Article

Current Topics in Agronomic Science

https://doi.org/10.5154/r.ctas.2022.06.10a

English version

Relevance of cold chain for meat products focusing on pork meat

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Article history:
Received: June 10, 2022
Accepted: December 2, 2022

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Abstract

Cold chain systems, as well as food safety and quality management systems, constitute tools used to prolong the shelf life of perishable products. Refrigerated storage conditions avoid development of pathogenic bacteria and other microorganisms that are associated with meat spoilage. This study aimed to determine cold chain management of fresh pork meat in four supermarkets located in Texcoco de Mora, Mexico. The surface temperature of the product located in different positions inside the self-service refrigerators of the supermarkets was recorded. A mixed model with repeated measurements over time and a completely randomized experimental design was used to analyze data. Results indicated that three of the four supermarkets that were evaluated exceeded the limits of temperature established by the Mexican regulation NOM-213-SSA1-2018. Low efficiency of refrigeration equipment and poor implementation of good management practices by the operator can be related to these temperature abuses. Non-compliant supermarkets are not able to ensure the quality of their products, essentially in terms of food safety.

Keywords: Bacteria, food safety, quality, spoilage, temperature.

Introduction

Perishable products, such as fruits, vegetables, and meat products, have a relatively short shelf life if there are not properly handled and stored. The conditions prevailing during these stages are determinant on the type of micro-organisms responsible for product spoilage (Koutsoumanis and Sofos, 2004). According to FAO and WHO (2003), the main outbreaks of foodborne diseases are mainly related to pathogenic microorganisms. Storage temperature is considered as the main factor affecting safety and quality in meat products, because it prevents bacterial growth and, therefore, sensory characteristics associated with spoilage (Casaburi, et al., 2015; Mercier, et al., 2017).

Controlling temperature, keeping it within the appropriate range for each product from processing to consumption, is the basis of the cold chain (Mercier et al., 2017; Taoukis et al., 2016). Bacterial growth dynamics are subject to the temperature range required for optimal growth. Thus, some species have the ability to reproduce even under refrigerated conditions, as is the case of some strains of *Pseudomonas*, becoming one of the main groups responsible for meat spoilage under these storage conditions (Rawat, 2015).

NOM-213-SSA1-2018 establishes that meat products with a moisture content greater than 35% must be kept at a temperature lower than 4 °C. Retail distribution centers are considered a critical control point in many cold chain

Please cite this article as follows (APA 7): Hernández-Magos, I. P., Maldonado-Simán E. J., Arriaga-Lorenzo, P., Martínez-Hernández, P. A., Castrellón-Montelongo, J. L., & Santiago-Figueroa, I. (2022). Relevance of cold chain for meat products focusing on pork meat. *Current Topics in Agronomic Science*, *2*(2), 9-13. http://doi.org/r.ctas.2022.06.10a

management systems, because the displays in these types of establishments generally have low efficiency in maintaining the proper temperature. This promotes temperature abuses at the recommended limit, which, in turn, generates product weight losses, decreased quality and shelf life (James and James, 2014; Mercier et al., 2017). Therefore, the objective of this research was to determine the cold chain management in fresh pork meat in four supermarkets in Texcoco de Mora, Mexico.

Materials and Methods

Temperature measurements

A total of 288 temperature records of fresh pork meat located in the self-service refrigerators of four supermarkets in the city of Texcoco de Mora, Mexico, were taken on Sundays from July to December 2021. Twelve measurements were taken each month, per supermarket, each one measured on the surface of the pork packaging, whose locations inside the refrigeration equipment were front, middle, and rear. Temperature was measured using an infrared thermometer (MASIONE GM320).

Data analysis

Mean differences between refrigerator positions were aggregated using the Student's t-test. The average temperature was determined and compared to the temperature requirement for meat products stipulated in NOM-213-SSA1-2018.

Results and Discussion

Monthly temperatures for the front, middle and rear positions are shown in Tables 1, 2 and 3, respectively. Mean temperatures were compared with the NOM-213-SSA1-2018 standard, which indicates that fresh meat products should be kept at a storage temperature no higher than 4 °C.

Table 1 corresponds to the frontal position. Mean monthly temperature reports indicate that, of the supermarkets analyzed, supermarkets 1, 3 and 4 failed to maintain the cold chain, since in all three cases the temperature was found to be higher than 4 °C. Supermarket 2 was the only one that had a lower risk level, because, although it was found outside the permitted range, its temperature was very close to that specified in NOM-213-SSA1-2018, and lower compared to the other supermarkets ($P < 0.05$), especially with the one identified as 1, which was found to be 5 °C above the established requirement.

As for the middle position (Table 2), temperatures of supermarkets 2 and 4 indicated they met the standard properly. Even when there were no statistically significant differences between supermarkets 2, 3 and 4 ($P > 0.05$), the mean of supermarket 3 was 0.18 °C above the allowed temperature level because, for three of the six months sampled, it was at least 1 °C above the reference document. However, its risk level was lower than that of supermarket 1, because its average was almost 6 °C above the maximum allowed.

Finally, Table 3, corresponding to the rear position, shows that, according to the mean of the supermarkets per month, most of the establishments evaluated correctly maintained the cold chain, because they maintained the temperature specified in the standard. However, according to the mean temperature of supermarket 1, it showed the highest temperature ($P < 0.05$), compared to the other supermarkets, because it was outside the range, with 1.39 °C above the permitted limit. Temperature was only maintained within the required range in the month of September.

Table 1. Monthly surface temperature (°C) of pork meat exposed in the front position of four supermarkets in Texcoco de Mora, Mexico, from July to December 2021.

Supermarket	Month						Mean
	July	August	September	October	November	December	
1	10.65± 0.58	8.78± 1.05	7.9± 1.21	10.04± 1.04	9.83± 0.90	9.53±1.19	9.45 a
2	2.88± 0.86	4.02± 0.41	4.28± 1.39	4.24± 0.38	4.73± 0.28	4.4± 0.35	4.08 b
3	7.68± 1.42	5.02± 2.18	7.83± 1.46	7.64± 1.44	8.75± 0.95	3.03± 1.14	6.65 c
4	5.60± 1.22	6.52± 1.34	4.30± 1.83	4.56± 0.76	5.43± 0.60	5.60± 1.72	5.33 bc
Mean	6.70	6.08	6.07	6.62	7.18	5.64	

Means with at least one letter in common are not statistically different ($P < 0.05$)

Table 2. Monthly pork surface temperature (°C) placed in the average position of four supermarkets in Texcoco de Mora, Mexico, from July to December 2021.

Supermarket	Month						Mean
	July	August	September	October	November	December	
1	11.23± 0.69	9.84± 0.79	8.25± 1.11	10.36± 1.30	9.75± 0.33	10.13± 1.14	9.93 a
2	1.43± 1.79	2.76+ 0.91	4.22± 1.11	2.84± 0.66	2.3± 1.51	3.10± 0.98	2.78 b
3	3.38± 2.66	2.98± 1.07	5.55± 1.68	5.12± 1.30	5.33± 0.93	2.75± 0.49	4.18 b
4	0.88± 2.28	2.28± 1.92	3.45± 1.97	1.96± 1.53	2.53± 2.14	4.65± 1.77	2.62 b
Mean	4.23	4.47	5.37	5.07	4.98	5.16	

Means with at least one letter in common are not statistically different ($P < 0.05$)

Table 3. Monthly temperature (°C) of the pork surface exposed in the back position of four supermarkets in Texcoco de Mora, Mexico, from July to December 2021.

Supermarket	Month						Mean
	July	August	September	October	November	December	
1	6.48± 0.82	4.70± 0.94	3.48± 1.13	6.0± 1.08	5.65± 0.76	6.05± 1.25	5.39 a
2	-0.03± 1.8	0.86± 1.11	0.80± 0.95	1.70± 0.85	0.38± 1.48	1.73± 1.04	0.91 b
3	-1.90± 2.18	-0.88± 0.98	0.30± 1.39	0.50± 0.65	0.55± 0.79	-1.13± 0.89	-0.43 b
4	-0.68± 1.26	0.22± 1.11	1.25± 1.86	1.26± 1.08	1.95± 0.47	0.35± 2.21	0.73 b
Mean	0.97	1.23	1.46	2.37	2.13	1.75	

Means with at least one letter in common are not statistically different ($P < 0.05$)

Similar results from this research have been reported in other studies regarding retail establishments selling perishable products, which correspond to one of the weakest elements in the cold chain. This is because the refrigerators where the products are exhibited are generally not the most efficient to preserve them, allowing temperature abuses over the recommended limit (Mercier et al., 2017; Nychas, Skandamis, et al., 2008). Authors from different countries have also confirmed this. Derens-Bertheau, et al., (2015), Morelli, et al., (2012) and Villeneuve, et al., (2002) conducted different studies in France, reporting that position, shape, and size of the product influence temperature variation in retail stores, with abuses of up to 6 °C above the established limit. In these studies, variations have been associated with the efficiency of refrigerators and handling by store employees. On the other hand, Likar and Jevšnik (2006), in Slovenia, noted that in retail establishments, greater preference is given to the appearance of the product over the processes that ensure its quality, emphasizing hygiene and management of the cold chain.

The position of products inside the refrigerator has been the subject of study due to its impact on product temperature differences. Baldera Zubeldia, et al., (2016) obtained similar data to the present research after analyzing the temperature of fresh meat during winter and summer in different supermarkets in Andalusia, Spain. The authors found that the season of the year and the position inside the refrigerator are highly related to temperature abuses and that 38.5 % of the analyzed sites did not meet the requirements in the "top" position during summer, while in winter it decreased to 16.7 %. Meanwhile, the "lower" and "middle" positions had smaller deviations.

These studies have highlighted that the front position is the one that shows the greatest deviation from the adequate range. These data coincide with the results obtained in the front position of this research (Table 1), where three of the four supermarkets analyzed were above the established limit. On the other hand, the middle and rear positions also showed deviations, although of smaller proportion than the front position.

Morelli et al. (2012) associated the relationship of temperature variation to type and use of the refrigerator and to the handling practices carried out by workers directly on

the product. In the present investigation, the refrigerators analyzed corresponded to the "open display" or "multi-story cooling cabinet" type, which are in contact with the environment next to the refrigerator. Hundy, et al. (2016) highlighted that this type of refrigerators are based on an air curtain that maintains the products at a temperature determined by the operator. However, even with good management, they are not the most efficient, because they tend to have deviations due to temperature gains from the environment.

Temperature abuses have several implications on perishable products, mainly on their quality. According to Yang, et al. (2021), the increase in temperature favors the degradation of muscle proteins, decreasing water retention capacity and, consequently, increasing fluid loss. Huff-Lonergan (2009) indicated that this phenomenon is particularly important because it modifies the visual acceptance by the consumer and reduces the nutritional quality of the product, since water, iron and proteins are lost in this liquid, mainly associated with the color of the meat.

On the other hand, Nychas et al. (2008) indicated that temperature abuses contribute to spoilage by microorganisms. Studies by Bruckner, et al. (2012), Koutsoumanis, et al. (2006) and Tang et al. (2013) agreed that storage temperature variations greater than 4 °C considerably decrease the shelf life of products, due to increased bacterial growth. These studies highlighted that, under these conditions, *Pseudomonas* is the main bacteria that dominates over *Brochothrix thermosphata*, lactic acid bacteria and *Enterobacteriaceae*. According to Casaburi et al. (2015) different species of the genus *Pseudomonas* produce a wide range of volatile organic compounds (VOCs), associated with the characteristic odor of spoiled meat, which in turn lead to the rejection of the product by the consumer.

The presence of pathogenic bacteria associated with foodborne illnesses can also occur following temperature abuses. Maintaining the cold chain reduces biological risks by these bacteria; however, it is essential to use a preventive approach by properly implementing good hygienic and distribution practices (Betic, et al., 2019). According to Raab, et al. (2011), staff training on issues related to quality and safety of perishable products is essential. In addition, temperature management, monitoring and control is equally relevant, using alternatives that facilitate its implementation, for example, the use of temperature indicators over time, or wireless technologies or the radio frequency identification system (RFID). Michael and McCathie (2005) reported that the use of the RFID system contributes to greater efficiency in temperature, bacterial growth, and quality monitoring processes. Furthermore, this system assures the use or consumption of products before the end of their shelf life.

Conclusions

The four supermarkets evaluated must correctly manage their cold chain, because they are not fulfilling the terms established by NOM-213-SSA1-2018, specifically in the section corresponding to storage conditions. These supermarkets showed temperature abuses during the commercialization of fresh pork, showing that the rear area of the refrigerator is the safest in terms of maintaining the temperature within the appropriate range. It is suggested to continue the research with the objective of determining causes and possible corrective actions for these temperature abuses that occur in these meat retail centers.

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