Meat technology update

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Frozen meat: loss of Water and Freezer Burn

MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

FOOD SCIENCE AUSTRALIA
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Freezing does not prevent 'evaporative' loss of water from meat products. Desiccation through the inadequate use of packaging materials can be a major problem with frozen meat and other foods. Moisture migration occurs in frozen foods and can have major effects on their chemical and physical properties. It can lead to several consequences, depending on the food:

- moisture loss by sublimation (direct conversion from ice to water vapour);
- moisture absorption and redistribution;
- recrystallisation of ice;
- drip loss during thawing.

This publication focuses mainly on moisture loss from meat and meat products, and the more significant manifestations of that loss.

Moisture loss

Historically, moisture loss, leading to desiccation was the main limiting factor in the storage life of frozen beef and lamb carcases. Even when appearance and other quality attributes are not affected, moisture migration has a significant quantitative (and economic) effect in the form of weight loss. For instance, the New Zealand experience was that typical weight losses during conventional meat processing amounted to 1 to 2% during chilling, 1% during freezing and about 0.5% per month during storage and transport unless the product was wrapped in an impervious film.

Freezer burn

Freezer burn can occur when freezing, storing and distributing bone-in beef, sheep or goat meat in single or double stockinette—or in stockinette-hessian, unless considerable care is taken. It can also occur when plastic bags or wrappings around individually wrapped pieces or cartoned meat are not tight enough to prevent air pockets adjacent to the meat surface, or when they are torn.

If the surfaces of frozen meat are exposed and, therefore, subjected to drying, the ice evaporates directly from the frozen state. Vapourisation from ice crystals results in voids where the crystals were and a honeycomb structure of minute air pockets in the meat surface. This results in the light-coloured blemish known as freezer burn.

In the early stages of freezer burn, most blemishes disappear on thawing and more severe burns sometimes disappear on cooking. Extensive freezer burn is

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completely irreversible, as the meat proteins have been denatured and will not rehydrate. This denaturation is often accompanied by the development of off-flavours from the concurrent oxidation of fat.

Moisture loss and freezer burn are usually caused by a combination of conditions during freezing and storage.

Freezing

Rapid freezing causes less weight loss then slow freezing, but very rapid freezing makes the meat more susceptible to freezer burn during subsequent storage.

The storage period before freezer burn appears may be increased by avoiding freezing the product quickly while its surface is still wet. The surface water creates a thin layer of ice with small crystals just under the surface. This ice layer predisposes the surface meat to early onset of freezer burn.

Storage

During storage, any condition or activity that causes evaporative weight loss can lead to freezer burn. Evaporative weight loss is reduced at relatively low air temperature and air velocity and comparatively high relative humidity.

Both fluctuations in temperature and elevated temperatures relative to normal storage conditions can increase dehydration. Typical values for the rate of weight loss from exposed meat carcases during frozen storage suggest that the rate of sublimation (evaporation) is halved for every 10°C fall in temperature. To minimise dehydration of frozen meat in freezer stores, the product temperature must be kept constant. In theory, the effects of small temperature fluctuations (e.g. 1-2°C) should be negligible. However, several physical phenomena may contribute to magnification of the effect of temperature fluctuations. One of these is irreversibility. For a porous food such as meat in a vapour-tight film, a small drop in the freezer temperature will cool the wrap. Water vapour will frost onto the inside of the film. This causes a drop in water vapour pressure between the meat surface and the wrap. Moisture within the fibres of the meat will sublime and diffuse to the wrap until the meat itself equilibrates to the new temperature. When the freezer environment warms slightly again, the ice on the wrap will sublime and should, in theory, diffuse back into the meat. However the fibres constrict or are capped by ice, preventing further resorption. Thus, after a cooling-warming cycle, there may be a net migration of water from the inside toward the surface and the wrap. This ‘cavity ice’ is a common occurrence in wrapped food after storage. Consequently, it is most important to control freezer store air temperature to give minimum variation of product temperature.

It is also important that the product should enter the freezer store at the same temperature as that of the store. If the meat temperature is higher than that of the surfaces and refrigeration coils in the freezer store, then water will evaporate from the warmer meat into the air stream and condense on those colder surfaces and coils. The greater the temperature difference, the faster water will be transferred and the quicker the meat will dehydrate.

Products with a large surface area, such as frozen hamburgers, are particularly susceptible to freezer burn caused by heat flow into or out of a carton. Most of the heat transfer occurs where the patties are in contact with the carton surface exposed to freezer air.

In a well-designed freezer store, temperature variations are minimised and air temperature is constant throughout the store. Minimising the heat entering the freezer store can reduce drying. Common sources include:

- heat transfer through the insulation;
- heat from lights and fans;
- heat generated by people and equipment working in the store; and
- most importantly, heat entry through open doors or poorly sealed closed doors.

Defrost procedures should also be checked.

'Hot spots' near the walls and floors of freezer stores can be avoided by the use of pallets or dunnage. This allows air to circulate and remove the incoming heat.

The higher the heat gain from the surrounding environment, the greater the operational period of the freezer store refrigeration system, which leads to increased moisture loss. The rate of moisture loss is known to be higher in summer than in winter. The better the insulation of the freezer store, the lower the heat gain.

The type of heat entering a freezer store is signification in determining the extent of moisture loss from meat. 'Dry' heat – from sources such as lights, electric motors and heat conduction through walls, floors and ceiling – has a greater effect than 'wet' heat which is heating accompanied by a high humidity. Sources of wet heat include that resulting from interchange or air at doorways. The fan motors of forced-draft evaporators are a significant heat-load component in a freezer store. In older style stores, refrigeration of the room was achieved via pipe coils adjacent to the walls or ceiling. This construction had the beneficial effect of shielding product from radiant heat transmitted through the walls. The result was less moisture loss from the product. Successful efforts have also been made to eliminate dry heat by using jacketed freezer stores in which cold air is circulated inside the double layer wall so as to remove the heat before it reaches the product. Although effective, such stores are expensive to build. In stores of conventional construction, the floor is the most likely source of dry heat. Heat that is conducted through walls generally has only local effects while the heat conducted through the ceiling is quickly removed via air flow.

High air velocity or low humidity around naked meat and stockinette-and/or hessian-wrapped meat will lead to increased weight loss. The smaller the temperature differential between the air and the evaporator, the higher the humidity. As in carcase chilling, the evaporator coil depth is a significant factor in moisture removal. Shallow coil depth with large face area will minimise moisture loss.

The presence of significant quantities of cartoned product in the same freezer store as naked carcases can accelerate desiccation if the cartons have the capacity to absorb moisture from the circulating air. The differential moisture levels between naked carcases and carton materials can lead to the transfer of moisture from the carcases to the cartons. Naked or stockinette-/hessian-wrapped carcases should not be stored with packaged frozen foods in cartons or other packaging capable of moisture absorption.

The absolute weight loss from goods stored in a freezer store or shipping container is almost independent of the actual amount of product in that store. This arises from the following facts:

- Heat gain into the store or container is independent of the product load.
- The evaporation capacity from frozen meat is considerable.
- Evaporator coil capacity is constant.

Thus, for a given set of freezer store/ container operating conditions, a given amount of water can be evaporated if it is available. If a freezer store is only partially loaded, and the product in it is packaged in a way that permits some loss of water vapour, the evaporative loss per unit weight of product will be greater from that partial load than from a full freezer load.

Consequently, it follows that a minimum weight loss can be attained only when:

- the freezer store/container is loaded to capacity with stockinette/hessian-wrapped product and the product is stacked with maximum compactness; or
- product is sealed in moisture-impermeable materials.

The practice of CO_2 snow-shooting of meat

wrapped in stockinette or stockinette-hessian in containers is also conductive to the development of freezer burn.

- Moisture will evaporate from the warmer meat surfaces into the dry, cold atmosphere produced by CO_2.
- This same atmosphere lowers the meat surface temperature. Then, as the surface temperature subsequently rises, as the product and environment equilibrate, moisture is again lost.

This also applies for snow-shooting of product that has a torn outer plastic cover.

Packaging

Moisture-proof packaging (e.g. meat completely enclosed and sealed in polyethylene of appropriate thickness) greatly reduces weight loss, and therefore freezer burn, by preventing the escape of water vapour but dehydration can still occur inside the packaging if voids are present.

It the temperature fluctuates, 'frosting' occurs on the inside of the packaging material when the air temperature fakks. Successive cycles of increasing and decreasing temperature cause the accumulation of ice on the inside of the packaging. This is due to moisture progressively evaporating from the meat and condensing on the inside of the packaging. If there are no plastic wrappers or if the packaging is punctured or torn, weight loss will be higher. Frosting is minimised by very tight packaging. It is eliminated in a skin packaging system, as there is no air space between the meat surface and the packaging film.

Most of the frosting in cartons of boneless meat occurs during the freezing process. There is a slight weight loss from the frozen meat but if the carton liner is tightly wrapped around the meat, the weight loss from the frozen meat after the initial equilibration with the freezer store air temperature is only about 0.0025% per week.

Moisture is also transferred between pieces of product in moisture-proof packages if there are air gaps between product. If heat flows from one piece of product to another, e.g. in a stack of patties, water can evaporate from the surface of the warmer piece and be deposited on the cooler piece. This can lead to freezer burn.

When each unit of meat is packed in moisture-proof material, neither air velocity nor humidity is important with respect to dehydration, since the packaging acts as a barrier. Under these conditions the packaging material, product temperature and variation in temperature are the major determinants of dehydration.

Where trade allows, packaging materials with low water vapour permeability (WVP) should be used to wrap or bag the product. A very long period of protection against freezer burn can then be expected provided the following precautions are taken.

- Always use a low WVP tight-fitting film such as polyethylene.
- Ensure that sealing is adequate.
- Minimise voids by ensuring maximum intimate contact between the packaging film and the product surfaces.
- Ensure careful handling of packaging films at low temperatures, as their flexibility decreases with temperature.

Note that when plastic film is creased or sealed, its WVP increases at these points. If cracks or splits occur in the film, freezer burn may result. For any type of film, the greater the thickness, the lower the WVP.

Where the trade requires stockinette and hessian packaging, appropriate 'weave' and weight per unit area are barrier-relevant properties.

Retail packs, including comminuted and added-value products

Although most retail meat is purchased chilled rather than frozen, many consumers still freeze meat in the domestic freezer. A 1980s survey in Brisbane indicated that nearly three-quarters of consumers home-freeze. Some of this meat will be stored for

some months before being consumed. Freezer burn and weight loss almost certainly occur to this meat.

Mince, burger patties, reformed steaks and related products have high surface area-to-thickness ratios. In addition, their rapid rates of manufacture and freezing can mean that ice may still be present within meat particles. In these cases, further ice formation will take place around these nuclei. These frozen meat products are particularly vulnerable to thawing and deterioration. For this reason they need to be packaged and transferred to cold stores as quickly as possible.

It is not usual to pack patties and similar products before freezing because of their soft nature and because of the decrease in rate of heat transfer caused by packaging and the air present in the pack.

It is well know that the development of freezer burn and other quality defects varies according to the type of freezing employed (cryogenic – with carbon dioxide or nitrogen; or mechanical) and according to how elaborate the packaging is.

Major issues

If excessive moisture loss and/or freezer burn occurs, they are commonly caused by combination of conditions such as:

- inadequate packaging;
- high freezer storage temperature and extended storage period;
- variable storage temperature;
- temperature differential between product and air;
- freezer stores subject to high 'dry' heat gain, particularly through the floor;
- high air velocity over the product;
- low occupancy of freezer store;
- naked (or stockinette-wrapped) carcases stored with cartons or other moisture-absorbent packaging;
- carbon dioxide (CO_2) snow-shooting of containers;
- inadequately packaged added-value and retail packs.

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Contact us for additional information

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