Meat Thawing

This Bulletin describes some of the different methods used to thaw meat or meat products, and presents guidelines for selecting and optimising meat thawing processes.

Freezing is a popular way to preserve meat. However, frozen meat must be thawed or partially thawed before it is further processed, or prepared for consumption.

The thawing conditions can significantly affect the thawing time and product quality.

This Bulletin outlines the range of thawing methods available, to enable meat processors to choose the method that best suits their particular applications in terms of production costs, production flexibility and product quality.

THE THAWING PROCESS

Thawing is essentially the reverse of freezing. However, during freezing a microbiologically and chemically unstable product is transformed into a more stable form, whereas during thawing the opposite is true. This has implications for process control, particularly the control of thawing temperatures and thawing times.

To achieve faster freezing, the temperature of the freezing medium (air, brine, or plates) can be reduced. Similarly, faster thawing can be achieved by increasing the temperature of the thawing medium, but for thawing there are two limitations:

- at temperatures between 0°C and about 40°C, the higher the temperature of the thawing medium, the faster the meat surface will reach temperatures that favour the growth of spoilage bacteria and pathogens;
- at temperatures above about 50°C, product appearance and texture begin to undergo changes associated with cooking.

Three important quality aspects of the thawing process are

- microbial growth
- drip loss
- the appearance of the thawed product.

Microbial Growth

Organisms that survive the freeze/thaw cycle will begin to grow once conditions become favourable, but this growth does not begin immediately upon thawing. Instead there is a lag phase, during which cell damage is repaired and enzyme systems are reactivated. The duration of the lag phase and the rate of growth thereafter depend on the organism, the degree of cell damage sustained during freezing and thawing, and the nutritional quality, temperature, and water activity of the thawed product.

Thawed meat is no more susceptible to microbial spoilage than fresh meat. However, any microbial deterioration that occurred before freezing will advance after thawing.

Drip Loss and Meat Appearance

During freezing and frozen storage, ice crystals form and grow, and solutes in the meat are concentrated. These changes damage the meat tissue and cause meat proteins to change, reducing the water-holding ability of the meat. On thawing, water (containing dissolved solutes) will be lost from the meat as 'drip'. The structural and chemical changes that occur in the meat during freezing, storage and thawing also affect the appearance of the thawed meat.

THAWING METHODS

Thawing methods rely on either external or internal heating of the product. In external heating methods, heat is transferred from an external heating medium to the product; in internal heating methods, heat is generated within the product.

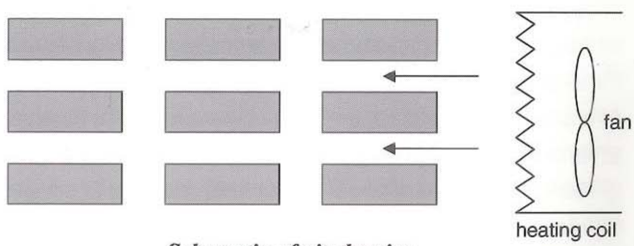
EXTERNAL HEATING METHODS

During external heating, heat is first transferred to the product surface through contact with a warm fluid or solid, then is transferred throughout the product by conduction. With this type of heating, the thawing rate depends on the resistance to heat transfer between the thawing medium and the product surface, the thermal conductivity of the product, the size and shape of the product, and the temperature difference between the product and thawing medium.

Thawing in air, thawing in water, thawing in steam under vacuum, and thawing by contact with heated plates are all based on external heating.

Air Thawing

Meat is commonly thawed in still air or a moving air stream. Meat can be air thawed in existing chillers, boning rooms, or conditioning and aging rooms that have been fitted with a heating system. Air thawing can therefore be implemented at relatively low cost if such rooms are already available. The same product handling systems used for chilling and freezing in air can be used for thawing in air.

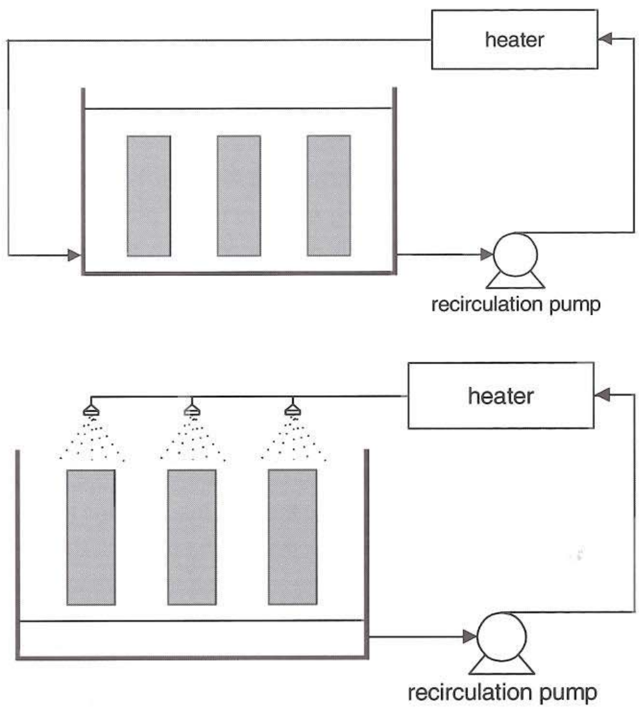


Schematic of air thawing.

The major disadvantage of air thawing is the low rate of heat transfer at the product surface. This results in long thawing times. Long thawing times reduce process flexibility and mean that more space will be required for a given thawing throughput. Unpackaged products (such as bare carcasses) thawed in air also tend to lose weight (over and above any drip losses) through evaporation of moisture from their surfaces.

Water Thawing

Water thawing is another common thawing method. The meat is either immersed in a water bath or is sprayed with water. For the same product thawed at the same temperature, water thawing is faster than air thawing because the rate of heat transfer at the product surface is higher. Water thawing reduces evaporative weight loss from the product during thawing, but can result in weight gains, which may be undesirable.

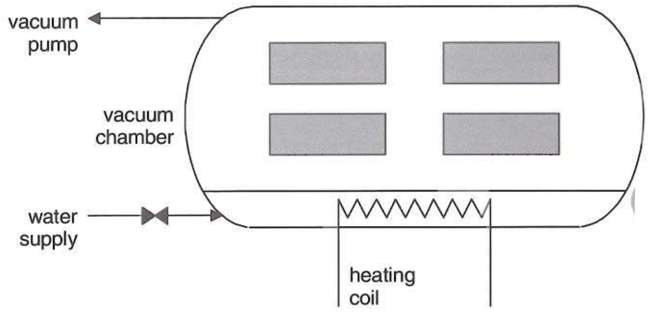


Schematic of water thawing: water bath (above) and spray (below).

If unpackaged meat is water thawed, its surface can appear pale after thawing. This may be a concern for meat thawed for retail display, although there is evidence that water-thawed meat will regain some or all of its colour after a short equilibration period in chilled air. Surface appearance is probably less important for meat destined for further processing. Another disadvantage of water thawing is the cost of water use and disposal.

Vacuum Thawing

Vacuum thawing systems use saturated steam under vacuum to thaw frozen product. At atmospheric pressure, steam condenses at 100°C, but at absolute pressures between 0.9 and 4 kPa, steam condenses at temperatures between 5 and 30°C. Thus, steam under vacuum can be used to thaw frozen meat without the risk of cooking it. When steam condenses on a cold surface, it releases its latent heat of vaporisation,



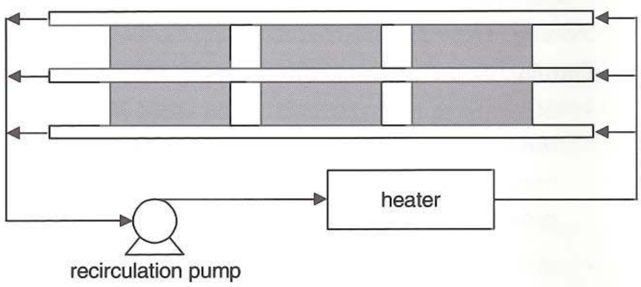
Schematic of vacuum thawing.

producing a high rate of heat transfer between the steam and the cold surface. This high rate of heat transfer makes vacuum thawing at least as fast as water thawing at the same temperature.

Vacuum-thawed unpackaged meat has the same appearance problems as water-thawed unpackaged meat. Another disadvantage is that vacuum-thawing equipment tends to be more expensive than that required for air or water thawing. However, vacuum thawing uses less water than immersion thawing, and vacuum-thawing systems are well suited to automatic cleaning-in-place.

Plate Thawing

Plate thawing is similar in concept to plate freezing, but the plates are heated, e.g. by a warm liquid such as water, instead of cooled. Contact between the plates and the product surface gives a high rate of heat transfer, and plate thawing times are comparable to those achieved by water or vacuum thawing.



Schematic of plate thawing.

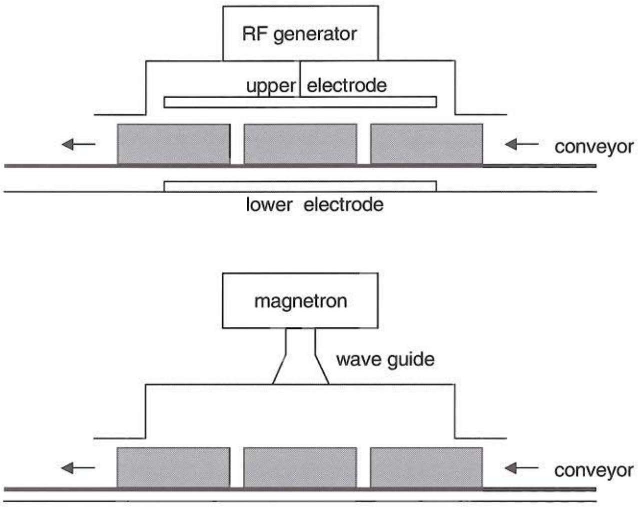
For unpackaged meat, plate thawing results in a better surface appearance than water- or vacuum thawing. However, plate thawing is suitable only for flat, slab, or brick shaped products.

INTERNAL HEATING METHODS

With internal heating methods an electric or electromagnetic field is applied to a product such that the energy of the applied field is converted to heat energy within the product. These methods do not rely on heat conduction through the product, and therefore have the potential to produce faster thawing rates.

The most common internal heating methods used in food thawing are capacitive heating (also referred to as dielectric or radio-frequency heating) and microwave heating. In capacitive heating, an alternating electric field is generated between two parallel metal plates that are separated by the

product. In microwave heating, an alternating electromagnetic field is applied to the product by means of electromagnetic radiation at microwave frequencies.



Schematics of capacitive thawing (above) and microwave thawing (below).

Capacitive and microwave heating are very rapid, and have the potential to achieve very short thawing times (typically 1 to 3 hours, depending on product size), which can be a major advantage in terms of process flexibility and process hygiene. Capacitive and microwave heating are also well suited to continuous operation. However, high capital costs and difficulties in maintaining even heating throughout the product have so far limited the widespread application of these methods to meat thawing.

The uneven (or 'runaway') heating that can occur with capacitive or microwave systems can seriously affect product quality. In extreme cases, parts of the product may be cooked while other regions remain frozen. To minimise problems with uneven heating, capacitive and microwave systems are best suited to products that have an even thickness (i.e. a block or slab shape); a homogeneous composition (e.g. no large fatty areas); and a uniform initial temperature distribution (i.e. product should be taken straight from cold storage, and should not be allowed to warm up or partially thaw before capacitive or microwave processing).

It is easier to achieve uniform heating with capacitive heating than microwave heating, and in tempering (where the product temperature remains below the initial freezing point) rather than complete thawing.

Capacitive thawing equipment has now been developed that is suitable for both tempering and complete thawing. However, microwave technology is usually restricted to tempering processes.

GUIDELINES FOR SELECTING AND OPTIMISING A THAWING PROCESS

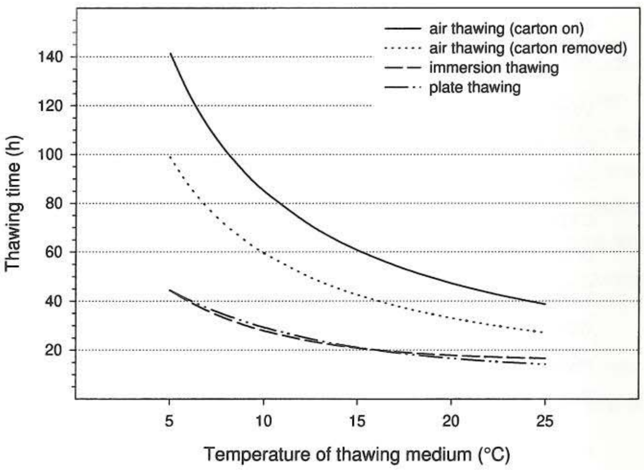
Ultimately, the selection of a suitable process for a given thawing operation will depend on many factors, including the size and shape of the product being thawed; the quality characteristics required of the thawed product; the desired cycle time for the process; the required product throughput; equipment already available to the plant that may be adapted for thawing (e.g. unused chillers or tanks); space limitations; regulatory requirements; and the capital, maintenance, and operating costs of the thawing equipment.

Once a suitable process has been selected, it is important that the process be optimised to achieve the most efficient and economic operation for the desired application. MIRINZ staff have conducted several studies investigating the effects of different thawing conditions on thawing times and product quality for air, water, and plate thawing processes. The following guidelines for operating such thawing processes have been summarised from this work.

General

For any thawing method, product should be thawed at the lowest temperature that allows thawing within the desired cycle time.

The figure below shows the variation of thawing time with temperature for 27.2 kg blocks of frozen beef thawed in air, in water, or between heated plates (these thawing times are indicative only, as they apply to a specific product thawed under specific conditions).



Indicative thawing times. (actual times depend on the process conditions)

To minimise microbial and quality deterioration, all thawed product should be further processed immediately after thawing, or should be chilled to 0°C immediately after thawing and held at this temperature until required for further processing.

Thawing conditions for batches of product should be kept as uniform as possible throughout each batch. This will prevent a large spread of thawing times within batches and minimise the chance of faster-thawing products in a batch spending long periods in the thawed state (with consequent quality deterioration) before the slower thawing products have completely thawed.

Uniform thawing conditions can be achieved by

- ensuring effective circulation of the thawing medium (e.g. air or water) to maintain uniform temperatures and flows throughout the thawing system;
- ensuring that all product items in a batch are packaged similarly and are of a similar size and shape.

Thawing times can be reduced by removing packaging such as cartons, polyliners, and carcass wraps before thawing.

Air Thawing

Air thawing is more suitable for smaller meat products (5 kg or less). Large meat products have long thawing times in air.

Air thawing may be the cheapest and simplest option for small, infrequent thawing operations. It is also suitable for tempering, even for large products, as tempering can be achieved in a much shorter time than complete thawing. Air velocities between 0.5 and 1 m/s are recommended as a compromise between achieving faster thawing times and reducing fan power and evaporative weight loss.

Within regulatory requirements, high relative humidities are recommended to limit evaporative weight loss from unwrapped products and to decrease thawing times for all types of product.

Water Thawing

Water thawing is suitable for large and small meat products, except where a pale surface colour immediately after thawing will significantly affect the acceptability of the thawed meat.

Water thawing is not generally suitable for tempering operations, as these operate below 0°C and thus require the use of brine solutions. However, products that can be safely exposed to brine solutions (e.g. vacuum-packed or cured products) may be tempered or thawed in brine. To minimise thawing time, product should be stacked such that the thawing water circulates effectively around each item. The thawing water should be well mixed, to ensure that water temperatures throughout the thawing tank are uniform.

In immersion thawing, water use can be reduced by recirculating water around the thawing tank rather than continuously or intermittently pumping fresh water through the tank to waste. There is no evidence to suggest that water recirculation increases the level of microbiological growth on the meat during thawing.

A thawing system with complete water recirculation at a constant water temperature will require some form of heating system to maintain and control water temperatures during thawing.

Immersion thawing with no active temperature control can be achieved by using a high initial water temperature that reduces during thawing as heat is taken up by the thawing product. The initial water temperature and the water-to-product ratio must be chosen to give the desired final water temperature at the end of thawing (e.g. less than 7°C). Thawing times and meat quality under such regimes will depend on the average water temperature during thawing, and are similar to immersion thawing at a constant temperature equal to that average temperature.

Spray thawing uses less water than immersion thawing, but is likely to be more capital intensive. At the same thawing temperature, spray thawing results in similar thawing times and meat quality to immersion thawing.

Plate Thawing

Plate thawing is suitable for thawing or tempering large or small products of regular geometry (i.e. flat, slab, or brick shaped products). It is especially suitable for thawing plate-frozen meat.

Plate thawing times are at least as fast as immersion thawing times at the same temperature. High contact pressure between the plates and the thawing product reduces plate thawing times, but excessive pressure can deform the thawing product, which may limit how much pressure can be applied.

Regulations

Regulations applicable to thawing vary from place to place and over time.

Persons installing a thawing process should consult the appropriate authorities to ensure that it meets regulatory requirements.

FURTHER READING

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