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Microbiological Food Safety Issues in Brazil: Bacterial Pathogens

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Abstract

The globalization of food supply impacts patterns of foodborne disease outbreaks worldwide, and consumers are having increased concern about microbiological food safety. In this sense, the assessment of epidemiological data of foodborne diseases in different countries has not only local impact, but it can also be of general interest, especially in the case of major global producers and exporters of several agricultural food products, such as Brazil. In this review, the most common agents of foodborne illnesses registered in Brazil will be presented, compiled mainly from official databases made available to the public. In addition, some representative examples of studies on foodborne bacterial pathogens commonly found in Brazilian foods are provided.

Introduction

Brazil is a great producer of food commodities (Ferraz and Felício, 2010), and it is a major exporter of poultry, beef, coffee, sugarcane, frozen concentrated orange juice, soybeans, corn, pork, and cocoa (Brazil, 2009a). Agriculture accounts for about 6% of gross domestic product (25% when agribusiness is included) and 36% of Brazilian exports (USDA, 2011). Systems for assurance of safety, quality, and traceability have been implemented in order to fulfill the demands of foreign and local markets (Guivant, 2002; Mauricio *et al.*, 2009).

The agencies responsible for food control in Brazil are the Ministry of Agriculture, Livestock and Food Supply and the Ministry of Health, through the National Health Surveillance Agency (ANVISA). In recent decades, these two agencies made a major stride in establishing food standards and technical regulations in order to develop foreign trade and guarantee food safety (Salay *et al.*, 2001; WHO, 2012; Brazil, 2001b).

Technical departments of the Ministry of Agriculture, Livestock and Food Supply are in charge of controlling the quality and safety of agricultural products at the production level, and created several monitoring programs, such as (1) AGROFIT—safe utilization of pesticides for plant protection purposes; (2) SIF—Federal Inspection System; (3) SISBOV—origin certification for beef and buffalo meat; (4) SISLEG—Federal agricultural legislative system; (5) PNCRC—control of residues and contaminants in animal products; (6) PNRP—pathogen reduction; (7) PNSA—poultry sanitation; and (8) PNCEBT—control and eradication of animal brucellosis and tuberculosis (Brazil 2009a).

ANVISA coordinates, supervises, and controls activities regarding registration, information, inspection, risk control, and rulemaking to assure health surveillance over food, beverages, water, ingredients, packages, technologies, contamination limits, and veterinary residues (Brazil, 2009b).

Following a global trend, Brazilian consumers have expressed increased concerns about risks derived not only from foodborne pathogens, but also from artificial chemical preservatives used to control them (Schuenzel and Harrison, 2002; Rodríguez *et al.*, 2003; Parada *et al.*, 2007; Castellano *et al.*, 2008). Brazilians have a relatively healthy diet, and eating outside the home is becoming more common, with an increasing demand for convenient ready-to-eat (RTE) and minimally processed foods (Canada, 2010; Sant'Ana *et al.*, 2012).

The most relevant agents causing foodborne illnesses in Brazil are highlighted in this review, based on data available from public official databases (Brazil, 2008a,b; Brazil, 2011). Also, examples of studies on occurrence of pathogenic bacteria in important food commodities consumed in Brazil are provided. With this review, we intend to contribute to improving food safety at local and global levels.

Epidemiology of Main Foodborne Diseases in Brazil

Data regarding foodborne diseases in Brazil are scarce and most reported foodborne outbreaks occurred in the South and

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Southeast regions, the most populated areas in the country (Brazil, 2011). The occurrence of outbreaks in other regions is not well known. Only a few Brazilian Federative States, mainly from the South and Southeast regions, have a structured foodborne diseases surveillance system and report regularly to the local or national health authorities (van Amson, 2006; Brazil, 2011).

From 2000 to 2011, 8663 foodborne disease outbreaks were registered, affecting 163,425 persons and causing 112 deaths (Brazil, 2011). Official data on epidemiology of foodborne diseases suggest that since 2008, there has been a decreasing trend in the number of outbreaks, despite the constant increase of the population (Brazil, 2011; IBGE, 2012).

Foods most commonly implicated in outbreaks were mixed meals, eggs and egg-related products, desserts, water, raw and processed beef, milk and dairy products, and chicken and pork (Brazil, 2011). Most outbreaks were caused by bacteria, mainly *Salmonella* spp., followed by *Staphylococcus* spp., *Bacillus cereus*, *Clostridium perfringens, Shigella* spp., and *Clostridium botulinum* (Araujo *et al.,* 2002; Brazil, 2011). However, for approximately 50% of the registered outbreaks, the etiological agent of the disease could not be determined (Brazil, 2008a; Brazil, 2011).

In the present review, a list of the most relevant foodborne pathogens was compiled based on (1) data published in 2008 and 2011 by the Department of Health, which is considered the official database of foodborne diseases in Brazil (Brazil, 2008a,b; Brazil, 2011), and on (2) the scientific literature available in PubMed and Web of Science. Prevalence or outbreak investigations included in the review were conducted in Brazil and published mainly from 2000 to 2012 (August) in English or Portuguese. The pathogens included in the survey are those listed by the Brazilian official database as commonly implicated in foodborne outbreaks in Brazil. The initial search in Web of Science and PubMed retrieved 52 possibly eligible studies using the following search terms in Title/Abstract: Food AND Brazil AND *Staphylococcus* OR *Salmonella* OR *Bacillus cereus* OR *Clostridium perfringens* OR botulism OR *Shigella*. Abstracts of the 52 eligible studies were analyzed and 37 of them were excluded because (1) the full article was not available, (2) results were inconclusive, (3) data were related to molecular or serological characterization of strains obtained in previous studies, and (4) the same paper was detected multiple times in different databases. Therefore, 15 studies were considered eligible and are compiled in Table 1.

A literature survey on data regarding *Listeria monocytogenes* was also done, but in Brazil, there have been no reported cases of listeriosis linked to the consumption of contaminated foods (Souza *et al.*, 2008), and in the indexed literature, there are only two reports of outbreaks of listeriosis in Brazil. The first one was reported by Landgraf *et al*. in 1999 and involved five neonates in São Paulo city, with meningitis due to *Listeria*, while the second outbreak was recently reported by Martins *et al*. (2010) to occur among elderly hospitalized patients, in the city of Rio de Janeiro. For both outbreaks, no source of infection was determined, but Martins *et al*. (2010) hypothesized that the bacterium was likely acquired via contaminated foods prepared in the hospital kitchen.

The registration of listeriosis cases is not mandatory in the National Notifiable Diseases Surveillance System (Brito *et al.*, 2008), but a few compiled data on occurrence and characterization are found, such as the paper published by Hofer *et al.* (2000) on the species and serovars of *Listeria* genus from different sources (1971–1997), including foods.

Following a global trend, in Brazil *Salmonella* Enteritidis (SE) has been associated with human foodborne infections caused by the ingestion of contaminated foods of animal origin, mainly undercooked poultry meat and eggs (Vaz *et al*., 2010). Geimba *et al*. (2004) affirmed that although Brazil is the second-largest producer of poultry meat in the world, few studies have been conducted in *Salmonella* isolates from this country.

Nunes *et al*. (2003) demonstrated that *S. enteritidis* phage type (PT) 4 was the type most commonly found among the SE Brazilian isolates from 1995 to 1997 (healthy and diseased chicken, outbreaks of human gastroenteritis related to the consumption of egg products, poultry meat, pipped embryos of broiler chicks, meat meal and the rearing environment, and diverse food products [i.e., cheese, mayonnaise, cake, and bacon]). Those authors concluded that the results obtained were in accordance with the worldwide trends in distribution patterns for different SE phage types. However, as stated by Kottwitz *et al*. (2012), it is important to note that since 2002, a decline of outbreaks caused by SE PT4 has been observed, probably as a result of the control measures adopted in the poultry production chain, which may have favored the introduction of other phage types such as the PT9 (Kottwitz *et al*., 2012).

Mürmann *et al*. (2011) pointed out that although chicken and eggs are the foods commonly associated with salmonellosis outbreaks, infections due to pork consumption also have been reported, mainly in regions where it is an important part of the human diet, as in the southern region of Brazil. *Salmonella enterica* was detected in 24.4% of the pork sausages samples analyzed in the city of Porto Alegre, southern Brazil (Mürmann *et al*., 2009) and thus, undercooked pork sausage may also represent a significant health risk for consumers.

Staphylococcus aureus is the second leading cause of bacterial foodborne disease in Brazil, usually linked to inadequate food handling (Rapini *et al.*, 2005). Coagulase-positive staphylococci produce heat-stable enterotoxins, with emetic activity. It is the main cause of food poisoning that occurs after ingestion of foods contaminated with *S. aureus* by improper handling and subsequent storage at elevated temperatures (Soares *et al*., 2012). In this sense, recently Soares *et al*. (2012) interviewed 166 food handlers via a questionnaire to determine levels of knowledge, attitudes, and practices in food safety. Also, the presence of coagulase-positive staphylococci species was analyzed on the hands of food handlers in municipal schools of Bahia, northeast Brazil. The authors revealed that despite a high prevalence of training and positive attitudes about food safety, 53.3% of the samples taken from hands presented coagulase-positive staphylococci.

Colombari *et al.* (2007) reported details of an outbreak caused by *S. aureus* in 1998, which affected approximately 180 people attending a benefit luncheon at a public school in São Paulo State. High counts of *S. aureus* were observed in a vegetable salad prepared with mayonnaise sauce, broiled chicken, and pasta with tomato sauce. Isolates from oropharyngeal secretions of food handlers and from the salad presented the same phage-type profile and resistance to antibiotics, belonged to the same RAPD cluster, and produced enterotoxin A, indicating improper handling during manufacture.

According to the official database of the National Secretary of Health Surveillance (SVE) of the Ministry of Health,

Table 1. Studies of Prevalence of Selected Foodborne Pathogens and Epidemiology of Outbreaks That Occurred in Brazil from 2000 to 2012[a]

Pathogen	*Kind of survey*[b]	*Samples analyzed* (n)	*Result*	*Federative states*[c]	*Reference*
Salmonella spp.	A	Eight trademarks of cooked ham (40)	30% positive samples	CE	Fai *et al.* 2011
	A	Untreated oysters (12) Ozone-treated oysters (12)	10% untreated oysters positive	SP	Ristori *et al.* 2007
	A	Sugarcane juice from street vendors (24)	All negative samples	SP	Oliveira *et al.* 2005
	B	Foodstuffs associated with *Salmonella* outbreaks (n.i.)	Foodstuffs contaminated: poultry meat (40%), cow meat (11%), desserts (8%), mayonnaise (6%), sausage (5%), unpasteurized shell eggs (4%), and other food sources (26%). Homemade mayonnaise: main vehicle for *Salmonella* foodborne outbreaks, and *Salmonella* Enteritidis (95%) of the isolates	SP	Tavechio *et al.* 2002
	A	*Lactuca sativa, Chicorium intybus, Eruca sativa, Nasturtium officinale, chicorium endívia* (172)	1% positive samples	SP	Takayanagui *et al.* 2001
	A	Pasteurized milk (250) and raw milk (50)	02 isolates of *Salmonella* Montevideo	PE	Padilha *et al.* 2001
	B	Foodstuffs associated with *10 Salmonella* outbreaks (19)	Food containing eggs, mayonnaise, or chicken were contaminated with *Salmonella* in eight outbreaks. Food containing mayonnaise had high counts of *Salmonella* ($>10^7$ MPN.g^{-1})	RS	Mürmann *et al.* 2008
Staphylococcus spp.	B	Meal prepared for a celebration: chicken, roasted beef, rice, and beans (n.i)	*S. aureus* (SEA)	MG	Do Carmo *et al.* 2004
	A	Raw milk (140)	All samples presented presumptive *Staphylococcus* colonies and 19% of the isolates produce enterotoxin (mainly D)	SP	Oliveira *et al.* 2011
	A	Soft cheese (45)	77% of the samples positive for *S. aureus* 08 samples (17.7%) counts $>10^3$ CFU g^{-1}	RJ	Araujo *et al.* 2002
	A	Milk, soft cheese, hard cheese, ice cream, yogurt, sweets, and snacks (172)	Coagulase-positive *Staphylococcus* in 26 (15.1%) samples	SP	Aragon-Alegro *et al.* 2007
	B	Minas cheese (homemade) and unpasteurized milk (outbreak 1) Unpasteurized milk (outbreak 2)	*S. aureus* (SEA, SEB, and SEC) with counts varying from 10^3–10^8 CFU g^{-1} Coagulase-negative staphylococci (SEC, SED) (10^8 CFU g^{-1})	MG	Do Carmo *et al.* 2002
Bacillus cereus	A	Ready-to-eat meal, spices, dairy products, starches, flours, variety of vegetable-and animal-origin products (157)	87.2% of the samples positive for *B. cereus* (10^2–10^4 CFU g^{-1} or mL^{-1})	n.i.	Aragon-Alegro *et al.* 2008
	A	Cassava sour starch (Factories A and B)	14 isolates of *B. cereus*	MG	Lacerda *et al.* 2005
Clostridium spp.	B	Food samples (81) from 117 suspected cases of botulism	Eight samples: 9.9% (soybean cheese, chicken pie with cheese cream, chicken pastry, chicken pie with peas and heart of palm and home-canned fish) positive for the botulinum neurotoxin (type A, AB, and nontyped)	AM, BA, CE, GO, MA, MT, MS, MG, PA, PR, PE, RJ, RN, RS and SP	Rowlands *et al.* 2010

[a]Results were compiled on August 2012. This is not intended to be a systematic review.
[b]A, Occurrence studies; and B, outbreak investigation.
[c]Brazilian Federative States: Amazonas (AM), Bahia (BA), Ceará (CE), Goiás (GO), São Paulo (SP), Pernambuco (PE), Rio Grande do Sul (RS), Minas Gerais (MG), Rio de Janeiro (RJ), Maranhão (MA), Mato Grosso (MT), Mato Grosso do Sul (MS), Pará (PA), Paraná (PR) and Rio Grande do Norte (RN).
n.i., not informed; CFU, colony-forming units; MPN, most probable number; SEA, Staphylococcal enterotoxins A; SEB, Staphylococcal enterotoxins B; SEC, Staphylococcal enterotoxins C; SED, Staphylococcal enterotoxins D.

Bacillus cereus is also an important etiological agent of bacterial foodborne diseases in Brazil. However, little is known about the prevalence and characteristics of this pathogen in Brazilian foods (Chaves *et al.*, 2011). Aragon-Alegro *et al.* (2008) reported that counts of *B. cereus* in ready-to-eat meals, spices, dairy products, starches, flours, and other foods varied from 10^2 colony-forming units (CFU)/g or /mL to 10^4 CFU/g or mL of food. All tested isolates were positive for at least one enterotoxin gene, reinforcing the risk to the consumer. Similar results were obtained by Chaves *et al.* (2011), who evaluated the genetic diversity, antimicrobial resistance, and toxigenic profiles of *B. cereus* strains isolated from various food items from the southwest region of Brazil. A high prevalence of toxin-encoding genes in the isolates was observed. Another study indicated that genes encoding enterotoxins were also widely spread among *B. cereus* and *B. thuringiensis* strains isolated from ground roasted coffee sold commercially in Brazil (Chaves *et al.*, 2012).

According to the World Health Organization (WHO, 2005), *Shigella* is considered one of the most important cause of bloody diarrhea worldwide, linked to the consumption of contaminated food or drinking water. However, as previously discussed, in Brazil there are few reports on foodborne shigellosis, probably because there is no current regulation that requires the investigation of *Shigella* in water or foods (De Paula *et al.*, 2010).

De Paula *et al.* (2010) investigated the antimicrobial resistance and molecular patterns of *Shigella* strains responsible for foodborne outbreaks that occurred in Rio Grande do Sul state from 2003 to 2007. Outbreaks were investigated by the state government Surveillance Service, and *Shigella* strains ($n = 152$) were isolated from foods and fecal samples of patients: 71.1% of the isolates were *S. flexneri*, 21.5% *S. sonnei*, and 0.7% *S. dysenteriae*. However, no specification about the kind of foods analyzed was provided.

Also, little is known about *Vibrio* spp. in Brazilian foods. Only a few reports on foodborne diseases caused by *Vibrio* spp. were reported, despite the high temperature of the seawater and the widespread occurrence of *Vibrio* spp. in the marine environment (Leal *et al.*, 2008). Araujo *et al.* (2007) reported the first case of severe infection caused by *V. vulnificus,* which occurred in Brazil in 1994. The patient was an 86-year-old man, who ingested seafood (mussels and octopus) at a seashore in São Paulo state, and he presented with vomiting, diarrhea, decreased intake of liquids, poor diuresis, and fever. Leal *et al.* (2008) described the investigation of a foodborne outbreak caused by *V. parahaemolyticus* that occurred in the northeast region of Brazil (Alagoas, Ceará and Pernambuco states). *V. parahaemolyticus* O3:K6 and O3:KUT were isolated from the stools of patients, and isolates were positive for virulence factors thermolabile haemolysin and thermostable direct haemolysin. No isolates were obtained from foods, but clinical and epidemiological investigations indicated that this was a foodborne outbreak. Costa-Sobrinho *et al.* (2010) conducted a study for estimation of the risks associated with consumption of oysters (*Crassostrea brasiliana*) from one important producing area located in São Paulo state coastal region. *V. parahaemolyticus* was detected in 99.2% (122/123) of the samples, with population densities varying between 0.78 and 5.04 log MPN/g, but only one isolate was Kanagawa positive and presented the *tdh* gene.

With regard to *Clostridium* genus, despite the considerable number of outbreaks caused by *Clostridium perfringens*, there are few reports in indexed literature from Brazil on these bacteria related to food safety (Schocken Iturrino *et al.*, 1986; Tortora and Zebral, 1988).

Botulism is a foodborne disease of mandatory notification in Brazil. The Reference Center for Botulism (CR BOT-CVE/SP), responsible for recording botulism cases and outbreaks that occurred in São Paulo state, confirmed 20 episodes of foodborne botulism between 1997 and 2010, with 5 deaths (CVE, 2010). Eduardo *et al*. (2007) reported on cases of botulism type A and B in São Paulo city due to the consumption of commercial pie made of chicken, hearts of palm, and peas. Moreover, data collected from all Brazilian regions (1999–2008) made available by the Federal Health Department (Brazil, 2008a) revealed 37 confirmed foodborne outbreaks of botulism associated with meats and home-canned vegetables. This year, a botulism outbreak (seven cases) was reported by the government of the state of Santa Catarina (south region), and it was caused by eating a commercial brand of mortadella, a kind of deli meat (Santa Catarina, 2012).

Prevalence of Foodborne Pathogens in Selected Brazilian Food Commodities

Retail meat

According the Association of Brazilian Beef Exporters (ABIEC), Brazil's cattle herd is estimated at 209 million. Per year, 5 billion poultry, 40 million bovine, and 30 million swine are slaughtered in the country. The productivity rates of Brazilian beef are constantly increasing and production costs are among the lowest in the world, conferring great competitiveness (ABIEC, 2012).

Bovine meat is a suitable environment for growth of many microorganisms, including pathogens. According to general literature data, *Salmonella* spp., *Escherichia coli* O157:H7, and *L. monocytogenes* are the main pathogens found in meats, but *Campylobacter* spp., *S. aureus*, *C. botulinum,* and *C. perfringens* may also be important (ICMSF, 2005; Aymerich *et al.*, 2008; Sofos, 2008).

In Brazil, studies conducted with raw meat at retail level (ground meat and/or meat cuts) indicated that prevalence of *Salmonella* spp. is around 10%–20% (Almeida *et al.*, 2002; Sigarini *et al.*, 2006). Aragon-Alegro *et al.* (2005) and Barros *et al.* (2007) observed that *L. monocytogenes* was present in 48.3% and 17.6% of the tested meat products, respectively, depending on the type of meat product.

Studies on *E. coli* O157:H7 and other Shiga toxin–producing *E. coli* (STEC) in raw meat and meat products in Brazil indicated that their prevalence is low. Rigobelo *et al.* (2008) observed that 1.4% of beef carcasses tested from an abattoir in São Paulo State were positive for STEC. Moreover, no *E. coli* O157 was detected in hamburgers produced by eight manufacturers in Brazilian southern states (Silveira *et al.*, 1999).

It is believed that cattle in Brazil are less frequently infected by STEC than in other countries, such as the United States or Mexico (Arthur *et al.*, 2002; Varela-Hernandez *et al.*, 2007), but more recent data indicate that this may not be true for all STEC serotypes (Oliveira *et al.*, 2008).

According to surveys conducted by Irino *et al.* (2005) with fecal samples of bovine cattle in São Paulo state, the isolation rate of STEC may range from 3.8% to 84.6% depending on the farm analyzed. Similarly, Oliveira *et al.* (2008) reported that the occurrence of STEC in healthy beef and dairy cattle and goats reared in Minas Gerais State ranged from 17.5% to 57.5%. Despite detection of STEC in Brazilian cattle, the occurrence of human illnesses caused by these bacteria is low. Only sporadic cases of gastrointestinal diseases and hemolytic uremic syndrome caused by non-O157 STEC strains have been reported (Guth *et al.*, 2002; Irino *et al.*, 2002; De Toni *et al.*, 2009).

Poultry

Poultry meat is an important constituent of the daily diet of Brazilians. Its cost is low if compared to other animal protein sources, and the consumption has increased significantly in recent years (Gonzalez, 2000; Capita *et al.*, 2007; Chiarini *et al.*, 2009). In addition, poultry meat plays an important role in the Brazilian agribusiness and international trade.

The main microbiological hazards in poultry meat are *Salmonella* and *Campylobacter* (ICMSF, 2005; Arsenault *et al.*, 2007). Many studies, carried out in different Brazilian regions, indicate that the overall prevalence of *Salmonella* in chicken carcasses varies between 5.4% and 46.6% (Fuzihara *et al.*, 2000; Matheus *et al.*, 2003; Reiter *et al.*, 2007; Asensi *et al.*, 2009; Duarte *et al.*, 2009). It is common sense that there are no control measures efficient to completely eliminate *Salmonella* spp. from poultry carcasses for commercial use (Ristori *et al.*, 2008). Hence, labeling of raw poultry with clear guidance for proper use, preparation and storage of the product is mandatory (Brazil, 2001a). In another food safety action, ANVISA launched in 2006 a national program to monitor the prevalence and antimicrobial resistance of enterococci and *Salmonella* in frozen poultry carcasses (PREBAF), which included verification of compliance with the labeling legislation (Brazil, 2006). Results indicated that 88% of the sampled carcasses were properly labelled and 3% were positive for *Salmonella* spp. Among these, *S.* Enteritidis was the most common serotype, confirmed in 50% of the *Salmonella* positive samples. *Enterococcus* spp. was present in 99% of the samples, and *E. faecalis* was the most common species (Brazil, 2008b).

Cheeses

Brazil is also a great producer of milk and several types of cheeses, largely consumed in the country. According to the United States Department of Agriculture (USDA, 2012), Brazil is the third largest cheese producer in the world, after the European Union and the United States. The most popular cheese in Brazil is Minas cheese, a fresh nonripened cheese obtained by enzymatic coagulation of pasteurized bovine milk with rennet or other coagulating enzymes. This cheese has high water activity, pH 6.6–6.8, low salt content (1.4%–1.6%), and no preservatives are added, so that the shelf-life scarcely exceeds 20 days under refrigeration (Gonzalez *et al.*, 2000; Moraes *et al.*, 2009; Alves *et al.*, 2011). Minas cheese is the most consumed cheese in the country (39%), followed by mozzarella (18%), prato (14%), and other types of cheeses (ricotta, provolone, and camembert) (29%) (Planzer *et al.*, 2009). Production of cheeses with raw milk for commercial purposes is prohibited in Brazil, unless they are submitted to a maturation period greater than 60 days (Brazil, 1997; Moraes *et al.*, 2009). However, homemade cheeses and informal sales of noninspected dairy products are common in some regions due to cultural and economic factors. For instance, Minas Gerais state permits commercialization of artisanal Minas cheese produced with raw milk, provided that good manufacturing practices are followed (Minas Gerais, 2002).

Moraes *et al.* (2009) were not able to detect *L. monocytogenes* and *Salmonella* spp. in Minas cheese samples collected from several noninspected commercial establishments, whereas coagulase-positive staphylococci were detected in 30.9% of the samples. Silva *et al.* (2003) conducted a study in Minas Frescal cheese processing facilities, monitoring the critical control points in the processing and the industrial environment, and detected *Listeria* spp. *in* 6.0% of the samples (4% *L. innocua*, 1% *L. monocytogenes*, and 1% *L. grayi*). A study by Brito *et al.* (2008) revealed that 11% of Minas cheese samples were positive for *L. monocytogenes*. Barancelli *et al*. (2011) studied the incidence of *L. monocytogenes* in three cheese manufacturing plants from the northeastern region of São Paulo (2008–2009) and the pathogen was found in samples from two plants, at percentages of 13.3% ($n=128$) and 9.6% ($n=114$), with the prevalence of isolates of the serotype 4b.

Sangaletti *et al.* (2009) reported that coagulase-positive *Staphylococcus* and *Salmonella* were not detected in samples of Minas cheese during 30 days of storage at 4°C. In another study carried out by Gonzalez *et al.* (2000), *E. coli* strains belonging to EPEC serogroups O127 and O128 were present in 11.3% of the soft white cheese samples.

Ready-to-eat and minimally processed foods

The global consumer trend is consumption of meals that are healthy and easy to prepare, with less time dedicated to cooking at home (Canada, 2010). Following this trend, Brazilians are increasing the demand for minimally processed products and RTE meals. It is widely known that such products can be vehicles for the transmission of bacterial, parasitic, and viral pathogens capable of causing human illness. It can be even speculated that modified atmosphere used in RTE foods may favor the survival of pathogens requiring reduced oxygen concentration for growth (Beuchat, 1996; Beuchat, 2002; Gomes and De Martinis, 2004). Fröder *et al.* (2007) and Sant'Ana *et al.* (2011) studied minimally processed vegetables sold in São Paulo city and observed that *Salmonella* was present in 3% and 0.4% of the samples, respectively. The prevalence of *Listeria* species in minimally processed vegetables commercialized in the city of Ribeirão Preto, São Paulo state was 2.5% for *L. innocua* and 1.2% for *L. monocytogenes* (Oliveira *et al.*, 2010). Sant'Ana *et al.* (2012) observed that 3.1% of the samples of RTE vegetables marketed in São Paulo were positive for the pathogen, with counts between 1.0×10^1 and 2.6×10^2 CFU/g.

Conclusion

Great progress has been achieved by Brazil in the last few decades in programs to guarantee food safety from farm to fork, in a concerted effort of agricultural and health agencies. However, as in many other countries, there is still a subnotification of foodborne bacterial diseases and lack of more complete official epidemiological data. Also, quantitative data on microbiological hazards in foods are needed if risk assessments programs are to be implemented.

Disclosure Statement

No competing financial interests exist.

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