Australian Government
Department of Agriculture, Water and the Environment

Guideline for the Application of the Refrigeration Index to Refrigeration of Meat and Meat Products.

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1 Background

According to the *Australian Standard for the Hygienic Production and Transportation of Meat and Meat Products for Human Consumption* (AS 4696), refrigeration processes in Australia are considered effective if they can reduce the temperature of the surface of carcases, sides, quarters or bone-in major separated cuts to no more than 7°C and other carcase parts at the site of microbiological concern to no more than 5°C, within 24h of stunning. In some cases, these requirements may be overly prescriptive, and allowance is made for alternate time and temperature regimes in the standard.

Hot boning (where carcases are boned before reaching a deep muscle temperature of 20°C) processors had difficulty meeting the requirements of the standard even though they could demonstrate equivalent microbiological outcomes to conventional processes. The use of microbiological data to demonstrate equivalence is problematic as bacteria are not homogeneously distributed on or throughout product making it difficult to interpret results. Microbiological data are also not available in real-time meaning that they are not useful for monitoring processes under a Hazard Analysis Critical Control Point (HACCP) program.

New Zealand authorities developed an approach to validate the hygienic performance of refrigeration of meat and meat products using time/temperature integration and predictive microbiology; dubbed the Product Hygiene Index. The index is a measure of the potential growth of mesophilic bacteria and provides a measuring stick by which processes can be compared. Similarly, researchers at the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) produced empirical models that were used to develop early chilling standards for use in hot boning processes. Subsequent to this a group of researchers from the CSIRO and the University of Tasmania, in collaboration with Australian industry and regulators, developed a more risk-based approach for determining the efficacy of chilling, utilising time/temperature integration and published predictive models developed by the University of Tasmania. The outcome of this work was the Refrigeration Index (RI).

The RI is a measure of the potential growth of generic *E. coli* at the monitored site. It is not a count of the number of *E. coli* at that site. The RI is used to measure the performance of the refrigeration process from the time chilling or freezing commences until all the sites of microbiological concern are at or below 7^{o}C.This reflects temperature at which enteric pathogens such as Shiga toxigenic *E. coli* (STEC) and *Salmonella* stop growing on meat. Since they will only grow at or above 7°C, the RI will not accumulate below that temperature. The RI is used to validate both existing and alternative refrigeration processes, and is an ongoing process verification measure used by meat processors over time.

2 Refrigeration

The outcome of refrigeration is defined in AS 4696 as:

The chilling and freezing of meat maintains and does not jeopardise its wholesomeness

Refrigeration is applied to reduce the temperature of product to a desired end-point. In the case of food safety this end point is generally considered to be ≤ 7°C. For the purpose of ensuring wholesomeness lower temperatures may be required to supress the growth of

spoilage bacteria. All raw meat and meat products will eventually spoil at temperatures above the freezing point of meat. Meat generally begins to freeze below -1.5°C, although high pH meat can start to freeze at higher temperatures i.e. above -1°C.

The effect of refrigeration is measured by achieving the required temperature at the site of microbiological concern, which is defined as the site on the meat or meat product where microorganisms of concern are likely to be located or the thermal centre (slowest cooling part). For example, for a carcase, this is the surface of the carcase, and in meat packed in a carton, it is at the thermal centre of the carton.

The following sections deal only with the microbial consequences of refrigeration.

2.1 Refrigeration Process

2.1.1 Refrigeration process for carcasses

Carcasses are chilled in air to prevent the growth of enteric bacteria such as *Salmonella* and to limit the growth of spoilage bacteria. Control of growth is achieved by reducing the surface temperature and by drying of the surface tissue. In the initial stages of chilling the carcass surface is hotter than the surrounding air resulting in evaporation of water from the carcass surface and its subsequent removal through condensation onto the coils of the refrigeration equipment. In the initial phases of chilling the rate of migration of moisture from underlying tissue to the carcase surface is slower than the evaporative loss, resulting in a lowering of the water activity at the carcase surface. The lower water activity prevents bacterial growth in the early stages of chilling when the surface temperature is high enough to support growth. When the air temperature and carcase temperature equilibrate the water activity of the surface rises and growth is controlled largely by temperature alone. Growth of enteric bacteria may occur during the early stages of chilling if surface drying is prevented or impeded. The amount of drying that occurs at the carcase surface is affected by carcases touching, shrouding of carcases, spray chilling, increasing humidity etc. When drying occurs, microbial growth is easily controlled for the first 18-24h of chilling even with relatively slow cooling regimes. Carcases are generally boned when their internal temperature has fallen below 20°C (cold boning). This places less burden on subsequent carton chilling/freezing for control of microbial growth.

Some carcases and/or carcase parts are frozen immediately after exiting the slaughter floor; this is particularly true for small-stock. Bacterial growth is controlled in the initial stages of freezing in much the same way as for chilled carcases. Most frozen carcases are shrouded prior to freezing, limiting surface drying, with bacterial growth controlled by a rapid reduction in the surface temperature.

2.1.2 Refrigeration process for cartoned product

Carton product is either chilled or frozen. Generally, primals are chilled (either vacuum packed or individually wrapped) while offal, lower grade cuts and manufacturing meat are usually frozen. Control of bacterial growth during carton chilling/freezing is dependent on the initial temperature of the product and the rate of cooling achieved during refrigeration. The rate of temperature reduction in blast chillers or freezers is dependent on the type of carton used, air velocity and set temperature. Solid fibreboard cartons are more efficient in allowing heat transfer than fluted cartons and higher air velocities help remove heat from cartons more effectively. For a given set

temperature, blast freezers are less effective in reducing the temperature of product than plate freezers. Once product has been placed into cartons there is no longer an opportunity for the surfaces to dry and therefore microbial growth is essentially controlled by temperature alone. The type of system used will depend on the individual process and will need to balance cost against the rate of temperature reduction required to meet food safety regulations

2.1.3 Refrigeration process for hot boned product

In hot boning, meat is removed from the carcase prior to any chilling when the temperature of the hottest part of the carcase may be 37°C or higher. The deep temperature of carcases immediately after slaughter may rise to above 40°C as a result of continuing metabolic activity without blood flow to remove heat from the cells. Some operators cool carcases for several hours before boning (warm boning) when the meat deep muscle temperature is between 20 to 25°C. The initial stages of refrigeration of hot boned product, when product temperatures at > 25°C, are critical in minimising growth of enteric bacteria such as *Salmonella* in meat.

2.1.4 Refrigeration process for offal

Offal can be considered "hot boned" as it is usually packed into cartons directly from the slaughter floor. Some offal are of more concern than others (i.e. livers, hearts, tripe) as they are bulky and have relatively high starting temperatures (≥37°C). Offal such as hot scalded tripe may have a very high starting temperature, although it is not clear what effect scalding has on subsequent microbial growth. Processors may choose to take preventative action to increase the rate of cooling of offal i.e.

- Cool individual offal products prior to packing
- Use thinner cartons to increase the rate of cooling
- Delay lidding of cartons to increase the rate of initial cooling

2.2 The significance of refrigeration for safety

Refrigeration is often set as a critical control point (CCP) in the processing of meat for human consumption. While refrigeration does not prevent or eliminate biological hazards on meat it may result in a reduction in the hazard. There is some evidence to suggest that numbers of enteric bacteria decrease during chilling and freezing by as much as 1-$\log_{10}$ (ten-fold), although in the case of chilling it is not clear if this decrease is real or just an artefact of cells entering a viable but non-culturable state. While refrigeration provides a means for controlling hazards it has the potential to result in large increases of the hazard if not carried out correctly.

As refrigeration is often included in an establishment's HACCP program, it is important that the process be monitored. Monitoring should include:

- Continuous recording of chiller/freezer return air temperature;
- Periodic measurement of the air velocity;
- Periodic measurement of a selection of carcase/carton temperatures during refrigeration; and
- Visual inspection, e.g. cleanliness, carcase spacing, condensation.

Effective monitoring does more than just verify chiller/freezer performance; it can help justify product disposition decisions in the case of refrigeration failures.

2.2.1 GHP and HACCP prior to refrigeration

Prerequisite programs, such as Good Hygienic Practice (GHP), ensure chillers are clean and do not pose a source of contamination of product. Rooms should be cleaned between loads and evaporators cleaned periodically to remove mould. When rooms are not in use they should be cleaned and allowed to dry. Drying of surfaces is critical in reducing bacterial loads in the chiller environment. Calibration of measuring equipment should be considered as part of the prerequisite program for refrigeration.

Most establishments include chilling and freezing as a CCP in their HACCP plans. This necessitates selection and validation of a critical limit. While AS4696 sets a critical limit of 7°C within 24h for carcases (5°C for carcase parts) this may not be suitable for establishments that bone meat prior to 24h i.e. 'bone on the curve'. A critical limit for carcase chilling should be set based on what is achieved at an individual establishment and complying with the RI requirements in the Export Control (Meat and Meat Product) Orders 2005 (see 2.4.2).

2.2.2 Hygiene of refrigeration

There is ample evidence that enteric bacteria such as *E. coli* and *Salmonella* will not grow on meat at temperatures ≤7°C. Growth at higher temperatures can be restricted on carcases by surface drying as previously mentioned. This in combination with a rapid temperature drop ensures that little if any growth of enteric bacteria occurs in the first 24h of carcase chilling. Growth of enteric bacteria in carton product (either hot boned or conventionally boned) is basically controlled by temperature, although product pH will have some effect.

Other pathogenic bacteria such as *Listeria monocytogenes*, *Yersinia enterocolitica* and *Aeromonas spp*. may be able to grow on fresh meat at temperatures of ≤7°C. However, there is no epidemiological evidence linking raw meat and meat products to cases of disease associated with these bacteria. Also, these bacteria are unable to compete with spoilage bacteria and raw meat and meat products will spoil before the numbers of these bacteria can increase to levels where they are of concern to human health.

Growth of bacteria on carcase surfaces during chilling will generally be aerobic i.e. in the presence of air. Growth in cartons or on vacuum package meat will generally be anaerobic (without oxygen). The enteric bacteria we are most concerned with will grow both aerobically and anaerobically on meat, although they will grow a little slower anaerobically.

2.3 Behaviour of enteric pathogens during refrigeration of meat

As previously discussed, the growth of bacteria on meat during refrigeration is dependent predominantly on temperature and in the case of carcases surface drying. When bacteria contaminate meat, they go through a series of phases. These phases are called;

- Lag phase;
- Logarithmic growth (log) phase;

- Stationary phase; and
- Death (decline) phase

When considering the impact of refrigeration on bacterial numbers we are only concerned with the lag and log phases. The period of the lag phase and the rate of growth (growth rate) during the log phase are controlled by both external and internal factors. Generally, bacterial contamination of carcases is from the hide or intestinal tract of the animal or companion animals. These bacteria require time to adapt to conditions on the carcase surface; this time is known as the lag phase. The duration of the lag phase depends on the condition of the bacteria at the time of contamination and the conditions on the carcase. The further the conditions on the carcases are from ideal at the time of contamination the longer the lag phase. Once bacteria have adapted to the conditions on the carcase they begin to grow. The rate of growth is determined by the type of bacteria and the conditions on the carcase surface. If the conditions on the carcase surface remain constant the growth rate remains constant until the stationary phase is reached. For carton product contamination is as a result of transfer of bacteria from the carcase surface to the meat during boning, or through cross-contamination from the environment during boning. Bacteria transferred to meat during boning may not have a significant lag as they may already have adapted to growing on meat.

2.3.1 Science of predictive microbiology

Predictive microbiology is based upon the premise that the responses of populations of microorganisms to environmental factors are reproducible, and that by considering environments in terms of the environmental factors having the largest effect on those responses it is possible, from past observations, to predict the responses of those microorganisms. The responses of microorganisms to environmental conditions such as temperature, pH and water activity (a measure of the availability of water to the microorganism) are the most significant. Predictive microbiology utilises mathematical models (developed with data from laboratory testing) to describe these responses.

It is possible to measure the lag and growth rate of different bacteria under different conditions of temperature, pH and water activity in the laboratory. Such measurements can be made in artificial media or on meat. Measurements on meat are preferred but are the more difficult of the two methods. Under the same conditions the lag and growth rate should be constant. If enough measurements, under varying conditions, are made then it is possible to develop predictive models that can be used to estimate the lag and growth rate over a range of temperatures, pH and water activities.

2.3.2 *E. coli* predictive model

Generic *E. coli* is considered a surrogate for pathogenic bacteria such as STEC and *Salmonella*. It has a similar lag and growth rate to *Salmonella* when grown on meat and has been extensively used to model growth of enteric bacteria on meat. Researchers at the University of Tasmania developed a model for the growth of *E. coli* on meat that combined terms for high and low temperature, high and low water activity, high and low pH and dissociated and undissociated lactic acid (Ross et al, 2003). The model was then validated (Mellefont, et al., 2003) against a large number

of observations of the behaviour of *E. coli* in meat and meat products under a range of conditions and found to provide a reliable prediction of *E. coli* growth. The model is available as the Refrigeration Index Calculator (RI Calculator) (https://www.mla.com.au/extension-training-and-tools/tools-calculators/refrigeration-index-calculator/).

2.3.3 Choosing input parameters

The factors affecting bacterial growth in meat rate include temperature, water activity and pH. Undissociated lactic acid is also important in inhibiting growth. The amount of lactic acid in meat is determined by the amount of glycogen in meat at the time of slaughter which in turn is determined by the activity of the animal prior to slaughter. The more active the animal (i.e. the more stressed) the lower the glycogen level in the meat and therefore the higher the ultimate pH. Lactic acid and pH are interrelated.

The RI Calculator is set up to allow the input of time-temperature data as the only environmental factor. The other parameters using in the model (pH, water activity and lactic acid concentration) are more difficult to measure and/or change during the refrigeration of meat. For this reason, a fixed value has been chosen for these parameters. The value chosen is within the expected range of values such that the value is most favourable to bacterial growth. For example, during carcase chilling, the surface of the carcase becomes dry and the water activity falls, but the model uses the water activity expected on a wet carcase. The model therefore overestimates the growth of *E. coli* on carcases.

The RI Calculator allows the selection of a number of products. The parameters associated with each product type are indicated in the table below:

Meat type	**pH**	**Lactate(mM)**	**Water activity**
Carcase	6.5	51.7	0.993
Boxed trim	6.5	51.7	0.993
Lean Primal	5.4	86.5	0.993
Fat Primal	6.8	0	0.990
Offal	6.8	25	0.995
Mechanically separated meat	6.8	51	0.995

The RI Calculator also allows a lag phase to be applied to the growth calculation. The lag phase can only be used for the refrigeration of an initially hot carcase or hot boned product or offal after removal from a carcase, since these are the only processes that occur soon after the transfer of the microorganisms onto the meat surface.

2.3.4 Choosing acceptable growth

Growth is usually expressed in generations, with one doubling of bacteria being one generation. However, because this measure is exponential i.e. 2 give rise to 4, 4 to 8, 8 to 16 etc. it is difficult to graph and therefore generations are usually converted to $\log_{10}$ for the purposes of expressing the growth of bacteria. One $\log_{10}$ growth is approximately 3.3219 generations or a ten-fold increase in numbers. Two logs growth is a 100-fold increase in numbers and so on.

The RI is an expression of the potential growth of *E. coli* at the site of microbiological concern, calculated through the RI calculator, expressed in $\log_{10}$ units.

The choice of acceptable RI criteria were based upon:

- The existence and application of a microbiological monitoring program for carcase chilling and microbiological criteria for acceptable results
- An understanding that the outcome of refrigeration processes could be variable from day to day
- Criteria being applied in the New Zealand system
- An intention to maintain the hygienic quality of product, and conformity to existing microbiological criteria
- An intention to ensure that refrigeration processes were applied in a way that ensured the hygienic quality of all product

2.4 Regulatory requirements for refrigeration

Regulation relating to the chilling and freezing of meat and meat products (including carcases and offal) is detailed in AS 4696 and the Export Control (Meat and Meat Products) Orders 2005.

2.4.1 General requirements

The outcome for chilling and freezing under AS 4696 is that it maintains and does not jeopardise the wholesomeness of the product. The standard therefore deals with both safety and suitability. Refrigeration of carcases must be continuous and capable of achieving a surface temperature of no warmer than 7°C for carcases (AS4696 subparagraph 11.6(a)(i)) and 5°C for carcase parts (AS4696 subparagraph 11.6(a)(ii)), within 24h of stunning. The standard also sets RI criteria for the chilling of hot boned carcases and offal.

2.4.2 RI criteria

The following RI criteria are specified in both AS 4696 (for hot boned carcases and carcase parts) and Export Control Orders (for all refrigeration programs) in $\log_{10}$ units;

i) The refrigeration index average is to be no more than 1.5: and
ii) 80% of refrigeration indices are to be no more than 2.0; and
iii) No refrigeration index above 2.5

The RI is measured at the site of microbiological concern and from the time that product is first placed under refrigeration until all sites of microbiological concern have fallen below 7°C.

It is important to note that while most refrigeration processes are likely to meet both the refrigeration requirements in AS 4696 and the RI criteria, there may be some processes that meet AS 4696 but fail to meet the RI criteria. This may be the case for a chilling process in which there is a relatively slow initial fall in temperature, but a final carcase surface temperature of 7°C is still achieved in 24h. In this case, the RI results should be considered in addition to the AS 4696 requirements. Section 4 of this document deals with how to respond to RI results above the limit

2.5 Food safety outcomes

The outcome of effective refrigeration is product that is wholesome. By meeting the RI criteria hazards have been effectively controlled while assuring that product remains acceptable to consumers. In general, the assumption is made that products covered under these guidelines are intended to be cooked prior to consumption thereby eliminating most microbial hazards.

Effective refrigeration ensures that the numbers of bacteria are not so high as to result in gross contamination of the pre-cooking environment.

Refrigeration processes are verified through the National Carcase Microbiology Monitoring Program and the National Carton Meat Microbiology Testing Program as described in the department's Microbiological Manual for Sampling and Testing of Export Meat and Meat Products.

From time to time industry-based surveys are conducted that survey products for a broader range of microorganisms (Phillips et al, 2006a, 2006b, 2012, 2013).

Results from national monitoring programs and industry surveys consistently demonstrate that meat produced according to AS 4696 is of a high standard with respect to wholesomeness and food safety.

3 Validation and verification of refrigeration using the RI

These Guidelines are supplemented with various materials that may be required or useful for the use of the RI:

- RI calculator https://www.mla.com.au/extension-training-and-tools/tools-calculators/refrigeration-index-calculator/
- Nationally recognised training, unit of competency AMPA400 *Utilise refrigeration index*
- Meat Industry Training Advisory Council *Refrigeration Index Training Kit*

3.1 Basic techniques

3.1.1 Measuring temperature at the site of microbiological concern

As previously discussed, the water activity at the carcase surface falls rapidly during the initial stages of chilling when the temperature difference between the muscle and air is large. It follows that areas of the carcase that cool more quickly will have a higher water activity than areas that cool more slowly. Therefore, the predicted growth of *E. coli* (RI) will be overestimated at sites that cool slowly.

For beef carcases, the outside of the neck or point-end brisket are suitable sites for monitoring the RI. Of these the brisket site is the easiest to access. Probes should be placed just under the surface tissue (1-2mm); too deep and the RI will be overestimated. For smallstock it is recommended that the surface temperature be measured on the outside of the hind leg.

For bulk-packed carton product water activity is not limiting and growth is largely controlled by temperature. The site of microbiological concern is the thermal centre of the carton. Alternately, probes can be placed between plastic sheets at the centre

of the carton and removed after freezing by splitting the meat apart. The site of microbiological concern for vacuum packaged or individually wrapped product is between touching product with the tip of the probe located at approximately half the depth of the carton. If in doubt several probes should be used to determine where the slowest cooling site is in a product. This can then be used for future reference.

Temperature measurement must continue until the product is permanently below 7°C (carcases) or 5°C (carcase parts). Since E. coli will only grow at, or above, 7°C, The RI will not accumulate between 5 and 7°C; the probe is left in place in case the temperature rises above 7°C.

Over time it is the intention that all carcase and carton product types have the opportunity to be measured ensuring that positions in the refrigeration chambers are varied.

3.1.2 Using the RI calculator

The calculator provides an index for the estimated $\log_{10}$ growth of *E. coli*. It predicts the expected growth of *E. coli* on meat based on the temperature history of the product and other fixed parameters. The model allows for the user to enter data on the temperature of the product over time, while other parameters such as pH and water activity are set by choosing the type of product. The model requires the user to answer some questions about the conditions and the product. It is important to understand the ramifications of these questions to ensure that an accurate prediction is obtained. The user must decide if the starting temperature is hot or cold. This determines if a lag should be applied or not. For carcase chilling and hot boned cartons or hot offal, the starting temperature should be set to hot (i.e. select yes). It is then simply a matter of selecting the type of product and then entering the time interval between temperature measurement and the temperature history. For most applications a time interval between temperature measurements of 15 minutes is sufficient. Selecting different products sets different parameters for the pH, lactic acid concentration and water activity based on published information for these parameters in various meat products.

3.1.3 Handling data from sequential refrigeration processes

The RI criteria specified in the Export Control Orders apply to refrigeration of product from the first time that the product is placed under refrigeration until all surfaces of microbiological concern are permanently under 7°C. Essentially this means that the RI is cumulative throughout the process from carcase chilling to chilling or freezing of carcase parts. In practice, this means that each process, such as carcase chilling and refrigeration of boneless meat, must be considered to determine the overall RI (e.g. an RI of 1.1 for carcase chilling and 0.4 from boning to carton chilling will give a total RI of 1.5 for the entire chilling process). For conventionally chilled carcases the RI will be low as will be the RI for subsequent cooling of cartons.

For non-integrated operations it is important for subsequent operators to understand the refrigeration history of the product they are processing and if a calculation of the RI for their process is required. This will be particularly true of off-site chilling and freezing operations.

3.2 Defining a process

The RI criteria specified in the Export Control Orders apply to all refrigeration processes until all sites of microbiological concern are permanently less than 7°C and are cumulative. Some examples of different processes that will need to be considered include;

- Integrated establishments - primary chilling of carcases, pre-trim, boning, carton chilling or freezing, storage, load out, transportation (where applicable)
- Hot boning establishments - boning to carton chilling or freezing, transportation of chilled and frozen products
- Warm boning establishments - primary chilling of carcases, boning to carton chilling or freezing, transportation of chilled and frozen products
- Offal - chilling or freezing process, load out, transportation (where applicable)
- Independent boning rooms - receival, further processing, carton chilling and load out
- Off-site freezing – carcase and/or carton load out, transportation, receival, handling, freezing and load out, transportation (where applicable)

3.3 Validation of refrigeration

3.3.1 Initial validation of a process

A refrigeration process must be validated prior to approval by the Department of Agriculture, Water and the Environment (the department).

A refrigeration process can be described by parameters such as the capacity of the refrigeration units, the set points of the refrigeration program, for example for return air temperature and fan speed, and the air velocity over the product surface. Once these variables have been set the ability to consistently meet the requirements of the Export Control (Meat & Meat Products) Orders can be assessed by monitoring at the site of microbiological concern (see 3.1.1) and the RI determined for product held in the refrigeration room/apparatus for a specified period.

A minimum of 30 time/temperature histories should be obtained from various locations throughout the room or across rooms if the same parameter/profile is covering multiple chambers. Data collected can then be used to calculate the RI.

3.3.2 Revalidation of a process

A refrigeration process must be re-validated when any change that will affect the temperature at the commencement of refrigeration or the cooling rate is made to the operation. Such changes could include:

Boning Room

- Changed boning or packing procedures that affect the interval between boning and carton closure.

Offal / Tripe

- When a process has been changed that significantly alters the starting packed temperature of the product (eg. new tripe cooking parameters, ice bath offals etc)
- Changed procedures that affect the time before carton closure.

Carcase Chillers

- When a refrigeration profile or setting for the chilling of carcases has been changed.

Carton Refrigeration chambers

- When a refrigeration profile or setting for the chilling or freezing of cartoned product has been changed.

Packaging

- Significant changes with packaging that affect the chilling of product

3.4 Verification

There are two approaches that establishments can use for verification of refrigeration.

1. Verification through recording of refrigeration parameters
2. Verification through measurement of RI

3.4.1 Verification through recording of refrigeration parameters

Refrigeration parameters, defined during validation or revalidation (3.3) should be continually monitored to provide real-time feedback on the efficacy of the process.

Visual checks of carcase dryness (or some check on spray coverage in spray chilling) and spacing is also important for verifying effective refrigeration.

Real-time monitoring of refrigeration parameters will allow timely corrective actions to be undertaken in the event of a failure and provide historical data that can be useful in determining the disposition of carcases or carcase parts that have not received the validated process. Real-time monitoring is to be conducted with calibrated measuring devices and must comply with company-based set-points identified during validation.

3.4.2 Verification through measurement of RI

On-going verification of the refrigeration process should include determination of the RI for product undergoing the process. The frequency of measurement should be –

- One measurement of each carcase chiller refrigeration profile (set of parameters) that is in use, monthly
- One measurement of each carton boning room product type per month i.e., boneless manufacturing meat, chilled primal, frozen primal, bone-in chilled primal, bone-in frozen primal. (This must be a combined RI assessment with the carcase chiller measurement through to carton chilling or freezing of product).

- One measurement of hot boned product daily so each product type and refrigeration method is covered over the week, i.e., boneless manufacturing meat, chilled primal, frozen primal, bone-in chilled primal, bone-in frozen primal. These RI values can be useful for determining if there are any gradual changes in the process that might otherwise go unnoticed.
- One measurement of each carton offal room product type per month, i.e. chilled offal, frozen offal, tripe. **Note** – When selecting the carton for measurement, target known slower cooling offals i.e. Livers, bulk pack or offal that does not get subjected to a cooling step prior to packing (immersion into ice slurry after packaging). This is to cover worse case scenario in temperature cooling.

4 RI and product disposition when there is a refrigeration breakdown

4.1 Measurements required

In order to make a disposition decision in the event of a departure from the required refrigeration parameters (i.e. time and temperature), the department will require as much of the following information as possible.

4.1.1 Interruption of active chilling or initial freezing process:

If product temperature is being actively logged at the time of the interruption (and such logging is not affected by the interruption) then disposition will be made based on the RI calculated from the logged data with consideration of the representativeness of this data.

Otherwise as much of the following information as possible should be provided.

- Sides, quarters or carcases
  - Time when carcases/sides left the slaughter floor
  - Initial temperature of product (estimated from the weight range and historical data)
  - Time at which room was closed, and active refrigeration commenced
  - Air temperature and fan speed throughout process including the interruption
  - Product temperature immediately prior to interruption
  - Time of interruption
  - Product temperature immediately before resumption of process
  - Time of resumption of process
  - Any data that may help aggregate affected product according to risk.
- Cartons
  - Whether the affected product was hot-, warm- or cold-boned
  - Temperature of the product at the time of carton closure (or similar historical data)
  - Carton dimensions, style and board type
  - Identity of product in cartons
  - Time of boning, and time at which active refrigeration commenced

- Details of temperatures before, during and after the interruption (air temperature and fan speed, refrigerant suction temperature for plate freezer)
- Time when refrigeration was interrupted
- Product temperature at the time of the interruption and resumption of the normal process (avoid unnecessary entries during interruption);
- Time refrigeration resumed.

- During storage of frozen product
  Interruptions during frozen storage will not usually impact the safety of the product as temperatures are unlikely to rise above 0°C. Disposition will be based on observation of thawing and market access requirements.

4.2 Product disposition based on wholesomeness and safety

All information relating to an interruption in refrigeration will be assessed. The opinion of an independent microbiologist may be sought. Ideally, temperature logger data will be available to calculate RI. If logger data are not available, they may be able to be estimated from the refrigeration parameters listed above In the latter case, RI can be calculated using the estimated time/temperature history. If information is not available to calculate an RI, microbiological testing may be appropriate. Depending on the nature of the product, its intended use and the information available a disposition decision will be made by the department.
If the RI can be estimated and is:

- within acceptable limits i.e. <2 then product will be considered to have met the requirements of the Export Control (Meat & Meat Products) Orders.
- greater than 2.0 it is possible that product has not received adequate refrigeration, but assessment should be made on a case-by-case basis.

For RI results above 2.0, consideration may be given to the export of product or release domestically after consultation with the relevant state authority, considering the nature of the product, its intended use.
In breakdown scenerios, often only one or a small number of RI values are available to assess refrigeration conditions of the affected lots. Because of the small number of RI values and associated uncertainty, an RI value of 2.0 has been selected as the basis for the disposition decisions described above.

4.3 Microbiological data

Microbiological sampling and testing may be necessary when sufficient information is not available.
In cases where RI values are not available, or where RI values are `borderline' (i.e. in the range 2–2.5) and need to be supplemented with additional information, refrigeration breakdown samples should be sampled according to the Microbiological Manual for Sampling and Testing of Export Meat and Meat Products, with the following microbiological guidance criteria (ICMSF, 1986) used to assist in assessing whether refrigeration was acceptable or not acceptable. For products affected by the breakdown, a total of 15 samples should be sampled and tested. Sampling should be representative of each of the product types in the affected lot. Where offal and

boneless meat are affected, microbiological testing should be applied to products that are the slowest to cool.

	Total Viable Count (cfu/g or cm^2)			
Product Type	n	c	m	M
• Carcase Meat				
- before chilling	15	3	10^5	10^6
- chilled	15	3	10^6	10^7
- frozen	15	3	5×10^5	10^7
• Edible Offal (Slowest cooling product)				
- chilled	15	3	10^6	10^7
- frozen	15	3	5×10^5	10^7
• Boneless Meat (Slowest cooling product)				
- frozen	15	3	5×10^5	10^7

Product subject to to a refrigeration breakdown may be assessed as acceptable for immediate sale according to the criteria above, but the department's disposition decision will need to also consider transport time to the intended market and allowance for sufficient shelf-life, particularly if shelf-life requirements are specified by the importing country.

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