CHILLER OPERATION AND QUALITY ASPECTS OF CHILLED AND FROZEN MEAT

Mr D.W. Roberts

Meat is refrigerated for four principal reasons:

(1) To maintain its hygiene status or wholesomeness,

(2) To prolong the shelf life of chilled meat,

(3) To prolong the shelf life of frozen meat,

(4) To modify its characteristics.

Maintaining hygiene status or wholesomeness

The matter of maintaining the hygiene status of meat by refrigeration is simply explained. No food poisoning bacteria will grow or produce toxins below 7°C, and so meat kept below this temperature will remain as wholesome as when it was first refrigerated, even though other bacteria may render it unacceptable. Although moulds may grow at temperatures very much below 7°C, they are not a hygiene problem.

Prolonging the Shelf Life of Chilled Meat

Many factors affect the rates at which a mixed population of bacteria on a particular meat surface or carcass will grow. It is generally accepted that the rate of spoilage of meat increases by 2½ to 3 times the rate at 0°C for each 5°C rise in temperature. Table 1 shows the approximate effect of rises in temperature on meat stored in various ways from 0°C to 10°C. It is important to note that cold temperatures do not kill bacteria but merely slow them down.

Table 1

Approximate Effect of Temperature on Shelf Life of Meat Stored in Various Ways

	SHELF LIFE - IN DAYS		
	0°C	5°C	10°C
Meat in polythene bag	7 - 10	2 1/3 - 3 1/3	1
Carcass in stockinette Air at 85 - 90% RH and 15 - 16m per minute	42 - 45	14 - 15	4 2/3 - 5
Vacuum packed meat with Nominal 75 day shelf Life at 0°C	75	25	8

.../2

Prolonging the shelf life of frozen meat

Meat is commercially considered frozen when it is at -10°C or lower, although it begins to freeze at -1.4°C. This is because some bacteria can grow on meat down to -8°C, and some fungi can grow down to about -12°C. At -10°C bacterial and fungal spoilage can be regarded as stopped. However, chemical and physical deterioration can still occur even at the lowest commercial temperatures. Such chemical changes will become slower as the temperature drops. They are usually manifested in the development of rancidity and their rate will also be affected by the nature of the fat of the animal, the more unsaturated fats will deteriorate fastest. Hence beef will keep longer than sheep meat at the same temperature, and sheep meat will keep longer than pork, poultry, and fish.

Modifying the characteristics of meat

It is now widely known that rapid cooling of meat before it is in rigor causes dramatic toughening. This effect is minimal at 15°C to 20°C and maximal at 0°C. It is not so well known that meat frozen before rigor and then thawed rapidly will become even tougher, although this phenomenon can be prevented by storing meat for 20 days at -12°C or by thawing it very slowly over, say, 72 hours.

The greatest economic consequences of over-refrigeration of carcasses can be overcome by the use of pelvic hanging or "Tender-Stretch". This method has not been well accepted and it may be that the newer technology of electrical stimulation of carcasses may find wider application in overcoming the problem.

On the other hand, too little refrigeration can aggravate the problem of pale, watery pork and of drip loss. Meat which is chilled too slowly after slaughter tends to be soft and pale. The problem in pork is of considerable economic significance when the meat is to be cured. In beef, it creates sloppy, flaccid meat which retailers consider undesirable. In primal cuts it aggravates drip. Problems with sheep and lambs in this connection are not reported, presumably because the large surface area to weight ratio seldom allows slow chilling.

.../3

The use of refrigeration when ageing meat to improve tenderness and flavour and, to a smaller extent, water-holding capacity is now standard practice. Table 2 illustrates the relationship between storage temperature and rate of ageing. The tenderness of all cuts of meat will improve with ageing but when it is completed, those cuts which were more tender to begin with still remain the more tender. Ageing typically halves the toughness of meat.

Table 2

Ageing Times at Various Temperatures

6.1°C	8 days
2.2°C	14 days
0.0°C	21 days
-1.4°C	28 days

Temperature control is important in portion control when the meat is generally "tempered" to around -2°C to -4°C, so that it is part-frozen but can be moulded in uniform shapes under pressure for slicing into pieces of identical size and thickness.

In meat reconstitution, it is normal practice to mix lean meat at lower temperatures, such as -3.5°C, with fat at higher temperatures, such as 2°C, to improve the texture and appearance of the final product.

In smallgoods manufacturing, where water-holding capacity and emulsification are important, a low temperature plays a significant part in improving both the yield and texture of the smallgoods.

Refrigeration and Desiccation

The lean tissue of carcasses is made up of approximately 77% water. Only about 5% of that is chemically bound to the various components and the other 95% is physically trapped. In the meat industry, water is profit and water loss is economic loss, not only in terms of loss of weight but in terms of loss of quality associated with textural and colour deterioration when meat dries out.

.../4

Refrigeration at both chiller and freezer temperatures has marked effects on the dehydration of meat. In chillers and freezers the interaction of FDC unit and chamber temperatures dictates relative humidities, and the interaction between the relative humidities in the chambers, the chamber temperature and the rates of air movement will dictate evaporation rates from carcasses. Overnight chiller shrink rates of 1% for beef and 1.5% for sheep and lambs are perfectly feasible.

It is worth recording that with a wet bulb temperature (FDC coil) of $1^{o}C$, and a dry bulb of $2^{o}C$, the relative humidity is 82%, whereas with the same wet bulb temperature and a dry bulb of $5^{o}C$, the relative humidity is only 38%.

It is most important to realise that at chiller temperatures even very small changes to solonoid settings can critically affect chiller humidities, with dramatic effects on carcass weights and on boning room yields.

At typical chiller temperatures, evaporator units should never need defrosting. If they do, then they are incorrectly adjusted with respect to temperature or their capacity is inadequate for the chiller size. It should be remembered in this connection that additional weight loss from carcasses involves additional work by the refrigeration plant to remove the extra latent heat of ice formation.

It is also important to remember that an excess drip loss of 0.5% is one which occurs on practically every day of the year. Consequently extra investment in additional evaporator units or in back pressure control valves is amply justified. It is often not realised that significant water losses can also occur from meat at freezer temperatures. This is clearly demonstrated in Table 3.

Table 3

Weight Loss from Lamb Carcasses stored for 9 Months at $-15^{o}C$, from Scale to Thawed Weight

	1st Grade	2nd Grade	3rd Grade
Stockinette only		6.27	7.61
Polythene and Stockinette	1.40	2.24	2.70

NOTE: Carcasses were thawed naked with evaporator at $2.5^{o}C$ and chamber at $3^{o}C$. Air movement 15 to 20 metres per minute for 48 hours.

.../5

In the storage of chilled meat, desiccation plays a critical part in prolongation of shelf life. For example, while meat stored in a polythene bag at $0^{o}C$ (relative humidity 100%) is likely to have a 7 - 10 day shelf life, the same product stored in double stockinette with air movement at 16 - 20 metres per minute could be expected to have a shelf life of 40 - 45 days at a relative humidity of 85 - 90%.

The difference is explained by the fact that no desiccation occurs in the polythene bag while some does occur in the stockinette wrapped meat. Sheep carcasses hung in this manner will lose approximately 1.5% weight per week depending upon the fat cover, while beef carcasses could be expected to lose in the vicinity of 1% per week.

The spacing of carcasses and sides in chillers is thus of the greatest importance, not only to ensure the circulation of cold in cooling carcasses, but to ensure that the surfaces dry out to some extent to give control, through both dehydration and the cold, of bacterial growth. Where carcasses are allowed to touch during chilling, the cooling of the carcass surface is not only reduced so that the bacteria are not slowed by cold, but neither is there any desiccation. Bearing in mind that bacterial contamination of carcasses can generally be regarded as limited to the surface of the meat, the significance of spacing carcasses to minimise the risk of Salmonella contamination is obvious.

Desiccated chilled meat becomes black and tough. The losses associated with it are weight loss, poor appeal, and the trimming losses of removing the dark desiccated surface.
Desiccation of frozen meat results in freezer burn which has an unacceptable bleached appearance. The meat is unacceptably tough, and burnt areas have to be removed. It has the additional disadvantage of generally being associated with rancidity.

.../6

Controlling Desiccation

The control of desiccation by design and adjustment of chillers and freezers has already been referred to.

The rate of desiccation of meat tissue is primarily related to the rate at which water can pass to the outside surface of the meat through the outer tissue surface. This is obvious when it is remembered that around 95% of the water in meat is only physically entrained. Because this rate of passage is lower in fat than lean tissue, carcasses with fat cover are less susceptible to the ill effects of desiccation, and this fact largely accounts for the preference for fat carcasses in former times. Modern control of desiccation has revolved around packaging materials, beginning with the early use of stockinette and hessian and culminating more recently in the use of plastic films for vacuum packaging, along with the use of simple plastic films for frozen meat. The use of vacuum packaging films totally eliminates desiccation but not drip. Table 3 shows the impact of wrapping lamb carcasses of various grades in stockinette and in plastic over time.

A promising method for controlling desiccation is the use of wax emulsion as a spray on chilled meat.

When frozen meat has been thawed, the rate of desiccation and darkening is greatly increased because microscopic damage to the membranes in the meat allows an increase in the rate of movement of water through it to the surface. Thawed meat needs to be treated with special care.

Thawing Meat

When meat is frozen, numerous ice crystals form within the tissue structure. The faster the rate of freezing, the smaller and more numerous they will be and, conversely, slower rates will give fewer and larger crystals. When meat is thawed slowly, there is less drip loss, presumably because the slower rate of thawing allows more time for the water to be resorbed by the meat tissue. In this connection, it is logical to expect that there would be less drip from fast-frozen meat thawed in the same time as meat which was frozen slowly, because the water melting from many small centres would be better distributed

.../7

than that melting from the fewer ice crystals. In addition, and perhaps more importantly, the smaller ice crystals are likely to have caused less damage to the membranes than the larger ice crystals.

As a general rule, meat should be thawed as slowly as is economically possible, say on a 42 - 48 hour cycle for sheep and lamb carcasses and 72 hours for beef. Ideal thawing conditions for carcasses or quarters are for them to be wrapped in stockinette and thawed at around $3^{o}C$ to $3.5^{o}C$, relative humidity of 85% to 90% and air movement of 15 to 20 metres per minute.

When meat has been frozen in a vacuum packed film, it is best left intact during thawing. However, over a 48 or 72 hour period, plastic films not of the vacuum pack type are generally best removed, but clearly a decision balancing the question of diminished shelf life in the 100% humidity environment of a plastic bag and the risk of surface desiccation must be made.

Double Freezing

The problem of re-freezing meat are generally well known but sometimes exaggerated within the industry. The undesirability of re-freezing arises from the fact that freezing itself kills few bacteria, and the meat builds up a larger population of bacteria at each thawing, so that thawed a second or third time it is likely to spoil very quickly indeed. The growth of these bacteria is further aided by the fact that many of the meat cell membranes are damaged during freezing and the nutrients of the meat are more available to bacteria for growth.

Frozen Meat in Plastic Films

While the advant of the plastic film has done a great deal to reduce weight loss and freezer burn, some problems still occur. The most common problem is localised freezer burn, together with ice crystal build-up when air spaces occur between the meat and the plastic film. The best solution to this problem is to eliminate such air spaces, but this is clearly not possible in many cases - for example, in small consumer packs of bone-in cuts. Fluctuations in temperature will result, in the case of a rise in temperature, in the meat surface being colder than the plastic covering, and ice from the

.../8

plastic will condense on the meat. When the temperature falls, ice from the meat will re-condense on the plastic. This will result in a steady build-up of ice. It can and does occur even without thawing, and if thawing does occur, the situation is exacerbated. The problem can be reduced by maintaining the packs at very steady temperatures.

Summary

Refrigeration offers a very flexible tool to control meat quality in general and shelf life in particular. Its use in conjunction with humidity manipulation and packaging materials extends its value and usefulness even further. Small temperature variations at the lower end of chiller temperatures can have considerable effects on meat quality and although meat may be considered frozen at $-8^{o}C$ or $-10^{o}C$, there can still be value in looking at much lower storage temperatures.

Careful use of refrigeration can make considerable differences to the economics of meat handling and of refrigeration plant operation.