foods prepared with raw ingredients.

It should be noted that this assessment has limitations and uncertainties associated with various factors, such as the availability of standardized and regular microbiological surveillance data for street food, food diversity, variability in preparation practices and sales locations, methodological differences among available studies, and specific consumption patterns. These uncertainties limit the assessment and the accuracy of the risk estimates.

7. Food Safety Regulations

To protect consumer health and promote quality, safety, and fairness in food production and marketing worldwide, regulatory frameworks are created that comprise a set of laws, standards, guides, regulations, directives, codes, or guidelines. These are developed, compiled, and/or coordinated by different international organizations such as the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO) through the Codex Alimentarius [11,78], the World Organization for Animal Health (WOAH) [79], the International Commission on Microbiological Specifications for Foods (ICMSF) [11], and the International Organization for Standardization (ISO), as well as by the regulatory agencies of various countries such as the Department of Agriculture (USDA) and Food and Drug Administration (FDA) in the United States of America [80,81] and the European Commission, European Parliament, Council of the European Union, and European Food Safety Authority (EFSA), with the latter acting as a scientific advisor in the European Union, which is a geopolitical entity made up of 27 countries [82–84].

International organizations such as the FAO/WHO, through the Codex Alimentarius, have established the Regional Code of Hygienic Practice for the Preparation and Sale of Street Foods (Latin America and the Caribbean) (CXC 43R-1995) [85]. This code outlines the requirements and practices that must be followed during the preparation and sale of food and beverages for direct consumption on the street. It applies to stalls where food is prepared and sold, as well as the means of transport used.

Meanwhile, in the European Union, street food establishments must comply with Regulation 852/2004 on the hygiene of foodstuffs, specifically Annex II, Chapter III, which establishes the requirements for movable and/or temporary premises (such as marquees, market stalls, mobile sales vehicles) used primarily as a private dwelling but where food is regularly prepared for placement on the market and vending machines. This encompasses various aspects such as personal hygiene and the cleanliness of surfaces and equipment [86].

In Mexico, food safety regulation is the responsibility of two government entities: 1. The Secretariat of Health (SSA), which focuses primarily on processed foods, food services, and municipal slaughterhouses through the Federal Commission for Protection against Sanitary Risks (COFEPRIS), and 2. The Secretariat of Agriculture and Rural Development (SADER), which focuses on primary food production through the National Service for Agrifood Health, Safety, and Quality (SENASICA) [87].

The Federal Commission for Protection against Sanitary Risks is responsible for monitoring and controlling the safety of food sold both formally and informally (street vendors) nationwide in Mexico [88]. Through the federal health system, COFEPRIS organizes, harmonizes, and coordinates with health authorities of the different states throughout the country, and the corresponding state public health laboratories supervise the actions of control, surveillance, and health promotion for the quality and safety of food products and services [89].

Likewise, local health authorities, such as health jurisdictions or municipal health regulation departments, are empowered to conduct inspections to detect violations of hygiene standards and impose sanctions at fairs, open-air markets, and/or areas with a high concentration of street food vendors [88].

The regulatory framework in Mexico consists of the General Health Law, the Sanitary Control Regulations for Products and Services, and various Official Mexican Standards (NOMs) that aim to guarantee food safety and protect consumer health. Article Four of the Political Constitution of the United Mexican States establishes the right to health, which guarantees that every person has the right to health protection, as well as to nutritious, sufficient, and quality food, and that the corresponding state is responsible for ensuring this right. For this purpose, the General Health Law is established for the regulation and sanitary control of products and services, including food, and it empowers authorities such as the Secretariat of Health (SSA) and COFEPRIS to issue sanitary standards and regulations [88].

The Sanitary Control Regulations for Products and Services aim to regulate and promote the sanitary aspects of the import and export of products, services, activities, and establishments related to food, beverages, tobacco, additives, and other items [90]. Mexican Official Standards (NOMs) are mandatory technical regulations applied throughout Mexico that establish various regulations pertaining to the classification, specifications, and testing methods applicable to a product, service, or process. There are also NMX standards, which are voluntary and serve as references for regulating the quality of products and services. It should be noted that, if a NOM standard references an NMX standard, the latter becomes mandatory [91].

NOM-251-SSA1-2009 is among the applicable regulations for ensuring food safety, including that of street vendors [92], which focuses on hygiene practices for the processing of food, beverages, and dietary supplements. It establishes the minimum requirements

for good hygiene practices that must be observed in the processing of food, beverages, and dietary supplements and their raw materials to prevent contamination throughout the process. It also outlines the guidelines for implementing a Hazard Analysis and Critical Control Points (HACCP) system. NOM-051-SCFI/SSA1-2010 [93] establishes the commercial and health information that must be included on the labels of pre-packaged foods and non-alcoholic beverages, whether manufactured domestically or abroad, and determines the characteristics of this information. While this standard does not regulate hygiene practices, it contributes to food safety from an informational perspective.

The standard NOM-127-SSA1-2021 [94] establishes the permissible quality limits that water for human use and consumption must meet, such as the absence of *E. coli* or thermotolerant coliforms in 100 mL of water. NOM-201-SSA1-2015 [95] establishes the sanitary specifications that must be met by water and ice for human consumption that are sold pre-packaged or in bulk by the establishments that are dedicated to the processing of these products, where the maximum permissible limit for total coliforms is <1.1 MPN/100 mL.

Finally, NMX-F-605-NORMEX-2018 [96] establishes the provisions for good hygiene and sanitation practices that food and beverage service providers must comply with to obtain the "H" distinction. This applies to fixed establishments that handle food and beverages in all phases: receiving, storage, preparation, and service. The "H" distinction is a recognition endorsed by the Ministry of Tourism and the Ministry of Health for establishments that meet hygiene standards; it applies to hotels, restaurants, daycare centers, hospitals, industrial cafeterias, etc. [97].

The Secretariat of Health, through the Federal Commission for Protection against Sanitary Risks (COFEPRIS), intending to disseminate and enforce applicable health legislations on hygiene practices, developed self-verification guides that describe the protection methods against health risks from food consumption by informing establishments dedicated to the preparation and serving of food about the elements that must be evaluated to maintain the sanitary conditions of food (facilities, equipment, utensils, storage, control of operations, waste management, water control, cleaning, hygiene of handlers, records, etc.), to efficiently comply with the sanitary provisions included in the applicable legislative framework [98].

Furthermore, it should be noted that, despite the regulatory framework in Mexico and the surveillance efforts undertaken, the latter may be limited by the large size and dispersion of the informal market (due to the lack of authorizations or registration), leading to risks of non-compliance with food safety standards in the products offered to the public. It is worth highlighting that, in many small towns, sanitary surveillance is practically nonexistent, while in large urban centers, inspection and control actions are targeted and/or occasional. Although training and regularization programs have been implemented in some municipalities, these are insufficient and have limited reach. Therefore, it is necessary to implement actions from a public health perspective, such as progressive formalization processes for vendors, regular and widespread informational programs to train and improve hygiene practices for producers and consumers, training in business management, credit support, and tax incentives for distributors [88].

This review has some limitations: the conceptualization of a broad term, i.e., street food, that introduces a degree of subjectivity, since specific parameters from an informal source cannot always be found directly in databases, and the information included in this review, due to the diverse styles in which the reported studies are conducted, located, compiled, or analyzed, may result in the omission of some relevant information.

8. Conclusions

Street food is considered an accessible, quick, inexpensive, and diverse source of food for the population. It varies in presentation and marketability, and its commercialization is constantly growing in Mexico, contributing primarily to the economy of low-income families.

The production and sale of street food in Mexico constitutes a multidimensional phenomenon of great cultural, social, and economic relevance, as it preserves food traditions, generates employment and income for thousands of families, and contributes to daily access to food for large sectors of the population. However, various microbiological studies of these foods have documented the presence of indicator microorganisms of contamination (mesophilic bacteria, coliforms, and fungi), as well as various pathogens such as *Salmonella* sp., *Shigella* sp., *Clostridium perfringens*, *Vibrio* sp., *Aeromonas* sp., *Escherichia coli*, *Listeria monocytogenes*, and *Staphylococcus aureus*; thus, posing a risk to public health and contributing to the occurrence of foodborne illnesses. Contamination of street food with various foodborne pathogens is generally associated with the absence or inadequate hygiene conditions and practices during food preparation and storage at the point of sale, as well as the lack of food hygiene knowledge of personnel who prepare, handle, and sell street food.

Likewise, consuming raw foods or foods that have not been adequately cooked increases the likelihood of contracting foodborne illnesses. Therefore, it is essential to strengthen food safety training for vendors and promote compliance with health regulations that guarantee the quality of the products offered. Similarly, consumers play a vital role in preventing illness by choosing establishments that maintain proper hygiene practices and opting for freshly prepared and thoroughly cooked foods before consumption. The combination of good hygiene practices and informed choices significantly contributes to protecting public health and improving the safety of street food.

To address public health challenges posed by street food, comprehensive actions are required from health authorities, the private sector, academia, consumers, and food vendors to develop, implement, and promote food hygiene training programs. Furthermore, health authorities must conduct regular health surveillance programs and procedures to ensure that street food remains an accessible, affordable, safe, and culturally important option for the population.

Another factor necessary to improve the safety of street food is improving basic sanitation services and public infrastructure (access to clean and safe water, clean sale areas, waste collection, street lighting, etc.). Moreover, incentives, financing, or loan programs should be established and promoted to support the improvement of and access to adequate infrastructure, facilities, and sanitary practices for street food vendors.

The assessment of microbiological hazards in street food is a fundamental tool in the sanitary surveillance of products. It allows for the collection of information that helps public health agencies determine the risks associated with street food, develop preventive and regulatory measures to reduce foodborne illnesses, and develop strategies related to public health protection.

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