Effect of Thawing on Frozen Meat Quality: A comprehensive Review

Sehar Akhtar, Muhammad Issa Khan and Farrukh Faiz

National Institute of Food Science & Technology, University of Agriculture Faisalabad

Corresponding author: drkhan@uaf.edu.pk

ABSTRACT

Meat and meat products provide essential nutrients such as protein, fat, vitamins and minerals by making an important role in dietary intake. The overall eating quality of meat and meat products is affected by characteristics like taste, texture, juiciness, appearance and odor. Texture is deemed to be most important characteristic of all. Nowadays in busy life meat in bulk quantity is purchased for further usage that required thawing i.e. a loss of nutrition as well. The quality of frozen foods is main concern in many cases due to less attention is paid towards thawing process. However, thawing is significant cause of quality damage in freezing process due to many reasons. Proper precautionary measures must be practiced during meat thawing process to avoid microbial spoilage, which includes temperature below danger zone and reduced thawing time. Improper thawing technique will lead to activation and multiplication of already residing dormant micro flora on meat surface. The purpose of this review is to describe the effects of thawing on the physicochemical quality parameters of meat.

Key words: Meat quality, Thawing methods, shelf stability, Texture

Background

The meat freezing is a practice to extend its shelf-life. Because of high quality product has been practiced for thousands of years, although most improvements in freezing technologies have occurred in the past century (Leygonie et al., 2012; Persson and Londahl, 1993). In food processing thawing of frozen materials is important. Thawing time should be minimum to reduce microbial growth, chemical deterioration and excessive loss of water caused by dripping or dehydration (Taher and Farid, 2001). Generally speaking, the quality of frozen food is closely related to freezing and thawing processes. Freezing rate and the small ice crystals formation in freezing are critical for minimizing tissue damage and drip loss during thawing. Thawing process is slow than freezing. During thawing process foods are subject to damage by chemical and physical changes and microbial attack (Fennema et al., 1973; Kalichevsky et al., 1995). For assurance of food quality quick thawing at low temperature avoiding notable rise in temperature and increased dehydration of food is desirable. Longer the thawing treatment time, higher will be the microbial growth on product surface. Nutritional quality reduction due to leaching of soluble proteins, high energy consumption and large quantities of loaded waste-water are also other disadvantages of conventional thawing (Roberts et al., 1998). Freezing and thawing process mainly affect the water fraction of meat. Since the water is present intermuscular and intramuscular fibers of the meat, compartments are created in the tissue, which complicates the process. With the freezing of water, the concentration of the remaining solutes (proteins, carbohydrates, lipids, vitamins and minerals) increases, thereby upsetting the homeostasis of the complex meat system (Lawrie, 1998). The changes in the immediate
environment of the muscle fibers affect the cell membrane characteristics, which in turn affect the quality of the meat (Fellows, 2000). A perception of the changes that freezing and thawing bring about in different meat types and cuts is essential to the meat industry, as their main objective is to produce better-quality products with high resale values that are both attractive and pleasant to the consumer (Renerre, 1990). Research conducted on freezing and thawing of meat has main focus on the reduction of moisture loss. Anon and Calvelo were the leaders in researching the effects of freezing on meat quality from the 1970s to the 1990s. Their work was later expanded on by Farouk and Swan (1998) from the 1990s into the 2000s. The shelf-life of meat is generally determined by appearance, texture, flavor, color, microbial activity and nutritive value (McMillin, 2008). Of these characteristics, flavor measurement is the most difficult. Flavor compounds may originate from lipid and peptide components in the muscle or meat (Spanier, 1992). All of these parameters are affected by freezing, frozen storage and subsequent thawing.

**How does freezing preserve foods?**

Most pathogens don’t replicate at freezer temperature and many of them die because their enzymes don’t work properly to sustain normal activity of cell. Also, pathogens need water to grow and freezing changes the available water into solid ice crystals. Slower the freezing process larger the crystals become and the more cells they damage. Speed of freezing in food depends on the amount of solutes (soluble salts, proteins and carbohydrates) which affect the temperature at which ice crystals are formed. The higher the level of solutes the lower the temperature must be for the food to freeze (Gill, C.O. 2002).

**Storage time for frozen food:**

If the temperature in a freezer fluctuates, the length of time you can keep frozen foods is considerably reduced. Freezer doors should be kept closed as much as possible, and only a small amount of unfrozen food should be added at one time.

**Thawing of meat**

Thawing refers to the melting process of conversion from a frozen to a liquid state (melt) or to become free from the effect (as stiffness, numbness, or hardness) of cold as a result of exposure to warmth.

Thawing is a quite important process following the freezing in terms of meat quality. There are various ways of thawing meat such as slow thawing, ambient temperature (counter-top) thawing, water immersion thawing, and microwave thawing (Xia et al., 2009). Despite the fact that the counter-top or ambient thawing increases the drip loss and is not suggested by the food codes and regulation due to the risk of microbial spoilage, almost 50% of consumers are still favoring this thawing method due to simplicity. The increased drip loss of muscle can lead to less acceptability, due to the loss of tasteful constituents, such as some amino acids or nucleotides. Also, nutritional constituents such as heme iron and heme pigment must be preserved by these processes as these pigments are mostly found in beef (Met et al., 2013).

**Methods of Thawing of meat:**

Speeding up the process of thawing runs the risk of food spending long periods in the temperature danger zone. Options for thawing raw meats, fish or chicken, and the
limitations of each conventional and novel method are summarized below.

**Conventional methods of thawing**
- Refrigerator Thawing
- Cold Water Thawing
- Microwave Thawing
- Thawing at room temperature

**Novel methods of thawing**
- High pressure thawing
- Ohmic thawing
- Acoustic thawing

**Refrigerator thawing**

Use a refrigerator thermometer to be sure the refrigerator temperature is consistently 40 F° or below. Place frozen meats and poultry products on a plate or cookie sheet in your refrigerator to prevent juices from dripping onto other foods. Place thawing foods on the bottom shelf or below ready to eat foods. This way the raw juices do not drip onto ready to eat foods. Plan ahead when thawing in the refrigerator; it usually takes at least 24 hours to completely thaw.

Different sizes of meat or poultry packages will require different amounts of time to completely thaw. For example, one pound of hamburger will take less time than large cuts of meat, such as a pot roast. Cook meat and poultry products within the following time frame, once they have been completely thawed in the refrigerator. Thaw raw meats, poultry, and seafood on the bottom shelf of the refrigerator. Have a plate or a pan under them to catch any juices that may drip.

**Cold water thawing**

Using cold water for thawing is a fast way to thaw out frozen foods but some precautions are needed. Place the frozen food in a leak proof bag and submerge in cold tap water. Change the tap water every 30 minutes until the frozen food is thawed. As soon as the food is thawed either cook it immediately or put it in the refrigerator until ready to cook. Different amounts of time are needed for different types of meat and poultry

- A 1-2 pound package of beef or poultry takes approximately 1 hour to thaw
- A 3 or more pound package of beef or poultry takes approximately 2-3 hours to thaw

**Microwave thawing**

A microwave oven is another fast way to thaw out frozen foods. When the microwave is used to defrost, it will start cooking the frozen item. When using this method, the food needs to be cooked right after it is thawed to prevent bacterial growth on the food. Do not put foods thawed this way in the refrigerator unless they have been cooked.

**Room temperature thawing**

Rapid thawing technique but Potential growth of pathogens on the surface initially, then inside if food temperature rises into the danger zone. Monitor the temperature regularly to keep food below 4°C. Require protection against flies, pests and domestic pets. Cook food immediately after using this method (Gill, C.O. 2002).

**High-pressure thawing**

High-pressure thawing would be another new application of high pressure on food industry. Though less attention has been paid to high-pressure thawing in comparison with high-pressure freezing, recently some research
revealed that high-pressure thawing can preserve food quality and reduce the necessary thawing time (Makita, 1992; Zhao et al., 1996; Zhao et al., 1998), suggesting its potential for the food industry. Makita (1992) found that high-pressure thawing at frozen meat required only one-third of the time necessary at atmospheric pressure but produced sensory qualities comparable to those of conventionally thawed products. High pressure thawing was more effective in texture improvement in frozen tofu than was atmospheric-pressure thawing. During high pressure thawing, the drip loss of beef was too small to detect and there were no negative effects (p < 0.05) on colour, penetration force or cooking loss of thawed beef (Zhao et al., 1998). The thawing rate depends only on the conduction of heat, as pressure is transmitted uniformly through the sample (Kalichevsky et al., 1995). Zhao et al. (1998) demonstrated that pressure level and treatment time affected thawing rate and product quality, while product characteristics, such as size and initial temperature, did not affect thawing rate, indicating that it is advantageous to thaw a larger amount of product at high pressure.

Limitations on the application of high-pressure thawing are mainly high cost, the same as high-pressure freezing encounters, and pressure-induced protein denaturation and meat discoloration (Kalichevsky et al., 1995; Mertens and Deplace, 1993). Therefore, studies on fundamental data influencing high-pressure thawing process and its optimization is important to its commercial application.

**Ohmic thawing**

When electric current passes through conducting food with high electrical resistance, heat is generated instantly inside the food, thus increasing the temperature of the food item (Fu and Hsieh, 1999). This heating technology is termed as ohmic heating or electro-heating. In the food industry, more attention has been paid to the application of ohmic heating on aseptic processing and pasteurisation of particulate foods. In comparison with microwave heating, ohmic heating is more efficient because nearly all of the energy enters the food as heat and ohmic heating has no limitation of penetration depth. Ohmic heating also has advantages over conventional heating such as high heating rate, high energy conversion efficiency, volumetric heating, etc. (Reznick, 1996; Fellows, 2000). Using ohmic heating to thaw frozen foods is an innovative method. Ohtsuki (1991, 1993) patented an ohmic thawing process where frozen foods positioned with negative electrons were introduced into a high voltage electrostatic field. Using this method, the thawing time for frozen tuna, beef and eggs was shortened to 1/4–1/3 of that under the same temperature condition. Yun, Lee, and Park (1998) examined ohmic thawing of frozen chucks of meat in combination with conventional water immersion thawing with 60–210V (A.C.) at frequencies of 60 Hz–60 kHz. It was found that frequency changes did not significantly affect thawing time and ohmically thawed samples showed reduced drip loss and improved water holding capacity when lower voltages were applied.

**Acoustic thawing**

The utilisation of acoustic energy to thaw frozen foodstuffs was investigated about 50 years ago; however, the negative aspects of poor penetration, localized heating and high power requirement hindered the development of this method (Brody and Antenevich, 1959). Recently, work on relaxation mechanism showed more acoustic energy could be absorbed by frozen foods when a frequency in the relaxation frequency range of ice
crystals in the food was applied (Kissam, et al., 1981). Kissam et al. (1981) illustrated the thawing process under the relaxation frequency. Experiments showed that blocks of cod required 71% less time by using acoustically assisted water immersion thawing than that with water immersion only when 1500 Hz acoustic energy at 60 watts was applied. Miles et al. (1999) applied high power ultrasound to thaw meat and fish, their work indicated that acceptable ultrasonic thawing was achieved at frequencies around 500 kHz, which conformed to relaxation mechanism. Therefore, acoustic thawing still is a promising technology in the food industry if proper frequencies and acoustic power are chosen.

**Meat quality attributes affected by freezing and thawing**

- Moisture
- Protein denaturation
- Oxidation of lipids and proteins
- Color (myoglobin proteins)
- pH
- Tenderness (shear force)
- Microbial count
- Drip loss
- Meat texture
- Meat structure

**Moisture content of meat**

Freezing and thawing alters both the content and the supply of moisture in meat tissue. Moisture as a quality characteristic in meat can be evaluated in several ways, including drip loss; thaw loss; cooking loss; water binding capacity and total moisture content. Moisture loss in meat is inevitable post mortem due to the decrease in pH (closer to the isoelectric pH of proteins), the loss of adenosine triphosphate (ATP), and the steric effects due to shrinkage of the myofibrils as a result of rigor mortis and conditioning (Huff-Lonergan and Lonergan, 2005). These factors all act to release water that was previously immobilised and bound to proteins into the intrafibrillar spaces.

The released water is then redistributed into the sarcoplasmic and extracellular spaces. Freezing and thawing are known to affect the amount of exudate (thaw loss and/or drip loss). In terms of thawing, major differences in opinion exist regarding the correlation between the rate of thawing and the extent of exudates formation. Gonzalez-Sanguinetti, Anon, and Cavelo (1985) concluded that a decrease in thawing time (time elapsed from −5 °C to −1 °C) to below 50 min resulted in a decrease in exudate. This was attributed to the melting of ice in the extracellular spaces causing an increase in water activity, resulting in the net flow of water into the intracellular spaces and its subsequent re-absorption by the dehydrated fibres. Haugland (2002) also proposed that an increased rate (or decreas in time) of thawing caused less exudate to form. Ambrosiadis et al. (1994) reported that rapid thawing of meat by submergence in water decreased the drip loss. On the other hand, it was found in the latter study that microwave thawing (35 min to reach 0 °C) increased the drip loss to within the same range as ambient air thawing (5–7 h), but this drip loss was still less marked than in the case of refrigerated thawing (28 h), which resulted in the highest drip loss.

**Protein Denaturation**

It has been traditionally thought that protein denaturation could result during freezing due to an increased
intracellular ionic strength following the migration of water to the extracellular spaces. Nonetheless, this mechanism has been refuted by several authors. Anon and Cavelo (1980), Mietsch et al. (1994) and Ngapo et al. (1999) all suggested that protein denaturation does not contribute significantly to quality loss, as they found no significant differences in the amount and composition of proteins in the drip collected from fresh samples and those samples that had been frozen and immediately thawed. It was, however, noted by these authors that the time and temperature of the sample storage may have influenced the results obtained and no new explanations were offered with regard to the loss of meat quality during freezing. It would consequently be very beneficial to evaluate the drip composition of such samples using more modern techniques, such as proteomics.

Oxidation of Lipids and Protein

The final temperature to which meat is frozen and stored determines the amount of unfrozen water that remains available for chemical reactions to proceed. Petrovic (1982) showed that biochemical reactions could still take place in meat frozen and stored at temperatures higher than −20 °C, since sufficient unfrozen water remained available at these temperatures for such reactions to occur. The optimum temperature for the frozen storage of meat has been reported to be −40 °C, as only a very small percentage of water is unfrozen at this point (Estevez, 2011). This fraction of water is believed to be bound to other food constituents and thus is chemically inactive (Nesvadba, 2008; Singh and Heldman, 2001). The freezing of the water fraction also causes an increase in the solute concentration both intracellularly and extracellularly, which is thought to be the reason for the increased chemical reactivity during frozen storage (Fennema, 1975). The ice crystals, depending on their size and location, will disrupt the muscle cells, resulting in the release of mitochondrial and lysosomal enzymes into the sarcoplasm (Hamm, 1979).

The fraction of unfrozen water is also important in terms of oxidation, since chemical reactions can occur during frozen storage that initiate primary lipid oxidation (peroxidation) in the meat. This can lead to radical secondary lipid oxidation upon thawing (Owen and Lawrie, 1975) leading to adverse changes in colour, odour, flavor and healthfulness. This phenomenon has been demonstrated by Akamittath et al. (1990) and Hansen et al. (2004), who reported accelerated lipid oxidation in frozen–thawed meat that was subjected to a refrigerated shelf-life study. The quality of the secondary products of lipid oxidation is generally measured using the thiobarbituric acid reactive substances (TBARS) method. These secondary products cause rancid, fatty, pungent and other off-flavours. The development of these flavours was noted by Vieira et al. (2009), who stated that TBARS of fresh meat were significantly lower than meat stored for 90 days at −20 °C. Such observations indicate that frozen storage is not necessarily sufficient to prevent oxidation from occurring. Although peroxidation was not measured in the aforementioned study, it would be expected that primary lipid oxidation would cease at such low temperatures by 90 days and secondary lipid oxidation would commence, which should be detected by the TBARS method. Benjakul and Bauer (2001) also found that freezing and thawing of muscle tissue resulted in accelerated TBARS accumulation and attributed this finding to the damage of cell membranes by ice crystals and the subsequent release of pro-oxidants, especially the haem iron. There is also increasing evidence to indicate that lipid oxidation takes place primarily at the cellular
membrane level and not in the triglyceride fraction. Therefore, lipid oxidation has been reported in both lean and fatty meats (Thanonkaew et al., 2006).

Protein oxidation can be linked to any of the pro-oxidative factors, such as oxidised lipids, free radicals, haem pigments and oxidative enzymes. Malonaldehyde is one of the substrates that react with protein derivatives to form carbonyls (ketones and aldehydes) (Xiong, 2000). Protein and lipid oxidation are, therefore, undoubtedly interlinked. Protein oxidation in meat may lead to decreased eating quality due to reduced tenderness and juiciness, flavour deterioration and discolouration (Rowe, et al., 2004). These changes are partially due to the formation of protein aggregates through both non-covalent and covalent intermolecular bonds as reactive oxygen species (ROS) attack the proteins. Other common changes in oxidised proteins include amino acid destruction; protein unfolding; increased surface hydrophobicity; fragmentation and protein crosslinking. These all lead to the formation of protein carbonyls (Benjakul et al., 2003; Liu et al., 2000; Xia et al., 2009). Freezing and thawing cause damage to the ultrastructure of the muscle cells with the ensuing release of mitochondrial and lysosomal enzymes, haem iron and other pro-oxidants. These increase the degree and rate of protein oxidation (Xiong, 2000). The amino acid residues that are mainly involved in these reactions are lysine, threonine and arginine, the oxidation of which leads to the polymerization of proteins as well as peptide scission (Liu et al., 2000; Xia et al., 2009; Xiong, 2000). These amino acids are mainly found in the myofibrillar proteins, which account for 55–65% of total muscle protein and are responsible for the majority of the physicochemical properties of muscle foods (Xia et al., 2009). Protein oxidation destabilises the protein matrix leading to increased toughness, loss of water-binding capacity and loss in protein solubility.

Color (Myoglobin Proteins)

Myoglobin has been identified in exudate by gel-electrophoresis, accounting in part for the change in the colour stability of meat after freezing and thawing (Anon and Cavelo, 1980). It has also been reported that denaturation of the globin moiety of the myoglobin molecule takes place at some stage during freezing, frozen storage and thawing (Calvelo, 1981). The denaturation leads to an increased susceptibility of myoglobin to autoxidation and subsequent loss of optimum colour presentation. This theory has been verified by many authors by comparing the degree of bloom and the ability of the meat to resist oxidation to metmyoglobin during refrigerated storage post freeze/thaw (Abdallah, Marchello, and Ahmad, 1999; Farouk and Swan, 1998; Lanari, et al, 1990; Lanari and Zaritzky, 1991; Leygonie, Britz, and Hoffman, 2011; Marriott, et al., 1980; Otremba et al., 1999). The existence of an enzyme system capable of reducing metmyglobin back to myoglobin was proposed by Livingston and Brown (1981) and was termed the metmyoglobin reducing activity (MRA). The theory is that in fresh muscle the enzyme is very active and the metmyoglobin formed is quickly reduced to deoxymyoglobin and oxygenated back to oxymyoglobin, thereby retaining the bloomed colour. However, as the meat ages or is frozen, the activity of the MRA is decreased and metmyoglobin begins to accumulate on the surface of the meat at a rapid rate (Abdallah et al., 1999). Also, MRA and/or co-factors, such as NADH, could be ‘lost’ from the post mortem sarcoplasmic environment by leaching as exudate during thawing, and/or due to
oxidation, and/or be used by reactions unrelated to MRA, which will all contribute to accelerated oxidation and loss of bloom (Abdallah et al., 1999).

**pH**

The pH of meat that has been frozen and thawed tends to be lower than prior to freezing (Leygonie, et al., 2011). As pH is a measure of the amount of free hydrogen ions (H+) in a solution, it is possible that freezing with subsequent exudate production could cause denaturation of buffer proteins, the release of hydrogen ions and a subsequent decrease in pH. Alternatively, the loss of fluid from the meat tissue may cause an increase in the concentration of the solutes, which results in a decrease in the pH. A further explanation for this finding may involve the deamination of proteins by microbial or enzymatic action, with the ensuing release of hydrogen atoms (Leygonie et al., 2011).

**Tenderness (shear force)**

There is general agreement in the literature that the tenderness of meat increases with freezing and thawing when measured with peak force (Farouke, et al., 2003; Lagerstedt, et al., 2008; Shanks, et al., 2002; Wheeler, et al., 1990). It has also been found that the increase in tenderness is correlated to the length of frozen storage and the degree to which the meat was aged prior to freezing. The tenderising effect of freezing seems to be negated when the meat was sufficiently aged prior to freezing (Vieira et al., 2009). The mechanism involved in the tenderisation is thought to be a combination of the breakdown of the muscle fibres by enzymatic action during proteolysis, ageing, and the loss of structural integrity caused by ice crystal formation. The formation of large, extracellular ice crystals disrupts the physical structure, largely breaking myofibrils apart and resulting in tenderisation. However, the formation of small intracellular ice crystals increases the rate of ageing probably by the release of protease enzymes (Vieira et al., 2009), although many alternative postulations exist in the literature.

Contradictory results have been obtained from sensory evaluation of tenderness (Lagersted et al., 2008), where a lower peak forces was reported in freeze/thaw samples compared to chilled meat. In this case the trained sensory panel rated the freeze/thawed meat significantly less tender than the chilled meat. This sensory result was attributed to the loss of fluid during thawing that resulted in less water available to hydrate the muscle fibres; thus, a greater quantity of fibres per surface area seemed to increase the toughness as perceived by the sensory panel. The decrease in the shear force was attributed to the loss in membrane strength due to the ice crystal formation thereby reducing the force needed to shear the meat (Lui et al., 2010).

**Microbial count**

Neither freezing nor thawing appears to decrease the number of viable microbes present in meat. During freezing, however, microbial spoilage is effectively terminated as the microbes become dormant. Unfortunately, they regain their activity during thawing (Londahl and Nilaaon, 1993). As thawing is a much slower process than freezing and is less uniform, certain areas of the meat will be exposed to more favourable temperature conditions for microbial growth. This is of particular concern when air thawing is employed. In addition to the risk of high temperature exposure, there is an increase in moisture and nutrients available to microbes post freeze/thaw due to exudates formation. The moisture lost during thawing is rich in proteins, vitamins
and minerals derived from the structural disarray caused by the freezing process, which consequently provides an excellent medium for microbial growth. For this reason, good hygiene and handling practices are even more important for meat that is to be frozen and thawed compared to that which is to be sold fresh (Pham, 2004). Vieira et al. (2009) found in their study that beef frozen for up to 90 days, previously aged for 3 and 10 days, did not spoil due to microbial growth. They did, however, report an increase in the levels of psychrotrophic bacteria during the 90-day frozen storage, which were probably favoured above the other bacteria by the thawing process (48 h at 4 °C in a cooler). Greer and Murray (1991) found that the lag phase of bacterial growth in frozen/thawed pork was shorter than for fresh meat, but that the time to develop spoilage odours was not affected. Literature on the microbial quality and shelf-life post freeze/thaw is limited for all species of meat, but that which is available seems to indicate that the microbiological shelflife of fresh and frozen/thawed samples is similar.

**Meat Structure**

Most severe fibre deterioration during freezing and subsequent thawing was due to forming inter- and intracellular 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 (Hansen, et al., 2003). 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 (Ngapo, et al., 1999). Nonetheless, it was noticed that after thawing, the ultra-structure of meat samples fully recovered from the totally damaged structure in the frozen samples (Ngapo, et al., 1999). RMN studies were combined with microscopy by Mortensen et al. (2006) 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.

**Meat Texture**

Meat texture is important sensory property for consumers and, implicitly, its juiciness. 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. (2002) 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. (2008) 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, (1994) 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., 2009).

**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. Ngapo et al., (1999) showed the influence of freezing rate on drip 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. (1999) 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. (1999) demonstrated that the freezing rate 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. (1995) 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. (1993) 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. (2003) 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. (1985) evidencing that, by lowering the thawing time the exudate is higher and Ngapo et al. (1999) 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. (2005) 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. (2009). 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.

**Conclusion**

As global trade increases and the distance between producer and consumer expand, there is great demand to freeze meat for transportation. Beef, lamb/mutton and chicken are the meat products that are produced worldwide in the greatest quantities majority of the research in the meat science discipline has main focus on these species. In this review effect of thawing on different parameters for assuring good quality meat are assessed. In recent years, the main focus of research into freezing and thawing mechanisms has been concentrated on the development of novel freezing and thawing methods. The commercial application of these processes is still disputed, however, even though scientific research indicates that they lead to an increase in the quality of meat.

**REFERENCES**


