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Review

Review

Food quality, food-borne diseases, and food safety in the Brazilian food industry

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Abstract

INTRODUCTION: In the recent decades, a global effort from food suppliers, industries, and governments has ensured that food production would meet the high quality required by the sanitary authorities, minimizing public health implications and economic losses caused by food-borne diseases.
BACKGROUND: Several programmes and initiatives have been developed worldwide both by government agencies and the private sector to achieve this goal. Food-borne diseases, caused by pathogens, natural toxins, and chemical contaminants, remain a global public health challenge, since new threats are continuously emerging while others are being controlled. Also, in many countries, the consumption of food prepared outside the home increases the exposure to the risks posed by poor hygiene in food service. In this context, a reliable sanitary surveillance system is urgently needed to identify potential hazards, conduct risk analysis, and control food-borne diseases outbreaks worldwide.
BRAZILIAN SAFETY POLICIES AND REGULATORY FRAMEWORKS: Brazil national agencies are tasked with controlling the hazards in the food chain by means of federal regulations based on a set of global sanitary authorities' guidelines.
CONCLUSION: The occurrence of food-borne diseases, control measures, policies, and regulatory frameworks in Brazil drawn to ensure the quality and safety of food are presented in this paper.

Key words: Brazilian food regulation; Food policies; Public health; Food safety.

Introduction

Brazil is a large country with a population estimated to be 206 081 432. The most populous Brazilian federative state is São Paulo, whose population is 44 749 699 (IBGE, 2016a). A combination of factors such as favourable climate, investments in technology, a large amount of arable land, and the quality of food have contributed to Brazil becoming one of the major producers and exporters of food in the world (FAO, 2014, 2015; MAPA, 2010). Brazil has been considered one of the top 10 countries in 2012 in livestock (including cattle, milk production, egg production) and crop production (based on net *per capita* crop production value) as well as one of the 20 countries with highest value of aquaculture production in 2013. Considering the agricultural trade, Brazil was the second world food exporter in 2012 (FAO, 2015). The agro-industry is an important activity for the Brazilian economy and this country is one of the world's leading manufacturers and exporters of agricultural commodities such as soybean and meat (FAO, 2014, 2015, 2016a). In 2015, the national crop production of grains, oilseeds, and vegetables was 209.4 million metric tonnes (MMT) (IBGE, 2016b). The Brazilian agricultural production is mainly based on soybeans, corn, rice, coffee, sugarcane, beef,

and poultry (MAPA, 2014). In 2015, Brazil was the second major producer (13 146 MMT) and the major exporter (4304 MMT) of poultry meat (ABPA, 2016).

Between 2008 and 2009, diet of Brazilians aged 10 or older was based on rice and beans, red meat (beef and pork), poultry, milk, roots and tubers (mostly cassava and potatoes), fruits, fish, vegetables, and eggs. Natural or minimally processed foods and culinary preparations made with these foods represent two-thirds of the total dietary energy intake of the Brazilian population. Also, foods such as breads and sandwiches, industrialized cakes, confectionary and biscuits, sodas, 'snack packs', cheeses, milk drinks, sausages, and other processed meats provide a lot of calories in the Brazilian diet (BRAZIL, 2015c). A high demand for meals prepared outside the home, fast food, food delivery, and an increasing demand for ready-to-eat/minimally processed foods and organic products can also be observed, depending on the region, sex, age, lifestyle, education, and occupation of the population (BRAZIL, 2015c).

Due to public health concerns and economic losses caused by food-borne diseases as well as by the presence of contaminants, there has been a recent global effort from food suppliers, industries, and governments to assure the quality and safety of food. Several programmes and initiatives have been developed worldwide to achieve this goal and also implemented in Brazil by food industries and services.

According to the report 'Estimates of the global burden of food-borne diseases', published by the World Health Organization (WHO) in 2015, as many as 600 million, or almost 1 in 10 people in the world, fell ill in 2010 after consuming food contaminated by 31 agents, comprising bacteria, viruses, parasites, toxins, and chemicals. Of these, 420 000 people died, including 125 000 children under the age of 5 years, despite the fact that they make up only 9% of the global population (WHO, 2015). A special concern is related to the consumption of hazardous foods by more susceptible people, such as young children, the elderly, pregnant women, and people with immune systems weakened by disease or medical treatment, or by the physiological condition process itself (FDA, 2016a).

The WHO Initiative to Estimate the Global Burden of Foodborne Diseases includes 31 food-borne hazards (11 diarrhoeal disease agents, 7 invasive infectious disease agents, 10 helminths and 3 chemicals). The most frequent causes reported for food-borne illness were diarrhoeal disease agents, particularly norovirus and *Campylobacter* spp. The main agent causing death was non-typhoidal *Salmonella enterica*, followed by *Salmonella* Typhi, *Taenia solium* (a tapeworm), hepatitis A virus, and aflatoxin. The main food-borne hazards were non-typhoidal *S. enterica*, enteropathogenic *Escherichia coli* (EPEC), *S.* Typhi, and *T. solium* (WHO, 2015).

Half of the global burden of food-borne diseases is caused by diarrhoeal diseases, affecting 550 million people and causing 230 000 deaths every year, mainly in children, with 220 million falling ill and 96 000 dying every year. Eating contaminated raw or undercooked meat, eggs, fresh produce, and dairy products are often the cause of diarrhea (WHO, 2015).

From 2007 to 2016, a total of 6848 food-borne diseases outbreaks were notified in Brazil to the national Notifiable Diseases Information System ('Sistema de Informação de Agravos de Notificação', SINAN) of the Brazilian Ministry of Health (data available until December 2016). During this period, 121 283 fell ill and 111 died (MS, 2016b; Sinan/SVS/Brazilian Ministry of Health, 2016) among the 610 465 people who were exposed to the hazards.

Food-borne diseases caused by pathogens, toxins, and chemicals, remain a global public health challenge for several reasons. New threats continuously emerge while others are controlled. The proportion of elderly in the population whose immune systems are weakened by disease or medical treatment and susceptible to severe outcomes from food-borne diseases is growing in many countries. Globalization of the food supply chain has led to the rapid and extensive distribution of foods worldwide, which has caused the spread of pathogens into new geographical areas. Visitors to new regions may be exposed to unfamiliar food-borne hazards in the new environment. On the other hand, changes in microorganisms have led to the steady evolution of new pathogens, the development of antibiotic resistance, and changes in the potency of known pathogens. In many countries, an increase in the consumption of food prepared outside the home is also a concern since exposure to the risks posed by poor hygiene and practice in commercial food-service settings becomes even greater (WHO, 2008). In this context, a reliable sanitary surveillance system is urgently needed to identify potential hazards, for risk analysis and for the control of food-borne disease outbreaks worldwide and Brazil is playing a key role in this scenario.

The aim of this review is to discuss the occurrence of food-borne diseases and other public health issues related to food in Brazil, and to present the policies and regulatory frameworks to ensure food quality and safety in this country.

Public Health Concerns Related to Food in Brazil

Occurrence of food-borne diseases outbreaks in Brazil

The diversity of geographic, climatic, economic, social, and cultural characteristics favours the production of a great variety of foods in Brazil, through different production technologies and at different scales, which are susceptible to different hazards, primarily contamination from pathogenic bacteria (Tondo *et al.*, 2015; MS, 2016b).

Table 1 shows the reported food-borne diseases outbreaks in Brazil from 2007 to 2016. Mixed meals were the most implicated sources (612 outbreaks), followed by water, eggs, and egg-based products (Table 2). *Escherichia coli*, *Salmonella* spp., and *Staphylococcus aureus* were the most frequently identified relevant agents causing diarrhea, abdominal pain, vomiting, and/or nausea. Diarrhea was the main identified symptom. Home, restaurants/bakeries, other institutions (accommodation, work), nursery schools, and schools were the main places where outbreaks occurred (MS, 2016b).

In a recent review, Tondo *et al.* (2015) indicated that 8871 food-borne disease outbreaks were registered in Brazil from 2000 to 2013. The etiological agent of the disease could be determined for approximately 50% of the registered outbreaks, and involved mainly bacteria (*Salmonella* spp., followed by *Staphylococcus* spp. and *E. coli*). Gomes *et al.* (2013) reported that the heat-stable enterotoxins produced by *S. aureus* are one of the major causes of food-borne illnesses in Brazil. Inappropriate handling of food during manufacture and its subsequent storage at inappropriate temperatures are associated with the high incidence of this pathogen in foods. The authors also report that the food-borne diseases associated with *Salmonella* Enteritidis are related mainly to the consumption of undercooked poultry meat, eggs, and undercooked pork sausage. Despite advances in the notification of food-borne

disease outbreaks in Brazil, their number is probably underestimated, because there are unrecognized, unreported, or even not investigated in several regions of the country (WHO, 2008; Gomes *et al.*, 2013; Tondo *et al.*, 2015).

Quantitative data on microbiological hazards in food are of paramount importance for the implementation of risk assessment programmes (Gomes *et al.*, 2013; Tondo *et al.*, 2015). Only a few Brazilian federative states, mainly from the southern (states of Rio Grande do Sul and Santa Catarina) and south-east (states of São Paulo, Rio de Janeiro, and Minas Gerais) regions, have an effective sanitary surveillance system, with reliable records on food-borne outbreaks (Gomes *et al.*, 2013; MS, 2016b).

In the state of São Paulo, food-borne disease outbreaks are identified through three surveillance subsystems coordinated by the Center for Epidemiologic Surveillance ('Centro de Vigilância Epidemiológica', CVE): diarrhea surveillance, outbreaks surveillance based on passive reports, and laboratory-based active surveillance, following the WHO guidelines. Data collected by the CVE from 1999 to 2007 indicated that food-borne disease in the state of São Paulo was mainly diarrhea caused primarily by serovars of *Salmonella* spp., in dishes containing raw or undercooked eggs prepared in restaurants and other commercial establishments. The authors suggested the introduction of specific sanitary regulations aimed at consumers through labelling of eggs and poultry, as well as an adequate training of workers in food services (Eduardo *et al.*, 2008).

The implementation of Good Farming Practices (GFPs), Good Agricultural Practices (GAPs), and Good Manufacturing Practices (GMPs) is essential for the prevention of food contamination by *Salmonella* spp. from primary production to consumption (CDC, 2015). The increasing antibiotic resistance of microorganisms and the cross-contamination should also be considered in the food production chain, as discussed by Capalonga *et al.* (2014) in a study of *S.* Enteritidis responsible for food-borne outbreaks in southern Brazil.

In the state of São Paulo in 2012, outbreaks were mainly associated with diarrhea (94.3%) that affected 6225 people (99.3% of sick people), followed by hepatitis A (4.5% of total outbreaks), clinical botulism with diarrhea (0.6% of total outbreaks), and exogenous intoxication (0.6% of total outbreaks) (Table 3). Among ill people, 2.7% were under the age of 1 year, 16.8% were between the ages of 1 and 4 years, 15.0% were between the ages of 5 and 19 years, 27.7% were between the ages of 20 and 49 years, 7.0% were greater than 50 years old, and the age of 30.9% ill people could not be identified. The outbreaks occurred at nurseries and schools (comprising 14% of sick people), elderly care facilities, home, restaurants, bakeries, fast food outlets, buffets, care units, or parties. The etiological agents responsible for the reported food-borne disease outbreaks and the deaths were identified as *Salmonella* sp. found in different

Table 1. Data of food-borne diseases outbreaks notified in Brazil from 2007 to 2016*.

Year	Outbreaks	Ill people	Exposed people	Dead people
2007	683	11879	25195	11
2008	641	8995	23275	26
2009	594	9431	24014	12
2010	498	8628	23954	11
2011	795	17884	52640	4
2012	863	14670	42138	10
2013	861	17455	64340	8
2014	886	15700	124359	9
2015	673	10676	35826	17
2016*	354	5965	194724	3
Total	6848	121283	610465	111

*Data available until 23 December 2016.
Source: Sinan/SVS/Brazilian Ministry of Health (2016).

Table 2. Foods implicated in diseases outbreaks notified in Brazil from 2007 to 2016*.

Foods	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016*	Total
Mixed meal	92	57	56	59	66	60	53	61	83	25	612
Water	26	32	25	25	35	49	56	96	43	29	416
Eggs and egg-based products	64	60	59	13	9	12	9	8	1	4	239
Milk and dairy products	21	21	25	17	21	23	16	12	12	15	183
Bovine meat and derived products	20	17	20	18	15	16	16	8	12	4	146
Confectionary and desserts	29	26	36	10	14	4	5	8	8	2	142
Cereals, farinaceous, and cereal-based products	7	11	15	9	19	17	11	15	12	2	118
Pork meat and derived products	15	7	9	10	9	25	12	7	8	2	104
Poultry meat and derived products	12	7	12	10	12	16	7	7	7	4	94
Fish and seafood, fresh or processed	7	11	6	8	4	8	2	4	3	4	57
Vegetables	2	2	1	3	12	9	5	11	5	3	53
Fruits, fruit-based products and related products	3	7	7	0	3	3	5	3	8	2	41
Non-alcoholic beverages	2	2	2	4	3	2	0	3	3	2	23
Spices, processed sauces and related products	0	3	2	4	10	2	2	0	0	0	23
Ice cream and related products	0	0	3	0	1	3	0	1	0	1	9
Other meats	0	0	0	1	0	0	1	0	0	0	2
Foods for special uses	0	0	0	0	0	1	0	0	0	0	1
Alcoholic beverages	0	1	0	0	0	0	0	0	0	0	1
Fats, oils, and emulsions	0	0	0	0	0	0	0	0	0	0	0
Soybean-based products	0	0	0	0	0	0	0	0	0	0	0
Sweetners	0	0	0	0	0	0	0	0	0	0	0
Total	300	264	278	191	233	250	200	244	205	99	2264

*Data available until 23 December 2016.
Source: Sinan/SVS/Brazilian Ministry of Health (2016).

foods such as mayonnaise and poultry meat (one death), coconut cake (one death), and *S.* Enteritidis found in mayonnaise (one death) (CVE/SP, 2012).

The notification of some diseases of public health concern such as botulism is compulsory in Brazil (MS, 2016a). The compulsory notification of suspected cases of botulism has facilitated the development of epidemiologic and sanitary investigation, and implementation of new sanitary measures to control and prevent this illness. Rowlands *et al.* (2010) reported a laboratory investigation of 117 suspected cases of botulism notified to the surveillance system in Brazil from January 2000 to October 2008. Among the 193 clinical samples analysed by the Adolfo Lutz Institute, a total of 22 (11.4%) presented the botulism neurotoxin (nine type A, five type AB, and eight with an unidentified type). In the 81 food samples analysed, a total of eight (9.9%) were positive for the neurotoxin (five type A, one type AB, and two with an unidentified type). The foods involved in the intoxication were home-canned meat, home pork liver pâté, industrialized canned liver pâté, canned tofu cream (soybean cheese), chicken pie with cheese cream, chicken pastry, chicken pie with peas and heart of palm, and home-canned fish.

In 2011, seven suspected cases of a botulism outbreak, with six confirmed cases and one death, were reported by the government of the state of Santa Catarina (southern region of Brazil). The food poisoning was caused by a commercial brand of mortadella, a deli meat. After the notification of the first suspected case of poisoning, the local sanitary authorities immediately developed an outbreak investigation. The control plan involved epidemiological, laboratory, and environmental investigations, information of the problem to the population through the mass communication media, recall of the suspect products from the market, and the destruction of all units by the responsible authorities (SANTA CATARINA, 2016a).

Table 3. Data of food-borne diseases outbreaks notified in the state of São Paulo, Brazil, in 2012 (CVE/SP, 2012).

Suspect food-borne disease outbreaks	968
Suspect cases	16 800
Confirmed food-borne disease outbreaks	158
Confirmed cases (ill people)	6270
Confirmed deaths by food-borne disease	3

Recalls of foods in Brazil

Current recalls of foods have been communicated in Brazil due not only to biological but also to chemical hazards. Article number 10, the Brazilian Law no. 8078 from 1990 (Code of Consumer Defense and Protection, 'Código de Proteção e Defesa do Condumidor', CDC) establishes that suppliers may not make available to the market any product or service that is known to present a high level of harm or danger to health or safety. If a hazard is identified by the producer, the occurrence must be immediately communicated to the proper authorities and consumers, through different media outlets such as radio and/or television, newspapers, and Internet. In addition, the product recall must to be done by the producers (BRAZIL, 1990).

The Ministry of Justice, which coordinates the National Consumer Defense System through the National Consumer Protection Secretariat ('Secretaria Nacional do Consumidor', SENACON), is the authority responsible for recall monitoring in Brazil. This authority also develops actions related to the prevention of the accidental consumption of hazardous products. In order to control recalls, the Ministry of Justice establishes the procedures that must be followed by suppliers during the recall (BRAZIL, 2015d). A regulation that defines the criteria and procedures for recalling foods was published in 2015 (ANVISA, 2015).

Throughout the last decade, there was an increase in the number of recalls in Brazil mainly due to better communication between involved agencies, an increased surveillance of national and international markets by responsible authorities, and a higher commitment of producer establishments (BRAZIL, 2014a, 2015a, 2015d). Table 4 shows recalls of foods in Brazil in 2013 and 2014. The contamination of food with chemical substances has been reported mainly in milk and beverages. The public health hazards were associated in 2013, for example, with the presence of cleaning substances in a soy beverage due to improper washing of the equipment before packaging, causing burns in the throat and digestive system of people who consumed the adulterated product (CVE/SP, 2013a).

Table 4. Recalls of foods in Brazil in 2013 and 2014 (BRAZIL, 2015d).

Product	Problem	Affected products	Confiscated products	% of confiscation
Whole and semi-skimmed UHT milk	Adulteration with water, urea, and formaldehyde in the raw milk before its processing.	774 000	0	0
Skimmed UHT milk	Adulteration with urea and formol.	92 880	2125	2.3
Soy beverage with apple flavour	Presence of caustic soda in the milk due to an operation failure in the cleaning-in-place equipment sanitizing procedure.	96	54	56.3
Whole UHT milk	Adulteration with urea and formol.	970 570	108 031	8.6
Whole UHT milk	Suspect of non-compliance and possible presence of formaldehyde.	101 220	1256	1.2
Whole UHT milk	Suspect of non-compliance and possible presence of formaldehyde.	199 800	0	0
Powder mixture for beverage preparation enriched with vitamins and minerals	Presence of traces of gluten not informed at the label. The ingestion of this product by people with celiac disease can cause adverse reactions.	228	0	0
Food supplement	Presence of traces of gluten not informed at the label. The ingestion of this product by people with celiac disease can cause adverse reactions.	564	0	0
UHT chocolate milk	Product with bitter taste, eventually causing gastrointestinal disorders.	6990	3332	47.7

Other public health concerns related to food in Brazil

Globalization has led to the emergence and evolution of severe diseases such as influenza A virus infection, with public health implications and economic losses (Zhou *et al.*, 2016). This infection is a highly contagious acute respiratory disease caused by different viral subtypes. It affects swine, poultry, and other species, including human (Ciacci-Zanella *et al.*, 2015).

There is no evidence that the avian and other zoonotic influenza viruses may affect humans through the consumption of properly cooked foods. Human cases of A(H5N1) and A(H7N9) infections have been associated mainly with direct or indirect exposure to infected live or dead poultry or contaminated environments. In order to minimize public health risk, quality surveillance in both animal and human populations, thorough investigation of every human infection and risk-based pandemic planning are essential (WHO, 2016b).

In 2003, the WHO developed the Global Agenda on Influenza Surveillance and Control that defines and prioritizes activities designed to reduce morbidity and mortality secondary to the annual influenza epidemics (Ibiapina *et al.*, 2005). In the poultry supply chain, the establishment of a poultry surveillance system for food safety by early detection of the influenza A virus is urgent and critical (Ping *et al.*, 2015).

In 2000, the Surveillance Influenza System ('Sistema de Vigilância da Influenza') was implemented in Brazil. The national intervention plan consisted of the site surveillance and the use of indirect data regarding morbidity and mortality associated with this illness. Information collected through this system indicated that H3N2 and H1N2, rather than H5N1, circulated in Brazil in 2003 (Ibiapina *et al.*, 2005).

Several tools that have been applied aimed at the prevention and control of a H5N1 epidemic in the poultry supply chain in Brazil, as follows: the vaccination of individuals at high risk of contamination through exposure to infected birds, the use of personal protective equipment by workers required to handle potentially contaminated birds, as well as the prophylactic administration of antiviral agents to such workers (Ibiapina *et al.*, 2005). Influenza A virus infection is endemic in pig producing countries worldwide such as Brazil, which is one of the most important producers and exporters of pig meat in the world. A study evaluated infection by this virus in 48 pig farms in Brazil showed that pandemic H1N1, as well as the H1N2 and H3N2 viruses, are widespread in Brazilian pig herds. The importance of the constant monitoring of this infection in pig farms, including characterization of subtypes emergence and evolution, was highlighted in a recent report (Ciacci-Zanella *et al.*, 2015).

GMPs and Hazard Analysis and Critical Control Point

Food Safety Management Systems in the food industry comprise quality control activities, quality assurance activities, and the evaluation of the performance of the implemented actions. Although several Food Safety Management Systems are available, they are all based on GMPs and Hazard Analysis and Critical Control Point (HACCP), which are the most important quality management tools used in the food industry in Brazil (Tondo *et al.*, 2015).

The main objective of the HACCP system is the prevention of risks to human health, as well as the prevention of adulteration of foodstuffs by means of risk control measures in each production step in which there is a probability of health hazards. HACCP may be applied to all production steps, from primary production (plant and animal cultivation), to processing and manufacture by the food industry and to the acquisition and consumption of the final product by the consumer. Programmes such as GMP and its prerequisite Standard Operating Procedures (SOPs) must be established before HACCP implementation (Oliveira *et al.*, 2016).

International food safety and quality standards

Factors such as the development of new technologies and products, immigration, export, and food-borne disease outbreaks helped to improve food quality and safety regulations worldwide. There are international organizations responsible for the establishment of food quality and safety standards to be used as a reference for international commerce, namely the WHO, the Food and Agriculture Organization of the United Nations (FAO), and the World Trade Organization (WTO) (Zach *et al.*, 2012).

The WHO coordinates international efforts to monitor food disease outbreaks, and sponsors programmes to prevent and treat related diseases (Zach *et al.*, 2012). Food safety is recognized as an essential public health function by the WHO member states (WHO, 2016a). Therefore, the WTO basic rules include an agreement of application of Sanitary and Phytosanitary (SPS) measures by governments, comprising food safety and animal and plant health measures. The Technical Barriers to Trade (TBT) Agreement of the WTO also intends to facilitate trade since member states' policies related to food safety can be based on international standards (Zach *et al.*, 2012; WHO, 2016a; WTO 2016). The FAO supports its members to ensure high-quality food, comprising the aspects of food security and good nutrition (FAO, 2016b).

The Joint FAO/WHO Food Standards Programme, established in 1963, has the Codex Alimentarius Commission as its principal organ. This commission is responsible for the establishment of international food standards, guidelines, and codes of practice to be used as a reference for food quality and safety, ensuring a fair trade between countries (FAO, 2016c).

Food safety policies, regulatory frameworks, and food safety assessment in Brazil

In Brazil, there is an established system of food safety control and regulation, which occurs at a federal level and that may occur also at a regional level (states and cities). The federal agencies responsible for food control include the Ministry of Agriculture, Livestock and Food Supply (Ministério da Agricultura, Pecuária e Abastecimento, MAPA), and the Ministry of Health, through the National Health Surveillance Agency (Agência Nacional de Vigilância Sanitária, ANVISA). Figure 1 shows the main government authorities responsible for ensuring food quality and safety management in Brazil, the monitoring programmes from MAPA, and the main kind of food under the responsibility of Brazilian agencies. It is worth mentioning some food products have overlapping regulations.

Brazil, as a member of Codex Alimentarius Commission, has implemented federal and regional regulations that comprise GMP, SOP, and HACCP programmes in order to meet Codex guidelines and WHO directives (Santana *et al.*, 2009; Tondo *et al.*, 2015). Regulations in Brazil are also in accordance with the Common

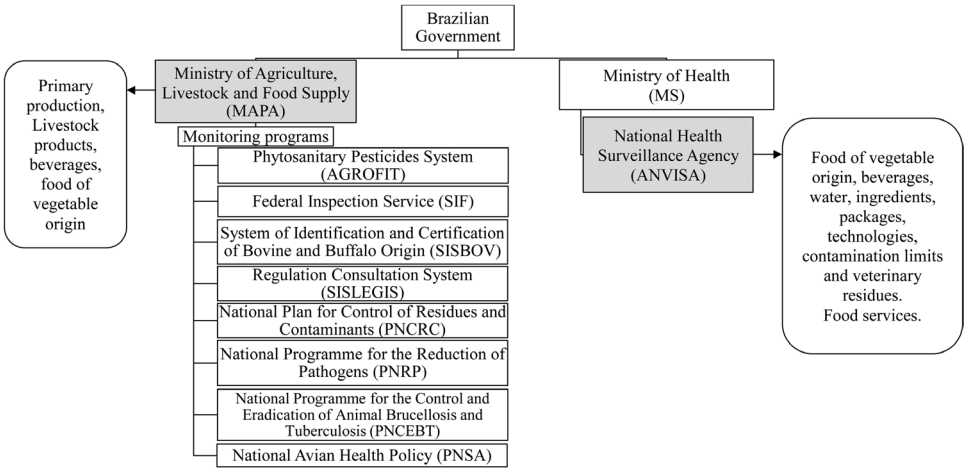

Figure 1. The main government authorities responsible for the coordination and control of the registration, information, inspection, risk control, and rule-making of food in Brazil. Grey boxes are authorities responsible for food quality and safety in this country.

Market of the South ('Mercado Comum do Sul', MERCOSUR or MERCOSUL) guidelines whenever possible (Figure 2). This South America's leading trading bloc aims to integrate the Latin America based on a political and strategic approach (BRAZIL, 2014b).

Table 5 shows the technical regulations in force established by MAPA and ANVISA in the last decades, and that meet international guidelines and directives. These regulations comprise GMP, SOP, and HACCP programmes in order to guarantee food safety and quality (Gomes *et al.*, 2013). Some instructions aiming at improving food safety management in Brazil were published by competent authorities such as those related to the development and implementation of Sanitation Standard Operating Procedures (SSOPs) and HACCP in the meat production chain intended for products exportation (MAPA, 2003), and to the establishment of self-control programmes comprising SSOPs, GMPs, and HACCP in animal-based products companies (MAPA, 2005). It is worth mentioning that the current microbiological standards for foods in force in Brazil are based on a regulation published by the Ministry of Health in 2001 (ANVISA, 2001) and that is being reviewed by ANVISA.

The HACCP and its prerequisites are mandatory and important tools used to control and prevent hazards in food. These measures allow the production of safe, high-quality food products for domestic consumption and/or export (Tondo *et al.*, 2015). HACCP and GMP in Brazil must be formally described in a document specific to each company (ANVISA, 1997, 2002b, 2004; MAPA, 1997, 1998a, 1998b, 2007).

The adoption of GMP and SOP became mandatory in Brazilian food industries and in food services, respectively, in 1997 and 2004 (ANVISA, 1997, 2004; MAPA, 1997; Santana *et al.*, 2009). Regulations on GMP establish the parameters and criteria for the hygienic-sanitary control in food companies (food industries and food services). It comprises personnel health control, water supply control, ingredients and suppliers control, integrated pest control (IPC), visitors' control, structure, buildings, facilities, equipment, utensil requirements, air exhaust systems, and personnel and environmental hygiene requirements (ANVISA, 1997, 2004; MAPA, 1997). Brazil also has regulations establishing hygienic-sanitary procedures that must be taken by specific food production chains, such as those published by ANVISA (food and beverages prepared with vegetables, natural mineral water and natural water, processed

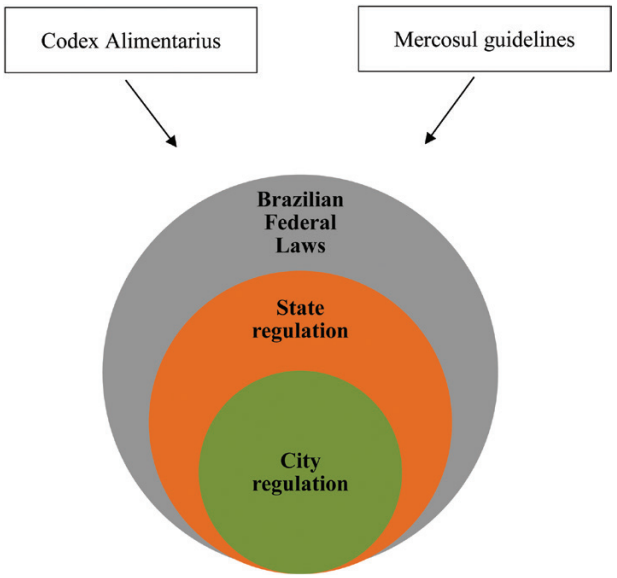

Figure 2. Main guidelines applied in Brazil for the establishment of food regulation intended for the domestic and/or international markets.

peanuts and derived products, canned fruits and vegetables, ice cream and related products, canned palm heart, salt for human consumption) (ANVISA, 2016).

The SOPs are specific prerequisites for good practices, and must be described in detail, monitored, and, if necessary, also corrected and verified. The SOPs, which were first introduced in Brazil in 2002, are defined as a document describing in a concise way, step-by-step, the procedures applied to routine and specific operations during food production, storage, and transport (ANVISA, 2002b). SOPs should be written in an easy-to-read format and adapted to meet the requirements of food producers, taking into account the diversity of companies in terms of production scale and applied technologies.

According to Brazilian regulation, food companies must accomplish SOPs requirements related to buildings, facilities, equipments, furniture, and utensils sanitation; potable water supply control; employee hygiene and health; waste management; equipment preventive maintenance and calibration; integrated control of vectors

Table 5. Current federal regulations on food quality and safety in Brazil. ANVISA, Agência Nacional de Vigilância Sanitária; GMP, Good Manufacturing Practice; HACCP, Hazard Analysis and Critical Control Point; MAPA, Ministério da Agricultura, Pecuária e Abastecimento; SOP, Standard Operating Procedure.

Agency	Objective	Reference
ANVISA	Guidelines for the implementation of Food Safety Management Systems (GMP; HACCP) in food manufacturing companies; guidelines for the definition of Identity and Quality Standards for food (foods under ANVISA responsibility).	ANVISA (1993)
ANVISA	Implementation of the hygienic-sanitary conditions and the GMP in food-manufacturing companies.	ANVISA (1997)
ANVISA	Implementation of SOP and purpose of a GMP checklist for food-manufacturing companies.	ANVISA (2002b)
ANVISA	Implementation of good practices in food services.	ANVISA (2004)
MAPA	Implementation of GMP in food-manufacturing companies.	MAPA (1997)
MAPA	Implementation of HACCP in food-manufacturing companies (beverages and vinegar).	MAPA (1998a)
MAPA	Implementation of HACCP in food-manufacturing companies (animal-based products).	MAPA (1998b)
MAPA	Implementation of GMP in feed-manufacturing companies.	MAPA (2007)

and urban pests; raw material, ingredients, and packaging selection; and food recall programme (ANVISA, 2002b).

Besides Brazilian regulations related to the adoption of the HACCP system throughout the industry, according to Tondo *et al.* (2015), in 2002, the Brazilian Technical Standards Association (Associação Brasileira de Normas Técnicas, ABNT) published a normative for the application of this system, NBr 14900:2002, later replaced by the normative ABNT/ISO NBr 22000/2006. The Brazilian government also has federal programmes aimed at improving technologies and infrastructure of establishments intended for food production, and consequently an enhancement of food quality and safety. It is estimated that from July 2016 until June 2017, the federal government through the Annual Agricultural and Livestock Plan will invest about US$ 56.4 billion in the production and commercialization of agricultural products (MAPA, 2016).

Besides the Brazilian government regulatory measures, primary producers and industries have been making efforts to adjust their regulations and procedures to the more restrictive standards and to the specific demands of the consumers market, especially those from other countries (Conchon and Lopes, 2012). Food companies should get certified to one of the Global Food Safety Initiative (GFSI) options, which allow them to international trade. GFSI is an industry-driven initiative aiming at recognizing the food safety management which meets internationally recognized minimum food safety requirements, set out in the GFSI Guidance Document (GFSI, 2016).

Food safety policies in other countries

In the USA, federal, state, and local agencies are responsible for the safety of foods. Food imported by this country should be in compliance with the same strict standards met by the US food manufacturers and producers in order to ensure food safety (Zach *et al.*, 2012). One of the aforementioned agencies is the U.S. Food and Drug Administration (FDA) that has recently reformed its food safety laws aiming at preventing rather than responding to contamination. The FDA Food Safety Modernization Act (FSMA), that came into force in 2016, establishes preventive control rules for human and animal food, including new standards for larger businesses. Food companies intending to export to the USA must comply with the Hazard Analysis and Risk-based Preventive Controls (HARPC) required by the FSMA (FDA, 2016b).

In the European Union (EU), the current food safety regulatory system has been recently redesigned, and is fully integrated and regulated by EU legislation that applies to all EU member countries (Chen *et al.*, 2015). This system is based on three key regulations from 2002 and 2004 (EC 2002a, 2002b, 2004) with further regulations, which establish specific hygiene procedures (EC, 2016). The main characteristics of the European system include an integrated farm-to-fork approach; the operator responsibility for food safety; a traceability mechanism; the improvement of the food safety regulatory and standardization system; a risk assessment; and a rapid alert system (Chen *et al.*, 2015). The European Food Safety Authority (EFSA) acts as a central coordinator of emerging risk activities regarding food and feed safety, animal health, and plant health in the EU (Costa *et al.*, 2016).

China has recently reformed its food safety regulatory system, taking into account the diversity within this country and the experience of other countries and regions in the world. The 'Food Safety Law of China' from 2009, with an amendment in 2015, and food safety management protocols currently in force in this country are based on co-regulation, centralization of the supervision and administration of food and drugs by the government authorities, farm-to-fork regulatory approach, food safety risk surveillance and assessment system, and operator responsibility (Chen *et al.*, 2015). The aforementioned co-regulation is an important tool to ensure the high quality and safety of food, since this strategy includes both self-regulation and legislative action (Chen *et al.*, 2015). A survey of 27 large- and medium-sized food enterprises in China indicated the HACCP system was implemented to enhance their competitiveness in the international market (Bai *et al.*, 2007).

Quality and Safety in Food Production Chains in Brazil

Despite regulations and efforts to assure food safety and quality in Brazil, the size of this country, and other characteristics such as its cultural diversity, still contribute to a high incidence of different hazards in foods, making the production of safe food challenging (Tondo *et al.*, 2015). In this section, the challenges for ensuring quality and safety in the production chain of several foods relevant in Brazil due to their economic and/or social importance will be discussed.

Animal-based foods

The production of foods from animal origin is of great importance for Brazilian economy (FAO, 2015; ABPA, 2016). The implementation of measures from food production (GFPs and GMPs) to consumption is essential for ensuring food safety in the animal production and derived products (FAO, 2009). The prevention of contamination should comprise good practices during animal health management; animal feeding and watering; animal and product handling; preparation and serving.

Meat traceability is an important tool to enhance food safety, allowing a better communication throughout the food chain, and also between industries and regulatory agencies, resulting in benefits for food quality and safety management, as well as increasing the productivity of this sector (Conchon and Lopes, 2012).

The traceability of products from animal origin is not mandatory in Brazil, but the basic requisites to it, such as documentation and records, are previewed in a federal regulation (MAPA, 1997). In relation to the traceability in the meat production chain, it is worth mentioning Brazil has a system called System of Identification and Certification of Bovine and Buffalo Origin ('Sistema de Identificação e Certificação de Bovinos e Bufalos', SISBOV), created and controlled by the MAPA. The records allow identifying the feedstock and its origin. The technical evaluation of these records allows preventive measures to be applied, such as product recall, when a threat to the public health has been identified (MAPA, 2006).

Beef production is a primary pillar of the Brazilian economy. Among other factors (expansion of cattle stocks, productivity per head of cattle, pasture area expansion, competitiveness due to monetary reform), technological progress in beef production such as cattle traceability has been key to complying with the high food safety and quality standards requested by the global market. This scenario explains the export boom of Brazilian beef in the 2000s, which has Russia as one of the major markets (Schierhorn *et al.*, 2016).

In the recent decades, outbreaks of the emergent new variant Creutzfeldt-Jacob disease (vCJD), related mainly to the consumption of food of bovine origin contaminated with the agent of Bovine Spongiform Encephalopathy (BSE), were reported in other countries (WHO, 2012). Due to the severity of this disease, that is a rare and fatal human neurodegenerative condition, measures based on WHO recommendations were taken worldwide aiming at surveilling and preventing it (WHO, 2012). In Brazil, several control measures were established by competent authorities in order to prevent CJD and its variant (Gattás *et al.*, 2007; CVE/SP, 2008; MS, 2016c). The notification of CJD outbreaks is compulsory in Brazil since 2005 (MS, 2016a, 2016b), thus helping to an early vCJD detection (Gattás *et al.*, 2007; CVE/SP, 2008; MS, 2016c). From 2005 to 2013, 522 of suspected cases of CJD were reported in 22 Brazilian states, with 170 confirmed cases (33%) and 98 (57.6%) deaths. About 1.8% of ill people were less than 30 years old (MS, 2016c), but no data on confirmed vCJD are available.

In order to prevent CJD and vCDJ in Brazil, the importation of products for use in human containing raw material from tissues/fluids of ruminant animals from bovines, sheeps, buffalos, and wild ruminants (ANVISA, 2002a, 2003) was controlled following international recommendations (WHO, 2012). Tissues, parts, or products of any animal suspected of contamination with a Transmissible Spongiform Encephalopathy should not enter the human or animal food chain, and the use of ruminant tissues in ruminant feed should be banned (WHO, 2012). In Brazil, the production, commercialization, and use of products containing proteins (except egg powder) and fats of animal origin in ruminant feed, as well as of products containing material from ruminants for veterinary use in ruminants, were banned (MAPA, 2004). The importation of ruminants, their products, and by-products for any purposes; of products for veterinary use containing material from ruminants; and of products and ingredients from animal origin intended for animal feed, originated or coming from high-risk countries, was prohibited as well (MAPA, 2008; Golinelli *et al.*, 2016). Golinelli *et al.* (2016) indicated the use of classical microscopic analysis along with the real-time quantitative PCR (qPCR) as a complementary method can be important to the detection of not allowed-animal derivatives in feeds samples.

The sanitary conditions of feeds are also a concern in the production of food from animal origin. The GMPs for the production of feed have been mandatory in Brazil since 2007 (MAPA, 2007). This regulation defines the basic hygiene practices that should be adopted for the production of feed, related to building, facilities, equipments, and utensils; employee hygiene; and the production. It defines the minimum requirements related to SOP, comprising requirements related to the following topics: suppliers qualification, and raw material and packaging control; buildings, facilities, equipments, and utensils sanitation; employee hygiene and health; potable water supply and water tank sanitation; cross-contamination prevention; equipments and instruments maintenance and calibration; integrated control of pests; wastes and effluents control; traceability and products recall programme. This regulation also presents an inspection checklist of GMP during the manufacturing process in related companies.

A cross-sectional study in four swine feed mills located in southern and south-east regions of Brazil (Pellegrini *et al.*, 2013) reported the correlation between the score of the inspection checklist defined by MAPA (2007), and the enumeration of total coliforms (in ingredients, final product, and on equipment) throughout the manufacturing process. The majority of non-compliances were related to the physical structure of the companies. The study indicated that there was no association between the score attained using the checklist and the level of the hygiene indicators verified in the equipment used in the manufacture of the feed. The surfaces of the equipment used for dosing and milling were found to be the most critical for microbial contamination. The authors indicated that measures related to control and microbiological monitoring throughout the production chain, and also compliance of procedures to the regulation should be implemented in order to ensure food quality and safety.

Dairy products.

Brazil's dairy industry has grown substantially in recent years (Dürr, 2006, 2012; BRAZIL, 2016). Milk contamination with chemical (formol, urea, antibiotics) and microbiological hazards, leading to food-borne diseases outbreaks, has been reported in Brazil (MAPA, 2011).

Brazilian regulations demand the pasteurization of raw milk used to make the majority of dairy products in this country, in order to reduce the contamination by bacteria and other microorganisms that may represent a risk to human health. Routine analyses of milk, performed upon receipt at dairies, are defined in Brazil by a federal regulation (MAPA, 2011). The results then obtained determine the approval or rejection of the received milk, due to poor sanitary conditions or even adulteration.

In 2016, authorities from the state of Santa Catarina communicated to the public a list of dairy products (yoghurt, cheese, butter, 'ricotta' cheese) that had been prepared with unpasteurized milk. The population was advised not to consume these products and to correctly discard them (SES/SC, 2016). An outbreak of pharyngitis accompanied by nephrotic syndrome in the state of Minas Gerais in 2012 and 2013 was attributed to the ingestion of home-made unpasteurized milk and dairy products, and probably also to the consumption of raw or uncooked meat. Laboratory analysis of the food confirmed the presence of *Streptococcus* and other pathogens in milk, ice cream, cheese, and milkshake, indicating poor sanitary conditions during their production. Appropriate actions were

immediately taken by local sanitary authorities to control this outbreak. Also consumers were warned not to eat raw food of animal origin (CVE/SP, 2013a).

The production and commercialization of traditional foods, usually made by means of artisanal techniques, in compliance with food safety and quality regulations, is also a concern in Brazil. That is the case of Serrano cheese, made in Campos de Cima da Serra, Brazil, as discussed by da Cruz and Menasche (2014). The data collected by these authors indicated that besides adapting production and expertise to food safety regulations, adding value to traditional food depends firstly on understanding the potential risks related to these products and secondly in recognizing and legitimizing traditional forms of knowledge.

A recent regulation defined requirements for the production of Serrano cheese from unpasteurized milk in the state of Santa Catarina (SANTA CATARINA, 2016b). This regulation states requirements related to the production (operations; building and facilities; water supply; raw milk), commercialization (registration with competent authority; packaging; transport), and inspection of the raw milk cheese. Producers should be aware of the importance of accomplishing all food safety management standards throughout the production chain in order to ensure cheese quality and safety that include a minimum of 60-day aging period of cheeses in order to reduce their contamination with pathogens (da Cruz and Menasche, 2014). This aging period, however, does not ensure product safety, since cheese made from unpasteurized milk can show contamination by different pathogens such as *Salmonella*, *Listeria monocytogenes*, *E. coli* O157:H7, and Shiga toxin-producing *E. coli*, as well as for generic *E. coli*, as recently verified by FDA (FDA, 2016c).

Antibiotic residues are also a concern to regulatory agencies and consumers worldwide, especially in the case of milk and other products of animal origin. Indiscriminate use of antibiotics has promoted the development of bacterial resistance, which has become a global issue. The administration of chloramphenicol for animal feeding has been banned by Brazilian regulation since 1998 (MAPA, 1998c). The National Program of Analysis of Veterinary Drugs Residues in Food exposed to Consumption ('Programa Nacional de Análise de Resíduos de Medicamentos Veterinários em Alimentos expostos ao Consumo', PAMVET) analyses 300 milk samples annually and established a maximum residual level for chloramphenicol of zero. Despite the prohibition of chloramphenicol in animal feed, residues of this antibiotic were detected in 28.6% of 84 raw milk samples at a dairy plant in Northern Parana, Brazil in October 2014 (Dos Santos *et al.*, 2016). The authors affirmed that the routine analysis of chloramphenicol in dairy establishments is necessary in order to assure the quality of processed milk produced in Brazil.

The surveillance of all these hazards in the dairy product supply chain is one of the goals of a MAPA project. This project aims at harmonizing the public policies of this federal authority, in order to improve the quality of the national food production chain, therefore enhancing its competitiveness in the international markets. This project is based on the technical assistance, investment in the modernization and costs of optimization in this sector, animal health control through the PNCEBT, quality control, and the promotion of milk consumption. Another goal of this project is to improve the quality of milk received in milk processing plants through continuous training of farmers, technicians, and transport staff.

The improvement of the milk quality and safety and the increase of the competitiveness of dairy products, through the implementation of the National Program to Increase Milk Quality and Control (PNQL), were very important for this growth (Dürr, 2006, 2012; BRAZIL, 2016). Monitoring of milk quality standards is conducted by the Brazilian Milk Quality Network (RBQL), which has accredited laboratories throughout the country to perform the analyses. A reference laboratory was also established to monitor the quality of services performed by other laboratories, which also provides technical support and training, and standard samples for equipment calibration. In addition, it also establishes operating protocols for harmonizing laboratory procedures, and accredits new laboratories (MAPA, 2015).

Vegetable-derived foods

Food-borne diseases can be associated with the consumption of fresh or processed vegetables and fruits. These foods are highly consumed in Brazil and therefore reliable GMP and HACCP programmes must be applied from harvesting to consumption in order to ensure safe products for consumers (Moretti, 2007; FDA, 2008).

The contamination of conventional vegetables is related to chemical and microbiological hazards. Organic fertilizers used in the production of these products consist of manure that may contain pathogenic microorganisms. Maffei *et al.* (2013) reported microbiological quality of organic and conventional vegetables sold in Brazil. The results obtained in the mentioned study showed that organic and conventional produce did not contain *Salmonella* spp., but contained mesophilic aerobic bacteria, yeasts and molds, total coliforms, and *E. coli*. The microbiological quality of organic produce was considered lower than those grown conventionally. Results also indicated the need for good practices from primary production to consumption. Therefore, the population should also be aware of the importance of applying good practices before the consumption of vegetables, which should minimize the risk of contamination and related food-borne diseases. Such practices could comprise hands washing before handling vegetables, cleaning and sanitation of utensils, cleaning and sanitation of vegetables with high microbiological quality water (Moretti, 2007; FDA, 2008).

Lettuce (*Lactuca sativa* L.), the leafy vegetable most consumed in Brazil, is most commonly contaminated with enterohemorrhagic *E. coli* and *S. enterica*. Ceuppens *et al.* (2014) assessed the microbiological quality and safety of this leafy vegetable, investigating differences between six different farms, and also between conventional and organic production. High temperature, flooding of lettuce fields, application of contaminated organic fertilizer, irrigation with water of inferior quality, and large distances between the field and toilets were identified as environmental and agro-technical risk factors for increased microbial load and pathogen prevalence in lettuce production. Control of the composting process of organic fertilizers and the irrigation water quality were considered crucial factors to improve and/or maintain the sanitary quality during the primary production of lettuce.

Rodrigues *et al.* (2014) investigated the status of the implementation of GAPs and management systems, and their impact on microbial contamination in organic lettuce production in the south of Brazil. The weak points in current organic farming practices in the three visited lettuce production farms were that manure composting was not adequately controlled and that the appropriate waiting time for the application as organic fertilizer to crop was not respected. In addition, the selection of the water source and the sanitary quality of the water used for irrigation were not under control. It was observed that the washing step with a sanitizing agent was not effective for reducing the microbial contamination of lettuce during its harvesting. Researchers recommended further communication and training on GAPs in order to assure the sanitary quality of the lettuce, thus avoiding the introduction of pathogens in the produce.

The consumption of ready-to-eat vegetables and fruits has increased in Brazil since their introduction in the national market in the 1990s, and occurs mainly because the expansion of restaurants, hotels, and institutional services, and also due to their convenience for use at home. Due to the characteristics of these perishable products, it is of paramount importance to develop reliable methods for preventing their contamination (Cenci, 2011; Silva *et al.*, 2011).

The estimation of the risk of infections due to consumption of ready-to-eat leafy vegetables contaminated with *Salmonella* and *L. monocytogenes* in Brazil suggested that effective mitigation strategies needed to be adopted for controlling food-borne infections (Sant'Ana *et al.*, 2014). Measures to reduce the risk of contamination of fresh foods should be implemented and controlled, such as an effective washing step of vegetables avoiding cross-contamination, and also the maintenance of a temperature lower than 5°C during storage and transport of the product. Strict control of the temperature during transport, storage, and consumption was established to be effective in the reduction of the risk and number of cases due to *L. monocytogenes* rather than to *Salmonella*.

Maistro *et al.* (2012) observed a satisfactory microbial quality of 172 samples of minimally processed vegetables marketed in Campinas, São Paulo, Brazil. The authors verified the presence of *Salmonella* in a sample of watercress and of *L. monocytogenes* in two of the analysed samples (watercress and escarole). Abuses in the temperature and time of exposure of the vegetables at supermarkets' displays were also observed, indicating the need for implementation of GMP and HACCP in this food chain. In Brazil, the maximum storage temperature recommended on labels for minimally processed vegetables is 7°C. It is appropriate to assure the quality and safety of these products during their shelf life, often set as 6 days. Temperatures higher than 7°C might lead to high rate of microbial growth in these products, therefore reducing their shelf life and increasing their microbiological risk.

The cold chain is an important measure to reduce the risk of microbial contamination and growth not only in fresh-cut but also in fresh produce. In the USA, the recommended temperature for fresh-cut produce during pre-cooling and storage is ≤41°F (≤5°C) (FDA, 2008).

Brazil is an important fruit and fruit-based products manufacturer, and therefore efforts to avoid hazards are of paramount importance in this food production chain. A major concern of the fruit juice industry is related to the incidence of toxigenic microorganisms that produce ascospores capable of surviving the pasteurization process. Among the mould species responsible for spoilage and degradation of processed fruit juices and fruit-based products, *Byssochlamys* sp. (mainly *Byssochlamys fulva*) and *Neosartorya fischeri* are of special concern, due to their heat resistance and production of toxins. Several studies have investigated the growth kinetics of these and other moulds in different juices (Salomão *et al.*, 2011, 2014; Zimmermann et al., 2011a, 2011b), as, for example, in apple juice, that has great economic importance in the southern region of Brazil (Longhi *et al.*, 2014; Tremarin *et al.*, 2015). The models developed by these authors for predicting the rate of microbial growth are important to determine the process/storage conditions and shelf life of juices, thus contributing to improving the quality and safety of these products.

Another public health concern related to food in Brazil is the Chagas disease. It is a parasitic infection caused by *Trypanosoma cruzi*, transmitted by triatomines (*Triatoma infestans*, *Rhodnius prolixus*, *Panstrongylus megistus*, among other species) (ANVISA, 2008; PAHO, 2009; FIOCRUZ, 2013).

A systematic review and meta-analysis of available population-based studies between 1980 and 2011 in 18 Brazilian states showed this disease was prevalent in the north-east region of the country (Martins-Melo *et al.*, 2014). These authors discussed that the proportion of new cases of Chagas disease in Brazil through the classical vector-borne transmission was dramatically reduced in the investigated period, due to measures such as systematic surveillance and control in endemic areas, although the oral transmission is considered an emergent food-borne disease in this country.

From 2000 to 2011, more than 1200 Chagas disease outbreaks were reported in Brazil, caused mainly by oral transmission (70%) (FIOCRUZ, 2013), through the consumption of contaminated food (ANVISA, 2008; FIOCRUZ, 2013). These outbreaks, that occurred mostly in the Amazon region, were related mainly to the consumption of locally grown *açaí* berries or unprocessed *açaí* pulp, an essential food in the diet from the northern Brazil. Recent outbreaks have been related mainly to the consumption of locally grown *açaí* berries or home-made unpasteurized *açaí* pulp in the Brazilian Amazon (ANVISA, 2008; Labello Barbosa *et al.*, 2012; Martins-Melo *et al.*, 2014). Outbreaks of this infection are also related to the consumption of other underprocessed or unappropriated stored foods such as sugarcane juice and *bacaba* (ANVISA, 2008). All these foods can be contaminated during harvesting, storage, transport, or processing from either the feces of infected triatomines or from the whole insect (PAHO, 2009; FIOCRUZ, 2013).

Due to the food-borne acute Chagas disease outbreaks notified in Brazil in the 2000s, and considering the severity of this disease, that is incurable and may cause death, Brazilian authorities and experts in food safety defined in 2007 an action plan aiming at improving the hygienic-sanitary quality of *açaí* pulp. Among the defined actions, GAPs and GMP have been implemented in the production chains of *açaí* berries and *açaí* pulp, respectively, for ensuring safe and high-quality products, taking also into account social, environmental, and economic features of this food (ANVISA, 2008; PAHO, 2009).

The heat treatment of *açaí* pulp above 43°C for 20 min is a practical and effective measure to prevent infection caused by *T. cruzi* (Labello Barbosa *et al.*, 2016), while cooling and freezing are not suitable methods for reaching this goal (Labello Barbosa *et al.*, 2012).

Competent authorities have been still working on sanitary surveillance preventive actions in food production chain in order to reduce contamination by *T. cruzi* (FIOCRUZ, 2013), but the education of local population on good practices for the preparation and processing of *açaí* berries and other foods seems to be an urgent priority for preventing contamination.

Food services

The microbiological quality and safety of meals prepared and served in nursery schools, child care centers, schools, and elderly care facilities is of great concern due to the higher vulnerability of young children and elderly to developing food-borne diseases (FDA, 2016a). The implementation and control of good practices and HACCP are therefore of paramount importance in such establishments. The risk prevention and control approach should also be considered for ensuring quality and safety of foods served in these places (Tondo *et al.*, 2015).

The National School Feeding Program ('Programa Nacional de Alimentação Escolar', PNAE), implemented in Brazil in 1955, is the largest food supplementation programme in Latin America. The PNAE offers meals that represent at least 20% of the daily value of nutritional needs (related to calories and proteins) to students up to

17 years of age from public schools. Its main purpose is to contribute to a healthy diet based on food safety and security (Carvalho and Castro, 2009; Libermann and Bertolini, 2015). One of the challenges of this programme is to assure food safety and quality, taking into account the susceptibility of those students to diseases. In order to reach this goal, the National Fund for Education Development ('Fundo Nacional de Desenvolvimento da Educação', FNDE) established a partnership with Brazilian universities for the creation of School Food and Nutrition Collaborative Centers ('Centros Colaboradores em Alimentação e Nutrição do Escolar', CECANE). As a result of this partnership, a checklist on good practices, based on national and regional regulations, was established in order to evaluate the adequacy of schools to food safety and quality requirements, and therefore apply corrective measures. The implementation of good practices and SOPs in these establishments is mandatory, and must be done by a responsible nutritionist (ANVISA, 2013a).

Santana *et al.* (2009) reported the microbiological quality and safety of meals served to children in public schools in Salvador city (state of Bahia, Brazil). An improvement of sanitary conditions for food preparation and serving (personnel education and training; cleaning and sanitation of physical facilities, utensils and equipment; time and temperature monitoring) was observed after the adoption of good practices in the food unit responsible for preparing the meals served to the students.

In Brazil, apart from major food companies and food services, also small- and medium-sized companies, and vendors of artisanal foods and foods sold on the streets play an important role in the production of safe and high-quality food. Therefore, it is imperative to apply effective tools to ensure quality and safety for food produced and marketed on different scales, by means of different technologies. Special attention should be given to food sold on the streets. It is a variety of ready-to-eat foods and beverages that are sold and sometimes prepared in public places, when the final preparation occurs when the meals are ordered by the customers. The unhygienic handling of raw materials, inadequate cleaning of the machines, knives, contact surfaces, clothes, manipulator's hands, and airborne contamination have been identified as the main sources of the microbial contamination of the food sold on the streets (Sousa, 2008).

Large gatherings.

A plan for food safety and quality control also was established by the Brazilian sanitary authorities during large gatherings that recently took place in Brazil, such as the 2014 FIFA World Cup and the Olympic and Paralympic Games 2016, in Rio de Janeiro (Cunha *et al.*, 2014; Da Silva, 2015; Tondo *et al.*, 2015). Large international events represent a risk for communicable disease outbreaks and rapid spread around the world (ECDC, 2016). Therefore, it was of paramount importance to develop reliable and effective strategies to minimize the risk of food-borne disease outbreaks, therefore protecting visitors as well as the local population (MS, 2014). In order to be prepared for these important international events, the Ministry of Health, the ANVISA, and the National Agency of Supplementary Health (ANS) published several regulations establishing rules for the organization of the events, which were applicable to the public and private sectors (MS, 2014).

A risk criterion for defining the priorities to be controlled in food services was established by ANVISA, which targeted the improvement of the sanitary surveillance actions during the 2014 FIFA World Cup (Cunha *et al.*, 2014; Tondo *et al.*, 2015). In 2015, an operational plan for the sanitary surveillance during the Olympic and Paralympic Games was published (BRAZIL, 2015b).

A technical normative with a risk-based instrument, elaborated before the 2014 FIFA World Cup, was based on Brazilian regulation related to good practices in food services, and on the opinion of a team of Brazilian experts in food safety (ANVISA, 2013b). This regulation aimed at evaluating and grading food service establishments in host cities with regards to their hygienic-sanitary aspects. Fifty-two items were evaluated, comprising requirements related to water supply; structure; sanitation of facilities, equipments, furniture, and utensils; integrated control of vectors and urban pests; food handlers; raw materials, ingredients, and packaging; food preparation; and storage, transport, and display of the prepared food. A raw score was established to each evaluated food service, in order to assess its risk of causing food-borne diseases outbreaks. This score was based on a literature review of the leading causes of food-borne diseases outbreaks in Brazil and elsewhere, and also on the HACCP principles, classifying items as control points or critical control points. The elaborated instrument allowed the grading of evaluated food services into five categories with further application of corrective measures aiming at avoiding food-borne outbreaks in the food services, when applicable (Cunha *et al.*, 2014; Tondo *et al.*, 2015).

Safe Food Programme

Despite the efforts of sanitary authorities, and food producers and services in Brazil, the adoption of good practices, SOPs, and HACCP still remains a challenge for a great number of food producers and services, due to limiting factors such as structure and budget. The Food Insurance Program ('Programa Alimentos Seguros', PAS) represents a solution to overcome these difficulties.

In Brazil, the creation of PAS, in 1998, was a pioneer initiative involving the private sector and government agencies, within a co-regulation approach, to cover from large to small food companies, as well as food services. It was a partnership between the National Service of Industrial Apprenticeship ('Serviço Nacional de Aprendizagem Industrial', SENAI), the Support Service for Micro and Small Enterprises ('Serviço Brasileiro de Apoio às Micro e Pequenas Empresas', SEBRAE), and MAPA. The programme, which is still in operation, has been developed for supporting governmental actions for the implementation of Food Safety Management Systems (SENAI, 2012; Tondo *et al.*, 2015).

The main goals of this programme are the communication and dissemination of food safety tools (GMP and HACCP), the development of a professional critical mass for the support of the implementation of these tools, the elaboration of technical material for consultants, technicians and managers, and the development of methodologies of food safety tools in food industries and food services (Tondo *et al.*, 2015). Nowadays the Industry Social Service ('Serviço Social da Indústria', SESI), Commerce Social Service ('Serviço Social do Comércio', SESC), National Service of Commercial Apprenticeship ('Serviço Nacional de Aprendizagem Comercial', SENAC), National Service of Rural Learning ('Serviço Nacional de Aprendizagem Rural', SENAR), and the Brazilian Agricultural Research Company ('Empresa Brasileira de Pesquisa Agropecuária', Embrapa) are also partners that facilitate the actions at the national level (SENAI, 2012; MAPA, 2014).

The activities of this programme cover different sectors of the food chain such as food industries, food services (PAS-Mesa), farms, food distribution, and transport. The programme also demands solutions for specific product chains such as honey, *açaí*, milk, grape, and beef meat (Tondo *et al.*, 2015). The PAS provides workshops, informative lectures, and training courses to the

company staff in the entire production chain from farms, to transport, processing, and distribution. It also covers food services by developing teaching materials and methodologies. In addition, the programme enables professionals to provide advice and consulting to firms and gives information to consumers about food safety. The implementation of the programme throughout Brazil has increased the safety and quality of food, increasing the competitiveness of the Brazilian food companies in the domestic and in international markets (SENAI, 2012).

The actions of PAS from January 2002 to August 2014 resulted in the award of 483 declarations of adequacy to the implantation of HACCP, mainly in the state of Rio Grande do Sul (southern of Brazil), the approval of 1213 plans and 193 revalidations of this system. In 2013, PAS actions covered 24 Brazilian federative states, comprising more than 56 000 h of consulting service mainly in the region of Rio Grande do Sul. There was an increase in the GMP programmes implemented by SENAC from 154 in 2008 to 189 in 2011, and 406 in 2013. From 2008 to 2013, a total of 1238 GMP programmes were implemented by PAS in Brazil, highlighting the importance of this programme for the improvement of food safety and quality in Brazil (Tondo *et al.*, 2015).

Final Considerations

Brazil is an important food producer and exporter and efforts to avoid hazards are of paramount importance in its food production chain. The scenario of food-borne disease outbreaks and relevant hazards in foods in Brazil shows that the use of a validated Food Safety Management System is essential to ensure safe and high-quality food.

The PAS is an important co-regulation strategy in Brazil and represents a solution to overcome some challenges for the adoption of good practices, SOPs, and HACCP in this country.

Several strategies can be taken in order to overcome difficulties found in Brazil for ensuring the production of safe and quality food. At first, it is crucial to update some Brazilian obsolete food regulations taking into account new technologies and hazards. Another question that must be addressed is the fact that Brazilian food quality and safety programmes should be focused on preventing contamination rather than responding to it. Legal requirements also need to be adapted to specific production systems from the small to large industries, producers and food services, and taking also into account traditional methods of food processing. Another issue that must be considered is a conflict of competences of Brazilian sanitary authorities due to overlapping regulations.

Also, producers should be aware of, and comply with, all legal obligations relevant to a quality and safe production of food. Competent authorities should train producers, thus contributing to the effective execution of regulations.

The adoption of safety and quality management programmes in some regions of Brazil still remains a challenge due to factors such as the unawareness of their importance by mainly the population but also the local producers, the lack of training of them, and the lack of systematic inspection by authorities. Training local leaders in GMP, GAP, GFP, and HACCP should overcome this issue, since it enables them as multipliers of these food safety and quality management programmes.

The development of technological solutions for the food production chain that suits the requirements and fits in the budget of local producers is also of paramount importance for ensuring quality and safe food in Brazil, taking also into account economic, social, and sustainable aspects.

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