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MINISTRY OF AGRICULTURE

Food and Agriculture Organization of the United Nations

Ministry of Agriculture

Export Abattoirs Inspection and Certification Directorate

Meat Cold Chain Guidelines for Export Abattoirs

December, 2021
Addis Ababa

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Acronyms

"	Inch
%	Percent
^{o}C	Degree Celsius
^{o}F	Degree Fahrenheit
ATP	Adenosine triphosphate
Cm	Centimeter
cm/h	Centimeter per hour
CO_2	Carbon dioxide
ECTAD	Emergency Centre for Transboundary Animal Diseases
DFD	Dark Firm and Dry
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot and mouth disease
Hrs	Hours
Kg	kilogram
m/sec	Meter per second
pH	Potentiel Hydrogène , Measure of acidity/ base level
PSE	Pale Soft and Oxidative
PVC	Polyvinylchloride
PVDC	Polyvinyliden chloride
RVF	Rift Valley fever
SOPs	Standard Operation Procedures
UV	Ultraviolet

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Acknowledgements

The first edition of this guidelines document, which served as the basis for the current revised version, was developed by Dr. Wondwosen Asfaw and Dr. Nega Tewolde while the current version was reviewed and updated by Dr. Amsalu Demissie. The contribution of Dr. Hassen Chaka (Coordinator, Improving Sanitary Capacity and Facilitating Export of Livestock and Livestock Products from Ethiopia Project of FAO-ECTAD Ethiopia), Dr. Ayalew Shumet (Director, Export Abattoirs Inspection and Certification Directorate, Ministry of Agriculture) and other technical experts of the Ministry of Agriculture for making this document to have its current form by providing insightful comments and suggestions at various stages of the review and revision process is highly appreciated.

Foreword

This technical document entitled “Meat Cold Chain Guidelines for Export Abattoirs” is one of the documents in a series of guidelines and Standard Operating Procedures that were developed from 2008 to 2010 by the Ministry of Agriculture and Rural Development in collaboration with the Ethiopian Sanitary and Phytosanitary and Livestock and Meat Marketing Program.

This Guidelines and Standard Operating Procedures document is at present reviewed and updated by the then Ministry of Agriculture in collaboration with the FAO-ECTAD Ethiopia, Improving Sanitary Capacity and Facilitating Export of Livestock and Livestock Products from Ethiopia Project. The main goal of project is to increase exports of meat and livestock to benefit Ethiopian livestock producers and exporters and to promote national economic development.

This guidelines document is intended to provide guidance for inspectors and export abattoirs operators with broad principles and minimum standards required to preserve the quality and safety of meat and meat products by controlling the temperature in each chain of events starting from slaughter floor to delivery of the product to the export markets. The guidelines highlight the scientific basis for the need of temperature control and hygienic practices in the production, processing, storage and transportation of meat together with outlining specific guidelines to follow in order to attain the desired outcome of supplying safe and quality meat to export markets in a feasible and consistent manner.

At this point, the Export Abattoirs Inspection and Certification Directorate of the Ministry of Agriculture would like to thank the FAO-ECTAD Ethiopia, Improving Sanitary Capacity and Facilitating Export of Livestock and Livestock Products from Ethiopia Project, for providing the necessary technical and financial support required for reviewing, updating and publishing this guideline.

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1. Introduction

Meat is a perishable product with a short shelf life and therefore short selling times. Raw meat and meat products are likely to support the growth of pathogenic microorganisms and/or spoilage bacteria, and should be kept at temperatures that do not result in a risk to health. The cold chain should not be interrupted at all times along the meat distribution chain. Therefore, cold chain management in meat supply is of utmost importance for the maintenance of quality and safety of meat/meat products.

Refrigeration, which includes both chilling and freezing, plays an integral role in the production and storage of meat products and its importance cannot be over-stressed. The primary purpose of refrigeration is to preserve meat products by slowing down the chemical and enzymatic changes which occur in tissues after slaughter, and by slowing down or stopping the multiplication of microorganisms which might give rise to spoilage or food poisoning.

In order to preserve the quality, bloom, and weight of meat, and be able to supply safe and quality meat product for the export markets, it is highly desirable to control the temperature of the meat and the environment in which meat and meat products are handled throughout the production, storage, transport and delivery chains.

2. Objective

The objective of this guideline is to provide a reference guide for export abattoir operators and regulatory inspectors for their efforts in ensuring supply of safe and quality fresh meat and meat products to the export markets through the application of cold chain management practices.

3. Scope

This document covers meat cold chain maintenance activities required in all chain of events performed in export abattoirs starting from the slaughter hall dressing of carcasses to the shipment and delivery of the meat product to the customers abroad. The guideline applies to meat and meat products derived from cattle, sheep, goats and camels.

4. Importance of temperature control for meat products

Bacterial growth and multiplication on meat requires availability of nutrients, water, oxygen (aerobic), carbon dioxide (anaerobic), correct acidity (pH) level and optimum temperature range. When conditions for growth are optimal, bacteria grow and reproduce the fastest.

After slaughter and dressing, the internal temperature of an animal carcass will generally be between 30°C and 39°C. This warm and wet surface provides ideal conditions for growth of food poisoning and meat spoilage organisms.

The time they take to double in numbers is the best indication of the growth capacity of the bacteria under given circumstances. Bacterial cells can double in numbers as quickly as every 30 minutes if conditions are favorable. This is called the generation time. Under unfavorable circumstances such as during cooling, the generation time may be as slow as 24-48 hours; so, bacteria double their numbers very quickly when conditions are such that the generation time is short. Under unfavorable conditions they multiply much more slowly resulting in the extension of the meat shelf life.

Table. 1. How 50 bacteria multiply over 8 hours at different generation times

Length of time in hours	**Generation time**			
	30 min	**1 hour**	**4 hours**	**8 hours**
0 hours	50	50	50	50
2 hours	800	200	-	-
4 hours	12 800	800	100	-
6 hours	204 800	3 200	-	-
8 hours	3 276 800	12 000	200	100

The number of microbes found on the surface of the meat immediately following slaughter will depend on how hygienically the work in the abattoir has been done. Presence of unpleasant odors and sliminess indicates the number of bacteria on the meat surface have reached to the level of 10^7 bacteria/cm^2. Controlling the temperature of carcasses during the slaughter process is a proven method not only to help control microbial growth, but also to assist in creating a quality meat product. The goal in meat production should be to get the carcasses into coolers within 40 to 45 minutes after the end of the slaughter process.

When meat is harvested, it still has ATP or energy stored in the muscles. Enzymes are also still active and these enzymes catalyze the ATP which causes the muscles to contract and relax. This will continue until there is no more energy left on the carcass. Physiologically, the contraction of muscles is caused by calcium while relaxation of muscles is caused by enzyme activity. A decrease in temperature will stop enzyme activity. If a carcass is chilled prior to

the completion of rigor mortis, the muscles may go into a state of contraction called cold shortening and the meat will be tough.

For beef and lamb, this will be avoided by specifying a minimum air temperature of 10°C for the first 10 hours of chilling or by the application of electrical stimulation. A high air velocity during this stage will increase the rate of chilling and reduce the drip loss on cutting. Rapid growth of bacteria occurs between 10 and 50^{o}C. Therefore, meat should not be allowed to remain at this temperature for a long time. As long as meat is stored at or under 10°C bacterial growth will be retarded so that it will not readily cause meat poisoning, though it may well undergo bacterial spoilage. However, storage of meat below -12°C will cease bacterial growth.

Table 2. Days required for spoilage to be apparent on the surface of meat under different storage temperatures.

Storage temperature in degree Celsius (^{o}C)	**Spoilage time from slaughter (days)**
0	20
5	10
10	5
15	4
20	3
25	2 – 3

5. Meat pH

The pH of living skeletal muscle is usually just above 7. It may decrease after slaughter from pH 5.4 to 5.7 in normal meat. If initial glycogen level is limited, the pH stays high and the meat remains Dark Firm and Dry (DFD). If the pH decline is rapid (affecting muscle proteins while still warm) or extensive (giving a low ultimate pH), the meat becomes Pale Soft and Oxidative (PSE). Thus, the pH of meat has a profound effect on color, firmness and water-holding capacity, as well as subtle effects on taste, tenderness and rate of post-mortem conditioning.

Acidification process due to lactic acid formation in muscle tissue limits growth of meat spoilage and food poisoning microbes. It also inactivates (kills) some disease pathogens that restrict export trade including FMD and RVF viruses.

For this reason:

- Meat should be chilled and maturated within 24 hrs. Sample carcasses should be tested for their pH levels in the middle of the Longissimus dorsi muscles in cattle and in the Psoas muscle in sheep and goats to ensure that it remains ≤ 5.8.
- Meat pH should be measured in sampled carcasses at 45 minutes and 24 hours postmortem.
- Veterinary inspectors and export abattoir personnel should be equipped with meat pH meter that should be calibrated daily.

6. Regulatory requirements for chilling, freezing and cold storage rooms

All chilling, freezing and cold storage facilities for meat should comply with the structural requirements contained in the Construction Guidelines for Export Abattoirs. The guidelines to follow include, but not limited to, the following:

- ❖ Refrigeration facilities should be designed and constructed to be capable of reducing all parts of the meat to the required preservation temperature within the required time, and/or; holding and storing the meat constantly at or below that temperature, and to minimize the possibility of contamination.
- ❖ Refrigeration facilities should be designed for the maximum capacity likely to be processed and held on the premises at any one time.
- ❖ The design and construction of refrigeration facilities should ensure that condensation drip on to carcasses or equipment is minimized.
- ❖ Rails and conveyors on which unprotected carcasses and their parts are transported or held should be designed and constructed to preclude contact of conveyed product with walls, floors, ceilings, structures, fittings, equipment and other product.
- ❖ Insulation should be adequate to minimize heat transfer between the chiller or freezer and the cold store
- ❖ Chillers and freezers should be equipped with dial thermometers or continuous thermo-recorders, to give an accurate indication of the air temperature within the room and should operate at all times while refrigeration facilities are in use.
- ❖ Temperature sensor(s) should be positioned so they accurately monitor the temperature within a room using a sufficient number to monitor the temperature range in different parts of the room. If only one temperature sensor is used it should be located in the return air flow to the evaporator unit, as this usually has the highest temperature.

- Rooms used for the storage of chilled meat products shall be capable of maintaining temperature of stored meat products at 0 to 2°C but should not be cold enough to cause the product to become frozen.
- Cold stores should be designed, constructed and operated to ensure that frozen meat is maintained at a core temperature of -12^0C or a room temperature of ($-18\ ^0$C or colder) during storage and loading.
- A refrigerated room used for slow freezing of a carcass or meat shall be operated at temperatures below -18^oC to freeze such carcass or meat within a period not exceeding 48 hours;
- A blast freezer used to freeze a carcass or meat within a period not exceeding 24 hours shall be maintained at a temperature of –30 to -35^oC and the mean air speed over the carcass or meat shall be maintained at a value exceeding 2.5 meters per second (2 to 4 m/s and up to 6 m/s);
- Chiller temperatures should be monitored by calibrated automatic temperature recording equipment. The room temperature should be recorded at intervals of no greater than 1 hour
- Cold store temperatures should be monitored by calibrated automatic temperature recording equipment. The room temperature should be recorded at intervals of no greater than 4 hours.
- Adequate and proper cold air circulation is required for maintaining the desired uniform temperature in all areas of the freezers and refrigerators where meat is stored.
- The rotation of stock throughout the cold chain should be organized according to the first in-first out rule that the first lots to be stored should be the first to be dispatched.

7. Temperature control in meat process rooms

The “meat cold chain” refers to the various stages that a refrigerated product passes through starting from slaughter of animals until it is unloaded from a delivery vehicle from its destination. From the moment an animal is slaughtered, the product starts to deteriorate. The deterioration of a product can be slowed by reducing the temperature at which it produced, stored and transported.

Temperature control of meat and meat products should be done throughout the whole production and supply chain. Process rooms include boning and cutting rooms, packaging and labeling, carcass cooling floors for overnight holding, conditioning and aging rooms and

thawing rooms. Process rooms should be designed and constructed to maintain the atmospheres in accordance with the requirements of the Guideline for Construction of Export abattoirs. The guidelines to follow in the process rooms include, but not limited to, the following:

- Slaughter hall should be fitted with sufficient exhaust fans to avoid hot and humid air in the slaughter area.
- To prevent or even to reduce the deterioration process of meat, particularly microorganism development, chilling has to be carried out quickly (within 40-45 minutes) at the end of the slaughter process.
- The dripping area should be equipped with refrigeration facilities capable of maintaining a temperature of 10^0C. The mean air speed should be above 0.80 to 0.9 m/sec.
- Temperatures of process rooms should be monitored by calibrated automatic temperature recording equipment. The room temperature should be recorded at intervals of no greater than 1 hour.

8. Chilling

Chilling is a fundamental operation in applying cold to meat to reduce its temperature quickly. Chilling is used for short term storage, while freezing is used for the long-term preservation of meat. Chilling is done in a cold chamber with intensive air movement. Rapid cooling of the meat surface not only slows and nearly stops the development of surface micro-organisms but also reduces weight loss and discoloration of the surface. Different systems of chilling are in use but air chilling is the most common.

After slaughter and dressing, the internal temperature of an animal carcass will generally be between 30°C and 39°C. This warm and wet surface provides ideal conditions for growth of food poisoning organisms. Chilling and drying restricts microbiological activity as well as chemical and physical changes that cause deterioration and spoilage of meat. Moreover, chilling reduces the rate of harmful chemical changes such as rancidity of fats and to improve handling qualities. The cold chambers where chilling takes place should have a low air temperature; a high air speed; a high relative humidity and a high refrigerating capacity. In this regard the air temperature should be in the region of 0°C (preferably, from 0 to 2°C), with no decrease below 0°C, which could freeze the meat surface and impair its appearance. Air speed can range from 0.75 to 1.5 m/s in the empty section of the cold chamber and the

relative humidity during the chilling operation should be kept between 90 and 95 percent to prevent excessive weight loss. If the humidity is too high, the carcasses will not dry, and if it is too low excessive dehydration and darkening of the meat will take place.

The ideal chilling room should inhibit the growth of surface bacteria; prepare a firm, dry carcass surface, where the risk of contamination during handling and transport will be much less; and causes a minimum mass loss of carcasses. The speed at which a carcass is chilled depends on certain properties of the carcass such as species, size and fat coverage; and chilling conditions such as the difference in temperature between the product and the air and the rate of movement of the surrounding air past the product. and the thickness of the meat to be chilled.

It is recommended that a period of exposure to moderate cold (10°C) is applied for about 12 hours before lowering the temperature down to chilling levels in order to avoid the risk of cold shortening, which can occur when a carcass is exposed too early to a temperature that is too low. After the period of exposure to moderate cold required avoiding cold shortening, a low temperature (0 to 2°C) is recommended in order to prevent or inhibit the growth of spoilage microorganisms. Depending on the equipment of the slaughterhouse, this low temperature can be achieved in blast chillers or directly in classic cold storage rooms.

8.1 Types of chilling practices

8.1.1 Normal chilling

The meat industry has long been attracted by the concept of accelerating the rate of carcass chilling but this has been inhibited by the risk that a rapid drop in muscle temperature can induce a condition known as cold-shortening which can result in unacceptably tough meat. To overcome this detrimental effect on eating quality, criteria have been established for the combination of post-slaughter time, temperature and pH necessary to avoid cold-shortening.

As a general rule, it has been recommended and widely accepted that the temperature of beef and lamb should not fall below 10^{o}C within 10 hours of slaughter. It has been shown that, if these time/temperature conditions are met, rigor mortis will have advanced sufficiently to avoid toughening of the meat.

8.1.2 Very fast chilling

It has been shown that reducing the core temperature of muscle to 0^{o}C in 5 hours *post mortem* produces tender meat. This unexpected result has been attributed to two mechanisms.

Firstly, the outer surface of the muscle may be frozen and act as a straitjacket to prevent cold shortening. Secondly, the intense cold releases bound calcium so that the tenderizing enzymes are stimulated. The enzymes break up enough protein chains in the meat to overcome the toughening effect of cold shortening.

8.2 Cooling performance standards for chilling

As a general rule, refrigeration of carcasses should begin promptly after the end of carcass dressing and the product should be cooled as quickly as possible. The export abattoir operators should ensure and demonstrate in an ongoing manner that they are achieving compliance with the following cooling performance indicators:

- The cooling of carcasses and products should be continuous, that is, the temperature of the carcass should be continually lowered until it reaches the desired level.
- The cold chambers where meat chilling takes place should have a low air temperature, a high air speed, a high relative humidity and a high refrigerating capacity.
- Air temperature of chillers should be in the region of 0°C (0 to 2°C), with no decrease below 0°C.
- As soon as the dressing operations are completed, carcasses, sides or quarters, should be moved to a room with a temperature of 10^0c (3^0c for offals) and the mean air speed at a level 0.75m/s or above to be kept for the first 12 hours to allow carcass maturation.
- The surface temperature of beef, lamb and goat meat should not fall below 10^oC within the first 10 hours of slaughter but should reach to 7°C or less within 24 hours of the end of carcass dressing.
- After initial cooling, the product's surface temperature should continue to go down in a continuous manner to 4°C or less. This should take place as quickly as possible and the cooling media (chilling room) shall be maintained within 0 to 2^oc and the mean air speed over the product above 0.75 m/s with relative humidity below 95%.
- If the meat product is to be stored for more than 72 hours, it should be kept in holding chillers with a temperature of 0 to 2^oc with a relative humidity below 90%.
- For the storage of offal, the temperature should be maintained below -2^oc but should be maintained below -10^oc if to be stored for more than 72 hours.

- The storage density of carcasses on hooks is dependent on the spacing of the rails, the height of suspension and the size of the carcasses, and very little on the unit weight of the carcasses.
- During cutting, boning, wrapping and packaging, the surface temperature of meat should be maintained at not more than 7ºC by means of an ambient temperature (the cutting room temperature) of not more than 10ºC.
- Relative humidity during the chilling operation should be kept fairly high to prevent excessive weight loss. The recommended rate is between 90 and 95 percent.
- Carcass temperature should be taken and recorded daily from 5 randomly spaced locations.
- Meat inspectors should be equipped with meat thermometer to check carcass temperature.
- Chillers should be fitted with thermometer, thermograph, hygrometer and alarm systems. The equipment should be fitted on the external walls of chillers so that the inspectors can easily monitor them.
- During the chilling operations, there should be adequate ventilation to prevent condensation on the surface of the meat.

8.2.1 Chilled storage

- Stored chilled meat is mainly intended to serve as buffer stock between production and shipment and/or consumption. When chilled meat is stored for long periods, a lower temperature without the risk of freezing should be used; normally 0°C (0 to 2^{o}c) is a reasonable choice. Relative humidity should be between 80 and 90 percent, which is a compromise between weight loss and microbial development; 80 percent is normally used for carcasses and quarters, and 85–90 percent for small meat cuts.
- The preservation of edible offal requires different conditions: -1°C rather than 0°C and a relative humidity close to saturation to avoid surface blemishes.
- Air circulation inside industrial chambers should be at a rate of 20–35 times per hour the volume of the empty cold room. When the chambers are used to store offal, it is advisable to use natural air circulation to maintain high humidity levels.
- Carcasses should be hung on rails in such a way that they are aligned in the direction of air circulation, avoiding contact with each other.

- Whenever a new product at a temperature different from that of the store is placed in store the product should be distributed around the room rather than concentrated in one place

Table 3. Storage conditions for chilled animal products

Commodity	Temperature (°C)	Relative humidity (%)	Practical storage life	
Beef	-1.5 to 0	90	3–5	weeks
Beef (10% CO_2)	-1.5 to -1	90–95	9	weeks
Lamb	-1 to 0	90–95	10–15	days

9. **Freezing**

Freezing is a process that consists in lowering the temperature of a product below its solidification point. Freezing reduces the temperature of a meat product below the freezing point, changing the state of water from liquid to solid form (ice). The formation of ice concentrates the dissolved solutes and reduces the water activity of the meat product. Freezing is usually limited to meat to be used as buffer stock, frequently intended for export or for storage with a view to later processing.

When the preservation period is longer than that acceptable for chilled meat, freezing should be used to minimize any physical, biochemical and microbiological changes affecting quality in storage. During freezing most of the water content of the meat, about 80 percent, solidifies into pure ice crystals, accompanied by a separation of dissolved solids.

A product can be considered frozen when its center has a temperature of -12°C or less. The speed of freezing is a very important factor as frozen meat quality depends mainly on the size of the ice crystal formed: the lower the speed of freezing the larger the size of the crystals.

The rate of freezing is important to prevent growth of microorganisms or production of their toxins prior to the product reaching freezing temperatures. Because of the physical nature of meat, the method of freezing affects quality and nutrient loss upon thawing. Oxidative rancidity and other organoleptic quality issues can occur if freezing rates are slow.

Export abattoir operators should validate that their processes reduce the core temperature of products preserved by freezing, to a core temperature of -18°C within a time frame allowing for the preservation of organoleptic and microbiological qualities. The speed of freezing is a very important factor as frozen meat quality depends mainly on the size of the ice crystal formed: the lower the speed of freezing the larger the size of the crystals. Slow freezing facilitates the formation of large crystals and the separation of solution and the migration of water out of the muscle cells.

Quick freezing conversely produces many small ice crystals, mainly formed within the muscle cells, and reduces water migration and separation of solution. It is obvious that quick freezing will preserve the meat closer to its original quality and, particularly during thawing, moisture loss will generally be lower. Meat can be refrigerated to a chilled condition before freezing. Cutting into quarters is usual, particularly for large animals, and the fat is removed from some parts because though it prevents surface desiccation it reduces the heat transfer rate, and is susceptible to damage during frozen storage.

The relationship between thickness and freezing speed favors cutting and deboning before freezing, either as lean meat packaged in cardboard boxes or cut into individual portions. This has many advantages:

- the mass to be frozen is reduced by 30 percent or more;
- storage density is increased by 100 percent;
- handling operations are easier;
- deboning after thawing, which causes hygienic and exudative problems, is avoided.

Factors affecting freezing time include the following:

- ***Air temperature:*** lower air temperature reduces the freezing time.
- ***Air speed:*** high air speed places a great working load on the refrigeration system, but reduces freezing time.

- ***Wrapping:*** covering the carcass with cheesecloth or polythene can double the freezing time. Boxes that are used for packing meat serve as insulation and freezing takes longer than if metal containers are used.
- ***Product thickness***: the thicker a cut, the longer it takes to freeze.

As in chilled storage, there are also weight losses, which can be between 1 and 4 percent in unpacked meat through evaporation during freezing.

9.1 Cooling performance standards for freezing

The export abattoir operator should ensure and demonstrate in an ongoing manner that they are achieving compliance with the following cooling performance indicators for freezing:

- When the preservation period in chiller rooms is longer than 72 hours, freezing should be used to minimize any physical, biochemical and microbiological changes affecting quality of meat in storage.
- Meat intended for freezing should be frozen without undue delay, taking into account where necessary, a stabilization period of carcass maturation before freezing.
- The freezing speed which is the velocity with which a temperature front moves through the body of the product (cm/h) should be from 2 to 5 cm/h. Slow freezing is considered to be below 1 cm/h and quick freezing above 5 cm/h.
- Freezing is performed in tunnels or in chambers with intense air circulation called blast chambers while air should circulate at high speed, from 2 to 4 m/sec up to 6 m/sec. Air temperatures should be in the range of -30°C to -35°C. The relative humidity should be maintained at 95 percent or above. The higher the relative humidity the better: a range of 95–98 percent prevents meat dehydration. Under the above conditions, half beef carcasses or quarters are frozen in about 16– 20 hours, cut-up meat in cardboard boxes measuring 54×34×16 cm in about 4 hours and small prepackaged cuts in about 1 hour.
- Meat exposed to circulating air will lose water and moisture constantly. This causes freezer burn of meat which is irreversible and results in changes of color, texture, flavor, and nutritive values. Freezer burn should be reduced by method of packaging (with plastic film, usually under cloth or jute fabric). Meat cuts are covered with plastic film, or vacuum-packed in plastic bags; they are placed inside cardboard boxes and usually frozen.
- Superficial fat should be eliminated before freezing to reduce the development of rancidity during storage.

- Small boxes and cuts, particularly of offal, are sometimes frozen in surface contact freezers (plate freezers): the product is pressed between two metallic plates cooled by direct expansion refrigerant. For items 3–5 cm thick, freezing time is as low as two to three hours.
- After freezing carcasses and quarters should be protected with plastic film, usually under cloth or jute fabric. Meat cuts are covered with plastic film, or vacuum-packed in plastic bags; they are placed inside cardboard boxes and usually frozen in these.
- When meat cuts are prepackaged without vacuum, air pockets should be avoided. A 2-cm space should be left in the upper part of the box to allow for expansion.

Table 4. Storage life of frozen meat under different temperatures

Products	Practical storage life in months		
	-18 °C	-25 °C	-30 °C
Beef carcass	12	18	24
Lamb carcass	9	12	24
Edible offal	4		

9.2 Frozen storage

- Meats properly frozen are transferred from the freezer to storage chambers where temperature, relative humidity and air circulation should be adequate and can be tightly controlled. In particular fluctuations in temperature should be kept to a very narrow time interval.
- As there is a certain degree of quality deterioration, even at very low temperatures, storage life is limited. The usual temperatures are in the range of -18° to -25°C for periods of preservation of one year or more. The higher the relative humidity the better: a range of 95–98 percent prevents meat dehydration.
- For frozen meats and other animal products storage incompatibility is low. The temperature level needed in the chamber is similar for all of them, and tainting is negligible owing to the low temperature and to the fact that most of the products are in adequately protective packages.
- The main problem with frozen storage is deterioration in organoleptic quality. There may be changes in meat texture, fat can become granular and crumble, and there can also be

some discoloration of the meat. Microbial enzymes also remain active, especially those that attack the fat.

- As in chilled storage, there are also weight losses through evaporation. This can be seen as freezer burn, i.e. superficial desiccated areas which can occur even in packaged meats when the packaging film is loose and temperature fluctuates inside the chamber.

10. Cold stores

- A meat cold store consists of a building (usually including a group of cold chambers) designed to keep meat in well-defined conditions of temperature and relative humidity. The chambers should be heat-insulated and artificially refrigerated, and have proper ventilation and pure air.
- Production cold stores are part of the slaughterhouse. Their main functions are primary chilling and carrying buffer stock.
- Cold stores can be used to keep refrigerated chilled meat or frozen meat or both, with independent refrigerated chambers for each purpose and the facility of changing from one cold operation to another.
- Chilled meats of different species should not be stored in the same room, but beef and mutton can be stored in the same room as they do not present temperature or tainting incompatibilities.

10.1 Cold stores management

The operation of cold rooms should take into account the storage requirements of the produce, rules for loading, maintenance and hygiene, and the running and maintenance of the refrigeration equipment. The loading plan will depend on the type of cold chamber, whether it is for preliminary chilling, for chilled storage or frozen storage.

Preliminary chilling, which is done in the slaughterhouse itself, depends on the slaughtering rate as this determines the amount of meat to be chilled hourly. The following guidelines should be followed:

- To avoid keeping the store door continuously open, freshly killed warm carcasses are separated into lots and introduced into the chilling chamber every defined time interval (such as half an hour, for instance.

- Carcass movement inside the store should be designed in such a way that warm and wet meat faces the air from already chilled carcasses.
- Overhead rails should be placed so carcasses are oriented in the sense of air circulation, and to prevent them from touching each other.
- It is sometimes advisable to divide the total chilling capacity among a few chambers, computed on two hours' slaughtering, when the capacity is high enough (10–40 t/day). Another option for high slaughtering capacity (over 40 t/day) is the continuous chilling system, where carcasses pass through a chilling tunnel transported by a mechanical conveyor for two to four hours and are then put in a cold chamber to undergo final chilling.
- Chilling facilities should be systematically emptied after chilling and before preparing for the following day's production.
- Already chilled carcasses should be placed in a refrigerated store rooms which should be at least equal in capacity to the chilling rooms.
- The storage density of carcasses on hooks is dependent on the spacing of the rails, the height of suspension and the size of the carcasses.
- Prepackaged under vacuum which then can be stacked inside rectangular boxes or cartons.
- Meat is frozen in full carcasses, or in halves for small and medium-size animals and in quarters for large animals. The disposition of meat in a freezing chamber or tunnel is similar to that in the chilling operation. However, frozen meat is not stored hanging from rails but loose on the floor, on racked pallets or in boxes when it is cut up and/or deboned.
- Meat packed in boxes and frozen meat on pallets are usually stacked. Stacking methods and height depend on several factors: resistance of the package, handling techniques and thermal state.
- Frozen carcasses and quarters are enclosed in polyethylene film and a cotton stockinette to protect against soiling and contamination; in this way they can be stored in piles or pallet boxes. Frozen small cuts are prepackaged like chilled cuts.
- The resistance of the package dictates the total weight the lowest can support. Carcasses of frozen meat can be stacked in bulk to heights of 8–10 m. When stored on pallets the height of the pallet load for carcasses can reach 1.9 m.
- Pallets can be equipped with corner supports of detachable metallic framework, placed around the load and transferring the weight from the upper pallet to the lower.

10.2 Condensation

A major problem experienced with refrigeration is condensation, which occurs when relatively warm, humid air strikes a cold surface or mixes with cold air (e.g. on the kill floor, at the entry of the cooler). Condensation should be reduced by:

- insulating cold surfaces,
- increasing air circulation within a room, and
- reducing the flow of warm air into refrigerated areas.

In rooms where condensation occurs, measures should be taken to protect meat products. This latter type of control may consist of the use of drip pans and ducts, the wiping or sponging of surfaces and the placement of exposed product in areas where the dripping of condensation does not occur.

11. Factors to be considered in chilling and freezing facilities

A refrigeration unit which has been well designed and well maintained may still not function effectively because of a number of reasons. Some of the major factors affecting refrigeration are indicated below:

11.1 Air circulation

Cold air should be distributed evenly throughout the room, following a circular flow pattern. The fan of the condenser should not direct the cold air directly on to the carcasses, as a deflection of the air movement will affect the effective cooling of other parts of the room. The more the air is forced to move around the product, instead of through open spaces, the better. It is preferable to have the air blown at right angles to the rails instead of along their lengths.

Carcasses should be spaced evenly in the chiller. The capacity of the chiller, which is determined by the rail lengths, should not be exceeded. This will overload the refrigeration unit and lead to inefficient cooling, with the possibility of faster spoilage.

As a result of the risk of condensation, warm carcasses should not be put into a cold room with chilled meat. It is not advisable to hang different kinds of carcasses or carcasses which differ considerably in size in the same room because the rate at which they cool down will differ.

11.2 Ice insulation of the refrigeration mechanism

It is normal for ice to form on the evaporation coil. Water which freezes on the spiral comes from:

- losses from the carcasses by evaporation;
- warm, moist air coming in through open doors;
- the insulation, especially if this is damaged; and
- cleaning activities which leave water behind in the room.

The ice should therefore be thawed and removed from the spiral at regular intervals. Excessive ice formation, which necessitates more frequent defrosting, can be avoided by:

- not overloading the chiller;
- closing the door;
- repairing damaged insulation; and
- mopping up all water during the cleaning process.

11.3 When heat loss exceeds the chilling capacity

When the refrigeration unit is overloaded, the temperature rises and remains higher than it should be until the unwanted cause is removed.

In cold storage rooms the sources of heat load include:

- Motors of fans, lights, staff
- Machinery/equipment, poor insulation of walls/floors
- The product load being greater than was provided for in the design
- Warm air coming in through the doors

Warm air coming in through the doors can be minimized by:

- air curtains can be useful to prevent warm air from entering the chiller.
- If this is not possible, the fans should be switched off whenever the doors are open.
- Another possibility is to use plastic curtains to reduce the loss of cold air while the doors of the cold storage room or freezer are open.
- Loading periods should be as brief as possible and doors of the cold-storage room should be closed as soon as the loading is completed.
- Avoid condensation on partly-chilled carcasses at all costs.

11.4 Factors affecting meat quality during chilling and freezing

Although there are many factors in favor of chilling meat, there are others which can have a deleterious effect on the quality of the meat. If the principles of refrigeration are correctly applied, however, the disadvantages can be kept to the minimum or eliminated.

11.4.1 Losses through evaporation

During initial cooling and cold storage lasting up to a week the total weight loss by a carcass is usually 2-2.5%. Most of this loss takes place during the hanging and chilling period, and represents the loss of water coming directly from the surface tissues. Weight loss resulting from evaporation during chilling and cold storage is unavoidable. But it can be limited by rapid cooling.

11.4.2 Drip loss

An additional loss of weight can take place for about the first two days of the chilling process in the form of drops from the cut surface. Rapid cooling reduces this loss as well. It is however well known that freezing causes more drip loss than chilling.

The rate of cooling should be monitored carefully so as to limit weight loss through evaporation and drip loss. It should be slow enough to preclude toughness (cold shrinkage) which is associated with too rapid chilling but should also be quick enough to minimize evaporation and drip losses.

11.4.3 Cold shrinkage

The muscles normally contract somewhat when rigor mortis sets in. If chilling takes place too soon after slaughter and the meat is still in the pre-rigor mortis stage, serious muscular contraction will take place. When rigor mortis does set in the muscles will remain in this contracted state. This happens when the meat is chilled within 10 hours to under 10°C, that is, before the pH can get down to less than 6.2. The meat will therefore be excessively tough when it is cooked and eaten.

11.4.4 Defrost shrinkage

When muscles are frozen before the onset of rigor mortis, that is within 10 hours of death and before the pH has fallen to 6.2, the chemical reactions which give rise to rigor mortis are ended until the muscle thaws again. The reaction is then resumed at a much faster speed, and toughness can be caused in the same way as with cold shrinkage.

11.4.5 Freezer burn

Freezer burn is the name given to the white or amber spots which appear on the surface of frozen meat; it arises when the meat is stored unprotected in air with low relative humidity. When unprotected meat surfaces are blast-frozen, a considerable amount of freezer burn usually occurs. The discolored spots are caused by the sublimation of ice crystals. This forms small air pockets on the surface of the meat; they diffuse incident light and give the tissues a

lighter color. These changes in the dried tissues on the surface are irreversible even after thawing.

The sublimation of the ice crystals takes place because the water vapor pressure over the spirals of the refrigeration units is much lower than that above the surface of the meat. This phenomenon results in a thickened layer of muscle tissue forming near the surface. In its turn this prevents water from passing through it from below. Maximum freezer burn occurs when meat is frozen and then stored under conditions which prevent evaporation.

11.4.6 Bone taint

This condition is restricted to the deep muscle tissues of heavy or excessively fat carcasses where cooling takes place very slowly. It is most frequent among animals that had been under stress, and generally occurs in the vicinity of the hip joint or sometimes in the shoulder of cattle. A characteristic sewage smell is unique to this condition, which is associated with high levels of volatile fatty acids.

12. Temperature capability

- A chiller used for chilling warm carcasses, sides, quarters or portions should be capable of providing uninterrupted cooling to reduce the surface temperature of the meat to 4^{o}C or less before dispatching.
- Frozen carcasses, portions and offal should not be removed from the freezer before a core temperature of -12^{o}C has been reached.
- The defrost mechanisms for freezers and chillers should prevent the build-up of ice on the evaporator coil surfaces to levels detrimental for temperature maintenance. For this to happen the following measures have to be taken:
    - Where a chiller or freezer contains meat during a defrosting cycle, defrosting of each evaporator coil should be completed within 30 minutes.
    - Drainage connections of ample size should be provided from drip trays of air-cooling units and should lead to ground level outside of the room or directly into the drainage system.
- A chiller or freezer should have a visible permanent notice fixed to the outside that states:
    - the cubic capacity of the room;

- the type of product which may be chilled, frozen or stored in it;
- the maximum permissible product load in kilograms or number of carcasses for that room;
- the final temperature required for the meat in degrees Celsius and the minimum period of time, in hours, which is necessary for this temperature to be achieved; and
- in the case of a storage chiller or freezer, the maximum permissible mean temperature value at which meat may be introduced.

13. Loading of chillers and freezers

- Meat should be chilled in a hanging position ensuring air circulation or, if packed in containers, stacked so as to ensure air circulation.
- Meat should not be stacked directly on the floor.
- Warm carcasses should not be loaded into a chiller containing chilled meat.
- No carcass or meat which is unfit for human consumption or may have a detrimental effect on other meat be stored in a chiller or freezer containing edible products.
- A carcass or meat should be removed immediately if it deteriorates to such a state as determined by the inspector.
- Exposed meat should not be stored in a freezer or chiller containing boxed products.
- Rough offal should not be stored in a holding freezer which contains carcasses, meat or red offal, unless all these products, including the rough offal, are wrapped and packed.
- Non-meat item or product other than meat should not be stored in a chiller or freezer.

Table 5. Carcass spacing on the rail

Type of animal	Initial Cooling	Chilling or Freezing
Cattle	0.5 m	0.5 m
Sheep & goats	0.3 m	0.3 m

Table 6. Rail height and spacing guidelines

Type of animal	Coolers		
	Minimum distance from top of rail to	Maximum distance from top of rail to shackle contact point on	Minimum spacing (distance) from walls, pillars, etc

	floor	carcass	
Cattle	3.1 m	30 cm	60 cm
Sheep and goat	2.0 m	30 cm	60 cm

Table 7. Density of storage of hanging carcasses

BEEF. Weight: 300 to 400 kg			
-	**in half-carcasses hanging from a high-level rail**		
	Height of rail from ground 3.80 to 4.00 m and point of hook 3.00 to 3.40 m		
	•	perpendicular to the track (3 half-carcasses per linear m, separation of tracks)	450 to 600 kg/m (1.00 m (minimum))
	•	parallel to the track (2×½ carcasses on the same track)	430 to 500 kg/m
		separation of tracks	0.90 m (minimum)
-	**in quarters, height of rail 2.60 to 3.00 m**		
	Point of hook 1.90 m above ground		
	•	perpendicular to the track:	
		- 4 quarters rear	400 kg/m
		- 4 quarters front	3.00
		separation of tracks	1.00 m
	•	parallel to the track	mean of 200 to 250 kg
MUTTON (or lamb). Weight: 15 to 30 kg			
-	on extension (4 mutton 15 to 20 kg in a circle of 0.70 m)		85 to 115 kg/m
-	on hangers (3 to linear m)		45 to 90 kg/m
-	in groups of 8 superimposed carcasses		290 to 400 kg/m
	separation of rails		0.80 m
-	on special aerial chassis with 10 hooks (10 carcasses/linear m)		150 to 300 kg/m
	separation between bars		1.40 to 2.00 m
	•	bars with double hangers	0.50 m
	•	bars in relation to the wall	0.50 m
	•	bars grouped in lots for the dispatch hall	0.50 m
OFFAL			
	These are on wall hooks spaced at 125 mm or disposed in tubs of 30 litres.		
-	hung on bars, wall hooks, superimposed, mounted on trucks on the ground		250 to 300 kg/m^2

14. Ice production

- The use of ice as a coolant in an export abattoir is subject to prior approval of the system by the inspector veterinarian.
- Ice, incorporated in any system or equipment, which is utilized for the chilling of meat should be made from potable water in compliance with the drinking water standards of Ethiopia.
- Facilities should be provided for its storage, handling and transport that will not contaminate the ice

- Equipment or systems incorporating ice as coolant for meat should be designed and operated in such a manner that water melting off the ice will not adversely affect the product or adjacent areas.

15. Defrosting or thawing

Thawing is considered as simply the reversal of the freezing process. Thawing is critical phase in the freezing process as it involves a change from ice crystals to melted water, which in turn is re-absorbed and enhances microbial reactivation. Thawing is used when cold de-boning and cutting of meat. The majority of the bacteria that cause spoilage or food poisoning are found on the surfaces of meat. During the freezing operation, surface temperatures are reduced rapidly and bacterial multiplication is severely limited, with bacteria becoming completely dormant below -10°C. In the thawing operation, these same surface areas are the first to rise in temperature and bacterial multiplication can recommence. The following guidelines should be followed during thawing:

- ❖ Thawing should take place in installations specifically designed for this purpose.
- ❖ Low temperature thawing, below 5°C, reduces the risk of microbial growth and produces a slow thawing rate which guarantees efficient re-absorption of the melted water. It is recommended that carcasses be thawed at 4° to 6°C, in a hanging position and without any covering (plastic or jute is removed), inside a cold chamber with a reasonably low level of air circulation of about 0.2 m/sec.
- ❖ Relative humidity should be kept low at the beginning (70 percent) to avoid frost forming on the meat surface, with an increase at the end of the thawing period up to 90–95 percent. In these conditions thawing of beef carcasses lasts about four to five days and of sheep and goat carcasses one to three days.
- ❖ Thawing should be considered finished when the temperature of the meat is about 0° to -1°C.

16. Sanitation in cold storage facilities

Cold chambers intended for meat chilling and chilled storage should be kept in a strictly hygienic condition as microbial invasion is a grave risk. The following operations are essential:

- Equipment used in chillers, freezers or cold storage facilities, that may come into direct contact with the meat should be kept in a clean and hygienic condition, and provision should be made for cleaning and sterilizing such utensils directly after use.
- Freezers and chillers should be free from vermin, mould and bacterial growths.
- Chillers, freezers and cold storage facilities should be free from odors which may be absorbed by meat. Before storing animal products in rooms that have contained strongly odorous products, deodorize by washing, prolonged ventilation and finally spraying with a solution containing ammonium salts.
- Chillers in regular use should be sanitized immediately after dispatching of all meat and before a fresh load of meat is to be loaded. Each time a room is emptied, or after rewarming rooms at low temperature, wash floors and walls with detergent and hot water, rinse them with clean water, and spray with a solution containing active chlorine (0.3 percent);
- Clean pallets and storage containers every four months;
- Ice formation in freezers should be prevented and freezers should be defrosted and sanitized as frequently as may be required by the inspector.
- Where a chiller or freezer contains meat during a defrosting cycle, defrosting of each evaporator coil should be completed within 30 minutes.
- Drainage connections of ample size should be provided from drip trays of air-cooling units and should lead to ground level outside of the room or directly into the drainage system.
- Disinfect chilled storage rooms for 48 hours at least twice a year and frozen product rooms when they are emptied;

17. Cutting and de-boning

In the meat production cycle, chilled meat is sold, as half or quarter carcasses or in smaller pieces called primals. De-boning is the term used in the industry to process carcasses into smaller primal cuts. In the absence of bone, the meat cuts are less bulky for chilling and freezing to be effected more rapidly and economically. “Cold shortening” can be avoided by de-boning in rooms at 7-10°C and holding the vacuum-packed cuts for at least 10 hours at these temperatures.

Maturation of meat to pH <5.8, de-boning and removal of visible lymphatic tissue greatly reduces any FMD viral infectivity and is often used as a risk reducing step when importing beef from countries that are not free from FMD.

The following guidelines should be followed:

- A carcass intended to be cut and de-boned should be cooled immediately after slaughter for carcass maturation with the ultimate aim of attaining carcass surface temperature of $7^{O}C$ within 24 hours of slaughter and consequently meat should be chilled to reduce and keep its surface temperature not exceeding $4^{O}C$.
- Carcasses should preferably be cut while hanging or on regularly cleaned surfaces, with tools frequently sterilized during operation and the meat stored in clean containers. The packaging material should be of good quality and clean.
- During the cutting and de-boning, wrapping and packaging process, the cutting and de-boning rooms temperature should not exceed $10^{o}c$.
- If cut and de-boned meat wrapped or packaged is not to be used within an hour of being produced, it should be chilled to a temperature no higher than 2°C (0 to 2°C) but if it is not to be used within 24 hours of being chilled, it should be frozen to a temperature of no higher than -18°C within 6 hours. These temperature requirements should be maintained during storage and transport.
- The freezer should be capable of reducing the core temperature of the meat to at least $-12^{o}C$ within 24 hours and should thereafter be maintained at or below that temperature and frozen meat may not be dispatched at core temperatures higher than $-12^{o}C$.

17.1 Wrapping

- Wrapping materials should not be kept in a cutting room in quantities greater than the daily requirement, and should be so stored and handled as to maintain them in a clean condition up to the moment of use.
- Exposed meat should not come into contact with boxes, except where waxed boxes are used.

17.2 Vacuum packing

Today the most widely used method employed to extend the storage life of fresh meat is vacuum packaging. Vacuum packaging is intended to preserve products from microbial contamination, from dehydration and from environmental factors that affect quality and nutrition. The guideline to follow include, but not limited to, the following:

- Meat should be packed in gas-permeable plastic laminated bags at 2-4°C and a pH of 5.5-5.8.
- Vacuum-packed product should not be loaded out until the meat temperature is at or below 0 to 2°C.
- The optimum storage and transport temperature for chilled meat is the lowest possible temperature at which no freezing occurs
- Therefore, the aim should be to reduce the meat temperature to 0 to 2°C as soon as possible after packaging.

17.3 Packing area

The packing area is a separate room, or area that receives wrapped product transported either manually or automatically from the boning-cutting room or vacuum packaging area for packaging into boxes.

- The packing area should be refrigerated to 10^{o}C or less.
- This area should be separated from the production area by a wall or "pass through" enclosure to maximize sanitation.
- The packing area should have adequate space to accommodate the vacuum packaging machines and limited supply of packaging material (bag and labels).
- Boxes should not be stored in this area.

17.4 Boxed meat blast freezing

The boxed meat blast freezer should be designed to freeze meat in a -28^{o}C with high velocity air movement.

17.5 Boxed meat storage

The boxed meat storage room is used to store boxed meat prior to loading and shipping.

- The room should be temperature controlled to 0 to 2^{o}C for chilled meat and -18^{0}C for frozen meat.
- The room should have storage racks and an inventory management system.
- Capacity of the room should be adequate to handle products equal to 4 days of production.

17.6 The cold chain for boxed meat export

Meat should be transported and exported in fiberboard boxes and should be packed in refrigerated shipping containers (*reefers*). There are three types of shipping containers that are used to export both chilled and frozen meat. These are 20-foot standard (20' x 8' x 8' 6"); 40-foot standard (40' x 8' x 8' 6"), and 40-foot-high cube (40' x 8' x 9' 6").

- All reefer containers should be fitted with integral refrigeration units which allow the temperature to be set to any value between –25°C and +30°C.
- Containers for frozen meat should be set at a temperature of –20°C and for chilled meat at 0°C.
- The meat should be at or close to the carriage temperature when loaded.
- Containers should not be pre-cooled before loading. When the doors of a pre-cooled container are opened, warm, moist air condenses on the cold internal surfaces. This condensation will need to be removed by the container refrigeration equipment. Otherwise, it will create ice on the evaporator coil and reduce cooling efficiency at the time when maximum cooling is required.

18. Meat transportation

Export abattoir operators and those who transport meat and meat products are required to protect meat from contamination and maintain its pre-loading temperature status during loading, transporting and unloading at the port of exit.

18.1 Land transport of meat to the air or see port

Vehicles for transporting meat and carcasses should be considered as an extension of the refrigerated storage. Appropriate temperatures should be continuously maintained throughout all phases of transport to ensure the quality and safety status of meat and meat products. The guidelines to follow include, but not restricted to the following:

- The loading dock of the abattoir should fit to a wide range of meat transport truck sizes.
- The dock should be refrigerated to 10^{o}C or less and should have dock doors and seals.
- In the absence of temperature-controlled loading facilities, and when significant heat transfer is likely to occur, product temperatures should be reduced below the preservation temperature to compensate for the anticipated heat gain.
- In case of carcasses, the loading dock should have overhead rails leading from each cooler to the dock door and it should be connected to the track refrigerated container to facilitate hygienic movement of meat.

18.1.1 Vehicle requirement

- Meat and carcasses should be transported from the abattoir to the port of exit in sealed and specially designed vehicles.
- The hooks on rail shall be of such a construction as to prevent the meat from falling down during transportation;

- Minimum space between rails should be 60 centimeters;

- Vehicles should be fitted with refrigeration system and minimum and maximum thermometer or another temperature sensing or recording device to monitor cold chain inside the meat container. The temperature reader should be located in a place where the driver can monitor while driving.
- Refrigeration units should be serviced regularly and the cooling unit should be in good repair and operation.
- Vehicle body should be sufficiently insulated and be in good repair with no holes in the body that might allow heat, dust, or other adulterants to enter the cargo area and ensure that the temperature of the meat should not rise more than 2oC during transportation;
- Vehicle doors and seals should be securely closed and that there will be no air leaks.
- Ensure any equipment or surfaces that contact meat products are made of nontoxic, noncorrosive materials that can be effectively cleaned.
- Vehicles should be free from residues of previous cargoes, cleaning and sanitizing compounds.
- Products shall not be loaded into any conveyances unless they have been reduced to their preservation temperature or any colder temperature required by an importing country.
- Pre-cooling of conveyances can reduce or prevent significant heat transfer.
- When temperature-controlled loading facilities are available, vehicles should be pre-cooled for at least 1 hour before loading to remove residual heat from the insulation, inner lining and the air of the trailer and it should be capable of maintaining the required temperature of the meat during the journey.
- For pre-cooling, the doors should be closed and the temperature setting of the unit should be no higher than -3°C.
- Inspect the vehicle before loading and remove items that may contaminate meat products.
- Vehicles should be properly cleaned, disinfected out and air-dried before they are allowed to transport meat and carcasses.

18.1.2 Loading of meat and meat products.

- Minimum rail spacing for hindquarters and boned cut meat shall be 40 centimeters and for forequarters 35 centimeters;
- No person shall be allowed to stay in the compartment where meat is kept during transport.

- The engine of a carrier shall not be allowed to run whilst loading or un-loading is in process and all doors and lids shall be securely closed before the engine is started.
- Fueling of carriers shall not take place whilst the doors or the lids of a carrier are open.
- Ensure that carcasses and other meat products are chilled to a surface temperature of 4°C or less for carcasses and 2-3°C for meat products in a chilling room kept at temperature of 0 to 2°C at the slaughter facility before loading. Similarly, ensure that frozen carcasses and other meat products are frozen to a core temperature of -12°C in a freezer room kept at temperature of -18°C or less at the slaughter facility before loading.
- Meat should be loaded into refrigerated containers and transported to the port or airport under strict temperature-controlled conditions that maintain a temperature of 0 to 2°C for chilled and at -18°C for frozen products.
- During loading, insulated containers with securely attached lids for smaller-sized products should be provided.
- Where practical, transport wrapped meat products in insulated containers with clean ice packs or ice from an approved source
- For products that are too large to fit in insulated containers, clean, designated protective tarp, shipping bags/ shrouds or other suitable covers should be provided.
- Chilled red meat carcasses, sides and quarters should be suspended without touching the floor and if stockinet is put on carcasses, it should be clean.
- Unwrapped meat should not be loaded directly onto the floor.
- Covers should be securely fastened during transport.

18.1.3 Meat transport to the airport

- Consider the time of the day and weather conditions, if high temperatures are forecasted, arrange to pick up the shipment during the cooler times of the day.
- Both the truck driver and plant personnel should regularly check the status of the trailer refrigeration unit.
- Temperature of product and the transportation environment should be recorded during shipment.
- Never allow meat products to be kept out of refrigeration for more than two hours unless other suitable means of maintaining temperatures are used.

18.1.4. Meat unloading at the airport

- Unloading of meat in the airport should be conducted in presence of veterinary inspectors.

- Air temperature of meat compartment should be monitored on arrival.
- The condition of the meat should be checked for contamination or refrigeration breakdown.
- If the temperature or condition of the meat has deteriorated the veterinary inspectors should take corrective actions which may include increasing refrigeration settings or disposal of the meat if spoiled and cleaning of vehicle of any contamination.
- Unloading of meat should be started as soon as possible within a short time interval and should be done in an appropriately chilled environment.
- Meat handlers should keep containers closed and minimize unloading times.
- Personnel at the port of unloading are required to record the temperature when meat is received as well as the temperature at load out.
- The meat inspecting officer at the air ports should check and conform that the meat or carcass is certified for export, transported in sealed and specially designed vehicles and that the minimum and maximum thermometer or other temperature sensing or recording device reading is maintained at 0 to 2°C) for chilled and at -18°C for frozen products.
- In case of flight schedule break downs, meat should be unloaded, stored and loaded by maintaining the required cold chain.
- Meat returned to an abattoir or cold storage facility may be received only after re-inspection by the inspector, and may only be sorted and salvaged for human consumption under conditions determined by the inspector.

18.2 Air transport

Although air-freighting of meat offers a rapid method of serving distant markets, there are many problems because the product is unprotected by refrigeration for much of its journey. Up to 80% of the total journey time is made up of waiting on the tarmac and transport to and from the airport. During flight, the temperature is normally maintained between 15 and 20°C. Perishable cargo is usually carried in standard containers, sometimes with an insulating lining and/or dry ice but is often unprotected on aircraft pallets. For this reason, the following measures should be taken:

- Insulated containers should always be used to reduce heat gain.
- Meat should always be held at the required temperature until loading.
- Containers should be filled to capacity.
- A thermograph should accompany each consignment.

- Products should be loaded onto aircraft as soon as possible.
- Preparing and loading of refrigerated meat products should be carried out in such a manner that any rise in product temperature is minimal.
- The use of carbon dioxide can be allowed to minimize temperature rises

18.3 Sea transport

Historically, it was the need to preserve meat during sea transport that lead to the development of mechanical refrigeration and the modern international trade in foodstuffs. Developments in temperature control, packaging and controlled atmospheres have substantially increased the range of meat and meat products that can be transported around the world in a chilled condition.

- Refrigerated containers should incorporate insulation and have refrigeration units built into their structure.
- The units should operate electrically, either from an external power supply on board the ship or in dock.
- When the containers are fully loaded and the cooled air is forced uniformly through the spaces between boxes, the maximum difference between delivery and return air should be less than 0.8 °C.
- The entire product in a container should be maintained to within ±1.0 °C of the set point.
- For bulk transportation of frozen meat, refrigerated cargo ships should be used.
- Frozen meat should generally be stored and transported at -18 °C or below.

18.4 Air and sea port cold storage

- Once a meat shipment for export has been received at airport and inspected by the meat inspectors, it should be immediately transferred to the cargo or placed in the air or sea port storage facility.
- The inspectors should inspect the air or see port storage facility to assure it is in good working order and that no substances known to be toxic or harmful are stored or maintained in the meat storage facility.
- A refrigerated room used for the storage of chilled carcasses, sides, quarters or portions should be maintained within the range of 0 to 2^{o}C and the mean air speed over the product shall be maintained above 0.5 meters per second and the relative humidity shall be maintained below 95%. If the product is to be stored for longer than 72 hours, the relative humidity should be maintained below 90%;
- A refrigerated room used for the storage of offal should be maintained at a temperature below –2^{o}C. If the offal is to be stored for longer than 72 hours, the temperature should be maintained below -10^{o}C.
- A refrigerated room used for the storage of frozen carcass, side, quarter or portion, shall be maintained at a temperature below –18^{o}C.

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Annexes:

Annex I. Providing temperature-controlled environments

Different meat products require different temperature levels to ensure their integrity throughout the travel process. Ensuring that meat shipment will remain within a temperature range for an extended period of time depends largely on the type of container that is used and the refrigeration method. Factors such as duration of transit, the size of the shipment and the ambient or outside temperatures are important factors in deciding what type of packaging is required. They can range from small insulated boxes that require dry ice or gel packs, rolling containers, to reefer with their own powered refrigeration units. The major cold chain technologies involve:

- **Dry ice**. Solid carbon dioxide has a temperature of about -80°C and is capable of keeping a shipment frozen meat for an extended period of time. Dry ice does not melt, instead it sublimates when it comes in contact with the air.
- **Gel packs**. Large shares of pharmaceutical and medicinal shipments are classified as chilled products, which means that they should be stored in a temperature range between 2 and 8°C. The common method to provide this temperature is to use gel packs, or packages that contain phase changing substances that can go from solid to liquid and vice versa to control an environment. Depending on the shipping requirements, these packs can either start off in a frozen or refrigerated state. Along the transit process, they melt to liquids, while at the same time capturing escaping energy and maintaining an internal temperature.
- **Eutectic plates**. The principle is similar to gel packs. Instead, plates are filled with a liquid and can be reused many times.

- **Liquid nitrogen**. An especially cold substance, of about -196°C, used to keep packages frozen over a long period of time. Mainly used to transport biological cargo such as tissues and organs which are considered as hazardous substance for the purpose of transportation.
- **Quilts**. Insulated pieces that are placed over or around freight to act as buffer in temperature variations and to maintain the temperature relatively constant. Thus, frozen freight will remain frozen for a longer time period, often long enough not to justify the usage of more expensive refrigeration devices. Quilts can also be used to keep temperature sensitive freight at room temperature while outside conditions can substantially vary (e.g. during the summer or the winter).
- **Reefers**. Generic name for a temperature-controlled container, which can be a van, small truck, a semi or a standard ISO container. These containers, which are insulated, are specially designed to allow temperature-controlled air circulation maintained by an attached and independent refrigeration plant.

Annex II. Setting and organization of cold chains

Moving a shipment of meat across the supply chain without suffering any setbacks or temperature anomalies requires the establishment of a comprehensive logistical process. This process concerns several phases ranging from the preparation of the shipments to final verification of the integrity of the shipment at the delivery point.

- **Shipment preparation**. A key issue here is the temperature of the meat which should already be at the desired temperature. Cold chain devices are commonly designed to keep a temperature constant but not to bring down the temperature of the meat to the desired level. So, they are unable to perform adequately if a shipment is not prepared well ahead of time. The other issue here includes the destination of the meat shipment and the weather conditions for those regions such as if the shipment will be exposed to extreme heat along the transport route.
- **Modal choice**. Several key factors play into how the meat shipment will be moved. Distance between the origin and the final destination (which often includes a set of intermediary locations), the size and weight of the meat shipment, the required exterior temperature environment and any time restrictions of the product all effect the available transportation options. Short distances can be handled with a van or truck, while a longer trip may require an airplane or a truck and a container ship.

- **Custom procedures**. If the freight crosses boundaries, custom procedures can become very important. This is because cold chain tend to be time sensitive and more subject to inspection than regular freight. The difficulty of this task differs depending on the nation (or economic bloc) and the gateways since there are variations in procedures and delays.
- **The "Last Mile**". The last stage is the actual delivery of the meat shipment to its destination, which in logistics terms is often known as the “last mile”. Key considerations when arranging a final delivery is not only the destination, but the timing. Trucks and vans, the primary modes of transportation for this stage, should meet the specifications necessary to maintain the cold chain. The final transfer of the meat shipment into the storage facilities is also important as there is potential for a breach of integrity.
- **Integrity and quality assurance**. After the shipment has been delivered, any temperature anomalies should be recorded and made known. This is the step of the logistical process that creates trust and accountability, particularly if liability for a damaged shipment is incurred. If problems or anomalies that compromise a shipment do occur, an effort should be made to identify the source and find corrective actions.

Annex III. Calibration of thermometers

- Mix ice and water in a thermos flask or an appropriate receptacle, allowing 5–10 minutes to equilibrate.
- Stir the closed receptacle for at least a minute to aid equilibration.
- Carefully insert the testing thermometer into the ice water slurry, ensuring the thermometer is inserted sufficiently into the slurry.
- Gently swirl the receptacle for a minute.
- After a further minute record, the temperature of the thermometer. The testing thermometer should read 0 °C.
- Place the calibrated thermometer inside the meat-carrying compartment next to the vehicle’s thermometer probe. After a minute check that the vehicle’s thermometer has the same reading as the calibrated thermometer.
- Calibration is carried out at least once every 12 months and results are kept.
- If the thermometer reading differs from 0°C more than 1°C the thermometer should be recalibrated.
- If there is still a difference in the accuracy of the thermometer:
    - the difference should be noted, or

- an adjustment should be made to the thermometer by the adjustment nut at the back of the thermometer.
- any corrective action should be noted in the Vehicle Calibration Record.
- If it cannot be calibrated, replace the thermometer.