

# Guidelines for the safe production of dry aged meat



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## Contents

<b>Glossary of terms and abbreviations.....</b>	<b>4</b>
<b>About these guidelines.....</b>	<b>6</b>
<b>Introduction .....</b>	<b>8</b>
<b>Part 1: Hazards and risks in dry aged meats .....</b>	<b>10</b>
Hazards .....	10
Risks .....	11
Bacteria - likelihood and ability to grow during the dry ageing process.....	11
Summary - bacterial hazards and risks.....	12
Moulds - likelihood and ability to grow during the dry ageing process.....	12
Summary – mould hazards and risks.....	13
<b>Part 2: Food Safety Plan (FSP) for dry aged meats.....</b>	<b>14</b>
Pre-requisite programs.....	14
HACCP plan.....	15
<b>Part 3: Dry aged meat.....</b>	<b>17</b>
GMPs.....	17
Calibration .....	17
Receiving and storing raw materials.....	18
Receiving and storing packaging material.....	18
Ultra Violet (UV) Lighting .....	18
Airflow .....	19
Relative humidity (RH) .....	19
Final product trimming and packing.....	19
Microbiological profile of dry aged meats.....	20
HACCP controls.....	21
RCP1: Receival of meat .....	21
RCP2: Storage and handling of meat .....	21
CP1: Temperature control.....	21
CP2: Relative humidity and airflow.....	21

<b>Part 4: Construction and cleaning</b> .....	<b>22</b>
Specific information for dry ageing .....	22
General information on construction and cleaning .....	23
Construction of the processing plant.....	23
Cleaning the plant.....	24
Soils .....	24
Cleaning.....	24
Detergents.....	24
Sanitisers .....	25
Applying cleaning solutions .....	25
Choosing systems and cleaning solutions .....	25
Costs of cleaning .....	25
Work instructions.....	26
Some do's and don'ts .....	26
<b>Part 5: Frequently asked questions</b> .....	<b>27</b>
How effective are salt walls? .....	27
Is dry aged meat wholesome? .....	27
What if mould grows on the meat during the dry ageing process?.....	28
Is it desirable to have mould growth on dry aged meat?.....	28
Thamnidium, Mucor and Rhizopus and enzyme production?.....	28
Do Rhizopus and Mucor cause illness in consumers? .....	29
Validation of the dry ageing process via testing for Thamnidium? .....	29
My auditor insists that I must validate shelf life of my dry aged product by testing for indicator bacteria – is there any scientific validity in this?.....	29
I vacuum pack my dry aged cuts – do they have extended shelf life?.....	29
<b>References</b> .....	<b>30</b>

## Glossary of terms and abbreviations

<b>Ambient temperature</b>	Temperature of the air around you or the product
<b>AMIC</b>	Australian Meat Industry Council
<b>CCP</b>	Critical Control Point. A point, procedure, operation or stage in a process at which a hazard is prevented, eliminated or reduced to an acceptable level
<b>CFU</b>	Colony Forming Unit, an estimate of viable number of bacteria
<b>CL</b>	Critical Limit – the limit to which a hazard must be controlled at a CCP to prevent or reduce to an acceptable level the occurrence of the identified food safety hazard
<b>Cold chain</b>	The process of maintaining foods under refrigeration, in either a chilled or frozen state, during storage, distribution and marketing
<b>Contaminant</b>	Something which may make food unsafe or unwholesome. Examples of contaminants are microorganisms, chemical residues or metal specks
<b>Controlling Authority</b>	The Commonwealth, State or Territory authority which is responsible for the enforcement of standards
<b>CP</b>	Control Point
<b>DA</b>	Dry aged (DA) meat is meat produced under defined conditions of time, temperature, relative humidity and air flow
<b>FSP</b>	Food Safety Plan
<b>GMP</b>	Good Manufacturing Practice
<b>HACCP</b>	Hazard Analysis Critical Control Point is the system which identifies and controls those hazards which pose a significant risk of food safety
<b>Hazard</b>	A biological, chemical or physical agent which may compromise or affect food safety
<b>Log</b>	Logarithm — used to express microbial counts e.g. log 2 is 100 is 10 <sup>2</sup> or, log 3 is 1,000 is 10 <sup>3</sup>
<b>Microbial count</b>	The number of microorganisms living in or on a food product

<b>Microbiological limits</b>	The maximum number of microorganisms specified for a food product
<b>Microorganisms</b>	Viruses, yeasts, moulds and bacteria
<b>MPN</b>	Most Probable Number. Method used to determine bacterial numbers based on probability concept instead of counting colonies
<b>Pathogen</b>	A microorganism which causes illness
<b>pH</b>	A measure of acidity or alkalinity
<b>Production</b>	Production is defined as in AS 4696:2007 clauses (c) and (d)
<b>PRP</b>	Pre-requisite program
<b>QCP</b>	Quality Control Points
<b>QUAT</b>	Quaternary ammonium compounds
<b>RCP</b>	Regulatory Control Point
<b>RI</b>	Refrigeration Index
<b>Shelf life</b>	Length of time that a commodity may be stored without becoming unfit for use or consumption, due to loss of quality, the presence of undesirable chemicals, toxins, or growth of pathogens
<b>Spoilage bacteria</b>	Bacteria which limit the shelf life of foods by producing objectionable odours, colour or slime
<b>SSOP</b>	Sanitation Standard Operating Procedures
<b>Toxin</b>	A chemical which can cause illness. Toxins may be produced in food by bacteria
<b>Validate, validation</b>	The process of obtaining evidence to demonstrate that hazards in a food process are controlled and compliance with standards
<b>Verify, verification</b>	Means applying methods, procedures, tests and other evaluations in addition to monitoring to determine whether a requirement is complied with or a matter is met
<b>Wet aged</b>	Wet aged meat is meat stored under vacuum conditions in sealed bags.

## About these guidelines

The purpose of these guidelines is to provide a nationally consistent set of principles for dry ageing (DA) of beef and sheep meat that ensures:

- public health and safety
- premium eating quality
- economic viability of production

Information about DA has been fragmented, incomplete, and difficult to find. Meat regulations are administered via state legislation and considerable variation exists between states for DA. These national guidelines will support export of DA meat as well as encourage production for the domestic market; companies will need to liaise with the Department of Agriculture and Water Resources (DAWR) if their intention is to export.

In November 2017 Meat & Livestock Australia (MLA) brought together scientists, processors of DA meats and regulators to consider the DA process from the food safety viewpoint. The team considered research and development projects undertaken in Australia, as well as international scientific publications, and commissioned a review by CSIRO on mycological hazards which might be associated with the DA process.

A writing group formulated these guidelines from information in the literature and a consensus of viewpoints expressed by the working group:

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## What you need to do after reading these guidelines

Review your work instructions or monitoring forms – only you can do this, for your individual operation, and for approval by your controlling authority.

Set out how to meet all the provisions of the *Australia New Zealand Food Standards Code*. You need to do this before your regulator will sign-off on your food safety plan:

- Standard 1.2 Labelling (ingredients, allergens, date marking)
- Standard 2.2.1 Meat and Meat Products
- Standard 3.1.1 (Interpretation and Application)
- Standard 3.2.1 (Food Safety Programs)
- Standard 3.2.2 (Food Safety Practices and General Requirements)
- Standard 3.2.3 (Food Premises and Equipment)
- Standard 4.2.3 (Production and Processing Standard for Meat)
- AS 4696:2007 (Australian Standard for Hygienic Production and Transportation of Meat and Meat Products for Human Consumption)

## What these guidelines help you do

In these guidelines, we aim to:

- update you on hazards and risks in your products,
- suggest ways you can reduce risk to your customers,
- supply scientific backing for your Food Safety Plan,
- provide background information so you meet regulatory requirement for skills and knowledge for safe production of all your products.



## Introduction

The eating quality of red meat has long been known to depend on ageing and this has been built into various guidelines for eating quality. For example, to be graded under the Meat Standards Australia (MSA) system chilled lamb has to be aged for a minimum of five days when electrical stimulation has been used during processing. During this time proteolysis reduces shear force that results in an improvement in tenderness and eating quality.

The extended ageing of meat beyond those specified for fresh meat requirement has been less common practice in the Australian meat industry. However, DA has been used since ancient times with the key principles being:

1. The formation of a dry crust on the surface of the meat formed by exposure to air and drying conditions that prevent microbial growth,
2. An extended ageing period in the order of 21 days or more to improve tenderness and flavour.

University of Melbourne research indicates that the market for DA in the USA was \$10.4 billion in 2015 and is estimated to reach \$11.2 billion by 2020. Key consumers are LOHAS (Lifestyles of Health and Sustainability), meat lovers, selective foodies and premium players for whom DA meat is an affordable luxury providing a unique sensory experience in flavour and tenderness.

In Australia DA is expected to bring new value of \$3.5 million to the sheep meat industry with a 20-30% premium over wet-aged lamb. In the beef sector DA beef is typically double the price of its wet-aged equivalent cut.

To measure the effect of dry *versus* wet ageing, the University of Melbourne undertook trials in which meat was aged, either wet or dry, for varying durations and then cooked steaks and submitted to 600 panelists (untrained) over ten sessions. Panelists assessed tenderness, juiciness, flavour plus overall like of steaks aged by the two methods and overwhelmingly preferred DA meat aged for 5 or 8 weeks over the wet aged meat (Warner *et al.* 2018).

In Australia DA is becoming popular among consumers prepared to pay a high price for a unique sensory experience and a number of studies have been undertaken both of the scientific and technical aspects of DA.

In April 2010, CSIRO published: *Dry ageing of beef* (Meat Technology Update 2/10), citing existing literature predominantly from USA, and focusing on a comparison with ageing in vacuum packs (so-called wet ageing). Consideration of the microbiological aspects of ageing was confined to recognising that wet ageing results in high numbers of lactic acid bacteria (LAB) favoured by the gaseous atmosphere in vacuum packs. In contrast, LAB do not grow on DA meat, which is likely to have a low bacterial population due to the reduced water activity at the meat surface once a dry crust forms.

Research undertaken by University of Melbourne undertook trials on dry and wet ageing of beef demonstrated that the DA process should:

- use meat with moderate to high fat cover with some marbling in the meat,
- be undertaken in a narrow temperature range close to 0°C,
- have sufficient airflow to dry the surface to prevent mould and bacterial growth,
- control humidity between 75-85% to enable drying with commercially-acceptable weight loss.

At the manufacturing level, two consumer studies have recently been undertaken at Australian processing plants. Firstly, Burvill (2016a, 2016b) provided information on DA lamb from a purpose-built facility in South Australia; microbiological information is included both on indicator and pathogenic bacteria, and on yeasts and moulds.

Secondly, dry ageing of beef was studied by Galletly (2016) who proposed DA Guidelines, including process parameters and a HACCP program (Galletly & Bonney, 2015), the latter providing material for the current document.

Presently there is some variability between jurisdictions on the hazards and risks accruing from the DA process and the primary purpose of these guidelines is to assess these in a risk assessment context.



## Part 1: Hazards and risks in dry aged meats

### Hazards

The DA process begins with carcasses and carcase parts which have been produced at premises with an arrangement approved and overseen by the relevant controlling authority and conforming with the *Australian Standard for the hygienic production and transportation of meat and meat products for human consumption* (AS 4696:2007). The approved arrangement (AA) is underpinned by a Food Safety Plan (FSP) and, in the guidelines, the term FSP will be used because it is term with which food businesses are familiar.

Under the Standard, meat enters the DA premises at no warmer than 7°C (carcasses and quarters) or 5°C (carcase parts), where it will be processed according to the regime described in Figure 3.1.

From the aspect of microbiology, the meat will normally be expected to have a range of bacteria and moulds which will include both spoilage and pathogenic organisms.

According to the US Food and Drug Administration “*HACCP Principles & Application Guidelines*” the purpose of the hazard analysis is to develop a list of hazards which are of such significance that they are reasonably likely to cause injury or illness if not effectively controlled. Hazards that are not reasonably likely to occur would not require further consideration within a HACCP plan.

Bacteria of primary importance in the DA process are pathogenic, disease-causing bacteria, of which those reasonably likely to be present on incoming meat include:

- *Salmonella* sp.
- pathogenic *Escherichia coli*
- *Staphylococcus aureus*
- *Listeria monocytogenes*

Note that *Clostridium botulinum* and *C. perfringens* are not included because they are anaerobic, and cannot grow during the dry ageing process.

The prevalence of pathogenic bacterial hazards reasonably likely to occur is presented in Table 1. Moulds reasonably likely to be present on meat include:

- *Penicillium* sp.
- *Aspergillus* sp.
- *Cladosporium* sp.
- *Thamnidium* sp.
- *Rhizopus* sp.
- *Mucor* sp.
- *Aureobasidium* sp.

## Risks

When assessing risk, two components require consideration:

1. The likelihood of the hazard being present in the product at a level which can cause illness when the product is consumed,
2. The severity of the consequences when exposure to the hazard occurs i.e. how serious is the illness.

### Bacteria - likelihood and ability to grow during the dry ageing process

The likelihood that pathogenic organisms will be present at the start of the DA process may be judged from Table 1.

**Table 1:** Prevalence of target bacterial pathogens on carcasses/carcase parts used for dry ageing (Phillips *et al.* 2012a, 2012b, except for \*\*)

	Beef	Sheep
<i>Salmonella sp.</i>	nd*	1.9%
<i>E. coli</i> O157:H7	0.1%**	0.25%
<i>Staph. aureus</i>	9.0%	4.7%
<i>L. monocytogenes</i>	0.1%	nt***

\* nd means that these bacteria were not detected ('found') in these particular surveys. In fact, these bacteria are found only very rarely on raw meat (and other foods).

\*\* Data available from *E. coli* Salmonella Monitoring (ESAM) program (SARDI personal communication)

\*\*\* nt means not tested

Since target pathogens will sometimes be present, the key question is: under the surface conditions resulting from the DA process can any of the pathogens grow to a level where they can cause illness?

It is well established that the temperature and ambient RH conditions of the DA process prevent growth of pathogenic bacteria (see ICMSF, 1996; AIFST, 2003). As seen from Table 2 none of the pathogens found on meat are able to grow under the DA process regime due to either temperature being too low and/or the water activity (dryness) being too low

**Table 2:** Expected growth of bacteria with the controls inherent in the DA process (Anon. 1996)

	Temperature (-0.5 to +3°C)	Dry surface crust (Ambient RH 75-85%)
<i>Salmonella sp.</i>	No growth	No growth
<i>E. coli</i> O157:H7	No growth	No growth
<i>Staph. aureus</i>	No growth	Very slow growth
<i>L. monocytogenes</i>	Slow growth	No growth

### Summary - bacterial hazards and risks

While there are several bacterial pathogens commonly present on raw meat, the low temperature and relative humidity of the DA process prevents their growth increasing from the very low levels normally present on raw meat in commerce.

### Moulds - likelihood and ability to grow during the dry ageing process

There are two key references describing the fungi which produce toxins (Anon. 1996; Pitt & Hocking, 2001), both focusing on the three main genera which produce mycotoxins: *Penicillium*, *Aspergillus* and *Fusarium*.

Brown (1982) lists a number of moulds found on raw meat, and states that they can “appear on the surface of chilled beef sides after 4-6 weeks storage”. Of these *Cladosporium* has a long history of being of economic importance because it produces black spots on frozen meat. Gill *et al.* (1981) and Gill and Lowry (1982) investigated meat with black spot in ten New Zealand abattoirs. They were able to isolate four species capable of producing black spot on meat held as cold as -6°C: *C. cladosporioides*, *C. herbarum*, *P. hirsutum* and *A. pullulans*.

The same authors also isolated *Aspergillus*, *Thamnidium* and *Chrysosporium* that were capable of growing at -1°C on NZ meat, though none produced black spots (Table 3).

**Table 3:** Moulds associated with meat held under refrigeration temperatures

Genus / species	Minimum temperature for growth (°C)	Reference
<i>Penicillium</i>	See Table 4	Brown (1982)
<i>P. hirsutum</i>	-5 to -6	Gill and Lowry (1982)
<i>Cladosporium</i>	-6	Brown (1982)
<i>C. cladosporioides</i>	-6	Gill and Lowry (1982)
<i>C. herbarum</i>	-5	Gill and Lowry (1982)
<i>Thamnidium</i>	-1	Brown (1982); Gill <i>et al.</i> (1981)
<i>Chrysosporium</i>	-1	Brown (1982), Gill <i>et al.</i> (1981)
<i>Mucor</i>	-1	Brown (1982)
<i>Rhizopus</i>	-1	Brown (1982)
<i>Aspergillus spp</i>	-1	Gill <i>et al.</i> (1981)
<i>Aureobasidium pullulans</i>	-5	Gill <i>et al.</i> (1981)

Again the key question is: can any potentially toxigenic genera produce toxin during the DA process?

Minimum temperatures for production of toxin by *Aspergillus* and *Penicillium* are summarised in Table 4 (Anon. 1996; Pitt and Hocking, 2003) and indicate that, even if these species were present on meat at the start of the DA process, toxin production would be unlikely provided the temperature and humidity conditions were met. Given the minimum temperatures for growth and toxin production (Table 4) there are no food safety implications from the fungal genera cited for DA prepared this way.

**Table 4:** Minimum temperatures for growth and toxin production of *Aspergillus* and *Penicillium* species (after Anon. 1996; Pitt and Hocking, 2003)

Organism	Minimum temperature (°C)	
	Growth	Toxin production
<i>A. flavus</i>	10-12	13
<i>A. parasiticus</i>	12	12
<i>A. ochraceous</i>	8	12
<i>A. versicolor</i>	9	unknown
<i>P. citreonigrum</i>	<5	10
<i>P. citrinin</i>	5-7	<15
<i>P. islandicum</i>	10	Unknown
<i>P. verrucosum</i>	0	4

### Summary – mould hazards and risks

While there are several mould genera commonly present on raw meat, no pathogenic or toxigenic species is capable of growing to a level associated with illness due to the low temperature and relative humidity used in the DA process.

The foregoing risk assessment is confirmed by information provided in a CSIRO report prepared by Olivier (2018) who states: “*There is no evidence that the moulds typically associated with red meat (cold-stored or dry-aged) are capable of producing mycotoxins at between -0.5 and +3°C and 75-85% RH, as typical during the dry ageing of red meat, and are therefore most unlikely to pose a risk to human health*”.

The full report “*Assessment of the mycological risks associated with the dry ageing of meat*” was reviewed and its findings supported by Australia’s pre-eminent mycologists, Dr Ailsa Hocking and Dr John Pitt.

## Part 2: Food Safety Plan (FSP) for dry aged meats

A food safety plan has three parts:

1. Good Manufacturing Practices (GMPs),
2. Sanitation Standard Operating Procedures (SSOPs),
3. Hazard Analysis Critical Control Points (HACCP).

The first two are sometimes called pre-requisite programs (PRPs) because they need to be specified and implemented before HACCP can successfully ensure a safe product.

### Pre-requisite programs

Pre-requisite programs underpin the Food Safety Plan. They contain all the steps and procedures that control the operations within the food business, together with the documents needed and the records that have to be kept. Often divided into Standard Sanitation Operating Procedures (SSOPs) and Good Manufacturing Practices (GMPs), these programs include:

1. Premises, both inside and outside must be properly constructed, lit and ventilated. Employees need access to toilets and hand wash stations. The water supply must be potable,
2. Premises need to be cleaned at various stages during the process (see Part 4) and kept free from pests,
3. Transport vehicles must be properly constructed and kept clean,
4. Suppliers should be approved and products stored according to AS 4696:2007,
5. Staff should be trained with the skills and knowledge sufficient to do their tasks,
6. A recall program is needed,
7. A regular maintenance schedule,
8. Calibration of equipment,
9. A pest control program.

Only when you have these pre-requisite programs set up can you operate a Food Safety Plan.

Part 4: Construction and cleaning provides the detailed information that you will need to develop your pre-requisite programs.

GMPs are covered in Part 3 (Food Safety Plan).



## HACCP plan

The HACCP plan controls food safety hazards at all stages of food production; it is based on a series of steps developed by the Codex Alimentarius Commission:

- Step 1: HACCP team roles and responsibilities
- Step 2: Description of each product type and packaging format
- Step 3: Intended use of each product
- Step 4: Process flow diagram
- Step 5: Verify the flow diagram
- Step 6: Identify all hazards
- Step 7: Determine Critical Control Points (CCPs)
- Step 8: Establish Critical Limits (CLs) for each CCP
- Step 9: Set up a monitoring and checking system at each CCP
- Step 10: Establish Corrective Actions
- Step 11: Establish a verification system
- Step 12: Maintain records

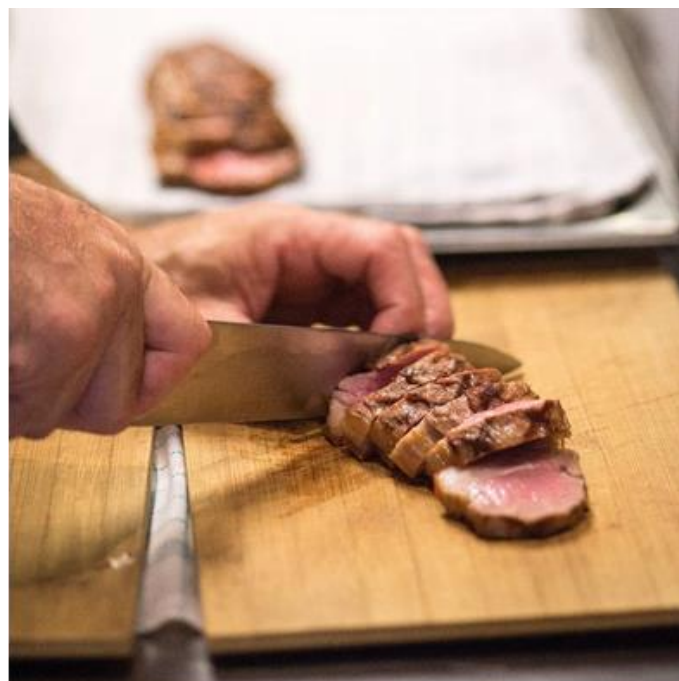
For an operation to fulfil the definition for a CCP it must achieve one of the following:

1. prevent the hazard, or
2. eliminate the hazard from the product, or
3. reduce the hazard to an acceptable level

A key question is - are there any CCPs in the DA process?

Considering the three criteria (above) which define a CCP:

- hazards can't be prevented because they will enter the DA facility on the meat itself (see Tables 1 and 3),
- the DA process won't eliminate hazards,
- the DA process won't reduce hazards to an acceptable level,
- there is a CCP for hazards in DA meat and it is the same as the CCP for all other forms of raw meat: cooking before consumption.





To construct a HACCP plan, hazard control worksheets, which describe how hazards are controlled at each stage of the process, need to be developed (for example as in Table 5). Some worksheets include a form of risk rating based on the likelihood of a hazard occurring and its severity when it does. Appendix 1 specifies risk ratings for each microbiological hazard.

**Table 5:** Example of a hazard control worksheet

Process step	Hazard	What can go wrong	Hazard control
	BIOLOGICAL		
	CHEMICAL		
	PHYSICAL		

CCPs are important parts of the process and require rigorous monitoring to ensure that the process stays in control and does not breach a Critical Limit - a criterion which separates acceptability from unacceptability. CCPs are monitored using a HACCP audit table similar to Table 6.

**Table 6:** Example of a HACCP audit table

Critical Operation	Hazard	Critical Limit	Monitoring				Corrective Action	Records	Verification
			What	How	When	Who			

Generic DA Hazard analysis and Hazard Audit Tables are presented by Galletly and Bonney (2016). It can be found at:

<https://www.mla.com.au/download/finalreports?itemId=3148>

## Part 3: Dry aged meat

Dry ageing of meat comprises a process of storage at low temperature and low humidity of carcasses and carcase parts for an extended period of time, after which products are prepared for retail sale and for further preparation in the food service sector.

A valid dry ageing process is one in which:

- Meat is received at a temperature which conforms with AS 4696:2007 (carcasses no warmer than 7°C and carcase parts no warmer than 5°C)
- The FSP specifies ranges for temperature, air speed and relative humidity under which the meat is held for the ageing process
- The process must be carried out only in a chamber capable of controlling the specified parameters, and in which only DA meat is stored
- Finished products must be wholesome and stored and transported no warmer than 5°C

### GMPs

In Figure 3.1, the process flow diagram for DA meat are presented. To undertake these operations, staff will need a set of work instructions. Since these are specific for each operation and will need to conform with the requirements of your controlling authority, we will not include them in the guidelines.

### Calibration

All equipment used to monitor a process must be checked for accuracy and calibrated regularly and in accordance with your Food Safety Plan.

The first step is to identify every piece of equipment which needs calibrating, such as:

- **Thermometers and gauges** on cool rooms need to be calibrated close to the range where the thermometer is routinely being used (close to 0°C). User manuals contain useful information on the thermometer and it is a good idea to keep them for reference. The CSIRO Meat Research Newsletter, Number 91/2 *'Thermometers'* also contains useful information on calibration. It can be found at: [http://www.meatupdate.csiro.au/data/MEAT\\_RESEARCH\\_NEWS\\_LETTER\\_91-2.pdf](http://www.meatupdate.csiro.au/data/MEAT_RESEARCH_NEWS_LETTER_91-2.pdf). Most medium and large-size premises have a reference thermometer calibrated by a National Association of Testing Authorities (NATA) accredited laboratory. This is used only for calibrating working thermometers. The reference thermometer should be calibrated annually by a service company accredited by NATA to perform the calibration.

- **Relative humidity probe** is a vital part of the monitoring equipment. It may be combined with a temperature measuring device or may be able to record RH on a data logger. Whichever type you use, it should be calibrated according to the manufacturer's instructions or in line with your approved Food Safety Plan.
- **Scales** should be calibrated according to the manufacturer's requirements or in line with your approved Food Safety Plan.

The next step is to make a schedule for calibrating all the equipment on the list.

#### **Receiving and storing raw materials**

When raw materials are received they need to be inspected for wholesomeness, and specifications such as temperature must be checked (no warmer than 5°C for carton meats and 7°C for carcasses).

Receival and storage temperatures are regulated under the Australian Standard (AS 4696: 2007) and there is no tolerance for temperatures warmer than those stipulated, except under an approved program.

Records must be kept so that any production lot/batch which causes a problem can be traced back.

Returned goods should be clearly identified and stored in a designated area.

Once accepted, raw materials should be:

- moved to storage or directed to processing as soon as possible,
- maintained at appropriate temperatures for safety and quality,
- protected against contamination or damage,
- stored in their own, or in clean, containers on racks or shelves to ensure no contact with the floor.

#### **Receiving and storing packaging material**

Packaging materials and packaging practice used should comply with the Australian Standard: AS 2070: 1999, *Plastics Materials for Food Contact Use*.

Store packaging in a dust and vermin proof room, on racks above the floor so that it is easy to clean underneath. Records of the packaging code and batch number need to be kept to ensure affected product can be traced if a problem occurs.

#### **Ultra Violet (UV) Lighting**

UV radiation is extremely effective in killing or damaging microorganisms on carcasses and carcass parts. Microorganisms take longer to begin to grow when they are exposed to UV light (i.e. their lag time is longer) and when they eventually do begin to grow, their rate of increase in numbers is slower.

UV lights will provide the best opportunity to control microorganisms in the DA room if they are focused on:

- air leaving the evaporator,
- air returning to the evaporator,
- direct product surfaces.

The UV light units need to be serviced according to the maintenance schedule and at intervals of 6 months. The service includes cleaning protective covers and changing of tubes regardless of tube performance.

The CSIRO Meat Tech Update of August 2002 ‘*UV light and its effect on fresh meat*’ provides useful information. It can be found at <http://www.meatupdate.csiro.au/UV-light.pdf>.

### **Airflow**

The speed that air flows over the meat surfaces is important for hardening the outer meat layers (“crust formation”) to minimise microbial growth. The recommended airflow at the meat surface is 0.2-0.5m/s; airflow faster than 0.5m/s will reduce product yield with no gain in food safety.

The evaporator needs to be checked to make sure it is clean and there is no impediment to airflow.

The evaporator is also pivotal in keeping the RH within your specified range (see below).

### **Relative humidity (RH)**

The range of RH recommended by CSIRO (2010) and the University of Melbourne studies is broad (75-85%); maintain it within this band to prevent excessive weight loss (<75%) and reduce the possibility of mould growth (>85%).

The evaporator is important and you will need to maintain:

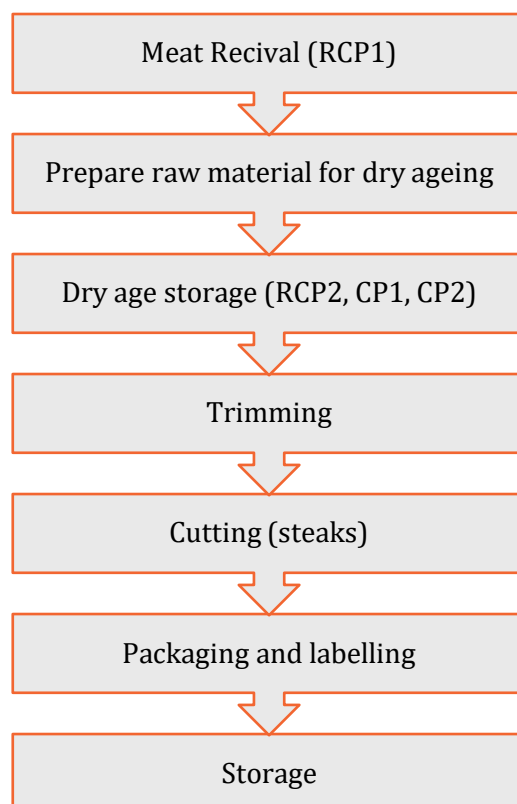
- performance of defrost – monitor time to defrost evaporators,
- fan blade condition – monitor blade damage, build up dust,
- fan motor condition - monitor amperage draw and bearing condition,
- protective covers - monitor cleanliness.

Control of RH depends on the type of refrigeration used in the ageing chamber. For large chambers a refrigeration engineer will be able to set the system to achieve the required RH range. Smaller DA chambers may have in-built humidity controls.

### **Final product trimming and packing**

When the DA process is completed, the meat is rendered wholesome by trimming and the trimmings are discarded as waste.

Finished products are placed on trays and transferred to the packaging area. Batch identification details are transferred to the packaging area to ensure traceability and accuracy in labelling.

**Figure 3.1:** Process flow diagram for dry age meat

### Microbiological profile of dry aged meats

Comprehensive microbiological data for Australian dry aged meat are not yet available. However, a small database exists from the work of Burvill (2016a, b). On entry to the dry ageing process, lamb primals (leg, loin and forequarters) had a loading of total bacteria (TVC) and *E. coli* typical of that established in national baseline surveys of Australian sheep meat. Yeasts were isolated from 5 out of 6 primals (mean log 0.6 cfu/cm<sup>2</sup>) and moulds from 1 out of 6 primals (1.25 cfu/cm<sup>2</sup>).

After 33 and 39 days of dry ageing at 0-2°C and 70-80% RH the total bacterial loading was reduced by two log scales (99%); *E. coli* was not detected from any of the six primals; yeasts were found on one primal (0.25 cfu/cm<sup>2</sup>) and mould on 2 out of 6 primals (0.25 and 0.75 cfu/cm<sup>2</sup>). *Salmonella* was recovered from none of four composite samples, each of 25g.

It is intended that further information on the microbiology of Australian DA meat will be collected in the near future.

## HACCP controls

There are Regulatory Control Points (RCPs) and Control Points (CPs) involved in the DA process.

### RCP1: Receival of meat

AS 4696:2007 specifies maximum receival temperatures of 7°C for carcasses and 5°C for carcass parts at the site of microbiological concern (meat surface). Both temperatures were set by Meat Standards Committee and reflect the minimum growth temperature for Gram-negative pathogens such as Salmonella and E. coli O157 (7°C) and the temperature specified in *Standard 3.2.2 - Food Safety Practices and General Requirements* of the code for food on display (5°C).

### RCP2: Storage and handling of meat

Temperatures for these phases are also regulated by AS 4696:2007 for receival of meat, with the exception being when meat is being processed, such as boning, slicing and packing, at which time the ambient temperature in the processing area may rise to 10°C.

### CP1: Temperature control

You will need to age meat in a temperature range specific for your operation (CSIRO recommend -1 to +2°C) and monitor on a daily basis.

### CP2: Relative humidity and airflow

CSIRO's Meat Technology Update "Dry ageing of beef" has information on airflow and relative humidity, available at:

[http://www.meatupdate.csiro.au/data/MEAT\\_TECHNOLOGY\\_UPDATE\\_10-2.pdf](http://www.meatupdate.csiro.au/data/MEAT_TECHNOLOGY_UPDATE_10-2.pdf)

You will need to age meat within the range of RH that suits your operation (CSIRO recommend a range of 75-85%) and monitor on a daily basis.

Airflow has an influence on RH and CSIRO recommend a range of 0.2-0.5m/s. The airflow will vary through the ageing room – fastest at the blowers and slowest at the far end of the room. The CSIRO recommendations are aimed at the parts of the room with the slowest airflow, so you will need to check all section of the room are in the specified zone.

Monitoring temperature and RH is straightforward device that you can purchase, which measures both elements. You can install data loggers which give you a record, or use handheld devices and record data for audit purposes.

## Part 4: Construction and cleaning

### Specific information for dry ageing

Dry ageing is done over many weeks during which you will probably be introducing product into your ageing room at various intervals. This will affect the temperature and RH of the room to a relatively small extent and both parameters should return to your specified range.

It is unlikely that your ageing room will be empty so you will need to clean it while product is present.

Here are some aspects to think about when cleaning your ageing room:

- do as much dry cleaning as possible – every time you bring in water the temperature and RH increase,
- use a scraper to free solids on the floor, and then remove them by brushing,
- if you need to clean using water, try to do it when the room is either empty or almost empty to prevent aerosols contaminating product,
- turn the fans off to prevent aerosols contaminating product,
- “spot clean” where needed using minimal quantities of water and detergent,
- use a no-rinse sanitiser such as a Quaternary Ammonium compound (QUAT) to minimise water use,
- dry all moisture off walls, floors and ceilings using squeegees, sponges and paper towels,
- routinely check the refrigeration unit – if there is mould on the fans, grilles and drip trays get up there and clean/sanitise, then dry them,
- in summary, forget the hose, just scrape and mop.

It is desirable to keep the level of mould spores in the air column as low as possible. If you encounter moulding of your meat one cause may be that there is a build-up of mould spores in the refrigeration unit and these are being blown constantly over the meat.

Using UV lights is one preventive mechanism but if the contamination in the refrigeration units is significant you have little choice but to shut it down, move product to another chiller and do a thorough clean of the unit.

Thorough cleaning and fogging is the best way to get the refrigeration unit clean again. Foggers saturate the atmosphere with sanitiser, which is then pushed all around the chiller by the blowers, including through the evaporator fins and both sides of the fan blades. A mobile fogger will suit most premises and your chemical supplier can assist with selecting a no-rinse sanitiser which is effective against mould spores and bacteria. A contact time around 15 minutes is sufficient and a further 30 minutes will allow the sanitiser to settle on all surfaces.

After fogging, dry large chambers with a hot air blower and then restore your target temperature and RH ranges before re-installing product.

## General information on construction and cleaning

### Construction of the processing plant

In this section we cover the design and construction of the premises.

It does not matter whether you operate a dedicated DA plant or make DA products in the back of a butcher's shop, you must work in clean premises and use equipment and techniques which supply safe products.

The AS 4696: 2007 contains information on how food businesses should be designed and built. Some states and territories also have individual standards that may apply.

In general, standards are either prescriptive or outcomes-based. Prescriptive standards specify every last detail that must be met e.g. the arc needed for coving between wall and floor. Outcomes-based standards specify only that you need to achieve a safe product. With outcomes-based standards, the details of how you achieve a safe product must be included in your food safety plan. Your local controlling authority will have copies of these standards.

There are some basic fundamentals that must be addressed in a well-designed and constructed premises. These include:

- having a safe water supply and one which supplies sufficient for all your food business needs,
- Maintaining food contact surfaces in good, clean condition,
- Preventing cross-contamination from insanitary objects,
- maintaining hand washing, hand sanitising and toilet facilities,
- protecting food, food packaging materials and food contact surfaces from adulteration with lubricants, fuel, pesticides, cleaning compounds, sanitising agents, condensate and other chemical, physical and biological contaminants,
- labelling, storing and using toxic compounds in a safe manner,
- controlling employee health,
- excluding pests,
- confining and removing wastes.

These elements prevent the contamination of materials and final products with microorganisms from people, equipment and the workplace environment, or with chemicals used in food plants. Pre-requisite programs need to be in place to manage these elements.

The requirements in *Standard 3.2.3 – Food Premises and Equipment* of the code will also need to be complied with. It is easy to read and follow and can be downloaded from the Food Standards Australia New Zealand (FSANZ) website, [www.foodstandards.gov.au](http://www.foodstandards.gov.au).



### **Cleaning the plant**

After you've finished trimming, boning, slicing and packing DA products your food business will need a clean down and, thanks to modern equipment, applying cleaning solutions to working surfaces is a straightforward process.

The cleaners need a plan, to be trained on how to carry it out and to have sufficient time for the job. Chemical safety is also important:

- For large operations chemicals need to be stored in a lockable room or caged area which is protected by bunds (low walls) to contain leaks; small to medium food businesses will need a lockable room,
- Staff need to be trained on how to use cleaning chemicals safely and what to do if they have an accident.

The cleaning plan needs to form part of your premises' Sanitation Standard Operating Procedures (SSOPs). Some of the essentials of hygiene and sanitation are covered in the following section.

### **Soils**

'Soils' is the term used to describe the build-up which is left on the food contact surfaces when production ceases. In meat plants the main soils are fat and protein, and in areas where the water is hard, calcium and magnesium are additional soils.

The soils which need to be removed have to be identified so the correct detergent can be purchased.

### **Cleaning**

The removal of soils like waste, dirt, grease, food scraps and blood from equipment and premises is termed cleaning. A detergent that has been designed to remove these specific soils so they can be rinsed away with water will be required. Cleaning must be done properly so equipment and surfaces are visibly free from soils and deposits.

### **Detergents**

All detergents are formulated to remove fat and protein from the food plant. They typically contain alkali (which removes fat) and chlorine (which removes protein) but the concentration of chlorine and alkali will vary according to the soil loading. For example, cleaning a grinder that is been working all day takes a heavy-duty chlorinated alkali detergent.

Detergents are also built to take into account the hardness of water, and reputable chemical suppliers won't sell you a detergent until they've tested your water supply.

### Sanitisers

As well as being soil-free, the cleaned surfaces of food plants must also have extremely low bacterial levels ( $<5/cm^2$ ). The role of the sanitiser is to destroy any bacteria remaining on the surface. Traditionally, hypochlorite has been the most widely used sanitiser, but it is corrosive and other forms of chlorine, such as chlorine dioxide, are becoming available. Quaternary ammonium compounds (QUATS) have also been used for many years and continue to be effective as no-rinse sanitisers when used at the correct concentrations, as is peroxyacetic acid. Some sanitisers have detergency built in making them a 'one-stop' cleaner/sanitiser.

### Applying cleaning solutions

Applying cleaning solutions is usually done with low pressure and low volume foaming wands, high-pressure pumps only blast solutions all over the plant. Typically, detergents are foamed onto surfaces and left for around 15 minutes (contact time) while the chemical reactions take place so that all the soil reacts with the detergent. Sanitisers are also foamed and left for the correct contact time needed for bacterial inactivation.

### Choosing systems and cleaning solutions

Reputable suppliers of cleaning chemicals are as much concerned with setting their customers up properly as they are with selling drums of soap. Producers can expect a number of 'add-ons' from chemical supplier such as:

- training the cleaning crew, both in technique and Work Health & Safety (WH&S) (concentrated cleaning chemicals are dangerous),
- trialling cleaning solutions and reporting on their effectiveness,
- providing work instructions on how to clean different equipment and areas,
- microbiological monitoring
- working out a cleaning budget.

### Costs of cleaning

The major costs for cleaning food factories are labour, cleaning chemicals and water. By far majority of the cost is labour so, if the aim is to reduce the overall cost of cleaning, a priority is to supply cleaning solutions and application systems which shorten the task of the cleaning crew. While one particular detergent may be cheaper it might also lengthen the time needed to clean, so ends up costing more on labour.

**Work instructions**

A protocol must be documented for each area to be cleaned. A typical protocol explains, sometimes with photographs, how to:

- remove food scraps (called dry cleaning),
- dismantle equipment,
- rinse with water,
- apply detergent and leave it in contact for the correct time,
- rinse the detergent with water, then allow to drain,
- apply sanitiser and leave for required contact time,
- rinse if required,
- reassemble and leave equipment so it's dry at production start-up.

All these steps can be combined into a one-page work instruction which can also include Workplace Health and Safety (WHS) instructions, where needed, and give the cleaner an idea of the time needed to clean the equipment.

**Some do's and don'ts**

- Don't use porous and absorbent items like rags or wooden handled tools - they harbour bacteria.
- Do use separate brushes for product and non-product surfaces - colour-coded is good e.g. red means only use for floor waste, green is used for product only.
- Do sanitise brushes and store them correctly between use.
- Do use low pressure cleaning systems to minimise splashing and aerosols.
- Do store hoses on reels or racks.
- Do clean shelving inside chillers about twice a week and door handles daily.
- Do have a look up at the blowers in the cool room – if they are covered in dust, or are dripping water, that's bad news for everything underneath.
- Always do a 'pre-op' inspection before work is started. Have a good look to see surfaces and equipment are clean and, if they aren't, do a clean down and sanitise. This will slow operations so, if this is the case, find out why it wasn't done properly first time around.

## Part 5: Frequently asked questions

### How effective are salt walls?

Salt is hygroscopic and can remove moisture from the air. Salt blocks are not necessary in a facility that has refrigeration units capable of maintaining the required relative humidity.

It is possible that salt blocks may reduce relative humidity but their use seems to be primarily for marketing purposes and it should be understood that they deteriorate over time and will need to be replaced.

### Is dry aged meat wholesome?

In the Australian Meat Standard (AS 4696: 2007) wholesome meats:

- a) are not likely to cause food-borne disease or intoxication when properly stored, handled and prepared for their intended use; and
- b) do not contain residues in excess of established limits; and
- c) are free of obvious contamination; and
- d) are free of defects that are generally recognized as objectionable to consumers; and
- e) have been produced and transported under adequate hygiene and temperature controls; and
- f) do not contain additives other than those permitted under the *Food Standards Code*; and
- g) have not been irradiated contrary to the *Food Standards Code*; and
- h) have not been treated with a substance contrary to a law of the Commonwealth or a law of the state or territory in which the treatment takes place.

*Standards 3.1.1 (2)* of the code has text under *Meaning of safe and suitable food*, which focuses on not causing harm if it was subjected to proper processes and consumed according to its reasonable intended use.

There are additional clauses precluding food which is damaged, deteriorated or perished.

### What if mould grows on the meat during the dry ageing process?

If mould grows, it means your process has failed because of one or more of the following reasons:

1. Temperature and/or relative humidity have exceeded the upper limit of your range – the meat has been stored too warm and too moist for too long.
2. Lack of airflow across all parts of the ageing chamber.
3. Meat not set up in the chamber so that all surfaces receive a flow of cold, dry air.

#### For Corrective Action:

- a) If the moulding is extensive then you should discard it to waste.
- b) If there are only small areas where the airflow has not penetrated you can trim them to waste and make the meat wholesome for sale.

#### For Preventive Action:

If the position is as described under (a), your process needs a complete revalidation. If it is only due to not getting sufficient cold, dry air around each piece of meat the preventive action is obvious.

### Is it desirable to have mould growth on dry aged meat?

Dashdorj *et al.* (2016) promotes the growth of “beneficial mold”, specifically *Thamnidium*, on DA meat, because its extracellular enzymes “bring about tenderness and taste”. By contrast, Jensen (1944) states: “There is a sharp difference of opinion on the question whether or not microorganisms aid in producing the organoleptic qualities demanded of aged beef or whether autolysis produces these effects.”

Further, in the Australian context, recent studies by researchers at University of Melbourne indicate that enhanced flavour and texture of DA meat is not dependent on mould growth (Robyn Warner personal communication).

### *Thamnidium*, *Mucor* and *Rhizopus* and enzyme production?

In one of the few publications which identifies moulds on DA meat, Jensen (1944) states: “During the holding period, molds of several genera appear on the cut surfaces of the meat (usually, species of *Thamnidium*, *Rhizopus* and *Mucor*)”.

Dashdorj *et al.* (2016), while singling out *Thamnidium* as a “beneficial mold” asserts that the other mould species (above) “do not provide any favourable characteristics for aging of meat”. Dashdorj *et al.* (2016) provide no scientific evidence to support either claim, the second of which re *Mucor* and *Rhizopus* is patently erroneous. Both genera have well-established extracellular enzyme production, leading to the approval of *R. niveus*, *R. oryzae*, *M. miehei* and *M. pusillus* on The US Food and Drug Administration list of “Enzyme Preparations Used in Food”; the list includes amyloglucosidase, carbohydrase, esterase-lipase and proteases and is accessed at:

<https://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/EnzymePreparations/default.htm>

**Do *Rhizopus* and *Mucor* cause illness in consumers?**

Dashdorj *et al.* (2016) state that *Rhizopus* and *Mucor* are “associated with human infectious diseases” provide no scientific backing for the claim, which is refuted by CSIRO who state that mycotoxin production by *Rhizopus* and *Mucor* is unknown and unlikely (Pitt and Hocking, 2009).

**Validation of the DA process via testing for *Thamnidium*?**

Dashdorj *et al.* (2016) assert that: “Dry aged meat products must be tested for mould to validate the procedure” and that: “If testing for mould shows that the results are positive, then confirmation that the mould is *Thamnidium* must be conducted”.

The CSIRO notes that Victorian processors of DA meat are directed by PrimeSafe Victoria to discard product if moulds other than *Thamnidium* spp. are detected and CSIRO concludes: “Based on the information reviewed here related to food safety risks associated with mould growth on cold-stored and dry-aged meat, fungi other than *Thamnidium* spp. are not indicative of a food safety risk, as mycotoxin production is not known to occur within the temperature (-0.5 to +3°C) and RH (75-85%) range suggested for the safe dry ageing of meat” (Olivier, 2018).

**My auditor insists that I must validate shelf life of my dry aged product by testing for indicator bacteria – is there any scientific validity in this?**

In Australia one jurisdiction requires testing of finished DA meats for *E. coli* and *Enterobacteriaceae* to validate shelf life, specifying Critical Limits (CLs) for each and mandating discarding of product if either CL is exceeded. No scientific evidence is provided to underpin this decision, which is at variance with microbiological performance criteria for export meat as set out in the Department of Agriculture Water and Resources Microbiological Manual (DAWR, 2017).

**I vacuum pack my dry aged cuts – do they have extended shelf life?**

No they don't. Dry aged meat has a shelf life similar to cuts of meat you'd take home from the butcher's shop – no more than seven days at cold chain temperatures. Vacuum packing protects the meat but doesn't extend its shelf life.

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