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Water Consumption in Meat Thawing under Running Water: Sustainability in Meal Production

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This study aimed to verify the level of drinking water consumption for the thawing of beef under running water in a restaurant. The consumption estimates were determined by obtaining tap water flows during five different days. The results revealed that consumption reached approximately 8,340 L of water to thaw 109.5 kg of beef. The average daily consumption reached 1,668 L of water for 21.9 kg of beef, approximately 76.2 L of water/kg of meat. The meat temperature and time consumed in thawing were, for the most part, above the recommended level for the meat temperature and thawing time. The average water flow was of 5.2 L/min, reaching 14.8 L/min. It was observed that there is a possibility of decreasing water consumption, especially by scheduling specific times to carry out the procedure. The information in this study can serve as a reference for restaurants when it comes to the reduction of water consumption.

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INTRODUCTION

Meeting human fundamental needs by preserving the environment is the essence of sustainable development, an idea that emerged in the 1980s from perspectives on the relationship between nature and society (World Commission on Environment and Development, 1987). In the pursuit of sustainable development, all human activities must promote economic growth with positive social and environmental impacts (Barbier, 1987).

The activities for production of meals in restaurants presents itself as having relevant responsibility on environmental impact (Calderón, Iglesias, Laca, Herrero, & Díaz, 2010). Waste generation, inappropriate product and package disposal, as well as the use of chemicals and the use of great amounts of water are some of the activities that environmentally affect the industry (Veiros & Proença, 2010). It is noteworthy that, in this scenario, the high consumption of water, often due to poor technique in food prepreparation, such as thawing under running water, aside from having an enormous environmental impact (Leung, Ching, Leung, & Lam, 2007; Shrestha, Schaffner, & Nummer, 2009), can compromise nutritional, sensorial (Hering, Proença, Sousa, & Veiros, 2006), and sanitary–hygienic aspects of foods (Bolton & Manusell, 2004; Shrestha et al., 2009).

The *Five Keys to Safer Food Manual*, published by the World Health Organization (WHO, 2006), advises thawing food only in refrigerators or in cool places. The National Sanitary Surveillance Agency determines sanitary standards regarding foodservices in Brazil. It establishes that food should be thawed under refrigeration, at a temperature below 5°C, or in a microwave oven when food is being cooked immediately (Agência Nacional de Vigilância Sanitária [ANVISA], 2004).

Considering that food thawing under refrigeration is the most recommended method, planning and organizing the meal production process is necessary (Energy Star, 2005). However, when food needs to be quickly thawed due to any unexpected situations or in emergency instances (such as having insufficient space in the refrigerator, burning meat, or receiving more people than expected at the restaurant), immersion of frozen food in water at a temperature above the melting point of the food is a favorable method (Leung et al., 2007; National Center for Home Food Preservation, 2010; U.S. Department of Agriculture, Food Safety and Inspection Service [USDA-FSIS], 2010). Some recommendations are made specifically for the thawing process and they confirm the use of water with a maximum temperature of 21°C (Food and Agriculture Organization [FAO], 1993; Food and Drug Administration [FDA], 2009; Centro de Vigilância Sanitária de

São Paulo [CVS-SP], 1999; Associação Brasilia das Empresas de Refeições Coletivas [ABERC], 2009).

When thawing food with water, heat transfer occurs due to the difference in the food's and liquid's temperatures. The process can be accelerated if running water is used, which increases the convection force as a result of changes in fluid density (Leung et al., 2007), given that running water flow is strong enough to agitate the food particles (FDA, 2009).

Placing food under running water is a thawing technique recommended by the *Codex Alimentarius* (FAO, 1993), a compendium of norms and guidelines developed by the FAO and the WHO, which is used internationally to guarantee the health of consumers in terms of food safety. The recommendation is also made by the United States (FDA, 2009; USDA-FSIS, 2010), Canada (Canadian Food Inspection Agency [CFIA], 2010), Brazil (ABERC, 2009; CVS-SP, 1999), and other countries. For this reason, thawing under running water is a technique that is widely used in restaurants, given that it reduces thawing time, and is a practice accepted by international legislation, and no prohibitions against its use have been found.

Yet, due to the lack of quantitative analysis on running water flows and excessive water consumption (Leung et al., 2007), the *Codex Alimentarius* and the *Food Code* indicate that a 4-hour period should not be exceeded (FAO, 1993; FDA, 2009). Brazilian recommendations on foods also observe a 4-hour maximum for food thawing under running water (ABERC, 2009; CVS-SP, 1999).

The CFIA (2010) has issued greater warnings, recommending restrictions on water flows and on the time for thawing food under running water, despite not specifying values for water flows and time.

Following the same line of action, and taking environmentally sustainable aspects of food preparation into account, the American Dietetic Association and North American government agencies advise food thawing only under refrigeration and never under running water (Energy Star, 2005; Harmon & Gerald, 2007; San Francisco Department of Public Health, 2009).

According to Leung et al. (2007) and Lo, Chan, and Wong (2011), most people who that food under running water do not understand the mechanisms involved, which can lead to errors in time control and excessive water consumption.

Meats are among the most frequently thawed foods (Leung et al., 2007) and are highly susceptible to microbial deterioration (Pardi, Santos, Souza, & Pardi, 2001). Thus, the usual recommendation and application of such method has become a reason for concern when considering the importance of meats, especially beef, in the Brazilian diet (Instituto Brasileiro de Geografia e Estatística, 2010), with the third highest meat consumption in the world, right after the United States and the European Union (USDA, Foreign Agricultural Service, 2011). It is important to highlight that thawing food under running water is a thawing technique used in Brazilian restaurants for meats other than beef, including poultry, pork, and fish, as well as for other foods.

OBJECTIVE

This study aimed to verify drinking water consumption in thawing of beef under running water in a restaurant, with a focus on sustainability.

METHOD

This is a descriptive study, with a qualitative and quantitative theoretical approach outlined as a case study that was conducted in 2010. The study was conducted over 25 days during May and June 2010, autumn in Brazil, a season characterized by average temperatures ranging from 18 to 27°C inside the restaurant. Temperature inside the restaurant is given because restaurants do not have temperature control systems and the indoor temperature varies with the seasons. During this period, 5 days were selected to monitor the process from meat removal from the freezer to preparation, encompassing all beef cuts for which the procedure was carried out.

The following criteria were considered for restaurant selection: served at least one main meal (lunch and/or dinner) on a daily basis, included meat-based dishes, thawed meat under running water; participation in the study was voluntary, though participants also had to have a nutritionist's supervision. Beef was chosen due to the frequency of consumption and its relevance to menus.

Direct observation and document analysis were used as data collection techniques. The entire preparation process was directly observed, from the moment beef was received through its preparation. For document analysis, menus, standardized recipe cards, bidding documents for beef acquisition, process monitoring records, and the Good Practice Guide (ANVISA, 2004) were assessed.

The technical procedures were based on the estimate of water used in induced beef thawing under running water by monitoring the water flow. The process was monitored from the time the meat was removed from the freezer up to prepreparation. To calculate the flow, a 1-L container was used and the filling was timed using the equation $F = v/t$, where F is the flow (L/min), v is the recipient volume (L), and t is the time (minutes) required to fill the recipient.

Measurements were performed on five nonconsecutive days during the 25-day monitoring period at the beginning of thawing. Subsequently, measurements were performed every 30 minutes, as well as each time the water flow rate was changed, and monitoring was continued until the process was completed. This data collection enabled calculation of the average flow and the consumption during each interval, resulting in total consumption for the whole procedure.

Meat temperature was measured at the beginning and end of the thawing process in order to assess the effect of the water flow. When different meat cuts were thawed in the same basin, the average temperature was considered. Water temperature was measured when the process began. Measurement of refrigerator and freezer temperatures was performed using thermometers containing internal sensors and external displays.

Two thermometers were used. One was a noncontact digital infrared thermometer (model MT-350, Minipa, Brazil), with a temperature range of −50 to +450°C, used to measure the external temperature of vacuum-packaged frozen meat, with no direct contact. The other was a calibrated digital thermometer with a stainless steel insertion probe with a temperature range of −50 to +150°C (model DT-625, Dellt, Brazil), used for the water and in the geometric center of thawed meats. Information on meat cut and weight were observed on outer labeling and invoices. Average and standard deviation of water consumption, meat weight, water flow and temperature were used to describe the central tendency and measure dispersion of the collected data.

RESULTS AND DISCUSSION

Characterization of Study Location

The study was carried out in a self-service restaurant that is open 7 days a week and serves lunch and dinner in addition to special events. The restaurant also provided meals to the staff, serving about 120 lunches on a daily basis during the data collection period.

The restaurant had eight weekly menus for meats, serving four options daily. Considering all meat dishes, 25% had poultry, 25% had fish, and 4% had pork. The other 46% were beef dishes, thus showing the beef's relevance in the meal preparation process in this restaurant.

Receiving of Beef in the Studied Food Production Unit

Meats were ordered and received weekly, articulated in a quarterly acquisition plan. The bidding included characteristics that are common to many beef cuts, such as vacuum packaging and good quality. The beef cuts were refrigerated and vacuum packaged when delivered, except for T-bones, which were packaged without a vacuum.

The use of the vacuum packaging system, as shown by Seideman and Durland (1983), extends the shelf life of meat during distribution and storage periods, also preserving sensory characteristics and improving palatability. Other features of this packaging system stand out, especially the possibility of preserving environmentally sustainable aspects, because the use of such packaging systems reduces both energy consumption in the maintenance of low freezing temperatures and water consumption during thawing.

Producers are responsible for establishing the storage criteria for foods that require special temperatures for preservation, in accordance with the techniques used in the industrial process. This information aims at providing safe guidance so that foods will not become improper for consumption, with contamination by pathogenic microorganisms to unacceptable levels (Brazilian Ministry of Agriculture, Livestock and Supply, 1984; Brazilian Ministry of Health, 1984). The shelf life of vacuum-packed meat depends on maintenance of low storage temperatures, transport conditions, and, low initial bacterial contamination (Rodas-González et al., 2011).

Despite being refrigerated and in vacuum packages when delivered, it was observed that the beef cuts were stored in the freezer, regardless of the recommendations provided on label information, which recommended storage at 0°C for 2 months. The freezing system employed did not comply with the recommendations, due to the absence of proper conditions for quick freezing. According to Pardi et al. (2001), the shorter the time between the moment cooling starts and the final temperature (−18°C or less), the smaller the ice crystals formed and the lower the water losses, which results in a final product presenting a uniform appearance.

Farouk, Wieliczko, and Merts (2003) suggested that, beyond the freezing rates, storage time may cause changes in meat quality.

The storage time did not harm the meat quality. The unit studied stored meat in the freezer for about a week, because purchase orders were placed and meat was received weekly. According to the following day's menu, meat was removed from the freezer in the morning and went through preprepared in the afternoon.

Prepreparation occurred in an independent and climate-controlled space, containing two basins with running water, as well as a stainless steel kitchen counter, a vertical refrigerator, and shelves to store spices.

Thawing Under Running Water

The time elapsed between removing meat from the freezer and its preparation did not allow thawing under refrigeration, which frequently led to the need to thaw meat under running water. Of the 25 days during which the unit was monitored, beef was thawed under running water on 11 days (44%).

Despite the fact that the freezer was regulated in order to maintain food at −18°C, the average temperatures measured were −13.3°C (±8.4) in the morning and −7.1°C (±3.1) in the late afternoon, which may be due to frequent door openings throughout the day. The average meat temperature, after its removal from the refrigerated chamber at −7.8°C, reaching −5.4°C was observed, which is above the recommended values to ensure food quality with satisfactory condition. The meat temperatures at the beginning and end of the thawing process, as well as the water temperature, are shown in Table 1.

The average water temperature was 20.6°C (±0.6) and exceeded 21°C at two measurement times. The meat temperature at the end of thawing, on the other hand, was above the recommended temperature of 4°C (FAO, 1993; CVS-SP, 1999). Table 2 presents the times and water flow rate for meat thawing under running water.

The average thawing time was 323.4 minutes (5 hours and 23 minutes), and on 4 out of the 5 days analyzed (80%) the average time exceeded the recommended 4 hours. The period of contact with water resulted in an increase in meat temperature. On the day the maximum time for thawing was observed—that is, 394 minutes (6 hours and 34 minutes)—the meat reached the highest temperature in the observed period of 18.3°C.

Pardi et al. (2001) reported that a temperature range of 0–2°C is the limit in which it is possible to protect food against pathogenic microorganisms, such as *Clostridium*, *Salmonella*, and *Staphylococcus*.

TABLE 1 Meat Temperatures at the Beginning and End of the Process and Water Temperature at the Beginning of Thawing in the Unit Studied

Day	Average meat temperature at the beginning of the process (°C)	Average meat temperature at the end of the process (°C)	Water temperature (°C)
1	−6.2	10.5	21.1
2	−5.4	18.3	21
3	−9.4	10.8	19.8
4	−6.8	10.2	21.2
5	−11.2	7.3	20.6

TABLE 2 Time and Water Flow Rate for Beef Thawing Under Running Water in the Unit Studied

Day	Time the process began	Time the process ended	Minimum flow (L/min)	Maximum flow (L/min)	Average flow (standard deviation)
1	10:50 a.m.	4:15 p.m.	3.53	5.4	4.3 (±0.6)
2	9:30 a.m.	4:04 p.m.	3.33	14.8	4.8 (±3.2)
3	9:10 a.m.	11:10 a.m.	3.73	5.9	4.4 (±0.7)
	11:33 a.m.	2:40 p.m.[a]			
4	12:00 p.m.	5:48 p.m.	4.15	10.3	6.9 (±2.7)
5	11:40 a.m.	3:20 p.m.	2.66	10.2	5.8 (±2.7)

Note. [a]This specific day presented two time intervals, because the tap remained closed from 11:10 a.m. to 11:33 a.m.

TABLE 3 Cuts, Packages, and Quantity of Beef Thawed Under Running Water and Prepared in the Unit Studied

Day	Total weight (kg)	Total time (minutes)	Total water consumption (L)[a]
1	22	325	1,411.8
2	30	394	1,971.9
3	16.5	330	1,367.8
4	19	348	2,380.4
5	22	220	1,208.3

Note. [a]The total consumption calculation considered individual water flows at the time intervals and not the average flow.

From the data shown in Table 3, longer periods to complete the procedure did not necessarily result in greater water consumption, a fact explained by differences in water volume. There was also no evidence that larger quantities of meat led to higher water consumption. On the fourth day, 2,300 L of water was used to thaw 19 kg of meat, more than the quantity necessary for 30 kg of meat on the second day.

On the first and fifth days, the same quantity of meat (22 kg) was thawed. Thawing times showed a 105-minute difference (32% more on the first day), yet water consumption presented similar results (difference of 203.5 L, or 14% more water on the first day). This can be explained by differences in the average flow rate, which was 35% higher on the fifth day.

The time necessary for process completion each day did not follow a pattern with respect to the quantity of meat. For example, on the third day, a smaller quantity of meat (16.5 kg) was in contact with water for a greater period than the 22 kg thawed on the fifth day. This situation may be related to not following a pattern of compliance with the conditions of the meat to complete the process; that is, only finishing the procedure when the employee could start the prepreparation.

The following recommendations were found in the prepreparation room: "Thawing through refrigeration below 4°C or under running water, only in case of emergency. If running water is used, its temperature should be a maximum of 21°C, and conducted until the meat reaches 4°C. Then, thawing should be continued under refrigeration." The habit of thawing food under running water is justified by the restaurant's own recommendation, which obeys Brazilian and international guidelines as reported in the Introduction.

The total amount of water consumed was related to the thawing routine carried out by the unit's employees rather than to the quantity of thawed meat, temperature monitoring, and/or control of the maximum recommended time.

A study conducted in 108 Brazilian restaurants found a low incidence of training of food handlers (21.7%). Thus, the need for qualification is emphasized in order to enable proper conditions for food security (Cavalli & Salay, 2007) and the preservation of environmental resources.

Research carried out in two commercial Chinese restaurants, which served on average 600 and 370 meals daily, found that about 48% of total water consumption was allotted for washing areas, followed by 30% of total water consumption for thawing of food under running water. The restaurants' employees had not received proper instruction on thawing techniques, leading to thawing under running water by opening the tap at the beginning of thawing and turning it off when they thought the food was completely thawed (Lo et al., 2011).

This was observed in the restaurant monitored, because employees had not received training in this procedure and switched off the tap when they had time for the prepreparation, without determining the condition of the food.

The characterization of wastage habits and the implementation of a specific program aimed at reducing water consumption in restaurants were raised as possible solutions (Companhia de Saneamento Básico do Estado de São Paulo [SABESP], 2010).

The results of this study revealed that approximately 8,340 L of water was consumed to thaw 109.5 kg of beef on the days analyzed. The average daily water consumption amounted to 1,668 L (±492) for every 21.9 kg of beef, representing a consumption rate of 76.2 L/kg of meat.

For meal production, the rate of water usage recommended by the SABESP is 25 L/meal (SABESP, 2010). Considering that, at the time of the study, the average daily water consumption amounted to 1,668 L and on average 120 people ate lunch in the restaurant daily, thawing beef under running water represented an additional consumption of 13.9 L of water per meal. For all meal production activities, the rate of water usage recommended by the SABESP is 25 L/meal (SABESP, 2010). Adding 13.9 L water consumption for thawing, it can be estimated that approximately 40 L of water were consumed per meal. It is important to highlight that only water consumption for the thawing of beef was assessed. If water consumption were assessed for all meats and other foods thawed under running water, as well as the number of restaurants in the country, it would be possible to obtain revealing data on how the meal production process may be environmentally unsustainable.

A survey conducted in 20 Brazilian federal university food courts, in which approximately 25,000 people circulate every day, found that 65% thawed meat under running water and 25% thawed meat in still water (Cardoso, Souza, & Santos, 2005).

According to Lo et al. (2011), thawing under running water is the traditional procedure in Chinese restaurants, and it also serves the cultural function of expelling foul flavors, removing impurities, and improving food texture, which necessitates greater water consumption than in restaurants elsewhere. For the two restaurants assessed by Lo et al. (2011), the estimated water consumption due to food thawing was approximately 47.8 and 60.2 L per meal.

Thus, there is a contradiction between the previously mentioned process of thawing in running water and the global efforts to control wate consumption, as established in the millennium goals presented by the United Nations (2010).

Heat Transfer in Food Thawing Under Running Water

With the large amount of water used to thaw meat, researchers have conducted numerical studies aimed at better understanding of heat transfer in food thawing under running water in an attempt to reduce its consumption (Chourot, Boillereaux, Havet, & Bail, 1997; Leung, Ching, Leung, & Lam, 2005; Leung et al., 2007).

Leung et al. (2005) immersed a small pork sample (5 cm in diameter), frozen at −18°C, into a water flow. The sample was thawed in about 84 minutes. In a later study, using the numerical model as a design tool, a simple cold water thawing device was designed to improve the thawing deficiency (Leung et al., 2007). The device consisted of a plastic tank, a stainless steel grid to keep food in a suspended position, and a water inlet at the bottom. An experiment was conducted with a pork sample of 5 cm in diameter and water flow of 0.5 L/min. The time required for sample thawing was 51 minutes. The device decreased the time used for thawing by 33 minutes by reversing the water inlet and keeping food in a suspended position. Due to its simplicity, the building of such a model could be encouraged, especially for emergency thawing in restaurants, though strict control over temperature and time should be emphasized.

In the restaurant studied, thawing was performed by placing the meat under running water, inside polyethylene containers. Thus, long periods were necessary in order to complete the process, in particular considering packaging sizes, which were usually over 7 kg. A package size of 2 kg is recommended when freezing and thawing is necessary (ABERC, 2009).

Water Flow for Thawing Under Running Water

As shown in Table 2, the maximum flow between all events monitored in the present study was 14.8 L/min. This condition of maximum flow remained for the final 42 minutes of thawing on the second day of measurements, in which 622.2 L of water was consumed, confirming that flow is a determinant of consumption.

Chinese researchers (Leung et al., 2007) have analyzed the effect of flow on water consumption and thawing efficiency. The results revealed that an increased flow rate increased heat transfer by convection, thus reducing thawing time. However, an increase in the flow rate of 100%, from 0.5 to 1 L/min, decreased thawing time by only 0.8% (0.3 minutes). Therefore, considering sustainable use within environmental and economic aspects, the authors recommend thawing under running water at a 0.5 L/min flow rate (Leung et al., 2007).

In the present study, the average flow rate used for thawing was 5.2 L/min. If the 0.5 L/min recommendation proposed by Leung et al. (2007) were adopted, the estimated savings in water consumption for meat thawing would be 98% in the unit studied. This fact is more compelling in relation to total consumption, considering other meats that are thawed under running water and the large number of units using this procedure.

Despite this alternative, the use of water for food thawing should be avoided and is recommended only in emergencies. In addition to sustainable aspects, the East Bay Municipal Utility District (2008) presented a cost-effectiveness analysis, justifying the acquisition and use of an extra refrigerator for thawing food rather than the use of water, thus meeting expectations for the rational use of water.

It is important to emphasize that the best option is the acquisition and preparation of refrigerated meats, without the need for freezing and subsequent thawing, by increasing the frequency of delivery if necessary and demanding the use of vacuum packaging systems by suppliers. However, if these conditions are not feasible, options such as the acquisition and maintenance of frozen meat, programming meat thawing, avoiding contact with water, halting the process for exchanges or even thawing at room temperature could be performed (Figure 1).

In a bid to cut water consumption in restaurants, it is necessary to organize production processes, train operators, and allow the specific intervention of a nutritionist or professional technician with skills and expertise to carry out the activities mentioned.

Most water conservation practices require simple modifications, of low or no cost, and only require changes in employees' daily routines. Thawing meat in refrigerators or with a reduced water flow is one of the ways indicated to save water in meal production. Foodservice establishments should be committed to sustainability and include water efficiency in employee training as well as in the company policy (Sustainable Food Service, 2011).

CONCLUSION

Water consumption for thawing, from an environmental sustainability perspective, is alarming, especially because the procedure is avoidable. The results showed that increased consumption occurred due to the flow rate used and the time necessary for the procedure. Yet, the total amount of

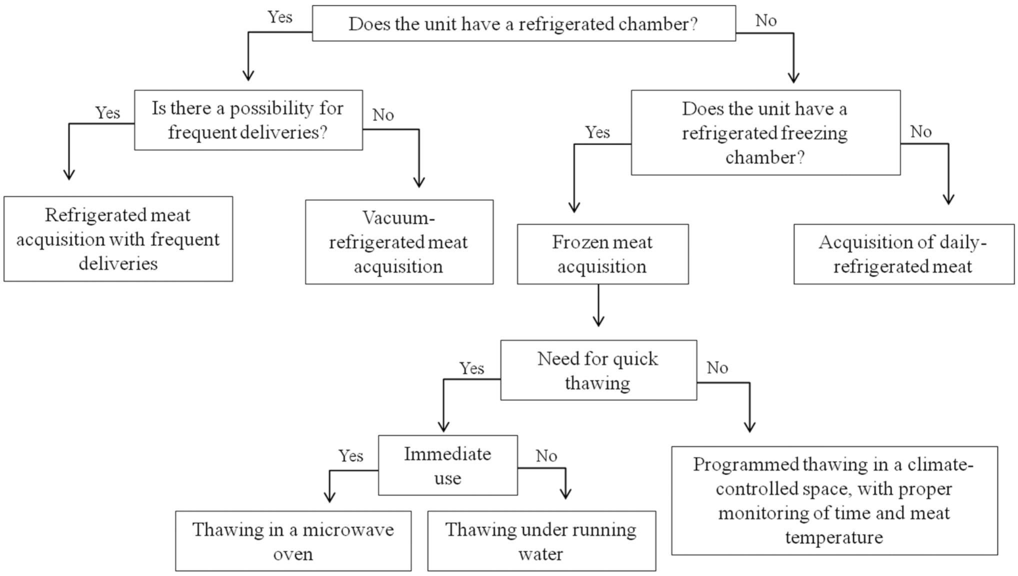

FIGURE 1 Recommendations for meat acquisition and thawing in restaurants.

water consumed had more relation to the completion of routine process, because the meat temperature and/or maximum time were not monitored, thus presenting results that were above the recommended almost every day the unit was monitored.

Therefore, the monitoring of a 0.5 L/min water flow can be added to the time and temperature recommendations for thawing under running water. An adaptation to the procedure is to provide a water inlet at the bottom of the container and keep the food in a suspended position. Studies are needed to enable reduced environmental impacts when induced thawing processes are necessary.

Nevertheless, the best option is the purchase of refrigerated meats that do not need to be maintained frozen and then thawed. If this option is not possible, frozen meat should be thawed in refrigerators. Running water should only be used as a final option, following the recommendations demonstrated in this article. To make these recommendations an organizational routine, it is essential to train and raise the awareness of all employees and to have a commitment from the company.

The results of this study may be potential stimulators for reducted water consumption in restaurants, contributing to the achievement of sustainable practices in the food production process.

For continuing the studies in this specific field, the water consumption from the thawing of other meats should be assessed, which is necessary to the consolidation of programs for rational use of water.

The need to compose a set of techniques that may contribute to the development of good sustainable practices in meal production is perceived.

The good sustainable practices refer to procedures to be adopted in restaurants in order to ensure sustainable practices in meal production, reducing the impacts on the environment and without affecting food quality.

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