Meat and Meat losses: influence on meat quality

Rimpika Devi[1], Prasad Rasane[1*], Sawinder Kaur[1], Jyoti Singh[1]

[1]*Department of Food Technology and Nutrition, Lovely Professional University, Phagwara, Punjab 144411, India.*

Abstract

Meat and meat products are known to be a potential source of vital nutrients, including protein, vitamins, minerals, and fats. For the preservation of these products, various processing techniques have been taken into consideration so as to provide all the nutrients to the consumers in an intact form. While employing these processing methods, several losses such as cooking, thawing, evaporation and drip loss take place; these are all interrelated to each other. These losses are affected by different factors, including the pH, relative humidity, time and temperature combination by cooking and freezing and many more. Different practices can be incorporated during processing and preservation in order to minimize these losses, avoid microbial spoilage and increase the retention of nutrients. Currently, quality work has not been done on these losses. Thus, this is the most important field to explore so as to minimize these nutritional losses.

Keywords- drip loss, cooking loss, thawing loss, evaporation loss, meat, meat products

Introduction

Since centuries, meat and meat products are consumed all over the world and is considered as an essential component of the food by many populations. The production and consumption of meat and meat products are increasing day by day. By the year 2020, the demand of meat and meat products will increase up to 85% in the developing countries as compared to the developed ones (IFPRI, 1999). Various types of meat viz. red meat, white meat, mutton chops; pork and beef are known to have a different nutritional composition and benefits. The nutritional composition is affected by several factors viz. Convenience, price, safety, nutritional and sensory properties, and safety. Approximate composition of the meat (average) is given in Table 1 and 2.

Table 1 Approximate composition of meat (per 100g)

Nutrients	Amount per serving gram	% daily value
Total fat	4.5g	7%
Saturated fat	1.3g	6%
Protein	22g	44%
Total carbohydrate	0g	0%
Dietary fiber	0g	0%
Sodium	51mg	2%
Cholesterol	70mg	3%
Ash	1.32g	6%
Water	70.2g	70-80%

Source: Greer and Murry 1991; Vieira et al., 2009

These are vital sources of protein, mineral, vitamin, fat, saturated fatty acid, cholesterol, and salt (Jimenez et al., 2001). The acceptance of meat is strongly affected by cooking methods that have worthy impact on eating quality. Eating quality of meat possess characteristics like taste, body, texture, color and appearance, juiciness and odor (Akhtar et al., 2013). The cooking methods should be selected such that it should produce high quality (nutritional composition should be maintained) meat products, appropriate texture and taste. However, while preparing the meat and meat products, several kinds of losses occur, such as drip loss, evaporation loss, cooking loss and thawing loss. Therefore, in order to obtain a high quality product these losses should be minimized. The paper focuses on the types of losses that occur, during processing of the meat, factors affecting the losses and way to reduce the losses.

Table 2 Nutritional composition of red and white meat (various varieties)

Nutrients	Red meat (100g)		White meat (100g)		
Fats(g)	Beef	Lamb	Pork	Chicken	Turkey
	3.5-9.3%	7.5-13.3%	3.7-10.1%	1.1-9.7%	2.0-6.6%
Protein (g)	30.40	27.50	24	24.68	29.9
Energy(kJ)	757.00	855.00		916	921
Thiamin (mg)	0.50	0.17			0.1
Riboflavin (mg)	0.21	0.39			0.2
Vitamin B6 (mg)	0.34	0.32			0.8
Vitamin B12(µg)	2.60	2.40	-		0.5
Zinc (mg)	6.30	4.70	2		2.9
Iron (mg)	3.80	2.50	8	1.16	1.9
Potassium(mg)	400.00	281.00	2		427
Sodium (mg)	55.00	78.00	55	67	89.6
Calcium (mg)	5.00	19.00	0		21.4
Selenium (µg)	8.70	6.00	-		44.9

(Williams, 2007; Cosgrove et al., 2007)

Types of losses

On the basis of the factors that affects the quality of meat and meat products, the losses are of various types such as evaporation, thawing, cooking and drip loss.

Drip loss

Drip loss is defined as the red rosy colored liquid which radiates from every single cut surface of meat that has been frozen and defrosted. It occurs at the time of meat amid the freezing and thawing (Emphy, 1933). It is also known as syneresis (Oliveria et al., 2015). Up till now, there is no any authenticated information available for drip loss, and therefore, the measurement procedure has to be effectively standardized. Drip loss relies on the shortening of sarcomeres. This shortening of the sarcomeres is controlled by the interaction of the muscle temperature, rigor development, and chilling condition. There are several external and internal factors affecting the rate of drip loss such as factors like pale, soft and exudative

(PSE), acid meat, dark firm and dry (DFD), radish-pink firm and nanoexudative (RFN)and pale, firm and nonexudative (PFN) (Fischer, 2007). Moreover, the duration of freezing and thawing, age of the animal, length of the period between slaughtering and freezing, period in solidifying state, sex of animal and breed, components of muscle with pH has an impact on rate of drip loss. Other factors such as mechanical and gravitational forces also plays a vital role in drip loss as higher the forces applied, more is the water and protein loss.

There are some factors that affect the acceptability of meat and meat products such as at the time of defrosting, the freezing rate and ice crystal formation in freezing plays significant role in minimizing the drip loss. The smaller the ice crystals, the lesser will be the drip loss. There are various thawing techniques; high pressure thawing is one of those techniques which reduce the level of drip loss particularly in beef (Zhao et al., 1998). Drip loss content is higher during the high temperature (Fischer, 2007). Thus, to increase the acceptability among the consumers, these factors should be minimized.

Prevalent highlights of drip loss:

Poor water holding limit is undesirable for several reasons. The most imperative one is the weight caused by the drip during the storage and retailing. Drip loss is bound to a time frame. Be that as it may, there is no for the most part legitimate definition, as the drip loss of portion of meat with given quality depend on the condition under which it is resolved, such as:

(i) Time of postmortem (after the slaughtering) and the duration of measurement of the water released is the basic characteristic of the particular loss and the potential of muscle to maintain that moisture. The percentage of drip loss is measured mostly by common bag method (Honikel, 1987) and filter paper wetness method (Kauffiman et al., 1986). As the measuring time increases, there is an increase in the drip loss, but this does not happen uniformly as it depends on the environmental conditions.

(ii) Size of meat- ultra thinner the slice of meat, higher will be the amount of the discharged fluid as the fluid need lesser time to leach out.

(iii) Measurement temperature- with the increase in temperature; the drip loss increases.

(iv) Microclimatic factors during packaging- package are closed or not. The packaging should be active, aseptic and proper.

(v) Position of the sample in the package- it should be in centre to avoid leakage, hanging of sample can also lead to drip loss. (Fischer, 2007).

Following are the some widespread causes of drip loss:

Generally Lean crisp meat has a watery substance (leached moisture) of around 70%. To maintain this moisture in meat, proper method of preparation of meat should be considered. When meat is cut, rosy red fluid solution of protein (drip) is discharged from the cut surfaces. During deboning, the volume of drip loss in the first 48 hours is usually 0.1 to 1% per kg of meat, while for slashes or steaks, the loss can further increase up to 10 times. In addition, if the meat is packed in small packages, then the drip loss would be more as the surface zone is proportionately more prominent per unit weight.

Cooking loss

Meat is an important source of high quality protein, fat, B complex vitamins, zinc, selenium, potassium, vitamin B12 and phosphorus. Before consumption of meat and meat products, cooking is the first and essential step. Cooking is the procedure done to eliminate food borne pathogens, microbial load and to give desirable texture to the food. The cooking temperature and time influences the physical properties and eating characteristics of meat. At the time cooking, there are some meat proteins that are denatured. This denaturation of protein results in eradication of cell films, shrinkage of meat strands, the total and gel arrangement of myofibrillar also, sarcoplasmic proteins, and shrinkage and solubilization of the connective tissue (Tornberg, 2005).

According to the consumer acceptance, the eating quality (nutritional quality) of meat plays a significant role. The quality and energy consumption of meat varies with cooking methods. There are various cooking methods viz. Conventional methods (roasting, baking, barbecue, broil, grilling, griddling, pan broiling, dry heat methods, moist heat methods, pan fry, simmer, poach deep frying, steam, braise, slewing, blanching), convection methods (ohmic cooking, oven cooking, sous vide, stewing method and many more are used in the preparation of the meat. With every cooking method, the tenderness, color, juiciness, shrinkage, cooking loss and other quality parameter (nutritional composition, taste and mouthfeel) of meat changes. Cooking method has great impact on eating quality of meat, and energy consumption is an important parameter to consider while selecting the cooking method. The energy requirement for well-cooked meat varies with cooking method and appliances. Energy consumption reduced during meat cooking may have the influence on global energy requirement. This article critically reviewed the effects on quality characteristics of meat and meat products by different cooking methods. .Factors affecting cooking loss (%) in different types of meat are given in Table 3.

Table 3 Factor affecting the cooking loss (%) in different type of meat

Type of meat	Cooking method	Cooking temperature	Cooking loss	References
Turkey meat	Forced convection (dry air, RH-8%) Low steam to high steam (RH-35% to RH-88%)	Oven cooking 100 ºC	15.9 - 32.2 %	Mora et al., 2011
Whole turkey meat	Ohmic treatment	100 ºC	25.2 - 31.3 %	Zell et al., 2010
Beef	Oven cooking	100 ºC	17 – 31 %	James and Yang, 2012
Pork	Ohmic treatment Water bath	100 ºC	9 – 38 %	Dai et al., 2014
Goat meat	Vacuum packed plastic bag retorted to the following internal temperature	50ºC	5 – 42 %	Liu et al., 2013
Mutton chops	Grilling (internal temperature)	100 ºC	5 – 32 %	Sen et al., 2014

Thawing loss

Since years, freezing plays a vital role in extending the shelf life of the meat and its products. However, in the past centuries only, a lot of modifications done in freezing technologies (Leygonie et al., 2012; Persson and Londahl, 1993). Although for the consumption of meat and meat products, thawing is important after freezing. Both, freezing and thawing processes mainly involves the water fraction of substance. Majorly, inter-muscular and intramuscular fibers of the meat constitute water. This water forms compartments in a tissue which complicates the process. When process of freezing starts, the concentration of the solutes (proteins, carbohydrates, lipids, vitamins and minerals) resulting in increases in the disturbance of the homeostasis of the complex meat system (Lawrie, 1998). In addition, the nutritional constituents such as heme iron and heme pigment are preserved by these processes as these pigments are mostly found in beef (Akhtar et al., 2013).

Thawing time should be minimized to reduce microbial growth, chemical deterioration and excessive loss of water caused by dripping or dehydration (Taher and Farid, 2001). Thawing is done to retain the quality attributes of the fresh and unfrozen meat. The process of the thawing plays vital role in maintaining the product quality (Ambrosiadis et al., 1994; Ngapo et al., 1999). Thus, several precautions such as reduction in thawing time and use of temperature below danger zone should be taken to reduce the microbial load. However, the use of improper thawing technique can lead to activation and multiplication of the existing microbes on the surface of the meat. Like in drip loss, freezing rate and ice crystal formation also plays major role in thawing loss (Fennema et al., 1973; Kalichevsky et al., 1995).

There are several methods of thawing of meat viz. slow thawing, ambient temperature thawing, water immersion thawing, and microwave thawing (Xia et al., 2009). The nutritional quality reduction due to leaching of soluble proteins, high energy consumption and large quantities of loaded waste-water are some disadvantages of conventional thawing (Roberts et al., 1998). Despite the fact that the countertop 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. To maintain the food quality, quick thawing at low temperature, avoiding a quick rise in temperature and increased dehydration of food is preferable.

Effects of freezing and thawing on the quality of the meat by various attributes

Moisture content

Moisture content is greatly affected by both freezing and thawing process. Moisture in meat can be assessed by taking various measurements such as drip loss, thaw loss, cooking loss, water binding capacity and aggregate moisture content.

Moisture content is considered to be the most important factor during post mortem as reduction in pH (closer to the isoelectric pH of proteins), the loss of adenosine triphosphate (ATP), and the steric impacts due to the shrinkage of the myofibrils as a result of rigor mortis and conditioning (Huff and Lonergan, 2005). These factors act either individually or in combination to discharge water that was previously bound to proteins.

The discharged water is now again realigned to the extracellular and sarcoplasmic spaces. The thaw loss as well as drip loss is affected by both freezing and thawing to an extent. In the process of thawing, if the rate of thawing increases, the thaw loss decreases (Haugland, 2002). Gonzalez et al. (1985) inferred that a reduction in thawing time (time ran from −5 to −1 °C) to beneath 50 min resulted in a decrease in exudate (drip loss/ thaw loss) and this was credited to the softening of ice in the extracellular spaces, causing an expansion in water movement, bringing about the net stream of water into the intracellular spaces and resulting in the re-retention by the dehydrated fibres. It is also reported in the study that fast thawing (defrosting) of meat by submerging in water decreases the thaw as well as the drip loss (Ambrosiadis et al., 1994). Contradictory, it is reported that thawing increases the drip loss. The study also shows that the maximum drip loss was found in refrigerated thawing (28 h). Then, in the ambient air thawing (5–7 h) and microwave thawing (35 min to reach 0 °C) (Ambrosiadis et al., 1994).

Protein Denaturation

Traditionally, it is believed that freezing results in the protein denaturation due to an increased intracellular ionic strength following the migration of water to the extracellular spaces. However, this process is opposed by numerous authors. Various studies recommended that there is no role of protein denaturation in the quality loss after freezing and thawing because no significant difference was found in the protein composition in the drip losses of the fresh and immediately thawed samples. The quality of the frozen meat might be affected by the time and temperature at which the sample is stored, however, no such valid explanation for the same is mentioned in studies (Anon and Cavelo, 1980; Mietsch et al., 1994; Ngapo et al.,1999). It would be very beneficial to evaluate the drip composition of such samples using more modern techniques, such as proteomics.

Oxidation of lipids and total protein

The final temperature at which meat is frozen and stored signifies the quantity of available water required to carry out the chemical reaction. It is observed that there are still reactions taking place when meat is frozen and stored at temperatures below than -20 ºC as due to free water availability in the meat (Petrovic, 1982). From the literature, it has been reported that the optimum temperature for freezing and storing the meat is -40ºC, as there is only negligible amount of free water present at this temperature (Estevez, 2011). This available free water bounds with other food constituents thus making it unavailable for the chemical reactions (Nesvadba, 2008; Singh and Heldman, 2001). The frozen water also increases the solute concentration at both intracellular and extracellular level resulting in the increased chemical reaction in frozen food (Leygonie et al., 2012). The formation of the ice crystals in the food lead to the disruption of the muscle cells which is responsible to the release of mitochondrial and lysosomes enzymes into the sarcoplasm (Hamm, 1979). This increases 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 (55–65% of total muscle protein) and are responsible for the majority of the physicochemical properties of muscle foods (Xia et al., 2009). In meat, the amount of available free water at time of freezing results in initiating the primary lipid oxidation (oxidation). However, when the frozen meat undergoes thawing, this peroxidation leads to radical secondary lipid oxidation upon thawing (Owen and Lawrie, 1975). The oxidation in meat upon freezing and thawing causes adverse changes in quality attributes of the meat such as odor, color, flavor, and many more (Akamittath et al., 1990; Hansen et al., 2004). The quality of the secondary products of lipid oxidation is generally measured using the thiobarbituric acid reactive substances (TBARS) method. Various adverse changes such as rancidity, fatty, pungent and other off-flavors were noted in the case of secondary products (meat stored for 90 days at −20 °C) as compared to the fresh meat (Vieira et al., 2009). Such results concluded that frozen storage is not enough to prevent it from oxidation from occurring. In a study, it is also inferred that there is more TBARS accumulation in case of frozen and thawed muscle tissue than that of fresh muscle tissue. This increase in the TBARS accumulation was due to the damage of the cell membrane by ice crystals and the subsequent release of pro-oxidants, especially the haem iron (Benjakul and Bauer, 2001). It was also observed that lipid oxidation primarily takes place at the cellular level instead of the triglyceride fraction. It is therefore, concluded that the lipid oxidation take place in both lean and fatty meats (Thanonkaew et al., 2006). Protein oxidation is found to be connected by several proxidative factor such as oxidized lipids, free radicals, haem pigments and oxidative enzymes. Carbonyls (aldehydes and ketones) are formed by the reaction of malonaldehyde and protein derivatives (Xiong, 2000) with stated that protein and lipid oxidation are interlinked. Protein and lipid oxidation are, therefore, undoubtedly interlinked. Protein oxidation in meat may lead to decreased eating quality due to reduced tenderness, juiciness, flavor deterioration and discoloration (Rowe et al., 2004). Covalent and non-covalent intermolecular bonds are the Reactive Oxygen Species (ROS) which attacks the protein and lead to the above mentioned changes in meat. Other common changes in oxidized 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). Oxidation in protein increase, the rate of toughness, loss of water binding capacity and loss in protein solubility. Freezing and thawing also affect the color (Myoglobin Proteins) stability of meat as myoglobin protein is found in drip loss (Anon and Cavelo, 1980). It is also reported that during freezing, storage and thawing, denaturation of the globin moiety of the myoglobin molecule takes place (Calvelo, 1981).This denaturation increases the susceptibility of myoglobin to autoxidation and consequent loss of optimum color. These changes were measured by comparing the degree of bloom and the ability of the meat to resist oxidation to metmyoglobin during refrigerated storage post freeze/thaw (Abdallah et al., 1999; Leygonie et al., 2011). Livingston and Brown (1981) Introduced an enzyme system that has ability of reducing metmyoglobin back to myoglobin and termed this system as the metmyoglobin reducing activity (MRA). In fresh muscles, the enzyme are active in nature and there is rapid reduction of metmyoglobin to the deoxymyoglobin which is again oxygenated back to oxymyoglobin resulting in the retention of the bloomed color. However, with the increase in the time of meat storage, MRA activity starts reducing. This reduction in MRA activity results in the rapid deposition of the substance on the surface of the meat (Abdallah et al., 1999). Moreover, MRA and/or co-factors, such as NADH are also lost in the exudate or thaw loss due to oxidation. These leaching out of compounds are further used by the other reactions unrelated to MRA that contributes in accelerating the oxidation and color loss (Abdallah et al., 1999).

pH

The pH of frozen and thawed meat is less as compared to that of fresh meat (Leygonie et al., 2011). During freezing, subsequent productions of exudate denatures the buffer protein leading to the release of hydrogen ions and gradually decreases the pH. On the other hand, loss of exudate from the meat tissue results in the increased amount of solute in it which is responsible for the reduction of pH in meat (Leygonie et al., 2011).

Tenderness (shear force)

During freezing and thawing, there is an increase in tenderness of the meat. The tenderness is usually measured by peak force (Farouke et al., 2003; Lagerstedt et al., 2008; Shanks et al., 2002; Wheeler et al., 1990). It also depends on the time of frozen storage and the degree at which meat was aged before freezing (Vieira et al., 2009). When combination of muscle fibres is degraded by the action of enzymes during proteolysis and aging, it results in the tenderization of the meat. In addition, tenderization of meat is also affected by the loss of structural integrity caused by ice crystal formation. If the sizes of the ice crystals are large, it leads to the disruption of myofibrils and subsequently, tenderizes meat. However, if the size of ice crystals is smaller, it increases the rate of aging by releasing the protease enzymes (Vieira et al., 2009). On the other hand, when sensory evaluation is done, contrary results are found viz. lower peak forces were reported in frozen/thawed samples as compared to chilled meat (Lagersted et al., 2008). This sensory result signified 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 is required to increase the toughness as suggested by the sensory panel. The decrease in the shear force leads to the loss in membrane strength due to the ice crystal formation, hence, reducing the force needed to shear the meat (Lui et al., 2010).

Microbial count

Both freezing and thawing processes does not affect the number of viable microbes in meat. During freezing, the viable microbes move to the dormant stage. However, a microbe again gets active upon thawing (Londahl and Nilaaon, 1993). Since thawing is far more slower process than freezing and also is also less uniform, certain portion of meat are more susceptible to the microbial growth due to the favorable temperature conditions. In addition, when meat is thawed, the formation exudate takes place that results in the increased availability of moisture and nutrients to the microbes. Hence during freezing and thawing, more care should be taken while handling the meat as compared to fresh meat (Pham, 2004). In a study it was found that frozen beef stored for 90 days did not get spoiled, but there was an increase growth of psychotropic bacteria. These bacteria favored the growth of other bacteria which spoil the beef upon thawing (48h at 4 °C in a cooler) (Vieira et al., 2009). It was also observed that lag phase of bacteria in frozen and thawed pork is shorter than the fresh meat however, the time needed to develop spoilage odours was not affected (Adhikari, 2014).

Meat Structure

Usually, severe deterioration of fiber takes place during freezing and thawing only due to the formation of inter and intracellular ice crystals. The formed ice crystals generate pressure in the opposite direction within the fibres which resulted in the separation of these fibres. However, slightly less deterioration is observed when intracellular ice crystals are formed as there ice crystals exerted force only in one direction. In addition, the structure of the meat is also determined by the size of the cavities which can be seen through microscopy. In the frozen meat, the cavities present within it depicts the size of ice crystals formed during freezing whereas, in the fresh meat, these empty spaces are filled with the extra-cellular fluid (Hansen et al., 2003). The studies showed that freezing meat at different rates resulted in different sized cavities and larger the size of cavity, more severe will be the deterioration of the muscle cell structure. Although, after thawing, the ultrastructure of meat completely recovers itself by the damage that was done during freezing (Ngapo et al., 1999). Mortensen et al. (2006) combined the microscopy with NMR studies with an objective to study the effect of freezing temperature and freezing rate on the ultra-structure of the thawed meat and thawing loss. The samples of meat were placed in freezing conditions at two different temperatures viz. -80°C (fast freezing) and -20°C (slow freezing) and stored at - 20°C for 30 months. When the samples were thawed after storing, then it was observed that the samples that were kept at fast freezing were more severely damaged than the samples that were kept at slow freezing. Similarly, thawing loss was found to be more in the case of fast freezing then that of slow freezing. This was due to the formation of large size ice crystals from the small size crystals and also because of recrystallization that happened in storage. It is also suggested that greater loss might be due to the slow thawing process.

Meat Texture

Meat texture is very essential property for determining the quality of meat and its products. There are various factors that contribute to the meat texture after thawing such as freezing process, meat ageing rate before and after freezing. There is notable difference in the shear force between the aged meat chilled, not frozen and frozen meat stored for 2 months. The prior showed a greater shear force than the latter one (Shanks et al., 2002). This lowering of the shear force in frozen and thawed sample was due to the deterioration of the muscular cells by the intracellular ice formed during freezing. Similar results were observed by Lagerstedt et al. (2008). Comparison between the values of the shear force in chilled meat sample and that of frozen sample after ageing was done in the study. Contrary results were found in the values of shear force and sensory evaluation. In the results of sensory evaluation, chilled meat was found to more tender than the thawed meat whereas the values of shear force was observed to be more for chilled meat as compared frozen meat. According to Dransfield,(1994), freezing rate plays an essential role in meat ageing. In addition, it was also concluded that the impact of fast freezing is three times greater than the slow commercial freezing on the rate of aging in chilled beef. It was justified by observing that with increase in the ageing rate, cellular lesions were found to be more prominent (Vieira et al., 2009).

Drip loss

Drip loss after thawing is a very important aspect from the meat industry point of view in term finance. Thus, factors that enhance the rate of drip loss after thawing should be investigated. Numerous studies claims that there is relation between drip loss, freezing rate and aging rate of the frozen meat (Ngapo et al., 1999). It was observed that when pork was fast frozen for 12 to 120 minutes, the amount of drip loss was same for that of refrigerated meat. However, when the pork was slow freeze for 240-900 minutes, the amount of drip loss is more comparatives. It was seen that there was no notable difference in protein concentration of drip of treated (frozen and thawed; frozen, stored and thawed) and that of fresh samples. To study the effect of freezing rate on the drip loss, meat was stored for about 4 weeks. In the period of 4 weeks, it was found that the quantity of drip loss was more in the case of stored samples than that of frozen samples. Thus, it was concluded that there is no influence of the freezing rate before storage on the drip loss (Ngapo et al., 1999). However, no correlation was found between freezing temperature (20 and -80°C) and drip loss (Sakata et al., 1995). Moreover, it is suggested that freezing speed is affective on the drip loss. It was seen that in both the cases (slow freezing and fast freezing) that with increase in the freezing speed, there is an increased effect on the deteriorations of fibres and micro-fibres, reduction of myofibrils proteins solubility, as well as great thawing loss (Petrovic et al., 1993). Use of pressure while freezing also influences the amount of loss. Cryogen-frozen and air frozen pork exhibits more amount of drip loss a compare to the pressure shift frozen sample of pork. This less leaching out of water from pressure shift frozen sample of pork might be due to the assumption that pressure leads to protein denaturation and the subsequent insoluble protein may have stopped the leaching of muscular fluid resulting in less amount of thaw loss (Hansen et al., 2003). Hence the relation between thawing rate, amount exudate and thawing time was established. However, conflicting results were found stating the effect the thawing time on drip loss. Gonzalez-Sanguinetti et al. (1985) concluded that if the thawing time is reduced, then the amount of exudate is more whereas Ngapo et al. (1999) it is observed that with the reduction in the thawing time, drip loss also gets reduced. There is higher drip loss in the case of slow thawing as during slow thawing, the fluid released from the fibre cannot be retain back. Moreover, in the case of slow thawing there is also the possibility of re-crystallising leading to high drip loss out of the fibres (Linares et al., 2005). It is found that postmortem time to freeze meat and drip loss is interrelated with each other. The optimum time for freezing meat is 45 min instead of 24h after slaughtering. This also resulted in the lesser drip loss after thawing (Yu et al., 2009). Hence, it is recommended that the earlier the meat would be frozen after slaughter, the lower drip loss will be there after thawing. It was due to the assumption that in this freezing phase, formation of more extracellular crystal than intercellular ones takes place.

Evaporation loss

Evaporation is one of the major moisture removal method to produce more concentrated liquid. It requires large amount of energy viz. more than 2200 kJ for every kilogram of water evaporated. During the evaporation process, around 5% of solids are removed in the form of impurities. Evaporation loss is directly related to the drip loss (loss of water and fluid). This loss is mainly from the evaporation of water from the muscle protein (actin and myosin). Evaporation loss also referred to as the loss of fluid in the gaseous form the surface of the meat. All the volatile materials are also included in the evaporation loss. Evaporation loss is negatively correlated with the cooking loss (nutrient loss). There are many positive correlations between thawing loss and evaporation loss (Jama et al., 2008). The percentage of weight loss is highly dependent on the size of the products. During the first 4-5 hours of chilling, there is maximum weight loss due to the evaporation from the surface of carcass as compared to the subsequent hour of chilling. Moisture losses by evaporation during freezing of non-packed carcasses amounts to between 0.5 and 1.2% of the total weight (Sun et al., 2010; Adam and Abugroun, 2015).

Evaporation loss = 100-[(weight after cooking) ÷ raw] ×100

Factors affecting evaporation loss:

The amount of water loss due to evaporation depends on numerous factors such as temperature of the carcass, humidity, velocity and temperature of air in the storage room. Usually heating is the main cause for the loss of water from the meat. Most of the evaporation usually take place through the macro and micro pores present on the surface of carcass (Cheng and Sun, 2008). There is constant permeability of meat and is anisotropic (fibres constitute a preferential direction for the moisture transport) in nature. An evaporation loss increases juiciness, and reduces fat content in products. Agents like salt, spices and moisture can be added to enhance the flavored and texture of the meat and also helps in compensating during the evaporation loss. During evaporation loss, time and temperature combination play a vital role, while the evaporation loss can be limited by cooking the meat either in water, steam or vacuum.

Similarities and differences between losses occurs in meat and meat products

The exudates, including thaw loss and/or drip loss, are influenced by freezing methods. A lot of studies have tried to elucidate the impacts of the freezing process on the drip loss; however, the outcomes were not similar. Ngapo et al. (1999) reported that when the freezing rate is increased, there is decrease in the drip loss of frozen meat. On the other hand, no significant effects of freezing rates on drip loss were observed when stored at -35 ±1ºC (rapid freezing) and at -10±1ºC (slow freezing) (Bailey, 1972). They reported that freezing rates along with the storage time affect the drip loss, but, there were no differences in the protein concentration and composition of drip (i.e. total protein concentration) in the pork samples were observed.

Anon and Calvelo, (1980) showed that neither drip loss nor protein concentration were affected in the beef samples that had been frozen at different freezing rates. Similar results were reported by Hong et al. (2013) in the case of bighead carp samples.

Various experiments have been carried out for the effect of thawing conditions on the drip loss of frozen meats. Some authors suggested that fast thawing lead to a lower amount of drip loss. For example, Ngapo et al. (1999) reported that drip loss from frozen pork at thawing time of 12 minutes was significantly lower than that from frozen pork at thawing time of 180 minutes. On contrary, Ambrosiadis et al. (1994) reported that fast thawing caused greater amounts of drip loss.

Conclusion

In this review paper, we have discussed about the different types of losses viz. cooking loss, drip loss, evaporation loss and thawing loss. These losses are correlated with each other as drip loss occurs both at the time of slaughter and at the time of thawing. The evaporation loss is there at the time of thawing and also on the time of cooking. These losses occur usually at the time of storage and cooking of the meat and meat products. There are different factors that increase the rate of losses in meat and meat products such as time and temperature combination used while cooking and freezing, relative humidity, microorganisms, pH and many more. Such losses can be reduced by controlling these factors like cutting the carcass in relatively thicker pieces than the thin pieces and taking care of appropriate temperature at which the meat and meat products is stored. Moreover, from the consumer point of view, these losses should be minimized in order to maintain the quality of the meat products. However, there is a need of detailed study that how much nutrients and what kind of nutrients are lost during these losses.

References

Abdallah, M. B., Marchello, J. A., and Ahmad, H. A. (1999). Effect of freezing and microbial growth on myoglobin derivatives of beef. Journal of Agricultural and Food Chemistry, 47, 4093-4099.

Adam, Y.S.I. and Abugroun, H.A. (2015). Evaluation of Traditional Cooking Methods on Eating Meat Characteristics and Chemical composition. Journal of Agriculture and Veterinary Sciences, 8, 12-17.

Adhikari, R.B. (2014). Isolation, identification and application of antimicrobial interventions against gas-producing spoilage organisms associated with raw beef products (Doctoral dissertation, Oklahoma State University).

Akamittath, J. G., Brekke, C. J., and Schanus, E. G. (1990). Lipid oxidation and colour stability in restructured meat systems during frozen storage. Journal of Food Science, 55, 1513-1517.

Akhtar, S., Khan, M.I. and Faiz, F. (2013). Effect of thawing on frozen meat quality: A comprehensive review. Pakistan Journal of Food Science, 23(23), 198-211.

Ambrosiadis, I., Theodorakakos, N., Georgakis, S., and Lekas, S. (1994). Influence of thawing methods on the quality of frozen meat and drip loss. Fleischwirtschaft, 74, 284-286.

Anon, M. C., and Cavelo, A. (1980). Freezing rate effects on the drip loss of frozen beef. Meat Science, 4, 1-14.

Bailey C. (1972). A preliminary experiment on the effect of freezing rate on drip and quality of small cuts of meat. Meat Research Institute Memorandum.19, 8.

Benjakul, S., and Bauer, F. (2001). Biochemical and physicochemical changes in catfish (Silurus glanis Linne) muscle as influenced by different freeze/thaw cycles. Food Chemistry, 72, 207-217.

Benjakul, S., Visessanguan, W., Thongkaew, C., and Tanaka, M. (2003). Comparative study on physicochemical changes of muscle proteins from some tropical fish during frozen storage. Food Research International, 36, 787-795.

Calvelo, R. J. (1981). Recent studies on meat freezing. In R. Lawrie (Ed.), Developments in meat science. London: Elsevier Applied Science Publishers, 2, 125-158.

Cheng, Q. and Sun, D.W. (2008). Factors affecting the water holding capacity of red meat products: a review of recent research advances. 48(2), 137-159.

Dai, Y., Lu, Y., Wu, W., Lu, X.M., Han, Z.P., Liu, Y., Li, X.M. and Dai, R.T. (2014). Changes in oxidation, color and texture deteriorations during refrigerated storage of ohmically and water bath-cooked pork meat. Innovative Food Science & Emerging Technologies, 26,341-346.

Emphy, W. A. (1933). Studies on the refrigeration of meat. Conditions determining the amount of “drip” from frozen and thawed muscle.Journal of the Society of Chemical Industry, 52,230T-236T.

Estevez, M. (2011). Protein carbonyls in meat systems: A review. Meat Science, 89, 259–279

Farouke, M. M., Wieliczko, K. J., and Merts, I. (2003). Ultra-fast freezing and low storage temperatures are not necessary to maintain the functional properties of manufacturing beef. Meat Science, 66, 171-179.

Fennema, R. O., Powrie, D.W., and Marth, E. H. (1973). Low-Temperature Preservation of Food and Living Matter, 109–368.New York, USA: Marcel Dekker Inc.

Fischer, K. (2007). Drip loss in pork: influencing factors and relation to further meat quality traits. Journal of Animal Breeding and Genetics, 124(s1), 12-18.

Gonzalez-Sanguinetti, S., Anon, M. C., & Cavelo, A. (1985). Effect of thawing rate on the exudate production of frozen beef. Journal of Food Science, 50, 697-700.

Greer, G. G., and Murray, A. C. (1991). Freezing effects on quality, bacteriology and retailcase life of pork. Journal of Food Science, 56, 891-894.

Hamm, R. (1979). Delocalization of mitochondrial enzymes during freezing and thawing of skeletal muscle. In O. R. Fennema (Ed.), Proteins at low temperatures. Advances in chemistry series. Washington, DC: American Chemical Society.

Manishaben Jaiswal “Big Data concept and imposts in business” International Journal of Advanced and Innovative Research (IJAIR) ISSN: 2278-7844, volume-7, Issue- 4, April 2018 available at: http://ijairjournal.in/Ijair_T18.pdf

Manishaben Jaiswal “ SOFTWARE QUALITY TESTING “ International Journal of Informative & Futuristic Research (IJIFR) , ISSN: 2347-1697 , Volume 6, issue -2 , pp. 114-119 ,October-2018 Available at: http://ijifr.com/pdfsave/23-12-2019214IJIFR-V6-E2-23%20%20OCTOBER%202018%20a2%20files%20mergeda.pdf

Hansen, E., Juncher, D., Henckel, P., Karlsson, A., Bertelsen, G., and Skibsted, L. H. (2004). Oxidative stability of chilled pork chops following long term frozen storage. Meat Science, 68, 479-484.

Hansen, E., Trinderup, R.A., Hviid, M., Darré, M. and Skibsted, L.H. (2003). 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. European Food Research and Technology, 218(1), 2-6.

Haugland, A. (2002). Industrial thawing of fish- To improve quality, yield and capacity. PhD in Engineering Thesis, Norwegian University of Science and Technology, Norway.

Honikel, K.O. (1987). How to measure the water-holding capacity of meat? Recommendation of standardized methods. In Evaluation and control of meat quality in pigs, 29-142. Springer, Dordrecht.

Huff-Lonergan, E. and Lonergan, S.M. (2005). Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Science, 71(1), 194-204.

Jama, N., Muchenje, V., Chimonyo, M., Strydom, P.E., Dzama, K. and Raats, J.G. (2008). Cooking loss components of beef from Nguni, Bonsmara and Angus steers. African Journal of Agricultural Research, 3(6), 416-420.

James, B.J. and Yang, S.W. (2012). Effect of cooking method on the toughness of bovine m. semitendinosus. International Journal of Food Engineering, 8(2).

Jiménez-Colmenero, F., Carballo, J. and Cofrades, S. (2001). Healthier meat and meat products: their role as functional foods. Meat Science, 59(1), 5-13.

Kalichevsky, M.T., Knorr, D. and Lillford, P.J. (1995). Potential food applications of high-pressure effects on ice-water transitions. Trends in Food Science & Technology, 6(8), 253-259.

Kauffman, R.G., Eikelenboom, G., Van der Wal, P.G., Engel, B. and Zaar, M. (1986). A comparison of methods to estimate water-holding capacity in post-rigor porcine muscle. Meat Science, 18(4), 307-322.

Lagerstedt, Å., Enfält, L., Johansson, L. and Lundström, K. (2008). Effect of freezing on sensory quality, shear force and water loss in beef M. longissimus dorsi. Meat Science, 80(2),457-461.

Lawrie, R.A. (1998). The eating quality of meat. Meat Science, 5, 184-223.

Leygonie, C., Britz, T. J., and Hoffman, L. C. (2011). Oxidative stability of previously frozen ostrich M. iliofibularis packaged under different modified atmospheric conditions. International Journal of Food Science and Technology, 46, 1171–1178.

Leygonie, C., Britz, T.J. and Hoffman, L.C. (2012). Impact of freezing and thawing on the quality of meat. Meat Science, 91(2), 93-98.

Linares, C.P., Saavedra, F.F., Serrano, A.B., Paz, L.E.S. and Sosa, A.R.T. (2005). Effects of freezing temperature and defrosting. Method on pork quality characteristics. Journal of Anffimal and Veterinary Advances, 4(12),976-979.

Liu, F., Meng, L., Gao, X., Li, X., Luo, H. and Dai, R. (2013). Effect of end point temperature on cooking losses, shear force, color, protein solubility and microstructure of goat meat. Journal of Food Processing and Preservation, 37(3), 275-283.

Liu, G., Xiong, Y. L., and Butterfield, D. A. (2000). Chemical, physical, and gel-forming properties of oxidized myofibrils and whey- and soy-protein isolates. Journal of Food Science, 65, 811–818.

Livingston, D. J., and Brown, W. D. (1981). The chemistry of myoglobin and its reactions. Food Technology, 35, 238–252.

Löndahl, G., and Nilaaon, T. (1993). Storage of frozen foods. In B. Caballero (Ed.), Encyclopaedia of food science and nutrition, 2732–2735, (2.). Oxford: Academic Press.

Lui, Z., Xiong, Y., and Chen, J. (2010). Protein oxidation enhances hydration but suppresses water-holding capacity in Porcine Longissimus muscle. Journal of Agricultural and Food Chemistry, 58, 10697–10704.

Mietsch, F., Halász, A., and Farkas, J. (1994). Untersuchung über Änderungen von Fleischproteinen während der gefrierlagung (Study of changes in meat protein during frozen storage). Die Nahrung, 38, 47–52.

Mora, B., Curti, E., Vittadini, E. and Barbanti, D. (2011). Effect of different air/steam convection cooking methods on turkey breast meat: Physical characterization, water status and sensory properties. Meat Science, 88(3), 489-497.

Mortensen, M., Andersen, H.J., Engelsen, S.B., and Bertram, H.C. (2006) Effect of freezing temperature, thawing and cooking rate on water distribution in two pork qualities, Meat Science, 72 , 34-42.

Nesvadba, P. (2008). Thermal properties and ice crystal development in frozen foods. In J. A. Evans (Ed.), Frozen Food Science and Technology, 1-25.

Ngapo, T.M., Babare, I.H., Reynolds, J., and Mawson, R.F. (1999). Freezing and thawing rate effects on drip loss from samples of pork. Meat Science 53(3): 149-158.doi:10.1016/S0309-1740(99)00050-9.

Ngapo, T.M., Babare, I.H., Reynolds, J., and Mawson, R.F. (1999). A preliminary investigation of the effects of frozen storage on samples pork, Meat Science, 53, 169-177.

Oliveira, M.R., Gubert, G., Roman, S.S., Kempka, A.P. and Prestes, R.C. (2015). Meat quality of chicken breast subjected to different thawing methods. Revista Brasileira de Ciência Avícola, 17(2),165-171.

Owen, J. E., and Lawrie, R. A. (1975). The effect of an artificially induced high pH (hydrogen-ion concentration) on the susceptibility of minced porcine muscle to undergo oxidative rancidity under frozen storage. Journal of Food Technology, 10, 169–180.

Persson, P.O. and Londahl, G., (1993). Freezing technology. Frozen Food Technology, 20-58.

Petrović, L. (1982). Investigation of effects of different freezing procedures on myofi- brillar proteins in beef M. longissimus dorsi. Doctoral dissertation, Faculty of Technology, University Novi Sad, Yugoslavia.

Petrović, L., Grujić, R. and Petrović, M., 1993. Definition of the optimal freezing rate—2. Investigation of the physico-chemical properties of beef M. longissimus dorsi frozen at different freezing rates. Meat Science, 33(3), 319-331.

Pham, Q. T. (2004). Thawing. In Jensen (Ed.), Encyclopaedia of meat science, vol. 3, 1150-1156. Oxford: Elsevier Academic Press.

Roberts, J.S., Balaban, M.O., Zimmerman, R., and Luzuriaga, D., (1998). Design and testing of prototype ohmic thawing unit. Computers and Electronics in Agriculture 19,211-222.

Rowe, L. J., Maddock, K. R., O'Lonergan, S. M., and Huff-Lonergan, E. (2004). Influence of early post mortem protein oxidation on beef quality. Journal of Animal Science, 82, 785–793.

Sakata, R., Oshida, T., Morita, H. and Nagata, Y. (1995). Physicochemical and processing quality of porcine M. longissimus dorsi frozen at different temperatures. Meat Science 39, 277–284.

Sen, A.R., Naveena, B.M., Muthukumar, M. and Vaithiyanathan, S. (2014). Colour, myoglobin denaturation and storage stability of raw and cooked mutton chops at different end point cooking temperature. Journal of Food Science and Technology, 51(5), 970-975.

Shanks, B. C., Wulf, D. M., and Maddock, R. J. (2002). 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, 80, 2122-2125.

Singh, R. P., and Heldman, D. R. (2001). Food freezing. Introduction to food engineering (pp. 410-444). (3). London: Academic Press.

Sun, T.R., Cang, L., Wang, Q.Y., Zhou, D.M., Cheng, J.M. and Xu, H. (2010). Roles of abiotic losses, microbes, plant roots, and root exudates on phytoremediation of PAHs in a barren soil. Journal of Hazardous Materials, 176(1-3), 919-925.

Taher, B.J. and Farid, M.M. (2001). Cyclic microwave thawing of frozen meat: experimental and theoretical investigation. Chemical Engineering and Processing: Process Intensification, 40(4), 379-389.

Thanonkaew, A., Benjakul, S., Visessanguan, W., and Decker, E. A. (2006). The effect of metal ions on lipid oxidation, colour and physicochemical properties of cuttlefish (Sepia pharaonis) subjected to multiple freeze–thaw cycles. Food Chemistry, 95, 591-599.

Tornberg, E. (2005). Effects of heat on meat proteins–Implications on structure and quality of meat products. Meat Science, 70(3), 493-508.

Vieira, C., M. Y., Diaz, B., Martínez and GarciaCachan, M.D. (2009). 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 83, 398–404

Wheeler, T.L., Miller, R.K., Savell, J.W. and Cross, H.R. (1990). Palatability of chilled and frozen beef steaks. Journal of Food Science, 55(2), 301-304.

Xia, X., Kong, B., Liu, J., Diao, X. and Liu, Q. (2012). Influence of different thawing methods on physicochemical changes and protein oxidation of porcine longissimus muscle. LWT-Food Science and Technology, 46(1), 280-286.

Xia, X., Kong, B., Liu, Q., and Liu, J. (2009). Physiochemical changes and protein oxidation in porcine longissimus dorsi as influenced by different freeze/thaw cycles. Meat Science, 83, 239-245.

Xiong, Y. L. (2000). Protein oxidation and implications for muscle food quality. In: Antioxidants in muscle foods (edited by E. Decker & C. Faustman), 3-23, Chichester: John Wiley & Sons.

Yu, X.L., Li, X.B., Xu, X.L., Zhou, G.H. and Boles, J.A. (2009). Definition of the optimum freezing time postmortem for manufacturing pork meat. Journal of Muscle Foods, 20(2),186-200.

Zell, M., Lyng, J.G., Cronin, D.A. and Morgan, D.J. (2010). Ohmic cooking of whole turkey meat–Effect of rapid ohmic heating on selected product parameters. Food Chemistry, 120(3), 724-729.

Zhao, Y., Flores, R.A. and Olson, D.G. (1998). High hydrostatic pressure effects on rapid thawing of frozen beef. Journal of Food Science, 63(2), 272-275.

Hong, H., Luo, Y., Zhou, Z., Bao, Y., Lu, H., and Shen, H. (2013). Effects of different freezing treatments on the biogenic amine and quality changes of bighead carp (Aristichthys nobilis) heads during ice storage. Food Chemistry, 138(2-3), 1476-1482.

Dransfield, E. (1994) .Optimization of tenderization, ageing and tenderness, Meat Science, 36: 105–121 16.

IFPRI, (1999). Livestock to 2020. The next food revolution. Food,Agriculture, and the Environment Discussion Paper, vol. 28.International Food Policy Research Institute (IFPRI), Washing-ton, DC.

Williams, P., 2007. Nutritional composition of red meat. Nutrition & Dietetics, 64(s4).

Cosgrove, M., Flynn, A. and Kiely, M., 2005. Consumption of red meat, white meat and processed meat in Irish adults in relation to dietary quality. British Journal of Nutrition, 93(6), 933-942.