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The Effect of Freezing and Thawing on Technological Properties of Meat: Review

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Abstract

This paper reviews the effects of freezing/thawing on technological properties of meat. Thus, the effects of freezing/thawing on drip loss have been presented. At the same time, novel thawing methods opposing conventional ones have been considered.

Keywords: freezing, thawing, meat, drip loss, texture

1. Introduction

Freezing and thawing are complex processes that involve heat transfer as well as a series of physical and chemical changes which can affect the quality of the product [1]. In recent years, food industry has relied more and more on using thawed meat in meat processing. Therefore, in order to obtain meat with technological properties closest to refrigerated meat it is very important to consider all the changes undergone by meat until thawing. In this respect, we must take into account the meat aging degree before freezing, the freezing type (fast or slow) as well as the storing conditions while freezing. The purpose of this review is to analyse the main factors affecting meat technological properties which are of utmost importance in further processing of thawed meat. For better understanding the freezing/thawing process, studies referring to the structure of frozen and thawed meat were presented. Furthermore, this review seeks to present the impact of the new thawing methods on thawed meat.

2. The influence of freezing/thawing on drip loss

A very important aspect in meat industry – especially from a financial point of view – is the drip loss after thawing. This is the reason why the factors which influence the drip loss after thawing should be identified.

Previous studies have reported the link between drip loss, freezing speed and aging rate of the freezing meat. Therefore, Anon and Calvelo [2], showed the influence of the freezing rate on the formation of ice crystals that underlies the mechanisms of damage during the freezing of meat tissue. In order to understand this mechanism one should differentiate between fast freezing and slow freezing rate. In the fast freezing rate, initially the small crystals are more numerous. In time they decrease in number but increase in size until there is one unique crystal per fibre. Unlike fast freezing, in slow freezing the partial fibre dehydration is caused by the migration of sarcoplasmic fluid towards extracellular area where extracellular ice is formed exclusively. Moreover, Ngapo et al., 1999 [3] showed the influence of freezing rate on dip loss. It was proven that in the case of fast frozen pork (for 12-120 minutes) the drip loss was the same as for refrigerated meat. Yet, in the case of slowly frozen meat (for 240-900 minutes) the drip loss was significantly higher than for refrigerated meat. Ngapo et al. [3, 4], suggested that protein concentration of drip obtained after different treatment (frozen and thawed and frozen, stored and thawed) and of drip of fresh samples showed that there are no significant differences between thawed samples and fresh ones. As regards the influence of freezing rate on drip loss for meat stored for 4 weeks, Ngapo et al. [3] demonstrated that the freezing rate

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used before storage did not influence drip loss. Moreover, drip loss at samples stored for 4 weeks were significantly higher that drip loss at samples which were not stored. Concerning freezing temperature, Sakata et al. [5] reported that no correlation between freezing temperature (-20°C and -80°C) and drip loss was found and no significant difference was noted. An analysis of the freezing speed was done by Petrovic et al. [6] and it was demonstrated that in both cases (slow freezing and fast freezing) happened considerable deteriorations of fibres and micro-fibres, reduction of myofibrils proteins solubility, as well as great thawing loss. Hansen et al. [7] found that using pressure while freezing affects the amount of exudate. Thus, drip loss from thawed, pressure-shift-frozen was not different from drip loss from fresh meat samples, while cryogen-frozen and air-frozen pork both had significantly higher drip loss. In this case it was assumed that pressure causes protein denaturation and the insoluble proteins blocked the drainage of the muscular fluid leading to smaller quantities of thawing loss.

It was tried to establish a relation between thawing rate and amount of exudate and it was noticed that meat exudate depends upon thawing time. Theories on the effect of thawing time on drip loss were contradictory, Gonzales-Sanguinetti et al. [8] evidencing that, by lowering the thawing time the exudate is higher and Ngapo et.al. [3] demonstrating that drip loss is lower, proportionally to shorter thawing time period. Related to obtaining higher drip loss in the case of slow thawing, Linares et al. [9] suggests that drip loss could be linked with the speed of the thawing rate, and in the case of slow thawing the fluid released from fibres cannot be reabsorbed. Similarly, in the case of slow thawing there is also the possibility of re-crystallising leading to high drip loss out of the fibres. A link between the optimum time post-mortem to freeze meat and drip loss was made by Yu et al. [10]. Thus, it was proven that freezing meat at 45 min instead of 24 h after slaughter resulted in lower drip loss after thawing. Consequently, it is recommended that the earlier the meat was frozen after slaughter, the lower drip loss at thawing, assuming that in this freezing phase more extra-cellular crystals than inter-cellular ones are formed. We know that storage while freezing is an important method of meat preservation.

This is the reason why an important matter is represented by temperature fluctuation which may appear while storage and transporting the meat. Xia et al. [11] showed the influence of freezing-thawing cycles on pork thawing loss. Furthermore, it was noticed that thawing loss is conditioned by the number of freezing-thawing cycles, i.e. thawing loss increases in direct ration with the number of freezing-thawing cycles, starting from 3.5% of loss in the first cycle to 18.27% in the fifth cycle. Apart from this, one of the studies conducted by. Xia et al. [12] on the functional properties (their capacity of emulsifying and jellifying) in the case of freezing-thawing cycles showed the loss of functional properties, especially caused by the denaturation of proteins and their tendency to aggregate.

3. The influence of freezing/thawing on meat texture

A sensorial property very important for consumers is meat texture and, implicitly, its juiciness. Therefore, it is important to look into how meat freezing influences or not the meat aging process, and consequently, its texture. In this respect, many studies showed that the freezing process as well as the meat aging rate before and after freezing could contribute to changes in meat texture after thawing. Thus, Shanks et al. [13] showed differences between the shear force of aged meat chilled not frozen and the shear force of meat stored frozen for 2 months, the latter representing a lower shear force. It was presumed that these results are a consequence of the fact that muscular cells were deteriorated because of intra-cellular ice forming during freezing which led to lowering the shear force in frozen and thawed samples. Similar results were obtained by Lagerstedt et al. [14] who, comparing the values of the shear force in chilled meat samples as well as of the frozen samples after aging, obtained lower values of the shear force in the frozen samples. In this case, although the values of the shear force were lower for frozen meat than for chilled meat these were not consistent with the sensory evaluation, the thawed meat being significantly less tender than the chilled meat.

As regards the freezing rate, Dransfield [15] considered that it plays an important role in meat aging. Thus, unlike slow commercial freezing, fast freezing increased the rate of aging 3 times more than in chilled beef. In this situation, these results were explained by the appearance of cellular lesions which led to an increase of aging rate. Vieira et al. [16]

considered that the formation of small ice crystals caused the increase of aging rate by releasing protease enzymes.

There are different points of view related to the aging degree of frozen meat, namely if meat should or should not be aged before freezing. Crouse et al. [17] showed that for the samples aged after freezing, the shear force was lower than for samples aged before freezing (aged for 6 days). Hence, it was suggested that these results were obtained probably due to the loss of Ca-dependent inhibitor of protease and freezing meat before aging could improve the post-mortem proteolisis. A different point of view belongs to Dransfield [15] who suggested that meat aging should take place before freezing. Dransfield [15] based his explanations on the theory that the activity of calpains is stopped while freezing and storage, being resumed after thawing. Thus, the tenderness of meat frozen three days after slaughtering remains at the same level regardless of the storage period and the aging process will continue after thawing, when the enzymatic activity is resumed. In order to clarify this aspect, we consider further studies necessary.

4. The influence of freezing / thawing on meat structure

A significant part of the studies focused on meat freezing and thawing tried to correlate the results related to technological properties of thawed meat with interpreting the images obtained with electronic microscopes (TEM or SEM).

Therefore, Rahelic et al. [18] analysed histological changes of beef which appeared at different freezing temperatures, noticing a link between the degree of meat deterioration and the position of ice crystals. It was proven that the most severe fibre deterioration was due to forming inter- and intra-cellular ice crystals, when the ice crystals formed between the fibres generate pressure which separates the fibres, while the ice crystals formed within the fibre generate pressure in the opposite direction. A less severe deterioration was noticed when only intra-cellular ice crystals were formed, when the pressure is generate in one direction only.

Moreover, the structure of the frozen meat was assessed according to the size of the cavities which become visible in the case of microscopy. In the case of frozen meat, these cavities can indicate the size of the ice crystals which appear during freezing, while for fresh meat they correspond to the space occupied by the extra-cellular fluid [7]. In this respect, studies on frozen meat at different rates showed the appearance of some big cavities which led to severe deterioration of the muscular cells structure [19]. Nonetheless, it was noticed that after thawing, the ultra-structure of meat samples fully recovered from the totally damaged structure in the frozen samples [19].

RMN studies were combined with microscopy by Mortensen et al. [20] in order to highlight the influence of the freezing temperature and of the freezing rate on the ultra-structure of the thawed meat as well as on thawing loss. The samples were frozen at temperatures of -80°C (fast freezing) and -20°C (slow freezing) and stored at -20°C for 30 months. After thawing it was noticed that in the case of the samples subjected to fast freezing the damages were more severe that in the case of the samples subjected to slow freezing, as well as the tendencies to have higher thawing loss. It is assumed that those small ice crystals turned into big ice crystals either as a consequence of re-crystallizing while storage or because of the slow thawing process.

5. Modern thawing methods versus conventional thawing methods

In recent years there has been a constant research interest to find alternative thawing technologies, being studied thawing by high pressure, micro-wave, ohmic, ultrasound. The thawing process can be faster by generating heat within the product but in the case of micro-wave or dielectric thawing there still are some restrictions regarding the choice of parameters as there might appear a fast and preferential heating of the surface of the product [21].

Kissam, [22] successfully applied ultrasound for thawing fish blocks immersed in water. Thus, using a frequency of 1500 Hz (chosen within the range of relaxation frequencies of the policrystalin ice particles for frozen fish) and a power of 60 W, a decrease in thawing time was obtained. As a consequence of the parameters chosen, a stimulation of the thermal transfer took place and led to the reduction of thawing time by 82% at phase changing (-5°C at -1°C). Similarly, the sensorial analysis of the fish thawed by ultrasound showed that there are no differences from the fish thawed by water immersion. Unlike Kissam, [22], Miles et al. [23] used high frequencies (500 kHz) and intensities of 0.5 W/cm^2

for meat thawing. Results showed that the heating rate in the thawed areas increases by ultrasound intensity and frequency, this reaching its highest peak when the ultrasound transmitting module is parallel with the muscular fibre. Concurrently, the fact that Miles et al. [23] used certain parameters for meat thawing was important as frequencies lower that 430 kHz and higher than 740 kHz led to over-heated areas and a weak ultrasound penetration of meat sample. Therefore, combining a frequency of 500 kHz with an intensity of 0.5 W/cm2 proved that thawing took place without excessive heating of the meat surface. High pressures were used experimentally in thawing process, being clear the distinction between high pressure-assisted (HPAT) and high pressure-induced thawing (HPIT). Otero and Sanz.[24] showed the difference between these two processes, high pressure-assisted thawing being characterised by low pressure and high temperature of samples during pressurization, while high pressure-induced thawing is characterised by higher pressure and lower temperature of samples during pressurization. High pressure thawing not only shortens thawing time but it also has no negative effects on the beef colour, drip loss and cooking loss. It was also shown that the pressure level and the treatment length can influence the quality of the product subject to thawing at high pressure [25]. In the case of fish fillets thawed by using high pressure of 200 MPa, Schubring, et al. [26] noticed that the organoleptic properties of fish thawed by high pressure-assisted thawing are not different from those of the fish thawed in water at 15°C, and thawing loss is low. More than that, Otero et al. [24] also presents a microbiological advantage of high pressure thawing, namely low temperature and high pressure can have a synergetic effect on lethality of micro-organisms. To conclude, researches showed that high pressure thawing preserves the product's properties and reduces thawing time suggesting a high potential for industry. Limiting this thawing method extensively would mean very high costs [27].

As in the case of micro-wave thawing the energy transfer from the micro-waves to the products is fast and with no substantial energy loss, it was noticed that microwave thawing requires little time and small processing areas. Studies done on pork led to contradictory results regarding thawing loss. Therefore, even if Chandirasekaran et al. [28] obtained satisfactory results in thawing loss, the meat sample was harder that when conventionally thawed. Kondratowicz et al. [29] noticed that thawing loss in the case of microwave thawing is lower than in the case of conventional thawing only for the pork stored frozen for a short period of time, but not for a longer period of time. Apart from these results, Xia et.al. [30] conducted a comparative study of thawing methods and found out that from all the conventional thawing methods analysed the greatest loss was obtained when pork was microwave thawed. More than this, microwave thawing had a negative effect on the quality of thawed pork, increasing cooking loss, cutting force, carbonyl content, thus the results related to the qualities of the meat thawed by this method being unsatisfactory.

As regards ohmic thawing which uses an electric current to thaw a product a study was done on beef by Icier et al. [31] for different voltages (10, 20, 30 V/ cm^2). It was noticed that for beef samples the increase of voltage results in shortening the thawing time, thus obtaining time differences between ohmic thawing (828, 703, 586 seconds) and conventional thawing (927seconds). Yet, the texture of the ohmic thawed meat was less tender than that conventional thawed.

The study of He et.al. [32] on the effects of high electrostatic field on pork showed the shortening of thawing time as well as reduction of the total microbial counts in thawed meat without affecting the thawed meat.

Using radio frequency for thawing beef, Farag et al. [33] noticed that this is an efficient thawing method, the drip and micronutrient loss being lower than conventional air thawing.

In order to shorten the thawing time, a quick method for boneless chicken breast proved to be thawing in warm water (60°C). A sensorial analysis showed that there were no significant differences between meat thawed in water at 60°C and meat refrigerator thawed. Nonetheless, the thawing loss proved to be less than when it was refrigerated thawed [34]. Even in the case of beef, thawing in water at temperatures of 20 ºC and 39 ºC proved to be efficient. Thus, Eastridge and Bowker [35] noticed a reduction of thawing time as well as less thawing loss than in the case of refrigerated thawing at 3-4 ºC without affecting meat juiciness.

New thawing methods such as high pressure, acoustic, microwave and ohmic thawing can shorten thawing time and, in some cases, improve the quality of the product. We hope that future studies will be conducted on meat freezing and thawing in order to implement some methods at industrial level.

6. Conclusion

This review has analysed the effects of meat freezing and thawing on certain important parameters such as thawing loss and tenderness. For a better understanding of the changes meat undergoes when freezing and thawing, an analysis of the ultrastructure was done. Also, the new thawing methods were presented. In brief, it can be noticed that these modern methods were applied in order to shorten the thawing time, without affecting the sensorial, technological, microbiological properties of meat. Although many of these methods are only in an experimental phase, they still represent starting points in implementing new technologies. More studies are further necessary in the freezing/thawing domain so that certain current contradiction will be clarified.

Compliance with Ethics Requirements

Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human and/or animal subjects (if exists) respect the specific regulations and standards.

References

1. Bing, Li; Da-Wen Sun., Novel methods for rapid freezing and thawing of foods – a review, *Journal of Food Engineering* **2002**, *54*, 175–182
2. Anon, M. C; Calvelo, A., Freezing rate effects on the drip loss of frozen beef, *Meat Science*, **1980**, *4*, 1- 14
3. Ngapo, T.M; Babare, I.H; Reynolds, J; Mawson, R.F., Freezing and thawing rate effects on drip loss from samples of pork, *Meat Science*, **1999**, *53*, 149-158
4. Ngapo, T.M; Babare, I.H; Reynolds, J; Mawson, R.F., A preliminary investigation of the effects of frozen storage on samples pork, *Meat Science*, **1999**, *53*, 169-177
5. Sakata, R; Oshida, T; Morita, H; Nagata, Y., Physico-chemical and processing quality of porcine M. Longissimus dorsi frozen at different temperatures, *Meat Science*, **1995**, *39*, 277- 284
6. Petrovic, L.; Grujic, R; Petrovic, M., Investigation of the physico-chemical properties of beef M. Longissimus dorsi frozen at different freezing rates Meat Science, **1993**, *33*, 319- 331
7. Hansen, E; Trinderup, R.A; Hviid, M; Darre, M; Skibsted, L.H., Thaw drip loss and protein characterization of drip from air-frozen, cryogen-frozen, and pressure-shift-frozen pork longissimus dorsi in relation to ice crystal size, *Eur Food Res Technol,* **2003**, 218,.2–6
8. Gonzalez-Sanguinetti, S; Anon, M.C; Calvelo, A., Effect of thawing rate on the exudates production of frozen beef, *Journal Food Science*, **1985**, *50*(3), 697–700
9. Linares, C.P; Saavedra, F.F; Serrano, A.B; Silva Paz, L.E; Tamayo Sosa, A.R., Effects of freezing temperature and defrosting .Method on pork quality characteristics, *Journal of Animal and Veterinary Advances* , **2005**, *4*, 976-979
10. Yu, X.; Li, X.B; Xu, X.L; Zhou, G.H; Boles, J.A., Definition of the optimum freezing time posrmorte for manufacturing pork meat, *Journal of Muscle Foods*, **2009**, *20*, 186–200
11. Xia, X; Kong, B; Liu, Q; Liu, J., Physicochemical change and protein oxidation in porcine longissimus dorsi as influenced by different freeze–thaw cycles, *Meat Science*, **2009**, *83*, 239–245
12. Xia, X; Kong, B; Xiong,Y; Ren, Y., Decreased gelling and emulsifying properties of myofibrillar protein from repeatedly frozen-thawed porcine longissimus muscle are due to protein denaturation and susceptibility to aggregation, *Meat Science*, **2010**, *85*, 481–486
13. Shanks, B. C; Wulf, D. M; Maddock, R. J., Technical note: The effect of freezing on Warner-Bratzler shear force values of beef longissimus steaks across several post-mortem aging periods**,** *Journal of Animal Science*, **2002**, *80*, 2122–2125
14. Lagerstedt, A; Enfalt, L; Johansson, L; Lundstrom, K., Effect of freezing on sensory quality, shear force and water loss in beef M. longissimus dorsi, *Meat Science,* **2008**, *80*, 457–461.
15. Dransfield, E., Optimization of tenderization, ageing and tenderness, *Meat Science*, **1994**, *36*, 105–121
16. Vieira, C; Diaz, M.Y; Martinez, B; Garcia-Cachan, M.D., Effect of frozen storage conditions (temperature and length of storage) on microbial and sensory quality of rustic crossbred beef at different stages of aging, *Meat Science*, **2009**, *83*, 398-404
17. Crouse, J. D; Koohmaraie, M., Effect of freezing of beef on subsequent postmortem ageing and shear force, *Journal of Animal Science*, **1990**, *55*, 573–574
18. Rahelic, S; Puac, S., Structure of beef Longissimus dorsi muscle frozen at various temperatures: Part 1- Histological changes in muscle frozen at -10, - 22, - 33, - 78, - 115 and - 196 C, *Meat Science*, **1980**, *14*, 63–72
19. Ngapo, T.M; Babare, I.H; Reynolds, J; Mawson, R.F., Freezing rate and frozen storage effects on the ultrastructure of samples of pork, *Meat Science*, **1999**, *53*, 159-168

20. Mortensen, M; Andersen, H.J; Engelsen, S.B; Bertram, H.C., Effect of freezing temperature, thawing and cooking rate on water distribution in two pork qualities, *Meat Science*, **2006**, *72* , 34–42
21. Chemat, F; Zill-e-Huma; Khan, M.K., Applications of ultrasound in food technology: Processing, preservation and extraction, *Ultrasonics Sonochemistry,* **2011**, *18*, 813–835
22. Kissam, A. D., Acoustic thawing of frozen food 1984, United States Patent No. 4464 401, filed 22.04.82.
23. Miles, C.A; Morley, M.J; Rendell, M., High power ultrasonic thawing of frozen foods, *Journal of Food Engineering*, **1999**, *39*, 151- 159
24. Otero, L.; Sanz , P.D., High pressure-assisted and high pressure- induced thawing: two different processes, *Journal of Food Science*, **2003**, *68*, 2523-2528
25. Zhao, Y; Flores, R. A; Olson, D. G., High hydrostatic pressure effects on rapid thawing of frozen beef , *Journal of Food Science*, **1998**, *63*, 272–275.
26. Schubring, R; Meyer, C; Schlulter, O; Boguslawski, S; Knorr, D., Impact of high pressure assisted thawing on the quality of fillets from various fish species, *Innovative Food Science and Emerging Technologies*, **2003**, *3*, 257–267
27. Kalichevsky, M. T; Knorr, D; Lillford, P. J., Potential food applications of high-pressure effects on ice-water transitions, *Trends in Food Science and Technology*, **1995**, *6*, 253–258
28. Chandirasekaran, V ; Thulasi, G., Effect of different thawing methods on physico-chemical characterisics of frozen buffalo meat, *Journal of Food Tehnology*, *8*(6), 239-242
29. Kondratowicz, J; Chwastowska-SiwieckaI; Burczyk, E., Technological properties of pork thawed in the atmospheric air or in the microwave oven as determined during a six-month deep-freeze storage, *Animal Science Papers and Reports*, **2008**, *26*(3), 175-181
30. Xia, X; Kong, B; Liu, J; Diao, X; Liu, Q., Influence of different thawing methods on physicochemical changes and protein oxidation of porcine longissimus muscle, *Food Science and Technology*, **2012**, *46*, 280-286
31. Icier, F; Izzetoglu, G.T; Bozkurt, H; Ober,A., Effects of ohmic thawing on histological and textural properties of beef cuts, *Journal of Food Engineering*, **2010**, *99*, 360–365
32. He, X; Liu, R; Nirasawa, S; Zheng, D; Liu, H., Effect of high electrostatic field tratament on thawing characteristics and post-thawing quality of frozen pork tenderloin meat, J*ournal of Food Engineering*, **2012**, doi.10.1016/j.jfoodeng.2012.10.023
33. Farag, K.W; Duggan, E; Morgan, D.J; Cronin, D.A; Lyng, J.G., A comparasion of conventional and radio frequency defrosting of lean beef meats:Effects on water binding characteristics, *Meat Science*, **2009**, *83*, 274–284
34. Shrestha, S; Schaffner, D; Nummer, B.A., Sensory quality and food safety of boneless chicken breast portions thawed rapidly by submersion in hot water, *Food Control*, **2009**, *20*, 706–708
35. Eastridge, J.S; Bowker, B.C., Effect of rapid thawing on the meat quality attributes of USDA select beef strip loins steaks, *Journal of Food Science*, **2011**, *76*(2), 156-162