MEAT & LIVESTOCK AUSTRALIA

Guidelines for the safe production of dry aged meat

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Images supplied by Tim Burvill (A Hereford Beefstouw)

Disclaimer

Contents

Glossary of terms and abbreviations

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

Microbiological limits	The maximum number of microorganisms specified for a food product
Microorganisms	Viruses, yeasts, moulds and bacteria
MPN	Most Probable Number. Method used to determine bacterial numbers based on probability concept instead of counting colonies
Pathogen	A microorganism which causes illness
pH	A measure of acidity or alkalinity
Production	Production is defined as in AS 4696:2007 clauses (c) and (d)
PRP	Pre-requisite program
QCP	Quality Control Points
QUAT	Quaternary ammonium compounds
RCP	Regulatory Control Point
RI	Refrigeration Index
Shelf life	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
Spoilage bacteria	Bacteria which limit the shelf life of foods by producing objectionable odours, colour or slime
SSOP	Sanitation Standard Operating Procedures
Toxin	A chemical, including ones which may be produced by bacteria or moulds, which can cause illness.
Validate, validation	The process of obtaining evidence to demonstrate that hazards in a food process are controlled and compliance with standards
Verify, verification	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
Wet aged	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 processes has been fragmented, incomplete, and difficult to find. These guidelines are intended to provide best practice advice to businesses seeking to adopt DA into their businesses. The guidelines are intended to support production of DA meat; however, in all instances businesses are urged to contact the relevant regulator for advice before applying practices or processes outlined in this document.

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.

N.B. This guideline is intended to be informative in nature and not directional i.e. it does not represent legal advice. Businesses seeking to apply information in this document to the production of DA meat are urged to seek professional advice and/or to contact the relevant regulator before commencing production of DA meat. Reasonable endeavours are taken to ensure that information is accurate and up-to-date as at the date of publication.

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 evidence to support proposed measures in your Food Safety Plan
- Provide background for safe production of your DA 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.

Though the extended ageing of meat beyond those specified for fresh meat requirements has not been common practice in the Australian meat industry, dry ageing 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 of 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 as steaks and submitted to 600 panellists (untrained) over ten sessions. Panellists assessed tenderness, juiciness, flavour plus overall liking 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*. 2017).

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 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.

The primary purpose of these guidelines is to describe the process of producing dry aged meat safely and which can be applied to commercial operations in all jurisdictions of Australia.

Part 1: Hazards and risks in dry aged meats

1.1 Hazards

The DA process begins with carcases 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 a term with which food businesses are familiar.

Under the Standard, meat enters the DA premises at no warmer than 7°C (carcases and quarters) or 5°C (carcase parts), where it will be processed according to the regime described in Figure 4.1 (page 25).

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

The Australian *"Guide to the implementation and auditing of HACCP"* (ARMCANZ, 1999) requires a list of all potential hazards associated with each step, a hazard assessment, and control measures to prevent, reduce or eliminate the hazard.

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 raw meat include:

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

1.2 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.

1.3 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 carcases/carcase parts used for dry ageing (Phillips *et al*. 2012a, 2012b, except for **)

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

*** 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 Relative Humidity (RH) conditions of the DA process prevent growth of pathogenic bacteria (see ICMSF, 1996; Hocking and Pitt, 2003). As seen from Table 2 none of the pathogens found on meat is 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 (ICMSF, 1996)

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

1.4 Microbiological profile of dry aged meats

In general, it has been shown that dry ageing has a positive effect in reducing the microbiological load on meat over longer periods, most likely due to the combined effect of chilling and drying. 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^2) and moulds from 1 out of 6 primals (1.25 cfu/cm^2).

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^2) and mould on 2 out of 6 primals (0.25 and 0.75 cfu/cm^2). *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.

1.5 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.

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

There are three key references describing production of toxins by fungi in food (ICMSF, 1996; Hocking & Pitt, 2003; Pitt & Hocking, 2009), all focusing on the genera *Penicillium*, *Aspergillus* and *Fusarium.* Fungi are significant to human health because under certain conditions they are able to produce toxins (mycotoxins). Of the three genera above, only two (*Penicillium*, *Aspergillus*) are found on meat, the other (*Fusarium*) being found in grain only.

Brown (1982) lists a number of moulds found on raw meat following chilling / cold storage for 4-6 weeks (Table 3), including *Penicillium* and *Aspergillus*. *Fusarium* spp. are associated with grains (ICMSF, 1996; Hocking & Pitt, 2003; Pitt & Hocking, 2009) and have not been noted in meat held under chilled conditions such as recommended for the dry ageing process (Table 3).

Table 3: Moulds associated with meat held under refrigeration temperatures

Genus / species	Reference
Penicillium	Brown (1982)
P. hirsutum	Gill and Lowry (1982)
Cladosporium	Brown (1982)
C. cladosporioides	Gill and Lowry (1982)
C. herbarum	Gill and Lowry (1982)
Thamnidium	Brown (1982); Gill *et al.* (1981)
Chrysosporium	Brown (1982), Gill *et al.* (1981)
Mucor	Brown (1982)
Rhizopus	Brown (1982)
Aspergillus spp.	Gill *et al.* (1981)
Aureobasidium pullulans	Gill *et al.* (1981)

Again the key question is: can any potentially toxigenic genera produce toxin during the DA process? Of the genera found in meat, *Aspergillus* and *Penicillium* are the only ones known to produce toxins, but are not capable of producing them at temperatures between -0.5 and +3°C, even if they are able to grow (Table 4) during the DA process. If DA occurs at, or above, 4°C then it is possible that a mould may produce a toxin (Hocking & Pitt, 2003).

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

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

1.7 Summary – mould hazards and risks

While there are several mould genera commonly present on raw meat, no toxigenic species is capable of growing and producing toxins at the recommended temperature/relative humidity conditions provided in this guideline.

The CSIRO report prepared by Olivier (2018) 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"*.

Part 2: Construction and cleaning

2.1 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 so you should closely monitor the operating conditions to ensure that they remain within the specified range in the FSP.

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 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.

Alternatively, consider moving all products to another chiller where possible to undertake a thorough clean down. Thorough cleaning and fogging (of an empty chiller) can be done by fogging/saturating 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.

2.2 General information on construction and cleaning

2.2.1 Construction of the processing plant

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

DA meat must be produced 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 detail that must be met, whereas 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 but are not limited to:

- Having a safe, potable water supply and one which supplies sufficient for all your food business needs
- Maintaining a cleaning and sanitation schedule for equipment in the business
- 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
- Monitoring temperature and relative humidity during the DA process
- 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. PRPs need to be in place to manage these elements.

The requirements in *Standard 3.2.2 – Food Safety Practices and General Requirements and standards 3.2.3 – Food Premises and Equipment* of the code must 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.

2.2.2 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, be trained on how to carry it out, and 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.

2.2.3 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.

2.2.4 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.

2.2.5 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.

2.2.6 Sanitisers

As well as being soil-free, the cleaned surfaces of food plants must also have extremely low bacterial levels. 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.

2.2.7 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.

2.2.8 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 and Safety (WHS) (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.

2.2.9 Costs of cleaning

The major costs for cleaning food factories are labour, cleaning chemicals, and water. By far the 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.

2.2.10 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.

2.2.11 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 surfaces that may come into contact with product
- 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 look up at the blowers in the cool room to ensure they are not dusty or dripping water
- 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 3: 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.

3.1 Pre-requisite programs

PRPs 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 2) 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 PRPs set up can you operate a Food Safety Plan.
Part 2: Construction and cleaning provides the detailed information that you will need to develop your PRPs.

GMPs are covered in Part 4 (Food Safety Plan).

3.2 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

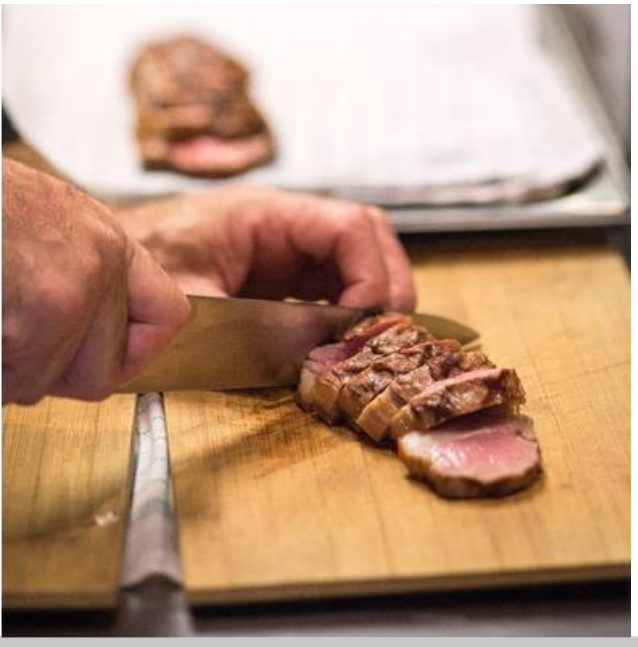
For an operation to fulfil the definition for a CCP it must achieve one of the following:

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.

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 4: Dry aged meat

Dry ageing of meat comprises a process of storage at low temperature and low humidity of carcases 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.

The recommended valid dry ageing process is one in which:

- Meat is received at a temperature which conforms with AS 4696:2007 (carcases no warmer than 7°C and carcase parts no warmer than 5°C)
- The FSP specifies a range for temperature (-0.5 to +3°C), air speed (0.2-0.5m/s) and relative humidity (75-85%) under which the meat is held for the duration of the ageing process (usually longer than 21 days)
- The process should be carried out only in a chamber capable of controlling temperature, air speed and humidity, and in which only DA meat is stored
- Finished products must be wholesome and stored and transported no warmer than 5°C, in accordance with AS4696:2007.

4.1 GMPs

In Figure 4.1 (page 25), the process flow for DA meat is 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.

4.1.1 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. 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.

4.1.2 Receiving and storing raw materials

When raw materials are received they need to be inspected for wholesomeness, in accordance with AS4696:2007 (including for obvious contamination and defects), and specifications such as temperature must be checked (no warmer than 5°C for carton meats and 7°C for carcases).

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.

4.1.3 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.

4.1.4 Ultra Violet (UV) Lighting

UV radiation is extremely effective in killing or damaging microorganisms on carcases and carcase 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.

UV light will lose efficiency if it is not designed for the ambient environment. Currently most units lose efficiency at temperatures approaching 0°C but can be efficient at 4°C and above. In additional energy consumption and added heat load to the room have also been improved in recent models. 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. You should consult a professional before making decisions on installation.
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.

4.1.5 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).

4.1.6 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.

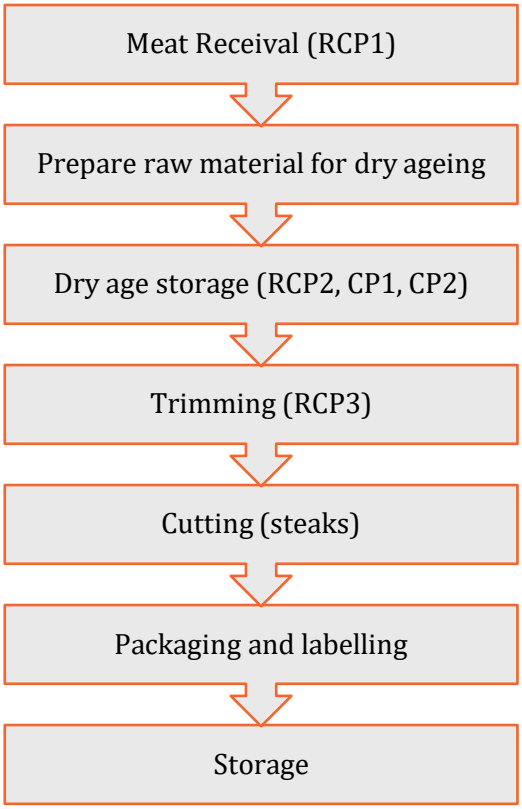
Control of RH depends on the type of refrigeration used in the ageing chamber. For large chambers a refrigeration engineer will be able to set the system to achieve the required RH range. Smaller DA chambers may have in-built humidity controls.

4.1.7 Final product trimming and packing

When the DA process is completed, the meat is rendered wholesome by trimming according to the AS 4696 and the trimmings likely 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.

Dry aged meat has a shelf life similar to other cuts of meat – usually about 7 days at refrigeration temperatures. A shelf life trial will determine what the shelf life of your product is (refer to FAQs). Vacuum packing protects the meat but may not extend its shelf life.

Figure 4.1: Process flow diagram for dry age meat



4.2 HACCP controls

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

4.2.1 RCP1: Receival of meat

AS 4696:2007 specifies maximum receival temperatures of 7°C for carcases and 5°C for carcase 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).

4.2.2 RCP2: Storage and handling of meat

Temperatures for storage and handling 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.

4.2.3 CP1: Temperature control

You will need to age meat in a temperature range specific for your operation (CSIRO recommend -0.5 to +3°C) and to monitor on a daily basis. If product has been held at or above 4°C during the process, then certain moulds may produce toxins.

4.2.4 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

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

4.2.5 RCP3: Trimming

After the DA process, the operator may need to trim the crust from the surface of DA, because it may be objectionable to consumers.

Part 5: Frequently asked questions

5.1 How effective are salt walls?

Salt is hygroscopic and can remove moisture from the air. 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.

The Standard AS 4696:2007 requires that the operator must ensure wholesomeness of meat and meat products. To that end, if the process requires humidity control to achieve this, salt blocks must not be used in isolation because although they may influence humidity, they cannot maintain or control it.

5.2 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 also 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.

Given the above, trimming may sometimes be necessary to remove tissue considered objectionable to the customer.

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

You will need to review your operations for one or more of the following causes:

1. Temperature and/or relative humidity have not been maintained within specified limits
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 consistent flow of cold, dry air.

For Corrective Action:

a) If the moulding is extensive then you should discard the product 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.

5.4 What impact does mould growth have on dry aged meat?

Whether mould growth on meat during the dry ageing process increases its flavour and tenderness is contentious.

Dashdorj *et al*. (2016) promotes the growth of *"beneficial mold"*, specifically *Thamnidium* on DA meat, because its extracellular enzymes *"bring about tenderness and taste" and* asserts that the other mould species (*Mucor* and *Rhizopus*) *"do not provide any favourable characteristics for aging of meat"*. There are some preliminary Korean studies (under different dry ageing conditions to those recommended in this document) suggesting that some yeasts and moulds may play an important role in palatability and flavour development (Ryu *et al*. 2018; Kim *et al*. 2018).

In contrast, Jensen (1944), who worked in the Research Laboratories of Swift & Company, notes that three closely-related moulds *Thamnidium, Rhizopus* and *Mucor* are often found on the cut surfaces of beef during the holding period and 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."*

In the Australian context, studies by researchers at University of Melbourne indicate mould growth is not associated with enhanced flavour and texture of DA meat since the enhanced flavour and texture attributes were achieved in the absence of mould growth (Warner *et al*. 2017).

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

Dashdorj *et al*. (2016) note that *Rhizopus* and *Mucor* are *"associated with human infectious diseases".* A review of the group to which these moulds belongs (the *Zygomycetes*) confirms that human infections occur when spores are inhaled or enter surgical wounds (Ribes *et al*. 2000). The authors also state that infections are rare and are associated only with immunocompromised individuals.

There is no report of illness being associated with the presence of these moulds in food, and CSIRO state that mycotoxin production by *Rhizopus* and *Mucor* is unknown and unlikely (Olivier, 2018).

Dashdorj et al. (2016), while favouring only *Thamnidium*, assert that *Mucor* and *Rhizopus* "do not provide any favourable characteristics for aging of meat". However, 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

5.6 How do I determine shelf life?

Shelf life ends when meat becomes unfit for human consumption or sale (due to growth of pathogens or to unacceptable odour or colour). MLA has written a detailed guide on how to determine shelf life in the publication *"Shelf life of Australian red meat, 2nd edition, 2016"* Table 8.9 and section 9.1.(MLA, 2016).

Microbiological testing

Micro testing is an aid in validating your process - the parameters reviewed and assessed by the relevant state regulator in your FSP are your process validation, and your process monitoring is the verification.

If testing is done, then it should be done on finished product as that is what the customer will receive.

DA meat is considered as raw meat and there are no microbiological standards for raw meat in the Australia New Zealand Food Standards Code.

Bacterial:

- Testing will be useful to verify your initial production and to monitor your process
- FSANZ (2018) states that *"total counts are likely to be quite high due to the bacterial flora normally present (10^6–10^7 cfu/g)."* and IFST (1997) recommend TVC of <10^6 or <10^5, noting that counts may reach up to 10^7 for finished products
- Your regulator or customer may require other tests.

Mould:

- Mould and yeast are common in environment and animal carcases, Brown (1982), Gill & Lowry (1982) and Gill *et al.* (1981) lists a number of moulds which can be found on meat
- As stated in this guide, If your process is within the temperature (-0.5 to +3°C) and RH (75-85%) ranges suggested, even if moulds are present on the meat they will not produce toxins (Olivier, 2018)
- For these reasons mould testing is not recommended, but your regulator or customer may require other tests.

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