Mapping of microbiological risks in the production of bovine meat at a food service

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Abstract

Objective: to map microbiological risks in a specific food service unit. **Methods**: a checklist has been applied based on Resolution n. 275 of the National Agency of Sanitary Surveillance to its suitability and validated by three professionals; interviews with the manager of the study unit and manipulators who had direct and indirect contact with food in every phase of the bovine meat production and its receiving units; and direct observation to help construct a real flowchart with details of the behavioural procedures of the employees involved. **Results**: with the application of these tools to map microbiological risk, a diagnosis of the situation was generated for every step of the production process and, consequently, a Corrective Action Plan for nonconformities. From the structural viewpoint, module 1, Building and installations, was considered the most negative and for the microbiological risks, the pre-processing industry was the most critical. **Conclusions**: based on the results, by identifying the control points for microbiological risks, there was the need for deployment of quality tools for the sanitary-hygienic control of the process and the final product, thus contributing to the provision of safer food.

Key words: Bovine meat. Management risks. Food services.

Introduction

The growing public's awareness of the need to consume healthier foods and that do not offer risks to health has forced the government agencies, industries, restaurants, academic and scientific institutions to review the entire conceptual framework and the instruments available in order to achieve this goal.

According to Silva Júnior (2001), among the diseases and health injuries caused by the ingestion of contaminated foods are those mostly from microbiological origin. Alimentary toxi-infections from microbial origin have been recognized today as the most severe worldwide collective health problem, causing decreased productivity and economic losses that impact countries, businesses and consumers.

It is everyone's right to keep the expectation that the foods they eat are safe and adequate for consumption (TONDO; BARTZ, 2011). The foodservice units (FSU) recognize that bacteria can be transferred to the users by the ingestion of contaminated food from the most diverse sources, besides the food itself, particularly from food matrices that have neither been submitted to thermal treatment nor properly heated.

According to Castillo (2006), meat foods are subject to microbial poisoning from various sources, and the animal itself can contribute to the emergence of biological hazards when pathogens or deteriorating organisms are present in their structures.

Bovine meat is a feedstock largely used in the collective foodservice industry and represents a considerable cost compared to other dishes available in the menus. Moreover, it is considered a means that is favorable to microorganisms' proliferation for having a considerable amount of water and proteins, among other nutrients, and for this reason it deteriorates rapidly, requiring special care throughout the handling and preparation processes. Accordingly, any stage or procedure of meat foods production that may be conducive to microbiological hazards is considered critical.

This study aimed to map the possible microbiological hazards in the meat foods production chain in a college cafeteria with the help of specific instruments and based on qualitative and quantitative survey, identifying critical control points and proposing actions for the process continuous improvement.

Methods

The research was based on descriptive and exploratory qualitative approach, and we used the case studies method. The field research to map the microbiological hazards was conducted in a college cafeteria in the city of Niterói, State of Rio de Janeiro, which offers an average of 3,300 lunches and 700 dinners every day. Customers are usually students, but it also serves the faculty and authorized visitors. It also provides transported meals to other two units located in other campuses.

Hazard analysis was not performed because risk managers were not available in the unit, and considering the author's intention that was

just to propose the deployment of corrective measures for the critical issues, aiming at the continuous improvement of the foodservice unit, and finally due to the fact that the focus of the study was to create mechanisms that would be instrumental in the delivery of safe foods, particularly meat-based dishes. The methodology was based on distinct and consecutive stages, as follows:

Field research: investigation phase

A qualitative and quantitative design analysis was conducted, comprising the investigation stage, direct intensive and structured observation, with the use of instruments designed to map the microbiological risks.

Checklist for *in loco* risks mapping

It was used on site from 23 to 26 November, 2010, in different employees' shifts and produced a consolidated checklist for the four-day application period. This instrument was used to detect possible critical points for the control of microbiological hazards in the diverse stages of the productive process of refrigerated bovine meat, i.e., receiving, storage, pre-preparation, cooking and distribution. This instrument was based on and adapted from the attached model of resolution RDC no. 275 of Anvisa (2002), and submitted to pretests performed by three nutritionists specialized in Collective Food Service.

Development of a flow diagram with identification of microbiological hazards

This phase was performed to identify the critical points of microbiological hazards. Along with the data obtained from the interviews and the on-site administration of the Checklist for Risks Mapping, it resulted in the development of a Corrective Actions Plan (CAP). The actual flow diagram was constructed based on on-site observation in the period of 23 to 30 November, 2010.

Structured interviews

Structured interviews are those whose questions are developed beforehand, and the interviewer must have the special attention to stick to questions, not evading them (SILVA JUNIOR, 2001). They were conducted with the manager of the foodservice unit and to direct and indirect food handlers in the diverse stages of the bovine meat process in the period of August 11 to 30, 2010.

The goal is to identify important aspects not included in the Checklist and which requires something beyond the on-site observation, namely the food handlers' testimony about the activities developed, their importance, health control and existing training programs. This phase was crucial for the approval of research project by the Ethics Committed of the Federal Fluminense University, which approved it under process no. 049/2010.

The analysis of the responses was made pursuant to the current legislation (BRASIL, 1978, 2003, 2004, 2009) and literature (CASTILLO, 2006; DEMING, 2003; SILVA JUNIOR, 2001; TONDO, 2011).

Propositional phase

Corrective Actions Plan (CAP)

This plan included the nonconformities described by the respondents and in the Checklist for Mapping On-Site Hazards, as well as a detailed study of the flow diagram of the bovine meat production in the studied unit. Nonconformities were defined when compared with the current sanitary legislation (BRASIL, 2002; 2004).

The CAP has the purpose of identifying all critical points of microbiological hazards that may compromise the quality of both raw material and the final product and contribute to continuous quality improvement with the use of the managerial method called Deming Cycle or PDCA ("*Plan*", *"Do"*, *"Check"* e "*Act*"), indicated for the development of routines, improvements and innovations. Deming (2003) states that the PDCA cycle is a proposed organized approach aiming to eliminate or correct any kind of problem. Thus, you can develop and implement the planned activities effectively and efficiently to solve a problem. The framework of this Corrective Actions Plan was based on the method of 4W and 1W (DEMING, 2003), which stand for, respectively: *what*?, *where*?, *when*?, *who*?, and *how*?.

Regarding the microbiological risks identified in the meat foods production process, corrective actions were proposed and 11 worksheets were developed to monitor the specific critical issues at every stage, and were attached to the CAP. The worksheets were named as: time and temperature of the meat at receiving, as delivered from suppliers; hygiene conditions of the vehicle and driver of transported meat preparations; time and temperature of the meats at storage: time and temperature of the meats at the pre-preparation stage; cleaning of utensils, equipment, cases and countertops of the diverse sectors; cooking time and temperature of bovine meat; time and temperature of the meat preparations during distribution; time and temperature of clean leftovers; time and temperature of the meat preparations at shipment from the central unit and delivery at the receiving unit; supervision of the bowls and isothermal containers at the receiving units.

Development of training courses for the employees

On August 03, 2011, a theoretical-practical training session was conducted at the meats pre-preparation sector, which is considered the most critical sector, and was attended by 19 participants.

Data treatment

The data obtained from the Checklist to map the risks *in loco* were schematically represented with the nonconformities found in a comparative analysis with the sanitary

legislation in force in the country (BRASIL, 2002; 2004) – see Figure 1 and Tables 1 and 2. The interviews were not tabulated because they are descriptive information, but they revealed control issues that should be reviewed by the manager of the unit under study.

The flow diagram of the meat production process was described, and the critical points of microbiological hazards were identified based on nonconformities. The status diagnosis as obtained from the application of these instruments produced the Corrective Actions Plan, as represented in Chart 1, with the development of monitoring worksheets of such control points.

Results

Checklist for *in loco* mapping of microbiological hazards

Pursuant to the current legislation, the FSU was classified into group II: according to the Checklist, the unit showed 52.3% of compliance with the procedures, which indicates the need of correcting the nonconforming procedures that were found. To illustrate and for further discussion of the results, Figure 1 indicates the percentage of nonconformities, besides non-applicable items and those not observed per module by the above instrument.

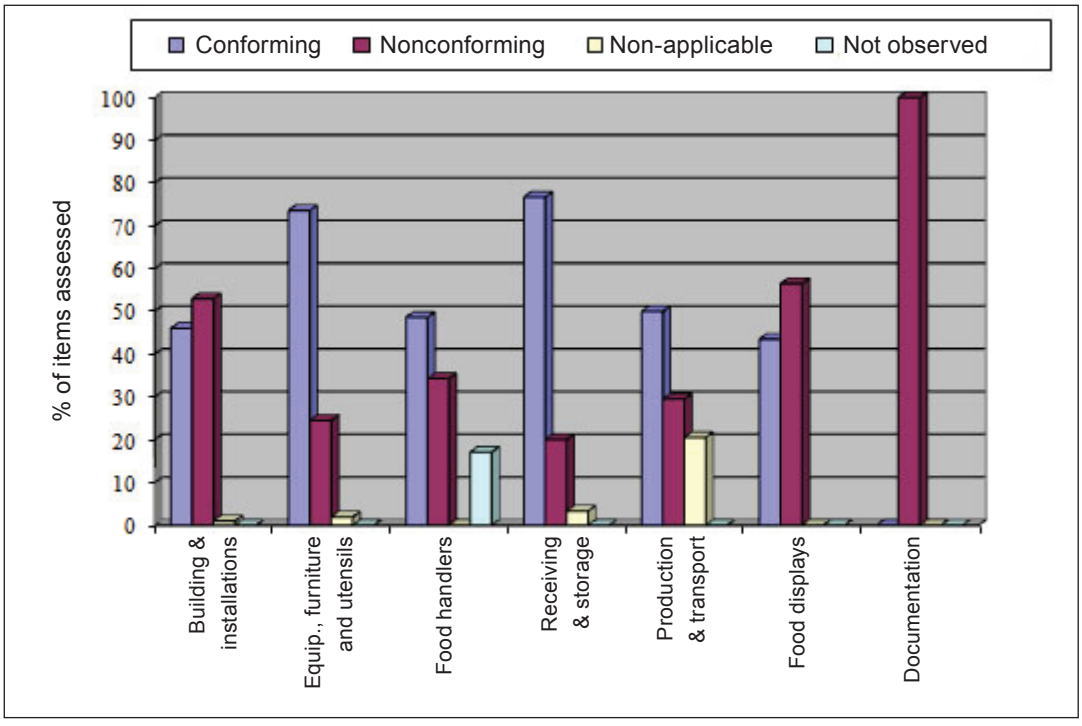

Figure 1. Percentage of conforming, nonconforming, non-applicable and not observed items per module

Table 1. Evaluation of the most critical area in relation to the total items observed. Niterói, RJ, 2010

Position	Module	% of NC*	% in relation to total items
1st	Module 7 - Documentation	100%	5%
2nd	Module 6 – Food displays	56.5%	4%
3rd	Module 1 – Building & facilities	53.2%	44%
4th	Module 3 – Food handlers	34.1%	10%
5th	Module 5 – Production & transport	29.5%	13%
6th	Module 4 – Receiving & storage	26.1%	9%
7th	Equipment, fixtures and fittings, utensils	24.5%	15%

* NC - Nonconformities

Table 2. Comparative results between module 1 and the other modules. Niterói, RJ, 2010

Module	Total of non-conforming items	Corresponding % to the total of non-conforming items
Module 1	84	57% of total NCs
Other modules	64	43% of total NCs

It is important to highlight the percentage of each module in relation to the total items assessed so as to not underestimate the most critical areas. The relation of each module to the total items assessed, according to their rating in relation to the nonconformities percentage is shown in Table 1.

To better understand the contribution of module 1 to the final result in relation to the other modules, Table 2 shows the comparative results between module 1 and the other modules in relation to the total of nonconforming items and the representation of its contribution in percentage of the total nonconforming items.

So, you can see that although module 7 has presented the highest percentage of nonconformities, module 1 corresponds to the greatest part of the total percentage of the items evaluated, thus being the most critical sector.

Structured interviews

According to the information provided by the unit's manager during the interview, there are training programs for the collaborators, but without a predefined schedule. He said that the unit conducts periodic medical examinations for the collaborators, including employees and the service providers, but this was inconsistent with the information provided by the collaborators in the interviews.

According to the manager, there are hygiene operating procedures implemented in the studied unit, but in practice, by direct observation and interviews with the food handlers in the diverse sectors, the use of this control instrument was not confirmed. The manager concluded by saying that the nutritionists are supervised by others to check whether the technical determinations are effectively being accomplished.

Briefly, according to the interviews with the direct and indirect handlers of all stages of the meat food process, some respondents' information were common to all: staff training programs that happens only sporadically; they enjoy the jobs performed; are not submitted to periodic medical examinations, and most of them reported that they do it on their own account, when they feel the need, but without a defined schedule.

Flowchart of the meat food production process

In general, in all sectors of the meat production process critical points for microbiological hazards were identified. Collaborators using jewelry or other ornaments, long, painted nails, some with the hair completely or partially uncovered, especially in the materials receiving and storage sectors, some wearing incomplete uniforms, open shoes and, when closed, made of fabrics. Many collaborators, at this stage

of the survey, were seen talking over the foods handling countertops without wearing disposable masks. Doors communicating with the outside environment are permanently open and without protection of millimeter fly screens, allowing the entry of pests, vectors and dirty into the indoor environment; other food processing sectors had their windows protected with millimeter screens but in poor maintenance and cleaning conditions. We observed an insufficient amount of some utensils, while the places to keep them were poorly cleaned and/or inappropriate.

We also found serious inadequacies in the preparation and use of the cleaning products because of nonexistent procedures for appropriate dilution and receptacles for sanitation of the utensils and detachable equipment parts. There is no systematic control of the foods time x temperature binominal at any stage of the production process, including transported meals, except when interns are willing to perform it. Some equipment requires repairs and/or replacement.

We also observed excessive time in handling the meats at the pre-preparation sector, and such meats become exposed because the storage sector releases it in too large amounts. We identified faulty cleaning of some equipment, like cooking pots and industrial oven. We also observed unskilled performance of the employees responsible for the rooms cleaning and in handling both organic and inorganic wastes.

There was also lack of support equipment for the food preparations that are waiting for replenishment at the thermal distribution countertops. The hygiene conditions inside the vehicle and of the driver that transports the meals are poor, and the isothermal boxes are laid directly on the rear portion of the vehicle floor, which is covered only by a wooden board that was also found to be poorly cleaned. All isothermal containers should be duly sanitized at the receiving units, but they return to the central unit with food residues, contaminating the vehicle and increasing the likelihood of cross contamination.

Corrective Actions Plan (CAP)

According to the instruments used in the analytical phase, it was possible to list the points considered critical for microbiological hazards and develop a Corrective Actions Plan, represented in Chart 1, with its respective monitoring worksheets.

Chart 1. Corrective Actions Plan (CAP). Niterói, RJ, 2011

WHAT?	WHERE?	WHEN?	WHO?	*HOW?*
Inexistent control of time and temperature at the receiving and storage stages, as well as for raw material	Materials receiving	Meats receiving and storage	Employees responsible for materials receiving or nutritionist	Monitor time and temperature with the help of specific worksheets and instruments such as watch or chronometer or thermometer
Inexistent control of the sanitary conditions of transportation and vehicles	Materials receiving	At delivery	Collaborators or nutritionist	Develop specific monitoring worksheets for items requiring inspections
No checking of sensory characteristics and packages of the received meats	Materials receiving	At delivery	Collaborators or nutritionist	Develop specific monitoring worksheets
Collaborators with adornments, without hair covers, long and painted nails	Throughout the production process stages and at the receiving units	Before entering the workplace	Collaborators, direct and indirect food handlers	Remove all adornments, use the hair nets or caps correctly, remove nail polish and trim nails.
Inexistent time and temperature control of cold storage chambers during storage	Refrigerated storage	During storage of bovine meat	Collaborators involved in materials storage and control and nutritionist	- Monitor with specific forms and instruments. - Remove card boxes and keep them in one-piece plastic packing, tightly closed and properly labeled - Release the meat in batches to the pre-preparation sector

Releasing large amounts of meat to the pre-preparation sector	Storage	From the stock to handling	Collaborators involved in this task or nutritionist	- Determine the adequate amount of meat to be removed from the stock - Monitor handling time per batch and monitor the meats surface temperature with thermometers and record the data in specific worksheets.
Inadequate cleaning and storage of utensils, equipment and handling countertops	Pre-preparation	Before and after use	Collaborators involved in this task and nutritionist responsible for the area and for the purchase of cleaning materials	- Keep the place designed for the storage of the utensils and equipment units properly sanitized. - Define SOP for this procedure and make it available to the collaborators. - Provide adequate training for dilution and proper use of chemical products. - Use of specific products for each kind of sanitation operation.
Inexistent time and temperature control during thermal treatment	Cooking	During thermal treatment of bovine meat	Collaborators involved in this task or nutritionist	- Monitor time and temperature of bovine meat cooking by means of specific instruments and worksheets
Inexistent time and temperature control of the foods in the hot/cold food counters	Distribution at the central cafeteria (lunch)	During distribution of meat foods	Collaborators involved in this task or nutritionist	- Monitor time and temperature of meat preparations by means of specific instruments and worksheets
Excessive time for the removal and storage of leftovers; nonexistent control of the leftovers cooling and re-heating temperature	Distribution at the central cafeteria (lunch)	After completing the users' servicing	Collaborators involved in the distribution area or nutritionist	- Monitor time and temperature of meat preparations by means of specific instruments and worksheets - Throw out leftovers in case of nonexistent strict hygiene-sanitary control of the production process stages.

Nonexistent time and temperature control of the foods preparation	Distribution at the central cafeteria (dinner)	During distribution	Collaborators involved in distribution or nutritionist	- Monitor time and temperature of meat preparations by means of specific instruments and worksheets - Throw out leftovers in case of nonexistent strict hygiene-sanitary control of the production process stages.
Nonexistent time and temperature control of the food preparations	Producing unit (shipment) and receiving units (receiving)	Before and after transportation	Nutritionist or technician	- Monitor time and temperature of meat preparations by means of specific instruments and worksheets.
Nonexistent inspection of the hygienic conditions of the vehicle and driver	Producing units and receiving units	At shipment and receiving of transported meals	Collaborators involved in the task and nutritionist	- Monitor the necessary items by means of specific instruments and worksheets.
Nonexistent sanitation of bowls and hot boxes after use	Receiving units	After servicing	Collaborators of this unit	Sanitize bowls and containers with specific cleaning products
Nonexistent time and temperature control of meat preparations	Receiving units	During distribution	Trained collaborators or nutritionist	- Monitor time and temperature with specific instruments and worksheets and discard leftovers.

Critical points monitoring forms

Various worksheets for monitoring of the critical points were developed according to the microbiological hazards described in the Corrective Actions Plan. Such forms can be completed by the nutritionist responsible for quality control or even by collaborators, if properly trained and conscious of the importance of this kind of control.

Checklist for daily monitoring of routine activities

A daily checklist was developed to be completed by the quality control nutritionist. It includes key aspects relating to: personnel, materials, sanitation, foods and equipment. With such assessment tool, internal competitions could be organized with rewards in the form of days-off or other arrangements for the collaborators and/sectors that achieve the highest scores in the evaluation. This instrument can also be a good indicator of needs for staff training and a more effective supervision of the technical teams in performing their routine activities.

Discussion

By mapping the microbiological hazards in the bovine meat processing in a FSU with the methods used, we could see that in various points of this process there are microbiological hazards and non-compliances with the current sanitary legislation (BRASIL, 1978; 2002; 2004; 2009) and with the surveyed literature (CASTILLO, 2006; DEMING, 2003; SILVA JUNIOR, 2001).

Nonexistent hygiene and sanitary control tools in the unit under study is an issue of concern because in foods production and preparation in Brazil and in many other countries, the main tools and systems to manage and ensure foods safety are Good Manufacturing Practices (GMP), the Sanitation Standard Operating Procedures (SSOP), Hazard Analysis and Critical Control Points (HACCP), ISO 9001 and 22000 standards, the latter being an important certification to the HACCP system and Hazards Analysis (SILVA JUNIOR, 2001; TONDO, 2011).

About 30-40% of the human populations are asymptomatic carriers of *Staphylococcus aureus*. Such microorganism can be found in the nasopharynx, ears, hands and skin of human beings, and their enterotoxins can probably be the main biological dangers coming from food handlers. Human feces can contain enteropathogenic *Salmonella, Shigella, E. coli,* intestinal parasites and viruses (TONDO, 2011). Therefore, the diverse critical points in the study unit – regarding the fulfillment of proper personal hygiene procedures and insufficient toilets for the staff's exclusive use, such as hands washing and other hygienic and sanitation habits – are issues of concern, due to the likelihood of foods cross contamination, especially if they are ready for consumption, when there will be no further thermal treatment to minimize or eliminate the microbial load in such foods (TONDO, 2011).

According to Tondo & Bartz (2011), sanitation/hygiene in foodservices is one of the most important factors to minimize risks, and must be considered a crucial procedure in foods production. Accordingly, the companies must have sanitation and hygiene plans that covers all premises, equipment, furniture, fixtures, and utensils, aiming to prevent contamination of the foods produced, which reinforces the need of implementing the proposed actions, such as critical points monitoring worksheets and the Checklist for Routine Procedures. When we consider proper sanitation of equipment and other surfaces that are in contact with foods, removal of food particles and residues and prevention of biofilms formation become crucially important.

We observed total absence of time and temperature control of the processes and foods throughout the bovine meat production process, and although RDC 216/2004 (BRASIL, 2004) does not establish criteria for foods receiving in the foodservice units in Brazil, the Regulation no. 78/2009 of the State of Rio Grande do Sul (BRASIL, 2009) specifies the following criteria: frozen foods, up to -12ºC; cooled foods, up to 7ºC, and all this control must be recorded in specific worksheets, dated and initialed. Thermal treatment at the foods cooking stage must be in accordance with the current legislation, i.e., at least 70ºC, but in the studied unit this control was not performed either.

In the foods distribution stage there is no kind of monitoring either, as well as in the cold counters line, both in the producing units and in the receiving units, and this can trigger a microbiological multiplication process. According to the regulation RDC 216/2004 (BRASIL, 2004), temperatures at the distribution counters for hot and cold food preparations must be higher than 60°C for a maximum of six hours and 10°C for a maximum of four hours, respectively. There are other temperature ranges for food preparations maintained in thermal counters, but the lower the temperature the lower the residence time in the counters.

The Medical Control and Occupational Health Program (MCOHP) was instituted by the Regulatory Norm no. 7, approved by the Secretariat of Work Safety and Health of the Ministry of Labor (BRASIL, 1978), on Dec. 29,1994, published in the Official Gazette of Dec. 30, 1994, modified on May 08, 1996 and republished on May 09, 1996. This regulation establishes that all employers and institutions must include their employees in the program to promote and preserve their health, and this requires periodic medical examinations, admission and dismissal medical examinations, return to the job and job rotation. However, this practice is not exactly what we found in the working environments, in a clear disobedience of the current legislation (BRASIL, 1978), and exposing to risks not only the health of the collaborators but also of the customers served by the unit under study by possible cross contamination.

Conclusion

Based on the findings of this study, the foodservice unit that was used as a parameter for evaluation requires implementation of effective management tools for hygiene and sanitary controls. There are gaps in the supply of safe foods to the regular consumers of the college cafeterias in several campuses of the Federal Fluminense Unversity, because most of the basic sanitation requirements and control, as required by the current legislation for the production of meat foods, are not fulfilled.

We found deficiencies in the physical structure, buildings and installations, and hygiene operating procedures. We also found split responsibilities which, in practice, should be jointly undertaken by both the employees and the services providers.

Concerning the application of the best practice principles in the production of foods, many inadequacies were found by the collaborators, direct and indirect food handlers, and the technical staff, who fails to control points widely known as critical. There is also inefficient systematic supervision in order that the collaborators comply with the basic personal, environmental and foods hygiene procedures, because training alone cannot ensure its compliance, which is aggravated by the high manpower turnover in the industry.

After the data survey, significant changes could be noticed in the premises and installations, which will contribute to the delivery of safer foods, but many other actions must be taken. In this context, taking into consideration the key role played by the food handlers in offering safe foods, we recommend more efforts towards the collaborators' qualification and strict control of compliance with hygiene standards.

Theoretical and practical training programs should be intensified and improvements encouraged by means of educational practices. And yet, to enhance the effectiveness of the proposed actions and considering the educational and extensive role of the university, we suggest a better integration of the institution with the services provided.

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References

BRASIL. Norma Regulamentadora nº 7, Portaria GM n.º 3.214, de 08 de junho de 1978. Estabelece a obrigatoriedade de elaboração e implementação, por parte de todos os empregadores e instituições que admitam trabalhadores como empregados, do Programa de Controle Médico de Saúde Ocupacional – PCMSO. *Diário Oficial de União*, Brasília, 06 de julho de 1978. Ministério do Trabalho e Emprego.

_____. Resolução RDC nº 275 de 21 de outubro de 2002. Dispõe sobre o Regulamento Técnico de Procedimentos Operacionais Aplicados aos Estabelecimentos Produtores / Industrializadores de Alimentos e a Lista de Verificação das Boas Práticas de Fabricação em Estabelecimentos Produtores / Industrializadores de Alimentos. *Diário Oficial de União*, Brasília, 23 de outubro de 2003. ANVISA – Agência Nacional de Vigilância Sanitária.

_____. Resolução RDC nº 216, de 15 de setembro de 2004. Dispõe sobre o Regulamento Técnico de Boas Práticas para Serviços de Alimentação. *Diário Oficial de União*, Brasília, 16 de setembro de 2004. ANVISA – Agência Nacional de Vigilância Sanitária.

_____. Portaria nº 78, de 28 de janeiro de 2009. Aprova a Lista de Verificação em Boas Práticas para Serviços de Alimentação, aprova Normas para Cursos de Capacitação em Boas Práticas para Serviços de Alimentação. *Diário Oficial do Estado*, Porto Alegre, 30 de janeiro de 2009. Secretaria da Saúde.

CASTILLO, C.J.C. *Qualidade da carne*. São Paulo: Varela, 2006.

DEMING, W.E. *Saia da crise:* as 14 lições definitivas para controle de qualidade. São Paulo: Futura, 2003.

MARCONI, M.A.; LAKATOS, E.M. *Metodologia Científica*. . 6ª. ed. São Paulo: Atlas, 2011.

SILVA JUNIOR, E.A.S. *Manual de controle higiênico sanitário em alimentos*. 4ª ed. São Paulo: Varela, 2001.

TONDO, E.C.; BARTZ, S. *Microbiologia e sistemas de gestão da segurança de alimentos*. Porto Alegre: Sulina, 2011.

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